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 (https://www.physics.wisc.edu/research/areas). We have a large professional staff: 45 full-time faculty (https://www.physics.wisc.edu/people/staff) 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), (https://www.library.wisc.edu/physics) 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).

The department offers the master of arts and master of science degrees in physics, a master of science degree in physics with a named option research programs in physics use the Physical Sciences Laboratory (PSL) (http://www.psl.wisc.edu).

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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.

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. This broad range of research opportunities makes the department especially attractive to beginning students who have not yet chosen a field of specialization. The program provides the background, experience, and credentials needed for employment as a professional physicist in research or education. Virtually all students admitted receive financial support in the form of teaching or research assistantships and fellowships.

ADMISSIONS

Please consult the table below for key information about this degree program’s admissions requirements. The program may have more detailed admissions requirements, which can be found below the table or on the program’s website.

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

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Detail</th>
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<tbody>
<tr>
<td>Fall Deadline</td>
<td>December 15</td>
</tr>
<tr>
<td>Spring Deadline</td>
<td>This program does not admit in the spring.</td>
</tr>
<tr>
<td>Summer Deadline</td>
<td>This program does not admit in the summer.</td>
</tr>
<tr>
<td>GRE (Graduate Record Examinations)</td>
<td>Required.</td>
</tr>
<tr>
<td>English Proficiency Test</td>
<td>Every applicant whose native language is not English or whose undergraduate instruction was not in English must provide an English proficiency test score and meet the Graduate School minimum requirements (<a href="https://grad.wisc.edu/apply/requirements/#english-proficiency">https://grad.wisc.edu/apply/requirements/#english-proficiency</a>).</td>
</tr>
<tr>
<td>Other Test(s) (e.g., GMAT, MCAT)</td>
<td>n/a</td>
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<tr>
<td>Letters of Recommendation</td>
<td>3</td>
</tr>
</tbody>
</table>

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, 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.
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 PHD STUDENTS IN PHYSICS

All admitted Ph.D. students 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. Tuition is remitted for teaching assistant and research assistant appointments greater than one-third time or greater. However, all students must still pay the segregated fees, which are about $600 per semester for full-time students, and any additional university fees.

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.

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.

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. 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).

FINANCIAL SUPPORT FOR MS STUDENTS IN PHYSICS-NAMED OPTION IN QUANTUM COMPUTING

Students admitted to the MS degree in Physics named option in Quantum Computing are not provided with a guarantee of funding support as this is a one year accelerated master’s program. Students cannot accept research, teaching, or project assistantships or other university appointments that grant remission or waivers of tuition and fees.

REQUIREMENTS

MINIMUM GRADUATE SCHOOL REQUIREMENTS

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

MAJOR REQUIREMENTS

MODE OF INSTRUCTION

<table>
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<tr>
<th>Mode of Instruction Definitions</th>
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<tr>
<td>Face to Face</td>
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<tr>
<td>Yes</td>
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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

<table>
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<th>Detail</th>
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<tr>
<td>Minimum Credit Requirement</td>
<td>51 credits</td>
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<tr>
<td>Minimum Residence Credit Requirement</td>
<td>51 credits</td>
</tr>
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</table>
Minimum Graduate Coursework Requirement  
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 (http://my.wisc.edu/CourseGuideRedirect/BrowseByTitle). No Physics courses below 500-level will be counted toward the 51 credit minimum. 300-level courses taken from departments outside of Physics in fulfillment of an external minor may be counted toward the 51 credit minimum.

Overall Graduate GPA Requirement  
3.00 GPA required.

Other Grade Requirements  
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.

Assessments and Examinations  
Physics doctoral students are required to pass the qualifying examination at the Ph.D. level by the end of their fourth semester.

Additionally, students are required to take a comprehensive preliminary/oral examination by the end of their fifth semester. An extension, which requires approval by the Chair, may be requested. 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.

Language Requirements  
Contact the program for information on any language requirements.

Doctoral Minor/ Breadth Requirements  
All doctoral students are required to complete a minor.

REQUICKED COURSES

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

<table>
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<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>PHYSICS 711</td>
<td>Theoretical Physics-Dynamics</td>
<td>3</td>
</tr>
<tr>
<td>PHYSICS 715</td>
<td>Statistical Mechanics</td>
<td>3</td>
</tr>
<tr>
<td>PHYSICS 721</td>
<td>Theoretical Physics-</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Electrodynamics</td>
<td></td>
</tr>
<tr>
<td>PHYSICS 731</td>
<td>Quantum Mechanics</td>
<td>3</td>
</tr>
<tr>
<td>PHYSICS 732</td>
<td>Quantum Mechanics</td>
<td>3</td>
</tr>
</tbody>
</table>

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 enroll in and attend PHYSICS 701 Graduate Introductory Seminars 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/ECE 525. PHYSICS 535 and/or PHYSICS 735 should be taken by students interested in high energy physics.

