Physics

Chair
Gang Xiao

The department aims to develop in its students a comprehensive grasp of the principles of physics, together with a productive capacity in research. The courses of study are flexible in subject matter and are conducted by means of lectures, seminars, laboratories, and colloquia. Undergraduate as well as graduate students have opportunities to carry out research in fields of current interest.

The principal research fields of the department are condensed matter physics, elementary particle physics, low-temperature physics, nonlinear optics, physical acoustics, astrophysics, biological physics, and cosmology. Interdisciplinary study and research, coordinated with other departments, is encouraged for students interested in brain and neural science, semiconductor physics, geophysics, physics of solid continua, polymer physics, and computational physics, as well as other fields. For additional information, please visit the department's website: http://www.brown.edu/academics/physics/

Physics Concentration Requirements

Physics is the scientific study of the fundamental principles governing the behavior of matter and the interaction of matter and energy. Mathematics is used to describe fundamental physical principles, the behavior of matter, and the interactions of matter and energy. As the most fundamental of sciences, physics provides a foundation for other scientific fields as well as the underpinnings of modern technology. The Physics department is unique because of the breadth of its faculty expertise and research, and the relatively intimate size of its classes above the introductory level. Physics concentrators may choose to pursue either the A.B. or the more intensive Sc.B. degree. Course work on either path covers a broad base of topics (for example, electricity and magnetism, classical and quantum mechanics, thermodynamics, and statistical mechanics). The Sc.B. degree requires additional advanced topics as well as a senior thesis project.

Standard concentration for the A.B. degree

Select one of the following Series:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 0070</td>
<td>Analytical Mechanics and Introduction to Relativity, Waves and Quantum Physics</td>
<td>2</td>
</tr>
<tr>
<td>PHYS 0160</td>
<td>Basic Physics A and Basic Physics B</td>
<td>2</td>
</tr>
<tr>
<td>PHYS 0030</td>
<td>Foundations of Mechanics and Foundations of Electromagnetism and Modern Physics</td>
<td>2</td>
</tr>
<tr>
<td>PHYS 0040</td>
<td>Electricity and Magnetism</td>
<td>1</td>
</tr>
<tr>
<td>PHYS 0050</td>
<td>Advanced Classical Mechanics</td>
<td>1</td>
</tr>
<tr>
<td>PHYS 0060</td>
<td>Experiments in Modern Physics</td>
<td>1</td>
</tr>
<tr>
<td>PHYS 1410</td>
<td>Quantum Mechanics A</td>
<td>1</td>
</tr>
<tr>
<td>PHYS 1530</td>
<td>Thermodynamics and Statistical Mechanics</td>
<td>1</td>
</tr>
</tbody>
</table>

One additional 1000-level course or a mathematics course beyond the introductory level.

Total Credits: 17

Honors

Candidates for honors in physics will be expected to pursue a more rigorous and extensive program than those merely concentrating in the subject. In addition they will be required to begin an honors thesis during the seventh semester and to complete it (as part of PHYS 1990) during the eighth semester. Honors candidates are also expected to take a special oral examination on the thesis at the end of the eighth semester. Further details about the program may be obtained from the chair of the department or the departmental honors advisor.

Astrophysics Track for the Sc.B. degree

Prerequisites:

Select one of the following Series:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 0070</td>
<td>Analytical Mechanics and Introduction to Relativity, Waves and Quantum Physics</td>
<td>2</td>
</tr>
<tr>
<td>PHYS 0160</td>
<td>Advanced Classical Mechanics</td>
<td>1</td>
</tr>
<tr>
<td>PHYS 0050</td>
<td>Experiments in Modern Physics</td>
<td>1</td>
</tr>
<tr>
<td>PHYS 0060</td>
<td>Quantum Mechanics A</td>
<td>1</td>
</tr>
<tr>
<td>PHYS 1410</td>
<td>Thermodynamics and Statistical Mechanics</td>
<td>1</td>
</tr>
</tbody>
</table>

One additional 1000-level course or a mathematics course beyond the introductory level.

Total Credits: 8

Program:

Select one of the following:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 0470</td>
<td>Electricity and Magnetism</td>
<td>1</td>
</tr>
<tr>
<td>PHYS 0050</td>
<td>Advanced Classical Mechanics</td>
<td>1</td>
</tr>
<tr>
<td>PHYS 0060</td>
<td>Experiments in Modern Physics</td>
<td>1</td>
</tr>
<tr>
<td>PHYS 1410</td>
<td>Quantum Mechanics A</td>
<td>1</td>
</tr>
<tr>
<td>PHYS 1530</td>
<td>Thermodynamics and Statistical Mechanics</td>
<td>1</td>
</tr>
<tr>
<td>PHYS 1560</td>
<td>Modern Physics Laboratory</td>
<td>1</td>
</tr>
</tbody>
</table>

Honors Linear Algebra

Honors Linear Algebra

Methods of Mathematical Physics

Gang Xiao

Chair

Physics
Select one of the following Math courses:  
APMA 0330 Methods of Applied Mathematics I, II  
APMA 0340 Methods of Applied Mathematics I, II  
APMA 0350 Applied Ordinary Differential Equations  
APMA 0360 Applied Partial Differential Equations I  
MATH 1110 Ordinary Differential Equations  
MATH 1120 Partial Differential Equations  
PHYS 0500 Advanced Classical Mechanics  
PHYS 0560 Advanced Biophysical Topics and Techniques  
PHYS 1250 Stellar Structure and the Interstellar Medium  
PHYS 1270 Extragalactic Astronomy and High-Energy Astrophysics  
PHYS 1280 Introduction to Cosmology  
Two additional 1000- or 2000-level courses in physics or a related field which are not listed as requirements.  
PHYS 1990 Senior Conference Course  

Total Credits 18  

A senior thesis is required. This is to be prepared in connection with under the direction of a faculty supervisor. The topic may be in a related department or of interdisciplinary nature. In any event, a dissertation must be submitted.

### Biological Physics Track for the Sc.B. degree

#### Foundations of Physics

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 0070 Analytical Mechanics</td>
<td>1</td>
</tr>
<tr>
<td>or PHYS 0050 Foundations of Mechanics</td>
<td>1</td>
</tr>
<tr>
<td>or ENGN 0040 Dynamics and Vibrations</td>
<td>1</td>
</tr>
<tr>
<td>PHYS 0160 Introduction to Relativity, Waves and Quantum Physics</td>
<td>1</td>
</tr>
<tr>
<td>or PHYS 0060 Foundations of Electromagnetism and Modern Physics</td>
<td>1</td>
</tr>
<tr>
<td>PHYS 0470 Electricity and Magnetism</td>
<td>1</td>
</tr>
<tr>
<td>PHYS 0500 Advanced Classical Mechanics</td>
<td>1</td>
</tr>
<tr>
<td>PHYS 1410 Quantum Mechanics A</td>
<td>1</td>
</tr>
<tr>
<td>PHYS 1530 Thermodynamics and Statistical Mechanics</td>
<td>1</td>
</tr>
</tbody>
</table>

Select one of the following Series:  

<table>
<thead>
<tr>
<th>Series</th>
<th>Course</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>PHYS 0720 Methods of Mathematical Physics</td>
<td>1-2</td>
</tr>
</tbody>
</table>
| B      | Select one of the following:  
APMA 0330 Methods of Applied Mathematics I, II  
APMA 0350 Applied Ordinary Differential Equations  
MATH 1110 Ordinary Differential Equations  
And select one of the following:  
MATH 0180 Intermediate Calculus  
MATH 0200 Intermediate Calculus (Physics/Engineering)  
MATH 0350 Honors Calculus  
MATH 0520 Linear Algebra  
MATH 0540 Honors Linear Algebra  
Basic Biology and Chemistry  
BIOL 0200 The Foundation of Living Systems (or placement out of BIOL 0200) | 1 |
|        | BIOL 0500 Cell and Molecular Biology         | 1 |
|        | CHEM 0330 Equilibrium, Rate, and Structure  | 1 |

### Mathematical Physics Track for the A.B. degree

#### Prerequisites:

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>MATH 0090</td>
<td>1</td>
</tr>
<tr>
<td>or MATH 0100</td>
<td>1</td>
</tr>
<tr>
<td>or MATH 0190</td>
<td>1</td>
</tr>
<tr>
<td>PHYS 0050 Foundations of Mechanics</td>
<td>1</td>
</tr>
<tr>
<td>or PHYS 0070 Analytical Mechanics</td>
<td>1</td>
</tr>
</tbody>
</table>

