GRADUATE PROGRAM GUIDE

Ken and Mary Alice Lindquist Department of Nuclear Engineering

The Pennsylvania State University

Academic Year 2024-2025

PennState College of Engineering

KEN AND MARY ALICE LINDQUIST DEPARTMENT OF NUCLEAR ENGINEERING

2024-2025 GRADUATE STUDENT HANDBOOK

TABLE OF CONTENTS

FACILITIES

COURSE DESCRIPTIONS

FACULTY RESEARCH INTERESTS

REPORTING RESOURCES

APENDIX

Introduction

Welcome to the Ken and Mary Alice Lindquist Department of Nuclear Engineering at Penn State. We are delighted to have you join our esteemed institution and embark on this exciting academic journey. As you begin your graduate studies, we want to extend our warmest greetings and offer our full support throughout your time here. The field of nuclear engineering is both dynamic and crucial to the advancement of science and technology. As a graduate student, you will have the opportunity to delve deep into this field, conducting groundbreaking research and contributing to the ever-evolving knowledge base. We encourage you to embrace this opportunity with enthusiasm and dedication. Nuclear engineering is a field that encompasses a broad range of disciplines and applications, making it a highly diverse and multidisciplinary field. We have world-class faculty members who are experts in areas such as reactor design and analysis, nuclear materials and fuel cycles, radiation protection, nuclear medicine, nuclear security, plasma fusion and nuclear waste management. During your time in the program, you will have access to state-of-the-art facilities and equipment, allowing you to conduct experiments and simulations at the forefront of nuclear engineering and related areas. The campus is home to several state-of-the-art core laboratories including the Radiation Science and Engineering Center, and Breazeale Nuclear Reactor. Also, be aware that as a high-quality research university, Penn State has a multitude of research and educational resources outside the department that can benefit you. Our esteemed faculty members will guide and mentor you, ensuring that you have the necessary resources and expertise to excel in your research endeavors. Collaboration and networking are integral to the success of doctoral students. We encourage you to engage with your peers and faculty members and participate in conferences, workshops, and seminars. These interactions will not only broaden your knowledge but also foster professional relationships that can last a lifetime. Some of you will also have the opportunity to gain teaching experience by assisting in undergraduate courses. This experience will enhance your communication and leadership skills and provide you with a well-rounded academic profile. We understand that pursuing an advanced degree can be both intellectually stimulating and challenging. Rest assured, our support services, including academic counseling, research funding opportunities, and career guidance, are available to assist you throughout your journey. We are committed to ensuring that you have a fulfilling and rewarding experience as you work towards your research goals. Once again, welcome to the Graduate Program in Nuclear Engineering. We are confident that your time here will be marked by intellectual growth, personal development, and significant contributions to the field. We wish you every success in your studies and look forward to witnessing your achievements in the years to come. Students enroll in classes using LionPATH. Any questions concerning registration procedures, dates and schedules can be directed to the Graduate Program Staff. You should consult your advisor before registering for classes to ensure proper academic progress is being made. **Please note that our main way to contact you is via e-mail**. You are assigned an e-mail address when you join Penn State; you are responsible for checking it often. All graduate students in the Nuclear Engineering Program must register for NUCE 590 Colloquium. Master's students need to register for this course throughout their graduate work, and Ph.D. students need to register continuously until they pass their comprehensive exam. These seminars are given by prominent researchers, officials, and industry leaders, and they represent an important part of a student's education in the field of nuclear engineering, well beyond what is taught in the classroom and what is learned in research. The student chapter of the American Nuclear Society (ANS) is a focal point of professional and social activity for students and faculty in Nuclear Engineering. The ANS organizes seminars, conducts field trips under Nuclear Engineering Program auspices, conducts public information programs, and provides services to the Program and undergraduate and graduate students. You are encouraged to join the chapter and to actively support it. The Institute for Nuclear Materials Management (INMM) or Women in Nuclear (WIN) may also be of interest to you. Additionally, I recommend you consider and participate in the activities of the Graduate Student Association (GSA). If you have any questions or problems, please see your academic advisor or the Nuclear Engineering Graduate Program Office. In addition, I am always willing to meet and discuss any issues or concerns you may have.

Best wishes for your success at Penn State!

Prof. Dipanjan Pan
Huck Chair Professor in Nanomedicine
Chair of Graduate Studies

GRADUATE PROGRAM OFFICE

Ashley Ammerman

Graduate Program Coordinator

The Graduate Program Office for Nuclear Engineering is located at 113 Hallowell Building. Ashley Ammerman is available to assist students as necessary. You can reach her via email at alb5678@psu.edu, or Microsoft Teams with any questions or to schedule an appointment.

GENERAL ADMINISTRATIVE POLICIES

ID CARDS

- Every Penn State campus has an office that issues id+ cards (20 HUB-Robeson Center). There is no charge for your first card.
- When you come to the id+ Office, you will need to present a valid form of ID: driver's license, passport, state-issued photo ID, military ID, government-issued photo ID, high school photo ID with a Social Security Card, college ID with a Social Security Card, or a Permanent Resident Card.
- Students transferring to University Park from another Penn State campus do not need a new id+ card.

PSU EMAIL

The Graduate Program Office uses e-mail to notify students of various announcements, events, etc. All graduate students are required to use their Penn State e-mail account for all correspondence regarding academics. If you choose to use an account other than the one provided you are responsible for all information contained in your PSU account. Please refer to the Information Technology Services (ITS) website for more information: http://identity.psu.edu/services/authentication-services/access-accounts/.

MAIL HANDLING

Incoming graduate student mail and items ordered for research will be placed in 311 Hallowell Building. Please check it often, as mail will not be held indefinitely.

The default mailing address for graduate students is: 206 Hallowell Building, Atherton St., University Park, PA 16802. This address should be used only for professional purposes.

PARKING

Every employee or student needs a parking permit to park on campus. Individuals enrolled in classes at Penn State are classified as students and must obtain student parking through the Parking Office. Please refer to policies and online registration procedures at: http://www.transportation.psu.edu/.

Parking registration must be completed online. All permits are sold on a first come, first served basis. PermitDirect™ will provide a printable temporary permit allowing students to park immediately.

OFFICES - Students will be provided with an office to perform their teaching or research assistantship duties. Emails will be sent at the beginning of each semester notifying students of desk location changes or reassignments based on assistantship duties.

BUILDING ACCESS - Hallowell is open to the public 7:00 am – 5:00 pm Monday through Friday and remains locked outside those specific hours. Access to Hallowell Building is gained by the use of the PSU student ID card. If you encounter issues with building access, please notify the graduate program staff.

GRADUATE STUDENT TRAVEL

As a graduate student in Nuclear, you may be presented with an opportunity to travel to conferences or other academic related activities. You are required to work with Madeleine McVey (mdm5975@psu.edu) and our Finance Team to ensure all steps have been taken to ensure that the travel expenses can be reimbursed ***prior to*** traveling. See Appendix, Page 28 for more information.

ASSISTANTSHIP RESPONSIBILITIES

A graduate student on a 1/2-time assistantship is expected to work a minimum of 20 hours per week. These work requirements can include thesis research activities.

All international students who have been offered assistantships which involve classroom interaction with undergraduate students are required to have passed the American English Oral Communicative Proficiency Test (AEOCPT), as a result of a State law and Penn State Faculty Senate Legislation. This test is administered before the semester begins by the Department of Applied Linguistics. (http://aplng.la.psu.edu/programs/about-the-aeocpt).

UNIVERSITY HEALTH SERVICES

University Health Services is in the Student Health Center, adjacent to the Eisenhower Parking Deck and the Bank of America Career Services Building off Bigler Road. Its facilities are available to all students, including graduate students at all levels of training.

HEALTH INSURANCE

Health insurance is mandatory for all Graduate Students and Students with RA or TA appointments. As a graduate student, you are eligible to purchase health care at a subsidized rate for the Graduate Assistant and Graduate Fellow medical, dental and vision plans. This is valid for you and for any eligible dependents. Students enrolled in the university health insurance plan have their premiums automatically deducted from their paycheck. You are encouraged to review the policies at https://studentaffairs.psu.edu/health and contact University Health Services directly at 814-865-6556 if you have any questions regarding Penn State Student Health insurance.

COUNSELING AND PSYCHOLOGICAL RESOURCES FOR GRADUATE STUDENTS

Counseling and Psychological Services (CAPS) can help students resolve personal concerns that may interfere with their academic progress, social development, and satisfaction at Penn State. Common concerns include difficulty with friends, roommates, or family members; depression and anxiety; sexual identity; lack of motivation or difficulty relaxing, concentrating or studying; eating disorders; sexual assault and sexual abuse recovery; and uncertainties about personal values and beliefs. All consultations are strictly confidential. You can contact their office by calling 814-863-0395 or visit their website for more information.
http://studentaffairs.psu.edu/counseling/

REPORTING RESOURCES

All members of the Penn State community are asked to remain mindful of their individual commitment to Penn State's core values of Respect, Integrity, Responsibility and Community by helping to keep the University a safe and ethical institution. In addition, as members of this community, everyone should be responsible stewards of university funds, whether generated from state, federal, student, or other sources. The University does not condone wrongful conduct by any member of the Penn State community, no matter what position he or she may hold.

Penn State University encourages the reporting of misconduct. **If you see something, say something.** You can report misconduct, in the assurance that the University will protect you from retaliation.

