Physics

Program of Study

Physics is concerned with the study of matter, energy, forces, and their interaction in the world and universe around us. The undergraduate curriculum in the Department of Physics leading to the BA in physics includes a strong emphasis on experiment and covers the broad fundamentals necessary for graduate study in theoretical physics, experimental physics, or astronomy and astrophysics, as well as some fields of engineering and many interdisciplinary specialties requiring a strong technical background (e.g., biophysics, medical physics, atmospheric and environmental sciences).

Students who are majoring in other fields of study may also complete a minor in physics. Information follows the description of the major.

Program Requirements

Courses

The curriculum leading to the BA degree in physics is designed for maximum flexibility consistent with a thorough coverage of the essential principles of physics. Degree requirements include introductory and advanced physics and mathematics courses, as well as physics electives that allow students to pursue specific interests. Students intending to pursue graduate work in astrophysics should consider the program leading to a BA in physics with a specialization in astrophysics, which is described later.

Students who plan to major in physics are encouraged to start course work in their first year. However, the program can be completed in three years, so one could start physics in the second year without delaying graduation. Two of the physics and two of the mathematics courses can be designated as general education courses, with fifteen courses remaining to fulfill the major.

In general, students should take the most advanced courses for which they have the appropriate prerequisites. Entering students will be given a placement for either PHYS 13100 Mechanics or PHYS 14100 Honors Mechanics based on their mathematics and physics background. Either course is appropriate for students planning to major (or minor) in physics.

Mathematics

The mathematics requirement is a calculus sequence (MATH 15100-MATH 15200-MATH 15300 or MATH 16100-MATH 16200-MATH 16300) followed by PHYS 22100. As an alternative to PHYS 22100, students taking an Analysis sequence (MATH 20300-MATH 20400-MATH 20500 or MATH 20700-MATH 20800-MATH 20900) may substitute MATH 20500 or MATH 20900 for PHYS 22100, though they will subsequently need to acquire certain math tools, as needed, on their own. However, students interested in pursuing further study in physics and mathematics should consider taking both PHYS 22100 and an Analysis sequence.
But please note that for students starting their program with the PHYS 13100-PHYS 13200-PHYS 13300 sequence, the MATH 15300/MATH 16300 requirement is replaced by PHYS 22000. This course in mathematical methods introduces tools typically used in the PHYS 14100-PHYS 14200-PHYS 14300 sequence, and ensures that a student taking PHYS 13100-PHYS 13200-PHYS 13300 will possess the mathematical background needed for subsequent physics course work.

Finally, entering students placing into MATH 13100 should consult the undergraduate program chair to plan a program of study.

**SUMMARY OF REQUIREMENTS**

**GENERAL EDUCATION**

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 13100-13200 Mechanics; Electricity and Magnetism</td>
<td>200</td>
</tr>
<tr>
<td>PHYS 14100-14200 Honors Mechanics; Honors Electricity and Magnetism *</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 15100-15200 Calculus I-II *</td>
<td></td>
</tr>
<tr>
<td>MATH 16100-16200 Honors Calculus I-II</td>
<td></td>
</tr>
</tbody>
</table>

**Total Units** 400

**MAJOR**

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 13300 Waves, Optics, and Heat</td>
<td>100</td>
</tr>
<tr>
<td>PHYS 14300 Honors Waves, Optics, and Heat *</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 15300 Calculus III *</td>
<td></td>
</tr>
<tr>
<td>MATH 16300 Honors Calculus III</td>
<td></td>
</tr>
<tr>
<td>PHYS 22000 Introduction to Mathematical Methods in Physics</td>
<td></td>
</tr>
</tbody>
</table>

Note: students in PHYS 13300 must take PHYS 22000.

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 22100 Mathematical Methods in Physics</td>
<td>100</td>
</tr>
<tr>
<td>MATH 20500 Analysis in Rn III</td>
<td></td>
</tr>
<tr>
<td>MATH 20900 Honors Analysis in Rn III</td>
<td></td>
</tr>
<tr>
<td>PHYS 15400 Modern Physics</td>
<td>100</td>
</tr>
<tr>
<td>PHYS 18500 Intermediate Mechanics</td>
<td>100</td>
</tr>
<tr>
<td>PHYS 23400-23500 Quantum Mechanics I-II</td>
<td>200</td>
</tr>
<tr>
<td>PHYS 21101-21102-21103 Experimental Physics I-II-III</td>
<td>200</td>
</tr>
</tbody>
</table>
PHYS 22500-22700  Intermediate Electricity and Magnetism I-II  200
PHYS 19700  Statistical and Thermal Physics  100
Three electives (to be selected from list of approved courses)  300

Total Units  1500

* Credit may be granted by examination.

