APPLIED PHYSICS

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, Computer Science, Earth & Planetary Sciences, Electrical & Computer Engineering, Engineering Sciences and Applied Mathematics 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 academics or in industry, and seeks to ensure that our graduates recognize and take advantage of scientific and technological opportunities wherever they may arise.

Additional resources:

• Program website (https://www.appliedphysics.northwestern.edu/)
• Program handbook(s)

Degrees Offered

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

Learning objective(s)/Students should be able to...

• Contribute original research to scholarly community and apply appropriate research methodology and analyses, given particular research question.
• Create and communicate professional development plan.
• Develop classroom activities for a specific discussion section.
• Read, understand, and critically discuss topical scientific literature, and demonstrate expertise in underlying fundamentals.
• Give oral presentation of own research results to an audience of peers and faculty (i.e. subject matter experts and scientists outside own field). Articulate broader impacts of research.
• Motivate/describe proposed research and highlight possibilities for discovery and advancement of knowledge.

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.
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)**
This course covers the mathematics of nonlinear oscillations, fractal
gallery, 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: Undergraduate level classical mechanics and familiarity
with computer programming.

**PHYSICS 465-0 Advanced Topics in Nonlinear Dynamics (1 Unit)**
Specialized lectures on current research topics in nonlinear dynamics.

**PHYSICS 441-0 Statistical Methods for Physicists and Astronomers (1 Unit)**
Data analysis in the modern age requires familiarity of many concepts
and methods from statistics. This course provides an introduction to the
basics as well as exposure to some of the most advanced techniques.
The emphasis will be on practical problems from physics and astronomy,
rather than on theory or on statistical methods from other fields. Prior
knowledge of statistics is not required.

**MECH_ENG 328-0 Computational Failure Analysis (1 Unit)**
The course will cover the use of the scientific method for accident
investigation, hypothesis development, and the use of the finite element
method to analyze the root cause of a failure. Practical application
problems for both civil and mechanical structures will be analyzed using
commercial finite element codes (Abaqus, Hypermesh, LS-Dyna).
Prerequisite: CIV_ENV 327-0 or MECH_ENG 327-0.

**COMP_SCI 449-0 Deep Learning (1 Unit)**
Deep learning is a branch of machine learning based on algorithms that
try to model high-level abstract representations of data by using multiple
processing layers with complex structures. Some representations
make it easier to learn tasks (e.g., face recognition or spoken word
recognition) from examples. One of the promises of deep learning is
replacing handcrafted features with efficient algorithms for unsupervised
or semi-supervised feature learning and hierarchical feature extraction.
In this course students will study deep learning architectures such as
autoencoders, convolutional deep neural networks, and recurrent
neural networks. They will read original research papers that describe
the algorithms and how they have been applied to fields like computer
vision, automatic speech recognition, and audio event recognition.
For projects, students can work on their own or in groups (recommended) to
write a codebase that reproduces a landmark research paper. This course
is aimed at advanced undergraduates, masters, and PhD students.
Prerequisites: CS 349 or CS PhD or Instructor permission.

**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)**
Introduction to microanalysis.

**MAT_SCI 461-0 Diffraction Methods in Material Science (1 Unit)**
Advanced theory of diffraction. Diffraction effects accompanying
imperfections. Thermal motion, cold-work, formation of solid solutions,
transformations, liquids, gases, dynamic scattering.

**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)**
First quarter of a two-quarter class on Electrodynamics. Topics
covered: Principles of Special Relativity and invariance. Relativistic
electrodynamics as a classical field theory and action principles: for
point particles, scalar fields, and vector fields, including Lagrangian
formulation, principle of least action, symmetry principles, gauge
invariance, the electromagnetic field tensor, covariant equations of electrodynamics and mechanics. Constant electromagnetic fields.

**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)**
The goal of Responsible Conduct of Research (RCR) training is for researchers to perform the most ethical research possible. RCR training is critical to prepare undergraduate students, graduate students, and postdoctoral researchers for ethical challenges that may arise when conducting research. RCR is mandatory for all Department of Chemistry researchers. Undergraduate researchers are required to complete the online course only.