PHYSICS (BS AND BA OPTIONS AVAILABLE)

Chair: Michael Wood (wood5@canisius.edu), PhD. (Research Website (https://sites.google.com/site/cmenpgroup/))

Introduction

The Canisius College Physics major provides a strong background in the scientific skills of analysis and experimentation and gives students a broad choice of career opportunities. The Physics major is a preparation for further study in graduate physics and related areas such as oceanography, geophysics, patent law, medicine, engineering and astronomy and entry into research and development employment. The specific goal for majors is a thorough knowledge of basic physical science and the mathematical and experimental application of this basis to the study of natural phenomena. Other offerings are intended to give non-majors an appreciation of the relation between science and the world within which they live.

Our department offers a number of degree tracks to match with the students’ interests and career goals.

- Bachelor’s of Science (BS) in Physics (p. 2) - curriculum is designed to prepare the student for graduate school in physics, engineering, or a related scientific field.
- Bachelor’s of Arts (BA) in Physics (p. 3) - curriculum is designed to cover the major topics in the Physics BS program with fewer requirements. This degree is optimal for students interested in a different career path such as teaching in secondary education, law, medicine, journalism, etc. The Physics BA is not meant as preparation for graduate school in physics or engineering. Curriculum easily allows for double majoring.
- Dual Degree Engineering Program (3+2 Physics/Engineering) (http://catalog.canisius.edu/undergraduate/college-arts-sciences/physics/pre-engineering-programs/3-2-program/) - the student spends 3 years studying Physics at Canisius College and the next 2 years in the Engineering Program at the University at Buffalo or Pennsylvania State University at Erie. At the end of the 5 years, the student will receive a Physics degree from Canisius College and a Engineering degree from the other school.
- Pre-engineering Program (2+2) (http://catalog.canisius.edu/undergraduate/college-arts-sciences/physics/pre-engineering-programs/2-2-program/) - the students spend their first 2 years at Canisius College taking the introductory physics, mathematics, and engineering courses. After transferring to the engineering school of their choice, they complete their engineering degree after the third and fourth years. This is a transfer program, and they are not awarded a degree from Canisius College.
- Dual Degree of Physics (Bachelor’s) and Education (Master’s) (p. 6) - Canisius College is now offering dual Bachelor of Arts degree in Physics and Master’s Degree in Education who wish to add teacher certification. The Physics BA (p. 3) requirements are unchanged, but students are counseled to add certain education courses as electives during the undergraduate years so they are prepared to pursue both Adolescence Education 7-12 certification in their content area and Adolescence 7-12 Teaching Students with Disabilities Generalist.

For a more detailed description of the program, faculty, facilities, academic and co-curricular opportunities please go to the Physics website (https://www.canisius.edu/academics/programs/physics/).

Qualifications

Students must maintain a 2.0 GPA in their major and a 2.0 overall average to graduate with a degree in Physics. For admission to the advanced program (Junior/Senior level), a student must have completed, with a grade of at least C, General Physics (PHY 223, PHY 224, PHY 225) and Mathematics through Differential Equations (MAT 222). To qualify for graduation with a degree in Physics, a grade of C- or higher is required in PHY 225, PHY 226, and all 300- and 400-level Physics courses. Students are expected to be prepared to take Calculus 1 (MAT 111) their first semester at Canisius.

Advisement

All students should have an advisor in the major and should contact the department directly to have an advisor assigned if they do not already have one. Meetings with academic advisors are required prior to students receiving their PIN for course registration each semester. All majors should work closely with their advisor in discussing career expectations, choosing their major electives, developing their entire academic program and planning their co-curricular or supplemental academic experiences.

Advising is particularly important for Physics majors due to the highly structured curriculum and numerous course prerequisites.

Major Experiences

Physics majors use modern physics equipment like a 3D printer, lasers, X-ray florescence, a multi-channel nuclear spectrometer, various radiation detectors, and an X-ray spectrometer. They have access to departmental computers. In addition, a large supply of other equipment is available for students to use as early as their first semester. In addition to the standard physics major, students may also wish to consider the Dual Degree Engineering Program, which offers students the option of completing a Physics Degree at Canisius and an Engineering degree at University at Buffalo (UB) or Pennsylvania State University at Erie. For those interested in Physics teaching, a Physics Education program is offered in conjunction with the education department. The Physics Club offers opportunities for social activities, technical tours, lectures and other activities.

The faculty in the department are active in research in the fields of experimental nuclear physics, robotics, physics education, and computational science. Students frequently join with a professor on his or her respective projects and perform a variety of research tasks. Students gain skills in large-scale computation, data analysis, electronics, and detector assembly and testing. In many cases, the research is interdisciplinary with the student working with a physics professor and a faculty member in the Mathematics (http://catalog.canisius.edu/undergraduate/college-arts-sciences/mathematics-statistics/), Computer Science (http://catalog.canisius.edu/undergraduate/college-arts-sciences/computer-science/), and Digital Media Arts (http://catalog.canisius.edu/undergraduate/college-arts-sciences/digital-media-arts/) Departments. Routinely, students present posters at local, statewide, and national conferences. Past students have conducted research through the National Science Foundation’s Research Experience for Undergraduates at institutions such as University of Rochester, University of Notre Dame, and Baylor University.

