APPLIED PHYSICS

**Director of undergraduate studies:** Daniel Prober (daniel.prober@yale.edu), 417 BCT, 432-4280; appliedphysics.yale.edu

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 on the basis of 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 DUSes 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 151 or MATH 120; and PHYS 301 (or APHY 194 with either MATH 222 or MATH 225 or MATH 226).

The recommended starting courses in physics are PHYS 200 and 201. 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 260 and 261 instead. Students who are less well prepared in physics and mathematics may choose to take PHYS 180 and 181 during their first year, or PHYS 200 and 201 during their sophomore year after they have taken more mathematics courses. One laboratory course, PHYS 166L or 206L, 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 471 and 472. All majors are also required to take APHY 322, APHY 439 or PHYS 440, and APHY 420, or equivalents. The three remaining advanced
courses should focus on a particular area of concentration. For example, a student interested in solid-state and/or quantum electronics might choose from APHY 321, 448, 449, EENG 320, and 325. A student interested in the physics of materials and/or nanoscience might choose from APHY 448, 449, CHEM 220, and MENG 285. Many other concentrations are possible.

**Credit/D/Fail** All courses required for the major, beyond the prerequisites, must be taken for a letter grade, with the single exception that one such course may be taken Credit/D/Fail with permission of the DUS. The senior special projects, APHY 471 and 472, may only be taken for a letter grade.

**SENIOR REQUIREMENT**
Seniors must complete an independent research project, taken as APHY 471 and 472. 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 for 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:

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<thead>
<tr>
<th>First-Year</th>
<th>Sophomore</th>
<th>Junior</th>
<th>Senior</th>
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<tbody>
<tr>
<td>APHY 151</td>
<td>APHY 322</td>
<td>APHY 472</td>
<td>APHY 448</td>
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<tr>
<td>PHYS 200</td>
<td>APHY 439</td>
<td>EENG 320</td>
<td>APHY 449</td>
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<tr>
<td>PHYS 201</td>
<td>PHYS 301</td>
<td>APHY 420</td>
<td>APHY 471</td>
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<tr>
<td>PHYS 206L</td>
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A student interested in alternative energy who starts physics in the sophomore year and conducts research in the senior year might elect:

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<th>Junior</th>
<th>Senior</th>
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<tbody>
<tr>
<td>MATH 120</td>
<td>PHYS 200</td>
<td>APHY 322</td>
<td>APHY 448</td>
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<td>APHY 439</td>
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<tr>
<td>PHYS 301</td>
<td>APHY 420</td>
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**REQUIREMENTS OF THE MAJOR**

**Prerequisites** PHYS 180, 181, or 200, 201, with appropriate math coreqs and PHYS 166L or 206L; APHY 151 or MATH 120; PHYS 301 (or APHY 194 with either MATH 222 or MATH 225 or MATH 226)

**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 concentration, with DUS approval

Specific courses required  APHY 322, APHY 439 or PHYS 440, and APHY 420, or equivalents

Substitution permitted  Any relevant course approved by DUS

Senior requirement  APHY 471 and 472

Contemporary science and engineering are becoming increasingly interdisciplinary. Traditional boundaries between fields have blurred, and new areas such as nanotechnology and artificially structured materials are constantly emerging. Applied physics combines study of the laws of nature at a fundamental level with a focus on technological applications to provide solutions for important societal problems. As a result, it provides an essential link between physics and engineering. The range of phenomena, materials, devices, and systems benefiting from research in applied physics is unmatched in scope and importance.

The Applied Physics major offers a unique combination of depth and flexibility, allowing students to maximize their professional development while pursuing their particular interests. Majors take courses in physics, engineering, and applied physics and are prepared for graduate study in physics, applied physics, engineering, nanoscience and, with appropriate prerequisites, medicine or law.

Prospective majors should start by taking courses in mathematics and physics appropriate to their level of preparation. Because computers are so fundamental to the practical applications of physics, students are also strongly encouraged to take a course on the use of computers early in their career. In addition to the prerequisites, all majors take three upper-level core courses in topics that are foundational for modern science and engineering:

• APHY 322, Electromagnetic Waves and Devices
• APHY 439, Basic Quantum Mechanics or PHYS 440, Quantum Mechanics and Natural Phenomena I
• APHY 420, Thermodynamics and Statistical Mechanics

The remaining requirements of the major allow students to focus their coursework and research on an individual area of scientific interest, provided it contains a significant physics component. Majors choose three electives in consultation with the director of undergraduate studies (DUS) and conduct two terms of independent research supervised by a faculty adviser from Applied Physics, Physics, one of the engineering departments, the Medical School, or related departments. The electives should relate to the research topic so that courses and research are intellectually coherent.

For more information, please contact the DUS, Daniel Prober (daniel.prober@yale.edu), who welcomes consultation with students about their programs at any time. Additional details about the program are available on the department website. For an overview of Applied Physics at Yale, watch the department’s YouTube video.
Applled Physics

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.

View Courses

Courses

[ APHY 110, The Technological World ]

APHY 151a / ENAS 151a / PHYS 151a, Multivariable Calculus for Engineers  Staff
An introduction to multivariable calculus focusing on applications to engineering problems. Topics include vector-valued functions, vector analysis, partial differentiation, multiple integrals, vector calculus, and the theorems of Green, Stokes, and Gauss. Prerequisite: MATH 115 or equivalent.  QR

APHY 194a / ENAS 194a, 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 320a / EENG 320a, Introduction to Semiconductor Devices  Mengxia Liu
An introduction to the physics of semiconductors and semiconductor devices. Topics include crystal structure; energy bands in solids; charge carriers with their statistics and dynamics; junctions, p-n diodes, and LEDs; bipolar and field-effect transistors; and device fabrication. Additional lab one afternoon per week. Prepares for EENG 325 and 401. Recommended preparation: EENG 200. PHYS 180 and 181 or permission of instructor  QR, SC

APHY 418b / EENG 402b, Advanced Electron Devices  Mengxia Liu
The science and technology of semiconductor electron devices. Topics include compound semiconductor material properties and growth techniques; heterojunction, quantum well and superlattice devices; quantum transport; graphene and other 2D material systems. Formerly EENG 418. Prerequisite: EENG 320 or equivalent.  QR, SC

* APHY 420a / PHYS 420a, Thermodynamics and Statistical Mechanics  Nicholas Read
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 301, 410, and 440 or permission of instructor.  QR, SC