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:

Course	Title
First Year:	
PHYSICS 140-1 & PHYSICS 140-2 & PHYSICS 140-3	Fundamentals of Physics and Fundamentals of Physics and Fundamentals of Physics
or PHYSICS 135-1 & PHYSICS 135-2 & PHYSICS 135-3	General Physics and General Physics and General Physics
PHYSICS 126-1 & PHYSICS 126-2 & PHYSICS 126-3	Fundamentals of Physics Laboratory and Fundamentals of Physics Laboratory and Fundamentals of Physics Laboratory
or PHYSICS 136-1 & PHYSICS 136-2 & PHYSICS 136-3	General Physics Laboratory and General Physics Laboratory and General Physics Laboratory
Sophomore year:	
PHYSICS 211-0	Mathematical Tools for Physical Sciences
PHYSICS 239-0	Foundations of Modern Physics
PHYSICS 250-0	Differential Equations and Fourier Analysis for Physics

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 Teacher Education 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/)

Learning Objectives

As the most foundational of the natural sciences, physics underlies nearly every aspect of modern science and technology. Physicists study nature across all scales, from stellar systems and galaxies to atoms, nuclei, and fundamental particles, and everything in between. A major in Physics provides a rigorous foundation in classical and modern physics, grounded in universal principles that govern physical phenomena. Through analytical reasoning, mathematical modeling, laboratory investigation, and computational approaches, students gain tools to solve complex problems and communicate effectively. These skills support success in physics and astronomy, as well as in scientific, engineering, and data-driven careers.

After completing a major in Physics at Northwestern University, students will be able to:

- **Outcome 1:** Demonstrate knowledge of core physical principles — including classical and quantum mechanics, electromagnetism, statistical mechanics, and potentially other subfields such as astronomy — and apply these concepts to explain, analyze, and predict physical phenomena. Synthesize knowledge across different areas of physics and astronomy to address complex or interdisciplinary problems.
- **Outcome 2:** Translate physical concepts into appropriate mathematical form and apply analytical, numerical, and computational methods to solve physical problems. Identify essential features, use estimation to build physical intuition, and employ tools such as visualization, coding, simulation, and modeling.
- **Outcome 3:** Design and conduct experiments, collect and analyze physical measurements, and draw conclusions about physical systems with appropriate consideration of uncertainty and error.
- **Outcome 4:** Evaluate the relationship between theory and experiment by formulating hypotheses, designing tests, and interpreting results to assess the validity and limitations of physical models.
- **Outcome 5:** Communicate technical concepts, reasoning, and findings clearly and effectively in oral and written formats, tailored to technical and non-technical audiences.
- **Outcome 6:** Formulate research questions, conduct investigations, and communicate findings in independent and collaborative settings, using scientific inquiry and appropriate methodologies.

For more detail on the learning objectives of the Physics major, see Program Learning Objectives page (https://physics.northwestern.edu/undergraduate/program-learning-objectives.html).

Physics and Astronomy Courses

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 101-7 College Seminar (1 Unit) Small, writing and discussion-oriented course exploring a specific topic or theme, and introducing skills necessary to thriving at Northwestern. Not eligible to be applied towards a WCAS major or minor except where specifically indicated. *SOC Additional Distro*

PHYSICS 101-8 First-Year Writing Seminar (1 Unit) Small, writing and discussion-oriented course exploring a specific topic or theme, and focused on the fundamentals of effective, college-level written communication. Not eligible to be applied towards a WCAS major or minor except where specifically indicated. *SOC Additional Distro*

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 Foundational Discipline SOC Additional Distro*

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 Foundational Discipline SoC Mathematics, Science, and Technology Distro*

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 Foundational Discipline SoC Mathematics, Science, and Technology Distro*

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 Foundational Discipline SoC Mathematics, Science, and Technology Distro*

PHYSICS 126-1 Fundamentals of Physics Laboratory (0.34 Unit) Introductory physics laboratory for students taking PHYSICS 125-1 and PHYSICS 140-1, with which it must be taken concurrently. *SoC Mathematics, Science, and Technology Distro*

PHYSICS 126-2 Fundamentals of Physics Laboratory (0.34 Unit) Introductory physics laboratory for students taking PHYSICS 125-2 and PHYSICS 140-2, with which it must be taken concurrently. *SoC Mathematics, Science, and Technology Distro*

PHYSICS 126-3 Fundamentals of Physics Laboratory (0.34 Unit) Introductory physics laboratory for students taking PHYSICS 125-3 and PHYSICS 140-3, with which it must be taken concurrently. *SoC Mathematics, Science, and Technology Distro*

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, PHYSICS 140, or PHYSICS 125 may not later receive credit for the comparable quarter of PHYSICS 130. Prerequisites: algebra, trigonometry, and concurrent enrollment in PHYSICS 136-1. *Natural Sciences Foundational Discipline SoC Mathematics, Science, and Technology Distro*