#### Mathematics Courses

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 0180 Intermediate Calculus</td>
<td>1</td>
</tr>
<tr>
<td>or MATH 0200 Intermediate Calculus (Physics/Engineering)</td>
<td>1</td>
</tr>
<tr>
<td>or MATH 0350 Honors Calculus</td>
<td>1</td>
</tr>
<tr>
<td>MATH 0520 Linear Algebra</td>
<td>1</td>
</tr>
<tr>
<td>or MATH 0540 Honors Linear Algebra</td>
<td>1</td>
</tr>
<tr>
<td>MATH 1110 Ordinary Differential Equations</td>
<td>1</td>
</tr>
</tbody>
</table>

Select at least one of the following:  

MATH 1060 Differential Geometry  
PHYS 1610 Biological Physics  
PHYS 1990 Senior Conference Course  

Elective Courses (four chosen from the following list, with at least two 1000-level courses, or additional courses approved by the concentration advisor):

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>APMA 0360 Applied Partial Differential Equations I</td>
<td>1</td>
</tr>
<tr>
<td>APMA 0410 Mathematical Methods in the Brain Sciences</td>
<td>1</td>
</tr>
<tr>
<td>APMA 0650 Essential Statistics</td>
<td>1</td>
</tr>
<tr>
<td>APMA 1070 Quantitative Models of Biological Systems</td>
<td>1</td>
</tr>
<tr>
<td>APMA 1080 Inference in Genomics and Molecular Biology</td>
<td>1</td>
</tr>
<tr>
<td>BIOL 0280 Biochemistry</td>
<td>1</td>
</tr>
<tr>
<td>BIOL 0470 Genetics</td>
<td>1</td>
</tr>
<tr>
<td>BIOL 1050 Biology of the Eukaryotic Cell</td>
<td>1</td>
</tr>
<tr>
<td>BIOL 1200 Protein Biophysics and Structure</td>
<td>1</td>
</tr>
<tr>
<td>BIOL 1270 Advanced Biochemistry</td>
<td>1</td>
</tr>
<tr>
<td>BIOL 1870 Techniques and Clinical Applications in Pathobiology</td>
<td>1</td>
</tr>
<tr>
<td>CHEM 0350 Organic Chemistry</td>
<td>1</td>
</tr>
<tr>
<td>CHEM 0360 Organic Chemistry</td>
<td>1</td>
</tr>
<tr>
<td>MATH 0090 Introductory Calculus, Part I</td>
<td>1</td>
</tr>
<tr>
<td>MATH 0170 Advanced Placement Calculus</td>
<td>1</td>
</tr>
<tr>
<td>MATH 0190 Advanced Placement Calculus (Physics/Engineering)</td>
<td>1</td>
</tr>
<tr>
<td>MATH 1610 Probability</td>
<td>1</td>
</tr>
<tr>
<td>MATH 1620 Mathematical Statistics</td>
<td>1</td>
</tr>
<tr>
<td>PHYS 0560 Experiments in Modern Physics</td>
<td>1</td>
</tr>
<tr>
<td>PHYS 1510 Advanced Electromagnetic Theory</td>
<td>1</td>
</tr>
<tr>
<td>PHYS 1560 Modern Physics Laboratory</td>
<td>1</td>
</tr>
<tr>
<td>PHYS 2620F Selected Topics in Molecular Biophysics</td>
<td>1</td>
</tr>
<tr>
<td>PHYS 1990 Senior Conference Course</td>
<td>1</td>
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</tbody>
</table>
Mathematical Physics Track for the Sc.B. degree

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 1120</td>
<td>Partial Differential Equations</td>
</tr>
<tr>
<td>MATH 1610</td>
<td>Probability</td>
</tr>
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</table>

**Physics Courses**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 0060</td>
<td>Foundations of Electromagnetism and Modern Physics</td>
</tr>
<tr>
<td>or PHYS 0160</td>
<td>Introduction to Relativity, Waves and Quantum Physics</td>
</tr>
<tr>
<td>PHYS 0470</td>
<td>Electricity and Magnetism</td>
</tr>
<tr>
<td>PHYS 0500</td>
<td>Advanced Classical Mechanics</td>
</tr>
<tr>
<td>PHYS 0560</td>
<td>Experiments in Modern Physics</td>
</tr>
</tbody>
</table>

Select at least two of the following:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 1410</td>
<td>Quantum Mechanics A</td>
</tr>
<tr>
<td>PHYS 1420</td>
<td>Quantum Mechanics B</td>
</tr>
<tr>
<td>PHYS 1510</td>
<td>Advanced Electromagnetic Theory</td>
</tr>
<tr>
<td>PHYS 1530</td>
<td>Thermodynamics and Statistical Mechanics</td>
</tr>
<tr>
<td>PHYS 1560</td>
<td>Modern Physics Laboratory</td>
</tr>
</tbody>
</table>

Total Credits: 12

1 Concentrators are required to take at least one course in mathematics and one in physics in each of their last two semesters.

### Prerequisites:

Select one of the following series:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 0070</td>
<td>Analytical Mechanics and Introduction to Relativity, Waves and Quantum Physics</td>
</tr>
<tr>
<td>PHYS 0050</td>
<td>Foundations of Mechanics and Foundations of Electromagnetism and Modern Physics</td>
</tr>
</tbody>
</table>

Select one of the following:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 190</td>
<td>Advanced Placement Calculus (Physics/Engineering)</td>
</tr>
<tr>
<td>MATH 0990</td>
<td>Introductory Calculus, Part I and Introductory Calculus, Part II</td>
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</tbody>
</table>

Required courses:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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</thead>
<tbody>
<tr>
<td>PHYS 0470</td>
<td>Electricity and Magnetism</td>
</tr>
<tr>
<td>PHYS 0500</td>
<td>Advanced Classical Mechanics</td>
</tr>
<tr>
<td>PHYS 0560</td>
<td>Experiments in Modern Physics</td>
</tr>
<tr>
<td>PHYS 1410</td>
<td>Quantum Mechanics A</td>
</tr>
<tr>
<td>PHYS 1530</td>
<td>Thermodynamics and Statistical Mechanics</td>
</tr>
<tr>
<td>MATH 0100</td>
<td>Intermediate Calculus and Intermediate Calculus (Physics/Engineering)</td>
</tr>
<tr>
<td>or MATH 0350</td>
<td>Honors Calculus</td>
</tr>
<tr>
<td>MATH 0520</td>
<td>Linear Algebra</td>
</tr>
<tr>
<td>or MATH 0540</td>
<td>Honors Linear Algebra</td>
</tr>
<tr>
<td>or PHYS 0720</td>
<td>Methods of Mathematical Physics</td>
</tr>
<tr>
<td>MATH 1260</td>
<td>Complex Analysis</td>
</tr>
<tr>
<td>Four additional 1000 or 2000 level Physics courses</td>
<td></td>
</tr>
<tr>
<td>Two additional 1000 or 2000 level Math courses</td>
<td></td>
</tr>
<tr>
<td>PHYS 1990</td>
<td>Senior Conference Course</td>
</tr>
</tbody>
</table>

Total Credits: 18-20

1 A senior thesis is required. This is to be prepared in connection with the direction of a faculty supervisor.

### Physics and Philosophy Concentration Requirements

The Physics and Philosophy concentration is for students with a deep interest in physics who do not need to acquire the laboratory and computational skills of a professional physicist. The concentration allows students to grapple with computational problems and deepen their investigation of conceptual and epistemological issues. By the end of the program, concentrators possess an excellent conceptual understanding of the most philosophically interesting physics, relativity and quantum mechanics.

This concentration should prepare a student either for graduate study, especially in a history and philosophy of science (HPS) program, or for employment in science education or journalism. Other professions such as law and medicine will look favorably on such concentrators for having versatile interests and being able to master difficult material. The concentration may serve as an excellent preparation for a law school since physics and philosophy both exercise a rigorous approach to problems of immediate relevance to life but at the same time assume two complimentary and sometimes competing viewpoints.

### Advising

Concentration advisors from the Departments of Physics and Philosophy will guide students working towards the A.B. degree.

### Curriculum

The curriculum builds around the fields of physics that have had the biggest impact on philosophy, especially Quantum Physics, and the fields of philosophy most relevant for physics, such as Epistemology, Metaphysics and Philosophy of Physics. It is strongly recommended that students complete at least one relevant history course.