Double Majors

Students who wish to expand their educational opportunities may decide to declare a double major. This decision may be based on career goals, planned graduate studies, and/or other student interests. Before a student declares a double major, it is important to meet with the appropriate academic departments for advisement. In order to declare a double major, the student must complete the appropriate double major request form and get
the signature of each department chairperson and the appropriate associate dean.

Per college policy, each additional major requires a minimum of 15 credits that do not apply to the student’s first or subsequent major. Some double major combinations can be completed within the minimum 120 credit hour degree requirement, but in other cases additional course work may be required. Please note that students will receive only one degree, regardless of the number of majors they complete.

Double majors in Physics BS (p. 2) and Computer Science (http://catalog.canisius.edu/undergraduate/college-arts-sciences/computer-science/), or Physics BS (p. 2) and Mathematics (http://catalog.canisius.edu/undergraduate/college-arts-sciences/mathematics-statistics/) are common and offer interesting career options. The Physics BA (p. 3) can be combined with almost any other program at the college.

Minors in Other Disciplines
Minors provide students the opportunity to pursue additional interests but generally do not require as many courses as a major. Minors generally range from five to eight required courses. The minors page (http://catalog.canisius.edu/undergraduate/minors/) provides a complete list of minors and provides links to each minor. Some majors and minors can be completed within the minimum 120 credit hour degree requirement, but in some cases additional coursework may be required. Students must complete the appropriate minor request form.

The Physics minor is particularly popular when combined with majors in Chemistry (http://catalog.canisius.edu/undergraduate/college-arts-sciences/chemistry/), Mathematics (http://catalog.canisius.edu/undergraduate/college-arts-sciences/mathematics-statistics/), or Computer Science (http://catalog.canisius.edu/undergraduate/college-arts-sciences/computer-science/).

Curriculum
Curriculum Requirements for a BS in Physics
An Ignatian Foundation
All undergraduate students must complete either the Canisius Core Curriculum (http://catalog.canisius.edu/undergraduate/academics/curricular-information/core-curriculum/) or the All-College Honors Curriculum (http://catalog.canisius.edu/undergraduate/academics/curricular-information/all-college-honors-program/). Many schools refer to their college-wide undergraduate requirements as "general education" requirements. We believe that the core curriculum and the honors curriculum are more than a series of required classes; they provide the basis for a Jesuit education both with content and with required knowledge and skills attributes that are central to our mission.

Free Electives
Students may graduate with a bachelor’s degree with more but not less than 120 credit hours. Free electives are courses in addition to the Canisius Core Curriculum or All-College Honors Curriculum and major requirements sufficient to reach the minimum number of credits required for graduation. The number of credits required to complete a bachelor’s degree may vary depending on the student’s major(s) and minor(s).

Major Requirements

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHY 104</td>
<td>Seminar for Physics and Pre-engineering Majors</td>
<td>0</td>
</tr>
<tr>
<td>CSC 111 &amp; 111L</td>
<td>Introduction to Programming and Introduction to Programming Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>PHY 223 &amp; 223L</td>
<td>General Physics for Physical Science Majors I and General Physics for Physical Science Majors I Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>PHY 224 &amp; 224L</td>
<td>General Physics for Physical Science Majors II and General Physics for Physical Science Majors II Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>PHY 225 &amp; 225L</td>
<td>General Physics for Physical Science Majors III and General Physics for Physical Science Majors III Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>PHY 226 &amp; 226L</td>
<td>Basic Electronics and Basic Electronics Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>PHY 330</td>
<td>Electrodynamics I</td>
<td>3</td>
</tr>
<tr>
<td>PHY 331</td>
<td>Electrodynamics II</td>
<td>3</td>
</tr>
<tr>
<td>PHY 332</td>
<td>Statistical and Thermal Physics</td>
<td>3</td>
</tr>
<tr>
<td>PHY 335</td>
<td>Mathematical Analysis for Physicists</td>
<td>4</td>
</tr>
<tr>
<td>PHY 350 &amp; PHY 351</td>
<td>Modern Physics Laboratory and Advanced Laboratory</td>
<td>2</td>
</tr>
<tr>
<td>PHY 443</td>
<td>Classical Mechanics</td>
<td>3</td>
</tr>
<tr>
<td>PHY 445</td>
<td>Special Topics in Physics</td>
<td>1</td>
</tr>
<tr>
<td>PHY 446</td>
<td>Quantum Mechanics I</td>
<td>4</td>
</tr>
<tr>
<td>PHY 447</td>
<td>Quantum Mechanics II</td>
<td>3</td>
</tr>
<tr>
<td>PHY 498</td>
<td>Senior Project</td>
<td>1-3</td>
</tr>
<tr>
<td>CHM 111 &amp; 111L</td>
<td>General Chemistry I and General Chemistry I Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>MAT 111</td>
<td>Calculus I</td>
<td>8</td>
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<tr>
<td>&amp; MAT 112</td>
<td>and Calculus II</td>
<td></td>
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<tr>
<td>MAT 211</td>
<td>Calculus III</td>
<td>4</td>
</tr>
<tr>
<td>MAT 222</td>
<td>Differential Equations</td>
<td>3</td>
</tr>
<tr>
<td>Science elective (Science Elective to be chosen from BIO 111, CHM 112, CSC 112, MAT 219 or MAT 351)</td>
<td>3-4</td>
<td></td>
</tr>
</tbody>
</table>

