APPLIED PHYSICS

https://www.appliedphysics.northwestern.edu/

Degree Types: PhD

The Applied Physics Graduate Program (https://www.appliedphysics.northwestern.edu) is a joint program between the McCormick School of Engineering & Applied Science and the Weinberg College of Arts & Sciences, and spans the departments of Physics & Astronomy, Biomedical Engineering, Chemistry, Earth & Planetary Sciences, Electrical & Computer Engineering, Computer Science, and Materials Science & Engineering. The program offers interdisciplinary PhD research opportunities for graduate students with a strong undergraduate background in Physics.

The Applied Physics Program is designed to allow students to complete their PhD studies in as little as five years. Students can complete the required courses during the first year, allowing them to fully focus their efforts on research starting as of the second year. Unlike programs based in a single department, Applied Physics students can take advantage of the scholarships, learning opportunities, and other resources offered by both the McCormick School of Engineering, the Weinberg College of Arts & Sciences, and nearby Argonne National Laboratory and Fermi National Accelerator Laboratory.

The program prepares graduates for professional careers in science and technology, either in academia or in industry, and seeks to ensure that our graduates recognize and take advantage of scientific and technological opportunities wherever they may arise.

Degrees Offered

- Applied Physics PhD (https://catalogs.northwestern.edu/tgs/applied-physics/applied-physics-phd)

Applied Physics Course Descriptions

APP_PHYS 499-0 Independent Study (1-3 Units)
See Dept for section number - May be repeated for credit. Permission of instructor required.

APP_PHYS 590-0 Research (1-3 Units)
See Dept for section number - Independent investigation of selected problems pertaining to thesis or dissertation. May be repeated for credit.

Computational Methods of Applied Physics

CHEM 448-0 Computational Chemistry (1 Unit)
The theory and application of molecular electronic structure methods, techniques for determining vibrational eigenfunctions and scattering properties, and molecular mechanics, molecular mechanics and Monte Carlo calculations. Included are extensive applications to chemical problems using Unix workstations.

CHEM_ENG 451-0 Applied Molecular Modeling (1 Unit)
Introduction to modern computational methods for calculating properties of reaction systems, as well as thermodynamics, transport, and structural properties of materials.

ELEC_ENG 475-0 Machine Learning: Foundations, Applications, and Algorithms (1 Unit)
The course covers the fundamentals of machine learning and numerical optimization, with many application examples.

ELEC_ENG 495-0 Special Topics in Electrical Engineering (1 Unit)

ELEC_ENG 463-0 Adaptive Filters (1 Unit)
Applications of adaptive filtering, autoregressive and moving average processes, linear prediction, Wiener filter, Least Mean Square (LMS) algorithm, lattice filter, least squares filtering, Kalman filter, convergence analysis.

ES_APPM 446-2 Numerical Solution of Partial Differential Equations (1 Unit)

MAT_SCI 458-0 Atomic Scale Computational Materials Science (1 Unit)
Theory and application of atomic-scale computational materials tools to model, understand, and predict the properties of real materials.

MECH_ENG 417-0 Multi-scale Modeling and Simulation in Solid Mechanics (1 Unit)
Introduction to modern computational methods such as molecular dynamics and continuum mechanics. Applications will be nanostructure and polymer composites.

MECH_ENG 416-0 Multi-scale Modeling and Simulation in Fluid Mechanics (1 Unit)
Introduction to modern computational methods such as molecular dynamics and continuum mechanics. Applications will be Biopolymer, Protein, DNA, Lipids.

MECH_ENG 423-0 Intro to Computational Fluid Dynamics (1 Unit)
Discretization methods, solution of Navier-Stokes equations, algorithms for fluid flow problems (pressure-based algorithms, fractional time-stepping schemes, etc.), three-dimensional, steady, unsteady flows.

MECH_ENG 426-1 Advanced Finite Element Methods I (1 Unit)
Discretization methods, weak and strong forms, Newton methods for constrained and unconstrained problems, explicit methods, continuation methods.
Prerequisite: MECH_ENG 327-0 or equivalent.

MECH_ENG 426-2 Advanced Finite Element Methods II (1 Unit)
Alternative mesh descriptions, Langrangian, Eulerian, and arbitrary Langrangian Eulerian, meshless methods and particle methods, continuum based shell formations, contract-impact.
Prerequisite: MECH_ENG 426-1.

PHYSICS 430-0 Nonlinear Dynamics & Chaos (1 Unit)

Experimental Methods of Applied Physics

MECH_ENG 433-0 Advanced Mechatronics (1 Unit)
Hands-on laboratory class on design and control of electromechanical systems. Real time operating systems, analog and digital electronics, sensors and actuators. Lectures, labs, and projects.

