Physics

Degrees Offered

• Master of Science
• Doctor of Philosophy

Nature of the Program

The graduate program is designed to provide a solid background in classical and modern physics, a broad understanding of major research fields, and concentrated research experience in one area. Applicants normally enter with a bachelor of science degree in physics. A student whose background is weak in a particular area is encouraged to register for the appropriate undergraduate course. The normal first-year courses include PHYS 611, PHYS 651, PHYS 631, and PHYS 633 plus possible electives. In the courses, no distinction is made between those students who intend a terminal M.S. degree and those who intend a Ph.D. degree. The minimum grade for credit in graduate courses is C, and a grade point average of 2.75 must be maintained.

Entry Requirements

Applicants are expected to have a bachelor’s degree in physics with upper-division courses in electricity and magnetism, mechanics, quantum mechanics, thermodynamics, and mathematical methods. Students lacking some of these courses may be admitted provisionally and will be allowed to remedy the deficiencies by taking the appropriate undergraduate courses. Both the GRE General Test and the GRE Physics Subject Test are required. If English is not the student’s native language, TOEFL or IELTS scores are also required. The application deadline is February 15. Contact the department for additional information.

Financial Aid

With rare exceptions, all students who are admitted receive financial support. Beginning students usually receive teaching assistantships; more advanced students receive research assistantships. Several fellowships are available for outstanding students, allowing full-time concentration on coursework and research and a more rapid progress toward the degree.

FACULTY

CHAIR

• David Lederman - Ph.D. (University of California - Santa Barbara)
  Robert L. Carroll Professor, Experimental Condensed Matter Physics

PROFESSORS

• Wathiq Abdul-Razzaq - Ph.D. (University of Illinois at Chicago)
  Physics Education
• Leonardo Golubovic - Ph.D. (University of Belgrade)
  Theoretical Condensed Matter Physics and Statistical Physics
• Mark E. Koepke - Ph.D. (University of Maryland)
  Plasma Physics, Experiment
• David Lederman - Ph.D. (University of California - Santa Barbara)
  Robert L. Carroll Professor, Experimental Condensed Matter Physics
• Earl E. Scime - Ph.D. (University of Wisconsin - Madison)
  Oleg Jefimenko Professor, Plasma Physics, Experiment

ASSOCIATE PROFESSORS

• Paul Cassak - Ph.D. (University of Maryland)
  Plasma Physics, Theory
• James P. Lewis - Ph.D. (Arizona State University)
  Computational Condensed Matter Physics
• Duncan Lorimer - Ph.D. (University of Manchester)
  Astrophysics
• Maura McLaughlin - Ph.D. (Cornell University)
  Astrophysics
• Aldo Romero - Ph.D. (University of California - San Diego)  
  Theoretical Condensed Matter Physics

ASSISTANT PROFESSORS
• Loren Anderson - Ph.D. (Boston University)  
  Astrophysics
• Alan Bristow - Ph.D. (University of Sheffield)  
  Experimental Condensed Matter Physics
• Cheng Cen - Ph.D. (University of Pittsburgh)  
  Experimental Condensed Matter Physics
• Edward Flagg - Ph.D. (University of Texas - Austin)  
  Experimental Condensed Matter Physics
• Mikel Holcomb - Ph.D. (University of California - Berkeley)  
  Experimental Condensed Matter Physics
• Sean McWilliams - Ph.D. (University of Maryland)  
  Astrophysics
• D.J. Pisano - Ph.D. (University of Wisconsin - Madison)  
  Astrophysics
• Julian Schulze - Ph.D. (Ruhr University - Bochum)  
  Plasma Physics, Experiment
• Tudor Stanescu - Ph.D. (University of Illinois)  
  Theoretical Condensed Matter Physics

TEACHING ASSISTANT PROFESSOR
• Paul Miller - Ph.D. (West Virginia University)  
  Physics Education Research

