# CONTENTS

<table>
<thead>
<tr>
<th>Welcome</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>2</td>
</tr>
<tr>
<td>Madison</td>
<td>2</td>
</tr>
<tr>
<td>The Department</td>
<td>2</td>
</tr>
<tr>
<td>Faculty &amp; Areas of Research</td>
<td>3</td>
</tr>
<tr>
<td>Professors</td>
<td>3</td>
</tr>
<tr>
<td>Associate Professors</td>
<td>5</td>
</tr>
<tr>
<td>Assistant Professors</td>
<td>6</td>
</tr>
<tr>
<td>Affiliated Professors</td>
<td>6</td>
</tr>
<tr>
<td>Directory</td>
<td>7</td>
</tr>
<tr>
<td>Department of Physics</td>
<td>7</td>
</tr>
<tr>
<td>Important Numbers</td>
<td>7</td>
</tr>
<tr>
<td>Faculty Listing by Area of Interest</td>
<td>8</td>
</tr>
<tr>
<td>Committee Assignments</td>
<td>10</td>
</tr>
<tr>
<td>Steps to a Ph.D. in Physics</td>
<td>11</td>
</tr>
<tr>
<td>Qualifying Exam</td>
<td>11</td>
</tr>
<tr>
<td>Ph.D. Coursework</td>
<td>11</td>
</tr>
<tr>
<td>Waivers of Core Courses</td>
<td>12</td>
</tr>
<tr>
<td>Testing Out of Core Courses</td>
<td>12</td>
</tr>
<tr>
<td>Other Courses to Consider</td>
<td>12</td>
</tr>
<tr>
<td>Minor</td>
<td>13</td>
</tr>
<tr>
<td>Minor Option A</td>
<td>13</td>
</tr>
<tr>
<td>Minor Option B</td>
<td>13</td>
</tr>
<tr>
<td>Research and Your Advisor</td>
<td>14</td>
</tr>
<tr>
<td>Preliminary Examination</td>
<td>14</td>
</tr>
<tr>
<td>Dissertator Status</td>
<td>15</td>
</tr>
<tr>
<td>Final Examination (Thesis Defense)</td>
<td>15</td>
</tr>
<tr>
<td>Steps to a M.A./M.S. in Physics</td>
<td>16</td>
</tr>
<tr>
<td>Professional Master of Science Program</td>
<td>16</td>
</tr>
<tr>
<td>Academic Master of Arts Program</td>
<td>17</td>
</tr>
<tr>
<td>Time Limits</td>
<td>17</td>
</tr>
<tr>
<td>Warrants</td>
<td>18</td>
</tr>
<tr>
<td>Transfer to the Ph.D. Program</td>
<td>18</td>
</tr>
</tbody>
</table>
Welcome to the UW-Madison Department of Physics! We have a long history of providing our students with a great educational experience. That experience will increase your understanding of the physical universe and provide you with the foundation for your research work and your future career. Expect hard work that pays big dividends.

If you have concerns about your studies in the department, you should discuss them with your advisor or the faculty members in charge of the courses you are interested in.

Other graduate students are also a great source of information about the department.

Apart from purely academic matters, we are interested in your personal well-being. If there is anything you think we can help with, ask a faculty member or contact Renee Lefkow, the graduate program coordinator.
MADISON

Madison is a city of approximately 208,000 people. Madison is home to a regional airport which provides service to each of these metropolitan areas daily. In addition, shuttle bus service is available to both Milwaukee's General Mitchell International Airport and Chicago's O'Hare International Airport.

The Chazen Museum of Art is one of the finest college galleries in the country and is currently undergoing an extensive expansion. The museum houses the famous collection of Japanese prints left to the University by J.H. Van Vleck, Nobel Laureate in Physics. There are at least a dozen organizations that produce live theater, dance, symphony, and opera in Madison. Madison is home to 150 parks, including the University of Wisconsin Arboretum, which is open year-round to visitors wishing to explore its 1,200 acres of natural forests, prairie and orchards.

Madison also provides extensive opportunities for the sports enthusiast. The city is home to three lakes which provide opportunities for a wide variety of water sports. There are 150 miles of bike trails, 100 miles of cross-country ski trails and 40 outdoor skating rinks. The UW campus is home to several recreation facilities including the South East Recreational Facility (SERF), cross-country ski trails and 40 outdoor skating rinks.

Sports. There are 150 miles of bike trails, 100 miles of sports enthusiast. The city is home to three lakes which provide opportunities for the sports enthusiast. The city is home to three lakes which provide opportunities for a wide variety of water sports. There are 150 miles of bike trails, 100 miles of cross-country ski trails and 40 outdoor skating rinks. The UW campus is home to several recreation facilities including the South East Recreational Facility (SERF), cross-country ski trails and 40 outdoor skating rinks.

Many research programs in physics use the Synchrotron Radiation Center (SRC) and the Physical Sciences Laboratory (PSL), two advanced UW facilities located approximately twelve miles from campus.

INTRODUCTION

THE DEPARTMENT

The Department occupies all of Chamberlin Hall and a portion of Sterling Hall, located in the central campus area. The Physics Library, in Chamberlin Hall, is large and convenient to use. It has complete electronic access to databases and, of course, copy machines and comfortable chairs.

The department maintains a fine instrument and machine shop and an electronics shop staffed by skilled electronics technicians. There is, in addition, a student-staff machine shop open to graduate students and supervised by an experienced machinist who assists and instructs shop users.

Several computers are available for general computing, and a number of smaller machines are used for on-line control of experiments and for data collection. The Division of Information Technology (DoIT) has a large professional staff which assists users, provides contract programming services and offers a wide variety of microcomputing courses. The Microcomputer Instructional Lab contains IBM and Macintosh microcomputers, popular software, laser printers and graphic scanners. Use of the lab is free for UW-Madison students, faculty and staff.

Many research programs in physics use the Synchrotron Radiation Center (SRC) and the Physical Sciences Laboratory (PSL), two advanced UW facilities located approximately twelve miles from campus.

Facility & Areas of Research

Professors

Balantekin, A. Baha, Ph.D., Yale, 1982. Theoretical physics at the interface of nuclear physics, particle physics, and astrophysics; mathematical physics; neutrino physics and astrophysics: fundamental symmetries; nuclear structure physics.

Barger, Vernon, Ph.D., Chicago, 1984. High-energy and fundamental particle physics; neutrino physics; electroweak gauge models; heavy quarks; supersymmetry; cosmology.


Carlsmitl, Duncan L., Ph.D., Chicago, 1984. High-energy and fundamental particle physics at the Tevatron and LHC.


Coppersmith, Susan N., Ph.D., Cornell, 1983. Theoretical condensed matter physics, nonlinear dynamics, quantum computation and information, biomineralization.

Dasu, S., Ph.D., Rochester, 1988. Experimental high energy and elementary particle physics; electro-weak symmetry breaking and search for new physics phenomena using the CMS experiment at the Large Hadron Collider; tigger and computing systems for high energy physics.


Forest, Cary B., Ph.D., Princeton, 1992. Experimental high energy and elementary particle physics; particle astrophysics; fundamental symmetries; mathematical physics; neutrino physics and astrophysics: fundamental symmetries; nuclear structure physics.


Associate Professors

Egedal, Jan, Ph.D., Oxford University, 1998. Experimental plasma physics.

Vavilov, Maxim, Ph.D., Cornell University, 2001. Condensed matter theory; nanoscale and low dimensional systems.

Affiliated Professors


Assistant Professors

Bai, Yang, Ph.D., Yale University, 2007. New physics beyond the Standard Model including the dark matter phenomenology, the Large Hadron Collider physics, the electroweak symmetry breaking models and the underlying dynamics of quark and lepton masses.

Vandenbroucke, Justin, Ph.D., University of California, Berkeley; 2009. Ice Cube project, gamma-ray astronomy and neutrino astronomy.