Total Credits: 69-72

Major Electives

Computer Science (http://catalog.canisius.edu/undergraduate/college-arts-sciences/computer-science/) and Mathematics (http://catalog.canisius.edu/undergraduate/college-arts-sciences/mathematics-statistics/) courses are highly recommended, particularly linear algebra.

Difference with the Physics BA Degree
The Physics BS degree program is designed to prepare the students for graduate school in Physics, Engineering, or a related scientific field. Therefore, it has more major course requirements than the Physics BA degree. The first 2 years of both programs are identical. The Physics BS degree requires more major courses in the third and fourth years in order to provide more depth or knowledge and experience. The student is advised to consult the BS and BA Roadmaps for the specific differences.

Additional Course Considerations

Courses in the Junior and Senior years rotate on a two year basis. Please consult your advisor about which set of courses is available in any given year.
Note: Course availability may be a factor in determining time to degree completion for transfer students. Discussion with department faculty is highly recommended for transfer students.

Roadmap

**Recommended Semester Schedule for Major Course Requirements for a BS in Physics**

**Freshman**

<table>
<thead>
<tr>
<th>Fall</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAT 111</td>
<td>MAT 112</td>
</tr>
<tr>
<td>PHY 104</td>
<td>PHY 104</td>
</tr>
<tr>
<td>PHY 223 &amp; 223L</td>
<td>PHY 224 &amp; 224L</td>
</tr>
<tr>
<td>CSC 111 &amp; 111L</td>
<td></td>
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</tbody>
</table>

**Sophomore**

<table>
<thead>
<tr>
<th>Fall</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAT 211</td>
<td>MAT 222</td>
</tr>
<tr>
<td>PHY 104</td>
<td>PHY 104</td>
</tr>
<tr>
<td>PHY 225 &amp; 225L</td>
<td>PHY 226 &amp; 226L</td>
</tr>
<tr>
<td>CHM 111 &amp; 111L</td>
<td></td>
</tr>
<tr>
<td>Science Elective&lt;sup&gt;1&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

**Junior**

<table>
<thead>
<tr>
<th>Fall</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHY 104</td>
<td>PHY 104</td>
</tr>
<tr>
<td>PHY 330</td>
<td>PHY 331</td>
</tr>
<tr>
<td>PHY 335</td>
<td>PHY 351</td>
</tr>
<tr>
<td>PHY 350</td>
<td></td>
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</tbody>
</table>

**Senior**

<table>
<thead>
<tr>
<th>Fall</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHY 104</td>
<td>PHY 104</td>
</tr>
<tr>
<td>PHY 446</td>
<td>PHY 332</td>
</tr>
<tr>
<td>PHY 443</td>
<td>PHY 445</td>
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<td>ruption</td>
<td></td>
</tr>
</tbody>
</table>

<sup>1</sup> Science Elective to be chosen from BIO 111, CHM 112, CSC 112, MAT 219 or MAT 351. The science elective may be taken in a subsequent semester if it requires a prerequisite. In this case, take a course in the Core Curriculum in the spring semester of the freshman year.