RESEARCH PROFESSORS
• Vladimir Demidov - Ph.D. (St. Petersburg University)  
  Plasma Physics and Plasma Chemistry
• Mohindar S. Seehra - Ph.D. (University of Rochester)  
  Experimental Condensed Matter Physics

RESEARCH ASSISTANT PROFESSORS
• Pavel Borisov - Ph.D. (University of Duisburg - Essen)  
  Experimental Condensed Matter Physics
• Yuri Giinka - Ph.D. (Shevchenko State University)  
  Condensed Matter Physics
• Amy Keesee - Ph.D. (Davidson College)  
  Plasma Physics

PROFESSORS EMERITI
• Martin Ferer - Ph.D. (University of Illinois)  
  Theoretical Condensed Matter Physics and Statistical Physics
• Larry Halliburton - Ph.D. (University of Missouri - Columbia)  
  Experimental Condensed Matter Physics
• Arthur S. Pavlovic - Ph.D.  
  Experimental Condensed Matter Physics
• Richard Treat - Ph.D. (University of California - Riverside)  
  Experimental Condensed Matter Physics
• H. Arthur Weldon - Ph.D. (Massachusetts Institute of Technology)  
  Particle Physics
DEGREE REQUIREMENTS

Degree Requirements
A minimum GPA of 2.75 is required in all courses.

Major Requirements 24-30
Total Hours 24-30

MAJOR REQUIREMENTS

Major Requirements

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
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</thead>
<tbody>
<tr>
<td>PHYS 611</td>
<td>Intro Mathematical Physics</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 631</td>
<td>Advanced Classical Mechanics 1</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 633</td>
<td>Electromagnetism 1</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 651</td>
<td>Quantum Mechanics 1</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 761</td>
<td>Statistical Mechanics</td>
<td>3</td>
</tr>
</tbody>
</table>

Physics Electives * 9-15

Total Hours 24-30

* Non-Thesis Option:

Thirty credit hours of Physics courses at the 600 or 700 level are required to complete a M.S. in physics without a thesis.

Thesis Option:

Students may earn a M.S. degree by performing research under the direction of a faculty advisor. The research results must be presented in a written thesis that is defended before a faculty committee. Twenty-four credit hours of physics courses at the 600 or 700 level are required to complete a M.S. in physics with a thesis.

Ph.D. Candidacy Examinations

To be admitted to candidacy for the Ph.D., a student must pass both a written and an oral candidacy examination. The written examination consists of three parts: a quantum mechanics exam in May, an electromagnetism exam in August, and a classical mechanics exam in January. To be eligible to take any candidacy exam, the student must be in good standing (see below).

The oral part of the candidacy exam is a presentation to the five faculty on the student’s doctoral committee. The student gives a lecture on some published research that has been assigned by his or her research advisor.

Requirements for Remaining in the Graduate Program

To be a graduate student in good standing requires the following:

• Maintain a GPA of 2.75 or better in graduate physics courses taken at WVU, excluding PHYS 797.
• Pass two sections of the written candidacy examination by the end of three years.
• Pass the remaining third section of the written candidacy examination by the end of four years.
• Select a Ph.D. committee of five faculty.
• Complete the oral candidacy examination within three semesters (after completing the third section of the written candidacy examination).

Students admitted as M.S. degree candidates are not expected to take the graduate qualifying exams but must maintain at GPA of 2.75 and complete their M.S. degree within three years.

