

# Physics and Astronomy

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## Degrees Offered

- Bachelor of Arts
- Bachelor of Science

Students may not earn both a B.A. and a B.S. in Physics.

## Nature of the Program

There are two degree options for students in physics. The bachelor of science degree is designed for students committed to a career in research. It can be followed by graduate work in physics, chemistry, materials science, optical sciences, astrophysics, engineering, or in other physical sciences such as meteorology, oceanography, etc. Some students instead pursue positions in industry or in a government laboratory immediately after completing the B.S. This degree program provides a comprehensive grounding in the fundamentals of physics and is usually accompanied by participation in one of the active research programs within the department.

The bachelor of arts degree is designed to prepare students for a career that utilizes physics preparation in conjunction with an applied emphasis. By allowing more free elective choices, it prepares a student for a career that combines a science background with subsequent professional training.

Typical career paths for this degree program include teaching, medicine, dental school, medical school, patent law, forensics, health physics, environmental engineering, science journalism, government policy, and business management.

The courses in physics provide a mix of theoretical concepts and practical examples. Each course within a degree plan builds upon the knowledge base acquired in previous courses and, together, these courses allow a student to acquire the combination of physical insight and mathematical skill needed for success in today's demanding job markets.

The department also offers introductory survey courses in physics and astronomy that are of interest to a broad range of students in the social sciences, fine arts, humanities, health sciences, and education. These courses use a minimum of mathematics to introduce the principles of physics and they provide many examples from the "real world" of the environment, energy, space, communications, transportation, and medicine.

For the B.S. degree, an Area of Emphasis is required. The Professional Preparation Area of Emphasis is the typical plan of study for graduate study in physics. Recommendations for the other areas of emphasis include:

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## APPLIED PHYSICS

Capstone research/senior design project must emphasize an applied physics topic. Students interested in completing this area of emphasis are encouraged to consider these courses as general electives: EE 311 Junior Instrumentation Lab; CPE 310 & CPE 311 Microprocessor Systems and Microprocessor Laboratory.

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## SPACE PHYSICS

Capstone research must emphasize a space physics topic. Students completing this area of emphasis are encouraged to consider the following courses as elective choices: PHYS 340 Experimental Space Physics; EE 223 Electrical Circuits & EE 224 Electrical Circuits Laboratory.

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## BIOPHYSICS

Capstone research must emphasize a biophysics topic. Students interested in this area of emphasis are encouraged to consider these courses as electives: BIOL 117 Introductory Physiology; BIOL 219 The Living Cell; PHYS 225 Medical Imaging Physics. Students considering medical school are encouraged to take CHEM 233 Organic Chemistry & CHEM 235 Organic Chemistry Laboratory in place of CHEM 231, and follow with CHEM 234 Organic Chemistry & CHEM 236 Organic Chemistry Laboratory as elective courses.

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## COMPUTATIONAL PHYSICS

Capstone research must emphasize a computational physics topic. Students interested in this area of emphasis are encouraged to consider these courses as electives: CS 221 Analysis of Algorithms; STAT 215 Introduction to Probability and Statistics.

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## **MATERIALS SCIENCE**

Capstone research must emphasize a materials science topic. Students interested in this area of emphasis are encouraged to consider these courses as electives: PHYS 321 Optics; CHEM 233 Organic Chemistry & CHEM 235 Organic Chemistry Laboratory. CHEM 233 & 235 are highly recommended for students interested in studying polymers.

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## **MEDICAL PHYSICS**

Capstone research must emphasize a medical physics topic. Students interested in this area of emphasis are encouraged to consider these courses as electives: BIOL 219 The Living Cell; BIOL 310 Advanced Cellular/Molecular Biology. Students considering medical school are encouraged to take CHEM 233 Organic Chemistry & CHEM 235 Organic Chemistry Laboratory in place of CHEM 231, and follow with CHEM 234 Organic Chemistry & CHEM 236 Organic Chemistry Laboratory as elective courses.

## **Minors**

All students have the possibility of earning one or more minors; view a list of all available minors and their requirements (<http://catalog.wvu.edu/undergraduate/minors/>) here. Please note that students may not earn a minor in their major field.