See AD67 or contact the Office of Ethics & Compliance for more information.

Additional reporting resources available for faculty, staff, students, and others are shown on page 23.

ACADEMIC PROCEDURES FOR GRADUATE STUDENTS

GRADUATE DEGREE PROGRAMS BULLETIN

The Graduate Degree Programs Bulletin (http://bulletins.psu.edu/bulletins/whitebook/index.cfm) contains policies mandated by the Graduate School regarding academic procedures, registration requirements, conduct, resolution of problems and procedures for termination, MS degree and Ph.D. degree requirements, as well as other procedures, regulations and requirements as related to graduate study.

GRADING SYSTEM

Grades shall be assigned to individual students based on the instructor's judgment of their scholastic achievement using the grading system below.

Undergraduate and Graduate Grading System

Quality of Performance		Grade	Grade Point Equivalent
Excellent	Exceptional Achievement	A	4.00
		A-	3.67
Good	Extensive Achievement	B+	3.33
		B	3.00
		B-	2.67
		C+	2.33
Satisfactory	Acceptable Achievement	C	2.00
(**Does not count for Graduate Degree**)		D	1.00
Failure	Inadequate Achievement	F	0.00

For graduate students, a minimum grade-point average of 3.00 for work done at the University is required for graduation.

UNSATISFACTORY SCHOLARSHIP

A graduate student who fails to maintain a satisfactory scholarship or to make acceptable progress in a degree program may be dropped from the University. One or more failing grades or a cumulative grade-point average below 3.00 for any semester or session or combination of semesters and/or sessions may be considered as evidence of failure to maintain satisfactory scholarship. Action may be initiated by the department or committee in charge of the graduate major or by the chair of the student's committee.

ENROLLING IN CLASSES

Course Registration – All students must register for classes prior to the end of the first week of classes. http://www.registrar.psu.edu/academic_calendar/calendar_index.cfm. If you do not register before that date, you will be assessed a late-add fee and a late registration fee. If you are on a half-time graduate assistantship, you must register for a minimum of 9 credits per semester. International students must be registered full-time, or for at least 9 credits, to maintain their visa status.

DROPPING and ADDING COURSES

If you need to drop a course, please consider if this will impact your visa status or your assistantship credit requirement and promptly consult the Graduate Program Office.

Penn State University maintains three periods relating to course drops: the pre-semester period, the add-drop period, and the late add-drop period.

1. The **pre-semester period** begins on the first day of scheduling and ends the day before the semester starts.
2. The **regular drop/add period** is the 5-day period, which begins the day courses start. During that timeframe, a course can be dropped or added without a drop/add penalty fee. Please refer to the Registrar's Academic Calendar for specific dates.
   - No fee
   - No record on your transcript
3. The **late add/drop period** starts the day after the regular drop period ends and runs until the late drop deadline (see the academic calendar),
   - A fee for each transaction
   - Courses are recorded on the student record as LD

AUDITING COURSES

Courses taken formally as audit are not included in the maximum number of credits required for assistantships or for satisfying visa requirements for international students. **The request to audit a course must be done within the regular drop/add period**. The adding of an audited course after the regular drop/add period is not permitted. Requests to audit a course must be made to the instructor who offers the course. Once instructor approval is granted, student must complete the Registration Drop/Add form found on the Registrar's Homepage.

Please note that the tuition costs remain the same for an audited course.

FULL-TIME ACADEMIC STATUS

Full-time academic status is achieved by taking appropriate course loads. Most loan granting agencies and other organizations consider a 9-credit course load to be full-time status, fulfilling their registration requirements. The U.S. Immigration and Customs Enforcement (ICE) requires that all international students on student visas must achieve "full-time Academic status" during the Fall and Spring semesters. Exceptions to this rule are possible under certain conditions. Students should contact the University Office of Global Programs for further information. A course load of 9 credits is considered full-time during Fall and Spring semesters, and during the Summer semester, international students do not have to register. Any graduate student registered for NUCE 601 (Note: Student must have passed the Ph.D. comprehensive exam in the prior semester) is considered full-time academic status.

For full details, see the Graduate Degree Programs Bulletin website at http://bulletins.psu.edu/bulletins/whitebook/index.cfm.

COURSE LOAD

Full-time students and students receiving fellowships should register for 12 credits per semester.

MS students are not required to register for course work or research once the course requirements have been met.

The Graduate School requires that all students receive a cumulative grade point average of 3.0 or better to graduate. After passing the comprehensive exam, all Ph.D. students must maintain "continuous registration," which requires them to register for NUCE 601 (Ph.D. Thesis Preparation) for the Fall and Spring semesters. If Ph.D. students plan to hold a milestone exam (comprehensive or final dissertation) during the Summer Session, they must be registered. Also, Ph.D. students must spend at least two semesters over some 12-month period during the interval between completion of the Qualifying exam and completion of the Ph.D. program as a registered full-time student. For full details, see the Graduate Degree Programs Bulletin website at http://bulletins.psu.edu/bulletins/whitebook/index.cfm .

TRANSFER OF CREDITS

Transfer of Credit from an External Institution
A student may request for a maximum of ten (10) credits of high-quality graduate work done at a regionally accredited institution or recognized degree-granting institution to be applied toward the requirements for a MS degree. Approval to apply any transferred credits toward a degree program must be granted by the Graduate Program Chair, and the Graduate School. However, credits earned to complete a previous MS degree, whether at Penn State or elsewhere, may not be applied to a second master's or doctoral degree at Penn State.

Transfer credits must meet the following criteria:

- Must have been earned at a recognized degree-granting institution in the United States;
- Must be of "A" or "B" grade value ("B-" grades are not acceptable; pass-fail grades are not transferable unless substantiated by the former institution as having at least "B" quality);
- Must appear on an official graduate transcript;
- Must be earned within the five years prior to the date of registration to a degree program at Penn State.

Forms for transfer of credit may be found at http://gradschool.psu.edu/current-students/

TRANSFER OF NON-DEGREE GRADUATE CREDITS

Approval to apply non-degree graduate credits toward a degree program must be granted by the Graduate Program Chair, and the Graduate School. A maximum of 15 credits earned at PSU as a non-degree student may be applied to a degree program.

- The credits must have been earned within five years preceding entry into the degree program.
- Only upper level undergraduate and graduate courses may be transferred.
- Only A, B, and C grades may be transferred.

Forms for transfer of credit may be found at http://gradschool.psu.edu/current-students/

COURSES

NUCE 590 (graduate seminar)

This course includes seminars by outside speakers (from academia, industry or government), faculty and senior graduate students. These seminars represent an important part of the student's education.

- All Nuclear Engineering graduate students registered full-time must schedule this course during the Fall and Spring Semesters, except PhD students who successfully complete the comprehensive exam.
- Credits earned from this course do not count towards the 30 credits required for graduation with an MS or MEng degree.

Requests for exceptions to the registration requirements listed above can be made to the course instructor and are evaluated case-by-case.

NUCE 596, 600 (610), 601 (611)

Graduate students registering for these courses must first consult with their advisor to ensure that they are registering for the appropriate course. Failure to select the correct course may require the student to pay retroactive drop/add fees and perhaps additional course-credit fees. NUCE Graduate Program staff can also assist graduate students in registering for the appropriate course.

NUCE 596 - INDIVIDUAL STUDIES "Research for Writing MEng paper" - Creative projects, including non-thesis research, that are supervised on an individual basis, and which fall outside the scope of formal courses. **NUCE 596 cannot be used for M.S. or Ph.D. thesis research**. At least 3 credits of NUCE 596, supervised by the student's advisor, are required when submitting a research paper. Achievement of a quality letter grade is required.

NUCE 600 (610 if research is Off-Campus) - THESIS RESEARCH - This course should be used to register for M.S. and Ph.D. thesis research. At least 6 credits of NUCE 600, supervised by the student's advisor, are required when submitting a thesis. There is no limit on the total number of credits of 600 a student can take. However, there is a maximum number of credits for which a student can receive a quality letter grade (A, B, etc.). A student must receive a non-letter grade (R, etc.) for any additional credits of 600. The R grade is assigned for satisfactory completion of research.

LIMITS ON RESEARCH CREDITS (NUCE 600)

Students registering for 600 or 610 should be aware that the Graduate Council has established limits on the total number of research credits that can be assigned letter grades in a student's program (i.e., other than R). Students are not permitted to have more graded credits of research than stated by policy.

NUCE 601 (611 Part time) **-** Ph.D. THESIS PREPARATION

Only Ph.D. students who passed the comprehensive exam can enroll in 601. Ph.D. students are eligible for 601 in the semester following their comprehensive exam and have met the two-semester residency requirement. Ph.D. students can register for one additional course either for credit or audit (up to 3 credits) when they are registered for NUCE 601/611. Students eligible must contact the NUCE Graduate staff to enroll in NUCE 601. ***Note: NUCE 601 cannot be used to meet the residency requirement***.

It is important that graduate students consult with their advisor prior to each semester's registration to ensure that they are registering for the appropriate courses.

MAINTAINING SATISFACTORY SCHOLARSHIP

A minimum grade point average of 3.00 is required to be granted a graduate degree in Nuclear Engineering.

