PHYSICS AND ASTRONOMY

physics.northwestern.edu

Physics seeks answers to fundamental questions about the natural world. Physicists study nature at all distance scales, from extremely large (stellar systems, galaxies, and the observable universe) to infinitesimally small (atoms, nuclei, and fundamental particles), as well as everything in between (biological systems, natural and artificial materials).

Many students in physics pursue career paths involving the natural sciences and engineering, both in academia and industry, while others find that the quantitative thinking and problem solving skills that characterize physics and astronomy can be fruitfully applied to many nonscience areas.

Majors normally take:

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Sophomore year:

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First-year students who have taken a calculus-level physics course in high school may waive parts of the introductory physics sequence in the following ways:

- A score of 5 on the College Board Advanced Placement Physics C (Mechanics) examination will give the student credit for PHYSICS 135-1 General Physics and lab course credit.
- A score of 5 on the College Board Advanced Placement Physics C (Electricity and Magnetism) examination will give the student credit for PHYSICS 135-2 General Physics and lab course credit.
- A score of 5 on the College Board Advanced Placement Physics 2 exam will give the student credit for PHYSICS 130-1 College Physics and lab course credit.
- A score of 5 on the College Board Advanced Placement Physics 2 exam will give the student credit for PHYSICS 130-2 College Physics and lab course credit.
- A passing score on the departmental placement examinations, given during Wildcat Welcome, will allow a student to place out of any or all parts of:

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Advanced Placement

Students intending to study physics or astronomy in graduate school should choose the advanced physics or astronomy concentrations. They should also consider taking 2 or 3 units of PHYSICS 398-0 Independent Thesis Research or PHYSICS 399-0 Independent Study under the supervision of a faculty member, consisting of a research project in the student’s area of concentration and, if possible, introductory graduate courses. Students intending graduate study in a subject other than physics or not planning to go to graduate school may select the flexible physics or astronomy concentration within the physics major.

While there is no formal major in astronomy, students may select the astronomy concentration within the physics major.

Advanced Placement

The Teaching of Physics

Weinberg College students pursuing a major in physics who also wish to be certified for secondary teaching must be admitted to the Secondary Teaching Program (https://catalogs.northwestern.edu/undergraduate/education-social-policy/secondary-teaching) in the School of Education and Social Policy and complete all requirements as outlined in the SESP chapter of this catalog. Students are urged to contact the Office of Student Affairs in SESP as early as possible in their academic careers.

Advanced Placement

First-year students who have taken a calculus-level physics course in high school may waive parts of the introductory physics sequence in the following ways:

- A score of 5 on the College Board Advanced Placement Physics C (Mechanics) examination will give the student credit for PHYSICS 135-1 General Physics and lab course credit.
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Programs of Study

- Physics Major (https://catalogs.northwestern.edu/undergraduate/arts-sciences/physics-astronomy/physics-major)
- Physics Minor (https://catalogs.northwestern.edu/undergraduate/arts-sciences/physics-astronomy/physics-minor)
- Physics Second Major for ISP Students (https://catalogs.northwestern.edu/undergraduate/arts-sciences/physics-astronomy/physics-second-major-isp-students)

Note: The laboratory components of first-year physics sequences require separate registration and bear separate credit. When a course in such a sequence is listed as a prerequisite for another course, the associated lab is also a prerequisite.

See below for Astronomy Courses (p. 4).

Physics Courses

PHYSICS 103-0 Ideas of Physics (1 Unit)  Topics in modern physics. Content varies-for example, relativity, the physics of music, and the progress of physics through history. Requires only high school mathematics and is designed for non-science majors. Natural Sciences Distro Area

PHYSICS 105-0 Music, Sound, Timbre (1 Unit)  Introduction to the interface of art, technology, and science. MIDI; musical analysis and
composition; physical acoustics and psychoacoustics; construction and acoustics of instruments; signal generation, recording, and analysis. Natural Sciences Distro Area