## **Certificate of Global Engagement**

Students in the Eberly College, regardless of their major, can earn a Certificate of Global Engagement. Completion of the Certificate demonstrates the student's knowledge of diverse cultures, as well as the ability to communicate and interact effectively with people of different cultural backgrounds. Students will be required to apply their knowledge of contemporary issues and global social contexts to their course work and their broader citizenship. For details regarding Certificate requirements, please visit the Eberly College page (<http://catalog.wvu.edu/undergraduate/eberlycollegeofartsandsciences/#otherdegreestext>).

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## **FACULTY**

### **CHAIR**

- Earl Scime - Ph.D. (University of Wisconsin - Madison)  
Oleg D. Jefimenko Professor, Plasma Physics

### **ASSOCIATE CHAIR**

- Daniel J. Pisano - Ph.D. (University of Wisconsin-Madison)  
Astrophysics/Astronomy

### **PROFESSORS**

- Wathiq Abdul-Razzaq - Ph.D. (University of Illinois - Chicago)  
Physics Education
- Paul Cassak - Ph.D. (University of Maryland)  
Plasma Physics, Theory
- Leonardo Golubovic - Ph.D. (University of Belgrade)  
Theoretical Condensed Matter Physics and Statistical Physics
- Matthew Johnson - Ph.D. (California Institute of Technology)  
Experimental Condensed Matter Physics
- Mark E. Koepke - Ph.D. (University of Maryland)  
Plasma Physics, Experiment
- James P. Lewis - Ph.D. (Arizona State University)  
Computational Condensed Matter Physics
- Lian Li - Ph.D. (University of Arizona)  
Carroll Professor, Experimental Condensed Matter Physics
- Duncan R. Lorimer - Ph.D. (University of Manchester)  
Astrophysics/Astronomy
- Maura McLaughlin - Ph.D. (Cornell University)  
Eberly Family Professor, Astrophysics/Astronomy
- Sheena Murphy - Ph.D. (Cornell University)  
Experimental Condensed Matter Physics
- Aldo Romero - Ph.D. (University of California - San Diego)  
Theoretical Condensed Matter Physics

- Earl E. Scime - Ph.D. (University of Wisconsin - Madison)  
Oleg D. Jefimenko Professor, Plasma Physics
- Gay Stewart - Ph.D. (University of Illinois-Urbana Champaign)  
Eberly Professor of SEM Education

## ASSOCIATE PROFESSORS

- Loren Anderson - Ph.D. (Boston University)  
Astrophysics/Astronomy
- Alan Bristow - Ph.D. (University of Sheffield)  
Experimental Condensed Matter Physics
- Cheng Cen - Ph.D. (University of Pittsburgh)  
Condensed Matter Physics
- Edward Flagg - Ph.D. (University of Texas - Austin)  
Condensed Matter Physics
- Mikel Holcomb - Ph.D. (University of California - Berkeley)  
Condensed Matter Physics
- Paul Miller - Ph.D. (West Virginia University)  
Physics Education Research
- D.J. Pisano - Ph.D. (University of Wisconsin - Madison)  
Astrophysics/Astronomy
- Tudor Stanescu - Ph.D. (University of Illinois)  
Theoretical Condensed Matter Physics
- John Stewart - Ph.D. (University of Illinois-Urbana Champaign)  
Physics Education Research

## ASSISTANT PROFESSORS

- Adam Kobelski - Ph.D. (University of Montana)  
Solar Physics, Physics Education Research
- Joonhee Lee - Ph.D. (Seoul National University)  
Biophysics
- Sarah Burke Spolaor - Ph.D. (Swinburne University of Technology)  
Astrophysics/Astronomy
- Sean McWilliams - Ph.D. (University of Maryland)  
Astrophysics/Astronomy
- Kathryn Williamson - Ph.D. (Montana State University)  
Astronomy Education Research
- Weichao Tu - Ph.D. (University of Colorado - Boulder)  
Space Plasma Physics

## RESEARCH PROFESSORS

- Vladimir Demidov - Ph.D. (St. Petersburg University)  
Plasma Physics and Plasma Chemistry

## ADJUNCT ASSOCIATE PROFESSORS

- Amy Keesee - Ph.D. (West Virginia University)  
Plasma Physics
- Julian Schulze - Ph.D. (Ruhur University - Bochum)  
Plasma Physics

