

**PHIL 362-0 Studies in the History of Ethical and Political Theory** Examination of one or more major figures or movements in the history of moral or political philosophy. May be repeated for credit with change of topic.

**PHIL 363-0 Kant's Moral Theory** Exploration of the moral and ethical thought of Immanuel Kant through careful study of *Groundwork of the Metaphysics of Morals* along with readings from the *Critique of Practical Reason*, *Metaphysics of Morals*, and *Religion within the Bounds of Mere Reason*.

**PHIL 364-0 Business and Professional Ethics** Application of ethical theories (Kantianism, utilitarianism, etc.) in a commercial setting. Topics include social responsibilities of corporations, public regulation, moral limits of marketing (e.g., marketing to children, noxious products), social justice versus fair compensation.

**PHIL 367-0 Studies in African American Philosophy** Study of the work of one or more important African American philosophers or philosophical movements of the 19th or 20th centuries. May be repeated for credit with change of topic.

**PHIL 369-0 Philosophy and Gender** Survey of approaches to sex and gender throughout the history of philosophy.

**PHIL 370-0 Philosophy and Literature** Issues involving the relationship between philosophy and literature.

**PHIL 380-0 Topics in the Philosophy of Art** Topics to be discussed might include the nature and purpose of art, art and perception, the nature of creativity, and the social responsibility of the artist.

**PHIL 390-0 Special Topics in Philosophy** May be repeated for credit with change of topic.

**PHIL 398-1,2 Senior Tutorial** Senior thesis. Grade of K given in 398-1. Prerequisite: consent of instructor.

**PHIL 399-0 Independent Study** Open to properly qualified students with consent of instructor.

## PHYSICS AND ASTRONOMY

[physics.northwestern.edu](http://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 PHYSICS 135-1,2,3/136-1,2,3 in the first year and PHYSICS 239 in the sophomore year. 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 or 399 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.

### Major in Physics

The physics major is designed to help students acquire a broad and varied background in physics and related fields; it provides an excellent intellectual foundation for many careers. The three basic steps toward completing the major are fulfilling prerequisites in introductory physics and calculus; taking a core sequence (common to all concentrations) of classical physics, modern physics, and mathematics; and completing a course concentration.

### Prerequisites

- MATH 220 and 224 *or* 212, 213, and 214
- PHYSICS 125-1,2,3/126-1,2,3 *or* 135-1,2,3/136-1,2,3

### Major requirements (units vary, depending on math courses and concentration selected)

- 10–11 core courses (depending on math concentration)
  - MATH 230, 234, and PHYSICS 311-1,2 *or* MATH 230, 234, 240, 250, and 351 *or* equivalent courses approved by the department
  - PHYSICS 239, 330-1, 332, 333-1, 339-1
  - 1 lab course from ASTRON 321; PHYSICS 357, 358, 359, 360 (may not also count toward the concentration)
- 5–6 courses in the chosen concentration (A course may not be counted toward more than one requirement.)
  - *Advanced physics (6 units)*
    - PHYSICS 330-2, 333-2, 339-2
    - 1 lab course from ASTRON 321; PHYSICS 357, 358, 359, 360
    - 2 other 300-level physics or astronomy courses other than PHYSICS 311-1,2; 335; 398; 399 and ASTRON 398, 399
  - *Astronomy (6 units)*
    - PHYSICS 330-2, 333-2, 339-2
    - ASTRON 220

- 2 other 300-level astronomy classes other than 398 and 399
- *Flexible (5 units)*
  - 3 300-level physics or astronomy lecture or lab courses
  - 2 courses from the following:
    - BMD ENG 305, 327
    - CHEM 307
    - EECS 360, 381
    - ES APPM 322
    - MAT SCI 315; 331; 351-1,2; 361; 376
    - MATH 354-1,2
    - MECH ENG 346, 385
  - Any 300-level physics or astronomy lecture or lab course that is not otherwise required
- PHYSICS 311-1,2; 335; 398; 399 and ASTRON 398, 399 may not count toward any of these requirements.