Curriculum

**Curriculum Requirements for a BA in Physics**

**An Ignatian Foundation**

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<td>PHY 104</td>
<td>Seminar for Physics and Pre-engineering Majors</td>
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<tr>
<td>CSC 111</td>
<td>Introduction to Programming and Introduction to Programming Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>PHY 223</td>
<td>General Physics for Physical Science Majors I &amp; 223L</td>
<td>4</td>
</tr>
<tr>
<td>PHY 222</td>
<td>General Physics for Physical Science Majors I &amp; 222L</td>
<td>4</td>
</tr>
<tr>
<td>PHY 224</td>
<td>General Physics for Physical Science Majors II &amp; 224L</td>
<td>4</td>
</tr>
<tr>
<td>PHY 225</td>
<td>General Physics for Physical Science Majors III &amp; 225L</td>
<td>4</td>
</tr>
<tr>
<td>PHY 226</td>
<td>Basic Electronics &amp; 226L and Basic Electronics Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>PHY 350</td>
<td>Modern Physics Laboratory or PHY 351 Advanced Laboratory</td>
<td>1</td>
</tr>
<tr>
<td>PHY 445</td>
<td>Special Topics in Physics</td>
<td>1</td>
</tr>
<tr>
<td>PHY 498</td>
<td>Senior Project</td>
<td>1-3</td>
</tr>
<tr>
<td>Choose 4 of the following upper division courses</td>
<td>12-14</td>
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</tr>
<tr>
<td>PHY 330</td>
<td>Electrodynamics I</td>
<td></td>
</tr>
<tr>
<td>PHY 331</td>
<td>Electrodynamics II</td>
<td></td>
</tr>
<tr>
<td>PHY 332</td>
<td>Statistical and Thermal Physics</td>
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<tr>
<td>PHY 335</td>
<td>Mathematical Analysis for Physicists</td>
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<td>PHY 443</td>
<td>Classical Mechanics</td>
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<tr>
<td>PHY 446</td>
<td>Quantum Mechanics I</td>
<td></td>
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<tr>
<td>PHY 447</td>
<td>Quantum Mechanics II</td>
<td></td>
</tr>
<tr>
<td>CHM 111</td>
<td>General Chemistry I &amp; 111L and General Chemistry I Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>MAT 111</td>
<td>Calculus I</td>
<td>4</td>
</tr>
<tr>
<td>MAT 112</td>
<td>Calculus II</td>
<td>4</td>
</tr>
<tr>
<td>MAT 211</td>
<td>Calculus III</td>
<td>4</td>
</tr>
<tr>
<td>MAT 222</td>
<td>Differential Equations</td>
<td>3</td>
</tr>
<tr>
<td>Science Elective (choose one of the following):</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>BIO 111</td>
<td>Introductory Biology I &amp; 111L Introductory Biology Laboratory</td>
<td></td>
</tr>
<tr>
<td>CHM 112</td>
<td>General Chemistry II &amp; 112L and General Chemistry II Laboratory</td>
<td></td>
</tr>
<tr>
<td>CSC 112</td>
<td>Data Structures &amp; 112L and Data Structures Laboratory</td>
<td></td>
</tr>
<tr>
<td>MAT 219</td>
<td>Linear Algebra</td>
<td></td>
</tr>
<tr>
<td>MAT 351</td>
<td>Probability &amp; Statistics I</td>
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</tr>
</tbody>
</table>

**Total Credits** 58-62
Major Electives
Computer Science (http://catalog.canisius.edu/undergraduate/college-arts-sciences/computer-science/) and Mathematics (http://catalog.canisius.edu/undergraduate/college-arts-sciences/mathematics-statistics/) courses are highly recommended, particularly linear algebra.

Difference with the Physics BS Degree
The Physics BA degree program is designed to provide the basic topics in the field of physics and the tools to apply mathematical and scientific skills to different disciplines. This program is not a preparation for graduate school in physics or engineering. The program does provide the students with the freedom to explore other programs like education, journalism, pre-law, pre-medicine, and finance, to name a few. The Physics BA is easier to double major than the Physics BS. Therefore, it has fewer major course requirements than the Physics BS degree. The first 2 years of both programs are identical. The Physics BA degree requires fewer major courses in the third and fourth years to allow the students to take a variety of electives and try different fields. The student is advised to consult the BS and BA Roadmaps for the specific differences.

Additional Course Considerations
Courses in the Junior and Senior years rotate on a two year basis. Please consult your advisor about which set of courses is available in any given year.

Note: Course availability may be a factor in determining time to degree completion for transfer students. Discussion with department faculty is highly recommended for transfer students.

Roadmap
Recommended Semester Schedule for Major Course Requirements for a BA in Physics

<table>
<thead>
<tr>
<th>Freshman</th>
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<tbody>
<tr>
<td>Fall</td>
<td>Spring</td>
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<tr>
<td>MAT 111</td>
<td>PHY 104</td>
<td>PHY 104</td>
</tr>
<tr>
<td>PHY 223 &amp; 223L</td>
<td>PHY 224 &amp; 224L</td>
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<tr>
<td>CSC 111 &amp; 111L</td>
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<table>
<thead>
<tr>
<th>Sophomore</th>
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</thead>
<tbody>
<tr>
<td>Fall</td>
<td>Spring</td>
<td></td>
</tr>
<tr>
<td>MAT 211</td>
<td>PHY 104</td>
<td>PHY 104</td>
</tr>
<tr>
<td>PHY 225 &amp; 225L</td>
<td>PHY 226 &amp; 226L</td>
<td></td>
</tr>
<tr>
<td>CHM 111 &amp; 111L</td>
<td>Science Elective</td>
<td></td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Junior</th>
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<th></th>
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</thead>
<tbody>
<tr>
<td>Fall</td>
<td>Spring</td>
<td></td>
</tr>
<tr>
<td>PHY 104</td>
<td>PHY 104</td>
<td></td>
</tr>
<tr>
<td>PHY 350</td>
<td>PHY 351 (if did not take PHY 350)</td>
<td>PHY elective</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Senior</th>
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</thead>
<tbody>
<tr>
<td>Fall</td>
<td>Spring</td>
<td></td>
</tr>
<tr>
<td>PHY 104</td>
<td>PHY 104</td>
<td></td>
</tr>
<tr>
<td>PHY elective</td>
<td>PHY 445</td>
<td></td>
</tr>
</tbody>
</table>

Minor
The physics minor requires seven courses, which are to be distributed as follows.