## RESEARCH ASSISTANT PROFESSOR

- Yanjun Ma - Ph.D. (University of Pittsburgh)  
Condensed Matter Physics
- Qiang Wang - Ph.D. (University of Colorado - Boulder)  
Condensed Matter Physics

## PROFESSORS EMERITI

- Larry E. Halliburton - Ph.D. (University of Missouri - Columbia)  
Condensed Matter Physics

- Arthur S. Pavlovic - Ph.D. (Columbia University)  
Condensed Matter Physics
- Mohindar S. Seehra - Ph.D. (University of Rochester)  
Eberly Family Professor, Condensed Matter Physics
- Richard Treat - Ph.D. (University of California – Riverside)  
General Relativity)
- H. Arthur Weldon - Ph.D. (Massachusetts Institute of Technology)  
Particle Physics

## Admissions

- First Time Freshmen with a minimum MATH ACT score of 22, or a minimum MATH SAT of 540, or who place via the placement test in MATH 126 are admitted directly into the B.A. or B.S. physics program.
- Students transferring from another major or from another institution must meet milestones set by the department: a GPA of 2.2 in math & physics courses with at least one math & physics course completed and a 2.0 overall GPA. Please see a departmental adviser for details.

For specific information on the following programs please see the links to the right:

### Degree Progress

- **GPA in the major:**
  - Students must have a cumulative GPA in the major requirements of 2.2 or better after completing two physics courses, or they will be placed on probation.
  - Students who do not raise their GPA in the major requirements above 2.2 after one semester on probation will be removed from the Major.
- **Repeated MATH and PHYS courses:**
  - Students not able to attain better than a D/F/W by the second attempt in a mathematics or physics course will be placed on probation.
  - A student with three grades of D/F/W in the same physics or mathematics course will be removed from the Major.

## Major Learning Outcomes

### PHYSICS

Upon successful completion of the B.S. degree, **Physics** majors will demonstrate:

1. An understanding of and ability to solve basic conceptual and quantitative problems in theoretical mechanics, electricity and magnetism, quantum mechanics, and thermodynamics.
2. An ability to perform accurate measurements of physical systems and communicate the results and implications of those measurements orally and in writing.
3. An ability to develop experiments to test basic or applied research questions, to perform accurate experimental measurements, and to critically evaluate others' answers to research questions.
4. Preparation for success in graduate school or in a post baccalaureate career.

Upon successful completion of the B.A. degree, **Physics** majors will demonstrate:

1. An understanding of and ability to solve basic conceptual and quantitative problems in foundational physics areas and to apply complex reasoning and problem solving skills developed in physics across disciplines, with focus on such application in a cognate area.
2. An ability to perform accurate measurements of physical systems and communicate the results and implications of those measurements orally and in writing.
3. An ability to develop experiments to test basic or applied research questions, to perform accurate experimental measurements, and to critically evaluate others' answers to research questions.
4. Preparation for success in a post baccalaureate career, or graduate or professional school in the cognate area.

The Physics B.A. is designed to prepare students for a career that utilizes physics preparation in conjunction with an applied emphasis. Some common examples are teaching, science journalism, medicine or patent law. Students work with their advisors to choose complementary courses tailored to suit the student's career aspirations. These hours are completed within the block of elective hours.

## Astronomy Minor

### Minor Code - U087

Physics majors may complete an astronomy minor, provided the ASTR courses counted toward the minor are not counted as electives toward the physics major. A minimum grade of C or better is required in each course counted toward the minor.

Students must earn a minimum overall GPA of 2.00 in all courses applied to the minor.

**Core Courses:**

PHYS 111	General Physics	4
PHYS 112	General Physics	4
PHYS 314	Introductory Modern Physics	4

**Upper Division Electives:** \*

Select three electives from any ASTR courses numbered 300 and above.

Total Hours 21

\* An ASTR course applied toward an ASTR minor may not be counted toward a PHYS minor.

\*\* Courses PHYS 490, 491, 493, 494, 495, 496, and 497 cannot be applied to the minor requirements.

## Physics Minor

### Minor Code - U026

A grade of C- or better is required in each course counted toward the minor:

**Core Courses:**

PHYS 111	General Physics	4
PHYS 112	General Physics	4
PHYS 314	Introductory Modern Physics	4

**General Electives:** 6

One PHYS course at the 300-level or above

One PHYS or ASTR course at the 300-level or above \*

Total Hours 18

\* An ASTR course applied toward an ASTR minor may not be counted toward a PHYS minor.