There are 11 required courses (5 in Physics, 5 in Philosophy or History, one course in mathematics) and a final project. The choice of the courses is dictated by the following considerations. The field of physics with both deepest philosophical implications and deepest influence on the rest of physics is Quantum Mechanics. Thus, a 1000-level course in Quantum Mechanics or a closely related field such as Statistical Mechanics is indispensable. The second field of physics most relevant for the concentration is Relativity. This field touches upon and serves as a foundation for a broad list of subjects with major philosophical implications of their own, for example: PHYS 1170, PHYS 1280, PHYS 1510, PHYS 1100. This requires another 1000-level physics course in the concentration. 1000-level Physics courses cannot be taken without certain preliminary work, most importantly, PHYS 0470, which serves as a prerequisite for most higher-level physics courses and which relies in turn on PHYS 0160 or PHYS 0060. Another lower-level physics course is necessary for a student to develop familiarity with the tools which have been employed in producing the physics knowledge.

A natural introduction into philosophy of physics comes from a course in Early Modern Philosophy. To a large extent, Early Modern Philosophy was shaped by scholars who combined interest in philosophy and physics (e.g., Rene Descartes, Blaise Pascal, Gottfried Wilhelm Leibniz). The influence of the XVII century physics revolution on other central figures such as Kant is unquestionable. Early Modern Philosophy sets an intellectual stage for many subsequent developments in the Philosophy of Physics and directly addresses some of the most perplexing issues like the connection (or lack thereof) between physics and religion. The core of the Philosophy requirement involves two courses in Epistemology, Metaphysics and Philosophy of Science. One course in this field would not be sufficient due to its very broad nature. Students are strongly advised to take a relevant History course. This requirement can be substituted by an additional philosophy course to reflect interests of those students who want a deeper background in Epistemology, Metaphysics and Philosophy of Science or have other related interests such as Ancient Natural Philosophy.

In addition to the above philosophy courses, PHIL 0210 (Science, Perception, and Reality) serves as a gateway into the concentration. It may be substituted by other relevant courses such as PHYS 0100 (Flat
Required courses for the A.B. degree are listed below:

**Physics Courses**

Select one of the following introductory courses in Modern Physics:

- PHYS 0060 Foundations of Electromagnetism and Modern Physics
- PHYS 0160 Introduction to Relativity, Waves and Quantum Physics

One course in Special Relativity and Classical Field Theory:

- PHYS 0470 Electricity and Magnetism

Select one of the following in Methods of Experimental and Theoretical physics:

- PHYS 0500 Advanced Classical Mechanics
- PHYS 0560 Experiments in Modern Physics

Select one of the following in Quantum Mechanics and its applications:

- PHYS 1410 Quantum Mechanics A
- PHYS 1530 Thermodynamics and Statistical Mechanics

One more 1000-level Physics course

**Philosophy Courses**

Select one of the following gateway courses:

- PHIL 0210 Science, Perception and Reality
- PHIL 0100 Critical Reasoning
- PHIL 0060 Modern Science and Human Values
- PHIL 0540 Logic

Select one of the following courses in Early Modern Philosophy:

- PHIL 0360 Early Modern Philosophy
- PHIL 1700 Locke, Berkeley, Hume and Others
- PHIL 1710 17th Century Continental Rationalism
- PHIL 1720 Kant: The Critique of Pure Reason

Select two of the following courses in Epistemology, Metaphysics and Philosophy of Science:

- PHIL 1590 Philosophy of Science
- PHIL 1620 Philosophy of Quantum Mechanics
- PHIL 1660 Metaphysics
- PHIL 1670 Time
- PHIL 1750 Epistemology

**History Courses**

Select one of the following courses in History of Science:

- HIST 0522N Reason, Revolution and Reaction in Europe
- HIST 1825M Science at the Crossroads
- HIST 1976I The World of Isaac Newton

**Calculus**

Select one of the following:

- MATH 0180 Intermediate Calculus
- MATH 0200 Intermediate Calculus (Physics/Engineering)
- MATH 0350 Honors Calculus

**Final Project**

Select one of the following:

- PHIL 1990 Independent Studies
- PHYS 1990 Senior Conference Course

A course from the PHIL 0990 Senior Seminar series

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Any graduate seminar in Philosophy

<table>
<thead>
<tr>
<th>Total Credits</th>
<th>12</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Or one more Philosophy course.</td>
</tr>
</tbody>
</table>

**Honors**

Seniors wishing to earn honors by presenting a senior honors thesis should consult their concentration advisor during their sixth semester or at the start of the seventh semester concerning procedures and requirements. Students may earn honors by presenting a senior thesis judged to be of honors quality by two readers. In addition to completing the usual nonhonors requirements, the student should also have a grade point average of over 3.4 in physics, philosophy and history of science courses (of which at least five must be taken for a letter grade). Honors theses are usually prepared over a period of two semesters with an advisor from the Department of Physics or the Department of Philosophy.

**Chemical Physics Concentration Requirements**

Chemical Physics is an interdisciplinary field at the crossroads of chemistry and physics and is administered jointly by the two departments. The concentration provides students with a broad-based understanding in fundamental molecular sciences, as well as a background for graduate studies in physical chemistry, chemical physics, or molecular engineering. Concentrators are required to take twenty courses in chemistry, physics, and mathematics, although approved courses in applied mathematics, biology, computer science, geological sciences, or engineering may be substitutes. Chemical Physics concentrators are also advised to take at least six courses in the humanities and social sciences. Chemical Physics concentrators at all levels (first-year through seniors) are actively involved in research with faculty members in both departments.

**Standard program for the Sc.B. degree**

Twenty-one semester courses in chemistry, physics, and mathematics, with a minimum of four semester courses in mathematics. The expectation is that courses required for a concentration in Chemical Physics will be taken for a letter grade. Core courses are:

- CHEM 0330 Equilibrium, Rate, and Structure
- CHEM 0350 Organic Chemistry
- CHEM 0500 Inorganic Chemistry
- CHEM 1140 Physical Chemistry: Quantum Mechanics
- PHYS 0070 Analytical Mechanics
- PHYS 0160 Introduction to Relativity, Waves and Quantum Physics
- PHYS 0470 Electricity and Magnetism

Select one of the following laboratory courses:

- CHEM 1160 Physical Chemistry Laboratory
- PHYS 0560 Experiments in Modern Physics
- PHYS 1560 Modern Physics Laboratory

Select one course in statistical mechanics:

- CHEM 1150 Physical Chemistry: Thermodynamics and Statistical Mechanics

Select one of the following laboratory courses:

- PHYS 1530 Thermodynamics and Statistical Mechanics
- MATH 0190 Advanced Placement Calculus (Physics/Engineering)
- MATH 0200 Intermediate Calculus (Physics/Engineering)
- MATH 0520 Linear Algebra

Seven courses, primarily at the 1000 or 2000 level, in chemistry or physics. Select two semesters of independent study:

- CHEM 0970/0980 Undergraduate Research
Honors Requirements for Chemical Physics

All ScB Chemical Physics concentrators who complete the following requirements are candidates for Honors; no separate application is necessary.

The requirements for Honors in Chemical Physics are:

* A strong grade record in concentration courses. This means a grade point average for the concentration that is higher than 3.50.
* Two semesters of Independent Study (CHEM 0970, CHEM 0980, PHYS 0990 or equivalent). Guidelines and requirements associated with Independent Study are in the Undergraduate Concentration Handbook which can be found at the department website (http://www.brown.edu/academics/chemistry/undergraduate).

* A Thesis in a form approved by the research advisor, and recommended by the research advisor. Additional information about thesis guidelines will be provided by the Concentration Advisor in the first half of the fall semester.

* A Poster presentation at the chemistry department's spring undergraduate poster session.

Engineering and Physics Concentration Requirements

The Sc.B. program in Engineering and Physics is sponsored jointly by the School of Engineering and the Department of Physics. The program is designed to ensure that students take a significant portion of the usual curriculum in Engineering and in Physics, obtain substantial laboratory experience, and take several upper-level elective courses, focusing on applied science. Students may take either the standard Physics or Engineering programs during their freshman and sophomore years and then switch to this combined program. The Sc.B. degree program in Engineering and Physics is not accredited by ABET.

The following standard program assumes that a student begins mathematics courses at Brown with MATH 0170 or its equivalent. Students who begin in MATH 0200 can substitute an additional science, engineering or higher-level mathematics course for the MATH 0170 or MATH 0190 requirement. To accommodate the diverse preparation of individual students, variations of the following sequences and their prerequisites are possible with permission of the appropriate concentration advisor and the instructors involved. We recommend that each student’s degree program be submitted for prior approval (typically in semester four) and scrutinized for compliance (in semester seven) by one faculty member from the Department of Physics and one faculty member from the School of Engineering.