Affiliated Professors


Vetsigian, Kalin, Ph.D., University of Illinois at Urbana-Champaign. 2005. Bacteriology. Dynamics of microbial interactions in natural and synthetic microbial communities.
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<th>Name</th>
<th>Room</th>
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<td>Zweibel, E.</td>
<td>6281</td>
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<td>Bai, Y.</td>
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<td>Carlsmith, D.</td>
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<td>Egedal, Jan</td>
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<td>Forest, C.</td>
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<td>Hanson, K.</td>
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### FACULTY LISTING—AREA OF INTEREST

#### Astrophysics & Cosmology

- **Experimental**
  - Center for Magnetic Self Organization (CMSO): Boldyrev | Egedal | Forest | Sarff | Schnack | Terry | Zweibel
  - IceCube: Halzen | Hanson | Karle | Vandenbroucke | Westerhoff
  - Observational Cosmology: Timbie
  - X-ray Astrophysics: McDermott
- **Theoretical**
  - Cosmological Cosmology: Chung | Shiu

#### Atomic, Molecular, & Optical Physics

- **Experimental**
  - Atomic Collisions: Lin
  - Atom Trapping: Walker
  - Nonlinear Optics and Atomic Physics: Saffman
  - Quantum Optics and Ultradian Physics: Torni
- **Theoretical**
  - Atomic, Molecular, & Optical: Lin | Walker
  - Neutral Atoms: Saffman

#### Biophysics & Condensed Matter Physics

- **Experimental**
  - Biophysics: Gilbert | McDermott
  - Magnetic Fields: McDermott | Rzchowski
  - Nanostructures: Eriksson | Gilbert | Himpel | Rzchowski
  - Polymer Photophysics and Structure: Winokur
  - Synchronization Radiation: Gilbert | Himpel | Odilon
- **Theoretical**
  - Complex Systems: McDermott
  - Low-Dimensional Systems: Vandenbroucke
  - Magnetic Fields: McDermott | Eriksson | Joynt | McDermott | Vandenbroucke
  - Strongly-Correlated Systems: Joynt

#### High Energy

- **Experimental**
  - ATLAS at CERN: Wu
  - Collider Detector Facility at FNAL: Carlsmith | Herndon
  - Compact Muon Solenoid at CERN: Carlsmith | Daou | Herndon
  - LBNF Project: Balantekin | Karle
  - Neutrino Physics at Daya Bay: Balantekin
- **Theoretical**
  - Particle Theory: Bui | Balantekin | Barger | Chung | Everett
  - Phenomenology: Bui | Barger | Everett | Halzen
  - String Theory: Hashimoto | Shiu

#### Neutrino and Astroparticle Physics

- **Experimental**
  - ARA Project: Halzen | Karle
  - Auger Project: Westerhoff
  - Days Bay Project: Balantekin
  - Deep Core Project: Halzen | Karle | Vandenbroucke | Westerhoff
  - DM-Ice: Karle
  - HAWC Project: Westerhoff
  - IceCube: Halzen | Hanson | Karle | Vandenbroucke | Westerhoff
  - MARE Project: McDermott
- **Theoretical**
  - Dark Energy: Chung
  - Neutrino Astrophysics: Balantekin | Barger | Everett

#### Plasma Physics

- **Experimental**
  - Center for Magnetic Self Organization (CMSO): Boldyrev | Egedal | Forest | Sarff | Schnack | Terry | Zweibel
  - CMTFO: Forest | Terry
  - CPTC: Boldyrev | Schnack | Terry | Zweibel
  - Madison Dynamo Experiment (MDE): Forest
  - Madison Plasma Dynamo Experiment (MPDEX): Forest | Zweibel
  - Madison Symmetric torus (MST): Forest | Sarff
  - Plasma-Couette Experiment (PCX): Boldyrev | Forest
  - Rotating Wall Machine (RWM): Forest | Sarff
- **Theoretical**
  - Fusion Reactor Physics: Barger | Zweibel
  - Fusion Turbulence: Barger | Zweibel
  - Transport in Fusion Devices: Barger | Zweibel

#### Quantum Computing

- **Experimental**
  - Quantum Computing: Coppesmith | Eriksson | McDermott | Sarff | Walker
- **Theoretical**
  - Quantum Computing: Coppesmith | Joynt

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**Facility List:**
- **FACULTY LISTING—ALPHABETICALLY**
- **FACULTY LISTING—AREA OF INTEREST**

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**Handbook for Graduate Students in Physics**

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**9**
2014–15 COMMITTEE ASSIGNMENTS

Administration

Department Chair: Karle
Associate Chair: Rachowski

Physics Council
Karle (Chair) | Rachowski (ex officio) | Boldyrev (yr. 1) | Dasu (for Chung) | McCammon (yr. 2) | TBD (yr. 1) | Anderson (yr. 2)

Faculty Senators
Carlsmith (Herndon) | Egedal (Alt) | Hashimoto (for Everett) | Vavilov (Alt)

Divisional Committee: Westerhoff (5/2016)

L&S Curriculum Committee: Timbie (5/2017)

Grad School Research Committee: Terry (5/2016)

New Staff (Faculty)

Smith (Chair) | Balantekin | Forest | Halzen | Lin | A. Lefkow

Undergraduate Program Committees

Advisors
AMEP: Forest

Majors, DARS, & Honors:
Winokur

McCammon

Westerhoff (in Training)

Placement: Winokur

Physics Club: Hashimoto

Major Program Student Learning Assessment Report: Timbie

Independent Study Review:
Rzchowski (Chair) | Carlsmith

Innovation and Garage Physics:

Carlsmith (Chair) | Unks

Extramural: Barger

Research:
Bai (Chair) | Barger

Instrument & Electronics Shop:
Yavuz (Chair) | McCammon | D. Den Hartog | DiVernois | A. Lefkow

General Education Committees

Ad Hoc Educational Assessment:
Timbie (Chair) | Rzchowski | TBD | TBD

Web:
Bai (Chair) | Hashimoto | Bradley | Bravo | A. Lefkow | Seys

STEPS TO A PH.D. IN PHYSICS

QUALIFYING EXAM

Every student, with or without a Master’s degree from another institution, must take and pass the Qualifying Examination. The Qualifying Exam is a written examination covering undergraduate physics, and is offered in September and February of each year. A list of exam topics (Appendix C), recent Qualifying Examinations, and an information sheet for students are available at our web site (www.physics.wisc.edu/grad/qualifiers/qualifiers.html).

The exam must be taken in the student's first semester and must be passed by the third semester with a maximum of three attempts. New students are required to pass the Qualifier in September. Students who pass the qualifying exam on the first try satisfy the requirement and are not required to retake the exam. Students who do not pass are encouraged to seek feedback and study advice from their advisors and members of the Qualifying Exam Committee. A notice of the date and time of the exam will be distributed to the students via email prior to the start of each term. Failure to pass the qualifying exam by the end of the 3rd semester will result in termination from the program at the end of the semester in which the final attempt is made.

PH.D. COURSEWORK

Prior to reaching dissertator status, a student holding a regular half-time teaching or project assistantship is expected to register for at least six credits (three courses are strongly encouraged after the student’s first semester). A student holding a research assistantship or a fellowship is required to carry at least eight credits (this can be partly or entirely Physics 990) each semester until dissertator status is achieved. Students are also required to take at least one physics course per semester until dissertator status is achieved. Those who have achieved dissertator status must register for three credits (typically Physics 990, but can be upper level courses related to research with advisor approval) each semester. To remain in good standing, a student must maintain a B average in course work.

Admissions & Fellowships:
Winokur

McCammon

Westerhoff (in Training)

Placement: Winokur

Physics Club: Hashimoto

Major Program Student Learning Assessment Report: Timbie

Independent Study Review:
Rzchowski (Chair) | Carlsmith

Innovation and Garage Physics:

Carlsmith (Chair) | Unks

Extramural: Barger

Research:
Bai (Chair) | Barger

Instrument & Electronics Shop:
Yavuz (Chair) | McCammon | D. Den Hartog | DiVernois | A. Lefkow

General Education Committees

Ad Hoc Educational Assessment:
Timbie (Chair) | Rzchowski | TBD | TBD

Web:
Bai (Chair) | Hashimoto | Bradley | Bravo | A. Lefkow | Seys

07282014
Ph.D. candidates are **required** to take five core courses: Physics 711 (Dynamics), 715 (Statistical Mechanics), 721 (Electrodynamics) and 731 & 732 (Quantum Mechanics). Each course must be repeated until a grade of at least a B is earned. (See Appendix B for the suggested sequence of core courses.) Most entering students take two of these core courses in the fall semester and two in the spring semester. All core courses must be completed by the end of the fourth semester of the student’s program. Evaluations of physics graduate level courses are on file in the Physics Department Administration Office (Room 2200B Chamberlin Hall).