If in a review of the student's grade point average, the minimum requirements are not met, a letter (signed by the advisor) to the student from the Graduate Studies Committee of Nuclear Engineering will state:

a) The requirement(s) which the student has failed to satisfy.
b) The requirement(s) which the student must meet by the end of the next semester.
c) If the next semester requirement(s) set forth in item b. is not met, the GSC will review the student's academic performance at a meeting convened prior to the end of the first two weeks of the subsequent semester. In the absence of extenuating circumstances, the student will be dismissed from the program as a graduate student immediately following the meeting.

The student may petition the Graduate Studies Committee of Nuclear Engineering for re-admission as a funded graduate student when their cumulative graduate course grade point average is elevated to 3.00 or greater.

MASTER OF ENGINEERING DEGREE PROGRAM

The Master of Engineering (MEng) degree is a professional master's degree. A minimum of 30 credits at the 400, 500, or 800 level is required. Twelve of those credits must be in Nuclear Engineering with at least 18 credits at the 500 level. Students are also required to take NUCE 450 Radiation Detection and Measurement – an alternate course has been created, NUCE 497 (1.00 credit) and is offered during summer only. **This requirement may be waived for students with a B.S. in Nuclear Engineering; however, the minimum of 30 credits is still required**. Students must petition the Graduate Studies Committee (GSC) to review their undergraduate transcripts to assess their eligibility for a waiver. This transcript should be emailed to Program Staff.

The program culminates with a scholarly paper completed while the student is enrolled in NUCE 596 (3 credits). The scholarly paper must be approved by the adviser, a faculty reader, and the graduate studies chair. Students should work to identify their paper topic, and their adviser in semesters prior to enrolling in NUCE 596 due to the deadlines set forth by the graduate school for paper submission.

ADMISSION REQUIREMENTS

Completion of an undergraduate degree in Nuclear Engineering or in another related engineering or science discipline is required for admission to the MEng degree program in Nuclear Engineering. Students must have at least a 3.00 (4.00 base) junior-senior average to be considered for admission.

NUCLEAR SECURITY OPTION - MENG

An option in Nuclear Security is available for students taking the MEng degree. To follow that option, students must complete 15 credits in the following courses: NUCE 441 (3 credits), NUCE 442 (3 credits), NUCE 542 (3 credits), NUCE 543 (3 credits), and NUCE 544 (3 credits). **Please note that you are required to notify the graduate program staff that you are seeking this option, so that is applied on your record.** Students who complete the requirements for that option will have on their diploma "M.Eng. in Nuclear Engineering, Nuclear Security Option."

PROGRAM REQUIREMENTS – MENG IN NUCE

Each of the following requirements must be met for a student to be approved for graduation:

1. A minimum of 30 graduate credits must be earned. Only grades of A, B, and C are accepted for graduate credit.
2. A minimum grade point average (GPA) of 3.00 is required.
3. At least twelve (12) 400- or 500-level course credits must be taken as NUCE courses.
    - A minimum of six credits must be NUCE 500-level courses.
4. At least eighteen (18) of the 30 required credits must be in 500-level courses.
    - This includes NUCE 596 as well as any 500-level NUCE courses taken to satisfy requirement #3 above. **NUCE 600 cannot be used as a substitute to meet this requirement.**
5. Students will write a paper on a topic mutually agreed upon by the advisor suitable for publication in a professional journal or presentation at a national or international conference. Students must take three (3) credits of NUCE 596 - Individual Studies in Nuclear Engineering representing formal recognition of the student's effort spent on writing a paper on an engineering subject. **A quality letter grade in NUCE 596 is required.**

- The final paper must be approved by the student's advisor, a faculty reader who is a current member of the Nuclear Engineering Graduate Faculty, and Chair of Graduate Studies.

6. The remaining credits must be courses at the 400- and/or 500-level as selected by the student with approval by the student's advisor as having significance and value for the degree program.

Specific course requirements:

a) **NUCE 480** *Foundation of Nuclear Engineering*
b) **NUCE 450** *Radiation Detection and Measurement* or **NUCE 497** *Radiation detection lab*

Students should take **NUCE 480** ***Foundations of Nuclear Engineering*** (3.00 credits) a reactor theory course, created as a substitute for NUCE 301 and 302. Students without a BS in NUCE are required to take this course.

NUCE 497 *Radiation Detection Lab* (1.00 credit) offered during Summer Sessions in a short course format, created as a substitute for NUCE 450. Note: This course has a brief in-person requirement held at the University Park campus.

Selection of a Faculty Reviewer (Paper Reader)
The scholarly paper reviewer/adviser is chosen by the student. The adviser must be a member of the Nuclear Engineering Graduate Faculty and appointed promptly to ensure they have enough time to review the work.

It is advised to have your research topic and adviser identified no later than the semester *prior to* the semester you will enroll in NUCE 596. It is also recommended that you have a draft of your paper already written and submitted to your adviser before the 596 semester begins.

If a reader is unable to be determined, one can be assigned by the Program Chair upon request.

*Every semester the Graduate School produces a calendar of deadline dates regarding graduation and thesis approval. This calendar is posted at: Academic Dates and Deadlines - J. Jeffrey and Ann Marie Fox Graduate School at Penn State (psu.edu)

MASTER OF SCIENCE DEGREE PROGRAM

The Master of Science (MS) degree program is designed for students to gain advanced knowledge for research, analysis, and design in nuclear engineering. A minimum of 30 credits at the 400, 500, 600, or 800 level is required, with least 18 credits at the 500 and 600 level combined. **Twelve credits must be in Nuclear Engineering**. Students need to take the NUCE 450 Radiation Detection and Measurement course (3 credits). This requirement may be waived for students with a B.S. in Nuclear Engineering; however, the minimum of 30 credits is still required. Students must petition the head of the graduate program to review their undergraduate transcripts to assess their eligibility for a waiver. Students must write a thesis, and at least 6 credits in thesis research (600 or 610) must be taken along with completing it. The thesis must be approved by the advisers and readers, the head of the graduate program, and the Graduate School.

ADMISSION REQUIREMENTS

Completion of an undergraduate degree in Nuclear Engineering or in another related engineering or science discipline is required for admission to the MS degree program in Nuclear Engineering. Students must have at least a 3.00 (4.00 base) junior-senior average to be considered for admission.

PROVISIONAL ADMISSION

Provisional admission is a temporary classification in which an applicant may stay for no longer than 2 semesters after admission or the time it takes to accrue 15 credits, whichever comes first. If the deficiencies that caused the provisional admission are not corrected by this time, the student may be dropped from the program.

NUCLEAR SECURITY OPTION – MS

An option in Nuclear Security is available for the MS degrees. To follow this option, students must complete 15 credits in the following courses: NUCE 441 (3 credits), NUCE 442 (3 credits), NUCE 542 (3 credits), NUCE 543 (3 credits), and NUCE 544 (3 credits).

PROGRAM REQUIREMENTS (MS)

Each of the following requirements must be met for the student to be approved for graduation:

1. All Nuclear Engineering students registered at a full-time level are required to schedule colloquium (NUCE 590), during the Fall and Spring Semesters.
2. A minimum of 30 graduate credits must be earned. Only grades of A, B, and C are accepted for graduate credit.
3. A minimum grade point average of 3.00 is required.
4. At least twelve (12) 400- or 500-level course credits must be NUCE courses.
    - A minimum of six credits must be NUCE 500-level courses.
5. At least eighteen (18) of the 30 required credits must be in 500-level courses.
    - This includes 6 credits of NUCE 600 Thesis Research, as well as any 500-level NUCE courses taken to satisfy requirement #3 above. **NUCE 596 cannot be used as a substitute to meet this requirement.**
6. The remaining credits must be courses at the 400- and 500-level as selected by the student with approval by the student's advisor as having significance and value for the degree program.

For students with a BS in Nuclear Engineering (some of) these requirements may have already been satisfied. Please consult with the Graduate Program Chair for verification.

Specific course requirements:

a) **NUCE 480** *Foundations of Nuclear Engineering*
b) **NUCE 450** *Radiation Detection and Measurement* or **NUCE 497***, Radiation Detec*tion Lab

Students should take **NUCE 480** *Foundations of Nuclear Engineering* (3.00 credits) a reactor theory course, created as a substitute for NUCE 301 and 302. Students without a BS in NUCE are required to take this course.

NUCE 497 *Radiation Detection Lab* (1.00 credit) offered during Summer Sessions in a short course format and is acceptable as a substitute for NUCE 450.

Note: This course has a brief in-person requirement held at the University Park campus.

Six (6) credits of thesis research, **NUCE 600**, must be taken followed by the submittal of a thesis that meets the Graduate School requirements. The thesis needs to be approved by the student's advisor, the Faculty Reader (a current member of the NUCE Graduate Faculty) and the Chair of Graduate Studies.

Summary of Master of Science Degree Requirements

It is the student's responsibility to ensure all requirements have been met promptly. Please read carefully the section of this manual titled *Academic Policies*.

* The Graduate School maintains a calendar of deadline dates regarding graduation and thesis approval. This calendar is posted http://gradschool.psu.edu/current-students/etd/thesisdissertationperformance-calendar/

DOCTOR OF PHILOSOPHY DEGREE PROGRAM

The Ph.D. program emphasizes scholarly research and helps students prepare for research and related careers in industry, government, and academia. Students are considered formally admitted as PhD candidates after passing written and oral portions of the Qualifying examination. The Ph.D. program is quite flexible, with minimal formal requirements. The Ph.D. degree is awarded upon completion of a program of advanced study that includes a minimum period of residence, the passing of the comprehensive exam, writing a PhD thesis and defend a thesis during the final oral examination as determined by the student's doctoral committee. Continuous registration is required of all Ph.D. students until the thesis is approved.