MAT_SCI 460-0 Electron Microscopy (1 Unit)

MAT_SCI 461-0 Diffraction Methods in Material Science (1 Unit)

MAT_SCI 465-0 Advanced Electron Microscopy & Diffraction (1 Unit)
Theories of electron diffraction; theories of diffraction contrast and their application to lattice disorder; phase transformation. Current topics in electron and other charged-particle microscopy.

**MAT_SCI 466-0 Analytical Electron Microscopy (1 Unit)**
Diversity of analytical techniques in modern TEM, fundamental concepts in quantitative x-ray, EELS, CBED microanalysis, advanced AEM instrumentation, techniques and applications to physical and life sciences.

**Other Required Course Descriptions**

**MAT_SCI 401-0 Chemical & Statistical Thermodynamics of Materials (1 Unit)**
Chemical thermodynamics via analytical and statistical approaches, including chemical potentials, conditions for equilibrium, distribution functions, ideal and regular solutions, and phase diagrams. Graduate core course.

**MAT_SCI 405-0 Physics of Solids (1 Unit)**
Reciprocal lattice representation, diffraction, Brillouin zone construction, bonding, lattice vibrations, phonon dispersion, and energy band structure of solids. Graduate core course.

**PHYSICS 411-1 Methods of Theoretical Physics (1 Unit)**
The topics covered will include: techniques for the solution of differential equations; approximations such as the method of steepest descent; techniques for integration; the special functions of mathematical physics; usage of Greens functions and eigenfunctions to solve differential equations; introduction to groups and group representations; probability and statistics (time permitting).

**PHYSICS 412-1 Quantum Mech (1 Unit)**
1. Vector spaces, linear operators, Hermitian operators, stationary states, bound states, harmonic oscillator, symmetry and conservation laws, intrinsic spin, Stern-Gerlach experiment, and spherically symmetric potentials. 2. Schrödinger’s equation, electromagnetic potentials, approximation methods, variational principles, Dirac’s theory of the electron, electron spin, magnetic moment of the electron, and fine structure of hydrogen. 3. Identical particles, exchange symmetry, atomic and molecular structure, coherent states, time-dependent perturbations, transition amplitudes, spontaneous emission, photoelectric effect, scattering theory, and light scattering.

**PHYSICS 412-2 Quantum Mechanics (1 Unit)**
1. Vector spaces, linear operators, Hermitian operators, stationary states, bound states, harmonic oscillator, symmetry and conservation laws, intrinsic spin, Stern-Gerlach experiment, and spherically symmetric potentials. 2. Schrödinger’s equation, electromagnetic potentials, approximation methods, variational principles, Dirac’s theory of the electron, electron spin, magnetic moment of the electron, and fine structure of hydrogen. 3. Identical particles, exchange symmetry, atomic and molecular structure, coherent states, time-dependent perturbations, transition amplitudes, spontaneous emission, photoelectric effect, scattering theory, and light scattering.

**PHYSICS 414-1 Electrodynamics (1 Unit)**
1. Electrostatics, boundary-value problems, multipoles, electrostatics of macroscopic media, conductors and dielectrics, magnetostatics, Maxwell’s equations, electromagnetic waves and gauge transformations, and conservation laws. 2. Special theory of relativity, Lorentz transformations, covariant formulation of electrodynamics, electrodynamics of charged particles, radiation by moving charges, retarded potentials, Cerenkov radiation, synchrotron radiation, and bremsstrahlung.

**PHYSICS 416-0 Introduction to Statistical Mechanics (1 Unit)**

**PHYSICS 422-1 Condensed-Matter Physics (1 Unit)**
1. Periodic potentials, x-ray diffraction; electrons in metals: semiclassical approximation, Fermi surface, and band structure; electronic, electrical, and thermal transport; Boltzmann equation; electron-electron interactions. 2. Phonons: classical and quantum theory; electron-phonon interaction and scattering; optical properties of solids; intrinsic and extrinsic semiconductors; heterostructures and quantum Hall effect. 3. In-depth treatment of selected topics, such as diamagnetism, paramagnetism, ferromagnetism, and formation of local moments. Phenomenological theory of superconductivity, transport and magnetic properties of superconductors, and superconducting devices.

**GEN_ENG 519-0 Responsible Conduct for Research Training (0 Unit)**
The primary focus of this course will be on education in the responsible conduct of research (RCR), especially as it pertains to the engineering disciplines. Ethical and moral reasoning will be developed through analysis of case studies on the topics of conflict of interest, mentoring and lab management, collaborative research, data ownership and management, peer review, authorship, misconduct and the processes for handling misconduct.

**PHYSICS 519-0 Responsible Conduct of Research Training (0 Unit)**

**CHEM 519-0 Responsible Conduct of Research Training (0 Unit)**