Physics

Physics is the discipline that deals with the most fundamental aspects of our universe, such as the properties of atoms, nuclei and elementary particles; the nature of the forces between them; and the collective behavior of atoms in solids, liquids and gases. It deals with the entire universe, from its birth to its ultimate fate.

At the same time, physics provides the tools that help us to understand extremely complex everyday things, like the behavior of sand piles, the strength of materials, or processes in the brain. Physics seeks to discover and understand the mathematical rules that govern the behavior of things. Its early successes in comprehending motion, thermodynamics, electricity and magnetism provided a foundation upon which other physical sciences have grown.

For students planning a career in science and technology or intending to pursue graduate studies in physics, astronomy, earth sciences, environmental sciences, medical physics, meteorology or oceanography, a major in physics provides a solid foundation. The program is sufficiently flexible to allow students to combine a physics major with a second major in chemistry, mathematics or engineering; with pre-medical studies; or with other disciplines in the humanities and social sciences. In addition to the fundamentals of physics, the program is designed to give students a broad range of skills in laboratory techniques, critical thinking, computer use and teamwork, which will serve them well in their chosen careers. In consultation with a faculty adviser, students may design a program of study to meet individual goals and interests. Physics majors are strongly encouraged to participate in physics research projects directed by faculty members.

Introductory Physics: The Physics 191–Physics 192 and Physics 191L–Physics 192L sequence is a calculus-based introduction to physics intended for adequately prepared students interested in majoring in science or engineering or undertaking pre-medical studies. Physics 191 fulfills the requirements for the Sam Fox School. The sequence uses interactive, active-learning techniques. Calculus I (Math 131) is a corequisite, although previous or concurrent enrollment in Calculus II (Math 132) is strongly recommended.

The department also offers several other courses of general interest to the non-science student. In most cases, these courses have no prerequisites.

Website: http://physics.wustl.edu

Faculty

Chair

Mark Alford (https://physics.wustl.edu/people/mark-g-alford)
Professor
PhD, Harvard University
Nuclear/particle physics

Endowed Professors

Ramanath Cowsik (https://physics.wustl.edu/people/ramanath-cowsik)
James S. McDonnell Professor of Space Sciences
PhD, University of Bombay
Astrophysics and space sciences

Kenneth F. Kelton (https://physics.wustl.edu/people/kenneth-f-kelton)
Arthur Holly Compton Professor of Physics
PhD, Harvard University
Condensed matter and materials physics

Professors

James H. Buckley (https://physics.wustl.edu/people/james-h-buckley)
PhD, University of Chicago
Experimental high-energy astrophysics

Anders E. Carlsson (https://physics.wustl.edu/people/anders-e-carlsson)
PhD, Harvard University
Biophysics

Willem H. Dickhoff (https://physics.wustl.edu/people/willem-h-dickhoff)
PhD, Free University, Amsterdam
Many-body theory

Martin H. Israel (https://physics.wustl.edu/people/martin-h-israel)
PhD, California Institute of Technology
Experimental cosmic-ray physics

Jonathan I. Katz (https://physics.wustl.edu/people/jonathan-i-katz)
PhD, Cornell University
Theoretical astrophysics

Henric Krawczynski (https://physics.wustl.edu/people/henric-krawczynski)
PhD, University of Hamburg
Experimental high-energy astrophysics

Zohar Nussinov (https://physics.wustl.edu/people/zohar-nussinov)
PhD, University of California, Los Angeles
Theoretical condensed matter physics
Joint Professors
PhD, University of Toronto
(Mechanical Engineering)
Lee G. Sobotka (https://physics.wustl.edu/people/lee-sobotka)
PhD, University of California, Berkeley
(Chemistry)
Experimental nuclear physics

Associate Professors
Francesc Ferrer (https://physics.wustl.edu/people/francesc-ferrer)
PhD, Universitat Autònoma de Barcelona
Theoretical astro-particle physics & cosmology
Kater Murch (https://physics.wustl.edu/people/kater-murch)
PhD, University of California, Berkeley
Quantum information and materials
Alexander Seidel (https://physics.wustl.edu/people/alexander-seidel)
PhD, Massachusetts Institute of Technology
Theoretical condensed matter physics
Li Yang (https://physics.wustl.edu/people/li-yang)
PhD, Georgia Institute of Technology
Condensed matter and materials science

Assistant Professors
Bhupal Dev (https://physics.wustl.edu/people/bhupal-dev)
PhD, University of Maryland, College Park
Theoretical astro-particle physics & cosmology
Erik Henriksen (https://physics.wustl.edu/people/erik-henriksen)
PhD, Columbia University
Condensed matter and materials science
Shankar Mukherji (https://physics.wustl.edu/people/shankar-mukherji)
PhD, Massachusetts Institute of Technology/Harvard Medical School
Systems cell biology
Ryan Ogliore (https://physics.wustl.edu/people/ryan-ogliore)
PhD, California Institute of Technology
Cosmochemistry, planetary science

Saori Pastore
PhD, Old Dominion University
Theoretical nuclear physics
Maria Piarulli
PhD, Old Dominion University
Theoretical nuclear physics
Mikhail Tikhonov (https://physics.wustl.edu/people/mikhail-tikhonov)
PhD, Princeton University
Microbiome, microbial ecology and evolution