\*\* Courses PHYS 490, 491, 493, 494, 495, 496, and 497 cannot be applied to the minor requirements.

## COURSES

### Astronomy

**ASTR 106. Descriptive Astronomy. 3 Hours.**

The celestial sphere, star time, solar time, Kepler's laws, H-R diagram and modern developments. No sophisticated mathematics used; only simple geometrical arguments employed.

**ASTR 107. Descriptive Astronomy Laboratory. 1 Hour.**

PR or CONC: ASTR 106. Introduction to modern astronomical techniques and practices through research-quality astronomical data collection and analysis, computer simulation, and hands-on activities. Includes study of objects in our solar system, in the Milky Way, and located much farther away in the vast reaches of space. Students engage in authentic scientific practices while exploring the universe.

**ASTR 110. Explosions in Space. 3 Hours.**

PR: MATH 124 or higher, or appropriate score on MATH placement test. Topics covered include: special and general relativity, supernovae, neutron stars, black holes, wormholes, time travel and gamma-ray bursts.

**ASTR 115. Honors Relativity. 1 Hour.**

PR: MATH 124 or higher or appropriate score on MATH placement test. Exploration of gravity as the geometry of four-dimensional space time; the legacy of Einstein.

**ASTR 290. Teaching Practicum. 1-3 Hours.**

**ASTR 293. Special Topics. 1-6 Hours.**

PR: Consent. Investigation of topics not covered in regularly scheduled courses.

**ASTR 298. Honors. 1-3 Hours.**

PR: Students in Honors Program and consent by the honors director. Independent reading, study, or research.

**ASTR 367. Astrophysics 1. 3 Hours.**

PR: PHYS 314. Physical description of the astronomical universe. Physical principles are used to explain the properties and evolution of stars. Physical properties and effects of the Milky Way's interstellar medium are examined.

**ASTR 368. Astrophysics 2. 3 Hours.**

PR: ASTR 367. Continuation of ASTR 367. Physical principles are applied to the properties and evolution of the Milky Way and galaxies and to the structure and evolution of the solar system. Physical properties of the universe are examined.

**ASTR 393. Special Topics. 1-6 Hours.**

PR: Consent. Investigation of topics not covered in regularly scheduled courses.

**ASTR 469. Observational Astronomy. 3 Hours.**

PR: PHYS 314. Laboratory course consisting of three detailed projects which aim to acquaint students with current techniques for astronomy data analysis and interpretation across the electromagnetic spectrum.

**ASTR 470. General Relativity. 3 Hours.**

PR: PHYS 314 and PHYS 331. Innovative 'physics-first' introduction to Einstein's relativistic theory of gravity. Topics covered include special relativity, curved space time, spherical stars, gravitational collapse, black holes, gravitational waves and cosmology.

**ASTR 490. Teaching Practicum. 1-3 Hours.**

PR: Consent. Teaching practice as a tutor or assistant.

**ASTR 491. Professional Field Experience. 1-18 Hours.**

PR: Consent. (May be repeated up to a maximum of 18 hours.) Prearranged experiential learning program, to be planned, supervised, and evaluated for credit by faculty and field supervisors. Involves temporary placement with public or private enterprise for professional competence development.

**ASTR 492. Directed Study. 1-3 Hours.**

Directed study, reading, and/or research.

**ASTR 493. Special Topics. 1-6 Hours.**

PR: Consent. Investigation of topics not covered in regularly scheduled courses.

**ASTR 494. Seminar. 1-3 Hours.**

PR: Consent. Presentation and discussion of topics of mutual concern to students and faculty.

**ASTR 495. Independent Study. 1-6 Hours.**

Faculty supervised study of topics not available through regular course offerings.

**ASTR 496. Senior Thesis. 1-3 Hours.**

PR: Consent.

**ASTR 497. Research. 1-6 Hours.**

Independent research projects.

**ASTR 498. Honors. 1-3 Hours.**

PR: Students in honors program and consent by the honors director. Independent reading, study, or research.