**Waivers of Core Courses**

Credit earned at another institution in an equivalent graduate level course may be counted toward the 5-course requirement if approved by the Graduate Program Director. A new graduate student who believes he or she qualifies for a waiver of the course requirement for a core graduate course must request the waiver form from the Graduate Student Coordinator during the first month he or she is enrolled in the graduate program in Physics.

**Testing Out of Core Courses**

Students can also demonstrate proficiency by passing an exam. A new graduate student who believes that he or she has had graduate level work in a subject comparable to that in a core course, but who does not clearly qualify for a waiver of the course requirement, has the option of testing out of the course. This will require passing the exams for the course at a level which would clearly lead to a grade of B or better. Requests to test out of core courses must be made to the Graduate Program Director during the student’s first month in the graduate program in Physics. The testing must be completed during the student’s first semester in the graduate program.

**Other Courses to Consider**

Entering graduate students should check that their undergraduate work was equivalent to a complete physics major. Students without the experience of a senior advanced laboratory course should consider Physics 507, Physics 623 (Electronic Aids to Measurement) and 625 (Applied Optics) are important for an understanding of experiments in most research areas and should be taken as soon as possible. The remaining 500 and 600 level courses in the student’s area of interest should also be taken as early as possible.

Physics 551 (Condensed Matter Physics) should be taken by students interested in Condensed Matter Physics or related areas such as spectroscopy. Students interested in space physics or astrophysics should take courses in astrophysics which are at least equivalent to the requirements for a minor in Astronomy. Physics 545 (Introduction to Atomic Structure) gives a good general introduction to atomic physics. Those interested in plasma physics should begin the sequence of plasma courses with Physics 525 (Introduction to Plasmas). Physics 535 (Introduction to High Energy Physics) and (or) Physics 725 (Particle Physics) should be taken by students interested in high energy physics.

All graduate students are required to attend the weekly colloquium, Physics 900. Students are also expected to regularly attend at least one of the weekly research seminars numbered above 900.

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**MINOR**

Each Ph.D. candidate in physics must complete a minor program with at least a B average, normally in a field (or fields) related to the candidate’s activities in physics. The minor is intended to broaden the candidate’s knowledge of physics or related fields, or to support the candidate’s research or prospective professional activities. The program selected should therefore be coherent and directed toward an identified objective. There are three options for satisfying the minor requirement: Option A consists of courses in a single department other than Physics. Option B Internal consists of courses exclusive to a specific department other than the Physics department, but outside the students major area, and Option B Interdepartmental which consists of courses in Physics and at least one other department. These options are discussed in detail below.

**Minor Option A**

Minor Option A consists of a program of courses in a single department other than Physics (for example: Astronomy, Chemistry, Computer Science, Geology & Geophysics, Mathematics, Atmospheric & Oceanic Science, Medical Physics, Radiology, or one of the departments in Engineering). The credit requirements for Minor Option A and suitable course programs are specified by the minor department, but the Graduate School requires a minimum of 10 credits.

**Minor Option B**

Minor Option B is also called the distributed minor. Within this minor, there are two options; interdepartmental and internal. Both consist of a program of 12 or more credits of course work.

**Option B: Interdepartmental**

This option consists of 12 credits from at least two departments. Up to nine of these credits may be from courses taken within the Physics Department numbered 500 or above, but must be outside the student’s area of research specialization. Required core courses may not be counted toward the minor. The program must be approved by the student’s advisor and the Physics Department Chair.

**Option B: Internal**

This option consists of a minor entirely within the physics department. It requires 12 credits in graduate physics courses numbered 500 or above in an area distinct from the major area of research specialization. Required core courses (711, 715, 721, 731, 732) and prerequisites for these core courses may not be counted toward the minor. The Option B Internal minor program must be coherent, and cannot include courses in other departments. The choice of one of the standard internal minor programs (see Appendix D) requires the approval of the student’s advisor—who must certify that the courses selected in the minor program do not significantly overlap the major area—the Physics Minor Committee Chair, and the Department Chair.

For all minor options, a Minor Agreement Form must be completed, signed, and submitted to the Graduate Student Coordinator at (or before) the time the Preliminary Warrant is requested. It is advised that the student discuss his/her minor with the advisor before any of the minor classes are taken, regardless of which minor option is chosen. Forms can be obtained from the Graduate Student Coordinator (in 2200H Chamberlin). The minor requirement in Physics for non-Physics students is 12 credits numbered above 300, each passed with a B or better. The program must be approved by the Physics Minor Committee Chair before it is completed.
RESEARCH AND YOUR ADVISOR

The Ph.D. is a research degree and is awarded for substantial original research, presented in the form of a dissertation. The requirements listed above are for the purpose of expediting the student’s contribution to research in physics.

The responsibility to acquire (choose and be accepted by) a major professor (advisor) is entirely with the student. Acceptance for Ph.D. research by a professor depends on the professor’s appraisal of the student’s potential for research and on the ability of the professor to accept a student at that time. Usually the major professor will be able to offer support in the form of a research assistantship, but this is not always the case, and occasionally a student may need to work as a teaching assistant while performing thesis research.

Graduate students should begin research work as early as possible. Students are encouraged to acquire a major professor and begin research by the end of the second semester. Summer is the ideal time to begin research unencumbered by course work or teaching. Students who do not acquire a research advisor and begin research by the end of their third semester may be dropped from the program.

PRELIMINARY EXAMINATION

The Preliminary Examination (Prelim) must be passed for admission to candidacy for the Ph.D. (dissertator status). The exam will test whether the student has mastered the physics and technology necessary to perform research in the chosen field. The Prelim must be taken no later than the end of the fifth semester in the program. An extension may be granted by the Department Chair for a single semester for extenuating circumstances. If the Prelim is failed the first time, it may be repeated once and it must be passed before the end of the sixth semester. The format of the examination is left to the major professor (subject to approval by the Departmental Prelim Committee). Ordinarily, the exam begins with a 1-hour presentation covering a subject in the student’s chosen area of research. The presentation is then followed by a question-and-answer period intended to assess the student’s background knowledge and research potential.

For each Ph.D. student, a thesis committee, consisting of the student’s advisor and two additional faculty members chosen by the student’s advisor, is assembled at the time of the Preliminary Examination. The committee is augmented by one member of the Departmental Prelim Committee for the Preliminary Examination. The thesis committee remains standing for the duration of the student’s dissertation work. It judges the student on the Preliminary Examination, provides advice during the dissertation work, and judges the Ph.D. final oral examination. A student planning to take the Preliminary Examination must be approved by the Departmental Prelim Committee. Ordinarily, the exam begins with a 1-hour presentation covering a subject area in the student’s chosen area of research. The presentation is then followed by a question-and-answer period intended to assess the student’s background knowledge and research potential.

For each Ph.D. student, a thesis committee, consisting of the student’s advisor and two additional faculty members chosen by the student’s advisor, is assembled at the time of the Preliminary Examination. The committee is augmented by one member of the Departmental Prelim Committee for the Preliminary Examination. The thesis committee remains standing for the duration of the student’s dissertation work. It judges the student on the Preliminary Examination, provides advice during the dissertation work, and judges the Ph.D. final oral examination. A student planning to take the Preliminary Examination must be approved by the Departmental Prelim Committee. Ordinarily, the exam begins with a 1-hour presentation covering a subject area in the student’s chosen area of research. The presentation is then followed by a question-and-answer period intended to assess the student’s background knowledge and research potential.