Select one of the following two course sequences:

<table>
<thead>
<tr>
<th>Total Credits</th>
<th>21</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 1990</td>
<td>Senior Conference Course</td>
</tr>
</tbody>
</table>

Other approved courses in applied mathematics, biology, computer science, geological sciences, or engineering may be substituted for some of the twenty-one.

Students are advised to take at least six courses in the humanities and social sciences.

A thesis under the supervision of a physics or engineering faculty member:

* PHYS 1990 Senior Conference Course
* or ENGN 1970 Independent Studies in Engineering
* or ENGN 1971 Independent Study in Engineering

* Students are also encouraged to take courses dealing with the philosophical, ethical, or political aspects of science and technology.

Astronomy Concentration Requirements

Along with Greek, Latin, and Mathematics, Astronomy counts as one of the oldest continuously taught subjects in the Brown curriculum. It is the study of the properties of stars, galaxies, and the Universe, and as such combines elements from the disciplines of both Physics and Planetary Geology. Students pursuing this concentration complete introductory coursework in classical mechanics, relativity, and astrophysics, along with mathematics and electromagnetism. They go on to complete courses in stellar and extragalactic astrophysics as well as cosmology. Facilities available to concentrators include the historic Ladd Observatory.

Standard concentration for the A.B. degree

Eleven or twelve courses are required (depending on the satisfaction of prerequisites).

Prerequisites

<table>
<thead>
<tr>
<th>Total Credits</th>
<th>19</th>
</tr>
</thead>
<tbody>
<tr>
<td>or MATH 0180</td>
<td>Intermediate Calculus</td>
</tr>
<tr>
<td>or MATH 0350</td>
<td>Honors Calculus</td>
</tr>
</tbody>
</table>

Select three additional higher-level math, applied math, or mathematical physics (PHYS 0720) courses.

<table>
<thead>
<tr>
<th>Total Credits</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSCI 0040</td>
<td>Introduction to Scientific Computing and Problem Solving</td>
</tr>
<tr>
<td>or CSCI 0150</td>
<td>Introduction to Object-Oriented Programming and Computer Science</td>
</tr>
<tr>
<td>or CSCI 0170</td>
<td>Computer Science: An Integrated Introduction</td>
</tr>
<tr>
<td>or CSCI 0190</td>
<td>Accelerated Introduction to Computer Science</td>
</tr>
<tr>
<td>ENGN 0510</td>
<td>Electricity and Magnetism</td>
</tr>
<tr>
<td>or PHYS 0470</td>
<td>Electricity and Magnetism</td>
</tr>
<tr>
<td>ENGN 1560</td>
<td>Optics</td>
</tr>
<tr>
<td>or PHYS 1510</td>
<td>Advanced Electromagnetic Theory</td>
</tr>
<tr>
<td>PHYS 0500</td>
<td>Advanced Classical Mechanics</td>
</tr>
<tr>
<td>or ENGN 1370</td>
<td>Advanced Engineering Mechanics</td>
</tr>
<tr>
<td>PHYS 1410</td>
<td>Quantum Mechanics A</td>
</tr>
<tr>
<td>PHYS 1420</td>
<td>Quantum Mechanics B</td>
</tr>
<tr>
<td>PHYS 1530</td>
<td>Thermodynamics and Statistical Mechanics</td>
</tr>
<tr>
<td>or ENGN 0720</td>
<td>Thermodynamics</td>
</tr>
<tr>
<td>ENGN 1620</td>
<td>Analysis and Design of Electronic Circuits</td>
</tr>
<tr>
<td>CHEM 0330</td>
<td>Equilibrium, Rate, and Structure</td>
</tr>
<tr>
<td>or ENGN 0310</td>
<td>Mechanics of Solids and Structures</td>
</tr>
<tr>
<td>or ENGN 0810</td>
<td>Fluid Mechanics</td>
</tr>
<tr>
<td>or PHYS 1600</td>
<td>Computational Physics</td>
</tr>
<tr>
<td>ENGN 0410</td>
<td>Materials Science</td>
</tr>
<tr>
<td>or ENGN 1690</td>
<td>Photonics Devices and Sensors</td>
</tr>
<tr>
<td>or PHYS 0560</td>
<td>Experiments in Modern Physics</td>
</tr>
<tr>
<td>PHYS 1560</td>
<td>Modern Physics Laboratory</td>
</tr>
<tr>
<td>or ENGN 1590</td>
<td>Introduction to Semiconductors and Semiconductor Electronics</td>
</tr>
</tbody>
</table>

or an approved 2000-level engineering or physics course.
Select one of the following Series: 1-2

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 0170 &amp; MATH 0180</td>
<td>Advanced Placement Calculus and Intermediate Calculus</td>
</tr>
<tr>
<td>MATH 0190 &amp; MATH 0200</td>
<td>Advanced Placement Calculus (Physics/ Engineering) and Intermediate Calculus (Physics/ Engineering)</td>
</tr>
<tr>
<td>MATH 0350</td>
<td>Honors Calculus (or equivalent)</td>
</tr>
<tr>
<td>PHYS 0470</td>
<td>Electricity and Magnetism</td>
</tr>
</tbody>
</table>

**Physics Graduate Program**

The department of Physics offers graduate programs leading to the Master of Science (ScM) degree and the Doctor of Philosophy (PhD) Degree. For more information on admission and program requirements, please visit the following website: http://www.brown.edu/academics/gradschool/programs/physics

**Master of Science (ScM)**

A total of 8 credits in 2000 level courses form the main requirement for the ScM degree in Physics, typically taken over 4 semesters. Of the eight required courses, four must be selected from the six core courses of the graduate program.

**Core Courses**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 2010</td>
<td>Techniques in Experimental Physics</td>
</tr>
<tr>
<td>PHYS 2030</td>
<td>Classical Theoretical Physics I</td>
</tr>
<tr>
<td>PHYS 2040</td>
<td>Classical Theoretical Physics II</td>
</tr>
<tr>
<td>PHYS 2050</td>
<td>Quantum Mechanics</td>
</tr>
</tbody>
</table>

Four additional credits at the 2000 level are required. These courses are to be selected from the remaining core courses or the large number of other upper level physics courses. Up to two of these can be taken in research, or taken in another department with prior approval of the program director.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 2020</td>
<td>Mathematical Methods of Engineers and Physicists</td>
</tr>
<tr>
<td>PHYS 2070</td>
<td>Advanced Quantum Mechanics</td>
</tr>
<tr>
<td>PHYS 2170</td>
<td>Introduction to Nuclear and High Energy Physics</td>
</tr>
<tr>
<td>PHYS 2280</td>
<td>Astrophysics and Cosmology</td>
</tr>
<tr>
<td>PHYS 2300</td>
<td>Quantum Theory of Fields I</td>
</tr>
<tr>
<td>PHYS 2320</td>
<td>Quantum Theory of Fields II</td>
</tr>
<tr>
<td>PHYS 2340</td>
<td>Group Theory</td>
</tr>
<tr>
<td>PHYS 2410</td>
<td>Solid State Physics I</td>
</tr>
<tr>
<td>PHYS 2420</td>
<td>Solid State Physics II</td>
</tr>
<tr>
<td>PHYS 2430</td>
<td>Quantum Many Body Theory</td>
</tr>
<tr>
<td>PHYS 2470</td>
<td>Advanced Statistical Mechanics</td>
</tr>
<tr>
<td>PHYS 2600</td>
<td>Computational Physics</td>
</tr>
<tr>
<td>PHYS 2980</td>
<td>Research in Physics or PHYS 2981</td>
</tr>
</tbody>
</table>

**Courses**

**PHYS 0030. Basic Physics A.**

Survey of mechanics for concentrators in sciences other than physics—including premedical and life science students. Students with more advanced math training are advised to take PHYS 0050, which covers the same topics in physics. PHYS 0030 employs the concepts of elementary calculus but little of the technique. Lectures, conferences, and laboratory. Six hours of attendance. Prerequisite: MATH 0090 or equivalent.

