PHYSICS, PH.D.

DEPARTMENT OVERVIEW

The Department of Physics has a strong tradition of graduate study and research in astrophysics; atomic, molecular, and optical physics; condensed matter physics; high energy and particle physics; plasma physics; quantum computing; and string theory. There are many facilities for carrying out world-class research. We have a large professional staff: 45 full-time faculty members; 11 faculty members holding joint appointments with other departments; 34 assistant, associate, and senior scientists; and 46 postdocs.

The department occupies all of Chamberlin Hall and a portion of Sterling Hall, located in the central campus area. The Physics Library (http://physics.library.wisc.edu), 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 (http://uw.physics.wisc.edu/~eshop) 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) (http://www.doit.wisc.edu) has a large professional staff which assists users, provides contract programming services and offers a wide variety of computing courses. Researchers have free access to large scientific computing resources (http://aci.wisc.edu/services/large-scale). Many research programs in physics use the Physical Sciences Laboratory (PSL) (http://www.psl.wisc.edu).

PH.D. DEGREE DETAILS

The Ph.D. degree requires successful completion of advanced course work in physics, completion of a minor, and passage of the qualifying and preliminary examinations. However, the Ph.D. is primarily a research degree, awarded only upon completion of substantial original research in some subfield of physics. The program provides the background, experience, and credentials needed for employment as a professional physicist in research or education.

The research program in physics is unusually broad in scope with active experimental and theoretical research programs in astrophysics; atomic, molecular, and optical physics; biophysics; condensed matter physics; elementary particle physics; nuclear physics; particle physics theory; phenomenology; and plasma physics. This broad range of research opportunities makes the department especially attractive to beginning students who have not yet chosen a field of specialization.

Research specialties include:

THEORETICAL PHYSICS

Astrophysics; atomic, molecular, and optical physics; condensed matter physics; cosmology; elementary particle physics; nuclear physics; phenomenology; plasmas and fusion; quantum computing; statistical and thermal physics; string theory.

EXPERIMENTAL PHYSICS

Astrophysics; atomic, molecular, and optical physics; biophysics; condensed matter physics; cosmology; elementary particle physics; neutrino physics; experimental studies of superconductors; medical physics; nuclear physics; plasma physics; quantum computing; spectroscopy.

The Department of Physics has a diverse group of graduate students who come from many countries around the world. There are typically 150–200 graduate students in the department. Virtually all students admitted receive financial support in the form of teaching or research assistantships and fellowships.

The information on courses and examinations provided in this catalog is only a brief summary of the procedures for graduate work in the department. Entering graduate candidates are supplied with additional details when they arrive. More complete information on the graduate program, the faculty, and research groups is available at the department website (http://www.physics.wisc.edu).

ADMISSIONS

Admission is competitive. All applicants are reviewed and evaluated on the basis of previous academic record, three letters of recommendation, statement of purpose for graduate studies, resume, and Graduate Record Exam (GRE) general and subject scores. The physics subject GRE exam is required. For applicants whose native language is not English, the department requires a minimum score of 580 (paper-based), 237 (computer-based) or 92 (internet-based) on the Test of English as a Foreign Language (TOEFL) exam, or 7 on the International English Language Testing System (IELTS) exam. All eligible applicants with complete files are considered for teaching or research assistantships and fellowships. To be considered for admission for summer or fall, students must submit all application materials (including test scores) via the Graduate School electronic application site (https://www.gradsch.wisc.edu/eapp/eapp.pl) by December 15. The department only rarely admits for spring term and cannot guarantee support in this case. Those interested in spring admission should submit all application materials listed above by November 1.

GRADUATE SCHOOL ADMISSIONS

Graduate admissions is a two-step process between academic degree programs and the Graduate School. Applicants must meet requirements of both the program(s) and the Graduate School. Once you have researched the graduate program(s) you are interested in, apply online (https://grad.wisc.edu/admissions).

FUNDING

GRADUATE SCHOOL RESOURCES

Resources to help you afford graduate study might include assistantships, fellowships, traineeships, and financial aid. Further funding information (https://grad.wisc.edu/funding) is available from the Graduate School. Be sure to check with your program for individual policies and processes related to funding.
PROGRAM RESOURCES

FINANCIAL SUPPORT FOR GRADUATE STUDENTS IN PHYSICS

All students admitted for summer or fall term are provided with a guarantee of financial support. Typically, a graduate student is first appointed as a teaching assistant. Teaching assistants assist faculty members in the introductory physics courses, generally by teaching discussion and laboratory sections. Later, as a research assistant, the student works with a major professor on a mutually agreed research program.

