PHYSICS

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FACULTY OF THE DEPARTMENT OF PHYSICS

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Associate Professors Helen Caines, Sarah Demers, †Thierry Emonet, Walter Goldberger, Jack Harris, Daisuke Nagai, †Corey O’Hern, Nikhil Padmanabhan, †Hongxing Tang

Assistant Professors †Murat Acar, †Eric Michael Brown, †Damon Clark, †Liang Jiang, Reina Maruyama, David Moore, David Poland, †Peter Rakich

Senior Lecturer Sidney Cahn

Lecturers Stephen Irons, Rona Ramos, Adriane Steinacker

†A joint appointment with primary affiliation in another department.


Introductory courses with no calculus requirement Physics courses numbered 120 or below are for students with little or no previous experience in physics who do not plan to major in the natural sciences. These courses have no college-level mathematics requirement and do not satisfy the medical school requirement.

Introductory calculus-based lecture sequences

1. PHYS 170, 171 is for students with little background in physics and mathematics who will probably not major in the physical sciences but who may be interested in medical and biological sciences. Knowledge of differential and integral calculus at the level of MATH 112 or equivalent is a prerequisite. MATH 115 should be taken concurrently with PHYS 171.

2. PHYS 180, 181 is for students with some previous background in physics and mathematics who plan to major in the physical sciences. Calculus at the level of MATH 112 is a prerequisite; MATH 115 and 120 should be taken concurrently.

3. PHYS 200, 201 is for students with a strong background in mathematics and physics who plan to major in the physical sciences. Calculus at the level of MATH 115 is assumed. MATH 120 and either MATH 222 or 225 are typically taken concurrently.

4. PHYS 260, 261 is intended for students who have had excellent training in and have a flair for mathematical methods and quantitative analysis; a solid foundation in physics is required. One of MATH 120, ENAS 151, PHYS 301, or MATH 230, 231 or equivalent should be taken concurrently with PHYS 260, 261.

If students have the appropriate mathematics background, they are advised to take a calculus-based physics course. Sir Isaac Newton developed calculus while trying to describe the world around him; it is the natural language of physics. Students enrolled in one of the calculus-based introductory courses will be invited to a series of Chairman’s Teas, which provide an opportunity to discuss topics on the frontiers of physics with faculty and peers. Completion of a calculus-based course also prepares students for the 340-level series of advanced physics electives, which cover special topics of interest to both majors and nonmajors.

A guide to selecting physics courses (http://physics.yale.edu/academics/undergraduate-studies/guide-introductory-physics-course) is available to aid in course selection. Questions about placement should be addressed to the director of undergraduate studies.

Introductory laboratories Two different introductory laboratory sequences are offered: PHYS 165L, 166L, and PHYS 205L, 206L. Each of these laboratory courses earns one-half course credit. Students normally take the laboratory courses associated with the introductory
physics sequence in which they are enrolled. Students should register for a section of the appropriate laboratory course during the first week of classes by logging onto Classes*v2 (http://classesv2.yale.edu).

1. PHYS 165L, 166L is an introductory laboratory for those students interested in the biological sciences and medicine, but without a strong high school physics laboratory preparation. Related lecture courses are PHYS 170, 171, and PHYS 180, 181.

2. PHYS 205L, 206L is for students who plan to major in the physical sciences. Related lecture courses are PHYS 180, 181, PHYS 200, 201, and PHYS 260, 261. Students who take the lecture courses in freshman year are advised to start this laboratory sequence with PHYS 205L in the spring of freshman year or in the fall of sophomore year.

**Advanced electives** A series of 340-level electives explores special topics of interest to both majors and nonmajors. The electives are open to any student in Yale College who has completed a year of introductory calculus-based physics (PHYS 170, 171, or 180, 181, or 200, 201, or 260, 261). The offerings for 2016–2017 include PHYS 343, Gravity, Astrophysics, and Cosmology and PHYS 344, Quantum and Nanoscale Physics.

**Major degree programs** Two different majors are offered in Physics: the B.S. and the B.S. with an intensive major. Students in either program acquire advanced training in physics, mathematics, and related topics through the core courses. They use electives to design individualized programs with more depth or breadth, depending on their needs and interests. Both degree programs require research experience through PHYS 471 and 472—one term for the B.S. degree and two terms for the B.S. degree with an intensive major. Both programs are excellent preparation for a wide variety of postgraduate activities, including professional school in business, law, or medicine; graduate school in engineering or other sciences; or careers in business, consulting, financial services, government service, or teaching.

The B.S. program with an intensive major is distinguished by depth of study in advanced physics courses and prepares students to study physics or closely related physical sciences in graduate school. The director of undergraduate studies can help students in the B.S. program prepare for graduate school in physics by recommending appropriate electives to supplement the core courses.