Fall  PHYS0030  S01  16499  MWF  11:00-11:50(16)  To Be Arranged
Fall  PHYS0030  S02  16500  MWF  12:00-12:50(15)  To Be Arranged
Fall  PHYS0030  L01  16501  T  8:30-10:20  To Be Arranged
Fall  PHYS0030  L02  16502  T  12:30-2:20  To Be Arranged
Fall  PHYS0030  L03  16503  T  2:30-4:20  To Be Arranged
Fall  PHYS0030  L04  16504  W  9:00-11:50  To Be Arranged
Fall  PHYS0030  L05  16505  W  1:00-2:50  To Be Arranged
Fall  PHYS0030  L06  16506  W  3:00-4:50  To Be Arranged
Fall  PHYS0030  L07  16507  Th  8:30-10:20  To Be Arranged
Fall  PHYS0030  L08  16508  Th  12:30-2:20  To Be Arranged
Fall  PHYS0030  L09  16509  Th  2:30-4:20  To Be Arranged
Fall  PHYS0030  L10  16510  F  9:00-10:50  To Be Arranged
Fall  PHYS0030  L11  16511  F  1:00-2:50  To Be Arranged
Fall  PHYS0030  L12  16512  Arranged  To Be Arranged
Spr  PHYS0030  S01  25076  MWF  12:00-12:50(05)  To Be Arranged
Spr  PHYS0030  C01  25080  Arranged  To Be Arranged
Spr  PHYS0030  C02  25081  Arranged  To Be Arranged
Spr  PHYS0030  C03  25082  Arranged  To Be Arranged
Spr  PHYS0030  L01  25077  W  9:00-10:50  To Be Arranged
Spr  PHYS0030  L02  25078  W  1:00-2:50  To Be Arranged
Spr  PHYS0030  L03  25079  W  3:00-4:50  To Be Arranged

1. PHYS 0050 and PHYS 0060 can be taken in lieu of PHYS 0160

To Be Arranged
PHYS 0040. Basic Physics B.
Survey of electricity, magnetism, optics, and modern physics for concentrators in sciences other than physics—including premedical students or students without prior exposure to physics who require a less rigorous course than PHYS 0050, 0060. Employs the concepts of elementary calculus but little of its technique. Lectures, conferences, and laboratory. Recommended: MATH 0090 or MATH 0100.
Spr PHYS0040 S01 25083 MWF 11:00-11:50(04) 'To Be Arranged'
Spr PHYS0040 S02 25084 MWF 12:00-12:50(05) 'To Be Arranged'
Spr PHYS0040 L01 25085 T 8:30-10:20 'To Be Arranged'
Spr PHYS0040 L02 25086 T 12:30-2:20 'To Be Arranged'
Spr PHYS0040 L03 25087 T 2:30-4:20 'To Be Arranged'
Spr PHYS0040 L04 25088 W 9:00-10:50 'To Be Arranged'
Spr PHYS0040 L05 25089 W 1:00-2:50 'To Be Arranged'
Spr PHYS0040 L06 25090 W 3:00-4:50 'To Be Arranged'
Spr PHYS0040 L07 25091 Th 8:30-10:20 'To Be Arranged'
Spr PHYS0040 L08 25092 Th 12:30-2:20 'To Be Arranged'
Spr PHYS0040 L09 25093 Th 2:30-4:20 'To Be Arranged'
Spr PHYS0040 L10 25094 F 9:00-10:50 'To Be Arranged'
Spr PHYS0040 L11 25095 F 1:00-2:50 'To Be Arranged'
Spr PHYS0040 L12 25096 Arranged 'To Be Arranged'

An introduction to Newtonian mechanics that employs elementary calculus. Intended for science concentrators. Potential physics students or students without prior exposure to physics who require a less rigorous course than PHYS 0050, 0060. Employs the concepts of calculus or written permission. Instructor permission required.
Fall PHYS0050 S01 16544 MW 8:30-9:50(01) 'To Be Arranged'
Fall PHYS0050 C01 16551 Th 5:00-6:20 'To Be Arranged'
Fall PHYS0050 C02 16552 F 8:30-9:50 'To Be Arranged'
Fall PHYS0050 C03 16553 F 1:00-2:20 'To Be Arranged'
Fall PHYS0050 L01 16554 M 12:30-2:20 'To Be Arranged'
Fall PHYS0050 L02 16555 T 2:30-4:20 'To Be Arranged'
Fall PHYS0050 L03 16556 W 1:00-2:50 'To Be Arranged'
Fall PHYS0050 L04 16557 W 3:00-4:50 'To Be Arranged'
Fall PHYS0050 L05 16558 Th 12:30-2:20 'To Be Arranged'
Fall PHYS0050 L06 16559 Th 2:30-4:20 'To Be Arranged'
Fall PHYS0050 L07 16560 Arranged 'To Be Arranged'

An introduction to the principles and phenomena of electricity, magnetism, optics, and the concepts of modern physics. Recommended for those who wish to limit their college physics to two semesters but seek a firm grounding in the subject, including but not limited to those with some previous knowledge of physics. Lectures, conferences, and laboratory. Six hours of attendance. Prerequisite: PHYS 0050. Recommended: MATH 0100.
Spr PHYS0060 S01 25097 MW 8:30-9:50(02) 'To Be Arranged'
Spr PHYS0060 C01 25110 Th 5:00-6:20 'To Be Arranged'
Spr PHYS0060 C02 25111 F 8:30-9:50 'To Be Arranged'
Spr PHYS0060 C03 25112 F 1:00-2:20 'To Be Arranged'
Spr PHYS0060 L01 25103 T 12:30-2:20 'To Be Arranged'
Spr PHYS0060 L02 25104 T 2:30-4:20 'To Be Arranged'
Spr PHYS0060 L03 25105 W 1:00-2:50 'To Be Arranged'
Spr PHYS0060 L04 25106 W 3:00-4:50 'To Be Arranged'
Spr PHYS0060 L05 25107 Th 12:30-2:20 'To Be Arranged'
Spr PHYS0060 L06 25108 Th 2:30-4:20 'To Be Arranged'
Spr PHYS0060 L07 25109 Arranged 'To Be Arranged'

A mathematically more rigorous introduction to Newtonian mechanics than PHYS 0050. For first-year students and sophomores who have studied physics previously and have completed a year of calculus. Lectures, conferences, and laboratory. Six hours of attendance. Prerequisites: high school physics and calculus or written permission. S/NC.
Fall PHYS0070 S01 16561 MWF 9:00-9:50(01) 'To Be Arranged'
Fall PHYS0070 L01 16562 T 12:30-2:20 'To Be Arranged'
Fall PHYS0070 L02 16563 T 2:30-4:20 'To Be Arranged'
Fall PHYS0070 L03 16564 W 1:00-2:50 'To Be Arranged'
Fall PHYS0070 L04 16565 W 3:00-4:50 'To Be Arranged'
Fall PHYS0070 L05 16566 Th 12:30-2:20 'To Be Arranged'
Fall PHYS0070 L06 16567 Th 2:30-4:20 'To Be Arranged'
Fall PHYS0070 L07 16568 Arranged 'To Be Arranged'

Physics has had a dramatic impact on our conception of the universe, our ideas concerning the nature of knowledge, and our view of ourselves. Philosophy, sometimes inspired by developments in physics, considers the impact of such developments on our lives. In this seminar, students will explore how classical and modern physical theory have affected our view of the cosmos, of ourselves as human beings, as well as our view of the relation of mathematical or physical structures to 'truth' or 'reality.' Through a study of physics as well as selected philosophical readings, we will consider how we can know anything, from seemingly simple facts to whether a machine is conscious. Enrollment limited to 19 first year students. Instructor permission required.
Fall PHYS0100 S01 16569 Th 2:30-3:30(03) 'To Be Arranged'

PHYS 0110. Excursion to Biophysics.
This new course aims at freshmen with good preparation in high school physics, chemistry and biology, but who have not had a set mind what specific disciplines to focus on in their college study at Brown. The course will introduce important physics concepts and techniques relevant to biology and medicine, such as diffusion and transport of molecules and intracellular components, Brown motion and active swimming of microbes, motion of particles confined by a harmonic potential, Boltzmann distribution, exponential growth or decay, and statistics of single molecule behavior. The goal of the course is to cultivate interest and provide essential basics for more rigorous study of biological physics as a branch of interdisciplinary science. Enrollment limited to 19 first year students. Instructor permission required.

PHYS 0111. Are There Extra Dimensions Under Your Bed?.
Discusses some of the most exciting questions confronting contemporary physical science in a fashion suitable for both humanists and scientists. What are particles, antiparticles, superstrings, and black holes? How are space and time related? How are mass and gravity related to space and time? Do we live in a three-dimensional world, or are there extra dimensions? The seminar will address such questions with conceptual explanations based upon current research on campus, and highlight the experiments at the energy frontier, being carried out by the world's largest scientific instrument to-date, the Large Hadron Collider, located in Geneva, Switzerland. Enrollment limited to 19 first year students.