PROGRAM REQUIREMENTS

A doctoral program in Nuclear Engineering, as in all other disciplines at The Pennsylvania State University, consists of a collection of a body of work, including state-of-the-art research that meets the minimum requirements of the Graduate School, is assessed by exams and is approved by the Doctoral Committee for each individual candidate. No specified number of courses completed, or credits earned are required by the Nuclear Engineering Program. Typically, 45-55 credits of 400-500 level courses (including your M.S. program) plus NUCE 600 credits are needed. The numbers above (45-55 credits) are not construed as requirements; they are given merely to indicate to the Ph.D. candidate the typical number of graduate course credits taken by students before attaining their Ph.D. A student's individual program is to be worked out in consultation with the student's major advisor and doctoral committee. About half of the course credits should be in Nuclear Engineering courses and the other half in other disciplines, such as math, physics, or another engineering field. Registration in NUCE 590 Colloquium is required until completion of the Comprehensive exam.

A student entering the Ph.D. program without an MS or BS in Nuclear Engineering must take the following courses.

Courses are:

a) NUCE 480
b) NUCE 450
c) 6.00 credits from NUCE 500-level courses- <u>This does not include NUCE 596</u>

NUCLEAR ENGINEERING QUALIFYING EXAM

Objective: The objective of the Qualifying Exam is to perform an in-depth assessment of the student's preparation and ability to perform doctoral level scientific research. To that end, the basic knowledge of the student is proven by completed coursework, detailed in their academic plan, and further explored during the Oral exam.

Format and Frequency: The Qualifying Exam (QE) will be held two times per year – one in the January/February time frame and the other in September/October time frame. The Chair of the Graduate Studies Committee will chair both sessions. Both sessions are the same in format and logistics. The QE consists of two parts: an approved academic plan and an oral exam. Each student has two attempts to pass the Qualifying Exam.

Eligibility:

- All students are encouraged to participate in the Qualifying Exam within 3 semesters (not counting summer) of entry into the doctoral program.
- All students must have earned 18 credits in courses eligible to be counted toward the graduate degree (these may be graduate credits earned previously at other recognized institutions from which transfer credits would be accepted).
- All students, with approval from their advisors, will select 3 NUCE 400-level courses (500-level courses are also acceptable) to demonstrate their advanced undergraduate-level knowledge in relevant area(s) of PhD research.
- Once all 3 courses are completed with the required grades, the PhD student can participate in the oral exam.

Overall Evaluation: The overall evaluation of the student's performance in the Qualifying Exam will take into account both the oral and the courses completed in the academic plan. The committee may decide if the student must re-take the oral exam or complete additional coursework. The decision made by the committee is final. If the student fails the Qualifying Exam twice, the student will not be admitted to the Ph.D. program in nuclear engineering.

Content of Background/Literature
Content of Subject Domain (Fundamentals of NE)
Critique of Paper
Oral presentation Skills
Use of Written/Spoken English

English Competency: The Graduate School requires a high level of competence in the use of the English language. You will be given an English Proficiency Exam during your Qualifying exam. Based upon the assessment, coursework in Speech Communication and English will be identified to improve English competency and enable the student to meet the requirement. Competency will be formally attested after examination during the oral part of the Qualifying exam. The paper write-up and oral presentation during the Qualifying Exam also serve for the committee to judge the student's competency in written and oral communication in English. The committee's evaluation will be communicated to the student and the Graduate School at the end of the exam.

The Qualifying Exam Committee and the student's advisor certifies whether adequate proficiency in the English language has been demonstrated based on the paper and the oral exam. A student may pass the Qualifying exam but not be certified in English proficiency. In this case, the complete exam need not be taken again; but simply to demonstrate English proficiency the student may be advised to take a Speech Communication or English course. Upon improvement of English skills, the student must write another paper, make a verbal presentation and respond to questions by the Qualifying Exam Committee and advisor in the same manner.

Add QE Guidelines

Residency Requirement: During some 12-month period between completion of the Qualifying Exam and completion of the Ph.D. degree, the candidate must spend at least two consecutive semesters (Fall/Spring or Spring/Fall) as a registered, full-time student engaged in academic work at University Park.

Note: NUCE 601 cannot be used to meet the Graduate Schools Residency requirement.

THE DOCTORAL COMMITTEE

After the student passes the Qualifying Exam, their doctoral committee needs to be formed within one year. The doctoral committee is responsible for administering the Comprehensive Examination and/or approving the written doctoral thesis and the oral thesis defense. The formation of the doctoral committee is governed by the requirements of the Graduate School:

- Must include at least four active members of the Graduate Faculty,
- Must include at least three graduate faculty members from the Nuclear Engineering Program,
- At least one member of the committee must be a Penn State Graduate Faculty member from outside Nuclear Engineering,
- The chair, or at least one co-chair of the committee must be a Graduate Faculty member in Nuclear Engineering, and
- The student must work with the Graduate Program Staff to appoint a committee. A required form must be completed and submitted to the Graduate School for approval.

The committee is not limited to four faculty members and may include additional members who can contribute technical advice regarding the research. External members, e.g., scientists from national laboratories or industry, who are not at the University can be included as special members of a committee. Special members require additional approval, and upon formation of the committee, the student must provide the Graduate Program Staff with the following information:

- Special member email address
- Special member current CV
- Brief statement on the special member's expertise and how it is beneficial to the student's research

The doctoral committee is formed by the student in consultation with the main research advisor.

COMPREHENSIVE EXAMINATION

Students are required to take the PhD comprehensive examination. The objective of the examination is to provide feedback on the student's thesis project. This examination is administered by the doctoral committee and usually consists of a literature review and thesis proposal. Additional questions can cover the major and related areas of study.

Requirements are as follows:

- Students may not have deferred or missing grades;
- Must be registered full- or part-time for the semester in which the comprehensive exam is taken, including summers. Being registered for one credit of NUCE 600 is sufficient;
- The examination must be taken at least 3 months before the final oral examination;
- Notice must be given to the Graduate School at least two weeks before the exam and;
- Must coordinate with the Graduate Program Staff to schedule the exam.

The comprehensive examination consists of written and oral parts. The written part includes preparation of a Comprehensive Paper which details the research plan to be conducted, methods and proposed approach. The paper should include the following: abstract,

introduction, literature review, dissertation research proposal, summary of the research performed to date, detailed research plan to complete research with time-table, and conclusions with summary of the envisioned original contributions. **The paper should be provided to the doctoral committee at least two weeks before the exam**. The oral part consists of the presentation of Comprehensive Paper and answers to questions of the PhD committee. These questions can relate both to research and to general topics of nuclear engineering. The exam is given and evaluated by the entire doctoral committee. A favorable vote of at least two-thirds of the members of the committee is required to pass. In case of failure, it is the responsibility of the doctoral committee to determine whether the candidate may retake the examination.

*If a period of eight years has elapsed between the passing of the comprehensive examination and the completion of the program, the student is required to pass a **second** comprehensive examination before the final oral examination can be scheduled.*

CONTINUOUS REGISTRATION

After a PhD candidate has passed the comprehensive examination and has also met the two-semester full-time residence requirement, the student must register continuously for each fall and spring semester until the Final Oral Exam is passed and the PhD thesis is accepted and approved by the doctoral committee. http://bulletins.psu.edu/graduate/degreerequirements/degreeReq2 Post-comprehensive PhD students can maintain registration by registering in the usual way, or by registering for noncredit 601 or 611, depending upon whether they are devoting full-time or part-time to thesis preparation. Students may take 601 plus up to 3 additional credits of course work for audit by paying only the dissertation fee. Students wishing to take up to 3 additional credits of course work for credit, with 601 may do so by paying the dissertation fee and an additional flat fee. Students who want to combine course work with thesis preparation must register for 600 or 611 (not for 601, which is full-time thesis preparation).

Note: the least expensive way for a student to work full-time on research and thesis preparation is to register for 601.

FINAL ORAL EXAMINATION/PHD THESIS DEFENSE

Upon recommendation of the doctoral committee, a doctoral candidate who has satisfied all other requirements for the degree will be scheduled by the Graduate Program Staff to take their final oral examination. **It is the doctoral candidate's responsibility to provide a copy of the thesis to each member of the doctoral committee at least two weeks before the scheduled examination date.**

Other requirements are as follows:

- The final oral examination may not be scheduled until at least three months have elapsed after the comprehensive exam was passed;
- Two-weeks' notice must be given to the Graduate School for scheduling;
- Must work with the Graduate Program Staff to schedule this exam;
- The deadline for holding the exam in each semester is published in a calendar found on the Graduate School website. A copy of this calendar can be obtained from the following site: Thesis, Dissertation, Performance and Oral Presentation Deadlines Calendar (psu.edu)
- The student must be registered full- or part-time during the semester in which the final oral exam is taken.

The final examination is an oral examination administered and evaluated by the entire doctoral committee. It consists of an oral presentation of the thesis by the candidate and a period of questions and responses. The examination is related largely to the thesis, but it may cover the candidate's whole field of study without regard to courses that have been taken either at this University or elsewhere. The defense of the thesis should be well prepared, including any appropriate visual aids. The portion of the exam in which the thesis is presented is open to the public.

A favorable vote of at least two-thirds of the committee is required to pass. If a candidate fails, the committee will determine whether another examination may be taken later.

