FISSION SYSTEMS AND RADIATION TRANSPORT

Introduction

The guidelines outlined in this document are intended to supplement the general information on graduate programs provided by Nuclear Engineering and Radiological Sciences (NERS), the College of Engineering, and the Rackham School of Graduate Studies.

Master's and Doctoral Degree Requirements

See the Rackham School of Graduate Studies Academic Policies website for graduation requirements information at: http://www.rackham.umich.edu/current-students/policies/academic-policies. Also, see the supplementary Master's and Ph.D. Graduation Requirements and corresponding checklists for Nuclear Engineering and Radiological Sciences. All checklists should be reviewed in the term prior to graduation for the master's degree and the term in which candidacy is achieved for the doctoral program.

Graduate Advising

Students will be assigned an advisor when they first join the graduate program. However, this assignment is tentative, and students should not be reluctant to change advisors once they have come to understand how their interests mesh with those of the various faculty members in the department. For students carrying out graduate research, the research supervisor is also their academic advisor. Before registering for a future term, the student must discuss courses with the advisor.

Fission Systems and Radiation Transport

This graduate option encompasses many related fields, including computational physics. The program encompasses some of the most exciting and challenging work in technology today. Various specific topics of research are:

- Production of energy
- Electric power generation design
- Reactor fuel design
- Design and construction of third and fourth generation power stations
- Nuclear reactor theory
- Thermal hydraulics
- Fuel cycle analysis
- Reactor kinetics
- Diagnostics, control, and optimization
- Computational simulations
- Neutron transport (theory and applications)
- Applications of these simulations in overlapping areas such as radiation protection, radiation cancer therapy, radiation-hydrodynamics, kinetic theory, and general computational physics
- Applications of radiation interactions and radiation transport through matter

A sample course schedule leading to the master's degree in 3 academic terms is outlined below. However, students working toward the Ph.D. degree or receiving financial support should engage in research and may not complete their master's requirements until their fourth term or later. The courses of special interest to students in fission systems and radiation transport are also listed in this guide, and a description of the topics covered on the fission systems and radiation transport Ph.D. candidacy exam is provided.

Sample Master's Program

A sample master's course sequence suitable for students interested in Fission Systems & Radiation Transport is presented in Table 1. Students are encouraged to design their own program of study in consultation with their graduate advisor, taking into account their specific backgrounds and professional goals. The following sample schedule would allow the student to obtain a master's degree in three full terms. It is possible to finish the master's degree in one calendar year but this will require taking courses (or NERS 599, Masters Project) in the spring or summer terms. This schedule is considered to be demanding; students usually elect fewer courses per semester, to allow time to work on a research grant or conduct independent research. Most students choose to take 6 credits of coursework rather than perform a MS project (NERS 599) and write a thesis. In addition, students working toward the Ph.D. program or being financially supported by the department are expected to be engaged in research throughout the year, and typically take only 3 classes per regular term and none in the spring or summer terms. Be sure to consult with your advisor concerning these issues.

The following schedule is based on the assumption that the student has already taken a senior-level undergraduate course in nuclear reactor theory, similar to NERS 441. If this is not the case, NERS 441 should be elected in place of NERS 543 in the fall semester. Other modifications to the sample schedule may be needed and should be determined in consultation with the student's graduate advisor.

Table 1. Sample Master's Program in Fission Systems and Radiation Transport

Fall Term			**Winter Term**		
NERS 515	Nuclear Measurements Lab	4	NERS 544	Monte Carlo Methods	2
NERS 543	Nuclear Reactor Theory II	3	NERS 551	Nuclear Reactor Kinetics	3
MATH 471	Introduction to Numerical Methods**	3	NERS 554	Radiation Shielding Design	2
			NERS 561	Nuclear Core Design and Analysis I	3

Fall Term		
NERS 462	Reactor Safety Analysis	3
NERS 546	Thermal Fluids for Nuclear Reactor Safety Analysis	3
EECS 501	Probability and Random Processes	4

* NERS elective – see Table 2 for other NERS courses
** Math elective (cognate) – Math 571-572 are also recommended

Courses

Table 2 lists undergraduate and graduate courses of particular interest to graduate students in fission systems and radiation transport. Courses at the 400 level and higher are generally available for graduate credit. In addition to the courses listed, special topics are periodically covered under the course numbers NERS 490 and NERS 590. These courses are usually announced by email and postings on the departmental bulletin boards prior to the semester during which the course will be offered.