**PHYSICS 110-6 First-Year Seminar (1 Unit)** WCAS First-Year Seminar

**PHYSICS 125-1 General Physics ISP (1 Unit)** General physics course relying extensively on calculus. Similar to PHYSICS 135-1 but more advanced and intended for ISP students. A concurrent advanced calculus course, MATH 281-1 is offered by the mathematics department. Prerequisite: first-year standing in ISP or consent of the department and concurrent enrollment in PHYSICS 126-1. Natural Sciences Distro Area

**PHYSICS 125-2 General Physics for ISP (1 Unit)** General physics course relying extensively on calculus. Similar to PHYSICS 135-2 but more advanced and intended for ISP students. A concurrent advanced calculus course, MATH 281-2, is offered by the mathematics department. Prerequisite: first-year standing in ISP or consent of the department and concurrent enrollment in PHYSICS 126-2. Natural Sciences Distro Area

**PHYSICS 125-3 General Physics for ISP (1 Unit)** General physics course relying extensively on calculus. Similar to PHYSICS 135-3 but more advanced and intended for ISP students. A concurrent advanced calculus course, MATH 281-3 is offered by the mathematics department. Prerequisite: first-year standing in ISP or consent of the department and concurrent enrollment in PHYSICS 126-3. Natural Sciences Distro Area

**PHYSICS 126-1 Physics for ISP Laboratory (0.34 Unit)** Introductory physics laboratory for students taking PHYSICS 125-1, with which it must be taken concurrently.

**PHYSICS 126-2 Physics for ISP Laboratory (0.34 Unit)** Introductory physics laboratory for students taking PHYSICS 125-2, with which it must be taken concurrently.

**PHYSICS 126-3 Physics for ISP Laboratory (0.34 Unit)** Introductory physics laboratory for students taking PHYSICS 125-3, with which it must be taken concurrently.

**PHYSICS 130-1 College Physics (1 Unit)** Algebra-based physics primarily for premedical students who do not need to take calculus-based physics. Topics covered are similar to those of PHYSICS 135-1. Students with credit for a quarter of Physics 135 may not later receive credit for the comparable quarter of Physics 130. Prerequisites: algebra, trigonometry, and concurrent enrollment in PHYSICS 136-1. Natural Sciences Distro Area

**PHYSICS 130-2 College Physics (1 Unit)** Algebra-based physics primarily for premedical students who do not need to take calculus-based physics. Topics covered are similar to those of PHYSICS 135-2. Students with credit for a quarter of Physics 135 may not later receive credit for the comparable quarter of Physics 130. Prerequisites: PHYSICS 130-1, PHYSICS 136-1, and concurrent enrollment in PHYSICS 136-2. Natural Sciences Distro Area

**PHYSICS 130-3 College Physics (1 Unit)** Algebra-based physics primarily for premedical students who do not need to take calculus-based physics. Topics covered are similar to those of PHYSICS 135-3. Students with credit for a quarter of Physics 135 may not later receive credit for the comparable quarter of Physics 130. Prerequisites: PHYSICS 130-2, PHYSICS 136-2, and concurrent enrollment in PHYSICS 136-3. Natural Sciences Distro Area

**PHYSICS 130-SG-1 Peer-Guided Study Group: College Physics 1 (0 Unit)** Peer-guided study group for students enrolled in PHYSICS 130-1. Meets weekly in small groups, along with a peer facilitator, to collaboratively review material, work through practice problems, and clarify course concepts. Enrollment optional. Graded S/U.

**PHYSICS 130-SG-2 Peer-Guided Study Group: College Physics 2 (0 Unit)** Peer-guided study group for students enrolled in PHYSICS 130-2. Meets weekly in small groups, along with a peer facilitator, to collaboratively review material, work through practice problems, and clarify course concepts. Enrollment optional. Graded S/U.

**PHYSICS 130-SG-3 Peer-Guided Study Group: College Physics 3 (0 Unit)** Peer-guided study group for students enrolled in PHYSICS 130-3. Meets weekly in small groups, along with a peer facilitator, to collaboratively review material, work through practice problems, and clarify course concepts. Enrollment optional. Graded S/U.