During the semester you are planning to graduate – please use the following process to complete and submit your final thesis/dissertation to the graduate school thesis and dissertation office (Different from the graduate program office).

MS Thesis	**PHD Dissertation**
Apply to graduate in Lionpath	Apply to graduate in Lionpath
Submit your format review (Front Matter, Back Matter, and a few chapters) to ETD site	Submit your format review (Front Matter, Back Matter, and a few chapters) to ETD site
Submit final thesis to ETD site	Pass final doctoral defense
Committee members approve thesis in ETD site	Submit final Dissertation to ETD site
	Committee members approve thesis in ETD site

SCHOLARSHIP AND RESEARCH INTEGRITY (CITI & SARI RCR)

Based on guidance provided by the Council of Graduate Schools in a report entitled "Graduate Education for the Responsible Conduct of Research (RCR)," the Scholarship and Research Integrity (SARI) program is an opportunity to engage graduate students broadly in a dialog surrounding issues pertinent to research ethics. The SARI program has two parts.

- SARI RCR (Responsible Conduct of Research) portion of SARI – complete during first year
- CITI (Collaborative Institutional Training Initiative) – complete during first semester

SARI RCR Overview

Every student must complete 5 hours of discussion-based SARI RCR (Responsible Conduct of Research) education **during their first year**. SARI RCR hours can be earned by attending SARI ORP events and/or SARI modules on Canvas. CITI online does not count toward the 5 hours of SARI RCR.

N**ot sure what you need to do to complete SARI?**

If you have any questions, ask Ashley by emailing alb5678@psu.edu.

CITI On-line Training

All graduate students in NUCE must complete the online CITI training program for engineering **within their first semester.** Completion of the CITI program will result in a certificate of completion. Failure to comply will preclude certification for graduation by the Graduate Program Staff.

1. Go to http://citi.psu.edu/
2. Select "Log in to CITI" under University Park
3. Enter your PSU credentials. (If this does not work, go to https://www.citiprogram.org/ instead, and create a username and password to access the CITI online training.)
4. Select the course called "Responsible Conduct of Research (RCR) – Basic"
5. Remember to email the certificate to after completing the course.

FACILITIES

The Radiation Science & Engineering Center (RSEC)
The RSEC facilities include the Penn State Breazeale Reactor, gamma-ray irradiation facilities (in-pool irradiator and dry irradiator), the Neutron Beam Laboratory, the Hot Cell Laboratory, the Radionuclear Applications Laboratory, the Radiochemistry Teaching Laboratory, the Nuclear Security Education Laboratory, the Subcritical Graphite Reactor Facility, and various radiation detection and measurement laboratories.

TRIGA Reactor
The TRIGA reactor system at the RSEC versatile reactor operating at a power level of 1 MW with a maximum thermal neutron flux of 2.7 x 10^{13} neutrons/cm^2-sec and can be pulsed to a peak power of 2000 MW with a maximum integrated output of 6 x 10^{16} neutrons/cm^2. The reactor core, suspended from a movable bridge, can be positioned in the "swimming pool" to provide the most effective experimental setup. Special equipment directly associated with the reactor includes a D_2O thermal column, pneumatic "rabbit" tubes, several beam ports, and a traversing experimental ridge. The reactor normally operates one shift per day, five days a week. More information is at https://www.rsec.psu.edu/

Neutron Beam Laboratory
The Neutron Beam Laboratory (NBL) is one of the most used facilities at the RSEC. Well-collimated beams of neutrons, thermalized by D_2O, are passed into the NBL for use in various neutron beam techniques. When the reactor core is placed next to the D_2O tank and graphite reflector assembly near the beam port locations, thermal neutron beams become available for neutron transmission and neutron radiography measurements from two of the seven existing beam ports.

The RSEC has a facility specifically designed to measure the ^{10}B concentration in neutron-absorbing materials and has been working in this field since 1998. The facility and the measurement method are used to characterize the effectiveness of most boron-based aluminum neutron-absorbing materials used by the nuclear industry. The neutron beam laboratory also houses a neutron imaging facility for the inspection of materials.

Nuclear Security Education Laboratory
The primary goal of this laboratory is to provide students with hands-on experience with radiation detection systems, sensors, devices, and source technologies. Students can become familiar with major radiation detectors/sensors and radiation sources, understand the principles of radiation interactions with matter, demonstrate an understanding of the principles of radiation detection and measurement, nuclear instrumentation, detectors/sensors, field

deployable devices, portal monitors, dosimeters, and nondestructive and destructive assay methods, as well as demonstrate an ability to conduct experiments, acquire data, and analyze and interpret the data. The following experiments are designed and included in the course designed for the equipment in this laboratory: neutron multiplicity measurements, identifying the differences between neutron emissions from (a, n) reactions and spontaneous fission sources by use of neutron counting and neutron coincidence counting measurements, gamma-ray spectroscopy systems for versatile in-situ counting (identification of unknown radionuclides with various gamma spectroscopy systems), environmental media characterization (soil, air, water, etc.), alpha source activity determination, special nuclear materials gamma-ray spectroscopy analysis, measurement of ^{235}U enrichment and quantity of uranium in a sample, Pu/U ratio analysis, Pu isotopic composition determination by gamma-ray spectroscopy, radiation counting of known source materials for counting statistics, precision and accuracy, and MDA determination, determinate corrections in radiation counting (absorption, backscatter, geometry considerations, detectors and supporting electronics), liquid scintillator detectors for pulse shape discrimination for neutron and gamma-ray sources, and absolute activity measurement using coincidence counting.

Radiochemistry Teaching and Research Laboratory
The RSEC recently created a new radiochemistry research laboratory. This wet chemistry laboratory is equipped with a radioactive materials capable fume hood, a HEPA-filtered inert atmosphere glove box for radiochemical use, and a suite of chemicals and laboratory materials for radiochemical applications. The radiochemistry teaching laboratory was created several years ago with funding from DOE – REAP and NRC curriculum development funds, and provides a space for undergraduate and graduate students to obtain hands on experience with essential radiochemical concepts and techniques for applications in radionuclide detection and separations, environmental studies, nuclear fuel reprocessing, and nuclear forensics.

Radionuclear Applications Laboratory (RAL)
The RSEC RAL provides technical assistance to research personnel and industrial users who need to use radionuclear techniques in their research. The laboratory houses four complete high-purity germanium detector systems with state-of-the-art electronics, multiple computer systems, and two automated sample changers. A Compton suppression system was added to enhance the sensitivity of measurements made in the laboratory. A pneumatic tube transport system allows samples to be transported safely and quickly between the reactor core and the laboratory workstation

Cobalt-60 Gamma Ray Irradiation
The Radiation Science and Engineering Center has two gamma-ray irradiation facilities, which provide flexibility for research and industry projects. The Center has a pool irradiator with movable sources that can be configured to suit the researcher. Discrete neutron sources can be inserted in the pool to provide a mixed field. There is also a dry cell gamma irradiator that has a much higher dose rate for samples that require it. Using these two facilities, doses of kiloRads to GigaRads can be provided to the researcher.

Hot Cells
The RSEC Hot Cell Laboratory (HCL) houses two shielded enclosures for work with significant amounts of radioactive materials. The cells can handle 100-350 curies of activity depending on the shielding configuration. Both cells have several access plugs including roof plugs to the reactor bay so samples can come from the reactor pool and into the cells without leaving a controlled area. The hot cells also have transfer capability from one cell to the other using the electro-mechanical manipulators. The cells are HEPA filtered and are kept at a negative

pressure during use. The HCL has its own loading dock and crane system that can move casks directly from the cells onto a waiting truck.

Subcritical Graphite Reactor
The graphite sub-critical reactor facility (GSR) was constructed at Penn State in 1958 as part of a graduate student project. The pile was intended to expand upon the research reactor facility's capabilities to educate students in the burgeoning field of nuclear engineering. Since then, it has been used continuously for 55 years as part of the reactor physics curriculum. Currently the GSR is used as the basis for teaching subcritical physics to approximately 100 undergraduate students each year. Additionally, the facility is used by researchers who require a well-thermalized neutron field for their experiments. Recently, the facility has been used to develop sensitive neutron detectors for nuclear safeguards purposes.

Nuclear Engineering for Medicine and Biology. Nuclear medicine is a field of healthcare that uses radioactive or non-reactive materials to diagnose and image internal body processes. It combines aspects of nuclear physics, medical radiology, and nuclear chemistry to provide valuable insights into a variety of medical conditions. Nuclear medicine is also used to treat complex diseases. Laboratory of materials in medicine is developing cutting edge technologies to address complex biomedical problems. Located in the Huck Institute of Life Sciences, this laboratory applies nuclear engineering principles covering diagnostics, imaging and therapy.

COURSE DESCRIPTIONS

Updated Course Schedule can be found on LionPATH or at http://launch.lionpath.psu.edu/

Undergraduate (400 Level Courses)

403 ADVANCED REACTOR DESIGN (3) Physical principles and computational methods for reactor analysis and design. Multigroup diffusion theory; determination of fast and thermal group constants; cell calculations for heterogeneous core lattices. Prerequisite: NUCE 302.

405 (CHEM 405) NUCLEAR AND RADIOCHEMISTRY (3) Theory of radioactive decay processes, nuclear properties and structure, nuclear reactions, interactions of radiation with matter, biological effects of radiation. Prerequisites: PHYS 237 or CHEM 452 or NUCE 301.