Electives

In addition to specified course work, the physics major requires three electives. These electives may be selected from the following courses:

All 20000-level physics courses (except PHYS 24300, PHYS 29100-29200-29300, and PHYS 29700)

Courses in Mathematics and Statistics (no more than two to be used as program electives):

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 20400</td>
<td>Analysis in Rn II</td>
</tr>
<tr>
<td>or MATH 20800</td>
<td>Honors Analysis in Rn II</td>
</tr>
<tr>
<td>MATH 20500</td>
<td>Analysis in Rn III</td>
</tr>
<tr>
<td>or MATH 20900</td>
<td>Honors Analysis in Rn III</td>
</tr>
</tbody>
</table>

Note: Neither MATH 20500 nor MATH 20900 can be counted toward electives if substituted for PHYS 22100.

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 27000</td>
<td>Basic Complex Variables</td>
</tr>
<tr>
<td>MATH 27200</td>
<td>Basic Functional Analysis</td>
</tr>
<tr>
<td>MATH 27300</td>
<td>Basic Theory of Ordinary Differential Equations</td>
</tr>
<tr>
<td>MATH 27400</td>
<td>Introduction to Differentiable Manifolds and Integration on Manifolds</td>
</tr>
<tr>
<td>MATH 27500</td>
<td>Basic Theory of Partial Differential Equations</td>
</tr>
<tr>
<td>STAT 23400</td>
<td>Statistical Models and Methods</td>
</tr>
<tr>
<td>or STAT 24400</td>
<td>Statistical Theory and Methods I</td>
</tr>
<tr>
<td>STAT 24500</td>
<td>Statistical Theory and Methods II</td>
</tr>
</tbody>
</table>

Other courses in the physical sciences:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTR 24100</td>
<td>The Physics of Stars and Stellar Systems †</td>
</tr>
<tr>
<td>ASTR 24200</td>
<td>The Physics of Galaxies and the Universe †</td>
</tr>
<tr>
<td>CHEM 26300</td>
<td>Chemical Kinetics and Dynamics</td>
</tr>
<tr>
<td>CHEM 26800</td>
<td>Computational Chemistry and Biology</td>
</tr>
<tr>
<td>CMSC 23710</td>
<td>Scientific Visualization</td>
</tr>
<tr>
<td>CMSC 28510</td>
<td>Introduction to Scientific Computing</td>
</tr>
<tr>
<td>GEOS 21200</td>
<td>Physics of the Earth</td>
</tr>
<tr>
<td>GEOS 23200</td>
<td>Climate Dynamics of the Earth and Other Planets</td>
</tr>
</tbody>
</table>

Courses in the biological sciences:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOS 29326</td>
<td>Introduction to Medical Physics and Medical Imaging</td>
</tr>
</tbody>
</table>

Or other courses approved by the program chair for physics
† Cannot be counted toward electives if used to satisfy requirements for the specialization in astrophysics.

Sample Programs

The sample programs below illustrate different paths for fulfilling requirements for the physics major.

In the first example, the Honors physics sequence PHYS 14100-14200-14300 is taken concurrently with calculus:

First Year

<table>
<thead>
<tr>
<th>Autumn Quarter</th>
<th>Units</th>
<th>Winter Quarter</th>
<th>Units</th>
<th>Spring Quarter</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 14100</td>
<td>100</td>
<td>PHYS 14200</td>
<td>100</td>
<td>PHYS 14300</td>
<td>100</td>
</tr>
<tr>
<td>MATH 15100 or 16100</td>
<td>100 MATH 15200 or 16200</td>
<td>100 MATH 15300 or 16300</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>200</td>
<td>200</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total Units: 600

The next example shows a PHYS 13100-13200-13300 pathway. Here, the required PHYS 22000 course replaces the third quarter of calculus.

First Year

<table>
<thead>
<tr>
<th>Autumn Quarter</th>
<th>Units</th>
<th>Winter Quarter</th>
<th>Units</th>
<th>Spring Quarter</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 13100</td>
<td>100</td>
<td>PHYS 13200</td>
<td>100</td>
<td>PHYS 22000</td>
<td>100</td>
</tr>
<tr>
<td>MATH 15100 or 16100</td>
<td>100 MATH 15200 or 16200</td>
<td>100 MATH 22000</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>200</td>
<td>200</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total Units: 600

The remaining required courses are typically distributed over the next three years, like so:

Second Year

<table>
<thead>
<tr>
<th>Autumn Quarter</th>
<th>Units</th>
<th>Winter Quarter</th>
<th>Units</th>
<th>Spring Quarter</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 15400</td>
<td>100</td>
<td>PHYS 18500</td>
<td>100</td>
<td>PHYS 23400</td>
<td>100</td>
</tr>
<tr>
<td>PHYS 22100</td>
<td>100</td>
<td></td>
<td>100</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>100</td>
<td>100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Third Year