The course will cover the significant developments in the detection and characterization of extra-solar planetary systems in the past almost 30 years. We will study the techniques for detecting planets outside of our solar system, the properties of the exoplanets discovered so far, and the prospects for future discoveries, with an emphasis on the search for "Earth-analogues" and the implications for astrobiology.
PHYS 0113. Squishy Physics.
A freshman seminar to explore everyday applications of physics. It offers practical training on project-based learning. The course involves hands-on experimentation, data analysis and presentation. The course is designed for students interested in any field of science with no pre-requisites. The topics covered include motion, forces, flow, elasticity, polymers, gels, electricity, energy, etc. Students will be guided to work on several projects over the semester. They are required to report their projects in both written and oral reports. There is no exam for the course. Students are required to register for one of the labs.

PHYS 0114. The Science and Technology of Energy.
Energy plays fundamental roles in society. Its use underlies improvements in the living standard; the consequences of its use are having a significant impact on the Earth’s climate; its scarcity in certain forms is a source of insecurity and political conflict. This course will introduce the fundamental laws that govern energy and its use. Physical concepts to be covered: mechanical energy, thermodynamics, the Carnot cycle, electricity and magnetism, quantum mechanics, and nuclear physics. Technological applications include wind, hydro, and geothermal energy, engines and fuels, electrical energy transmission and storage, solar energy and photovoltaics, nuclear reactors, and biomass. Enrollment limited 19. Spr PHYS0114 S01 25119 TTh 2:30-3:50(11) 'To Be Arranged'.

PHYS 0120. Adventures in Nanoworld.
Richard Feynman famously said, "There's plenty of room at the bottom," about the possibility of building molecular-size machines operating according to Quantum Mechanics. Scientists are now learning the art, and in this course we will use basic physics and simple mathematical models to understand the phenomena and materials in the nanoworld.
Non-science concentrators and potential science concentrators alike will learn about important classes of nanosystems such as macromolecules, nanotubes, quantum dots, quantum wires, and films. We will learn how people make nanosystems and characterize them. We will consider existing and potential applications of nanotechnology, including molecular motors, nanoelectronics, spintronics, and quantum information. Enrollment limited to 19 first year students.

PHYS 0121. Introduction to Environmental Physics: The Quantum Mechanics of Global Warming.
We will use basic physics and simple mathematical models to investigate climate change, energy and entropy, the dispersal of pollutants, solar power, and other aspects of environmental science. Lectures will be supplemented with demonstrations of key physical principles. Emphasis will be placed on quantitative reasoning.

PHYS 0150. The Jazz of Modern Physics.
This course, aimed at both students in the humanities and sciences, will explore the myriad surprising ways that jazz music is connected to modern physics. No background in physics, mathematics or music is required, as all of these foundational concepts and tools will be introduced.
The Jazz of Physics has three interconnected components:
1. Using concepts and analogies from music and acoustics to explore the key conceptual ideas in modern physics such as quantum mechanics/information, general relativity, particle physics, dark energy and big bang cosmology.
2. Exploring the parallels between jazz and physics through the lens of 20th century physics and jazz history, as well as key innovations in both fields with an eye towards future innovations.
3. Students will learn the tools of signification in physics and develop group projects with a final product.
The course will consist of lectures, related homework sets, weekly discussion meetings, and a final study where groups of students will select a topic of interest.
Fall PHYS0150 S01 16570 MW 8:30-9:50(01) 'To Be Arranged'.

PHYS 0160. Introduction to Relativity, Waves and Quantum Physics.
A mathematically rigorous introduction to special relativity and quantum mechanics. The second course in the three-semester sequence (PHYS 0470 being the third) for those seeking the strongest foundation in physics. Also suitable for students better served by an introduction to modern physics rather than electromagnetism. Lectures, conferences, and laboratory. Six hours of attendance. Prerequisite: PHYS 0070 or 0050.
Recommended: MATH 0180 or 0200. S/NC
Spr PHYS0160 S01 25121 MWF 9:00-9:50(02) 'To Be Arranged'.
Spr PHYS0160 L01 25123 T 12:30-2:20 'To Be Arranged'.
Spr PHYS0160 L02 25124 T 2:30-4:20 'To Be Arranged'.
Spr PHYS0160 L03 25125 W 1:00-2:50 'To Be Arranged'.
Spr PHYS0160 L04 25126 W 3:00-4:50 'To Be Arranged'.
Spr PHYS0160 L05 25127 Th 12:30-2:20 'To Be Arranged'.
Spr PHYS0160 L06 25128 Th 2:30-4:20 'To Be Arranged'.
Spr PHYS0160 L07 25129 Arranged 'To Be Arranged'.

This course is an introduction to many major concepts in physics. It is intended for a general audience, and calculus is not required. Along the way, we will address the question “what goes into making a scientific theory?” using the works of Euclid, Galileo, Newton and others as examples. Concepts range historically from planetary motion (addressed at least as early as Ancient Greece) to modern physics topics that are still under debate today. These concepts include (but are not limited to) motion, forces, energy, electricity and magnetism, special relativity and quantum mechanics.

PHYS 0220. Astronomy.
An introduction to basic ideas and observations in astronomy, starting with the observed sky, coordinates and astronomical calendars and cycles, the historical development of our understanding of astronomical objects. Particular emphasis is placed on the properties of stars, galaxies, and the Universe as a whole, including the basic ideas of cosmology. The material is covered at a more basic level than PHYS 0270. Knowledge of basic algebra and trigonometry is required, but no experience with calculus is necessary. The course includes evening laboratory sessions.

PHYS 0270. Introduction to Astronomy.
A complete survey of basic astronomy, more rigorous than is offered in PHYS 0220. Requires competence in algebra, geometry, trigonometry, and vectors and also some understanding of calculus and classical mechanics. Laboratory work required. This course or an equivalent required for students concentrating in astronomy. The course includes conferences and evening laboratory sessions.
Fall PHYS0270 S01 16571 TTh 1:00-2:20(08) 'To Be Arranged'.

PHYS 0470. Electricity and Magnetism.
Electric and magnetic fields. Motion of charged particles in fields. Electric and magnetic properties of matter. Direct and alternating currents. Maxwell’s equations. Laboratory work. Prerequisites: PHYS 0040, 0060, or 0160; and MATH 0180, 0200 or 0350. Labs meet every other week.
Fall PHYS0470 S01 16572 MWF 10:00-10:50(14) 'To Be Arranged'.
Fall PHYS0470 L01 16573 T 9:00-11:50 'To Be Arranged'.
Fall PHYS0470 L02 16574 T 2:30-5:20 'To Be Arranged'.
Fall PHYS0470 L03 16575 W 2:00-4:50 'To Be Arranged'.
Fall PHYS0470 L04 16576 Th 9:00-11:50 'To Be Arranged'.
Fall PHYS0470 L05 16577 Th 2:30-5:20 'To Be Arranged'.
Fall PHYS0470 L06 16578 F 2:00-4:50 'To Be Arranged'.

Dynamics of particles, rigid bodies, and elastic continua. Normal modes. Lagrangian and Hamiltonian formulations. Prerequisites: PHYS 0070, 0160 or 0050, 0060 and MATH 0180 or 0200, or approved equivalents.
Spr PHYS0500 S01 25131 MWF 10:00-10:50(03) 'To Be Arranged'.

8 Physics
PHYS 0560. Experiments in Modern Physics.
Introduction to experimental physics. Students perform fundamental experiments in modern quantum physics, including atomic physics, nuclear and particle physics, and condensed matter physics. Visits to research labs at Brown acquaint students with fields of current research. Emphasizes laboratory techniques, statistics, and data analysis. Three lecture/discussion hours and three laboratory hours each week. Required of all physics concentrators. Prerequisites: PHYS 0070, 0160 or 0050, 0060, 0470.

Fall PHYS0560 S01 25132 MWF 11:00-11:50(04) 'To Be Arranged'
Spr PHYS0560 S01 25133 TTh 2:00-2:50(07) 'To Be Arranged'
Spr PHYS0560 S02 25134 Th 9:00-10:50(10) 'To Be Arranged'
Spr PHYS0560 S03 25135 Th 2:30-5:20(11) 'To Be Arranged'
Spr PHYS0560 S04 25136 T 2:30-4:50(12) 'To Be Arranged'
Spr PHYS0560 S05 25137 F 2:00-4:50(13) 'To Be Arranged'

PHYS 0720. Methods of Mathematical Physics.
This course is designed for sophomores in physical sciences, especially those intending to take sophomore or higher level Physics courses. Topics include linear algebra (including linear vector spaces), Fourier analysis, ordinary and partial differential equations, complex analysis (including contour integration). Pre-requisites: PHYS 0060 or 0160, MATH 0180, 0200 or 0350, or consent of the instructor.
Fall PHYS0720 S01 16579 MWF 11:00-11:50(16) 'To Be Arranged'

An introduction to the principles of quantum mechanics and their use in the description of the electronic, thermal, and optical properties of materials. Primarily intended as an advanced science course in the engineering curriculum. Open to others by permission. Prerequisites: ENGN 0040, APMA 0340 or equivalents.
Fall PHYS0790 S01 16580 TTh 9:00-10:20(02) 'To Be Arranged'

PHYS 1100. Introduction to General Relativity.
An introduction to Einstein's theory of gravity, including special relativity, spacetime curvature, cosmology and black holes. Prerequisites: PHYS 0500 and MATH 0520 or MATH 0540 or equivalent, or permission of the instructor. Recommended: PHYS 0720. Offered every other year.