Lecturer
Mairin Hynes (https://physics.wustl.edu/people/kathryn-mairin-hynes)
PhD, Washington University

Research Professors
Sachiko Amari (https://physics.wustl.edu/people/sachiko-amari)
PhD, Kobe University
Robert Binns (https://physics.wustl.edu/people/w-robert-binns)
PhD, Colorado State University
Alexander Meshik (https://physics.wustl.edu/people/alex-meshik)
PhD, Vernadsky Institute of Cosmochemistry
Michael Nowak
PhD, Stanford University

Research Associate Professor
Olga Pravdivtseva (https://physics.wustl.edu/people/olga-pravdivtseva)
PhD, Vernadsky Institute, Russian Academy of Sciences

Research Assistant Professors
Nan Lui (https://physics.wustl.edu/people/nan-liu)
PhD, University of Chicago
Brian Rauch (https://physics.wustl.edu/people/brian-rauch)
PhD, Washington University

Professors Emeriti
Carl M. Bender (https://physics.wustl.edu/people/carl-bender)
Wilfred R. and Ann Lee Konneker Professor of Physics
PhD, Harvard University
Claude W. Bernard (https://physics.wustl.edu/people/claude-bernard-0)
PhD, Harvard University
Thomas Bernatowicz (https://physics.wustl.edu/people/thomas-j-bernatowicz)
PhD, Washington University
John W. Clark (https://physics.wustl.edu/people/john-w-clark)  
Wayman Crow Professor of Physics  
PhD, Washington University

Mark S. Conradi (https://physics.wustl.edu/people/mark-s-conradi)  
PhD, Washington University

Peter A. Fedders (https://physics.wustl.edu/people/peter-fedders)  
PhD, Harvard University

Michael W. Friedlander (https://physics.wustl.edu/people/michael-w-friedlander)  
PhD, University of Bristol

Patrick C. Gibbons (https://physics.wustl.edu/people/patrick-c-gibbons)  
PhD, Harvard University

Charles M. Hohenberg (https://physics.wustl.edu/people/charles-m-hohenberg)  
PhD, University of California, Berkeley

Kazimierz Luszczynski (https://physics.wustl.edu/people/kazimierz-luszczynski)  
PhD, University of London

James G. Miller (https://physics.wustl.edu/people/james-g-miller)  
Albert Gordon Hill Professor of Physics  
PhD, Washington University

Peter R. Phillips (https://physics.wustl.edu/people/peter-r-phillips)  
PhD, Stanford University

John H. Scandrett (https://physics.wustl.edu/people/john-h-scandrett)  
PhD, University of Wisconsin-Madison

James S. Schilling (https://physics.wustl.edu/people/james-s-schilling)  
PhD, University of Wisconsin-Madison

Stuart A. Solin (https://physics.wustl.edu/people/stuart-solin-0)  
Charles M. Hohenberg Professor of Experimental Physics  
PhD, Purdue University

Wai-Mo Suen (https://physics.wustl.edu/people/wai-mo-suen-0)  
PhD, California Institute of Technology

Clifford Will (https://physics.wustl.edu/people/clifford-m-will)  
PhD, California Institute of Technology

**Majors**

**The Major in Physics**

Total units required: 42

Required courses: Majors in physics are required to complete the following courses:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics 191</td>
<td>Physics I</td>
<td>3</td>
</tr>
<tr>
<td>Physics 191L</td>
<td>Physics I Laboratory</td>
<td>1</td>
</tr>
<tr>
<td>Physics 192</td>
<td>Physics II</td>
<td>3</td>
</tr>
<tr>
<td>Physics 192L</td>
<td>Physics II Laboratory</td>
<td>1</td>
</tr>
<tr>
<td>Physics 322</td>
<td>Physical Measurement Laboratory</td>
<td>3</td>
</tr>
<tr>
<td>Physics 411</td>
<td>Mechanics</td>
<td>3</td>
</tr>
<tr>
<td>Physics 421</td>
<td>Electricity and Magnetism</td>
<td>3</td>
</tr>
</tbody>
</table>

Total Units: 17

Physics 201 and 204 are also recommended for physics majors.

**One quantum physics course.** Choose from the following:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics 217</td>
<td>Introduction to Quantum Physics</td>
<td>3</td>
</tr>
<tr>
<td>Physics 318</td>
<td>Introduction to Quantum Physics II</td>
<td>3</td>
</tr>
<tr>
<td>Physics 471</td>
<td>Quantum Mechanics</td>
<td>3</td>
</tr>
</tbody>
</table>

Note that Physics 217 does not fulfill the requirement of an upper-level course.

**One additional upper-level laboratory course.** Choose from the following:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics 316</td>
<td>Optics and Wave Physics Laboratory</td>
<td>3</td>
</tr>
<tr>
<td>Physics 321</td>
<td>Electronics Laboratory</td>
<td>3</td>
</tr>
<tr>
<td>Physics 360</td>
<td>Biophysics Laboratory</td>
<td>3</td>
</tr>
<tr>
<td>Physics 435</td>
<td>Nuclear and Radiochemistry Lab</td>
<td>3</td>
</tr>
</tbody>
</table>

**Upper-Level Courses.** Majors are required to complete a minimum of 21 units of advanced courses (300-level or higher), excluding Physics 341, Physics 342, Physics 441, Physics 442, Physics 499 and Physics 500. These 21 units include courses listed above.