<table>
<thead>
<tr>
<th>Autumn Quarter</th>
<th>Units</th>
<th>Winter Quarter</th>
<th>Units</th>
<th>Spring Quarter</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 23500</td>
<td>100</td>
<td>PHYS 22500</td>
<td>100</td>
<td>PHYS 22700</td>
<td>100</td>
</tr>
<tr>
<td>PHYS 21101</td>
<td>000</td>
<td>PHYS 21102</td>
<td>100</td>
<td>PHYS 21103</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>200</td>
<td>200</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fourth Year

<table>
<thead>
<tr>
<th>Autumn Quarter</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 19700</td>
<td>100</td>
</tr>
<tr>
<td>PHYS 19700</td>
<td>100</td>
</tr>
</tbody>
</table>

Total Units: 1000

In addition, three electives (selected from a list of approved courses) must be taken. In deciding when to take electives, students should be mindful of any course prerequisites.

The required laboratory sequence PHYS 21101-21102-21103 is a year-long study of experimental physics. (Please note: PHYS 21101 carries no credit and is graded P/F.)
It is recommended, but not required, that Experimental Physics be taken in the third year, concurrent with PHYS 23500.

Progress through the physics program can be accelerated by "doubling up" on some of the required courses. For example, PHYS 23500 and PHYS 19700 may be taken concurrently in the third year, and PHYS 22500/PHYS 22700 may be concurrent with PHYS 18500/PHYS 23400 in the second year. This provides more options in the third and fourth years for electives, as well as research or graduate course work. Note that it is possible to complete all program requirements in three years.

The specialization in astrophysics might be pursued by taking ASTR 24100, ASTR 24200, and ASTR 28200 in either the third or fourth year.

Finally, the sample programs shown here are only meant to be illustrative. Students are encouraged to speak with the departmental counselors in planning individual programs, especially regarding selection of mathematics courses and program electives.

Introductory Course

The introductory course for students in the physical sciences is divided into two variants—PHYS 13100-PHYS 13200-PHYS 13300 and PHYS 14100-PHYS 14200-PHYS 14300—so students may learn with others who have comparable physics and mathematics backgrounds. The co-requisite for both is a first-year calculus sequence: MATH 15100-MATH 15200-MATH 15300 or MATH 16100-MATH 16200-MATH 16300 (or completion of MATH 13100-MATH 13200-MATH 13300). The essential physics content of these two sequences is the same, but the 140s sequence covers material at a higher mathematical level. Both PHYS 130s and PHYS 140s prepare students for further courses in the physics major or minor.

First-year students are assigned to either PHYS 13100 or PHYS 14100 based on Advanced Placement test scores. In addition, physics placement may be adjusted by consulting the undergraduate program chair (KPTC 205) during Orientation week. Transfer students who have satisfactorily completed calculus-based introductory physics courses at another university may be granted appropriate transfer credit upon petition to and approval by the program chair.

Another introductory sequence, PHYS 12100-PHYS 12200-PHYS 12300, is intended for students pursuing studies in biology or medicine. The prerequisite is completion of a calculus sequence and general chemistry. While topics are similar to the 130s and 140s sequences, PHYS 120s cannot serve as a prerequisite for further courses in physics, and thus cannot be used for the physics major or minor.

A student who completes PHYS 14100 or PHYS 14200 with a grade below C is normally required to move to PHYS 13200 or PHYS 13300 the following quarter. Petitions for a waiver of this requirement must be presented to the undergraduate program chair before the second day of the succeeding course. A student who receives an A or A- in PHYS 13100 may petition the undergraduate program chair to move to PHYS 14200.
Advanced Placement

Students who took the Physics C Advanced Placement examinations prior to matriculation in the College may receive credit for some or all of PHYS 12100-PHYS 12200-PHYS 12300. Consult the section on Advanced Placement Credit in this catalog for more information.

Accreditation

Accreditation examinations are administered for the content of PHYS 12100-PHYS 12200-PHYS 12300 and PHYS 14100-PHYS 14200-PHYS 14300. The first examination may be taken by incoming students only at the time of matriculation in the College. Students who pass the first examination (for PHYS 12100 or PHYS 14100) will receive credit for the lecture part of the course only and will then be invited to try the next examination of the sequence. All students who receive advanced standing on the basis of a physics accreditation examination are interviewed by the undergraduate program chair to determine the extent of their lab experience. Additional laboratory work may be required.