PHYS 1170. Introduction to Nuclear and High Energy Physics.
A study of modern nuclear and particle physics, with emphasis on the theory and interpretation of experimental results. Prerequisites: PHYS 1410, 1420 (may be taken concurrently), or instructor permission.
Spr PHYS1170 S01 25138 MWF 2:00-2:50(07) 'To Be Arranged'

PHYS 1250. Stellar Structure and the Interstellar Medium.
This class is an introduction to the physics of stars and their environment. The course covers the fundamental physics that set the physical properties of stars, such as their luminosity, size, spectral properties and how these quantities evolve with time. In addition, it includes a study of the physics that takes place in the gaseous environment surrounding stars, the InterStellar Medium (ISM). The ISM is very important because it contains a wealth of information on the evolutionary history of galaxies, their composition, formation and future. Prerequisites: PHYS 0270, PHYS 0470, or instructor permission. PHYS 1530 (perhaps taken concurrently) is strongly recommended but not required.
Fall PHYS1250 S01 16581 TTh 1:00-2:20(08) 'To Be Arranged'

PHYS 1280. Introduction to Cosmology.
The course presents an introduction to the study of the origin, evolution and contents of the Universe. Topics include the expansion of the Universe, relativistic cosmologies, thermal evolution, primordial nucleosynthesis, structure formation and the Cosmic Microwave Background. Prerequisites: PHYS 0160, MATH 0190, MATH 0200, or MATH 0350, or instructor permission.

PHYS 1410. Quantum Mechanics A.
A unified treatment of quanta, photons, electrons, atoms, molecules, matter, nuclei, and particles. Quantum mechanics developed at the start and used to link and explain both the older and newer experimental phenomena of modern physics. Prerequisites: PHYS 0500 and 0560; and MATH 0520, 0540 or PHYS 0720; or approved equivalents.
Fall PHYS1410 S01 16583 MWF 9:00-9:50(01) 'To Be Arranged'

PHYS 1420. Quantum Mechanics B.
See Quantum Mechanics A. (PHYS 1410) for course description.
Spr PHYS1420 S01 25156 MWF 9:00-9:50(02) 'To Be Arranged'

PHYS 1510. Advanced Electromagnetic Theory.
Maxwell's laws and electromagnetic theory. Electromagnetic waves and radiation. Special relativity. Prerequisites: PHYS 0470; and MATH 0180, 0200, or 0350; or approved equivalents.
Fall PHYS1510 S01 16584 TTh 2:30-3:50(03) 'To Be Arranged'

PHYS 1530. Thermodynamics and Statistical Mechanics.
The laws of thermodynamics and heat transfer. Atomic interpretation in terms of kinetic theory and elementary statistical mechanics. Applications to physical problems. Prerequisites: MATH 0180 or 0200 or 0350.
Corequisite: PHYS 1410.
Fall PHYS1530 S01 16585 TTh 10:30-11:50(13) 'To Be Arranged'

PHYS 1560. Modern Physics Laboratory.
A sequence of intensive, advanced experiments often introducing sophisticated techniques. Prerequisites: PHYS 0470, 0500 and 0560; and MATH 0520, 0540 or PHYS 0720; or approved equivalents.
Spr PHYS1560 S01 25139 TTh 9:00-10:20(01) 'To Be Arranged'
Spr PHYS1560 L01 25140 TTh 2:30-4:50(02) 'To Be Arranged'
Spr PHYS1560 L02 25141 WF 2:00-4:50(03) 'To Be Arranged'

PHYS 1600. Computational Physics.
This course provides students with an introduction to scientific computation, primarily as applied to physical science problems. It will assume a basic knowledge of programming and will focus on how computational methods can be used to study physical systems complementing experimental and theoretical techniques. Prerequisites: PHYS 0070, 0160 (or 0050, 0060) and 0470 (or ENGN 0510); MATH 0180 or 0200 or 0350; the ability to write a simple computer program in Fortran, Matlab, C or C++.
Spr PHYS1600 S01 25142 TTh 2:30-3:50(11) 'To Be Arranged'

PHYS 1610. Biological Physics.
Introduction on structures of proteins, nucleotides, and membranes; electrostatics and hydration; chemical equilibrium; binding affinity and kinetics; hydrodynamics and transport; cellular mechanics and motions; biophysical techniques including sedimentation, electrophoresis, microscopy and spectroscopy. Suitable for undergraduate science and engineering majors and graduate students with limited background in life science. Prerequisites: MATH 0180.
Fall PHYS1610 S01 16586 MWF 1:00-1:50(06) 'To Be Arranged'

PHYS 1970A. Stellar Physics and the Interstellar Medium.
No description available.

PHYS 1970B. Topics in Optics.
Introduction to optical principles and techniques. Offered to students who have a foundation in physics and are especially interested in optics. The course covers the interaction of light with matter, geometric and wave optics, polarization, fluorescence, and optical instruments (e.g., interferometer, spectrometer, microscope and telescope). Recommended are one physics course (PHYS 0440, PHYS 0600, or ENGN 0440) and one calculus course (MATH 0180, MATH 0200, or MATH 0350), or per instructor's permission.
This course will concentrate on String Theory. It will be given at
introductory/intermediate level with some review of the background
material. Topics covered will include dynamical systems, symmetries and
Noether’s Theorem; nonrelativistic strings; relativistic systems (particle
and string); quantization, gauge fixing, Feynman’s sum over paths;
electrostatic analogy; string in curved space-time; and supersymmetry.
Some advanced topics will also be addressed, i.e., D-Branes and M-
Theory. Recommended prerequisites: PHYS 0470 and 0500, or 0160.
Fall PHYS1970C S01 16598  TTh 9:00-10:20(02)  ‘To Be Arranged’

PHYS 1970F. Quantum Information.
Quantum information is the modern study of how to encode and transmit
information on the quantum scale—in many ways fundamentally different
from classical information. This course will connect a standard treatment
of Quantum mechanics with information theory. Some topics will overlap
with phys 1410, but information will be presented from a different viewpoint
and with new applications. Topics covered will include: measurement,
quantum states, bits, density of states, entanglement, quantum information
processing, computing, and some special topics. Students will be
expected to complete an end of term project for successful completion of
the course.

Topology is a study of the robust properties of geometry, the global stuff
that survives wiggles. Topological matter is matter that possesses robust
properties that can survive a bit of crud, to the delight of its discoverers. It
has breathed new life into topics that have been in textbooks for 75 years.
Topics covered include Band Theory, Berry Phase, Topological Insulators,
and the Quantum Hall Effect.

PHYS 1970J. Introduction to Fluids.
An introduction to fluids from the perspective of a physicist, this course will
use discussion-based, small-group, and interactive pedagogy to explore
and learn fundamental aspects of fluids: ideal, viscous, and planetary flows
as well as turbulence, boundary layers, and waves. Student preference
and feedback will be a major component in determining the topics to be
covered as well as how class time is spent. This is recommended as an
advanced undergraduate course for Physics majors who have completed
their core coursework.

Designed for undergraduates to participate, individually or in small groups,
in research projects mentored by the physics faculty. Students must have
taken one year of college level physics. An average of 8 to 10 hours
per week of guided research is required as are weekly meetings with
the supervising faculty member. Students should consult with faculty
to find a mutually agreeable research project and obtain permission to
enroll. Section number varies by instructor (students must register for the
appropriate section).

PHYS 1990. Senior Conference Course.
Preparation of thesis project. Required of candidates for the degree of
bachelor of science with a concentration in physics. Section numbers vary
by instructor. Please check Banner for the correct section number and
CRN to use when registering for this course.

PHYS 2010. Techniques in Experimental Physics.
No description available.
Fall PHYS2010 S01 16588  W 3:00-5:30(17)  ‘To Be Arranged’
Spr PHYS2010 S01 25144  M 3:00-5:30(13)  ‘To Be Arranged’

An introduction to methods of mathematical analysis in physical science
and engineering. The first semester course includes linear algebra and
tensor analysis; analytic functions of a complex variable; integration in
the complex plane; potential theory. The second semester course includes
probability theory; eigenvalue problems; calculus of variations and
extremum principles; wave propagation; other partial differential
equations of evolution.