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHY 223 &amp; 223L</td>
<td>General Physics for Physical Science Majors I and General Physics for Physical Science Majors I Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>PHY 224 &amp; 224L</td>
<td>General Physics for Physical Science Majors II and General Physics for Physical Science Majors II Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>PHY 225 &amp; 225L</td>
<td>General Physics for Physical Science Majors III and General Physics for Physical Science Majors III Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>MAT 211</td>
<td>Calculus III</td>
<td>4</td>
</tr>
<tr>
<td>MAT 222</td>
<td>Differential Equations</td>
<td>4</td>
</tr>
<tr>
<td>PHY 335</td>
<td>Mathematical Analysis for Physicists</td>
<td>4</td>
</tr>
<tr>
<td>PHY 447</td>
<td>Quantum Mechanics II</td>
<td>4</td>
</tr>
<tr>
<td>CHM 301 &amp; 301L</td>
<td>Fundamental Physical Chemistry and Fundamental Physical Chemistry Laboratory</td>
<td>4</td>
</tr>
</tbody>
</table>

Total Credits: 24-28

1. PHY 331 requires PHY 330 as a prerequisite.
2. PHY 446 is required for PHY 447.
3. PHY 335 is highly recommended as a co-requisite for PHY 330.
4. PHY 443 requires MAT 222 as a prerequisite.
5. If CHM 301 is used for Group II, PHY 332 cannot be used for Group I.

Note: MAT 111 and MAT 112 are prerequisites for one or more of the courses listed above. The Physics minor is particularly popular when combined with majors in Chemistry, Mathematics, or Computer Science.
Courses

PHY 104 Seminar for Physics and Pre-engineering Majors 0 Credits
A key aspect of science is the communication of ideas. The seminar is one method of sharing scientific ideas and results. This course gathers Physics and Pre-engineering majors to learn about advances in their respective fields, about related careers, and about the research performed by the department faculty.
Prerequisite: None. Corequisite: None.
Offered: every fall & spring.

PHY 129 Introduction to Astronomy 3 Credits
Understanding modern astronomy by using ideas from basic physics. Mathematics minimized. Naming and viewing stars and constellations is included.
Fulfills College Core: Field 6 (Natural Sciences)
Offered: once a year.

PHY 130 Introductory Geology 3 Credits
For science and non-science majors alike, this course covers the fundamental concepts of physical geology, including the rock cycle; erosion; tectonic processes including earthquakes and volcanism; the importance of water from oceans to rivers to glaciers; and society's dependence on energy and mineral resources from the Earth. Our planet is an interacting system of matter and energy, giving us mountains, lowlands, oceans, rivers, earthquakes, volcanoes, and the resources we need for human prosperity.
Offered: occasionally.

PHY 131 Earthquakes: Seismology and Society 3 Credits
The science behind earthquakes: causes, locations, frequency and measurement; affects on geography, human structures and society.
Fulfills College Core: Field 6 (Natural Sciences), Global Awareness
Offered: once a year.

PHY 201 College Physics I 3 Credits
College Physics for biological-science students. Mechanics of rigid bodies, mechanics of fluids, thermal energy and thermodynamics.
Prerequisite: MAT 110 or MAT 111. Corequisite: PHY 201L.
Fulfills College Core: Field 6 (Natural Sciences)
Offered: every fall.

PHY 201L College Physics I Laboratory 1 Credit
Laboratory for College Physics I for biological-science students.
Prerequisite: MAT 110 or MAT 111. Corequisite: PHY 201.
Offered: every fall.

PHY 202 College Physics II 3 Credits
College Physics for biological-science students. Electricity and magnetism, geometrical and physical optics.
Prerequisite: minimum grade of C- in PHY 201 and 201L. Corequisite: PHY 202L.
Offered: spring.

PHY 202L College Physics II Laboratory 1 Credit
Laboratory for College Physics II for biological-science students.
Prerequisite: min grade of C- in PHY 201 and 201L Corequisite: PHY 202.
Offered: spring.

PHY 223 General Physics for Physical Science Majors I 3 Credits
Prerequisite: MAT 110 or MAT 111. Corequisite: PHY 223L.
Fulfills College Core: Field 6 (Natural Sciences)
Offered: every fall.

PHY 223L General Physics for Physical Science Majors I Laboratory 1 Credit
Laboratory for calculus-based general physics I.
Prerequisite: MAT 110 or MAT 111 Corequisite: PHY 223.
Offered: every fall.

PHY 224 General Physics for Physical Science Majors II 3 Credits
Calculus-based general physics. Electricity and magnetism, geometrical and physical optics.
Prerequisite: minimum grade of C- in PHY 223 and PHY 223L. Corequisite: PHY 224L.
Offered: every spring.