## Physical Science

**PHSC 101. Introductory Physical Science 1. 4 Hours.**

(For Elementary Education majors only.) Emphasis on practicing reasoning abilities necessary to carry out simple scientific inquiry. Major concepts include properties of matter and astronomy. Majority of class time is spent in laboratory activities and solving problems using an activity-based approach.

**PHSC 102. Introductory Physical Science 2. 4 Hours.**

PR: PHSC 101. Continuation of PHSC 101. Concepts include electricity, motion, heat and temperature, energy, and chemistry.

**PHSC 293. Special Topics. 1-6 Hours.**

PR: Consent. Investigation of topics not covered in regularly scheduled courses.

**PHSC 490. Teaching Practicum. 1-3 Hours.**

PR: PHYS 105 or consent. Teaching practice as a tutor or assistant. Opportunity to help teach an activity-based science course under the direction of experienced instructors. Emphasis on developing inquiry teaching skills useful for all levels of classroom instruction.

**PHSC 491. Professional Field Experience. 1-18 Hours.**

PR: Consent. (May be repeated up to a maximum of 18 Hours.) Prearranged experiential learning program, to be planned, supervised, and evaluated for credit by faculty and field supervisors. Involves temporary placement with public or private enterprise for professional competence development.

**PHSC 494. Seminar. 1-3 Hours.**

PR: Consent. Presentation and discussion of topics of mutual concern to students and faculty.

**PHSC 496. Senior Thesis. 1-3 Hours.**

PR: Consent.

**PHSC 498. Honors. 1-3 Hours.**

PR: Students in Honors Program and consent by the honors director. Independent reading, study or research.

## Physics

### **PHYS 101. Introductory Physics. 4 Hours.**

PR or CONC: MATH 128 or MATH 129 or MATH 150 or MATH 153 or MATH 154 or MATH 155 or MATH 156 or consent or satisfactory performance on MATH departmental placement exam. The fundamental philosophy and principles of physics are applied to studies of mechanics, sound, heat, and thermodynamics through demonstrations, problems, and experiments. Pre-requisites and/or co-requisites may differ on regional campuses.

### **PHYS 102. Introductory Physics. 4 Hours.**

PR: PHYS 101. The fundamental philosophy and principles of physics are applied to studies of electricity, magnetism, optics, light, and atomic and nuclear physics through demonstrations, problems, and experiments. Pre-requisite(s) and/or co-requisite(s) may differ on regional campuses.

### **PHYS 103. Physics 101 Lab Alternative. 1 Hour.**

PR: PHYS 101 with a grade of C or higher. Laboratory component of survey of classical mechanics, thermodynamics and waves. (This lab is an alternative for students who transfer PHYS 101 without laboratory and need to complete the lab only).

### **PHYS 104. Physics 102 Lab Alternative. 1 Hour.**

PR: PHYS 102 with a grade of C or higher. Laboratory component of survey of electricity, magnetism and optics. (This laboratory is an alternative for students who transfer PHYS 102 without laboratory and need to complete the lab only).

### **PHYS 105. Conceptual Physics. 4 Hours.**

Basic principles of physics and their relationship to our modern technological society. Major topics include properties of matter, electricity, optics, motion, heat and temperature, and energy. Nonmathematical approach emphasized.

### **PHYS 107. Physics of Music. 3 Hours.**

For all students including those in the liberal and fine arts. (No science or music prerequisites.) The physical and psychophysical principles underlying the nature, production, transmission, reception, and reproduction of sound.

### **PHYS 108. Light, Vision and Color. 3 Hours.**

For all students including those in liberal and fine arts. Descriptive course emphasizing the basic principles of light with applications to color vision and optical phenomena in everyday environment and technology.

### **PHYS 111. General Physics. 4 Hours.**

PR: MATH 155 with a grade of C or better or (MATH 153 with a grade of C or better and PR or CONC: MATH 154). Survey of classical mechanics, thermodynamics and waves.

### **PHYS 112. General Physics. 4 Hours.**

PR: PHYS 111. Survey of electricity, magnetism, and optics.

### **PHYS 113. General Physics Honors. 1 Hour.**

Additional honors hour companion course for Physics 111 in the spring semester and Physics 112 in the fall semester.

### **PHYS 114. Physics 111 Lab Alternative. 1 Hour.**

PR: PHYS 111 with a grade of C or higher. Laboratory component of survey of classical mechanics, thermodynamics and waves. (This lab is an alternative for students who transfer PHYS 111 without laboratory and need to complete the lab only.).