**Math courses required for the physics major:**

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Math 131</td>
<td>Calculus I</td>
<td>3</td>
</tr>
<tr>
<td>Math 132</td>
<td>Calculus II</td>
<td>3</td>
</tr>
<tr>
<td>Math 233</td>
<td>Calculus III</td>
<td>3</td>
</tr>
<tr>
<td>Math 217</td>
<td>Differential Equations (We recommend that Math 217 precede Physics 411)</td>
<td>3</td>
</tr>
</tbody>
</table>

Total Units: 12

**Math courses recommended for the physics major:**

- Math 308 Mathematics for the Physical Sciences or ESE 318 Engineering Mathematics A (We recommend that this course precede Physics 421.)
- Math 309 Matrix Algebra (We recommend that Math 309 precede Physics 471.)
• Physics 501/Math 501 and Physics 502/Math 502 also are recommended.

**Science-breadth requirement:** Majors must select three of the following courses to satisfy the science-breadth requirement. One of the three courses must be Chem 105, Chem 106, Chem 111A, Chem 112A, Chem 401 or Chem 402.

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chem 105</td>
<td>Introductory General Chemistry I</td>
<td>3</td>
</tr>
<tr>
<td>Chem 106</td>
<td>Introductory General Chemistry II</td>
<td>3</td>
</tr>
<tr>
<td>Chem 111A</td>
<td>General Chemistry I</td>
<td>3</td>
</tr>
<tr>
<td>Chem 112A</td>
<td>General Chemistry II</td>
<td>3</td>
</tr>
<tr>
<td>Chem 151</td>
<td>General Chemistry Laboratory I</td>
<td>2</td>
</tr>
<tr>
<td>Chem 152</td>
<td>General Chemistry Laboratory II</td>
<td>2</td>
</tr>
<tr>
<td>Chem 401</td>
<td>Physical Chemistry I</td>
<td>3</td>
</tr>
<tr>
<td>Chem 402</td>
<td>Physical Chemistry II</td>
<td>3</td>
</tr>
<tr>
<td>Chem 445</td>
<td>Instrumental Methods: Physical Chemistry</td>
<td>3</td>
</tr>
<tr>
<td>CSE 131</td>
<td>Introduction to Computer Science</td>
<td>3</td>
</tr>
<tr>
<td>CSE 132</td>
<td>Introduction to Computer Engineering</td>
<td>3</td>
</tr>
<tr>
<td>CSE 247</td>
<td>Data Structures and Algorithms</td>
<td>3</td>
</tr>
</tbody>
</table>

**Biophysics Track**

Physics majors may concentrate in the subfield of biophysics by taking the following (as part of their distribution requirement):

**Physics requirement:**

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics 463</td>
<td>Statistical Mechanics and Thermodynamics</td>
<td>3</td>
</tr>
</tbody>
</table>

One of the following:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics 450</td>
<td>Physics of the Brain</td>
<td>3</td>
</tr>
<tr>
<td>Physics 455</td>
<td>Physics of Vision</td>
<td>3</td>
</tr>
</tbody>
</table>

One of the following:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics 454</td>
<td>Physics of Living Systems</td>
<td>3</td>
</tr>
<tr>
<td>Physics 509</td>
<td>Nonlinear Dynamics</td>
<td>3</td>
</tr>
<tr>
<td>Physics 563</td>
<td>Topics in Theoretical Biophysics</td>
<td>3</td>
</tr>
</tbody>
</table>

**Biology requirements:**

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biol 2960</td>
<td>Principles of Biology I</td>
<td>4</td>
</tr>
<tr>
<td>Biol 2970</td>
<td>Principles of Biology II</td>
<td>4</td>
</tr>
</tbody>
</table>

**Note:** Students wanting to have the biophysics track displayed on their transcript must send an email to the director of undergraduate studies (dus@physics.wustl.edu) at least one semester before their graduation date.

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**The Major in Astrophysics**

Total units required: 47

**Required courses:** Majors in astrophysics are required to complete the following courses:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics 191</td>
<td>Physics I</td>
<td>3</td>
</tr>
<tr>
<td>Physics 191L</td>
<td>Physics I Laboratory</td>
<td>1</td>
</tr>
<tr>
<td>Physics 192</td>
<td>Physics II</td>
<td>3</td>
</tr>
<tr>
<td>Physics 192L</td>
<td>Physics II Laboratory</td>
<td>1</td>
</tr>
<tr>
<td>Physics 312</td>
<td>Introduction to Astrophysics</td>
<td>3</td>
</tr>
<tr>
<td>Physics 322</td>
<td>Physical Measurement Laboratory</td>
<td>3</td>
</tr>
<tr>
<td>Physics 411</td>
<td>Mechanics</td>
<td>3</td>
</tr>
<tr>
<td>Physics 421</td>
<td>Electricity and Magnetism</td>
<td>3</td>
</tr>
</tbody>
</table>

Total Units: 20

Physics 201 and 204 are recommended for physics majors.