PHY 224L General Physics for Physical Science Majors I Laboratory 1 Credit
Laboratory for calculus-based general physics II.
Prerequisite: min grade of C- in PHY 223 and PHY 223L Corequisite: PHY 224.
Offered: every spring.

PHY 225 General Physics for Physical Science Majors III 3 Credits
Prerequisite: MAT 211 & minimum grade of C- in PHY 224. Corequisite: PHY 225L.
Offered: every fall.

PHY 225L General Physics for Physical Science Majors III Laboratory 1 Credit
Laboratory for calculus-based general physics III.
Corequisite: PHY 225.
Offered: every fall.

PHY 226 Basic Electronics 3 Credits
Circuit analysis, power supplies, semiconductor physics, operational amplifiers, digital electronics. Integrated circuit techniques. Includes laboratory work each week.
Prerequisite: minimum grade of C- in PHY 224. Corequisite: PHY 226L.
Offered: spring.

PHY 226L Basic Electronics Laboratory 1 Credit
Laboratory for basic electronics course.
Corequisite: PHY 226.
Offered: every spring.

PHY 330 Electrodynamics I 3 Credits
Static and time-varying classical electric and magnetic fields in free-space and matter. Prior completion of or concurrent registration for PHY 335 is strongly encouraged.
Prerequisite: PHY 224. Offered: fall of odd-numbered years.

PHY 331 Electrodynamics II 3 Credits
Primary topic: electromagnetic waves in free-space and matter, beginning with the Maxwell equations. Additional topics: radiation and special relativity.
Prerequisite: PHY 330. Offered: spring of even-numbered years.

PHY 332 Statistical and Thermal Physics 3 Credits
Develops statistical concepts and methods used to relate macroscopic to microscopic descriptions of many particle systems.
Prerequisite: PHY 225. Offered: spring of odd-numbered years.
PHY 335 Mathematical Analysis for Physicists  4 Credits
Theory and applications of infinite series, Fourier series, Green's functions, Fourier integrals, vector calculus, linear algebra, partial differential equations, and complex variable.
Prerequisite: MAT 222 or permission of instructor.
Offered: fall of odd-numbered years.

PHY 350 Modern Physics Laboratory  1 Credit
This course covers the basic principles of 20th century modern physics. The topics include blackbody radiation, particle/wave duality, x-ray diffraction, Bohr's model of the atom, quantum tunneling, and the Schrodinger equation.
Prerequisite: PHY 225.
Fulfills College Core: Advanced Writing-Intensive
Offered: every fall.

PHY 351 Advanced Laboratory  1 Credit
This course emphasizes advanced experiments and experimental technique. Topics include, but are not restricted to, dosimetry, radiation detection, gamma-ray spectroscopy, Rutherford scattering, atomic spectroscopy, thin-film deposition, and magnetic resonance.
Prerequisite: PHY 225.
Fulfills College Core: Oral Communication
Offered: every spring.

PHY 443 Classical Mechanics  3 Credits
One, two, and three dimensional motion of a particle, non-inertial systems, classical scattering, rigid-body motion. Lagrange and Hamilton equations, calculus of variations, oscillations.
Prerequisite: PHY 224 & MAT 222.
Offered: fall of even-numbered years.

PHY 445 Special Topics in Physics  1 Credit
This course will cover model formation and development using archival journal articles in physics. The subject material will rotate by semester among topics such as astrophysics, quantum theory, and thermodynamics. Students will be expected to read and critique journal articles, lead discussions on journal articles, and trace the development of an area of physics through assigned readings.
Prerequisite: permission of instructor. Restriction: must be physics major or minor with senior standing.
Offered: spring of odd-numbered years.

PHY 446 Quantum Mechanics I  4 Credits
Corequisite: PHY 225 & MAT 222.
Offered: fall of even-numbered years.

PHY 447 Quantum Mechanics II  3 Credits
Application of Schrodinger's equation, Hamiltonian mechanics, angular momentum, intrinsic spin, parity, and time-dependent quantum mechanics. PHY 446 is highly recommended.
Offered: spring of odd-numbered years.

PHY 449 Nuclear Physics Lab  1 Credit
Introduction to experimental nuclear physics. Experiments study nuclear instrumentation, characteristics of radiation and nuclear spectra.
Prerequisite: PHY 446.
Fulfills College Core: Advanced Writing-Intensive
Offered: occasionally.

PHY 498 Senior Project  1-3 Credits
A one-semester research project done under the supervision of a faculty member.
Prerequisite: permission of department chair. Restriction: senior standing in physics.
Offered: spring.

PHY 499 Independent Study  1-3 Credits
An independent study with a faculty member of the Physics Department. Independent studies require an application and approval by the associate dean.
Prerequisite: permission of the instructor, department chair, & associate dean. Restriction: permission of the chair.
Offered: fall & spring.