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, PHYSICS 140, or PHYSICS 125 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 Foundational Discipline SoC Mathematics, Science, and Technology Distro*

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, PHYSICS 140, or PHYSICS 125 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 Foundational Discipline SoC Mathematics, Science, and Technology Distro*

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. Must be taken concurrently with PHYSICS 136-1. Prerequisites: MATH 220-1, MATH 220-2; MATH 230-1 OR MATH 290-1 OR MATH 291-1 (may be taken concurrently). *Natural Sciences Foundational Discipline SoC Mathematics, Science, and Technology Distro*

PHYSICS 135-2 General Physics (1 Unit) Calculus-based physics for science and engineering majors and premedical students. Electricity and magnetism. Must be taken concurrently with PHYSICS 136-2. Prerequisites: MATH 220-1, MATH 220-2, MATH 230-1 OR MATH 290-1 OR MATH 291-1, PHYSICS 135-1; MATH 230-2 OR MATH 290-2 OR MATH 291-2 (may be taken concurrently).". *Natural Sciences Foundational Discipline SoC Mathematics, Science, and Technology Distro*

PHYSICS 135-3 General Physics (1 Unit) Calculus-based physics for science and engineering majors and premedical students. Introduction to wave phenomena, optics, and modern physics. Must be taken concurrently with PHYSICS 136-3. Prerequisites: MATH 220-1, MATH 220-2, MATH 230-1 OR MATH 290-1 OR MATH 291-1, PHYSICS 135-2. *Natural Sciences Foundational Discipline SoC Mathematics, Science, and Technology Distro*

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. *SoC Mathematics, Science, and Technology Distro*

PHYSICS 136-2 General Physics Laboratory (0.34-0.5 Unit) Introductory physics laboratory for students taking PHYSICS 130-2 or PHYSICS 135-2, with which it must be taken concurrently. *SoC Mathematics, Science, and Technology Distro*

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. *SoC Mathematics, Science, and Technology Distro*

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: MATH 220-1, MATH 220-2; concurrent enrollment in PHYSICS 126-1 and MATH 230-1. *Natural Sciences Foundational Discipline SoC Mathematics, Science, and Technology Distro*

PHYSICS 140-2 Fundamentals of Physics (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 126-1; concurrent enrollment in PHYSICS 126-2. *Natural Sciences Foundational Discipline SoC Mathematics, Science, and Technology Distro*

PHYSICS 140-3 Fundamentals of Physics (1 Unit) Introduction to fundamental 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 126-2; concurrent enrollment in PHYSICS 126-3. *Natural Sciences Foundational Discipline SoC Mathematics, Science, and Technology Distro*

PHYSICS 211-0 Mathematical Tools for Physical Sciences (1 Unit) Introduction to mathematical tools for modeling, interpreting, and reasoning about the physical world. While topics mirror math curriculum, the approaches emphasize the physics mindset in how to apply the tools to a problem. Selected topics include dimensional analysis, complex numbers, series expansions, single and multi-dimensional integrals, and probabilities and probability distributions. Prerequisites: PHYSICS 135-1, PHYSICS 140-1, or equivalent; MATH 230-1 or equivalent. *SoC Mathematics, Science, and Technology Distro*

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 240-0; MATH 250-0 or PHYSICS 250-0, which may be taken concurrently. *Natural Sciences Foundational Discipline SoC Mathematics, Science, and Technology Distro*

PHYSICS 250-0 Differential Equations and Fourier Analysis for Physics (1 Unit) This course teaches differential equations and Fourier methods as mathematical tools for modeling, interpreting, and predicting the behavior of physical systems. Topics include ordinary and partial differential equations, Fourier series and transforms, canonical systems such as the wave, heat, and Laplace equations, and basic numerical methods. Prerequisites: PHYSICS 135-1 or PHYSICS 140-1, MATH 230-1, MATH 240-0, or equivalents. *SoC Mathematics, Science, and Technology Distro*

PHYSICS 312-0 Scalar and Vector Field Methods in Physics (1 Unit) PHYSICS 312-0 Scalar and Vector Field Methods in Physics (1Unit) 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: MATH 230-1,MATH 230-2, MATH 240-0, and PHYSICS 250-0 or MATH 250-0, or equivalents. *SoC Mathematics, Science, and Technology Distro*

PHYSICS 330-1 Classical Mech (1 Unit) Introduction to classical mechanics and mathematical methods of physics. Newtonian mechanics, oscillations, the Lagrangian and Hamiltonian formalisms, central-force motion. Prerequisites: PHYSICS 135-1 or equivalent and MATH 230-2 and MATH 240-0; PHYSICS 250-0 or MATH 250-0 or equivalent. *SoC Mathematics, Science, and Technology Distro*