**One quantum physics course.** Choose from the following:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics 217</td>
<td>Introduction to Quantum Physics</td>
<td>3</td>
</tr>
<tr>
<td>Physics 318</td>
<td>Introduction to Quantum Physics II</td>
<td>3</td>
</tr>
<tr>
<td>Physics 471</td>
<td>Quantum Mechanics</td>
<td>3</td>
</tr>
</tbody>
</table>

**One additional laboratory course.** Choose from the following:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics 316</td>
<td>Optics and Wave Physics Laboratory</td>
<td>3</td>
</tr>
<tr>
<td>Physics 321</td>
<td>Electronics Laboratory</td>
<td>3</td>
</tr>
<tr>
<td>Physics 435</td>
<td>Nuclear and Radiochemistry Lab</td>
<td>3</td>
</tr>
</tbody>
</table>

**Required advanced courses:** In addition to the above requirements, students who are earning the astrophysics major are required to complete three advanced electives from the following list:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics 446</td>
<td>Galactic Astrophysics</td>
<td>3</td>
</tr>
<tr>
<td>Physics 456</td>
<td>Stellar Astrophysics</td>
<td>3</td>
</tr>
<tr>
<td>Physics 460</td>
<td>X-Ray &amp; Gamma-Ray Astrophysics</td>
<td>3</td>
</tr>
<tr>
<td>Physics 478</td>
<td>From Black Holes to the Big Bang</td>
<td>3</td>
</tr>
</tbody>
</table>

They must also complete one additional course from the preceding list of four courses or one from the following list of courses (3 units):

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics 422</td>
<td>Electricity and Magnetism II</td>
<td>3</td>
</tr>
<tr>
<td>Physics 474</td>
<td>Introduction to Particle Physics</td>
<td>3</td>
</tr>
<tr>
<td>Physics 477</td>
<td>Physics of Finite and Infinite Nuclear Systems</td>
<td>3</td>
</tr>
<tr>
<td>Physics 547</td>
<td>Intro to Elementary Particle Physics</td>
<td>3</td>
</tr>
</tbody>
</table>
Math courses required for the astrophysics major:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Math 131</td>
<td>Calculus I</td>
<td>3</td>
</tr>
<tr>
<td>Math 132</td>
<td>Calculus II</td>
<td>3</td>
</tr>
<tr>
<td>Math 233</td>
<td>Calculus III</td>
<td>3</td>
</tr>
<tr>
<td>Math 217</td>
<td>Differential Equations</td>
<td>3</td>
</tr>
<tr>
<td>Total Units</td>
<td></td>
<td>12</td>
</tr>
</tbody>
</table>

Science-breadth requirement: Majors must select one of the following courses to satisfy the science-breadth requirement:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chem 105</td>
<td>Introductory General Chemistry I</td>
<td>3</td>
</tr>
<tr>
<td>Chem 106</td>
<td>Introductory General Chemistry II</td>
<td>3</td>
</tr>
<tr>
<td>Chem 111A</td>
<td>General Chemistry I</td>
<td>3</td>
</tr>
<tr>
<td>Chem 112A</td>
<td>General Chemistry II</td>
<td>3</td>
</tr>
<tr>
<td>Chem 151</td>
<td>General Chemistry Laboratory I</td>
<td>2</td>
</tr>
<tr>
<td>Chem 152</td>
<td>General Chemistry Laboratory II</td>
<td>2</td>
</tr>
<tr>
<td>Chem 401</td>
<td>Physical Chemistry I</td>
<td>3</td>
</tr>
<tr>
<td>Chem 402</td>
<td>Physical Chemistry II</td>
<td>3</td>
</tr>
<tr>
<td>Chem 445</td>
<td>Instrumental Methods: Physical Chemistry</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 201</td>
<td>Earth and the Environment</td>
<td>4</td>
</tr>
<tr>
<td>Total Units</td>
<td></td>
<td>14</td>
</tr>
</tbody>
</table>

Additional Information

Senior Honors: Students are encouraged to work toward Latin Honors (i.e., cum laude, magna cum laude, and summa cum laude). To qualify, students must meet the academic requirements of the college and successfully complete a suitable project under the supervision of a faculty member in the department. The project, whether experimental or theoretical, should demonstrate the student's capacity for independent work.

Honors candidates must apply to the Undergraduate Studies Committee no later than the the first day of classes of their senior year. The application should include a description of the proposed project that has been co-signed by the supervising professor. A written report of the completed work must be submitted to the committee by a deadline in March. By enrolling in Physics 499, students may earn up to 6 units of credit for the honors project.

The physics department also offers physics majors the possibility to earn departmental distinctions. These distinctions require the same grade-point average cutoffs as Latin Honors (http://bulletin.wustl.edu/undergrad/artsci/honors) but are calculated exclusively from the grades in physics courses (i.e., all courses with the prefix L31). Three levels of distinction are offered: (1) highest distinction; (2) high distinction; and (3) distinction. The highest and high distinctions require at least one semester of undergraduate research and a senior thesis describing the results; these distinctions are limited to the top 15 percent (highest distinction) and the top 15 to 50 percent (high distinction) of the physics majors in their senior year as ranked by their GPA in the physics courses. Students who meet the GPA cutoff but who do not undertake undergraduate research and a senior thesis may only receive the third level of distinction.