Grading

All regular (nonresearch) physics courses must be taken for quality grades. All courses used to satisfy prerequisites must be taken for quality grades. The Department of Physics requires students to pass PHYS 13100-PHYS 13200-PHYS 13300/PHYS 14100-PHYS 14200-PHYS 14300, PHYS 15400, PHYS 18500, and PHYS 23400 with an average of 2.0 or higher to continue in the program.

Opportunities for Participation in Research

The physics program offers unique opportunities for College students to become actively involved in the research being conducted by faculty of the department. Interested students are welcome to consult with the departmental counselors. The focus of much of the undergraduate research is structured around the Bachelor’s Thesis (PHYS 29100-PHYS 29200-PHYS 29300). Alternatively, third- or fourth-year students majoring in physics may register for research for academic credit (PHYS 29700). In addition to these formal arrangements, students at any level may become involved in research by working in a faculty member’s lab or research group on an extracurricular basis.

Honors

There are two routes to receiving a BA with honors. Both require a minimum GPA of 3.0 in the courses listed under Major in the preceding Summary of Requirements section. In the first route, the student must register for PHYS 29100-PHYS 29200-PHYS 29300 and earn a grade of B or higher based on a bachelor’s thesis describing an approved research project completed during the year. The second route to receiving a BA with honors is to pass an approved set of three graduate courses, with a grade of B or higher in each. One such set of courses is PHYS 34100-PHYS 34200 and PHYS 35200; however, other 30000-level courses may be used with approval from the program chair.
DEGREE PROGRAM IN PHYSICS WITH SPECIALIZATION IN
ASTROPHYSICS

The program leading to a BA in physics with a specialization in astrophysics is a
variant of the BA in physics. The degree is in physics, with the designation "with
specialization in astrophysics" included on the final transcript. Candidates are
required to complete all requirements for the BA degree in physics, plus a two-
quarter sequence in astrophysics (ASTR 24100 and ASTR 24200), plus either a third
course in astrophysics (ASTR 28200 ) or a senior thesis project in physics (PHYS
29100-PHYS 29200-PHYS 29300) on a topic in astrophysics. If the latter option is
chosen, the thesis topic must be approved by the program chair. (This thesis may
simultaneously fulfill part of the requirements for honors in physics.) A grade of at
least C- must be obtained in each course.

MINOR PROGRAM IN PHYSICS

The minor in physics is designed to present a coherent program of study to
students with a strong interest in physics but insufficient time to pursue the major.
The courses required for the minor are:

One of the following: 100

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 13300</td>
<td>Waves, Optics, and Heat</td>
</tr>
<tr>
<td>PHYS 14300</td>
<td>Honors Waves, Optics, and Heat</td>
</tr>
</tbody>
</table>

One of the following: 100

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 15300</td>
<td>Calculus III</td>
</tr>
<tr>
<td>MATH 16300</td>
<td>Honors Calculus III</td>
</tr>
<tr>
<td>PHYS 22000</td>
<td>Introduction to Mathematical Methods in Physics</td>
</tr>
</tbody>
</table>

Note: students in PHYS 13300 must take PHYS 22000.

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 15400</td>
<td>Modern Physics</td>
</tr>
<tr>
<td>PHYS 18500</td>
<td>Intermediate Mechanics</td>
</tr>
<tr>
<td>PHYS 22100</td>
<td>Mathematical Methods in Physics</td>
</tr>
<tr>
<td>PHYS 23400</td>
<td>Quantum Mechanics I</td>
</tr>
</tbody>
</table>

Two electives, at least one of which is: 200

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 19700</td>
<td>Statistical and Thermal Physics</td>
</tr>
<tr>
<td>PHYS 22500</td>
<td>Intermediate Electricity and Magnetism I</td>
</tr>
<tr>
<td>PHYS 23500</td>
<td>Quantum Mechanics II</td>
</tr>
</tbody>
</table>

The second elective may be any course that is required by the major or can be
used as an elective for the major.

Total Units 800

The mathematics requirement for the minor is identical to the requirement for the
major; please consult the description of the major for more information, particularly
regarding PHYS 22000 and PHYS 22100. Note that PHYS 22000 and PHYS 22100
may be replaced by equivalent courses, as approved by the undergraduate program
chair. Note also that the PHYS 13300/PHYS 14300, PHYS 22100, and MATH 15300/
MATH 16300/PHYS 22000 requirements will be waived for those who must take
these courses to satisfy the requirements of a major or another minor. Consequently, the number of additional courses needed for the minor will vary between five and eight.

Students who elect the minor program in physics must meet with the physics undergraduate program chair before the end of Spring Quarter of their third year to declare their intention to complete the minor. The approval of the program chair for the minor program should be submitted to a student's College adviser by the deadline above on a form obtained from the College adviser. Courses for the minor are chosen in consultation with the program chair.