### **PHYS 115. Physics 112 Lab Alternative. 1 Hour.**

PR: PHYS 112 with a grade of C- or higher. Laboratory component of survey of electricity magnetism and optics. (This laboratory is an alternative for students who transfer PHYS 112 without a laboratory and need to complete the lab only).

### **PHYS 191. First-Year Seminar. 1-3 Hours.**

Engages students in active learning strategies that enable effective transition to college life at WVU. Students will explore school, college and university programs, policies and services relevant to academic success. Provides active learning activities that enable effective transition to the academic environment. Students examine school, college and university programs, policies and services.

### **PHYS 199. Orientation to Physics. 1,2 Hour.**

Orientation to degree programs and requirements, departmental resources, curriculum options, student responsibilities and opportunities.

### **PHYS 211. Introduction to Mathematical Physics. 3 Hours.**

PR: MATH 251 and PHYS 112. Review of basic calculus with application to Physics; e.g. vector calculus and Maxwell's Equations, Fourier Series and the vibrating string, eigenvalues, eigenvectors and coupled oscillators. Complex algebra, linear algebra, differential equations, practical differential equations, Bessel functions, Legendre Polynomials, and Fourier Transforms.

### **PHYS 212. Oscillations and Thermal Physics. 3 Hours.**

PR: PHYS 111 and PHYS 112 with a minimum grade of C- in each. Introduction to wave analysis of a variety of physical systems, as well as introductory thermodynamics. Topics covered include pendula, oscillatory circuits, mechanical and sound waves, Fourier series and transforms, the Doppler effect, heat transfer, gases, fluids, entropy and the basic elements of diffraction and apertures.

### **PHYS 225. Medical Imaging Physics. 3 Hours.**

Introduces the physics of medical imaging and is intended for non-physics majors. The fundamental concepts and clinical applications of the major imaging techniques are presented. The subject matter is ideal for pre-med majors.

**PHYS 290. Teaching Practicum. 1-3 Hours.**

**PHYS 293. Special Topics. 1-6 Hours.**

PR: Consent. Investigation of topics not covered in regularly scheduled courses.

**PHYS 301. Computational Physics. 3 Hours.**

PR: MATH 261 and PHYS 314. Using basic numerical techniques to gain insight into physical systems. Numerical solutions for projectile motion, chaotic systems, and motion in a gravitational field (including N-body simulations). Numerical solutions to Maxwell's equations, the diffusion equation, the wave equation, Schrodinger's equation, and the hydrogen atom. Implementation of discrete Fourier Transforms and wavelet methods for analysis of time series.

**PHYS 313. Introductory Electronics. 3 Hours.**

PR: PHYS 111 and PHYS 112. Principles and applications of integrated circuits and digital electronics.

**PHYS 314. Introductory Modern Physics. 4 Hours.**

PR: PHYS 112 and MATH 156. Topics of modern physics of interest to science majors and engineers; atomic and molecular structure and spectra, solid state and nuclear physics, relativity, and elementary particles.

**PHYS 315. Advanced Physics Problem Solving. 1 Hour.**

PR: PHYS 314. Development of advanced problem solving techniques for all areas of physics. Topics covered include: mechanics, optics and waves, quantum mechanics, atomic physics, nuclear and particle physics, relativity and thermodynamics.

**PHYS 321. Optics. 3 Hours.**

PR: PHYS 111 and PHYS 112 and MATH 156. A basic course in physical optics covering wave mathematics, propagation, polarization, interference, and diffraction; applications in geometrical optics and selected topics in scattering and quantum optics.

**PHYS 325. Atomic Physics. 3 Hours.**

PR: PHYS 314. Relativistic mechanics, atomic structure, and spectra.

**PHYS 331. Theoretical Mechanics 1. 3 Hours.**

PR: PHYS 111 and PHYS 112 or equiv. PR or Conc: MATH 261. Scalar, vector, and tensor fields; curvilinear coordinate systems. Kinematics and dynamics of particles, systems of particles and rigid bodies.

**PHYS 332. Theoretical Mechanics 2. 3 Hours.**

PR or CONC: MATH 261 and PHYS 331 or equivalent. Scalar, vector, tensor fields; curvilinear coordinate systems. Lagrangian and Hamiltonian formulation. Relativistic motion.