Doctor of Philosophy

Course requirements: The Ph.D. requires thirty-six hours of courses at the 600 or 700-levels with a GPA of 2.75 or better. These twelve courses must include seven of the following basic courses:

<table>
<thead>
<tr>
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<th>Hours</th>
</tr>
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<tbody>
<tr>
<td>PHYS 611</td>
<td>Intro Mathematical Physics</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 631</td>
<td>Advanced Classical Mechanics 1</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 633</td>
<td>Electromagnetism 1</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 634</td>
<td>Electromagnetism 2</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 651</td>
<td>Quantum Mechanics 1</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 652</td>
<td>Quantum Mechanics 2</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 761</td>
<td>Statistical Mechanics</td>
<td>3</td>
</tr>
</tbody>
</table>
Select at least two from the following:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 772</td>
<td>Semiconductor Physics</td>
</tr>
<tr>
<td>PHYS 773</td>
<td>Collective Phenomena in Solids</td>
</tr>
<tr>
<td>PHYS 774</td>
<td>Optical Properties of Solids</td>
</tr>
<tr>
<td>PHYS 783</td>
<td>Adv Kinetic Theory of Plasmas</td>
</tr>
<tr>
<td>PHYS 784</td>
<td>Adv Magnetohydrodynamic Thry-Plasma</td>
</tr>
<tr>
<td>PHYS 791</td>
<td>Advanced Topics</td>
</tr>
</tbody>
</table>

and/or

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTR 702</td>
<td>Stellar Structure &amp; Evolution</td>
</tr>
<tr>
<td>ASTR 703</td>
<td>Galactic Astronomy</td>
</tr>
<tr>
<td>ASTR 704</td>
<td>General Relativity</td>
</tr>
</tbody>
</table>

Plus three additional graduate courses in physics or astronomy

Total Hours: 36

RESEARCH REQUIREMENTS

Research is the central focus of the degree and is directed by a faculty advisor over a period of several years. When the research is completed, the student must write a dissertation and defend it before the doctoral committee of five faculty. The average completion time for the Ph.D. is five years beyond the B.S. Research specialties within the department include astrophysics, computational physics, condensed matter physics, fluid mechanics, nonlinear dynamics, and plasma physics.

ASTRONOMY COURSES

ASTR 591A-Z. Advanced Topics. 1-6 Hours.
PR: Consent. Investigation in advanced topics that are not covered in regularly scheduled courses.

ASTR 592A-Z. Directed Study. 1-6 Hours.
Directed study, reading, and/or research.

ASTR 593A-Z. Special Topics. 1-6 Hours.
A study of contemporary topics selected from recent developments in the field.

ASTR 594A-Z. Seminar. 1-6 Hours.
Special seminars arranged for advanced graduate students.

ASTR 595. Independent Study. 1-6 Hours.
Faculty-supervised study of topics not available through regular course offerings.

ASTR 691A-Z. Advanced Topics. 1-6 Hours.
PR: Consent. Investigation in advanced topics that are not covered in regularly scheduled courses.

ASTR 692A-Z. Directed Study. 1-6 Hours.
Directed study, reading, and/or research.

ASTR 693A-Z. Special Topics. 1-6 Hours.
A study of contemporary topics selected from recent developments in the field.

ASTR 694A-Z. Seminar. 1-6 Hours.
Special seminars arranged for advanced graduate students.

ASTR 695. Independent Study. 1-6 Hours.
Faculty-supervised study of topics not available through regular course offerings.

ASTR 696. Graduate Seminar. 1 Hour.
PR: Consent. Each graduate student will present at least one seminar to the assembled faculty and graduate student body of his or her program.

ASTR 697. Research. 1-15 Hours.
ASTR 697. Research. I, II, S. 1-15 hr. PR: Consent. Research activities leading to thesis (697), problem report (697), research paper or equivalent scholarly project (697), or a dissertation (797). (Grading is S/U.).

ASTR 698. Thesis or Dissertation. 2-4 Hours.
PR: Consent. This is an optional course for programs that wish to provide formal supervision is needed during the writing of student reports (698), theses (698), or dissertations (798). (Grading is Normal.).
ASTR 699. Graduate Colloquium. 1-6 Hours.
PR: Consent. For graduate students not seeking coursework credit but who wish to meet residency requirements, use the University’s facilities, and participate in its academic and cultural programs. Note: Graduate students who are not actively involved in coursework or research are entitled, through enrollment in their department’s 699/799 Graduate Colloquium, to consult with graduate faculty, participate in both formal and informal academic activities sponsored by their program, and retain all of the rights and privileges of duly enrolled students. Grading is normal; colloquium credit may not be counted against credit requirements for masters programs. Registration for one credit of 699/799 graduate colloquium satisfies the University requirement of registration in the semester in which graduation occurs.