Courses in the minor (1) may not be double counted with the student's major(s) or with other minors and (2) may not be counted toward general education requirements. Courses in the minor must be taken for quality grades, and students must have a GPA of 2.0 or higher in the minor. More than half of the requirements for the minor must be met by registering for courses bearing University of Chicago course numbers.

**PHYSICS COURSES**

**PHYS 12100-12200-12300. General Physics I-II-III.**
This is a one-year sequence in the fundamentals of physics for students in the biological sciences and pre-medical studies. Topics include classical mechanics, fluids, electricity and magnetism, wave motion, optics, and modern physics. Where appropriate, attention will be drawn to interdisciplinary applications, such as in biology or medicine. Calculus is used as needed. The first two courses meet the general education requirement in physical sciences. (L)

**PHYS 12100. General Physics I. 100 Units.**
This is a one-year sequence in the fundamentals of physics for students in the biological sciences and pre-medical studies. Topics include classical mechanics, fluids, electricity and magnetism, wave motion, optics, and modern physics. Where appropriate, attention will be drawn to interdisciplinary applications, such as in biology or medicine. Calculus is used as needed. The first two courses meet the general education requirement in physical sciences. (L)
Terms Offered: Autumn
Prerequisite(s): MATH 13300 or 15300 or 16300; CHEM 11300 or 12300.

**PHYS 12200. General Physics II. 100 Units.**
No description available.
Terms Offered: Winter
Prerequisite(s): PHYS 12100

**PHYS 12300. General Physics III. 100 Units.**
No description available.
Terms Offered: Spring
Prerequisite(s): PHYS 12200
PHYS 12200. General Physics II. 100 Units.
No description available.
Terms Offered: Winter
Prerequisite(s): PHYS 12100

PHYS 12300. General Physics III. 100 Units.
No description available.
Terms Offered: Spring
Prerequisite(s): PHYS 12200

PHYS 13100-13200-13300. Mechanics; Electricity and Magnetism; Waves, Optics, and Heat.
This is a one-year introductory sequence in physics for students in the physical sciences. Univariable calculus is used extensively. The first two courses meet the general education requirement in physical sciences. (L)

  PHYS 13100. Mechanics. 100 Units.
  Topics include particle motion, Newton's Laws, work and energy, systems of particles, rigid-body motion, gravitation, oscillations, and special relativity. (L)
  Terms Offered: Autumn
  Prerequisite(s): MATH 13100-13200-13300 or 15100-15200-15300 or 16100-16200-16300. (MATH 15100-15200-15300 or 16100-16200-16300 may be taken concurrently.)

  PHYS 13200. Electricity and Magnetism. 100 Units.
  Topics include electric fields, Gauss' law, electric potential, capacitors, DC circuits, magnetic fields, Ampere's law, induction, Faraday's law, AC circuits, Maxwell's equations, and electromagnetic waves. (L)
  Terms Offered: Winter
  Prerequisite(s): PHYS 13100 or 14100

  PHYS 13300. Waves, Optics, and Heat. 100 Units.
  Topics include mechanical waves, sound, light, polarization, reflection and refraction, interference, diffraction, geometrical optics, heat, kinetic theory, and thermodynamics. (L)
  Terms Offered: Spring
  Prerequisite(s): PHYS 13200 or 14200

PHYS 13200. Electricity and Magnetism. 100 Units.
Topics include electric fields, Gauss' law, electric potential, capacitors, DC circuits, magnetic fields, Ampere's law, induction, Faraday's law, AC circuits, Maxwell's equations, and electromagnetic waves. (L)
Terms Offered: Winter
Prerequisite(s): PHYS 13100 or 14100

PHYS 13300. Waves, Optics, and Heat. 100 Units.
Topics include mechanical waves, sound, light, polarization, reflection and refraction, interference, diffraction, geometrical optics, heat, kinetic theory, and thermodynamics. (L)
Terms Offered: Spring
Prerequisite(s): PHYS 13200 or 14200
This is a one-year introductory sequence in physics for students in the physical sciences. A strong background in univariable calculus is assumed. Multivariable and vector calculus will be introduced and used extensively. The first two courses meet the general education requirement in physical sciences. (L)

PHYS 14100. Honors Mechanics. 100 Units.
Topics include particle motion, Newton's Laws, work and energy, systems of particles, rigid-body motion, gravitation, oscillations, and special relativity. (L)
Terms Offered: Autumn
Prerequisite(s): MATH 13100-13200-13300 or 15100-15200-15300 or 16100-16200-16300. (MATH 15100-15200-15300 or 16100-16200-16300 may be taken concurrently.)

