PLASMAS AND FUSION

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/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 or in 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. Funding for graduate research assistants (GSRA appointments) is typically provided from research grants obtained by individual faculty members. If you decide to change advisors, the source of your support will also change, which could mean GSRA or GSI (graduate student instructor) support.

Plasmas and Fusion Research
This guide is intended for graduate students in Nuclear Engineering and Radiological Sciences who are interested in coursework and research in plasmas and fusion. The plasmas option is primarily designed for students who wish to continue training in this field through the Ph.D. level. The purpose of this document is to aid you in selecting a sequence of courses of both intermediate and long-term value. Some topics of research include:

- Aerospace plasmas related to boundary-layer dynamics and control
- Atmospheric-pressure nonthermal-plasmas for environmental and energy applications
- Compact laser-plasma radiation sources
- Computational plasma-physics
- High-intensity and high-power lasers
- High energy-density physics
- High-power microwave sources driven by long pulse, intense, relativistic, electron beams
- Inertial confinement fusion energy
- Lasers, lighting sources, displays
- Laser plasma driven particle accelerators
- Laser plasma interactions
- Multi-phase plasma interactions (e.g., liquids, aerosols, “dust”)
- Plasma-assisted materials processing
- Plasma based space propulsion
- Plasma medicine, biotechnology and agriculture
- Pulsed-power science and technology
- Theoretical plasma-physics
- Z-pinch plasma science
Departmental Curriculum Guidelines

A sample course program is outlined below. It is emphasized that this is a suggested curriculum and not a set of rigid requirements. It is meant primarily as a guide to students and advisors during the earlier phases of the student’s graduate career. Required courses to achieve Ph.D. candidacy are:

- NERS 515 Nuclear Measurements Laboratory
- NERS 571 Intermediate Plasma Physics I
- NERS 572 Intermediate Plasma Physics II
- NERS 575 Plasma Generation and Diagnostics Lab
  
  Graduate level mathematics

In addition, NERS 471 Introduction to Plasmas is required for students entering without undergraduate training in plasmas or fusion, subject to Advisor approval.

Sample PhD Program in Plasmas and Fusion

The following sample PhD program will enable a student to advance to candidacy and fulfill academic requirements for a PhD in Plasmas and Fusion by the end of the second winter term. Students are encouraged to design their own program of study in consultation with their graduate advisor.

<table>
<thead>
<tr>
<th>1st Fall Term</th>
<th>1st Winter Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>EECS 530 / PHYS 405** Electromagnetic Theory / Inter. Electricity &amp; Magnetism</td>
<td>3</td>
</tr>
<tr>
<td>NERS 515† Nuclear Measurements Laboratory</td>
<td>4</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>2nd Fall Term</th>
<th>2nd Winter Term</th>
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</thead>
<tbody>
<tr>
<td>NERS 990</td>
<td>NERS 990</td>
</tr>
<tr>
<td>Cognate c or Breadth class †b</td>
<td>1-3</td>
</tr>
<tr>
<td>Plasmas and Fusion class</td>
<td>3</td>
</tr>
<tr>
<td>NERS 990</td>
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<tr>
<td>Cognate c or Breadth class †b</td>
<td>1-3</td>
</tr>
<tr>
<td>Plasmas and Fusion class</td>
<td>3</td>
</tr>
</tbody>
</table>

* Required for Plasmas and Fusion Option PhD.
† Required for NERS PhD with grade of B or better.
‡ 6 credit hours of breadth classes required for NERS PhD
§ 4 hours of cognate classes required

Some suggested courses are listed below. Note that this is not an exhaustive list and students are encouraged to review current course listings in the College of Engineering and Graduate School bulletins and discuss with Nuclear Engineering and Radiological Sciences staff on appropriate course offerings in consultation with their advisor.
### Plasmas and Fusion Classes (‡ required,  can count as cognate classes)

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
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<tbody>
<tr>
<td>EECS 598</td>
<td>Special Topics: Plasma Chemistry and Plasma Surface Interactions</td>
</tr>
<tr>
<td>EECS 598</td>
<td>Special Topics: Laser Plasma Diagnostics</td>
</tr>
<tr>
<td>NERS 471</td>
<td>Introduction to Plasmas</td>
</tr>
<tr>
<td>NERS 472</td>
<td>Fusion Reactor Technology</td>
</tr>
<tr>
<td>NERS 571</td>
<td>Intermediate Plasma Physics I</td>
</tr>
<tr>
<td>NERS 572</td>
<td>Intermediate Plasma Physics II</td>
</tr>
<tr>
<td>NERS 573</td>
<td>Plasma Engineering</td>
</tr>
<tr>
<td>NERS 574</td>
<td>Introduction to Computational Plasma Physics</td>
</tr>
<tr>
<td>NERS 575 ‡(EECS 519)</td>
<td>Plasma Generation and Diagnostics Laboratory</td>
</tr>
<tr>
<td>NERS 576</td>
<td>Charged Particle Accelerators and Beams</td>
</tr>
<tr>
<td>NERS 577</td>
<td>Plasma Spectroscopy</td>
</tr>
<tr>
<td>NERS 578 (EECS 517)</td>
<td>Physical Processes in Plasmas</td>
</tr>
<tr>
<td>NERS 671</td>
<td>Theory of Plasma Confinement in Fusion Systems</td>
</tr>
<tr>
<td>NERS 673</td>
<td>Electrons and Coherent Radiation</td>
</tr>
<tr>
<td>NERS 674</td>
<td>High Intensity Laser-Plasma Interactions</td>
</tr>
<tr>
<td>SPACE 545</td>
<td>High Energy Density Physics</td>
</tr>
</tbody>
</table>