**PHYS 333. Electricity and Magnetism 1. 3 Hours.**

PR: PHYS 111 and PHYS 112 or equiv. and PR or Conc.: MATH 261. Electrostatics, electrostatics in matter, magnetostatics, magnetostatics in matter.

**PHYS 334. Electricity and Magnetism. 3 Hours.**

PR or CONC: PHYS 333 or equiv. and MATH 261. Maxwell's equations, reflection and refraction, wave guides and cavities.

**PHYS 340. Experimental Space Physics. 3 Hours.**

PR: PHYS 112. Laboratory course consisting of an experimental project designed to acquaint students with current techniques for the design and construction of scientific payloads for suborbital and orbital space missions.

**PHYS 341. Advanced Laboratory. 1-3 Hours.**

PR: PHYS 111 and PHYS 112 and PHYS 314. Experiments in physics designed to complement theory courses, give experience in data taking and instrumentation, and learn methods of data evaluation and error analysis.

**PHYS 376. Research Methods. 3 Hours.**

PR: PHYS 112 and PR or CONC: ARSC 220. An introduction to the tools and mathematics that scientists use to solve scientific problems. Mathematical modeling, experimental design, hypothesis formulation, data collection, use of statistics, reading and evaluating the scientific literature, writing and reviewing scientific papers, and oral presentation of scientific research.

**PHYS 393. Special Topics. 1-6 Hours.**

PR: Consent. Investigation of topics not covered in regularly schedule courses.

**PHYS 451. Introductory Quantum Mechanics. 3 Hours.**

PR: PHYS 314 and MATH 261. Fundamental principles of quantum mechanics; wave functions in position and momentum space, operators, Schrodinger's equation, applications to one-dimensional problems, approximation methods, the hydrogen atom, angular momentum and spin.

**PHYS 452. Quantum Mechanics 2. 3 Hours.**

PR: PHYS 451 and MATH 261. Angular momentum operators, including spin, and time-dependent perturbation theory. Applications of quantum mechanics, including the properties of atoms (hydrogen and multi-electron atoms), molecules, solids, identical particles of atoms (hydrogen and multi-electron atoms), molecules, solids, identical particles ( e.g. black-body spectrum, Bose-Einstein condensation, and the free electron gas), and quantum effects of adiabatic changes.

**PHYS 461. Thermodynamics and Statistical Mechanics. 3 Hours.**

PR: PHYS 314 or equiv and MATH 251. Introduction to the statistical foundations of thermodynamics; applications of the fundamental laws of thermodynamics to physical and chemical systems.



**PHYS 463. Nuclear Physics. 3 Hours.**

PR: PHYS 314 and MATH 251. Study of characteristic properties of nuclei and their structure as inferred from nuclear decays and reactions, leading to a knowledge of nuclear forces and models.

**PHYS 471. Solid State Physics. 3 Hours.**

PR: PHYS 314 or equiv and MATH 251. Properties of crystalline solids; includes crystal structure, interatomic binding, lattice vibrations, electron theory of metals, and the band theory of solids with some applications.

**PHYS 481. Plasma Physics. 3 Hours.**

PR: PHYS 111 and PHYS 112 and PR or Conc: PHYS 334. Introductory course in the physics of ionized gases; particle and fluid treatment of plasmas, waves, equilibrium and stability, kinetic theory, and nonlinear effects.

**PHYS 490. Teaching Practicum. 1-3 Hours.**

PR: Consent. Teaching practice as a tutor or assistant.

**PHYS 491. Professional Field Experience. 1-18 Hours.**

PR: Consent. (May be repeated up to a maximum of 18 Hours.) Prearranged experiential learning program, to be planned, supervised, and evaluated for credit by faculty and field supervisors. Involves temporary placement with public or private enterprise for professional competence development.

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Faculty supervised study of topics not available through regular course offerings.

**PHYS 496. Senior Thesis. 1-3 Hours.**

PR: Consent.

**PHYS 497. Research. 1-6 Hours.**

PR: Consent. Independent research projects.

**PHYS 498. Honors. 1-3 Hours.**

PR: Students in Honors Program and consent by the honors director. Independent reading, study, or research.