**Credit/D/Fail courses** Courses taken Credit/D/Fail may not be counted toward the requirements of either major.

**B.S. degree program** The prerequisites are an introductory lecture course sequence with a mathematics sequence equivalent to, or more advanced than, the corequisite of the physics sequence. The following options are appropriate: PHYS 170, 171 with MATH 112, 115; or PHYS 180, 181 with MATH 115, 120; or PHYS 200, 201 with MATH 120 and either 225 or 222; or PHYS 260, 261 with MATH 120, ENAS 151, PHYS 301, or MATH 230, 231 or equivalent. In addition, the laboratory sequence PHYS 205L, 206L or PHYS 165L, 166L is required. Students who take these physics and mathematics courses starting in their freshman year may satisfy the prerequisites by the middle of their sophomore year. Students who begin taking physics courses in their sophomore year may also complete either the standard or the intensive major. Students are advised to take mathematics courses throughout their freshman year at the appropriate level.

Eight courses are required beyond the prerequisites, including the senior project. Students must take a mathematics course at the level of, or more advanced than, PHYS 301. Three courses at the core of the major involve advanced study of fundamental topics common to all branches of physics, and must be taken in order. The first two, PHYS 401 and 402, pertain to advanced classical physics (mechanics, statistical physics and thermodynamics, and electromagnetism), and the third, APHY 439 or PHYS 440, covers quantum mechanics. Three advanced elective courses are also required. Suitable advanced courses include the PHYS 340-level electives, an advanced laboratory such as PHYS 382L, and 400-level courses in Physics. Students may also find suitable advanced courses in other departments in the sciences, engineering, and mathematics. Courses taken to satisfy these requirements must be approved by the director of undergraduate studies. In order to pursue their individual interests in sufficient depth, many students choose to take more than the required number of advanced courses.

**Senior requirement for the B.S. degree program** The senior requirement for the standard B.S. degree is fulfilled by receiving a passing grade on a one-term research project in PHYS 471 or 472 or equivalent. Students should consult the director of undergraduate studies for further information.

**B.S. degree program, intensive major** The prerequisites for the B.S. degree with an intensive major are the same as for the standard program. Ten courses are required beyond the prerequisites, including the senior project. Students must take a mathematics course at the level of, or more advanced than, PHYS 301. Five courses at the core of the major involve advanced study of fundamental topics common to all branches of physics. Three of the courses pertain to advanced classical physics: mechanics (PHYS 410), statistical physics and thermodynamics (PHYS 420), and electromagnetism (PHYS 430). Two other courses incorporate quantum mechanics (PHYS 440 and 441). These courses must be taken in order because the ideas build progressively: PHYS 410 precedes 440, which precedes 441, 420, and 430.

Because experiment is at the heart of the discipline, the intensive major requires one term of advanced laboratory (PHYS 382L or equivalent) and at least two terms of independent research (PHYS 471, 472 or equivalent). One advanced elective course is required to complete the program. Suitable advanced courses include the PHYS 340-level electives and 400-level courses in Physics. Students may also find suitable advanced courses in other departments in the sciences, engineering, and mathematics. Courses taken to satisfy these requirements must be approved by the director of undergraduate studies. In order to pursue their individual interests in sufficient depth, many students choose to take more than ten advanced courses.
Senior requirement for the B.S. degree program, intensive major The senior requirement for the intensive major is fulfilled by receiving a passing grade on a two-term research project in PHYS 471, 472 or equivalent. Students should consult the director of undergraduate studies for further information.

Sequence of courses For both the standard B.S. degree and the B.S. degree with an intensive major, students are advised to begin the program in their freshman year to allow the greatest amount of flexibility in course selection. It is possible, however, to complete either program in a total of six terms, as illustrated below.

A program for a student completing the Physics B.S. in three years might be:

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<th>Freshman or Sophomore</th>
<th>Sophomore or Junior</th>
<th>Senior</th>
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<td>PHYS 206L</td>
<td>APHY 439 or PHYS 440</td>
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<td>PHYS 301</td>
<td>PHYS 471 or 472</td>
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<td>Mathematics corequisites</td>
<td>PHYS 401</td>
<td>Two advanced electives</td>
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Approval of programs All Physics majors in the sophomore, junior, and senior classes must have their programs approved by the director of undergraduate studies. Freshmen and undeclared sophomores who are interested in Physics or related majors are encouraged to meet with the director of undergraduate studies to discuss their questions and proposed programs.

Requirements of the major

B.S. Degree

Prerequisites PHYS 170, 171, or 180, 181, or 200, 201, or 260, 261, with appropriate math coreqs; PHYS 205L, 206L, or PHYS 165L, 166L

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

Specific courses required PHYS 301 or other advanced math course; PHYS 401, 402, and either APHY 439 or PHYS 440, in sequence

Distribution of courses 3 advanced electives approved by DUS

Senior requirement PHYS 471 or 472 or equivalent

B.S. Degree, Intensive Major

Prerequisites PHYS 170, 171, or 180, 181, or 200, 201, or 260, 261, with appropriate math coreqs; PHYS 205L, 206L, or PHYS 165L, 166L

Number of courses 10 term courses beyond prereqs (incl senior req)

Specific courses required PHYS 301 or other advanced math course; PHYS 410, 440, 441, 420, 430, in sequence; PHYS 382L

Distribution of courses 1 advanced elective approved by DUS

Senior requirement PHYS 471 and 472