Minors

The Minor in Physics

Units required: 17

Required courses:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics 191</td>
<td>Physics I</td>
<td>3</td>
</tr>
<tr>
<td>Physics 191L</td>
<td>Physics I Laboratory</td>
<td>1</td>
</tr>
<tr>
<td>Physics 192</td>
<td>Physics II</td>
<td>3</td>
</tr>
<tr>
<td>Physics 192L</td>
<td>Physics II Laboratory</td>
<td>1</td>
</tr>
<tr>
<td>Physics 217</td>
<td>Introduction to Quantum Physics</td>
<td>3</td>
</tr>
<tr>
<td>Physics 318</td>
<td>Introduction to Quantum Physics II</td>
<td>3</td>
</tr>
<tr>
<td>Total Units</td>
<td></td>
<td>14</td>
</tr>
</tbody>
</table>

Elective courses:

At least one course at the 300 level or above (with the exception of Physics 303, Physics 304, Physics 341, Physics 342, Physics 441, Physics 442, Physics 499 and Physics 500) with a grade of C- or better.

The Minor in Astrophysics and Astroparticle Physics

Units required: 20

Required courses:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics 191</td>
<td>Physics I</td>
<td>3</td>
</tr>
<tr>
<td>Physics 191L</td>
<td>Physics I Laboratory</td>
<td>1</td>
</tr>
<tr>
<td>Physics 192</td>
<td>Physics II</td>
<td>3</td>
</tr>
<tr>
<td>Physics 192L</td>
<td>Physics II Laboratory</td>
<td>1</td>
</tr>
<tr>
<td>Physics 217</td>
<td>Introduction to Quantum Physics</td>
<td>3</td>
</tr>
<tr>
<td>Physics 312</td>
<td>Introduction to Astrophysics</td>
<td>3</td>
</tr>
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<td>Total Units</td>
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<td>14</td>
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Two of the following six courses:

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<tr>
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</tr>
</thead>
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<tr>
<td>Physics 318</td>
<td>Introduction to Quantum Physics II</td>
<td>3</td>
</tr>
<tr>
<td>Physics 456</td>
<td>Stellar Astrophysics</td>
<td>3</td>
</tr>
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</table>
The Minor in Biomedical Physics

Units required: 17

Required courses:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics 191</td>
<td>Physics I</td>
<td>3</td>
</tr>
<tr>
<td>Physics 191L</td>
<td>Physics I Laboratory</td>
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<tr>
<td>Physics 192</td>
<td>Physics II</td>
<td>3</td>
</tr>
<tr>
<td>Physics 192L</td>
<td>Physics II Laboratory</td>
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<td>Total Units</td>
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Elective courses:

Two of the following three courses:

<table>
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<tr>
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<th>Title</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>Physics 350</td>
<td>Physics of the Brain</td>
<td>3</td>
</tr>
<tr>
<td>Physics 354</td>
<td>Physics of Living Systems</td>
<td>3</td>
</tr>
<tr>
<td>Physics 355</td>
<td>Physics of Vision</td>
<td>3</td>
</tr>
</tbody>
</table>

One of the following four laboratory courses:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics 316</td>
<td>Optics and Wave Physics Laboratory</td>
<td>3</td>
</tr>
<tr>
<td>Physics 321</td>
<td>Electronics Laboratory</td>
<td>3</td>
</tr>
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<td>Physics 322</td>
<td>Physical Measurement Laboratory</td>
<td>3</td>
</tr>
<tr>
<td>Physics 360</td>
<td>Biophysics Laboratory</td>
<td>3</td>
</tr>
</tbody>
</table>

Additional Information

This is a minor for students interested in the discussion and application of methods and techniques from physics to topics in the area of biology and medicine. The program may be of interest to the pre-medicine student or the research-oriented science major. New courses are being developed that will also satisfy these requirements.

Courses


L31 Physics 101A Basic Physical Science

An introduction to the concepts and modes of thought involved in understanding the physical world. The focus is not only on everyday phenomena (e.g., falling objects, skidding cars, the tides) but also on questions of cosmic significance (e.g., relativity, the Big Bang, black holes, the origin of the elements). Verbal reasoning is emphasized. No prerequisites.

Credit 3 units. A&S IQ: NSM, AN BU: SCI

L31 Physics 107A How Things Work

Why is the sky blue? How can a baseball curve? Natural and manmade phenomena can be understood by simple and basic ideas of physics. This course illustrates these underlying principles by using examples from everyday life as well as from physics and other fields. Because the phenomena are many and the principles are few we find that apparently very different events sometimes have similar explanations; we come to understand how the stretching of a rubber band is related to ice skating, and how the blue of the sky is related to the red of the sunset and the white color of milk. No prerequisites.

Credit 3 units. A&S IQ: NSM, AN Art: NSM BU: SCI

L31 Physics 110A Awesome Ideas in Physics

The ideas of physics that have revolutionized our perception of the world and reality. Emphasis is on understanding a selected set of crucial concepts without losing track of the numbers. Using the writings of Hawking, Feynman and Lightman, a study is made of such topics as energy and conservation laws, the relativity of time, the wave-particle duality, the modern picture of matter at the smallest and the largest distance scales, and the history of the universe. Must be taken for a letter grade. No prerequisites.