Teaching Assistantships

The typical first appointment for a beginning graduate student is a teaching assistantship (TA). A teaching assistantship is both a teaching position and a means of support for graduate study. It is normally advantageous for a graduate student to hold a TA position 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.

Teaching assistants and project assistants with combined graduate assistant appointments of one-third time or greater receive a remission of all in-state and out-of-state fees, except for the segregated fees ($630.12 per semester for full-time students in the 2017–18 year). Tuition is also waived. TA appointments are granted for a semester at a time. Based on a 50% appointment at the standard rate, a TA earns approximately $8,000 per semester.

Teaching Assistant Appointments

Initial appointments to regular teaching assistantships are made by the chairperson on the recommendation of the department’s Committee on Assistantships and Fellowships. Criteria for appointment as a teaching assistant include:

1. A good academic record in an undergraduate physics major, as a graduate student in physics, or other firm evidence of mastery of undergraduate physics.

2. Working knowledge of oral and written English.

3. Ability to communicate effectively with undergraduate students.

4. Good standing as a graduate student in the University of Wisconsin. This is a university requirement for holding an assistantship. “Good standing” is defined in terms of quantity of academic work carried (number of credit hours) and the quality of the work (B average for a graduate student).

5. When several candidates are qualified according to the preceding criteria, we give preference to those who show the most promise for Ph.D. research as judged by the Committee on Assistantships and Fellowships.

6. Last-minute or short-term appointments may be made on a temporary (one semester) basis by the chairperson. Such limited term appointments do not carry any assurance of continuing support.

7. Reappointments (from limited-term status) to teaching assistantships with assurance of continuing support are made by the department after receiving the recommendation of the Teaching Assistant Review Committee. In addition to the criteria listed under (1), the criteria for reappointment as a teaching assistant include:

8. Satisfactory performance as a teaching assistant.

9. Satisfactory progress as a graduate student, as discussed above. 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.

10. 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 option 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 half-time appointment. The amount of time spend on the assignments may, of course, fluctuate from week-to-week.

Courses // Assignment

PHYSICS 103, PHYSICS 104 // 3 laboratory-discussion sections
PHYSICS 109 // 4 laboratory sections PHYSICS 201, PHYSICS 202, PHYSICS 207, PHYSICS 208 // 2 laboratory-discussion sections

Representative breakdowns of allocation of the 360 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 TA review committee. The appointments of teaching assistants who are given unsatisfactory ratings may be terminated. Outstanding teaching assistants may be nominated for one of the 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 often valuable for self-evaluation and improvement.

Research Assistantships

Research assistantships are made available by individual professors to students who have decided on their field of research. Most departmental RA appointments are made for an annual (12 months) period. Both in-state and out-of-state tuition will be waived for research assistants holding combined graduate assistant appointments of one-third time or greater. However, all students must still pay the segregated fees, which are $630.12 per semester for full-time students for the 2017–18 year.
Applicants who wish to be considered for an RA appointment should contact the faculty (https://www.physics.wisc.edu/people/faculty) directly.

Fellowships
Fellowships, including University Fellowships and Advanced Opportunity Fellowships, are awarded by the Graduate School upon recommendation of the Department of Physics. In addition, the department may have additional fellowships—funded by endowments from physics department alumni—available for first-year graduate students. Information on these fellowships is available on the department website (https://www.physics.wisc.edu/academics/gradstudents/fellowships).

Information on nondepartmental fellowships can be found on the Graduate School funding page (http://grad.wisc.edu/studentfunding/types).

REQUIREMENTS

MINIMUM GRADUATE SCHOOL REQUIREMENTS

Review the Graduate School minimum academic progress and degree requirements (http://guide.wisc.edu/graduate/policiesandrequirementstext), in addition to the program requirements listed below.

MAJOR REQUIREMENTS

MODE OF INSTRUCTION

<table>
<thead>
<tr>
<th>Face to Face</th>
<th>Evening/Weekend</th>
<th>Online</th>
<th>Hybrid</th>
<th>Accelerated</th>
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<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
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</table>

Mode of Instruction Definitions

Evening/Weekend: These programs are offered in an evening and/or weekend format to accommodate working schedules. Enjoy the advantages of on-campus courses and personal connections, while keeping your day job. For more information about the meeting schedule of a specific program, contact the program.