Introduction
The Dual Degree Program (http://catalog.canisius.edu/graduate/school-education-human-services/educator-preparation/dual-degree-content-and-msed-swd/#curriculumtext) offers a BA in Physics as well as a MSEd in Adolescence 7-12 Teaching Students with Disabilities Generalist. This dual degree program leads to Initial Adolescence Certification in Physics as well as Initial Certification in Adolescence 7-12 SWD Generalist. Since it leads to two teaching certificates, candidates must meet the content requirements for both over the course of their curriculum. In most cases, the content area major covers those requirements. In some instances New York State has additional requirements. Please note, this dual degree program can be completed in as little as 5 years if one summer is included.

Curriculum
An Ignatian Foundation
All undergraduate students must complete either the Canisius Core Curriculum (http://catalog.canisius.edu/undergraduate/academics/core-curriculum/) or the All-College Honors Curriculum (http://catalog.canisius.edu/undergraduate/academics/core-curriculum/all-college-honors-program/). Many schools refer to their college-wide undergraduate requirements as “general education” requirements. We believe that the core curriculum and the honors curriculum are more than a series of required classes; they provide the basis for a Jesuit education both with content and with required knowledge and skills attributes that are central to our mission.

Free Electives
Students may graduate with a bachelor’s degree with more but not less than 120 credit hours. Free electives are courses in addition to the Canisius Core Curriculum or All-College Honors Curriculum and major requirements sufficient to reach the minimum number of credits required for graduation. The number of credits required to complete a bachelor’s degree may vary depending on the student’s major(s) and minor(s).

Major Requirements
Curriculum Requirements for a BA in Physics

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHY 104</td>
<td>Seminar for Physics and Pre-engineering Majors</td>
<td>0</td>
</tr>
<tr>
<td>CSC 111 &amp; 111L</td>
<td>Introduction to Programming and Introduction to Programming Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>PHY 223 &amp; 223L</td>
<td>General Physics for Physical Science Majors I and General Physics for Physical Science Majors I Laboratory</td>
<td>4</td>
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</tbody>
</table>
Physics (BS and BA Options Available)

PHY 224 & 224L General Physics for Physical Science Majors II and General Physics for Physical Science Majors I Laboratory 4
PHY 225 & 225L General Physics for Physical Science Majors III and General Physics for Physical Science Majors III Laboratory 4
PHY 226 & 226L Basic Electronics and Basic Electronics Laboratory 4
PHY 350 or PHY 351 Modern Physics Laboratory 1
PHY 445 Special Topics in Physics 1
PHY 498 Senior Project 1-3
Choose 4 of the following upper division courses 12-14
PHY 330 Electrodynamics I
PHY 331 Electrodynamics II
PHY 332 Statistical and Thermal Physics
PHY 335 Mathematical Analysis for Physicists
PHY 443 Classical Mechanics
PHY 446 Quantum Mechanics I
PHY 447 Quantum Mechanics II
CHM 111 General Chemistry I & 111L General Chemistry I Laboratory 4
MAT 111 Calculus I
MAT 112 Calculus II
MAT 211 Calculus III
MAT 222 Differential Equations 3
Science Elective (choose one of the following): 4
BIO 111 Introductory Biology I & 111L Introductory Biology Laboratory I
CHM 112 General Chemistry II & 112L General Chemistry II Laboratory
CSC 112 Data Structures & 112L Data Structures Laboratory
MAT 219 Linear Algebra
MAT 351 Probability & Statistics I
Total Credits 58-62

Curriculum Requirements for a Master’s Degree in Education
The education curriculum is provided below for the MSeD portion of the dual degree programs. Notice that several foundation courses are taken at the undergraduate level intermingled with other undergraduate requirements. The graduate courses begin at the 500 level and continue until completion.