A graduate student becomes a “dissertator” when he/she has:
1. passed the Qualifying Examination;
2. satisfied the Ph.D. graduate-level credits requirement;
3. satisfied the minor requirement;
4. passed the Preliminary Examination; and
5. completed the required courses (711, 715, 721, 731, 732) with a grade of B or better.

Dissertators must register for three credits per semester (including the Summer Session if on an appointment and/or if student is depositing their dissertation with the Graduate School in the summer term). Official determination of dissertator status is made only at the Graduate School. Continuous registration is required from the time a student has achieved dissertator status through the filing of the Ph.D. dissertation in the Graduate School. (This includes Fall and Spring semesters, and if holding an appointment, Summer semesters, while on or off campus.)

*Note: Students should notify the Department’s Payroll Office once dissertator status is achieved.

FINAL EXAMINATION (THESIS DEFENSE)

The Final Examination is an oral defense of the thesis and must be taken within five years of passing the Preliminary Examination. The doctoral committee must have at least five members, four of whom must be Graduate Faculty or former Graduate Faculty up to one year after resignation or retirement. The required fifth member of the doctoral committee must be from outside the Physics major (often from the Minor field). The fifth member can be graduate faculty, visiting professor, faculty from another institution, other tenure-track faculty, academic staff (including scientists and emeritus faculty), post-doc scholar, or other individual deemed qualified by the Major Professor and the Department Chair. The Final Oral Committee Approval Form can be obtained from the Graduate Student Coordinator in room 2320H Chamberlin Hall.
STEPS TO A M.A./M.S. IN PHYSICS

Students may be admitted directly to the Masters program in Physics or earn either a Master of Arts (M.A.) or Master of Science (M.S.) en route to a Ph.D. in Physics.

**Please Note:** effective summer term 2014 all masters degrees will require 30 credits.

**PROFESSIONAL MASTER OF SCIENCE PROGRAM**

The M.S. program is a terminal professional program designed to strengthen the student's physics background, and enhance his or her opportunities for employment as a physicist or in physics education. The program is full time and should be completed within two years.

To earn the M.S. degree in the Department of Physics, a student must satisfy the Department's minimum graduate-level credit requirement. The Physics Department requires at least 30 credits at the 300 level or above. Fifteen of the 30 credits must be earned from taking the physics core graduate courses, each passed with a grade of B or better. These courses are Physics 711 (Dynamics), 715 (Statistical Mechanics), 721 (Electrodynamics), 731 (Quantum Mechanics I), and 732 (Quantum Mechanics II). The remaining 15 credits may be earned through a combination of coursework, directed study, and research to be determined in consultation with the student's academic advisor. An overall 3.0 GPA must be maintained.

In addition to the credit requirements for the M.S. degree, the student must present satisfactory evidence of scientific writing and presentation skills. This will be done through the submission of a Master's Thesis written at a satisfactorily professional level, together with an oral presentation of the project in a departmental seminar or through a Preliminary Examination.

A Master of Science Degree is awarded to a student who has:

1. satisfied the graduate-level credits requirements and Physics course requirements,
2. passed the Qualifying Examination in Physics at the Master's level,
3. completed a Master's project, and
4. made a presentation of a research project or passed prelim examination.

The Master's project, which will result in the Master's Thesis, is a directed physics research project which can be completed in one to two semesters. It is intended to give the student direct experience with real physics problems, and a chance to demonstrate his or her ability to carry a project through to completion and prepare a description of the results written at a professional level.

No later than the end of the fourth week of the second semester in residence, every Master's student should acquire an advisor who agrees to supervise the Master's project. The project must be written up as a Master's Thesis. The thesis must be approved by the student's advisor, and a second faculty member appointed by the Graduate Program Director. If the Master's project is to be used to satisfy the scientific communication requirement, the results must be reported orally in a departmental seminar, and the advisory and second faculty member must certify that the student's writing and speaking skills are at a satisfactory professional level.

**ACADEMIC MASTER OF ARTS PROGRAM**

The M.A. program is an academic, course-based program designed to strengthen the student's physics background, and enhance his or her opportunities for employment as a physicist or in physics education. The program is full time and should be completed within two years.

To earn the M.A. degree in the Department of Physics, a student must satisfy the Department's minimum graduate-level credit requirement. The Physics Department requires at least 30 credits at the 300 level or above. Fifteen of the 30 credits must be earned from taking the physics core graduate courses, each passed with a grade of B or better. These courses are Physics 711 (Dynamics), 715 (Statistical Mechanics), 721 (Electrodynamics), 731 (Quantum Mechanics I), and 732 (Quantum Mechanics II). The remaining 15 credits may be earned through a combination of coursework, directed study, and research to be determined in consultation with the student's academic advisor. An overall 3.0 GPA must be maintained.

Prior to the end of the first semester in residence, each Master's student must acquire an academic advisor. The advisor will consult with the student prior to the start of each term to assist the student in selecting coursework to help the student achieve his or her professional goals.

A Master of Arts Degree is awarded to a student who has:

1. satisfied the graduate-level credits requirements and Physics course requirements, and
2. passed the Qualifying Examination in Physics at the Master's level.

**Time Limits**

A Master's Program should normally be completed in two years or less. The program must be completed in three years. The time limit may be extended by the Chair for Master's candidates who were accepted into the program on a part-time basis, and present an acceptable plan for completing the degree.

Ph.D. candidates who wish to obtain a Master's degree in Physics may do so at any time prior to earning the Ph.D. by completing the requirements for either the M.S. or the M.A.
Warrants
A warrant from the Graduate School is required to receive the M.S. or the M.A. degree. The warrant will not be issued if the student has a grade of “Incomplete” on their record. It is the responsibility of the student to inform the Graduate Student Coordinator at least six weeks before the end of the semester that the degree is expected and to determine that all required work has been completed.

Transfer to the Ph.D. Program
Students admitted initially only to a Master’s program must reapply to the Physics Admissions Committee if they wish to enter the Ph.D. program. Acceptance into the Ph.D. program is not automatic, and will be decided on the basis of the student’s record and prospects for completing the Ph.D.

Credit Requirements

<table>
<thead>
<tr>
<th>Degree</th>
<th>Minimum Graduate-Level Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Master’s Degrees</td>
<td>30</td>
</tr>
<tr>
<td>MFA, Specialists</td>
<td>30</td>
</tr>
<tr>
<td>Ph.D.</td>
<td>51</td>
</tr>
</tbody>
</table>

Minimum Graduate-Level Credit Requirements
The credit requirements shown to the left reflect the minimum number of graduate level credits needed to earn a degree from the University of Wisconsin-Madison. Graduate-level credits include those courses in physics numbered 500 or above as well as those courses in other departments numbered 300 or above.

- The minimum credit requirement for the Ph.D. must be completed prior to achieving dissertator status. The Graduate School will not “transfer” any graduate work done at another institution toward fulfillment of the minimum UW-Madison credit requirement. All graduate-level credits, including those taken during the summer, will count toward fulfillment of the minimum credit requirement. Students must earn at least a 3.0 GPA in their graduate coursework in order to graduate. A graduate-level course taken at a distance will count toward the minimum credit requirement only if the course is a UW-Madison course.

- The normal full time program consists of 8 to 12 credits of graduate work per semester, and 2-3 credits for the 8-week Summer Session. Students may not register for more than 15 graduate credits during a semester, or more than 12 graduate credits in the 8-week Summer Session, without prior credit overload approval from the Graduate School. In order to have access to University facilities graduate students must be registered for at least two graduate level credits during the regular academic year.
Course Loads for R.A.s, T.A.s, P.A.s and Fellows

An R.A. or Fellow must carry a full graduate load (8-12 credits per semester, and at least 2 graduate credits, typically Physics 990, in the summer) until dissertator status is achieved. T.A.s and P.A.s are expected to carry a minimum of 6 credits. It is recommended that T.A.s take only 6 credits during their first semester in graduate school followed by 9 credits each subsequent semester until dissertator status is reached. No student should take three core courses in one semester. Note: All students must receive advisor approval of course load prior to enrolling each term.