ASTR 700. Radio Astronomy. 3 Hours.
Introduction to radio astronomy theory and techniques suitable for graduate students. Topics covered include radio-wave fundamentals, antenna theory, radiation mechanisms, extragalactic sources, pulsars and cosmology.

ASTR 701. Computational Astrophysics. 3 Hours.
Introduction to C programming to solve astrophysical problems. Topics covered include hypothesis testing, Monte Carlo simulations and Fourier techniques for analysis of astronomical data.

ASTR 702. Stellar Structure & Evolution. 3 Hours.
Comprehensive discussion of birth, life cycle and end products of stars. Topics covered include main-sequence evolution, giant stars, white dwarfs, supernovae, neutron stars and black holes.

ASTR 703. Galactic Astronomy. 3 Hours.
Detailed study of galactic structures. Topics covered include galactic dynamics, rotation and spiral density waves, the interstellar medium and supernova remnants.

ASTR 704. General Relativity. 3 Hours.
Innovative ‘physics-first’ introduction to Einstein’s relativistic theory of gravity. Topics covered include special relativity, curved space time, gravitational collapse and black holes.

ASTR 791A-Z. Advanced Topics. 1-6 Hours.
PR: Consent. Investigation in advanced topics that are not covered in regularly scheduled courses.

ASTR 792A-Z. Directed Study. 1-6 Hours.
Directed study, reading, and/or research.

ASTR 793A-Z. Special Topics. 1-6 Hours.
A study of contemporary topics selected from recent developments in the field.

ASTR 794A-Z. Seminar. 1-6 Hours.
Special seminars arranged for advanced graduate students.

ASTR 795. Independent Study. 1-9 Hours.
Faculty supervised study of topics not available through regular course offerings.

ASTR 796. Graduate Seminar. 1 Hour.
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PHYSICS COURSES

PHYS 554. Outline of Modern Physics. 3 Hours.
PR: One year introductory college physics. (Primarily for education majors; not open to physics majors.) Elementary study of atomic and molecular structures and spectra, solid state and nuclear physics, relativity and elementary particles.

PHYS 593A-Z. Special Topics. 1-6 Hours.
A study of contemporary topics selected from recent developments in the field.
PHYS 611. Intro Mathematical Physics. 3 Hours.
PR: Calculus, differential equations, PHYS 111 and PHYS 112 or equivalent. Complex variables: series, contour integration and conformal mapping; ordinary differential equations; Fourier series, Laplace transforms; Fourier transforms; special functions; Bessel functions and Legendre, Hermite differential equations; Poisson's equation, wave equation, and Laquerre polynomials; introduction to partial differential equations.

PHYS 621. Optics. 3 Hours.
PR: PHYS 112 or equivalent and MATH 251. A basic course in physical optics covering radiation theory, diffraction, interference, polychromatic waves, scattering, polarization, double refraction, and selected topics in quantum optics.

PHYS 631. Advanced Classical Mechanics 1. 3 Hours.
PR: PHYS 331 and PHYS 332 and differential equations. Lagrange and Hamilton form of equations of motion, rigid bodies, small and nonlinear oscillations. Transformation theory, relativistic dynamics, and systems with an infinite number of degrees of freedom.

PHYS 633. Electromagnetism 1. 3 Hours.

PHYS 634. Electromagnetism 2. 3 Hours.

PHYS 651. Quantum Mechanics 1. 3 Hours.

PHYS 652. Quantum Mechanics 2. 3 Hours.