Credit 3 units. A&S IQ: NSM, AN Art: NSM BU: SCI

L31 Physics 111 Variational Calculus — A Mathematical Blade for Cutting-Edge Science

Variational calculus, a fancy generalization of ordinary calculus, is the study of functionals. In variational calculus one tries to find the special function that extremizes a functional. The applications of variational calculus are ubiquitous in modern science. Variational calculus is the mathematical setting for describing the physical world. In all areas of classical and quantum physics, the physical world is expressed in terms of functions that extremize specific functionals. In this seminar variational calculus is explained at an elementary level and many of its applications in science are examined. A good understanding of elementary first-year calculus is required to take this seminar.

Credit 3 units. A&S: FYS

L31 Physics 125A Solar System Astronomy

Designed for the nonscience major, this course deals with the planets, their moons and rings, comets, meteorites and interplanetary dust particles. In order to understand both classical astronomy and the results obtained from modern telescopes and the space program, basic scientific ideas (including optics and the laws of motion) are reviewed first. There also is some discussion of astronomical history to show how we have arrived at our present ideas of the structure and evolution of the solar system. Prerequisites: high school algebra and trigonometry or concurrent enrollment in Math 131.

Credit 3 units. A&S IQ: NSM, AN Art: NSM BU: SCI

L31 Physics 126A Stars, Galaxies and Cosmology

Intended as a general survey for the nonscience major. Topics include the structure and evolution of stars, such as red giants, white dwarfs, neutron stars, pulsars and black holes; galaxies and quasars; cosmology and the Big Bang theory. Prerequisites: high school algebra and trigonometry, or concurrent enrollment in Math 131.

Credit 3 units. A&S IQ: NSM, AN Arch: NSM Art: NSM BU: SCI
L31 Physics 141 Selected Topics in Physics I
Topics of special interest (e.g., superconductivity, quasicrystals, neural networks, chaos, etc.) may be studied under the supervision of a faculty member, variously by lectures, seminars or individual study or research. Students hoping to arrange such a course must prepare a proposal and secure consent to undertake direction of the course from a faculty member and finally secure approval of the department chair. Credit variable, maximum 3 units. A&S IQ: NSM; AN: BU: SCI

L31 Physics 142 Selected Topics in Physics I
Topics of special interest (e.g., holography, relativity, nuclear power, computer applications in physics, etc.) may be studied under the supervision of a faculty member, variously by lectures, seminars or individual study or research. Students hoping to arrange such a course must prepare a proposal and secure the instructor's consent to undertake direction of the course from a faculty member and finally secure approval of the department chair. Credit variable, maximum 3 units. A&S IQ: NSM; AN: BU: SCI

L31 Physics 171A Physics and Society
Introduction to physics as it applies to the world we have built for ourselves. Energy as a unifying principle of physics and society's use of energy. Atoms, heat, and power. Essentials of conventional and alternative forms of energy. Nuclear energy, including radiation, waste, and weapons. Global climate change. Credit 3 units. A&S IQ: AN; Art: NSM; BU: SCI

L31 Physics 191 Physics I
A calculus-based introduction to the concepts, laws, and structure of physics. Topics include kinematics, Newton's laws, energy, linear momentum, angular momentum, the conservation laws, gravitational force, harmonic motion, wave motion and interference, sound, and special relativity. There are two required evening exams followed by a required final exam. Prerequisite/corequisite: Math 131; previous or concurrent enrollment in Math 132 is also strongly recommended. A combination of Physics 191 and 191L is a replacement for Physics 197. Students may not receive credit for more than one of the following: Physics 117A, 197, and 191. Credit 3 units. A&S IQ: AN; Art: NSM; BU: SCI

L31 Physics 191F Physics I — First-Years Only
This section of Physics 191 is for rising first-years only. Any non-first-year student enrolled in this section will be removed from the course; these students should enroll in Physics 191U. A calculus-based introduction to the concepts, laws, and structure of physics. Topics include kinematics, Newton's laws, energy, linear momentum, angular momentum, the conservation laws, gravitational force, harmonic motion, wave motion and interference, sound, and special relativity. There are two required evening exams followed by a required final exam. Prerequisite/corequisite: Math 131; previous or concurrent enrollment in Math 132 is also strongly recommended. A combination of Physics 191 and 191L is a replacement for Physics 197. Students may not receive credit for more than one of the following: Physics 117A, 197, and 191. Credit 3 units. A&S IQ: AN; Art: NSM; BU: SCI

L31 Physics 191U Physics I — Sophomores, Juniors, and Seniors Only
This section of Physics 191 is for rising sophomore, juniors, and seniors only. Any first-year student enrolled in this section will be removed from the course; first-year students should enroll in Physics 191F. A calculus-based introduction to the concepts, laws, and structure of physics. Topics include kinematics, Newton's laws, energy, linear momentum, angular momentum, the conservation laws, gravitational force, harmonic motion, wave motion and interference, sound, and special relativity. There are two required evening exams followed by a required final exam. Prerequisite/corequisite: Math 131; previous or concurrent enrollment in Math 132 is also strongly recommended. A combination of Physics 191 and 191L is a replacement for Physics 197. Students may not receive credit for more than one of the following: Physics 117A, 197, and 191. Credit 3 units. A&S IQ: AN; BU: SCI

L31 Physics 191L Physics I Laboratory
Laboratory experience is an integral component of introductory physics. It is designed to provide a hands-on opportunity to explore concepts introduced in the lecture course and to develop careful measurement and documentation skills. Prerequisite/corequisite: Physics 191. Students may not receive credit for Physics 191L if they have already received credit for Physics 117A or 197. Credit 1 unit.