Summer Session Enrollment

Graduate Students who have served as graduate assistants with tuition waivers during the previous academic year enjoy the same waiver during the Summer Session. A student holding a research assistantship during a Summer Session must be concurrently registered for at least two credits. Graduate students who are T.A.s during the Summer Session do not have to be registered; however, the department recommends that all students register for summer to obtain summer university privileges and for tax reasons. Dissertators must register for three credits in the summer if they will graduate that summer term. The three credits do not have to be in Research 990; however, coursework taken must reflect strongly on the student’s area of research and be an upper graduate level course (numbered 500 or above) approved by the advisor.

TEACHING ASSISTANTSHIPS

A teaching assistantship allows the student to gain valuable teaching experience, enhances knowledge of undergraduate physics and provides a means of support for graduate study. It is normally advantageous for a graduate student to hold a teaching assistantship for at least a semester during graduate studies, since the teaching activity solidifies and deepens the teaching assistant’s undergraduate education in physics and also helps prepare for a possible career in teaching.

APPOINTMENTS TO TEACHING ASSISTANTSHIPS

Initial appointments to regular teaching assistantships are made by the Department Chair on the recommendation of the Committee on Admissions and Fellowships. Criteria for appointment as a teaching assistant include:

• A good academic record in an undergraduate physics major, as a graduate student in physics, or other evidence of mastery of undergraduate physics.
• Proficiency in oral and written English.
• Ability to communicate effectively with undergraduate students.
• Good standing as a graduate student in the Physics Department at the University of Wisconsin as outlined in the Criteria for Satisfactory Academic Progress.
• When several candidates are qualified according to the preceding criteria, the department gives preference to those who show the most promise for Ph.D. research as judged by the Committee on Admissions and Fellowships.

Last-minute or short-term appointments may be made on a temporary (one semester) basis by the Department Chair. Such limited term appointments do not carry any assurance of continuing support.
Reappointments (from limited-term status) to teaching assistantships with a guarantee of continuing support are made by the Department after receiving the recommendation of the Teaching Assistant Policy & Review Committee. In addition to the criteria listed above, the criteria for reappointment as a teaching assistant include:

- Satisfactory performance as a teaching assistant,
- Submission of a short (<200 word) research plan

Whenever possible, teaching assistantships are half-time appointments. However, appointments less than half-time may be used to meet a special need of an individual appointee, or to cover special, often last-minute, teaching assignments.

If a teaching assistant transfers to another department, the commitment to continuing support is terminated. However, exceptions may be made for joint Ph.D. programs or in other special circumstances, at the discretion of the Department.

**REGULAR HALF-TIME TEACHING ASSIGNMENTS**

The following assignments are typical half-time assignments. A teaching assistant should be able to do a satisfactory job in one of these assignments without exceeding the 360-hour per semester workload for a half-time appointment. The amount of time spent on the assignments may, of course, fluctuate from week-to-week.

<table>
<thead>
<tr>
<th>Courses</th>
<th>Assignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>103, 104</td>
<td>3 laboratory-discussion sections</td>
</tr>
<tr>
<td>109</td>
<td>4 laboratory sections</td>
</tr>
<tr>
<td>201, 202, 207, 208</td>
<td>2 laboratory-discussion sections</td>
</tr>
</tbody>
</table>

Representative breakdowns of hours among duties such as preparation, meeting classes and labs, attending lectures and course meetings, conferences with individual students, helping with registration, etc., is available in the department office.

**EVALUATION OF TEACHING PERFORMANCE**

The teaching performance of each teaching assistant is evaluated every semester by the Teaching Assistant Policy & Review Committee. The appointments of teaching assistants who are given unsatisfactory ratings may be terminated. Outstanding teaching assistants may be nominated for departmental or campus-wide teaching awards. Material considered in the review will include the results of teaching evaluation questionnaires filled out by the students in the teaching assistant’s sections, the evaluation of the teaching assistant by the faculty member in charge of the course, and any other relevant information submitted to the Committee by students, faculty, the teaching assistant in question, or other teaching assistants. A summary of the results of the evaluation is sent to each TA, and a copy is maintained by the Department. Teaching assistants are required to look at this information after the review, since it is valuable for self-evaluation and improvement.

**SATISFACTORY PROGRESS AS A GRADUATE STUDENT**

A student is making satisfactory progress toward the Ph.D. degree if the student does all of the following:

1. Carries at least six credits if a TA (until dissertator status) and eight credits if a Fellow or an RA (until dissertator status) unless granted special permission by the Chair to register for less (in recognition of substantial outside commitments)
2. Completes all core courses by the end of the fourth semester.
3. Enrolls in at least one physics course per semester until the preliminary exam is passed (990 course is acceptable with advisor approval)
4. Does satisfactory course work (average grade B or better overall, and achieves at least a grade of B in each required course)
5. Passes the Qualifying Examination by the third semester of graduate work in physics.
6. Acquires a major professor or at least begins work with some research group by the beginning of the third semester.
7. Takes the Preliminary Examination no later than the end of the fifth semester in the program, and passes it before the end of the sixth semester.
8. Makes satisfactory progress in research work as judged by the major professor.

A student who fails to make satisfactory progress in graduate studies may be dropped from the Department.
DELAYS

Delays in the Qualifier or Preliminary deadlines can only be granted by the Physics Department Chair. Delays in passing the Qualifier by the student's fourth semester must involve unusual circumstances. Delays in taking the Preliminary Exam beyond the 5th semester in the program may be granted on a semester basis. The extension request for the Prelim Exam must be submitted to the Department Chair, in writing, from the student's major professor and must confirm the student is making satisfactory progress in their research. The major professor should also include a general timeline for taking the prelim. Failing to pass the Qualifier on the first attempt does not normally constitute grounds for delaying the Preliminary Examination schedule. The use of delays for the Preliminary Exam is intended (for example) to aid those students who encounter unavoidable delays in the choice of a permanent major professor.

LEAVE OF ABSENCE POLICY

While in most cases participation in the program is continuous through time, students sometimes find it necessary to take a temporary leave of absence. A student requesting a leave of absence should submit a timeline for the leave and reasons for the request. Written requests for a one semester or full year leave of absence should be addressed to the Department Chair and turned into the Graduate Advisor. If a student is granted a one semester leave of absence, the milestone due dates and terminal deadlines are pushed back approximately one semester. If a student is granted a full year leave of absence, all due dates and deadlines are pushed back one year.

Students may be granted a leave of absence for no more than one year. Students who do not register for more than one year will be considered inactive. Students should follow the following process when requesting a leave of absence.

1. Write a letter requesting a leave of absence that includes the reason and time for the leave.
2. Obtain a leave of absence form from the Graduate Student Coordinator.
3. Have the advisor approve the absence.
4. Give letter to the Graduate Coordinator. The Graduate Programs Committee decides on all the requests.
5. Notify the Office of Graduate Admissions, room 217 Bascom Hall, of the semester of reentry.
6. Return leave of absence form to Graduate Coordinator.

RE-ENTRY POLICY FOR DEPARTMENT OF PHYSICS

Graduate students who leave the program in good standing may request re-entry to the program by completing the Graduate School application for admission. The Department Admissions Committee in consultation with the student's advisor will review the request and approve the request based on information provided. A leave of absence request on file will enhance the re-entry approval process.

TIME LIMITS FOR THE PH.D.

Any student who has not enrolled in the past 5 years, must submit an online application to the Graduate School and pay the application fee.

Ph.D. students who do not take the final oral examination within five years after passing the preliminary examination, must retake the preliminary examination to be awarded dissertator status.

Appeals to Time Limit Policy (after 5 years): The department can submit a written request to the Graduate School Office of Academic Services if they believe an appeal is appropriate. An appeal should provide information demonstrating that the student has remained current in their field of study; for example, a resume showing applicable work experience and/or official transcripts from other schools attended. At the time of re-admission, the department should recommend to the Graduate School which credits, if any, should be counted toward the Graduate School Minimum Credit Requirement for work done more than five years ago.
STUDENT CODE OF CONDUCT

Students are expected to conform to accepted codes of conduct. This includes avoidance of disruptive or harassing behavior and sensitivity toward issues related to race, gender, disability, and sexual orientation.