408 RADIATION SHIELDING (3): Radiation sources in reactor systems; attenuation of gamma rays and neutrons; point kernel methods; deep penetration theories; Monte Carlo methods.

409 (MATSE 409) NUCLEAR MATERIALS (3) Nuclear reactor materials: relationship between changes in material properties and microstructural evolution of nuclear cladding and fuel under irradiation. Prerequisite: PHYS 203 or 204

420 RADIOLOGICAL SAFETY (3) Ionizing radiation, biological effects, radiation measurement, dose computational techniques, local and federal regulations, exposure control. Prerequisites: MATH 251, PHYS 237 or 265, or NUCE 301.

428 RADIOACTIVE WASTE CONTROL (3) Nature, sources, and control of radioactive wastes; theory and practice of disposal processes. Prerequisites: NUCE 301 or instructor permission.

430 DESIGN PRINCIPLES OF REACTOR SYSTEMS (3) Nuclear power cycles; heat removal problems; kinetic behavior of nuclear systems; material and structural design problems. Prerequisites: M E 412; NUCE 301 or 401.

431 NUCLEAR REACTOR CORE DESIGN SYNTHESIS (4) Technical and economic optimization of nuclear systems. Prerequisites: ENGL 202C; NUC E 403 and 430.

441 NUCLEAR SECURITY THREAT ANALYSIS AND ASSESSMENT (3) Nuclear threat assessment and analysis for non-state actors to nuclear and radiological facilities and supply lines. Prerequisite: NUCE 301

442 NUCLEAR SECURITY SYSTEM DESIGN (3) Science and engineering associated with the design, evaluation, and implementation of systems to secure nuclear and radiological materials. Prerequisite: NUCE 302

450 RADIATION DETECTION AND MEASUREMENT (3) Theory and laboratory applications of radiation detectors, including proton, neutron, charged particle detectors. NIM devices, and pulse-height analysis. Prerequisite: NUCE 301 or NUCE 405.

451 EXPERIMENTS IN REACTOR PHYSICS (3) Acquisition and processing nuclear and atomic data; application to nucleonic phenomena of importance in nuclear engineering. Prerequisites: NUCE 450, EE 305.

460 NUCLEAR SYSTEMS RISK ASSESSMENT (3) Probability concepts and distributions, failure data, reliability and availability of simple systems, fault and event tree analysis, risk concepts, nuclear power risks, WASH-1400. Prerequisite: NUCE 309 or STAT 401.

470 POWER PLANT SIMULATION (3) Basic knowledge necessary for intelligent simulation and interpretation of simulations of transients in nuclear power plants. Prerequisite(s): ME 33, MATH 251, NUCE 302

480 FOUNDATIONS OF NUCLEAR ENGINEERING (3) An intensive course providing introduction to NUCE to undergraduate co-op students, non-NucE graduate, and returning students.

490 (AERSP 490, EE 490) INTRODUCTION TO PLASMAS (3) Plasma oscillations; collisional phenomena; transport properties; orbit theory; typical electric discharge phenomena. Prerequisite: EE 361 or PHYS 467.

Graduate (500 Level Courses)

501 REACTOR ENGINEERING (3) Thermal hydraulic fundamentals including thermal hydraulic characteristics of power reactors, thermal design principles, reactor heat generators, thermal analysis of fuel elements and size and two-phase heat transfer in heated channels. Prerequisites: NUCE 302; NUCE 430

502 REACTOR CORE THERMAL-HYDRAULICS (3) In-depth analysis of the thermal hydraulic design in LWRs. Topics include: LWR design criteria, fuel rod design, subchannel analysis, uncertainties analysis, and system design. Prerequisite: NUCE 501

505 REACTOR INSTRUMENTATION AND CONTROL (3) Reactor control principles; classical control methods; operational control problems; control simulation using modern mainframe and microcomputer software packages; reactor instrumentation. Prerequisite: NUC E 302 or NUCE 401

511 NUCLEAR REACTOR KINETICS AND DYNAMICS (3) Analytical kinetics and dynamics modeling for reactivity-induced transients, applications including reactor accident kinetics methods for simple and complex geometries, experimental methods.

512 NUCLEAR FUEL MANAGEMENT (3) Develop advanced techniques for reloading nuclear reactors using sophisticated neutronic codes. Emphasis on calculational techniques in reactor optimization and design, and economic value through the fuel cycle. Prerequisite: NUCE 302.

521 NEUTRON TRANSPORT THEORY (3) Derivation of Boltzmann equation for neutron transport; techniques of approximate and exact solution for the monoenergetic and spectrum regenerating cases. Prerequisite: NUCE 403 or PHYS 406

523 ENVIRONMENTAL DEGRADATIONS OF MATERIALS IN NUCLEAR POWER PLANTS (3) covers the electrochemistry and materials aspect of the in-reactor degradation processes that affect materials performance. Uniform and localized cladding corrosion, stress-corrosion cracking irradiation creep and growth.

525 MONTE CARLO METHODS (3) Fundamentals of the probability theory and statistics, analog and non-analog Monte Carlo methods and their applications, random processes, and numbers. Prerequisite: CMPSC 201, MATH 141, NUCE 309 or STAT 401.

530 PARALLEL/VECTOR ALGORITHMS FOR SCIENTIFIC APPLICATIONS (3) Development/analysis of parallel/vector algorithms (finite-differencing of PDEs and Monte Carlo methods) for engineering/scientific applications for shared and distributed memory architectures. Prerequisites: AERSP 424 or CSE 457.

542 SOURCE AND DETECTOR TECHNOLOGIES FOR NUCLEAR SECURITY (3) Theory and technology behind detectors, sensors, and source technologies including portal monitors and field deployable detection systems. Prerequisite: NUCE 450

543 NUCLEAR SECURITY EDUCATION LABORATORY (3) Hands-on experience with the radiation detection systems, sensors, devices, and source technologies for nuclear security. Prerequisites: NUCE 450, NUCE 542

544 GLOBAL NUCLEAR SECURITY POLICIES (3) Reviews historical development and examines the current state of American and International policies and laws related to global nuclear security.

597 NUCLEAR AND PARTICLE PHYSICS FOR NUCLEAR SCIENCE (3) Fundamental forces, elementary particles, the Standard Model and beyond, nuclear decay and reactions, quantum theory. Prerequisites: NUCE 403, NUCE 450.

597 NUCLEAR MEDICINE (3) Clinicians practice nuclear medicine every day with help from nuclear biologists, chemists, and medical physicists. The field of nanomedicine, on the other hand combines nanomaterials, biological and nanoelectronics devices, biosensors, and possibly molecular nanotechnology to treat diseases.

See also the seminar and thesis courses on pages 6 and 7.

Faculty Research Interests

The Department actively conducts research to generate new knowledge that will strengthen and support undergraduate and graduate education at Penn State, in the United States, and the World. More information on each of our research areas can be found at: https://www.nuce.psu.edu/research/index.aspx

TO MAKE A REPORT

A summary of types of misconduct and how to report is available at http://reporting.psu.edu

Crime or emergency situation

- Contact the campus police (814-863-1111) or security office
- In an emergency, dial **911**

If at any point you are unsure where to report a non-emergency, you may contact:

- The Office of Ethics and Compliance, Monday-Friday, 8am-5pm ET: 814-867-5088

The Penn State Hotline, 24/7: 800-560-1637 or http://hotline.psu.edu

Penn State has established a Responsible Action Protocol in response to the University Park Undergraduate Association's campaign for a medical amnesty policy. Effective January 2018, the Responsible Action Protocol was updated and now reflects the following:

- A student who acts responsibly by notifying the appropriate authorities (e.g. calling 911, alerting a resident assistant, contacting police) AND meets one or more of the following criteria typically will not face University conduct action for his or her own use or possession of alcohol or drugs. However, the student will be required to attend an approved alcohol or drug education program, such as BASICS or the Marijuana Intervention Program (MIP); the fee will be waived. When the student's behavior involves other Code of Conduct violations (e.g., vandalism, assault, furnishing to minors) the additional behavior may be subject to conduct action. If a student exhibits a pattern of problematic behavior with alcohol or drugs, that student may be subject to conduct action.
- The criteria which invoke the Protocol are:
    - A student seeks medical assistance *for himself or herself* when experiencing an alcohol or drug overdose or related problems
    - A student seeks medical assistance *for a peer* suffering from an alcohol or drug overdose or related problems
    - A student suffering from an alcohol or drug overdose or related problems, *for whom another student seeks assistance* will also not be subject to conduct action for alcohol violations.