Table 2. NERS Courses Relevant to Fission Systems and Radiation Transport

NERS 421	Nuclear Engineering Materials	3	NERS 531	Nuclear Waste Management	3
NERS 425	Applications of Radiation	4	NERS 543	Nuclear Reactor Theory II	3
NERS 441	Nuclear Reactor Theory I	4	NERS 544	Monte Carlo Methods	2
NERS 442	Nuclear Power Reactors	2	NERS 546	Thermal Fluids for Nuclear Reactor Safety Analysis	3
NERS 444	Fundamentals of Heat and Mass Transfer	3	NERS 547	Computational Fluid Dynamics for Industrial Applications	3
NERS 462	Reactor Safety Analysis	3	NERS 551	Nuclear Reactor Kinetics	3
NERS 490	Nuclear Technology, Policy, and Society	3	NERS 554	Radiation Shielding Design	42
NERS 515	Nuclear Measurements Lab	4	NERS 561	Nuclear Core Design and Analysis I	3
NERS 521	Radiation Materials Science I	3	NERS 644	Transport Theory	3
NERS 524	Nuclear Fuels	3			

Ph.D. Candidacy Exam

Prior to taking the written candidacy exam in fission systems and radiation transport, students should declare themselves to be in one of three "tracks": "Fission Systems and Radiation Transport" ("Fission-RT");"Fission Systems and Thermal Hydraulics" ("Fission-TH"); or "Fission Systems, Policy and Design" (Fission-PD). The only distinction between the tracks is that the written candidacy exams will differ.

All students taking either exam will be required to answer six out of seven questions in both the morning and afternoon parts of the exam. The seven morning questions and the first three afternoon questions will be the same for all students, and will test basic Fission Systems material from the following NERS courses: 344, 441, 444, 462, 551, and 561.The final four afternoon questions will differ. The Fission-RT exams will have questions based on more advanced material from NERS 543, 551, and 561; the Fission-TH students based on material from NERS 444 and 546; and the Fission-PD students based on material from NERS 462 and 490 (Nuclear Technology, Policy, and Society).

Mathematics Courses

Master's or Ph.D. students are expected to continue studying mathematics at the graduate level. Many 500 and 600 level NERS courses require significant mathematical knowledge, including advanced linear algebra, boundary value problems, Laplace and Fourier transforms, complex variables, numerical methods, and computer programming. This material can be obtained by individual study or by selecting courses such as Math 417 (Matrix Algebra I), 419 (Linear Spaces and Matrix Theory), 454 (Boundary Value Problems for Partial Differential Equations), 471 (Introduction to Numerical Methods), 555 (Introduction to Functions of a Complex Variable with Applications), 571 (Numerical Linear Algebra), and 572 (Numerical Methods for Differential Equations). Other courses within the College of Engineering that cover related mathematical techniques are AOSS 555 (Spectral Methods), EECS 451 (Digital Signal Processing and Analysis), EECS 501 (Probability and Random Processes), EECS 502 (Stochastic Processes), IOE 511 (Continuous Optimization Methods), and IOE 515 (Stochastic Processes).

Additional Cognate Courses

A number of 400 and 500 level courses offered by other departments are relevant to those interested in fission systems and radiation transport. These courses include:

AEROSP 523 and 623 – Computational Fluid Dynamics I and II,
AEROSP 550 – Linear Systems Theory,
AEROSP 551 – Nonlinear Systems and Control,
AEROSP 588 – Multidiscplinary Design Optimization,
AOSS 532 – Radiative Transfer,
BIOMEDE 464 – Inverse Problems,
EECS 402 – Computer Programming for Scientists and Engineers,
EECS 445 – Introduction to Machine Learning,
EECS 460 – Control System Analysis and Design,
EECS 545 – Machine Learning - CSE,
EECS 563 – Hybrid Systems Analysis and Control,
EECS 587 – Parallel Computing.
IOE 410 – Advanced Optimization and Computational Methods,
IOE 473 – Advanced Data Analytics,
MECHENG 520 and 521 – Advanced Fluid Mechanics I and II,
MECHENG 527 – Multiphase Flow,
MECHENG 530 – Advanced Heat Transfer,
MECHENG 533 – Radiative Heat Transfer,
MECHENG 535 – Thermodynamics III,
MECHENG 624 – Turbulent Flow.

The Michigan Institute for Computational Discovery and Engineering (MICDE) also maintains a relevant list of courses that support the PhD in Scientific Computing

Primary Faculty in the Fission Systems and Radiation Transport Option:

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