### Supporting classes relevant to Plasmas and Fusion (all can count as cognate classes)

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>AERO 523</td>
<td>Numerical Methods in Fluid Dynamics I</td>
<td>3</td>
</tr>
<tr>
<td>AERO 623</td>
<td>Numerical Methods in Fluid Dynamics II</td>
<td>3</td>
</tr>
<tr>
<td>EECS 438</td>
<td>Advanced Lasers and Optics Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>EECS 503</td>
<td>Introduction to Numerical Electromagnetics</td>
<td>3</td>
</tr>
<tr>
<td>EECS 530</td>
<td>Electromagnetic Theory I</td>
<td>3</td>
</tr>
<tr>
<td>EECS 537</td>
<td>Classical Optics</td>
<td>3</td>
</tr>
<tr>
<td>EECS 539</td>
<td>Lasers</td>
<td>3</td>
</tr>
<tr>
<td>EECS 546</td>
<td>Ultrafast Optics</td>
<td>3</td>
</tr>
<tr>
<td>EECS 587</td>
<td>Parallel Computing</td>
<td>3</td>
</tr>
<tr>
<td>EECS 633</td>
<td>Numerical Methods in Electro-magnetics</td>
<td>3</td>
</tr>
<tr>
<td>EECS 634</td>
<td>Nonlinear Optics</td>
<td>3</td>
</tr>
<tr>
<td>MATH 556</td>
<td>Methods of Applied Mathematics I</td>
<td>3</td>
</tr>
<tr>
<td>MATH 557</td>
<td>Methods of Applied Mathematics II</td>
<td>3</td>
</tr>
<tr>
<td>MATH 571</td>
<td>Numerical Methods in Scientific Computing I</td>
<td>3</td>
</tr>
<tr>
<td>MATH 572</td>
<td>Numerical Methods in Scientific Computing II</td>
<td>3</td>
</tr>
</tbody>
</table>
Breadth Requirement Classes (6 credit hours required)
All Ph.D. students must take and obtain a grade of B (3.0/4.0 scale) or better in 6 credit hours of NERS courses selected from outside the student's option, as defined by the following lists of courses. A laboratory course used to satisfy this breadth requirement cannot be used to satisfy the laboratory requirement.

- Fission Systems and Radiation Transport: NERS 441, 543, 551, 554, 561
- Materials: NERS 521, 522, 622
- Measurements: NERS 518, 481, 580, 531, 484, 582, 583, 586, 587

Ph.D. Candidacy Exam
The written candidacy exam in the plasmas and fusion area covers the required plasma courses NERS 471, NERS 571, NERS 572, NERS 575 and electromagnetism knowledge equivalent to PHYS 405.

Primary Faculty in the Plasmas and Fusion Option and their Specialties

**Low Temperature Plasmas**
- John E. Foster: Professor, Nuclear Engineering and Radiological Sciences
- Mark J. Kushner: Professor, Nuclear Engineering and Radiological Sciences
- Carolyn Kuranz: Associate Professor, Nuclear Engineering and Radiological Sciences

**High Energy Density Physics**
- Ronald M. Gilgenbach: Professor and Chair, Nuclear Engineering and Radiological Sciences
- Carolyn Kuranz: Associate Professor, Nuclear Engineering and Radiological Sciences
- Y.Y. Lau: Professor, Nuclear Engineering and Radiological Sciences
- Ryan D. McBride: Associate Professor, Nuclear Engineering and Radiological Sciences

**High Intensity Laser-Plasma Physics**
- Karl M. Krushelnick: Professor, Nuclear Engineering and Radiological Sciences
- Karl M. Krushelnick: Professor, Electrical Engineering and Computer Science
- Karl M. Krushelnick: Professor, Physics
- Karl M. Krushelnick: Director of the Center for Ultrafast Optical Sciences
- Alexander G.R. Thomas: Associate Professor, Nuclear Engineering and Radiological Sciences
- Alexander G.R. Thomas: Associate Professor, Physics
- Alexander G.R. Thomas: Associate Professor, Electrical Engineering and Computer Science