### Minor in Physics

The minor in physics gives students an understanding of the most essential concepts in the field and carries the same prerequisites as the major, followed by a lighter set of requirements.

#### Prerequisites

- MATH 220 and 224 *or* 212, 213, and 214
- PHYSICS 125-1,2,3/126-1,2,3 *or* 135-1,2,3/136-1,2,3

#### Minor requirements (9 units)

- MATH 230, 234, and PHYSICS 311-1,2 *or* MATH 230, 234, 240, 250 *or* equivalent courses approved by the department
- PHYSICS 239, 330-1, 333-1
- 2 other 300-level physics or astronomy courses other than PHYSICS 311-1,2; 335; 398; 399; and ASTRON 398, 399

### Physics Second Major for ISP Students

The Integrated Science Program is a highly selective BA program in Weinberg College that includes PHYSICS 125-1,2,3/126-1,2,3 and 339-1,2,3 (337 may substitute for 339-3) and ASTRON 331 as part of its curriculum. Application to this program is made directly to ISP. It is possible to complete a double major in physics and ISP by completing the following 6 additional upper-level courses:

- PHYSICS 330-1,2 *or* PHYSICS 333-1,2
- 3 courses chosen from 300-level physics or astronomy courses other than PHYSICS 311-1,2; 335; 398; 399; ASTRON 398; 399; and those required by ISP (PHYSICS 339-1,2,3 *or* 337; ASTRON 331)
- 1 lab course from ASTRON 321; PHYSICS 357, 358, 359, 360
- Students pursuing an ISP/physics double major may not substitute ISP 398 for any physics or math course in the

ISP curriculum. They do not have to choose a physics course concentration.

### Honors in Physics and Astronomy

Majors with strong records in their physics, astronomy, and mathematic courses and an interest in pursuing honors should notify the director of undergraduate studies in October of senior year. Eligible students must enroll for 2 units of 398 by the time of graduation. They participate in research culminating in a written report.

Students whose research reports and grades meet department criteria are recommended to the college for graduation with honors. For more information consult the director of undergraduate studies and see Honors in the Major on page 39.

### 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 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 and/or C-Electricity and Magnetism examination will give the student credit for 135-1/136-1 and/or 135-2/136-2, respectively.
- A score of 5 on the College Board Advanced Placement Physics 1 and/or Physics 2 exam will give the student credit for 130-1/136-1 and/or 130-2/136-2, respectively.
- 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 the 130-1,2,3 *or* 135-1,2,3 sequences plus relevant labs. (No college credit is given for placing out of the courses.)
- 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.

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**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.**

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## Physics Courses

**PHYSICS 103-0 Ideas of Physics** 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 nonscience majors.

**PHYSICS 105-0 Music, Sound, Timbre** 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.

**PHYSICS 125-1,2,3 General Physics for ISP** General physics course relying extensively on calculus. Similar to 135-1,2,3 but more advanced and intended for ISP students. A concurrent advanced calculus course, MATH 281-1,2,3, is offered by the mathematics department. Prerequisite: first-year standing in ISP or consent of the department and concurrent enrollment in 126-1,2,3.

**PHYSICS 126-1,2,3 General Physics Laboratory for ISP** (.34 units each quarter) Introductory physics laboratory for students taking 125-1,2,3, with which it must be taken concurrently.

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

**PHYSICS 135-1,2,3 General Physics** Calculus-based physics for science and engineering majors and premedical students. **1.** Mechanics. Prerequisites: MATH 220, 224; concurrent enrollment in 136-1 and MATH 230. **2.** Electricity and magnetism. Prerequisite: 135-1/136-1 and concurrent enrollment in 136-2. **3.** Introduction to modern physics; wave phenomena. Prerequisite: 135-2/136-2 and concurrent enrollment in 136-3. Students with credit for a quarter of 135 may not later receive credit for the comparable quarter of 130.

**PHYSICS 136-1,2,3 General Physics Laboratory** (.34 units each quarter) Introductory physics laboratory for students taking 130-1,2,3 or 135-1,2,3, with which it must be taken concurrently.

