APPLIED PHYSICS

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Physics is the study of the fundamental laws of nature. Applied physics uses these laws to understand phenomena that have practical applications. Engineering in turn makes use of these phenomena for human purposes. Applied physics thus forms a link between the fundamental laws of nature and their applications. Students majoring in Applied Physics take courses in both physics and engineering, as well as courses specifically in applied physics. Students completing the program in Applied Physics are prepared for graduate study in applied physics, in physics, in nanoscience, or in engineering, and, with appropriate prerequisites, in medicine; or they may choose careers in a wide range of technical and commercial fields, or in fields such as technical writing or patent law that draw on interdisciplinary subjects.

Contemporary physical science and engineering are becoming increasingly interdisciplinary. Traditional boundaries between fields have blurred, and new areas are constantly emerging, e.g., nanotechnology. The Applied Physics major provides a flexible framework on which students can build a curriculum tailored to their own interests, in consultation with the director of undergraduate studies (DUS).

PREREQUISITES

During their first year, students interested in Applied Physics should start by taking courses in mathematics, and in physics if possible, appropriate to their level of preparation. The choice between different starting points is generally made based on performance on Advanced Placement tests. The multiplicity of choices facing students interested in this general area indicates the importance of informed advice for first-year students. Students should consult freely with DUSs and individual faculty members in their departments of interest to optimize choices and to ensure maximum flexibility at the time a major is selected.

The required prerequisites for students interested in Applied Physics include two physics courses and one physics lab; APHY 1510 or MATH 1200; and PHYS 4000 (or APHY 1940 with either MATH 2220 or MATH 2250 or MATH 2260).

The recommended starting courses in physics are PHYS 2000 and 2010. These courses should be taken in the first year by students who have a strong preparation in mathematics and physics. Students with a particularly strong background in physics and mathematics may take PHYS 2600 and 2610 instead. Students who are less well prepared in physics and mathematics may choose to take PHYS 1800 and 1810 during their first year, or PHYS 2000 and 2010 during their sophomore year after they have taken additional mathematics courses. One laboratory course, PHYS 1660L or 2060L, should be taken at some time during the first or second year.

REQUIREMENTS OF THE MAJOR

The major in Applied Physics requires eight courses beyond the introductory sequence. Two of these must be APHY 4710 and 4720. All majors are also required to take APHY 3220, APHY 4390 or PHYS 4400, and APHY 4200, or equivalents. The three remaining advanced courses should comprise an area of focus. For example, a student

interested in solid-state and/or quantum electronics might choose from APHY 3210, 4480, 4490, ECE 3200, and 3250. A student interested in the physics of materials and/or nanoscience might choose from APHY 4480, 4490, CHEM 2200, and MENG 2615. Many other focus areas are possible.

Credit/D/Fail No more than one course taken Credit/D/Fail may be applied toward the requirements of the major with permission of the DUS. The senior special projects, APHY 4710 and 4720, may only be taken for a letter grade.

Outside credit Courses taken at another institution or during an approved summer or term-time study abroad program may count toward the major requirements with DUS approval.

SENIOR REQUIREMENT

Seniors must complete an independent research project, taken as APHY 4710 and 4720. The independent research project is under the supervision of a faculty member in Applied Physics, Physics, Engineering, or related departments. The project may be started in the junior year and continued into the senior year. Students planning to do a research project should contact the DUS as early as possible to discuss available options and general requirements.

ADVISING

The Applied Physics major provides various programs corresponding to a range of student interests. Substitutions of equivalent courses may be permitted. Students interested in an Applied Physics major should contact the DUS as early as possible, and in any case by the end of their sophomore year.

A well-prepared student interested in materials physics or quantum electronics who starts the senior research in the junior year might elect the following course sequence:

First-Year	Sophomore	Junior	Senior
APHY 1510	APHY 3220	APHY 4720	APHY 4480
PHYS 2000	APHY 4390	ECE 3200	APHY 4490
PHYS 2010	PHYS 4000	APHY 4200	APHY 4710
PHYS 2060L			

A student interested in alternative energy who starts physics in the sophomore year and conducts research in the senior year might elect:

First-Year	Sophomore	Junior	Senior
MATH 1200	PHYS 2000	APHY 3220	APHY 4480
	PHYS 2010	APHY 4390	APHY 4710
	PHYS 2060L	ECE 3200	APHY 4720
	PHYS 4000	APHY 4200	ECE 4061

REQUIREMENTS OF THE MAJOR

Prerequisites PHYS 1800, 1810, or PHYS 2000, 2100, with appropriate math coreqs and PHYS 1660L or 2060L; APHY 1510 or MATH 1200; PHYS 4000 (or APHY 1940 with either MATH 2220 or MATH 2250 or MATH 2260)

Number of courses 8 term courses beyond prereqs (incl senior req)

Distribution of courses 3 adv courses in physical or mathematical sciences or engineering in area of focus, with DUS approval
Specific courses required APHY 3220; APHY 4390 or PHYS 4400; and APHY 4200, or equivalents
Substitution permitted Any relevant course approved by DUS
Senior requirement APHY 4710 and 4720

FACULTY OF THE DEPARTMENT OF APPLIED PHYSICS

Professors Charles Ahn, †Sean Barrett, Hui Cao, Michel Devoret, Paul Fleury (*Emeritus*), †Steven Girvin, †Leonid Glazman, †Jack Harris, Victor Henrich (*Emeritus*), Sohrab Ismail-Beigi, Simon Mochrie, †Corey O'Hern, Vidvuds Ozolins, Daniel Prober, Nicholas Read, Peter Schiffer, Robert Schoelkopf, †Ramamurti Shankar, †Mitchell Smooke, A. Douglas Stone, †Hongxing Tang, Robert Wheeler (*Emeritus*), Werner Wolf (*Emeritus*)

Associate Professors †Michael Choma, Peter Rakich

Assistant Professors Yu He, Owen Miller, Shruti Puri

†A joint appointment with primary affiliation in another department.