L31 Physics 191U Physics I — Sophomores, Juniors, and Seniors Only
This section of Physics 191 is for rising sophomore, juniors, and seniors only. Any first-year student enrolled in this section will be removed from the course; first-year students should enroll in Physics 191F. A calculus-based introduction to the concepts, laws, and structure of physics. Topics include kinematics, Newton's laws, energy, linear momentum, angular momentum, the conservation laws, gravitational force, harmonic motion, wave motion and interference, sound, and special relativity. There are two required evening exams followed by a required final exam. Prerequisite/corequisite: Math 131; previous or concurrent enrollment in Math 132 is also strongly recommended. A combination of Physics 191 and 191L is a replacement for Physics 197. Students may not receive credit for more than one of the following: Physics 117A, 197, and 191. Credit 3 units. A&S IQ: AN; BU: SCI

L31 Physics 197 Physics I
Calculus-based introduction to the central concepts, laws, and structure of physics, presented in an active learning environment. The course is structured around three themes that are treated in-depth: conservation laws, Newtonian physics, and special relativity. A daily regimen of homework and reading, as well as weekly homework assignments, small-group problem-solving exercises, and active class participation are integral parts of this course. Concurrent registration in a Physics 197 lab section is required. Prerequisite: previous or concurrent enrollment in Calculus I (Math 131) is required; previous or concurrent enrollment in Calculus II (Math 132) strongly recommended. Credit may not be obtained for both Physics 117A and Physics 197, and students may not simultaneously enroll in both courses. Credit 4 units. A&S IQ: AN; Art: NSM; BU: SCI

L31 Physics 198 Physics II
Continuation of Physics 197. An advanced, calculus-based introduction to central concepts in physics for students who desire to major in physics or another physical science, or who have a special interest in physics. The course is structured around three themes that are treated in depth: electricity and magnetism, quantum physics, and statistical and thermal physics. A daily regimen of homework and reading as well as active class participation are integral parts of the course. Prerequisites: Physics 197 and Calculus II. Students who have not taken Physics 197 may not register for Physics 198. Concurrent registration in a Physics 198 lab section is required. Credit may not be obtained for both Physics 118 and Physics 198. Credit 4 units. A&S IQ: AN; Art: NSM; BU: SCI

L31 Physics 201 Honors Problem Solving I
This is a problem-solving course for students considering a physics- or mathematics-heavy major. The problems we will
focus on will be more difficult and sophisticated than those encountered in Physics 197. However, the content will be tightly linked to the weekly schedule of Physics 197, and the course will be taught by a Physics 197 instructor. This course is for incoming first-year students and rising sophomores. Prerequisites: concurrent enrollment in Physics 197 or AP physics and permission of the instructor.
Credit 1 unit.

L31 Physics 204 Honors Problem Solving II
This is a problem solving course for students considering a physics or mathematics heavy major. The problems we will focus on will be more difficult and sophisticated than those encountered in Physics 198. However, the content will be tightly linked to the weekly schedule of Physics 198, and the course will be taught by a 198 instructor. This course is for incoming first-year students and rising sophomores. Prerequisites: Concurrent enrollment in Physics 198, AP physics, and permission of the instructor.
Credit 1 units.

L31 Physics 216 Introduction to Relativity: The Special Theory
Introduction to the special and general theories of relativity. Einstein's postulates of the principle of relativity and the constancy of the speed of light. Simple kinematics and dynamics: simultaneity, time dilation, space-time diagrams, twin and other "paradoxes," E=mc², laws of motion, Elements of general relativity; curved spacetime, experimental tests, black holes, gravitational waves. Prerequisite: Physics 117A, Physics 197 or permission of the instructor.
Credit 1 unit. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L31 Physics 217 Introduction to Quantum Physics
Theoretical and experimental basis for quantum mechanics, following the historical development of 20th-century physics. Failure of classical physics; the Bohr theory of the atom; the Heisenberg uncertainty principle; the Schroedinger equation; atomic and molecular structure. Prerequisites: Physics 117A and 118A or Physics 197 and 198.
Credit 3 units. A&S IQ: NSM, AN Art: NSM BU: SCI

L31 Physics 241 Selected Topics in Physics II
Topics of special interest (e.g., superconductivity, quasicrystals, neural networks, chaos, etc.) may be studied under the supervision of a faculty member, variously by lectures, seminars or individual study or research. Students hoping to arrange such a course must prepare a proposal and secure the instructor's consent to undertake direction of the course from a faculty member and finally secure approval of the department chair.
Credit variable, maximum 3 units. A&S IQ: NSM Art: NSM BU: SCI