PHYS 14200. Honors Electricity and Magnetism. 100 Units.
Topics include electric fields, Gauss' law, electric potential, capacitors, DC circuits, magnetic fields, Ampere's law, induction, Faraday's law, AC circuits, Maxwell's equations, and electromagnetic waves. (L)
Terms Offered: Winter
Prerequisite(s): PHYS 14100

PHYS 14300. Honors Waves, Optics, and Heat. 100 Units.
Topics include mechanical waves, sound, light, polarization, reflection and refraction, interference, diffraction, geometrical optics, heat, kinetic theory, and thermodynamics. (L)
Terms Offered: Spring
Prerequisite(s): PHYS 14200

PHYS 14200. Honors Electricity and Magnetism. 100 Units.
Topics include electric fields, Gauss' law, electric potential, capacitors, DC circuits, magnetic fields, Ampere's law, induction, Faraday's law, AC circuits, Maxwell's equations, and electromagnetic waves. (L)
Terms Offered: Winter
Prerequisite(s): PHYS 14100

PHYS 14300. Honors Waves, Optics, and Heat. 100 Units.
Topics include mechanical waves, sound, light, polarization, reflection and refraction, interference, diffraction, geometrical optics, heat, kinetic theory, and thermodynamics. (L)
Terms Offered: Spring
Prerequisite(s): PHYS 14200
PHYS 15400. Modern Physics. 100 Units.
This course is an introduction to quantum physics. Topics include Einstein’s quantum theory of light, the wave nature of particles, atomic structure, the Schrödinger equation, quantum mechanics in one and three dimensions, angular momentum and spin, and the hydrogen atom. Applications to nuclear and solid-state physics are presented. (L)
Terms Offered: Autumn
Prerequisite(s): PHYS 14300, or PHYS 13300 and PHYS 22000

PHYS 18500. Intermediate Mechanics. 100 Units.
Topics include a review of Newtonian mechanics, the calculus of variations, Lagrangian and Hamiltonian mechanics, generalized coordinates, canonical momenta, phase space, constrained systems, central-force motion, non-inertial reference frames, and rigid-body motion.
Terms Offered: Winter
Prerequisite(s): PHYS 13100 or 14100, and PHYS 22100 or MATH 20300

PHYS 19700. Statistical and Thermal Physics. 100 Units.
This course develops a statistical description of physical systems. Topics include elements of probability theory, equilibrium and fluctuations, thermodynamics, canonical ensembles, the equipartition theorem, quantum statistics of ideal gases, and kinetic theory.
Terms Offered: Autumn
Prerequisite(s): PHYS 23400, and PHYS 22100 or MATH 20500

PHYS 21101-21102-21103. Experimental Physics I-II-III.
This is a year-long laboratory sequence, offering experiments in atomic, molecular, solid-state, nuclear, and particle physics. Additional material, as needed, is presented in supplemental lectures. Content varies from quarter to quarter. P/F grading in Autumn. (L)
Note(s): Open only to students who are majoring in Physics.

PHYS 21101. Experimental Physics I. 000 Units.
This is a year-long laboratory sequence, offering experiments in atomic, molecular, solid-state, nuclear, and particle physics. Additional material, as needed, is presented in supplemental lectures. Content varies from quarter to quarter. P/F grading in Autumn. (L)
Note(s): Open only to students who are majoring in Physics.
Terms Offered: Autumn
Prerequisite(s): PHYS 23400

PHYS 21102. Experimental Physics II. 100 Units.
No description available.
Terms Offered: Winter
Prerequisite(s): PHYS 21101

PHYS 21103. Experimental Physics III. 100 Units.
No description available.
Terms Offered: Spring
Prerequisite(s): PHYS 21102
PHYS 21102. Experimental Physics II. 100 Units.
No description available.
Terms Offered: Winter
Prerequisite(s): PHYS 21101

PHYS 21103. Experimental Physics III. 100 Units.
No description available.
Terms Offered: Spring
Prerequisite(s): PHYS 21102

PHYS 22000. Introduction to Mathematical Methods in Physics. 100 Units.
This course, with concurrent enrollment in PHYS 13300, is required of students who plan to major in physics. Topics include infinite series and power series, complex numbers, linear equations and matrices, partial differentiation, multiple integrals, vector analysis, and Fourier series. Applications of these methods include Maxwell’s equations, wave packets, and coupled oscillators.
Terms Offered: Spring
Prerequisite(s): MATH 15200 or 16200, and PHYS 13200

PHYS 22100. Mathematical Methods in Physics. 100 Units.
Topics include linear algebra and vector spaces, ordinary and partial differential equations, calculus of variations, special functions, series solutions of differential equations, and integral transforms.
Terms Offered: Autumn
Prerequisite(s): PHYS 14300, or PHYS 13300 and PHYS 22000

PHYS 22500-22700. Intermediate Electricity and Magnetism I-II.
Topics include electrostatics, magnetostatics, electromagnetic induction, electric and magnetic fields in matter, plane electromagnetic waves, reflection and refraction of electromagnetic waves, and electromagnetic radiation.