**PHYSICS 135-1 General Physics (1 Unit)** Calculus-based physics for science and engineering majors and premedical students. Mechanics. Prerequisites: MATH 220-1, MATH 220-2; concurrent enrollment in PHYSICS 136-1 and MATH 230-1. Natural Sciences Distro Area

**PHYSICS 135-2 General Physics (1 Unit)** Calculus-based physics for science and engineering majors and premedical students. Electricity and magnetism. Prerequisite: PHYSICS 135-1, PHYSICS 136-1 and concurrent enrollment in PHYSICS 136-2. Natural Sciences Distro Area

**PHYSICS 135-3 General Physics (1 Unit)** Calculus-based physics for science and engineering majors and premedical students. Introduction to modern physics; wave phenomena. Prerequisite: PHYSICS 135-2, PHYSICS 136-2 and concurrent enrollment in PHYSICS 136-3. Natural Sciences Distro Area

**PHYSICS 135-SG-1 Peer-Guided Study Group: General Physics 1 (0 Unit)** Peer-guided study group for students enrolled in PHYSICS 135-1. Meets weekly in small groups, along with a peer facilitator, to collaboratively review material, work through practice problems, and clarify course concepts. Enrollment optional. Graded S/U.

**PHYSICS 135-SG-2 Peer-Guided Study Group: General Physics 2 (0 Unit)** Peer-guided study group for students enrolled in PHYSICS 135-2. Meets weekly in small groups, along with a peer facilitator, to collaboratively review material, work through practice problems, and clarify course concepts. Enrollment optional. Graded S/U.

**PHYSICS 135-SG-3 Peer-Guided Study Group: General Physics 3 (0 Unit)** Peer-guided study group for students enrolled in PHYSICS 135-3. Meets weekly in small groups, along with a peer facilitator, to collaboratively review material, work through practice problems, and clarify course concepts. Enrollment optional. Graded S/U.

**PHYSICS 136-1 General Physics Laboratory (0.34 Unit)** Introductory physics laboratory for students taking PHYSICS 130-1 or PHYSICS 135-1, with which it must be taken concurrently.

**PHYSICS 136-2 General Physics Laboratory (0.34 Unit)** Introductory physics laboratory for students taking PHYSICS 130-2 or PHYSICS 135-2, with which it must be taken concurrently.

**PHYSICS 136-3 General Physics Laboratory (0.34 Unit)** Introductory physics laboratory for students taking PHYSICS 130-3 or PHYSICS 135-3, with which it must be taken concurrently.

**PHYSICS 140-1 Fundamentals of Physics (1 Unit)** Introduction to fundamentals topics in classical mechanics for physics majors and minors and students with a strong interest in physics. Prerequisites: MATH 220-1, MATH 220-2; concurrent enrollment in PHYSICS 136-1 and MATH 230-1. Natural Sciences Distro Area

**PHYSICS 140-2 Fundamentals of Physics (1 Unit)** Introduction to fundamentals topics in electricity and magnetism for physics majors and minors and students with a strong interest in physics. Prerequisites: PHYSICS 140-1, PHYSICS 136-1; concurrent enrollment in PHYSICS 136-2. Natural Sciences Distro Area
PHYSICS 140-3 Fundamentals of Physics (1 Unit) Introduction to fundamentals topics in wave phenomena and modern physics for physics majors and minors and students with a strong interest in physics. Prerequisites: PHYSICS 140-2, PHYSICS 136-2; concurrent enrollment in PHYSICS 136-3. Natural Sciences Distro Area

PHYSICS 239-0 Foundations of Modern Physics (1 Unit) Principles of waves, probability, quantum theory, and selected topics from special relativity, statistical mechanics, optics, and atomic structure. Prerequisites: PHYSICS 135-1, PHYSICS 135-2, and PHYSICS 135-3 or equivalent; MATH 250-0 or equivalent or concurrent enrollment. Natural Sciences Distro Area

PHYSICS 311-1 Mathematical Tools for the Physical Sciences (1 Unit) Introduction to tools for solving physics problems, including integral calculus, complex numbers and complex algebra, matrices and vector spaces, differential equations, and Fourier analysis. Prerequisites: PHYSICS 135-1 and PHYSICS 135-2 or equivalent (concurent enrollment in PHYSICS 135-2 is sufficient); MATH 230-1. Formal Studies Distro Area