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/phd) is the repository for all of the program's policies and requirements.

PRIOR COURSEWORK

Graduate Work from Other Institutions

Prior coursework from other institution may count toward any graduate degree in physics as allowed by the Graduate School policy on prior coursework.

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

Grade of B or better in all coursework and a minimum cumulative graduate GPA of 3.0 are required.

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 subjected to a review of their status in 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.

OTHER

Typical funding is through 50% assistantships. Virtually 100% of enrolled PhD 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 Ph.D. graduate students who will be Teaching Assistants (TA) receive extensive TA training during a week long, comprehensive program designed and implemented by our Director Undergraduate Studies. Students are also encouraged to join the DELTA program on campus which provides excellent training and mentorship for those interested in teaching. Each spring the course PHYSICS 603 Workshop in College Physics Teaching is offered. 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. Demonstrate mastery of the core physical concepts (Classical Mechanics, Electricity & Magnetism, Quantum Mechanics, and Statistical Mechanics).
2. Evaluates or synthesizes information pertaining to questions or challenges in physics.
3. Engages appropriately and communicates clearly with other research professionals in physics.
4. Formulates and plans original research.
5. Creates research, scholarship, or performance that makes a substantive contribution to the field of physics.
6. Gains a broad awareness of the status of contemporary research beyond the student’s area of specialization.

PEOPLE

FACULTY

More detail about each faculty member (https://www.physics.wisc.edu/people/faculty) and the research areas (https://www.physics.wisc.edu/research/areas) can be found on the Physics website.

Yang Bai, Associate Professor
Baha Balantekin, Eugene P. Wigner Professor
Vernon Barger, Vilas Professor and Van Vleck Professor
Keith Bechtol, Assistant Professor
Kevin Black, Professor
Stanislav Boldyrev, Professor
Tulika Bose, Professor
Victor Brar, Assistant Professor
Duncan Carlsmith, Professor
Daniel Chung, Professor
Susan Coppersmith, Robert E. Fassnacht Professor and Vilas Professor
Mark Egedal, Professor
Sridhara Dasu, Department Chair & Professor
Jan Egedal, Professor
Pupa Gilbert, Vilas Distinguished Achievement Professor
Lisa Everett, Professor
Cary Forest, Prager Professor of Experimental Physics
Pupa Gilbert, Vilas Distinguished Achievement Professor
Francis Halzen, Gregory Breit Professor and Hilldale Professor
Kael Hanson, Professor, WIPAC Director
Aki Hashimoto, Professor
Matthew Herndon, Professor
Lev Ioffe, Professor
Robert Joynt, Professor
Albrecht Karle, Professor, IceCube Associate Director, Science & Instrumentation
Shimon Kolkowtz, Assistant Professor
James Lawler, Arthur and Aurelia Schawlow Professor
Alex Levchenko, Associate Professor
Dan McAmmon, Professor
Robert McDermott, Professor
Marshall Onellion, Professor
Kimberly Palladino, Assistant Professor
Yibin Pan, Associate Professor
Brian Rebel, Visiting Associate Professor
Mark Rzchowski, Associate Chair and Professor
Mark Saffman, Professor
John Sarff, Professor
Gary Shiu, Professor
Paul Terry, Professor
Peter Timbie, Professor
Justin Vandenbroucke, Assistant Professor
Maxim Vavilov, Professor
Thad Walker, Professor
Sau Lan Wu, Enrico Fermi Professor and Vilas Professor
Deniz Yavuz, Professor
Ellen Zweibel, William L Kraushaar Professor of Astronomy & Physics

AFFILIATED FACULTY
David Anderson, Professor, Electrical & Computer Engineering
Chang-Beom Eom, Professor, Materials Science & Engineering
Chris Hegna, Professor, Engineering Physics
Sebastian Heinz, Professor, Astronomy
Mikhail Kats, Assistant Professor, Electrical & Computer Engineering
Irena Knezevic, Professor, Electrical & Computer Engineering
Max Lagally, Professor Emeritus, Materials Science & Engineering
Alexandre Lazarian, Professor, Astronomy
Carl Sovinec, Professor, Engineering Physics
Kalin Vetsigian, Assistant Professor, Bacteriology