**PHYSICS 238-0 Energy and Nuclear Power** Energy problems and different energy sources. Basics of the physics of atoms and nuclei. Chain reactions, criticality, and nuclear reactors. The dream and prospects for fusion power. Prerequisites: 130-1,2,3/136-1,2,3; 135-1,2,3/136-1,2,3; or equivalent.

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

**PHYSICS 311-1,2 Mathematical Tools for Physical Sciences** 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 for 311-1: 135-1,2 or equivalent (concurrent enrollment in 135-2 is sufficient); MATH 230. Prerequisites for 311-2: 135-3 (or concurrent enrollment); 311-1 or equivalent.

**PHYSICS 330-1,2 Classical Mechanics 1.** Newtonian mechanics, oscillations, the Lagrangian and Hamiltonian formalisms, central-force motion. **2.** Motion in a non-inertial reference frame, kinematics of rigid bodies, systems with many degrees of freedom. Prerequisites: 135-1 or equivalent *and* MATH 234 *and* 311-1,2; or MATH 240, 250; or equivalent.

**PHYSICS 332-0 Statistical Mechanics** Ideal gas, Boltzmann distribution, transport phenomena, fluctuation theory, Bose-Einstein and Fermi-Dirac statistics. Prerequisites: 135-1,2,3; MATH 234 or equivalent.

### PHYSICS 333-1,2 Advanced Electricity and Magnetism

**1.** Electrostatics and magnetostatics, multipole expansion, solutions of Laplace's equation, images, analytic functions. **2.** Maxwell's equations, electromagnetic equations, electromagnetic wave propagation and radiation, microwave cavities, diffraction. Prerequisites: 135-1,2,3 *and* MATH 234 *and* 311-1,2; or MATH 240, 250; or equivalent.

**PHYSICS 335-0 Physics of Magic** 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: 135-1; MATH 220, 224, or equivalent.

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

**PHYSICS 339-1,2 Quantum Mechanics** Introduction to quantum theory. Applications to atomic and molecular systems. The harmonic oscillator, the one-electron atom, the hydrogen molecule, barrier penetration. Prerequisites for 339-1: second-year standing in ISP *or* 135-1,2,3 or equivalent; 239; 330-1; 311-1 or MATH 240. Prerequisites for 339-2: 339-1, second-year standing in ISP *or* 311-2 or MATH 250, 351.

**PHYSICS 339-3 Particle and Nuclear Physics** 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: 339-1,2.

**PHYSICS 345-0 Introduction to General Relativity** Review of special relativity and Newtonian gravity; curved spacetime; geodesics and conservation laws; Schwarzschild geometry; tests of general relativity; black holes; linearized gravity

and gravitational waves; and big bang cosmology. Prerequisites: 330-1,2 or consent of instructor.

**PHYSICS 352-0 Introduction to Computational Physics**

Application of computing to physics: Monte Carlo simulation, numerical integration of equations of motion, discrete element methods in electromagnetism. Prerequisites: 135-1,2,3 or equivalent; MATH 250 or equivalent (concurrent enrollment is sufficient); EECS 110 or equivalent prior programming experience.

**PHYSICS 357-0 Optics Laboratory** 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.

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

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

**PHYSICS 360-0 General Physics Laboratory** Classic experiments in atomic, nuclear, and solid-state physics using modern electronics and microcomputers. Independent work. Prerequisites: 333-1,2 or consent of instructor.

**PHYSICS 361-0 Classical Optics and Special Relativity**

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: 333-1,2.

**PHYSICS 371-0 Nonlinear Dynamics and Chaos** 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: 330-1,2.

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

**PHYSICS 399-0 Independent Study** 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** 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 120.

**ASTRON 102-0 Milky Way Galaxy** 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 120.

**ASTRON 103-0 Solar System** The planets and their moons, the sun, comets, asteroids. For nonscience majors who want to take a more detailed course after completing 120.

**ASTRON 111-0 Introduction to Astrobiology** 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.

**ASTRON 120-0 Highlights of Astronomy** Acquaints students with modern ideas about the solar system, stars, galaxies, and the universe. Emphasizes fundamental principles and underlying concepts.