PHYSICS 311-2 Mathematical Tools for the Physical Sciences (1 Unit) Introduction to tools for solving physics problems, including integral calculus, complex numbers and complex algebra, matrices and vector spaces, differential equations, and Fourier analysis. Prerequisites: PHYSICS 135-3 (or concurrent enrollment); PHYSICS 311-1 or equivalent. Formal Studies Distro Area

PHYSICS 312-0 Scalar and Vector Field Methods in Physics (1 Unit) Physically contextualized introduction to the field concept, the associated methods of calculus, and the solution of key physical partial differential equations. Three lectures and one discussion per week. Prerequisites: PHYSICS 311-1, PHYSICS 311-2, or MATH 230-1, MATH 230-2, MATH 240-0, and MATH 250-0, or equivalents.

PHYSICS 330-1 Classical Mech (1 Unit) Newtonian mechanics, oscillations, the Lagrangian and Hamiltonian formalisms, central-force motion. Prerequisites: PHYSICS 135-1 or equivalent and MATH 230-2 and PHYSICS 311-1 and PHYSICS 311-2; or MATH 240-0, MATH 250-0; or equivalent.

PHYSICS 330-2 Classical Mechanics (1 Unit) Motion in a non-inertial reference frame, kinematics of rigid modes, systems with many degrees of freedom.

PHYSICS 332-0 Statistical Mechanics (1 Unit) Ideal gas, Boltzmann distribution, transport phenomena, fluctuation theory. Bose-Einstein and Fermi-Dirac statistics. Prerequisites: PHYSICS 135-1, PHYSICS 135-2, and PHYSICS 135-3; MATH 230-2 or equivalent.

PHYSICS 333-1 Advanced Electricity & Magnetism (1 Unit) Electrostatics and magnetostatics, multipole expansion, solutions of Laplace's equation, images, analytic functions. Prerequisites: PHYSICS 135-1, PHYSICS 135-2, and PHYSICS 135-3 and MATH 230-2 and PHYSICS 311-1 and PHYSICS 311-2; or MATH 240-0, MATH 250-0; or equivalent.

PHYSICS 333-2 Advanced Electricity & Magnetism (1 Unit) Maxwell's equations, electromagnetic equations, electromagnetic wave propagation and radiation, microwave cavities, diffraction. Prerequisites: PHYSICS 135-1, PHYSICS 135-2, and PHYSICS 135-3 and MATH 230-2 and PHYSICS 311-1 and PHYSICS 311-2; or MATH 240-0, MATH 250-0; or equivalent.

PHYSICS 335-0 Physics of Magic (1 Unit) Magic tricks, illusion, and deception used to discuss the rarely explored but often surprisingly flexible boundaries of what is physically possible. Does not fulfill 300-level requirement for majors or minors. Prerequisites: PHYSICS 135-1; MATH 220-1, MATH 220-2, or equivalent.

PHYSICS 337-0 Physics of Condensed Matter (1 Unit) Emergent properties and collective descriptions when simple components of matter are combined into larger systems with varying degrees of order. Prerequisite: PHYSICS 339-1; PHYSICS 332-0 recommended.

PHYSICS 339-1 Quantum Mechanics (1 Unit) Introduction to quantum theory. Applications to atomic and molecular systems. The harmonic oscillator, the one-electron atom, the hydrogen molecule, barrier penetration. Prerequisites: second-year standing in ISP or PHYSICS 135-1, PHYSICS 135-2, and PHYSICS 135-3 or equivalent; PHYSICS 239-0; PHYSICS 330-1; PHYSICS 311-1 or MATH 240-0.

PHYSICS 339-2 Quantum Mechanics (1 Unit) Introduction to quantum theory. Applications to atomic and molecular systems. The harmonic oscillator, the one-electron atom, the hydrogen molecule, barrier penetration. Prerequisites: PHYSICS 339-1, second-year standing in ISP or PHYSICS 311-2 or MATH 250-0, MATH 351-0.

PHYSICS 339-3 Particle and Nuclear Physics (1 Unit) Nuclei and their constituents; nuclear models; alpha and beta decay; nuclear fission and fusion; the strong, electromagnetic, and weak interactions; and the fundamental particles and particle schemes. Prerequisites: PHYSICS 339-1 and PHYSICS 339-2.