Suspected ethical or policy violations

(including fraud, theft, conflict of interest, abusive or intimidating behavior, retaliation, athletics integrity or NCAA compliance)

- Report employee misconduct to your supervisor or HR Strategic Partner
- Report student misconduct to the Office of Student Conduct or call **814-863-0342**
- Use the Penn State Hotline at **800-560-1637** or http://hotline.psu.edu. Both are anonymous and available 24/7

Child abuse, including child sexual abuse

- Contact the Pennsylvania Child Welfare Services "ChildLine" at **800-932-0313** or https://www.compass.state.pa.us/cwis
- If the child is in immediate danger, dial **911** first
- You must also email AD72@psu.edu communicating that a report has been made. For more information on AD72 (Reporting Suspected Child Abuse), see https://guru.psu.edu/policies/AD72.html
- Further details can be found in the "Building a Safe Penn State: Reporting Child Abuse" training available on the Learning Resource Network at http://lrn.psu.edu

Behavioral threat

- Contact the Behavioral Threat Management Team at **855-863-BTMT (2868)**, **814-863-BTMT (2868)**, or http://btmt.psu.edu/

Bias, discrimination, or harassment

- To report behavior *by an employee*, contact the Affirmative Action Office at **814-863-0471**
- Visit the Report Bias website: http://equity.psu.edu/reportbias (For student reporting only)
- Acts of intolerance by students may be reported to the Office of Student Conduct at **814-863-0342**

Sexual harassment and other forms of sexual misconduct**

To make a report to the University:

- Contact the University's Title IX Coordinator at **814-867-0099** or titleix@psu.edu.
- **To file an online report:** Visit the Office of Sexual Misconduct Prevention and Response's website at http://titleix.psu.edu/filing-a-report/ to file an online report
- **To file an anonymous report:** The Penn State Hotline is available 24/7 at 800-560-1637 or http://hotline.psu.edu. Both are anonymous and available 24/7.

**** Additional information regarding information and resources available in relation to incidents of sexual harassment and/or misconduct (including a campus-specific list of victim support services and confidential reporting options) can be found at http://titleix.psu.edu/**

To file a discrimination or harassment complaint outside of the University:

- The Office for Civil Rights (Philadelphia Office) at **215-656-8541** or email OCR.Philadelphia@ed.gov
- The Equal Employment Opportunity Commission (Philadelphia District Office) at **800-669-4000**
- The Pennsylvania Human Relations Commission (Harrisburg Regional Office) at **717-787-9780**

Student misconduct

- Contact the Office of Student Conduct at **814-863-0342** or http://studentaffairs.psu.edu/conduct or report at https://pennstate.qualtrics.com/jfe/form/SV_8qYxyWYciWERPGI
- Hazing by any student organization or individual is against Penn State's code of conduct, and also a violation of Pennsylvania law. To report instances of hazing within any student organization or group, including fraternities and sororities, contact the Office of Student Conduct (http://studentaffairs.psu.edu/conduct or **814-863-0342**) or the Penn State Hotline at **800-560-1637** or http://hotline.psu.edu

Research-related

- Any research-related concerns should be directed to the Office for Research Protections at **814-865-1775** or orp@psu.edu
- Research misconduct concerns should be directed to 814-865-1775 or researchconcerns@psu.edu

RESOURCES

- Policy AD88 - Code of Responsible Conduct
- By-laws of The Pennsylvania State University (section 8.13): http://news.psu.edu/story/143476/2013/01/04/employees-reminded-disclose-conflicts-interest
- Policy HR91 – Conflict of Interest: https://guru.psu.edu/policies/OHR/hr91.html
- Policy RP02 - Addressing Allegations of Research Misconduct: https://guru.psu.edu/policies/RP02.html
- Policy RP06 – Disclosure and Management of Significant Financial Interests: https://guru.psu.edu/policies/RA20.html
- Policy AD74 - Compliance with Clery Act: https://policy.psu.edu/policies/ad74
- Policy AD77 - Engaging in Outside Professional Activities (Conflict of Commitment): http://guru.psu.edu/policies/AD77.html

- Policy AD85 - Sexual and/or Gender-Based Harassment and Misconduct (including Sexual Harassment, Sexual Assault, Dating Violence, Stalking, and Related Inappropriate Conduct): https://guru.psu.edu/policies/AD85.html
- Policy AD86 – Acceptance of Gifts and Entertainment: https://guru.psu.edu/policies/AD86.html
- Policy AD91 - Discrimination and Harassment and Related Inappropriate Conduct: https://guru.psu.edu/policies/AD91.html

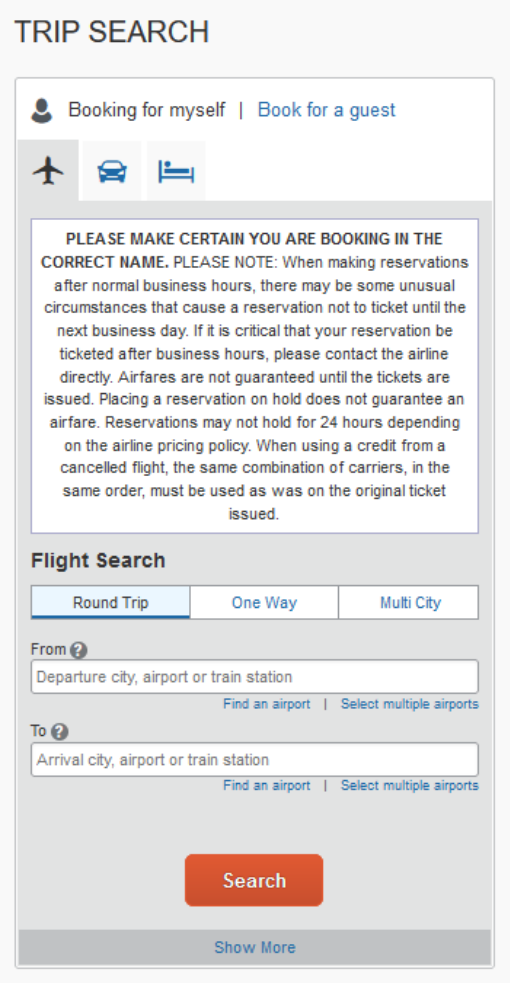
If it is not clear where to turn for assistance, any of these offices will guide you to someone who can help:

- Office of Human Resources Employee Relations Division at **814-865-1412** or http://ohr.psu.edu/employee-relations/
- Office of University Ethics and Compliance at **814-867-5088** or http://www.universityethics.psu.edu/
- Office of Affirmative Action at **814-863-0471** or http://www.psu.edu/dept/aaoffice/
- Office of Sexual Misconduct Prevention and Response at **814-867-0099** or titleix@psu.edu
- Office of Student Conduct at **814-863-0342** or http://studentaffairs.psu.edu/conduct
- Office of Internal Audit at **814-865-9596** or http://www.internalaudit.psu.edu/
- Clery Act Compliance Manager at **814-863-1273** or http://www.police.psu.edu/clery/
- Your campus, college, or unit's Human Resources Strategic Partner. Contact information is available at http://ohr.psu.edu/content/hr-strategic-partner-and-consultant-directory

APPENDIX

Traveling through SAP Concur

When booking your flight, Anthony Travel provided in SAP Concur can help you. Anthony Travel acts as a booking agent for Penn State University. The "Trip Search" can be found on the home page of SAP Concur. The University strongly insists you to book through SAP Concur. Anthony Travel benefits include, but not limited to:



* Access to an after-hours (24/7) service so travelers can quickly resolve issues when on the road outside of normal business hours
* No comparisons needed when requesting travel reimbursement since Anthony Travel is the University's approved travel agency
* No booking fees
* Access to deeper discounts through Anthony Travel's vast international network of travel industry partners
* A dedicated account team from Anthony Travel that supports Penn State travelers' requests during the University's business hours and mirrors Penn State's holiday schedule

PSU has contracts with National and Enterprise that can be booked through www.travel.psu.edu/rental-cars. If cheaper, please reserve a fleet vehicle.
If there is nothing available, you may rent a vehicle through a different source, however, you must document the reasoning through travel on-lion. *Reminder: traveling more than 7,500 miles requires a flight.*

HELPFUL TIP:
When traveling, keeping a log would be useful to provide to the financial assistant. This could include dates and times of what your day looked like.

Anthony Travel is there to help you!

Need help with business related Travel Reservations? Contact ANTHONY TRAVEL
Call **814-258-6111 / 833-827-3331** or email
pennstate@anthonytravel.com

Timeline

Planning the trip

This will be anything you can reserve prior to leaving.

Example

-Flight

Book on SAP Concur using Anthony Travel

-Hotel

-Anything necessary (car rental (book through SAP Concur), etc)

**Save all confirmations to submit for reimbursement.

Taking the trip

Make sure ALL expenses can be accounted for. Always collect receipts or confirmations.

Example

-Check bags

-Car Rental/Uber

-Parking

Returning from the trip

This is where you will collect all your information and submit it

Upload all receipts and information to the Financial Assistant within 60 days of returning. Provide all information pertaining to the business trip. Please include the Internal Order (IO) you would like the trip to be charged to.

When submitting, provide a description that includes the "5 W's".
Who, What, When, Where, Why

<u>This is necessary for the report to be completed.</u>

Include: -If you paid out of pocket for all meals or if you attended any luncheons etc.

-Itinerary of the event/conference that was attended

-Reasoning on the attached documents

-If receipts cannot be obtained like cab fare, parking, etc. provide this information amongst the email

*Without providing all this information, your reimbursement may not get approved.

-Per Diem

Depending on where you are traveling will depend on the Per Diem rate. You can only collect this if you did not attend provided meals.

Helpful Links

https://sapconcur.psu.edu/
https://ers.psu.edu/mobile-apps-ers
https://virusinfo.psu.edu/travel-guidelines/
https://tsn.psu.edu/

Traveler Reimbursement Checklist used for domestic and international travel
https://guru.psu.edu/Forms/travel-reimbursement-checklist-CONUS-SIMBA.pdf
https://guru.psu.edu/Forms/travel-reimbursement-checklist-OCONUS-SIMBA.pdf

Common Questions

What if I did not book through Anthony Travel in SAP Concur?