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

**ASTRON 314-0 Planetary Astrophysics** 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 biosignatures. Prerequisites: PHYSICS 330-1,2 or equivalent.

**ASTRON 321-0 Observational Astrophysics** 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: 220.

**ASTRON 325-0 Stellar Astrophysics** 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: 220.

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

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

**ASTRON 390-0 Current Topics in Astronomy** 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.

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

## POLITICAL SCIENCE

[polisci.northwestern.edu](http://polisci.northwestern.edu)

Political science is the study of politics and power from domestic, international, and comparative perspectives. It entails understanding political ideas, ideologies, institutions, public policies, and behavior, as well as groups, classes, government, diplomacy, law, strategy, and war. A background in political science is valuable for citizenship and political action, as well as for future careers in government, law, business, media, or public service.

Northwestern's Department of Political Science offers classes in the four major subfields of the discipline—American politics, comparative politics, international politics, and political theory—but many courses cut across subfields. Political science faculty are closely associated with other departments in Weinberg College, Pritzker School of Law, and the Kellogg School of Management, as well as several interdisciplinary programs, including the Buffett Institute for Global Studies, the Institute for Policy Research, the Program of African Studies, the Gender and Sexuality Studies Program, the Chicago Field Studies Program, the Environmental Policy and Culture Program, and the Center for Civic Engagement.

### Major in Political Science

The major in political science provides an opportunity for students to learn about politics in a variety of realms and settings. Students generally begin the major with 200-level courses, which provide a general introduction to subfields of political science as well as background for 300-level courses. Majors should choose 200-level courses from at least two subfields: American politics, comparative politics, international politics, and political theory.

While some students choose courses from within one or two subfields, most take a wide variety across different areas. Concentrations are not required; however, majors may consult with department advisers to design programs of study. Students might design concentrations around, for instance, themes such as race, ethnicity, and politics; global transformation; representation and law; social and economic inequalities; terrorism and national security; and citizenship studies.

Students planning to major in political science are advised to complete the 200-level gateway courses and at least 1 300-level course in political science by the end of sophomore year. Majors should complete their methodology requirement by the end of junior year and before taking the 395 research seminar. Students should plan to take

395 in junior year or early in senior year. Those who plan to pursue honors must take 395 in junior year.

### Major requirements (12 units)

- 3 gateway courses chosen from 201, 220, 221, 230, 240, 250. Since the gateway courses expose students to a variety of subfields, students may take no more than 2 from the American politics courses (220, 221, and 230) to fulfill this requirement.
- 1 methodology course in political science chosen from 210, 211, 310, 311, 312, 315
- 395
- 7 additional 300-level courses in political science; CFS 391, 394, 396, or 397 may substitute for at most 1 of these courses with consent of the director of undergraduate studies
- At most 2 political science courses taken abroad may count toward the major but may not replace any of the 200-level gateway courses.

### Minor in Political Science

The minor in political science offers students the opportunity to acquire a foundation in the discipline as well as significant exposure to advanced courses.

Students may want to choose courses that complement and deepen their major area of study. For example, an economics major may want to focus on political economy courses. A history major might study contemporary politics in an area on which he or she is focusing. A philosophy major may study political theory. Alternatively, students can choose to broaden their knowledge of political science in areas unrelated to their majors. Students should consult with a member of the departmental undergraduate advising team to develop an individual program of study.

### Minor requirements (6 units)

- At least 2 200-level courses chosen from 201, 220, 221, 230, 240, 250
- 4 additional political science courses, including at least 3 at the 300 level

### Honors in Political Science

Majors (including students studying abroad) with strong academic records and an interest in pursuing honors should submit an application to the honors program by March of junior year. Interested students should complete at least 7 of the 11 courses required for the major, including the methodology and research seminar requirements, before senior year. Accepted students enroll in the 2-quarter seminar 398-1,2, which provides guidance in writing a senior thesis; these courses do not count toward the major. Students interested in pursuing honors in more than one major are encouraged to pursue interdisciplinary honors.

Students whose theses and grades meet department criteria are recommended to the college for graduation with