Courses

* **APHY 0500a / ENAS 0500a / PHYS 0500a, Science of Modern Technology and Public Policy** Daniel Prober
Examination of the science behind selected advances in modern technology and implications for public policy, with focus on the scientific and contextual basis of each advance. Topics are developed by the participants with the instructor and with guest lecturers, and may include nanotechnology, quantum computation and cryptography, renewable energy technologies, optical systems for communication and medical diagnostics, transistors, satellite imaging and global positioning systems, large-scale immunization, and DNA made to order. Enrollment limited to first-year students. SC

* **APHY 0800b and APHY 1000b / ENAS 0800b and ENAS 1000b / EPS 0800b / EVST 0080b and EVST 1000b / PHYS 0800b and PHYS 1000b, Energy, Environment, and Public Policy** Daniel Prober
The technology and use of energy. Impacts on the environment, climate, security, and economy. Application of scientific reasoning and quantitative analysis. Intended for non–science majors with strong backgrounds in math and science. Tours are be conducted of major examples of good energy design at Yale, including the Yale Power Plant and Kroon Hall. Students who take this course are not eligible to take APHY 100. Prerequisites: High school chemistry, physics, and Math. Calculus is not required. Enrollment limited to first-year students. QR, SC

APHY 1940a / ENAS 1940a, Ordinary and Partial Differential Equations with Applications Staff
Basic theory of ordinary and partial differential equations useful in applications. First- and second-order equations, separation of variables, power series solutions, Fourier series, Laplace transforms. Prerequisites: ENAS 151 or MATH 120 or equivalent, and knowledge of matrix-based operations. QR

APHY 3220a, Electromagnetic Waves and Devices Michael Hatridge
Introduction to electrostatics and magnetostatics, time varying fields, and Maxwell's equations. Applications include electromagnetic wave propagation in lossless, lossy, and metallic media and propagation through coaxial transmission lines and rectangular waveguides, as well as radiation from single and array antennas. Occasional experiments and demonstrations are offered after classes. Prerequisites: PHYS 1800, 1810, or 2000, 2010. QR, SC

* **APHY 4200a / PHYS 4500a, Thermodynamics and Statistical Mechanics** Steven Girvin
This course is subdivided into two topics. We study thermodynamics from a purely macroscopic point of view and then we devote time to the study of statistical mechanics, the microscopic foundation of thermodynamics. Prerequisites: PHYS 4000, 4100, and 4400 or permission of instructor. QR, SC

APHY 4390a / PHYS 4390a, Basic Quantum Mechanics John Sous
The basic concepts and techniques of quantum mechanics essential for solid-state physics and quantum electronics. Topics include the Schrödinger treatment of the harmonic oscillator, atoms and molecules and tunneling, matrix methods, and perturbation theory. Prerequisites: PHYS 1810 or 2010, PHYS 3010, or equivalents, or permission of instructor. QR, SC

APHY 4480a / PHYS 4480a, Solid State Physics I Yu He
The first term of a two-term sequence covering the principles underlying the electrical, thermal, magnetic, and optical properties of solids, including crystal structure, phonons, energy bands, semiconductors, Fermi surfaces, magnetic resonances, phase transitions, dielectrics, magnetic materials, and superconductors. Prerequisites: APHY 3220, 4390, PHYS 4200. QR, SC

APHY 4490b / PHYS 4490b, Solid State Physics II Vidvuds Ozolins
The second term of the sequence described under APHY 448. QR, SC

* **APHY 4500a / ENAS 450 / MENG 4850a and MENG 8850a, Advanced Synchrotron Techniques and Electron Spectroscopy of Materials** Charles Ahn
Introduction to concepts of advanced x-ray and electron-based techniques used for understanding the electronic, structural, and chemical behavior of materials. Students learn from world-leading experts on fundamentals and practical applications of various diffraction, spectroscopy, and microscopy methods. Course highlights the use of synchrotrons in practical experiments. Prerequisites: physics and quantum mechanics/physical chemistry courses for physical science and engineering majors, or by permission of instructor. QR, SC

APHY 4580a / PHYS 4580a, Principles of Optics with Applications Hui Cao
Introduction to the principles of optics and electromagnetic wave phenomena with applications to microscopy, optical fibers, laser spectroscopy, and nanostructure physics. Topics include propagation of light, reflection and refraction, guiding light, polarization, interference, diffraction, scattering, Fourier optics, and optical coherence. Prerequisite: PHYS 4300. QR, SC

* **APHY 4700a / ECON 4446a, Statistical Methods with Applications in Science and Finance** Sohrab Ismail-Beigi
Introduction to key methods in statistical physics with examples drawn principally from the sciences (physics, chemistry, astronomy, statistics, biology) as well as added

examples from finance. Students learn the fundamentals of Monte Carlo, stochastic random walks, and analysis of covariance analytically as well as via numerical exercises. Prerequisites: ENAS 194, MATH 222, and ENAS 130, or equivalents. QR, SC