Online: These programs are offered primarily online. Many available online programs can be completed almost entirely online with all online programs offering at least 50 percent or more of the program work online. Some online programs have an on-campus component that is often designed to accommodate working schedules. Take advantage of the convenience of online learning while participating in a rich, interactive learning environment. For more information about the online nature of a specific program, contact the program.

Hybrid: These programs have innovative curricula that combine on-campus and online formats. Most hybrid programs are completed on-campus with a partial or completely online semester. For more information about the hybrid schedule of a specific program, contact the program.

Accelerated: These on-campus programs are offered in an accelerated format that allows you to complete your program in a condensed time-frame. Enjoy the advantages of on-campus courses with minimal disruption to your career. For more information about the accelerated nature of a specific program, contact the program.

CURRICULAR REQUIREMENTS

Minimum Credit Requirement

<table>
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<th>Minimum Residence Credit Requirement</th>
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<td>51 credits</td>
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<th>Minimum Graduate Coursework Requirement</th>
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<tr>
<td>Half of degree coursework (26 credits out of 51 total credits) must be completed graduate-level coursework; courses with the Graduate Level Coursework attribute are identified and searchable in the university’s Course Guide (<a href="http://my.wisc.edu/CourseGuideRedirect/BrowseByTitle">http://my.wisc.edu/CourseGuideRedirect/BrowseByTitle</a>). No 300-level courses will be counted toward the 51 credit minimum.</td>
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<tr>
<th>Overall Graduate GPA Requirement</th>
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<tr>
<td>3.00 GPA required.</td>
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<tr>
<th>Other Grade Requirements</th>
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<td>The Graduate School requires an average grade of B or better in all coursework (300 or above, not including research credits) taken as a graduate student unless conditions for probationary status require higher grades. Grades of Incomplete are considered to be unsatisfactory if they are not removed during the next enrolled semester.</td>
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<th>Assessments and Examinations</th>
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<td>Physics doctoral students are required to pass the qualifying examination at the Ph.D. level by the end of their third semester. Additionally, students are required to take a comprehensive preliminary/oral examination by the end of their fifth semester. All Incomplete and Progress grades (other than research and thesis) must be cleared from the student’s record prior to taking the preliminary examination. A final oral defense and deposit of the doctoral dissertation in the Graduate School is required.</td>
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<th>Language Requirements</th>
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<tr>
<td>Contact the program for information on any language requirements.</td>
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<tr>
<th>Doctoral Minor/Breadth Requirements</th>
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<tbody>
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<td>All doctoral students are required to complete a minor.</td>
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REQUIRED COURSES

All graduate degree candidates are required to take five core courses:

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<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>PHYS 711</td>
<td>Theoretical Physics-Dynamics</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 715</td>
<td>Statistical Mechanics</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 721</td>
<td>Theoretical Physics-Electrodynamics</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 731</td>
<td>Quantum Mechanics</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 732</td>
<td>Quantum Mechanics</td>
<td>3</td>
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Each course must be repeated until a grade of at least a B is earned. 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. All first year graduate students are required to attend the Graduate Introductory Seminar Series held each fall.
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 and PHYSICS 625 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 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 gives a good general introduction to atomic physics. Those interested in plasma physics should begin the sequence of plasma courses with PHYSICS/E C E/N E 525. PHYSICS 535 and / or PHYSICS 735 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.

**POLICIES**

**GRADUATE SCHOOL POLICIES**

The Graduate School's Academic Policies and Procedures (https://grad.wisc.edu/acadpolicy) provide essential information regarding general university policies. Program authority to set degree policies beyond the minimum required by the Graduate School lies with the degree program faculty. Policies set by the academic degree program can be found below.

**MAJOR-SPECIFIC POLICIES**

**GRADUATE PROGRAM HANDBOOK**

The Graduate Program Handbook (https://www.physics.wisc.edu/sites/default/files/grad_handbook_2017-18b.pdf) is the repository for all of the program's policies and requirements.

**PRIOR COURSEWORK**

**Graduate Work from Other Institutions**

No coursework from other institution may count toward any graduate degree in physics.

**UW–Madison Undergraduate**

Up to 7 credits in courses numbered 500 or above may be used to satisfy minimum degree requirements.

**UW–Madison University Special**

With program approval and payment of difference in tuition (between Special and graduate tuition), students are allowed to count no more than 15 credits of coursework numbered 500 or above taken as a UW-Madison University Special student. Coursework earned five or more years prior to admission to a doctoral degree is not allowed to satisfy requirements.

**PROBATION**

The Graduate School regularly reviews the record of any student who earned grades of BC, C, D, F, or Incomplete in a graduate course (300 or above), or grade of U in research credits. This review could result in academic probation with a hold on future enrollment or in being suspended from the Graduate School.