PHYSICS 345-0 Introduction to General Relativity (1 Unit) Review of special relativity and Newtonian gravity; curved space-time; geodesics and conservation laws; Schwarzschild geometry; tests of general relativity; black holes; linearized gravity and gravitational waves; and big bang cosmology. Prerequisites: PHYSICS 330-1 and PHYSICS 330-2 or consent of instructor.

PHYSICS 352-0 Introduction to Computational Physics (1 Unit) Application of computing to physics: Monte Carlo simulation, numerical integration of equations of motion, discrete element methods in electromagnetism. Prerequisites: PHYSICS 135-1, PHYSICS 135-2, and PHYSICS 135-3 or equivalent; MATH 250-0 or equivalent (concurrent enrollment is sufficient); COMP SCI 110-0 or equivalent prior programming experience.

PHYSICS 357-0 Optics Laboratory (1 Unit) Optics/laser lab focusing on optical instruments widely used in medical/biological studies, including optical microscopy, fluorescence spectroscopy, tumor detection in optical scattering, and optical fibers in endoscopes. Prerequisite: consent of instructor. Natural Sciences Distro Area

PHYSICS 358-0 Nanolithography (1 Unit) Advanced lab involving fabrication of metallic nanometer-scale structures by electron-beam lithography. Characterization of these structures by atomic force microscopy. Prerequisite: PHYSICS 135-1, PHYSICS 135-2, and PHYSICS 135-3 or equivalent.

PHYSICS 359-0 Electronics (1 Unit) Introduction to modern electronics, construction of elementary analog and digital circuits. Prerequisites: PHYSICS 333-1 and PHYSICS 333-2 or consent of instructor.

PHYSICS 360-0 Advanced Physics Laboratory (1 Unit) Modern experimental techniques and data analysis methods. Both classic and modern experiments in atomic/nuclear physics, electricity and magnetism, optics, condensed matter physics, and nonlinear dynamics. This laboratory emphasizes independent work. There are two one-hour lectures and two three-hour laboratories per week. Prerequisites: PHYSICS 239-0 or PHYSICS 339-1, and PHYSICS 333-1, or permission of instructor.

PHYSICS 361-0 Classical Optics and Special Relativity (1 Unit) Advanced topics following from electrodynamics, including advanced classical optics, Fraunhofer and Fresnel diffraction, radiation from
accelerated charges, wave guides and/or antennae, and special relativity, including dynamics. Prerequisites: PHYSICS 333-1 and PHYSICS 333-2.

PHYSICS 371-0 Nonlinear Dynamics and Chaos (1 Unit) Advanced topics following from classical mechanics. The focus will be on nonlinear dynamics and chaos theory, though coupled oscillations and continuous systems will also be covered. Prerequisites: PHYSICS 330-1 and PHYSICS 330-2.

PHYSICS 398-0 Independent Thesis Research (1-2 Units) Individual study under the direction of a faculty member. Open only to advanced students pursuing departmental honors.

PHYSICS 399-0 Independent Study (1-2 Units) Opportunity to study an advanced subject of interest under the individual direction of a faculty member. Open to all advanced students; consent of instructor required.

Astronomy Courses

All 100-level astronomy courses are specifically designed for students without technical backgrounds and require a mathematics background of only high school algebra.

ASTRON 101-0 Modern Cosmology (1 Unit) Modern views on the structure of the universe, its past, present, and future. For nonscience majors who want to take a more detailed course after completing ASTRON 120-0. Natural Sciences Distro Area

ASTRON 102-0 Milky Way Galaxy (1 Unit) Structure of the galaxy, star formation, interstellar clouds and dust, star clusters, neutron stars and black holes, the galactic center. For nonscience majors who want to take a more detailed course after completing ASTRON 120-0. Natural Sciences Distro Area

ASTRON 103-0 Solar System (1 Unit) The planets and their moons, the sun, comets, asteroids. For nonscience majors who want to take a more detailed course after completing ASTRON 120-0. Natural Sciences Distro Area