PHYSICS 330-2 Classical Mechanics (1 Unit) Introduction to classical mechanics and mathematical methods of physics. Motion in a non-

inertial reference frame, kinematics of rigid modes, systems with many degrees of freedom. Prerequisites: PHYSICS 330-1 or equivalent; PHYSICS 250-0 or MATH 250-0 or equivalent. *SoC Mathematics, Science, and Technology Distro*

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; PHYSICS 125-3 or PHYSICS 239-0 (concurrent registration allowed). *SoC Mathematics, Science, and Technology Distro*

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; MATH 230-2; PHYSICS 250-0 or MATH 250-0 or equivalent. *SoC Mathematics, Science, and Technology Distro*

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; MATH 230-2; PHYSICS 250-0 or MATH 250-0 or equivalent. *SoC Mathematics, Science, and Technology Distro*

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. *SoC Mathematics, Science, and Technology Distro*

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: PHYSICS?135-1,?PHYSICS?135-2,?PHYSICS?135-3, PHYSICS?239-0,?PHYSICS?330-1,?MATH?240-0 or second-year standing in ISP. *SoC Mathematics, Science, and Technology Distro*

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 250-0 or MATH 250-0 and MATH 351-0. *SoC Mathematics, Science, and Technology Distro*

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. *SoC Mathematics, Science, and Technology Distro*

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. *SoC Mathematics, Science, and Technology Distro*

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; PHYSICS 250-0 or MATH 250-0 or equivalent (concurrent enrollment is allowed); COMP_SCI 110-0 or equivalent prior programming experience. *SoC Mathematics, Science, and Technology Distro*

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. *SoC Mathematics, Science, and Technology Distro*

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. *SoC Mathematics, Science, and Technology Distro*

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. 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. *Advanced Expression SoC Humanities and Fine Arts Distro SoC Mathematics, Science, and Technology Distro*

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. *SoC Mathematics, Science, and Technology Distro*

PHYSICS 371-0 Nonlinear Dynamics and Chaos (1 Unit) This course covers the mathematics of nonlinear oscillations, fractal geometry, chaotic dynamics, the dynamics of complex systems, and physics applications of these ideas. Projects involving applications of nonlinear dynamics and chaos are integral to this course. Prerequisites: PHYSICS 330-1 and PHYSICS 330-2, and some familiarity with computer programming. *SoC Mathematics, Science, and Technology Distro*

PHYSICS 390-0 Topics in Physics (1 Unit) This course will explore a specialized or current topic of research in a field of physics. 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 the instructor.
SOC Additional Distro

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. *SOC Additional Distro*

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 Foundational Discipline SoC Mathematics, Science, and Technology Distro*

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 Foundational Discipline*

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 Foundational Discipline SoC Mathematics, Science, and Technology Distro*

ASTRON 105-7 College Seminar (1 Unit) Small, writing and discussion-oriented course exploring a specific topic or theme, and introducing skills necessary to thriving at Northwestern. Not eligible to be applied towards a WCAS major or minor except where specifically indicated. *SOC Additional Distro*

ASTRON 105-8 First-Year Writing Seminar (1 Unit) Small, writing and discussion-oriented course exploring a specific topic or theme, and focused on the fundamentals of effective, college-level written communication. Not eligible to be applied towards a WCAS major or minor except where specifically indicated. *SOC Additional Distro*

ASTRON 106-0 A Brief Journey Through the Invisible Universe (1 Unit) A conceptual course exploring the invisible radio universe. Topics include: the historical development of the radio sky, how radio telescopes are fundamentally different than optical telescopes, numerous discoveries with multiple Nobel Prizes over the last century (pulsars, quasars, the Big Bang cosmic microwave background radiation, organic molecules, shadows of supermassive black holes) and search for radio signals from alien civilizations. *Natural Sciences Foundational Discipline SoC Mathematics, Science, and Technology Distro*

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 Foundational Discipline SoC Mathematics, Science, and Technology Distro*

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 Foundational Discipline SoC Mathematics, Science, and Technology Distro*

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). *SoC Mathematics, Science, and Technology Distro*

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.) *SoC Mathematics, Science, and Technology Distro*

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. *SoC Mathematics, Science, and Technology Distro*

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. *SoC Mathematics, Science, and Technology Distro*

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. Prerequisite: ASTRON 220-1 or ASTRON 220-2. *Advanced Expression SoC Humanities and Fine Arts Distro SoC Mathematics, Science, and Technology Distro*

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 220-1 or ASTRON 220-2. *SoC Mathematics, Science, and Technology Distro*

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 220-1 or ASTRON 220-2. *SoC Mathematics, Science, and Technology Distro*

ASTRON 331-0 Astrophysics for 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. *SoC Mathematics, Science, and Technology Distro*

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. *SOC Additional Distro*

ASTRON 398-0 Honors Independent Study (1-2 Units) *SOC Additional Distro*

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. *SOC Additional Distro*