Grievances on such issues should be referred to your major professor or the Department Chair. Please refer to the "Appeals and Grievances" section in this handbook for more details on grievance procedures.

APPEALS & GRIEVANCES

The following comes directly from the Graduate School Academic Policies and Procedures.

If a student feels unfairly treated or aggrieved by faculty, staff, or another student, the University offers several avenues to resolve the grievance. Students’ concerns about unfair treatment are best handled directly with the person responsible for the objectionable action. If the student is uncomfortable making direct contact with the individual(s) involved, they should contact the advisor or the person in charge of the unit where the action occurred (program or department chair, section chair, lab manager, etc.). Many departments and schools/colleges have established specific procedures for handling such situations; check their web pages and published handbooks for information. If such procedures exist at the local level, these should be investigated first.

In addition, the following administrative offices have procedures available for addressing various concerns:

- **Offices of the Dean of Students**
  (for all grievances involving students)
  75 Bascom Hall students.wisc.edu (608) 263-5700

- **Office for Equity and Diversity**
  (for discrimination or harassment issues)
  179A Bascom Hall (608) 262-2378 oed.wisc.edu

- **Employee Assistance**
  (for conflicts involving graduate assistants and other employees)
  256 Lowell Hall (608) 263-2987 eao.wisc.edu

- **Ombuds Office for Faculty and Staff**
  (for graduate students and post-docs, as well as faculty and staff)
  523-524 Lowell Center (608) 265-9992 ombuds.wisc.edu

- **Graduate School**
  (for informal advice at any level of review and for official appeals of program/departmental or school/college grievance decisions)
  217 Bascom Hall (608) 262-2433 grad.wisc.edu
**Graduate School Appeal Process**

An official review of procedures can be initiated by the Graduate School if a student feels that their grievance was not appropriately handled or resolved at the program/department or school/college level or through consultation with other resources listed above. Initial contact may be made through the Associate Dean in the student’s division (Arts and Humanities, Biological Sciences, Physical Sciences, or Social Studies; (608) 262-1044) or through the Assistant Dean of Graduate Admissions and Academic Services (AAS; (608) 262-2433).

If the student wishes to file an official appeal of a grievance decision, they should consult with the Assistant Dean of AAS and then send the following material to the Assistant Dean in 217 Bascom Hall:

- A detailed statement on the situation of the grievance and efforts to resolve the situation
- Copies of any previous communications regarding the situation
- Any determinations or actions taken by the program/department/School/College or other resource office.

Upon receipt of all of the above materials:

- The Assistant Dean will forward the formal grievance to the appropriate divisional Associate Dean for consultation and follow-up.
- The student will be notified in writing, within 20 days after the materials arrive in the Graduate School, acknowledging the receipt of the formal appeal and giving the student a time line for the review to be completed.
- If necessary, the Associate Dean will request additional materials relevant to the issues raised in a student's grievance from the student and/or the program/department (i.e., departmental handbook explaining grievance procedures).
- If necessary, the Associate Dean will arrange a meeting with the student and an appropriate designee of the Graduate School’s Office of Admissions and Academic Services.
- If necessary, the Associate Dean will arrange a meeting with the advisor and/or program/department chair and the same member of the Graduate School's Office of Admissions and Academic Services.
- The Associate Dean will meet with the other Divisional Associate Deans who will vote on a decision. The Dean of the Graduate School will not vote on this decision.
- The Associate Dean will notify the student, the advisor and/or program/department chair, in writing, of the decision, with a copy to the Assistant Dean for AAS.

**Graduate School Final Appeal Process**

If a student is not satisfied with the initial appeal to the Graduate School Associate Deans, they may make a final appeal to the Graduate Faculty Executive Committee (GFEC) within 30 days of date of the above written decision:

- The student should send a request for a final appeal to the Assistant Dean for AAS, asking to reopen their file and including any new information pertinent to the appeal.
- The Assistant Dean for AAS will forward the complete file to the Dean of the Graduate School for follow-up.
- The Dean of the Graduate School will appoint five members from GFEC to review the appeal. At least two of the members, but not all the members should be representative of the student's academic division. One of the two divisional members will chair the committee. The Graduate School Associate Deans will not be a part of the appointed GFEC subcommittee.
- The Dean of the Graduate School will issue an official charge and an appropriate time frame (usually two to three months during the academic year) for completing a review.
- The GFEC subcommittee will review the student's final appeal, including all materials previously submitted, and will determine if additional information and/or meeting with the student and/or program/department is needed.
- Once determined, the subcommittee will report its recommendation to the next appropriate GFEC meeting. (Meetings occur every October, November, December, February, March, April, and sometimes May.) The full GFEC, with the exception of the Dean and Associate Deans, will vote on the appeal and advise the Graduate School Dean of its recommendation. The final decision, made on the basis of this recommendation and all other pertinent material, will be conveyed in writing by the Graduate School Dean to the student and the program, with a copy to the Assistant Dean for AAS.
- No further appeals are allowed.
CLIMATE & DIVERSITY

We are committed to providing an optimal environment for intellectual achievement at both the undergraduate and graduate levels. All members of the physics department are expected to do their part to maintain this positive academic climate. We do not tolerate harassment of any member of our community.

The Office for Equity and Diversity (OED, http://oed.wisc.edu/) can assist with concerns about any type of prohibited harassment or discrimination, including harassment based on gender, race, religion, ethnicity, age, disability, and sexual orientation. University guidelines are at www.oed.wisc.edu/sexualharassment/

Concerns should be first addressed to Luis Pinero, Dir. of Equity and Diversity Resource Center (3-2378). Other resources include the Office of Legal Affairs, Student Advocacy and Judicial Affairs (3-5700), the University Ombudsman office (5-9992), Stephen Appell, complaint investigator.

Less serious concerns about the climate in our department should be referred to your advisor or the Department Chair. Advice about conflict resolution is available at www.ohrd.wisc.edu/onlinetraining/resolution/index.asp

APPENDIX A

PHYSICS DEPARTMENT COURSE CATALOGUE

307 Intermediate Laboratory-Mechanics and Modern Physics. 1 cr. Experiments in mechanics and modern physics, mainly associated with the subject matter of Physics 241 and 311. P: Physics 202 or 208. Physics 205, 241, or 244 or con reg recommended.

308 Intermediate Laboratory-Electromagnetic Fields and Optics. 1 cr. Experiments in electromagnetic fields and optics, mainly associated with the subject matter of Physics 322 and 325. P: Physics 202 or 208. Physics 205, 241, or 244 recommended. Physics 322 and 325 or con reg recommended.

311 Mechanics. 3 cr. Origin and development of classical mechanics; mathematical techniques, especially vector analysis; conservation laws and their relation to symmetry principles; brief introduction to orbit theory and rigid-body dynamics; accelerated coordinate systems; introduction to the generalized-coordinate formalisms of Lagrange and Hamilton. P: Physics 202 or 208, & Math 320 or 319 or cons inst.

321 Electric Circuits and Electronics. 4 cr. Direct current circuits, circuit theorems, alternating current circuits, transients, non-sinusoidal sources, Fourier analysis, characteristics of semiconductor devices, typical electronic circuits, feedback, non-linear circuits; digital and logic circuits; three lectures and one three-hour lab per week. P: Physics 202 or 208, & Math 320 or 319 or cons inst.

322 Electromagnetic Fields. 3 cr. Electrostatic fields, capacitance, multi-pole expansion, dielectric theory; magnetostatics; electromagnetic induction; magnetic properties of matter; Maxwell’s equations and electromagnetic waves; relativity and electromagnetism. Experiments for this course are covered in Physics 308. P: Physics 311.

