**PHYSICS**

Chair: Michael Wood, PhD

**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.

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. Major advisors are normally assigned in the sophomore year, but may be requested in the freshman year to supplement a student’s freshman advisor (their GRIF 101 facilitator). 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 high-resolution spectroscopy equipment, lasers, high vacuum apparatus, 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, Computer Science, and Digital Media Arts Departments. Routinely, students present posters at local, statewide, and national conferences. Past students have conducting 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.

**Dual Majors**

Students who wish to expand their educational opportunities may decide to declare a dual major. The decision may be based on career goals or planned graduate studies. Before a student declares a dual major, it is important to meet with the appropriate academic departments for advisement. Some dual major combinations can be completed within the minimum 120 credit hour degree requirement, but in some cases additional course work may be required. In order to declare a dual major, the student must complete the appropriate dual major request form and get the signature of each department chairperson and the appropriate associate dean.

Dual majors in Physics and Computer Science, or Physics and Mathematics are common and offer interesting career options.

**Minors**

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, Mathematics, or Computer Science.

**General Education Requirements**

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).

**Free Electives**

Free electives are courses in addition to the Core Curriculum or Honors Curriculum and major requirements sufficient to reach the minimum of 120 credit hours required for graduation. Students may graduate with more but not less than 120 credit hours.
Major Requirements

PHY 107 & 107L  Computer Programming for Science and Computer Programming for Science Laboratory 4
PHY 223 & 223L  General Physics for Physical Science Majors I and General Physics for Physical Science Majors I Laboratory 4
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 330  Electrodynamics I 3
PHY 331  Electrodynamics II 3
PHY 332  Statistical and Thermal Physics 3
PHY 335  Mathematical Analysis for Physicists 4
PHY 350 & PHY 351  Modern Physics Laboratory and Advanced Laboratory 2
PHY 443  Classical Mechanics 3
PHY 445  Special Topics in Physics 1
PHY 446  Quantum Mechanics I 4
PHY 447  Quantum Mechanics II 3
PHY 498  Senior Project 1-3
CHM 111 & 111L  General Chemistry I and General Chemistry I Laboratory 4
MAT 111 & MAT 112  Calculus I and Calculus II 8
MAT 211  Calculus III 4
MAT 222  Differential Equations 3
Science elective (Science Elective to be chosen from BIO 111, CHM 112, CSC 112, MAT 219 or MAT 351) 3-4

Total Credits 69-72

Major Electives

Computer Science and Mathematics courses are highly recommended, particularly linear algebra.

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.

Recommended Semester Schedule for Major Course Requirements

Freshman

Fall  Spring
CHM 111  Science Elective 1
MAT 111  MAT 112

Sophomore

Fall  Spring
MAT 211  MAT 222
PHY 224  PHY 225  PHY 226

Junior

Fall  Spring
PHY 330  PHY 331
PHY 350  PHY 351
PHY 335

Senior

Fall  Spring
PHY 446  PHY 447
PHY 332  PHY 498
PHY 443

PHY 445

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.

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;
• Objective D: Demonstrate the correctness of a solution by showing that it yields expected results in limiting and other special cases.

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;
Objective D: Draw sound conclusions from the results of data analysis.

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.

Physics Minor

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

Four Required Courses:

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<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>PHY 223 &amp; 223L</td>
<td>General Physics for Physical Science Majors I and Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>PHY 224 &amp; 224L</td>
<td>General Physics for Physical Science Majors II and Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>PHY 225</td>
<td>General Physics for Physical Science Majors III</td>
<td>3</td>
</tr>
<tr>
<td>MAT 211</td>
<td>Calculus III</td>
<td>4</td>
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Select three courses from the following two groups. At least one of these three must be selected from Group I:

Group I:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>PHY 330</td>
<td>Electroynamics I</td>
<td>1</td>
</tr>
<tr>
<td>PHY 331</td>
<td>Electro dynamics II</td>
<td>1</td>
</tr>
<tr>
<td>PHY 332</td>
<td>Statistical and Thermal Physics</td>
<td>5</td>
</tr>
<tr>
<td>PHY 443</td>
<td>Classical Mechanics</td>
<td>4</td>
</tr>
<tr>
<td>PHY 446</td>
<td>Quantum Mechanics I</td>
<td>2</td>
</tr>
</tbody>
</table>

Group II:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>PHY 226</td>
<td>Basic Electronics</td>
<td></td>
</tr>
<tr>
<td>Two of PHY 350, PHY 351, PHY 445 Advanced Lab</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAT 222</td>
<td>Differential Equations</td>
<td></td>
</tr>
<tr>
<td>PHY 335</td>
<td>Mathematical Analysis for Physicists</td>
<td></td>
</tr>
<tr>
<td>PHY 447</td>
<td>Quantum Mechanics II</td>
<td></td>
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<tr>
<td>CHM 301</td>
<td>Classical Physical Chemistry</td>
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</tbody>
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Total Credits: 15

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.

PHY 107L Computer Programming for Science Laboratory 1 Credit
Required laboratory for computer programming with the C/C++ and Matlab-equivalent languages. Examples and applications for science.
Corequisite: PHY 107.
Offered: fall.

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: fall.

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: fall.

PHY 133 Dinosaurs 3 Credits
An introduction to dinosaurs and their world through an examination of their anatomy, evolution, phylogeny, behavior, metabolism and the cause of their extinction. Exploration of geological concepts such as uniformitarianism, stratigraphy, sedimentation, fossilization and taphonomy will help to explain how this knowledge was extracted from the rocks.
Fulfills College Core: Field 6 (Natural Sciences)
Offered: spring.

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: spring.

PHY 201L College Physics I Laboratory 1 Credit
Laboratory for College Physics I for biological-science students.
Corequisite: PHY 201.
Offered: 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. Corequisite: PHY 202L.
Offered: spring.

PHY 202L College Physics II Laboratory 1 Credit
Laboratory for College Physics II for biological-science students.
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: spring.

PHY 223L General Physics for Physical Science Majors I Laboratory 1 Credit
Laboratory for calculus-based general physics I.
Corequisite: PHY 223.
Offered: spring.

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. Corequisite: PHY 224L.
Offered: fall.
PHY 224L General Physics for Physical Science Majors I Laboratory 1 Credit
Laboratory for calculus-based general physics II.
Corequisite: PHY 224.
Offered: fall.

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

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

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.

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: fall of even-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: fall of even-numbered years.

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: fall of odd-numbered years.

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 444 Quantum Mechanics I 4 Credits
Corequisite: PHY 225 & MAT 222.
Offered: spring.

PHY 445 Special Topics in Physics 1-3 Credits
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 even-numbered years.

PHY 446 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 447 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.