**PHYSICS AND ASTRONOMY**

physics.northwestern.edu

Physics seeks 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 non-science areas.

Majors normally take:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Year:</td>
<td></td>
</tr>
<tr>
<td>PHYSICS 140-1</td>
<td>Fundamentals of Physics and Fundamentals of Physics</td>
</tr>
<tr>
<td>&amp; PHYSICS 140-2</td>
<td>and Fundamentals of Physics</td>
</tr>
<tr>
<td>&amp; PHYSICS 140-3</td>
<td>and Fundamentals of Physics</td>
</tr>
<tr>
<td>or PHYSICS 135-1</td>
<td>General Physics</td>
</tr>
<tr>
<td>&amp; PHYSICS 135-2</td>
<td>General Physics</td>
</tr>
<tr>
<td>&amp; PHYSICS 135-3</td>
<td>General Physics</td>
</tr>
<tr>
<td>PHYSICS 136-1</td>
<td>General Physics Laboratory</td>
</tr>
<tr>
<td>&amp; PHYSICS 136-2</td>
<td>and General Physics Laboratory</td>
</tr>
<tr>
<td>&amp; PHYSICS 136-3</td>
<td>and General Physics Laboratory</td>
</tr>
<tr>
<td>Sophomore year:</td>
<td></td>
</tr>
<tr>
<td>PHYSICS 239-0</td>
<td>Foundations of Modern Physics</td>
</tr>
</tbody>
</table>

Majors also take a sequence of mathematics courses in their first and second years. The remaining requirements are a set of 300-level courses that depend on the chosen concentration, taken during sophomore, junior, and senior years.

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

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 concentration, which can be tailored to their interests. All declared and prospective majors should meet with the director of undergraduate studies before the end of sophomore year, if not earlier.

**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 college-level physics course in high school may be eligible to place ahead in the introductory physics sequence in the ways listed below. For details please refer to the First-Year Focus (https://www.physics.northwestern.edu/undergraduate/first-year-focus.html) section of the departmental webpage.

- A score of 5 on the College Board Advanced Placement Physics C (Mechanics) examination posts as PHYSICS 135-1 General Physics and lab course credit.
- A score of 5 on the College Board Advanced Placement Physics C (Electricity & Magnetism) examination taken either before or after calendar year 2020 posts as PHYSICS 135-2 General Physics and lab course credit.
- A score of 5 on the College Board Advanced Placement Physics C (Electricity & Magnetism) examination taken in 2020 posts as 1.0 unit of PHYSICS 1XX and 0.34 units lab credit posted as PHYSICS 1XL. A sufficient score on the departmental assessment exam can convert these units to PHYSICS 135-2 General Physics and PHYSICS 136-2 General Physics Laboratory.
- A score of 5 on the College Board Advanced Placement Physics 1 exam posts as PHYSICS 130-1 College Physics and lab course credit.
- A score of 5 on the College Board Advanced Placement Physics 2 exam posts as PHYSICS 130-2 College Physics and lab course credit.
- Students who took college-level physics on the campus of an accredited college while in high school may apply to have the credit transferred to Northwestern. A transcript from the college is needed. “College-level” classes taken at a high school are not eligible for transfer credit. For more details see Transferring Credit from Other Colleges (https://www.weinberg.northwestern.edu/undergraduate/first-year-transfer/first-year/placement-and-credit/transfer-college-credit.html).

**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 106-0 A Brief Journey through the Invisible Universe (1 Unit) A conceptual course exploring the world of the invisible radio universe. The topics include: the historical development of the radio sky, the connection between cosmic rays and the radio sky, how radio telescopes work and numerous discoveries made over the last 90 years (pulsars, quasars, the Big Bang cosmic microwave background radiation, organic molecules, the shadow of a supermassive black hole), and the physics of radio astronomy. 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 fundamental topics in classical mechanics for physics majors and minors and students with a strong interest in physics. Prerequisites:
PHYSICS 333-2 Advanced Electricity & Magnetism (1 Unit) Introduction to fundamental 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 333-0 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 359-0 Electronics (1 Unit) Construction of elementary analog and digital circuits. Prerequisites: PHYSICS 333-1 and PHYSICS 333-2 or consent of instructor.

PHYSICS 357-0 Optics Laboratory (1 Unit) Optics/laser lab focusing on optical techniques and data analysis methods. Both classic and modern experiments in atomic/nuclear physics, electricity and magnetism, optics, condensed matter physics, and nonlinear dynamics.

PHYSICS 356-0 Advanced Physics Laboratory (1 Unit) Modern experimental techniques and data analysis methods. 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 sufficient); COMP_SCI 110-0 or equivalent prior programming experience.

PHYSICS 351-0 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 333-1 and PHYSICS 333-2 and PHYSICS 311-1 and PHYSICS 311-2; or MATH 240-0, MATH 250-0; or equivalent.
This laboratory emphasizes independent work. This course consists primarily of two four-hour sessions per week, which may have lecture and laboratory periods. 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 390-0 Topics in Physics (1 Unit)**
This is a special topics course, and each time it is offered could be a completely different topic. Although the topic can change, it is expected that independent of the content, this is an advanced physics course that builds on core physics knowledge. Prerequisites vary by offering. It would generally require knowledge of at least one core physics course (Physics 330, 332, 333, 339) or the equivalent mathematics or Permission from Instructor.

**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 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 106-0 A Brief Journey through the Invisible Universe (1 Unit)**
A conceptual course exploring the world of the invisible radio universe. The topics include: the historical development of the radio sky, the connection between cosmic rays and the radio sky, how radio telescopes work and numerous discoveries made over the last 90 years (pulsars, quasars, the Big Bang cosmic microwave background radiation, organic molecules, the shadow of a supermassive black hole), and the physics of radio astronomy. *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 220-1 Introduction to Astrophysics I: Life Cycle of Stars and Planets (1 Unit)**
The course will explore the origin and evolution of star/planet systems, focusing on underlying physical processes and observational techniques. We will discuss the recent discovery of thousands of planets orbiting stars other than our Sun - a.k.a. "exoplanets". We will also discuss stellar remnant black holes. (Prerequisites: PHYSICS 135-1, PHYSICS 135-2 (concurrent registration in PHYSICS 135-2 is acceptable. Students who have taken ASTRON 220-0 should not take this course and take ASTRON 220-2 instead). *Natural Sciences Distro Area*

**ASTRON 220-2 Introduction to Astrophysics II: Galactic Evolution and Cosmology (1 Unit)**
The course will explore modern cosmology, including dark matter, the Big Bang, curved space-time, the origin and evolution of the first stars and galaxies, cosmic acceleration, and dark energy. In all cases, the focus will be on the underlying physical processes and the observational techniques used. (Prerequisites: ASTRON 220-1 or all of PHYSICS 135-1, PHYSICS 135-2, and PHYSICS 135-3.) *Natural Sciences Distro Area*

**ASTRON 305-0 Basics of Radio Astronomy (1 Unit)**
Radio astronomy is the study of natural radio emission from the sky, providing important clues about the history of the universe. Topics include how a radio telescope receives invisible signals, how dramatically the radio sky differs from the optical sky, and interferometry. Prerequisites: PHYSICS 135-1, PHYSICS 135-2, PHYSICS 135-3 (or equivalent) or PHYSICS 332-0; 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 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 220-1, or ASTRON 220-2.

**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 220-1, or ASTRON 220-2.

**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 220-1, or ASTRON 220-2.

**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. Prerequisites: PHYSICS 135-1, PHYSICS 135-2, & PHYSICS 135-3, or equivalent.

**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.