**ADVISOR / COMMITTEE**

All students are assigned a temporary advisor upon matriculation. The responsibility to acquire (choose and be accepted by) a major professor (permanent 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 (advisor) and begin research by the end of the second semester. Summer is the ideal time to begin research unencumbered by coursework 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.

At the time of the preliminary examination (the student's fifth semester), the major professor and three additional faculty members will form a committee that will evaluate and advise the student. This committee will meet regularly with the student from the time the preliminary examination is passed to the time of the final oral defense. The committee will report the student's progress annually to the director of graduate studies.

At the time of the final oral defense, a fifth member will be added to the Preliminary Examination Committee. All Final Oral Defense Committee members will serve as readers of the student's thesis.

**CREDITS PER TERM ALLOWED**

15 credits

**TIME CONSTRAINTS**

Doctoral degree students who have been absent for ten or more consecutive years lose all credits that they have earned before their absence. Individual programs may count the coursework students completed prior to their absence for meeting program requirements; that coursework may not count toward Graduate School credit requirements.

A candidate for a doctoral degree who fails to take the final oral examination and deposit the dissertation within five years after passing the preliminary examination may be required to take another preliminary examination and to be admitted to candidacy a second time.

**OTHER**

Typical funding is through 50% assistantships. Virtually 100% of enrolled students are funded for the duration of their degree. All programs are full time and require full-time student enrollment during fall and spring terms.
PROFESSIONAL DEVELOPMENT

GRADUATE SCHOOL RESOURCES
Resources to help you afford graduate study might include assistantships, fellowships, traineeships, and financial aid. Further funding information (https://grad.wisc.edu/funding) is available from the Graduate School. Be sure to check with your program for individual policies and processes related to funding.

PROGRAM RESOURCES

PROFESSIONAL DEVELOPMENT OPPORTUNITIES FOR PHYSICS GRADUATE STUDENTS
Our students have multiple opportunities for professional development throughout their graduate careers. As an integral part of research experience, students regularly work at CERN, national laboratories (Argonne, FermiLab), IceCube Neutrino Observatory at the South Pole etc.

Students are encouraged to travel to relevant conferences across the U.S. and the globe. Our students regularly attend the annual American Physical Society (APS) March Meeting and are encouraged to attend APS meetings in their sub-field throughout the year. We also encourage students to attend summer schools at various host institutions to expand their knowledge and to interact with fellow scientists in their field.

All incoming graduate students receive extensive TA training during a week long, comprehensive program designed and implemented by our Director of Introductory Labs. Students are also encouraged to join the DELTA program on campus which provides excellent training and mentorship for those interested in teaching. Each spring we offer a for credit course PHYSICS 603 Workshop in College Physics Teaching. This gives our students the opportunity to learn effective teaching methods, do research into new teaching practices, and provides a forum for students and the instructor to openly discuss challenges and rewards of teaching.

Students are also encouraged to attend Graduate School sponsored Professional Development events and participate in Graduate School Professional Development resources, such as the Individual Development Plan (IDP).

LEARNING OUTCOMES

1. Formulates and plans original research.
2. Formulates ideas, concepts, designs, and/or techniques beyond the current boundaries of knowledge within the field of physics.
3. Creates research, scholarship, or performance that makes a substantive contribution to the field of physics.
4. Gains a broad awareness of the status of contemporary research beyond the student’s area of specialization.
5. Gains a deep awareness of the status of research in the student’s area of specialization.
6. Advances contributions in the field of physics to society.
7. Learns to engage and communicate with other research professionals.
8. Fosters ethical and professional conduct.

PEOPLE

Faculty: Professors Dasu (chair), D. Anderson, Balantekin, Barger, Boldyrev, Carlsmith, Chung, Coppersmith, Eom, Eriksson, Everett, Forest, Gilbert, Halzen, Hanson, Hashimoto, Hegna, Heinz, Herndon, Ioffe, Joynt, Karle, Knezevic, Lagally, Lawler, Lazarian, Lin, McCammon, McDermott, Onellion, Rzchowski, Saffman, Sarff, Shiu, W. Smith, Sovinec, Terry, Timbie, Vavilov, Walker, Westerhoff, Winokur, Wu, Yavuz, Zweibel; Associate Professors Egedal, Levchenko, Pan; Assistant Professors Bai, Bechtol, Brar, Kats, Kolkowitz, Palladino, Vandenbroucke, Vetsigian