ASTRON 110-6 First-Year Seminar (1 Unit) WCAS First-Year Seminar

ASTRON 111-0 Introduction to Astrobiology (1 Unit) The modern scientific perspective on the question of life elsewhere in the universe. The prospects for life on Mars. The discovery of extrasolar planets and the search for extrasolar biospheres. Natural Sciences Distro Area

ASTRON 120-0 Highlights of Astronomy (1 Unit) Acquaints students with modern ideas about the solar system, stars, galaxies, and the universe. Emphasizes fundamental principles and underlying concepts. Natural Sciences Distro Area

ASTRON 220-0 Introduction to Astrophysics (1 Unit) Use of introductory physics (mechanics, electromagnetism, thermodynamics, and modern physics) to cover astrophysical topics starting with the solar system and ending with the largescale structure of the universe and cosmology. Prerequisites: PHYSICS 135-1, PHYSICS 135-2, and PHYSICS 135-3, or equivalent. Natural Sciences Distro Area

ASTRON 305-0 Basics of Radio Astronomy (1 Unit) Radio astronomy is the study of natural radio emission from celestial objects. The human eye is blind to most electromagnetic emissions, including those waves providing important clues about the history of our universe. Radio astronomy uses new tools to explore the sky over a wide range of frequencies in ways that cannot be viewed or understood in the optical wavelengths. We will learn the components of a radio telescope and study the emission mechanisms that produce radio radiation from astrophysical objects applying the topics covered in PHYSICS 135, especially thermodynamics. The topics of this course include spectroscopy, interferometry and radiation processes in astrophysics. At the end of the quarter, students will be able to explain how electromagnetic radiation is received by a radio telescope, how interferometry works and how the radio sky differs from the optical sky. Prerequisites: PHYSICS 135-1, PHYSICS 135-2, PHYSICS 135-3 (or equivalent); MATH 220-2 or equivalent. Natural Sciences Distro Area

ASTRON 314-0 Planetary Astrophysics (1 Unit) Methods of exoplanet detection. The observed architecture of exoplanetary systems. Formation and evolution of planetary systems. Modeling exoplanet interiors and atmospheres. Exoplanet habitability and the search for bio-signatures. Prerequisites: PHYSICS 330-1 and PHYSICS 330-2, or equivalent.

ASTRON 321-0 ObservationalAstrophysics (1 Unit) Geometric optics applied to design of optical and x-ray telescopes; diffraction and the Airy disk; radio and optical interferometry and aperture synthesis; adaptive optics; recent developments in detector technology; quantum and thermal noise in astronomy. Independent research projects using the CCD camera and 18-inch refractor in Dearborn Observatory. Offered alternate years. Prerequisite: ASTRON 220-0.

ASTRON 325-0 Stellar Astrophysics (1 Unit) Physics of stellar interiors, stellar atmospheres, and star formation. Specific topics include simple stellar models, nuclear energy generation, overview of evolutionary phases, white dwarfs, neutron stars, interstellar gas and dust grains, gravitational collapse. Prerequisite: ASTRON 220-0.

ASTRON 329-0 Extragalactic Astrophysics and Cosmology (1 Unit) Big bang cosmology, thermal history of the universe, primordial nucleosynthesis, microwave background, dark matter, largescale structure, galaxy formation, spiral and elliptical galaxies, groups and clusters of galaxies. Prerequisite: ASTRON 220-0.

ASTRON 331-0 Astrophysics ISP (1 Unit) Stellar structure and evolution: nucleosynthesis, supernova phenomena, white dwarfs, neutron stars, and black holes. Limited to students enrolled in ISP or with consent of the physics department. Prerequisite: PHYSICS 339-3.

ASTRON 390-0 Current Topics in Astronomy (1 Unit) Explores in detail an area of current research interest in astrophysics. Contact the department or instructor for specifics. May be repeated for credit with change of topic. Prerequisites vary. Natural Sciences Distro Area

ASTRON 398-0 Honors Independent Study (1-2 Units)

ASTRON 399-0 Independent Study (1-2 Units) Opportunity to study an advanced subject under the individual direction of a faculty member. Open to all advanced students. Consent of instructor required.