While the University highly recommends you to book through SAP Concur, you may go through another booking agent. When doing this, you MUST provide screenshots showing amounts elsewhere to show why the purchase was made outside of SAP Concur.
*Without providing this extra information, your reimbursement may not get approved.

Is there anything I need to do prior to international travel?

Anytime there is international travel involved with business related, the trip needs documented to the TSN-Travel Safety Network. This needs done prior to the travel NOT afterwards. Failure to do so can jeopardize reimbursement of expenses and this at the discretion of the university. https://tsn.psu.edu/

Reimbursing expenses incurred during travel

SAP Concur mobile App https://ers.psu.edu/mobile-apps-ers

- Book flights, rental cars, hotel, and travel directions directly through App
- Check status of reports

How long will it take to be reimbursed if I pay with my own funds?

If you are paid by PSU, your reimbursement will be direct deposited into your same account as your pay within roughly 3-5 business days after approval. If you aren't paid by PSU, a check will be cut and mailed to the address you indicate on the form, and you should receive the check roughly 5-7 days business days depending on where the address is.

Qualifying Exam Guidelines and Procedures

The objective of the Qualifying Exam (QE) is to assess (i) the student's basic knowledge of a breadth nuclear engineering topics and (ii) the ability of the student to perform research while reading and evaluating the literature, as well as to think on their feet and answer scientific questions. In addition, the QE is also the means by which the writing and speaking abilities of the student are officially evaluated.

Preparing the Proposal

1. The students should (i) let the NucE Graduate Program Coordinator know they intend to take the exam in a given semester by the due date published and (ii) select 3 areas out of the 8 listed below, while specifying three courses (one course in each area) that the student has taken with a grade of B+ or higher[1]. See attached document "*Topic Areas and Associated NucE Courses*".
2. Student writes a half-page summary of the QE research proposal by the due date published. The summary should address how the courses taken have prepared the student for the intended research. For each of the courses listed, the student should mention what has been learned and how that knowledge can help future research.

Once all the students who wish to take the QE exam are tallied, their QE proposals are evaluated by the Graduate Studies Committee (GSC), and the students are informed about GSC's decisions. A specific QE date for each student will then be established. A QE Committee also will be established. To the extent possible, its composition will be based on the areas the student has selected. The student's advisor may attend the exam for support but will not serve as a member of the QE Committee.

The QE Steps/Timeline

1. The advisor should choose a research paper for the student to present to the committee during the QE[2]. The paper will be given to the student exactly10 days before the scheduled QE date and the student's review (instructions annexed) is due to the QE Committee 3 days before the scheduled exam.
2. The first hour of the QE is devoted to a presentation of the paper chosen by the advisor. The presentation should not last more than 35 minutes before questions. The student should follow the attached guidelines for an effective presentation.
3. During the second hour, the student will be quizzed by the QE Committee on three topic areas from the attached list that the student has chosen with the advisor.
4. The grading of the paper review by the student is based on (i) the depth of the student's knowledge of the subject matter in the paper, (ii) the ability to express

[1] Courses must be 400-level and above. Note that the advisor's research area must be one of the chosen areas picked. Also note that up to one course outside the department may exceptionally be considered. Finally, note that the same course cannot be used for two areas.

[2] See attached document "*Orientation for Advisor to Choose the QE Paper*".

the ideas the student has on the paper in clear English (grammar and spelling do count), and (iii) the ability of the student to critically evaluate the research presented in the paper to demonstrate their ability to absorb information for their own research. The grading of the paper also serves as evidence that the student is proficient in English writing for a scientific audience.

5. The grading of the student's presentation of the paper is based on (i) clarity of the presentation, (ii) factual accuracy of the paper review, and (iii) answers to the questions posed by the QE Committee. Students should look at the advice for effective presentations (see attached "*Guideline for Preparing and Delivering Effective Presentations*").
6. For the second hour, the student will be graded on their basic knowledge of the three areas chosen as demonstrated by the answers to the QE Committee's questions. The assessment of the student presentation serves as evidence that the student can effectively communicate scientific concepts in clear English.
7. The student's overall performance is assessed during the QE exam. If approved, the student becomes a PhD candidate in nuclear engineering. Finally, the QE Committee may request specific courses or remediation strategies to address any possible shortcomings.

Guideline for Preparing and Delivering Effective Presentations

Preparing the Presentation

1. To communicate to the audience the contents of the critical review of the assigned paper, the student should address the following:

    a. Background for the work: Explain why the work was done. Consider preparing some additional background material suitable for the audience.
    b. Content: What was done and why, and what is the significance of the work. Was there significant impact on the literature in the subsequent years?
    c. Critical Review: What shortcomings or limitations characterize the investigation reported in the paper. What was especially important about the paper.

2. Remember to aim the presentation at an audience that, while technically knowledgeable, may not have any direct expertise in the specific field of work of the student thesis. The student should not assume that the audience is as knowledgeable about the subject as they are.

3. Organize the presentation into sections using a Table of Contents, or Outline. The first section should give the background of the assigned paper. It should be understandable to other students in nuclear engineering and include an effective explanation of the motivation of the work reported in the paper.

4. It is good practice to use the slides as a reminder of important points that need to be made during the presentation and their references. Bulleted lists are an effective way of doing that.

5. When preparing the presentation, count on spending between 1 and 2 minutes per slide. This means that for a 35-minute presentation the student should prepare between 18 and 35 slides.

6. Make the slides readable using large print, use color to illustrate the main points, and limit the amount of information to the level that the audience can absorb within the presentation time.

7. Rehearse the presentation. Have friends and colleagues participate and ask simple questions about the importance of the research performed in the paper, and about nuclear engineering in general.

Delivering the Presentation

1. Understand the message to be conveyed, make it simple and direct. Do not display material that could elicit unwelcome questions. Use backup slides to answer anticipated questions (if any).

2. Speak with a clear voice and face the audience (the QE Committee) during the presentation not the screen or board. Make eye contact with the audience.

3. Rehearse the presentation in front of an audience (possibly fellow graduate students), or in front of a mirror.

4. Time the presentation to ensure that it can be performed within the allotted time limit and encourage feedback from fellow students.

Orientation for Advisor to Choose the QE Paper

The paper selected should follow these constraints:

1. It should be a paper within the advisor's area of expertise, but not directly on the student's research topic.

2. Choose a paper that contains impactful research, preferably containing some data (simulated and/or experimental) analysis.

3. Avoid selecting a comprehensive review paper as starting PhD students will have a difficult time evaluating it.

4. The paper should not be overly long nor overly short, approximately 8-12 journal pages.

Topic Areas and Associated NucE Courses

#	Area	Courses	Topics
1	Fundamentals of Nuclear Physics	420, 450, 480	Nuclear Reactions (fission, capture, particle emission, transmutation) Atomic Reactions Stability/Instability of Nuclei Radioactive Decay Alpha, Beta, X-ray/Gamma, Neutron, Ion Radiation Interaction of Radiation with Matter Counting Statistics Fissile/Fertile/Fissionable Enrichment Neutron Moderator Thermal and Fast Neutrons

2	Reactor Physics	403, 451, 525	Nuclear Chain Reaction 4/6 Factor Formula Delayed Neutrons/Criticality Reactivity Coefficients, Doppler Effect (temperature, void) Neutron Poison and Burnable Absorber/Poison PWR, BWR, Breeder Reactor Neutron Flux Control Rods

3	Thermal Hydraulics	430, 501 502	Reactor Design (fuel, cladding, core, channels, PWR/BWR, containment, balance of plant) Safety Concepts: Design Basis Accidents Defense-in-Depth/ Redundancy Emergency Core Cooling System Rod Bundle Heat Transfer (including thermal limits - CHF, DNB, dryout) Thermal Efficiency
4	Materials	409, 509, 597[3], 523	Materials Used in Reactor Atomic Displacements/Microstructure Development Ductility/Embrittlement Radiation Damage to Materials Stress/Strain Curve, Deformation under Irradiation Chemical Effects - Corrosion

[3] Computational Materials

5	Nuclear Security	441, 442, 542, 543, 544, 597[4]	Radiation Detection Systems for Nuclear Security (passive versus active) Special Nuclear Materials/NORM Signatures Nuclear Security Policies Threat Analysis and Assessment Security Systems for Nuclear Facilities (commercial/research nuclear reactors, enrichment, fuel fabrication, fuel reprocessing) Nuclear Security versus Safety versus Safeguards

[4] Safeguards by Design

6	Health Physics	420	Radiation Dose: REM/Rad and Sievert/Gray units Absorbed Dose versus Equivalent Dose Radiation dose Limits Natural Background Radiation Linear Non-Threshold Model and ALARA Shielding for Different Radiation Types Radiation Protection Concepts Biological Effects of Radiation: (short term versus long term, deterministic versus stochastic)
7	Nuclear fusion	497[5] and 597[6]	Fusion Reactions Plasma Plasma Containment Strategy (ICF/tokamaks), Magnets Breeding Blankets Plasma instabilities Fusion Neutrons and Radiation Damage

[5] Introduction to Fusion
[6] Plasma Physics

8	Radioactive Waste and Radiochemistry	428 and 405	Fundamentals of Reprocessing Geologic Disposal of Radioactive Waste Waste Release Mechanisms Radionuclide Migration Dry Storage Spent Fuel Pool Decay Times Fission Products and Actinides