PHYS 691A-Z. Advanced Topics. 1-6 Hours.
PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

PHYS 693A-Z. Special Topics. 1-6 Hours.
A study of contemporary topics selected from recent developments in the field.

PHYS 697. Research. 1-15 Hours.
PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project, or a dissertation. (Grading may be S/U.)

PHYS 710. Nonlinear Dynamics. 3 Hours.
PR: PHYS 631. Flows, fixed-point analysis, and bifurcations in 1D, 2D, and 3D using analytical, numerical, and geometrical approaches. Limit cycles, chaos, fractals, strange attractors, iterated maps, and Hamiltonian systems.

PHYS 725. Adv Atomic/Molecular Physics 1. 3 Hours.

PHYS 761. Statistical Mechanics. 3 Hours.
PR: PHYS 461 and PHYS 651. Ensemble theory, applications to noninteracting systems, as well as perturbative and approximate treatment of interactions. Typical applications include equilibrium constants, polymers, white dwarfs, metals, superfluids, magnetic transitions.

PHYS 771. Intro - Solid State Physics. 3 Hours.
PR: PHYS 471 and PHYS 651 or equivalent. Crystal structure and reciprocal lattices. Waves in crystals. Band structure and metals.

PHYS 772. Semiconductor Physics. 3 Hours.

PHYS 773. Collective Phenomena in Solids. 3 Hours.

PHYS 774. Optical Properties of Solids. 3 Hours.

PHYS 781. Principles of Plasma Physics. 3 Hours.
Plasmas occur naturally in electrical discharges and are produced artificially in laboratory devices. This course is a survey of plasma phenomena using fluid and kinetic models.
PHYS 782. Computer Simulation of Plasma. 3 Hours.
PR: (PHYS 481 or PHYS 781) and PHYS 633; programming proficiency in C, FORTRAN, or BASIC. Projects teach mathematical and physical foundations of computer simulation algorithms and develop and refine physical understanding and intuition of phenomena encountered in plasma research.

PHYS 783. Adv Kinetic Theory of Plasmas. 3 Hours.
PR: PHYS 481 and PHYS 631 and PHYS 634. The Vlasov equation, quasilinear theory, nonlinear phenomena. Plasma waves and instabilities. Landau damping and finite-Larmor-radius effects.

PHYS 784. Adv Magnetohydrodynamics. Thry-Plasma. 3 Hours.

PHYS 790. Teaching Practicum. 1-3 Hours.
PR: Consent. Supervised practice in college teaching of physics. Note: This course is intended to insure that graduate assistants are adequately prepared and supervised when they are given college teaching responsibility. It will also present a mechanism for students not on assistantships to gain teaching experience. (Grading will be P/F.).

PHYS 791A-Z. Advanced Topics. 1-6 Hours.
PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

PHYS 792A-Z. Directed Study. 1-6 Hours.
Directed study, reading, and/or research.

PHYS 793A-Z. Special Topics. 1-6 Hours.
A study of contemporary topics selected from recent developments in the field.

PHYS 794A-Z. Seminar. 1-6 Hours.
Special seminars arranged for advanced graduate students.

PHYS 795. Independent Study. 1-9 Hours.
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PHYS 796. Graduate Seminar. 1 Hour.
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PHYS 797. Research. 1-15 Hours.
PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project, or a dissertation. (Grading may be S/U.).

PHYS 798. Dissertation. 1-6 Hours.
PR: Consent. This is an optional course for programs that wish to provide formal supervision during the writing of student reports (698), or dissertations (798). Grading is normal.

PHYS 799. Graduate Colloquium. 1-6 Hours.
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PHYS 930. Professional Development. 1-6 Hours.
Professional development courses provide skill renewal or enhancement in a professional field or content area (e.g., education, community health, geology.) These tuition-waived continuing education courses are graded on a pass/fail grading scale and do not apply as graduate credit toward a degree program.