PHYS 2030. Classical Theoretical Physics I.
No description available.
Fall PHYS2030 S01 16590  TTh 9:00-10:20(02)  ‘To Be Arranged’

PHYS 2040. Classical Theoretical Physics II.
No description available.

PHYS 2050. Quantum Mechanics.
No description available.
Fall PHYS2050 S01 16591  MWF 10:00-10:50(14)  ‘To Be Arranged’

PHYS 2060. Quantum Mechanics.
No description available.
Spr PHYS2060 S01 25146  MWF 10:00-10:50(03)  ‘To Be Arranged’

PHYS 2070. Advanced Quantum Mechanics.
No description available.
Fall PHYS2070 S02 16593  TTh 1:00-2:20(08)  ‘To Be Arranged’
Spr PHYS2100 S01 25149  TTh 1:00-2:20(08)  ‘To Be Arranged’

PHYS 2100. General Relativity and Cosmology.
Given every other year.
Spr PHYS2100 S01 25149  TTh 1:00-2:20(08)  ‘To Be Arranged’

PHYS 2140. Statistical Mechanics.
No description available.
Spr PHYS2140 S01 25151  TTh 1:00-2:20(08)  ‘To Be Arranged’

PHYS 2170. Introduction to Nuclear and High Energy Physics.
No description available.

PHYS 2280. Astrophysics and Cosmology.
This course serves as a graduate-level introduction to modern cosmology,
including current topics of research on both observational and theoretical
fronts. Topics include relativistic cosmology, inflation and the early
Universe, observational cosmology, galaxy formation. Prerequisites for
undergraduates: PHYS 1280 and PHYS 1530.

PHYS 2300. Quantum Theory of Fields I.
No description available.
Spr PHYS2300 S01 25152  TTh 9:00-10:20(01)  ‘To Be Arranged’

PHYS 2320. Quantum Theory of Fields II.
No description available. Instructor permission required.
Fall PHYS2320 S01 16594  TTh 10:30-11:50(13)  ‘To Be Arranged’

PHYS 2340. Group Theory.
Offered every other year.

PHYS 2410. Solid State Physics I.
No description available.
Fall PHYS2410 S01 16595  MWF 12:00-12:50(15)  ‘To Be Arranged’

PHYS 2420. Solid State Physics II.
No description available.
Spr PHYS2420 S01 25153  TTh 10:30-11:50(09)  ‘To Be Arranged’

PHYS 2430. Quantum Many Body Theory.
No description available.
Fall PHYS2430 S01 16596  TTh 10:30-11:50(13)  ‘To Be Arranged’

PHYS 2450. Exchange Scholar Program.
Fall PHYS2450 S01 15330  Arranged ‘To Be Arranged’
Spr PHYS2450 S01 24213  Arranged ‘To Be Arranged’

PHYS 2470. Advanced Statistical Mechanics.
No description available.

PHYS 2600. Computational Physics.
This course provides students with an introduction to scientific
computation at the graduate level, primarily as applied to physical science
problems. It will assume a basic knowledge of programming and will focus
on how computational methods can be used to study physical systems
complementing experimental and theoretical techniques. Prerequisites:
PHYS 2030, 2050, 2140; the ability to write a simple computer program in
Fortran, Matlab, C or C++.
Spr PHYS2600 S01 25154  TTh 2:30-3:50(11)  ‘To Be Arranged’

PHYS 2610A. Selected Topics in Modern Cosmology.
Aims to provide a working knowledge of some main topics in modern
cosmology. Combines study of the basics with applications to current
research.

PHYS 2610B. Theory of Relativity.
No description available.
PHYS 2610C. Selected Topics in Condensed Matter Physics.
The course is an advanced exploration of condensed matter physics. Selected topics include: nanoscale physics, materials, and devices; spintronics and magnetism; high temperature superconductivity; strongly correlated systems; Bose-Einstein condensates; and applications of condensed matter physics. Additional topics may be introduced based on current research. The course will help students broaden their scope of knowledge in condensed matter physics, learn how to leverage their existing background to select and conduct research, and develop a sense of how to build their professional career based on condensed matter physics.

PHYS 2610D. Selected Topics in Condensed Matter Physics.
The course is the graduate version of Phys 1610, Biological Physics. The course will cover major aspects of conducting physics analysis from colliders, with the emphasis given to physics at the Large Hadron Collider. The course will cover basic aspects of conducting precision measurements and searches for new physics at modern high-energy colliders, with the emphasis given to physics at the Large Hadron Collider. The course will cover major aspects of conducting physics analysis from the underlying theory to experimental methods, such as optimization of the analysis, multivariate analysis techniques, use of statistical methods to establish a signal or set the limit. There will be reading assignments, in-class student presentations, and hands-on exercises offered as part of the course. Prerequisites: PHYS 1170 or 2170. Open to graduate students in Physics and Math.

PHYS 2980. Research in Physics.
For graduate students who have met the tuition requirement and are paying the registration fee to continue active enrollment while preparing for a preliminary examination. Section numbers vary by instructor. Please check Banner for the correct section number and CRN to use when registering for this course.

PHYS 2981. Research in Physics.
For graduate students who have met the residency requirement and are paying the registration fee to continue active enrollment while preparing for a preliminary examination. Section numbers vary by instructor. Please check Banner for the correct section number and CRN to use when registering for this course.

PHYS 2970. Preliminary Examination Preparation.
For graduate students who have met the tuition requirement and are paying the registration fee to continue active enrollment while preparing for a preliminary examination. Section numbers vary by instructor. Please check Banner for the correct section number and CRN to use when registering for this course.

PHYS 2710. Seminar in Research Topics.
Instruction via reading assignments and seminars for graduate students on research projects. Credit may vary. Section numbers vary by instructor. Please check Banner for the correct section number and CRN to use when registering for this course.

PHYS 2711. Seminar in Research Topics.
See Seminar In Research Topics (PHYS 2710) for course description. Section numbers vary by instructor. Please check Banner for the correct section number and CRN to use when registering for this course.

PHYS 2790. Thesis Preparation.
For graduate students who have met the residency requirement and are continuing research on a full-time base.

PHYS 2710F. Selected Topics in Physics of Locomotion.
The special topics graduate course deals with the physical processes involved in the locomotion of organisms, with a particular focus on locomotion at small scales in fluids. Topics include mechanisms of swimming motility for microorganisms, fluid mechanics at low Reynolds number, diffusion and Brownian motion, physical actuation, hydrodynamic interactions, swimming in complex fluids, artificial swimmers, and optimization. Prerequisites: (PHYS 0470 or ENGN 0510) and (PHYS 0500 or ENGN 0810 or ENGN 1370), or permission of the instructor.

PHYS 2620A. Astrophysical and Cosmological Constraints on Particle Physics.
No description available.

PHYS 2620B. Green's Functions and Ordered Exponentials.
No description available.

PHYS 2620C. Introduction to String Theory.
No description available.

PHYS 2620D. Modern Cosmology.
No description available.

PHYS 2620E. Selected Topics in Quantum Mechanics: Fuzzy Physics.
No description available.

PHYS 2620F. Selected Topics in Molecular Biophysics.
No description available.

PHYS 2620G. The Standard Model and Beyond.
Topics to be covered will include: Yang-Mills theory, origin of masses and couplings of particles, effective field theory, renormalization, confinement, lattice gauge theory, anomalies and instantons, grand unification, magnetic monopoles, technicolor, introduction to supersymmetry, supersymmetry breaking, the Minimal Supersymmetric Standard Model, and dark matter candidates. Prerequisite: PHYS 2300.

PHYS 2630. Biological Physics.
The course is the graduate version of Phys 1610, Biological Physics. The topics to be covered include structure of cells and biological molecules; diffusion, dissipation and random motion; flow and friction in fluids; entropy, temperature and energy; chemical reactions and self-assembly; solution electrostatics; action potential and nerve impulses. The graduate level course has additional pre-requisites of Phys 0470 and 1530, or equivalents. It requires homework assignments at the graduate level. The final grades will be assigned separately from those who take the course as Phys 1610, although the two groups may be taught in the same classroom.
Font Notice

This document should contain certain fonts with restrictive licenses. For this draft, substitutions were made using less legally restrictive fonts. Specifically:

Helvetica was used instead of Arial.

The editor may contact Leepfrog for a draft with the correct fonts in place.