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>EDS 101</td>
<td>Human Growth and Social Development: Adolescence</td>
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<tr>
<td>EDS 223</td>
<td>Foundations of Adolescent Literacy</td>
<td>3</td>
</tr>
<tr>
<td>SPE 341</td>
<td>Inclusive Strategies</td>
<td>3</td>
</tr>
<tr>
<td>EDS 360</td>
<td>Evaluation and Teaching Strategies</td>
<td>3</td>
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<tr>
<td>EDS 360L</td>
<td>Teaching Strategies Lab</td>
<td>0</td>
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<tr>
<td>EDS 250</td>
<td>Foundations of Education</td>
<td>3</td>
</tr>
<tr>
<td>EDS 406</td>
<td>Methods of Teaching Social Studies: Adolescence</td>
<td>3</td>
</tr>
<tr>
<td>or EDS 402</td>
<td>Methods of Teaching English: Adolescence</td>
<td>3</td>
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<tr>
<td>or EDS 403</td>
<td>Methods of Teaching Mathematics: Adolescence</td>
<td>3</td>
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<tr>
<td>or EDS 405</td>
<td>Methods of Teaching Science: Adolescence</td>
<td>3</td>
</tr>
<tr>
<td>SPE 640</td>
<td>Learning and Behavioral Disabilities (LBD); Etiology and Research Based Interventions</td>
<td>3</td>
</tr>
<tr>
<td>SPE 652</td>
<td>Functional Curriculum for Students with Severe Disabilities and ASD</td>
<td>3</td>
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<tr>
<td>SPE 649</td>
<td>Transition Issues for Adolescents with Disabilities</td>
<td>3</td>
</tr>
<tr>
<td>SPE 580</td>
<td>Classroom Management</td>
<td>3</td>
</tr>
<tr>
<td>SPE 631</td>
<td>Reading and Writing Process for Students with Learning and Behavioral Disorders</td>
<td>3</td>
</tr>
<tr>
<td>EDU 615</td>
<td>Research Methods</td>
<td>3</td>
</tr>
<tr>
<td>EDU 644</td>
<td>Collaborative Practices on a Transdisciplinary Team</td>
<td>3</td>
</tr>
<tr>
<td>EDU 556</td>
<td>Assessment for Diverse Learners</td>
<td>3</td>
</tr>
<tr>
<td>SPE 698</td>
<td>Seminar in Teaching and Assessment</td>
<td>3</td>
</tr>
<tr>
<td>SPE 693</td>
<td>Student Teaching</td>
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<tr>
<td>SPE 697</td>
<td>Student Teaching Seminar</td>
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<tr>
<td>EDU 595</td>
<td>Child Abuse Workshop</td>
<td>0</td>
</tr>
<tr>
<td>EDU 596</td>
<td>Prevention of School Violence Workshop</td>
<td>0</td>
</tr>
<tr>
<td>EDU 597</td>
<td>Dignity for All Students Workshop</td>
<td>0</td>
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<tr>
<td>Total Credits</td>
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Roadmap
Recommended Semester Schedule for Major Course Requirements for a Dual Degree of BA in Physics and MS SWD Adolescence Generalist
Freshman
Fall
MAT 111
PHY 104
PHY 104
PHY 223 & 223L
CHM 111 & 111L
SPE 341
EDU 250
Junior
Fall
PHY 104
PHY 225 & 225L
CHM 111 & 111L
EDU 250
Senior
Fall
PHY 104
PHY 350
PHY 351 (if did not take PHY 350)
PHY elective
EDS 223
EDS 360
or EDS 402
or EDS 403
or EDS 405
SPE 640
SPE 652
SPE 650
SPE 649
SPE 580
SPE 631
EDU 615
EDU 644
EDU 556
SPE 698
SPE 693
SPE 697
EDU 595
EDU 596
EDU 597

Sophomore
Fall
MAT 211
PHY 104
PHY 225 & 225L
CHM 111 & 111L
Science Elective
EDU 250
Spring
MAT 222
PHY 226 & 226L
SPE 341
EDU 250

Senior
Fall
PHY 104
PHY 104
PHY 350
PHY 351 (if did not take PHY 350)
PHY elective
EDS 223
EDS 360
or EDS 402
or EDS 403
or EDS 405
SPE 640
SPE 652
SPE 650
SPE 649
SPE 580
SPE 631
EDU 615
EDU 644
EDU 556
SPE 698
SPE 693
SPE 697
EDU 595
EDU 596
EDU 597

Total Credits 57
Physics (BS and BA Options Available)

SPE 580
SPE 631
SPE 640

PHY 498
PHY elective 
EDS 405

1 Graduate Education Course

Fifth Year
Fall
EDU 556
SPE 650
SPE 652
SPE 698

Spring
SPE 595
EDU 596
EDU 597
EDU 615

Summer
SPE 644
SPE 649
EDU 556
Student Teaching

1 Science Elective to be chosen from BIO 111, CHM 112, CSC 112, MAT 219 or MAT 351. The science elective may be taken in a subsequent semester if it requires a prerequisite. In this case, take a course in the Core Curriculum in the spring semester of the freshman year.

2 Choice of upper division courses: PHY 330, PHY 331, PHY 332, PHY 335, PHY 443, PHY 446, and PHY 447

Learning Goals & Objectives

Student Learning Goal 1
Physics majors will know how to learn physics.
Students will:
  • Objective A: Critically assess written expositions of physics, contrasting those ideas which are fundamental from those which are consequential;
  • Objective B: Identify the circumstances under which a principle applies.

Student Learning Goal 2
Physics majors are critical thinkers that can produce analytical solutions to physical problems.
Students will:
  • Objective A: Identify a problem and generate equivalent statements of a problem;
  • Objective B: Delineate the principles of physics and analytical techniques used to obtain a solution to a problem;
  • Objective C: Apply the principles and techniques of physics to obtain a solution to a problem.

Student Learning Goal 3
Physics majors possess the technical skills needed to function effectively in a physics laboratory.
Students will:
  • Objective A: Collect a broad range of data with an ability to adapt to new experimental methods, apparatus and tools;
  • Objective B: Apply fundamental statistical methods to analyze data;
  • Objective C: Display data with clarity.

Student Learning Goal 4
Physics majors communicate ideas in physics with precision and clarity.
Students will:
  • Objective A: Produce precise and clear expository written material about physics;
  • Objective B: Produce well-organized and clear oral presentations of physics material.