325 Wave Motion and Optics. 3 cr. Wave phenomena with specific applications to waves in media and electromagnetic phenomena. Wave equations, propagation, radiation, coherence, interference, diffraction, scattering. Light and its interactions with matter; geometrical and physical optics. Experiments for this course are covered in Physics 308. P: Physics 205, 241, or 244, Physics 311, and 321 (or equiv intro to Fourier analysis). Physics 322 or con reg recommended.

371 Acoustics for Musicians. 3 cr. Intended for music students who wish to learn about physical basis of sound, sound perception, musical scales, musical instruments, and room acoustics. May not be taken by Physics majors to count as physics credit. P: Undergrad or Grad st in music, HS algebra. Degree cr not given for both Physics 109 & 371.

406 Special Topics in Physics. 1-4 cr. Special topics in physics at the advanced undergraduate level. P: Physics 241 or cons inst.

407 Advanced Laboratory. 1-2 cr. Advanced experiments in classical and modern physics, many associated with the subject matter of Physics 415, 448, 449. Possible experiments include beta decay, muon lifetime, nuclear magnetic resonance, Stern-Gerlach atomic beam, Mossbauer scattering, velocity of light, Zeeman effect, and Compton scattering. Techniques for the statistical analysis of experimental data are emphasized. One (two) credit students will typically perform 4 (8) experiments. P: Physics 307 or 308 or cons inst.
415 Thermal Physics. 3 cr. Thermodynamics, kinetic theory of gases, and statistical mechanics. P: Physics 241, 244, or 205 & 311.

448 Atomic and Quantum Physics. 3 cr. First semester of a two-semester senior course. Review of atomic and other quantum phenomena and special relativity; introduction to quantum mechanics treating the more advanced topics of atomic physics and applications to molecular, solid state, nuclear, and elementary particle physics and quantum statistics. Experiments underlying this course are covered in Physics 407. P: Physics 205, 241, or 244, and Physics 311 and 322. Not open to those who have had Physics 531.


463 Radioisotopes in Medicine and Biology. (Crosslisted with Med Phys) 2-3 cr. Physical principles of radioisopes used in medicine and biology and operation of related equipment; lecture and lab. P: Intro physics.

472 Scientific Background to Global Environmental Problems. (Crosslisted with Atm Ocn, Envr St) 3 cr. A one-semester course designed to provide those elements of physics, atmospheric sciences, chemistry, biology and geology which are essential to a scientific understanding of global environmental problems. Specific examples of such problems include global warming, stratospheric ozone depletion, acid rain and environmental toxics. Three lectures per week. P: HS algebra & 1 sem college level chem or physics, or cons inst.

498 Directed Study. 1-3 cr. P: Cons inst.

499 Directed Study. 1-3 cr. P: Cons inst.

501 Radiological Physics and Dosimetry. (Crosslisted with Med Phys, H ONcol, BME) 3 cr. Interactions and energy deposition in radiation in matter; concepts, quantities and units in radiological physics; principles and methods of radiation dosimetry. P: Calculus and modern physics.

505 Topics in Physics. 1-3 cr. Discussions of recent research. To be offered as need and opportunity arise. Different sections may be offered simultaneously in two or more areas of physics. May be repeated for credit. P: Cons inst.

507 Graduate Laboratory. 2 cr. Students perform typically advanced modern physics experiments and utilize advanced statistical techniques for data analysis. Scientific writing is emphasized and one scientific paper is required. P: Physics 307 or 407 or equiv or cons inst.

522 Advanced Classical Physics. 3 cr. Selected topics in classical physics such as vibrations, non-linear mechanics, elasticity, hydrodynamics, acoustics, chaos, and electromagnetic theory. P: Physics 311 and 322 or equiv.

525 Introduction to Plasmas. (Crosslisted with N E, ECE) 3 cr. Basic description of plasmas: collective phenomena and shocks, collisional processes, single particle motions, fluid models, equilibria, waves, electromagnetic properties, instabilities, and introduction to kinetic theory and nonlinear processes. Examples from fusion, astrophysical and materials processing processing plasmas. P: One course in electromagnetic fields beyond elem physics.

527 Plasma Confinement and Heating. (Crosslisted with ECE, N E) 3 cr. Principles of magnetic confinement and heating of plasmas for controlled thermonuclear fusion: magnetic field structures, single particle orbits, equilibrium, stability, collisions, transport, heating, modeling and diagnostics. Discussion of current leading confinement concepts: tokamaks, tandem mirrors, stellarators, reversed field pinches, etc. P: Neep/Phys/ECE 525 or equiv.

531 Introduction to Quantum Mechanics. 3 cr. Historical background and experimental basis, de Broglie waves, correspondence principle, uncertainty principle, Schrodinger equation, hydrogen atom, electron spin, Pauli principle; applications of wave mechanics. P: Physics 311 & 322 or a course in modern physics, or equiv, or cons inst. Not open to those who have had Physics 448.

535 Introduction to Particle Physics. 3 cr. Introduction to particles, antiparticles and fundamental interactions: detectors and accelerators; symmetries and conservation laws; electroweak and color interactions of quarks and leptons; unification theories. P: Physics 531 or equiv.

545 Introduction to Atomic Structure. 3 cr. Nuclear atom; hydrogen atom; Bohr-Sommerfeld model, wave model, electron spin, description of quantum electron spin, description of quantum electrodynamic effects; external fields; many-electron atoms; central field, Pauli principle, multipole periodic table, x-ray spectra, vector coupling, systematics of ground states; nuclear effects in atomic spectra. P: A course in quantum mechanics or cons inst.

546 Lasers. (Crosslisted with ECE) 2-3 cr. General principles of laser operation; laser oscillation conditions; optical resonators; methods of pumping lasers, gas discharge lasers, e-beam pumped lasers, solid state lasers, chemical lasers, and dye lasers; gain measurements with lasers; applications of lasers. P: Physics 322 or ECE 420 or equiv; Physics 545, or 449 or 531.

551 Solid State Physics. 3 cr. Mechanical, thermal, electric, and magnetic properties of solids; band theory; semiconductors; crystal imperfections. P: A course in quantum mechanics or cons inst.

561 Introduction to Charged Particle Accelerators. (Crosslisted with N E, ECE) 3 cr. Charged particle accelerators and transport systems, behavior of particles in magnetic fields, orbit theory, stability criteria, acceleration theory Applications to different types of accelerators. P: Math 322, EMA 202 or Phys 311, Phys 323 or cons inst.

619 Microscopy of Life. (Crosslisted with Anatomy, BME, Chem, Med Phys, Phmcol-M, Radolv) 3 cr. Survey of state of the art microscopic, cellular and molecular imaging techniques, beginning with subcellular microscopy and finishing with whole animal imaging. P: 2nd semester intro physics including light & optics (e.g. 104, 202, 208) or cons inst.

623 Electronic Aids to Measurement. (Crosslisted with Atm Ocn) 4 cr. Fundamentals of electronics, electronic elements, basic circuits; combinations of these into measuring instruments. Three lectures and one three-hour lab per week. P: Physics 321 or cons inst.


711 Theoretical Physics-Dynamics. 3 cr. Lagrange’s equations, Principle of Least Action, orbits and scattering, kinematics of rotation, rigid body dynamics, small oscillations, special relativistic dynamics, Hamiltonian formulation, canonical transformations, Hamilton-Jacobi theory, chaos, continuum mechanics, introduction to general relativity. P: Physics 311 or equiv.

715 Statistical Mechanics. 3 cr. Statistical foundations, Liouville’s theorem, ensembles, classical and quantum distribution functions, entropy and temperature, connection with thermodynamics, partition functions, quantum gases, non-ideal gases, phase transitions and critical phenomena, non-equilibrium problems, Boltzmann equation and the H-theorem, transport properties, applications of statistical mechanics to selected problems. P: Physics 711, 531 & 415, or equiv.

717 Relativity. 3 cr. Special and general theories of relativity, relativistic electrodynamics, cosmology, unified field theories. P: Physics 721.

