Advanced Placement

First-year students who have taken a calculus-level physics course in high school may waive parts of the introductory physics course 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 1 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, is NOT reflected on the transcript as college credit but will allow a student to place out of any or all parts of:

### 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 135-1 General Physics (1 Unit) Calculus-based physics for science and engineering majors and premedical students. Mechanics. Prerequisites: MATH 220-0, MATH 224-0; concurrent enrollment in PHYSICS 136-1 and MATH 230-0. 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 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 220-0, MATH 224-0; concurrent enrollment in PHYSICS 136-1 and MATH 230-0. 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 211-1 Mathematical Tools for Physical Sciences (1 Unit) Introduction to the tools necessary to solve physics problems, including integral calculus, complex numbers and complex algebra, matrices and vector spaces, differential equations, and Fourier analysis. Prerequisites: MATH 230-0 and MATH 234-0. Formal Studies Distro Area

PHYSICS 211-2 Mathematical Tools for Physical Sciences (1 Unit) Introduction to the tools necessary to solve physics problems, including integral calculus, complex numbers and complex algebra, matrices and vector spaces, differential equations, and Fourier analysis. Prerequisites: MATH 230-0 and MATH 234-0. Formal Studies 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 (concurrent enrollment in PHYSICS 135-2 is sufficient); MATH 230-0. 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 330-1 Classical Mech (1 Unit)
Newtonian mechanics, oscillations, the Lagrangian and Hamiltonian formalisms, central-force motion.

PHYSICS 330-2 Classical Mechanics (1 Unit)
Motion in a non-inertial reference frame, kinematics of rigid modes, systems with many degrees of freedom. Prerequisites: PHYSICS 135-1 or equivalent and MATH 234-0 and PHYSICS 311-1 and PHYSICS 311-2; or MATH 240-0, MATH 250-0; or equivalent.

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 234-0 or equivalent.

PHYSICS 333-1 Advanced Electricity & Magnetism (1 Unit)
Electrostatics and magnetostatics, multipole expansion, solutions of Laplace's equation, images, analytic functions.

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 234-0 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 220-0, MATH 224-0, 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); EECS 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 399-0 Independent Study (1-2 Units)
Individual study under the direction of a faculty member. Open only to advanced students pursuing departmental honors.

PHYSICS 398-0 Independent Thesis Research (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 310-0 Basics of Radio Astronomy (1 Unit)**  Survey of radio astronomy, emphasizing technical aspects; radiation, antennas, receivers, radio spectroscopy, interferometer arrays and aperture synthesis; radio emission mechanisms and cosmic rays. *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 Observational Astrophysics (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.