PHYS 22500. Intermediate Electricity and Magnetism I. 100 Units.
Topics include electrostatics, magnetostatics, electromagnetic induction, electric and magnetic fields in matter, plane electromagnetic waves, reflection and refraction of electromagnetic waves, and electromagnetic radiation.
Terms Offered: Winter
Prerequisite(s): PHYS 13200 or 14200, and PHYS 22100 or MATH 20300

PHYS 22700. Intermediate Electricity and Magnetism II. 100 Units.
Terms Offered: Spring
Prerequisite(s): PHYS 22500

PHYS 22600. Electronics. 100 Units.
This hands-on experimental course is intended to develop confidence, understanding, and design ability in modern electronics. It is not a course in the physics of semiconductors. In two lab sessions a week, we explore the properties of diodes, transistors, amplifiers, operational amplifiers, oscillators, field effect transistors, logic gates, digital circuits, analog-to-digital and digital-to-analog converters, phase-locked loops, and more. Lectures supplement the lab. (L)
Terms Offered: Spring
Prerequisite(s): PHYS 12200 or 13200 or 14200
PHYS 22700. Intermediate Electricity and Magnetism II. 100 Units.
Terms Offered: Spring
Prerequisite(s): PHYS 22500

PHYS 23400-23500. Quantum Mechanics I-II.
Quantum Mechanics I-II

PHYS 23400. Quantum Mechanics I. 100 Units.
A study of wave-particle duality leading to the basic postulates of quantum mechanics is presented. Topics include the uncertainty principle, applications of the Schrödinger equation in one and three dimensions, the quantum harmonic oscillator, rotational invariance and angular momentum, the hydrogen atom, and spin.
Terms Offered: Spring
Prerequisite(s): PHYS 15400, and PHYS 22100 or MATH 20400

PHYS 23500. Quantum Mechanics II. 100 Units.
A review of quantum mechanics is presented, with emphasis on Hilbert space, observables, and eigenstates. Topics include spin and angular momentum, time-independent perturbation theory, fine and hyperfine structure of hydrogen, the Zeeman and Stark effects, many-electron atoms, molecules, the Pauli exclusion principle, and radiative transitions.
Terms Offered: Autumn
Prerequisite(s): PHYS 23400

PHYS 23500. Quantum Mechanics II. 100 Units.
A review of quantum mechanics is presented, with emphasis on Hilbert space, observables, and eigenstates. Topics include spin and angular momentum, time-independent perturbation theory, fine and hyperfine structure of hydrogen, the Zeeman and Stark effects, many-electron atoms, molecules, the Pauli exclusion principle, and radiative transitions.
Terms Offered: Autumn
Prerequisite(s): PHYS 23400

PHYS 23600. Solid State Physics. 100 Units.
Topics include a review of quantum statistics, crystal structure and crystal binding, lattice vibrations and phonons, liquid helium, the free-electron model of metals, the nearly-free-electron model, semi-conductors, and optical properties of solids.
Terms Offered: Winter
Prerequisite(s): PHYS 23500 and 19700

PHYS 23700. Nuclei and Elementary Particles. 100 Units.
This course covers topics such as nuclear structure, processes of transformation, observables of the nucleus, passage of nuclear radiation through matter, accelerators and detectors, photons, leptons, mesons, and baryons, hadronic interactions, and the weak interaction.
Terms Offered: Spring
Prerequisite(s): PHYS 23500
PHYS 25000. Computational Physics. 100 Units.
This course introduces the use of computers in the physical sciences. After an introduction to programming basics, we cover numerical solutions to fundamental types of problems, techniques for manipulating large data sets, and computer simulations of complex systems. Additional topics may include an introduction to graphical programming, with applications to data acquisition and device control. (L)
Terms Offered: Autumn
Prerequisite(s): PHYS 13300 or 14300 required; knowledge of computer programming not required

PHYS 26000. Fluid Dynamics. 100 Units.
This course is an introduction to the dynamics of liquids and gases. Starting with the basic equations of motion, we consider the behavior of an ideal fluid, vorticity, viscous dissipation, shock formation, chaos and turbulence, and other phenomena associated with both slow and fast fluid flow.
Terms Offered: Spring
Prerequisite(s): PHYS 18500; PHYS 22100 or MATH 20400