721 Theoretical Physics-Electrodynamics. 3 cr. Electrostatics, magnetostatics, Green functions, boundary value problems, macroscopic media, Maxwell’s equations, the stress tensor and conservation laws, electromagnetic waves, wave propagation, dispersion, waveguides, radiation, multipole expansions, diffraction and scattering, special relativity, covariance of Maxwell’s equations, Lienard-Wiechert potentials, radiation by accelerated charges. P: Physics 322 or equiv.

722 Advanced Classical Theoretical Physics. 3 cr. Selected topics in dynamics, electromagnetism, or other areas. P: Physics 721.

724 Waves and Instabilities in Plasmas. (Crosslisted with ECE, N E) 3 cr. Waves in a cold plasma, wave-plasma interactions, waves in a hot plasma, Landau damping, cyclotron damping, magnetohydrodynamic equilibria and instabilities, microinstabilities, introduction to nonlinear processes, and experimental applications. P: Neep/ECE/Physics 525 & Physics 721 or ECE 740 or cons inst.
725 Plasma Kinetic Theory and Radiation Processes. (Crosslisted with ECE, N E) 3 cr. Coulomb Collisions, Bottman equation, Fokker-Planck methods, dynamical friction, nonclassical diffusion, collision operators and experimental applications. P: Physics, ECE, Neep 525 & Physics 721 or ECE 740 or cons inst.

726 Plasma Magnetohydrodynamics. (Crosslisted with N E, ECE) 3 cr. MHD equations and validity in hot plasmas; magnetic structure and magnetic flux coordinates; equilibrium in various configurations; stability formulation, energy principle, classification of instabilities; ideal and resistive instability in various configurations, evolution of nonlinear tearing modes; force-free equilibria; helicity, MHD dynamic; experimental applications. P: Neep/ECE/Physics 525 & Physics 721 or ECE 740 or cons inst.


732 Quantum Mechanics. 3 cr. Interaction of electromagnetic radiation with matter; quantization of the electromagnetic field, spontaneous transitions, identical particles and spin, addition of angular momenta, tensor operators, complex atoms, Hartree approximation, molecules, Dirac equation, relativistic effects in atoms. P: Physics 721 & 731.

735 Particle Physics. 3 cr. Structure of elementary particles, quarks and gluons, introduction to calculational techniques of particle interactions (Feynman diagrams), constituent models of electroweak and strong interactions and associated phenomenological techniques. P: Physics 535, 731 or equiv or cons inst.

736 Experimental Techniques in Particle Physics. 3 cr. Interaction of particles with matter; gas detectors (proportional and drift chambers); low noise electronics; techniques of calorimetry; triggering; event recording and data handling; motion of charged particles in accelerators and storage rings; colliding beam machines and detectors. P: Physics 535 or cons inst.

746 Quantum Electronics. (Crosslisted with ECE 3 cr.) Elementary aspects of Lagrange theory of fields and field quantization; Bose, Fermi and Pauli operators; interaction of fields; quantum theory of damping and fluctuations; applications to lasers, nonlinear optics, and quantum optics. P: ECE-Physics 546. Physics 721 or ECE 740.

748 Linear Waves. (Crosslisted with ECE) 3 cr. General considerations of linear wave phenomena; one dimensional waves; two and three dimensional waves; wave equations with constant coefficients; inhomogeneous media; random media. Lagrangian and Hamiltonian formulations; asymptotic methods. P: ECE 440 or Physics 323 or cons inst.

749 Coherent Generation and Particle Beams. (Crosslisted with ECE, N E) 3 cr. Fundamental theory and recent advances in coherent radiation charged particle beam sources (microwave to X-ray wavelengths) including free electron lasers, wigglers/wave-particle dynamics, Cerenkov masers, gyrotrons, coherent gain and efficiency, spontaneous emission, beam sources and quality, related accelerator concepts experimental results and applications. P: ECE 740 or Physics 721, or equiv or cons inst.

751 Advanced Solid State Physics. 3 cr. Lattice dynamics; band theory; Fermi surfaces; electrodynamics of metals; optical properties; transport properties. P: Physics 731 and 551 or equiv.


764 Charged Particle Accelerator Theory. (Crosslisted with N E, ECE) 3 cr. Application of Lagrangian and Hamiltonian methods to the analysis of particle motion in charged particle accelerators; linear and nonlinear single particle orbit motion; high intensity collective effects. Lecture. P: Phys 322 and 711 or equiv.

771 Physics of Space. 3 cr. Physics of the solar atmosphere; particles and fields in interplanetary space; dynamical behavior, composition, and interactions of interplanetary plasma. P: Physics 322 and 415.
SUGGESTED SEQUENCE OF CORE COURSES

The core courses should be taken as soon as possible in the graduate career. Finishing the core courses allows the most rapid entry into research, and you will find that you need to know much of the material for more advanced work in your research specialty. Usually, students take two core courses in each semester of their first year.

Core courses are typically offered as follows:

- **Fall Semester:** 711, 715, 731
- **Spring Semester:** 715 (may not be offered due to unavailability of faculty), 721, 732

In general, 731 should be taken before 732, but otherwise none of the courses is a strict prerequisite for any other. Most students take 731 and 732 in the fall and spring semesters of their first year. Beyond this, the sequence in which the courses are taken tends to vary slightly, according to the interests of the individual student and his/her research area. In Astrophysics, Space Physics, and Plasma Physics, students may wish to emphasize electricity and magnetism and complete 721 in the first year. In Particle and Nuclear Physics, students may wish to complete 711 and 721 in the first year. In Atomic, Molecular & Optical, and Condensed Matter Physics, 715 and 721 may be good choices. Individual students may tailor their choice of courses to their own needs after a discussion with their advisor. Each group may have a recommended sequence of courses. Advisors are expected to review course selections each semester before a student enrolls.

QUALIFYING EXAMINATION INFORMATION

Qualifying Examination

**Representative List of Topics**

**Part I (10/10 questions—7 minutes: 200–299 level)**

- Mechanics
- Mechanics, possibly vibrations or sound
- Electric Circuits
- Electromagnetism (not circuits)
- Waves
- Light
- Thermodynamics
- Kinetic Theory
- Atomic
- Any Physics Topic

**Part II (10/15 questions—12 minutes: 300–499 level)**

- Astro Physics
- Condensed Matter/Solid State
- Quantum Mechanics
- Thermodynamics
- E&M
- Statistical Mechanics
- Experimental Techniques
- Thermodynamics and/or Kinetic Theory
- Plasmas
- Nuclear Physics
- Particle Physics
- Circuits
- Atoms and/or Molecules
- Relativity
- Light and Optics
## OPTION B: INTERNAL MINORS IN PHYSICS

### Advanced Experimental Physics: Suitable for Theorists
- 546 Lasers
- 623 Electronic Aids to Measurement
- 625 Applied Optics
- 736 Experimental Techniques in Particle Physics
- 746 Quantum Electronics
- 805 Special Topics in Physics

### Advanced Theoretical Physics: Suitable for Experimentalists
- 522 Advanced Classical Physics
- 717 Relativity
- 722 Advanced Classical Theoretical Physics (course under revision)
- 751 Advanced Solid State Physics
- 752 Many-Body Problems in Solid State Physics
- 801 Topics in Theoretical Physics
- 815 Advanced Statistical Mechanics
- 831 Advanced Quantum Mechanics
- 832 Advanced Quantum Mechanics
- 833 Advanced Math in Quantum Field Theory

### Astrophysics
- 717 Relativity
- 771 Physics of Space
- 772 Physics of Space
- 801 Special Topics in Theoretical Physics (if astrophysics, cosmology related)
- 805 Special Topics in Physics (if astrophysics, cosmology related)

### Atomic Physics
- 545, Introduction to Atomic Structure
- 546, Lasers
- 625 Applied Optics
- 722 Advanced Classical Theoretical Physics
- 746 Quantum Electronics

### Atomic and Plasma Physics
- 525 Introduction to Plasmas
- 527 Plasma Confinement and Heating
- 545, Introduction to Atomic Structure
- 546, Lasers
- 625 Applied Optics
- 724 Waves and Instabilities in Plasmas
- 725 Plasma Kinetic and Radiation Processes
- 746 Quantum Electronics

### Foreword

### Appendix D