PHYS 26400. Spacetime and Black Holes. 100 Units.
This course is an introduction to general relativity, focusing on metrics and geodesics, and treating gravity as the curvature of four-dimensional spacetime. It will begin by fully exploring special relativity, and will then introduce the basic tools of physics in curved spacetime. It will also study black holes, including aspects of the event horizon and singularity, and the properties of orbits in black hole spacetimes.
Terms Offered: Autumn
Prerequisite(s): PHYS 18500 or consent of instructor

PHYS 26500. Topics in General Relativity and Cosmology. 100 Units.
This course follows from PHYS 26400 (Spacetime and Black Holes). It will introduce curvature and the Einstein equations, and will use these to explore rotating black holes and gravitational waves. The rest of the course will provide an introduction to cosmology, ranging from the big bang and inflation to the cosmic microwave background and the growth of large-scale structure.
Instructor(s): Staff Terms Offered: Winter
Prerequisite(s): PHYS 26400

PHYS 29100-29200-29300. Bachelor’s Thesis.
This yearlong sequence of courses is designed to involve the student in current research. Over the course of the year, the student works on a research project in physics or a closely related field (e.g., astrophysics) leading to the writing of a bachelor’s thesis. A student who submits a satisfactory thesis, earns a grade of B or higher based on the project, and achieves a GPA of 3.0 or higher in the required undergraduate physics courses is eligible to receive a BA with honors. The project may be one suggested by the instructor or one proposed by the student and approved by the instructor. In either case, all phases of the project (including the literature search, design and construction of the experiments, and analysis) must be done by the student. The instructor, the faculty adviser, post-docs, and graduate students are, of course, available for consultation.
PHYS 29100. Bachelor’s Thesis. 100 Units.
This yearlong sequence of courses is designed to involve the student in current research. Over the course of the year, the student works on a research project in physics or a closely related field (e.g., astrophysics) leading to the writing of a bachelor’s thesis. A student who submits a satisfactory thesis, earns a grade of B or higher based on the project, and achieves a GPA of 3.0 or higher in the required undergraduate physics courses is eligible to receive a BA with honors. The project may be one suggested by the instructor or one proposed by the student and approved by the instructor. In either case, all phases of the project (including the literature search, design and construction of the experiments, and analysis) must be done by the student. The instructor, the faculty adviser, post-docs, and graduate students are, of course, available for consultation.
Terms Offered: Autumn
Prerequisite(s): Open to students who are majoring in Physics with fourth-year standing and consent of instructor.
Note(s): Students are required to submit the College Reading and Research Course Form in Autumn Quarter. Students receive a grade in each quarter of registration: P/F grading in Autumn and Winter Quarters, and a quality grade in Spring Quarter.

PHYS 29200. Bachelor’s Thesis. 100 Units.
No description available.
Terms Offered: Winter
Prerequisite(s): PHYS 29100
Note(s): Students are required to submit the College Reading and Research Course Form in Autumn Quarter. Students receive a grade in each quarter of registration: P/F grading in Autumn and Winter Quarters, and a quality grade in Spring Quarter.

PHYS 29300. Bachelor’s Thesis. 100 Units.
No description available.
Terms Offered: Spring
Prerequisite(s): PHYS 29200
Note(s): Students are required to submit the College Reading and Research Course Form in Autumn Quarter. Students receive a grade in each quarter of registration: P/F grading in Autumn and Winter Quarters, and a quality grade in Spring Quarter.

PHYS 29200. Bachelor’s Thesis. 100 Units.
No description available.
Terms Offered: Winter
Prerequisite(s): PHYS 29100
Note(s): Students are required to submit the College Reading and Research Course Form in Autumn Quarter. Students receive a grade in each quarter of registration: P/F grading in Autumn and Winter Quarters, and a quality grade in Spring Quarter.
PHYS 29300. Bachelor's Thesis. 100 Units.
No description available.
Terms Offered: Spring
Prerequisite(s): PHYS 29200
Note(s): Students are required to submit the College Reading and Research Course
Form in Autumn Quarter. Students receive a grade in each quarter of registration: P/F
grading in Autumn and Winter Quarters, and a quality grade in Spring Quarter.

PHYS 29700. Participation in Research. 100 Units.
By mutual agreement, students work in a faculty member’s research group.
Participation in research may take the form of independent work (with some
guidance) on a small project, or of assistance in research to an advanced graduate
student or research associate. A written report must be submitted at the end of the
quarter. Students may register for PHYS 29700 for as many quarters as they wish;
students need not remain with the same faculty member each quarter. (L)
Terms Offered: Autumn, Winter, Spring, Summer
Prerequisite(s): Consent of instructor and departmental counselor. Open to students
who are majoring in Physics with third- or fourth-year standing.
Note(s): Students are required to submit the College Reading and Research Course
Form. May be taken for P/F grading with consent of instructor.