L31 Physics 242 Selected Topics in Physics II
Topics of special interest (e.g., holography, relativity, nuclear power, computer applications in physics, etc.) may be studied under the supervision of a faculty member, variously by lectures, seminars or individual study or research. Students hoping to arrange such a course must prepare a proposal and secure the instructor's consent to undertake direction of the course from a faculty member and finally secure approval of the department chair.
Credit variable, maximum 3 units. A&S IQ: NSM Art: NSM BU: SCI

L31 Physics 314 Physics of the Heart
A lecture and demonstration course that may be of particular interest to premedical and life-science students. Basic physics of the human cardiovascular system. Elasticity of vessels: properties of elastin and collagen. Energetics of the circulation: arterial and venous blood pressure, total fluid energy, gravitational potential energy, kinetic energy. Streamline flow and turbulence: effects of stenosis. Static and dynamic energy consumption of the heart: cardiac efficiency, the tension-time integral, Laplace's law, Starling's law. Metabolism of cardiac muscle. Electrophysiology: the heartbeat and cardiac arrhythmias. The physics of phonocardiograms, echocardiograms and other non-invasive techniques for physical assessment of cardiac abnormalities, including ischemia and myocardial infarction. Models of mechanical properties: contractile element, series elastic and parallel elastic elements. Corequisite: Physics 118A, Physics 198 or permission of instructor.
Credit 3 units. A&S IQ: NSM, AN Arch: NSM Art: NSM BU: SCI EN: BME T, SU, TU

L31 Physics 316 Optics and Wave Physics Laboratory
Introduction to optics and to treatment of experimental data. Experiments and lectures on refraction, interference, diffraction, polarization and coherence properties of waves with emphasis on light. Data analysis using statistical methods. Prerequisites: Physics 117A–Physics 118A or Physics 197–Physics 198.
Credit 3 units. A&S IQ: NSM, AN Arch: NSM Art: NSM BU: SCI

L31 Physics 318 Introduction to Quantum Physics II
Application of elementary quantum principles to atomic and molecular physics, solid-state physics, and nuclear and particle physics. Prerequisite: Physics 217.
Credit 3 units. A&S IQ: NSM, AN Arch: NSM Art: NSM BU: SCI

L31 Physics 321 Electronics Laboratory
Elements of linear and nonlinear circuits, amplifiers, feedback, with applications in experimental physics. Prerequisite: Physics 118A, Physics 198 or permission of instructor. Two three-hour laboratories and two one-hour lectures a week.
Credit 3 units. A&S IQ: NSM, AN Art: NSM BU: SCI EN: BME T, DU, SU, TU

L31 Physics 322 Physical Measurement Laboratory
A variety of classical and modern experiments in physics, including five experiments in nuclear radiation. Use of computers in experiment control, data acquisition, and data analysis. Development of skills in writing lab notebooks and formal
L31 Physics 341 Selected Topics in Physics III
Topics of special interest (e.g., superconductivity, quasicrystals, neural networks, chaos, etc.) may be studied under the supervision of a faculty member, variously by lectures, seminars or individual study or research. Students hoping to arrange such a course must prepare a proposal and secure consent to undertake direction of the course from a faculty member and finally secure approval of the department chair.
Credit variable, maximum 3 units. A&S IQ: NSM; SCI EN: TU

L31 Physics 342 Selected Topics in Physics III
Topics of special interest (e.g., holography, relativity, nuclear power, computer application in physics, etc.) may be studied under the supervision of a faculty member, variously by lectures, seminars or individual study or research. Students hoping to arrange such a course must prepare a proposal and secure the instructor's consent to undertake direction of the course from a faculty member and finally secure approval of the department chair.
Credit variable, maximum 3 units. A&S IQ: NSM; SCI

L31 Physics 344 Energy and Environmental Physics
This intermediate-level course applies basic physics principles to this increasingly important area. It is designed for all science and engineering majors with an interest in energy and environmental issues. Topics covered include population trends, fossil fuel use, renewable energy sources, energy storage strategies and climate change. Particular emphasis is given to the use of the fundamental laws of physics, such as energy conservation, as well as more general concepts such as local and global stability, chaotic behavior, probability and risk. The aim of the course is the development of analytical skills and familiarity with important concepts, in order to enable an independent and informed view of environmental problems and possible solutions. A one-year introductory physics class on the level of Physics 117-118 or 197-198 is required. This course also may be taken as Physics 444, which requires an additional independent project.
Credit 3 units. A&S IQ: NSM, AN BU: SCI

L31 Physics 350 Physics of the Brain
Concepts and techniques of physics are applied to study the functioning of neurons and neuronal circuits in the brain. Neurons and neural systems are modeled at two levels: (1) at the physical level, in terms of the electrical and chemical signals that are generated and transmitted, and (2) at the information-processing level, in terms of the computational tasks performed. Specific topics include: neuronal electrophysiology, neural codes, neural plasticity, sensory processing, neural network architectures and learning algorithms, and neural networks as dynamical and statistical systems. Course grade is based primarily on an individualized term project. Prerequisites: Physics 117A–118A, Physics 197–198, or permission of the instructor.
Credit 3 units. A&S IQ: NSM; BU: SCI EN: BME T, TU

L31 Physics 351 Introduction to Biomedical Physics
Principles and application of key physical methods used in the diagnosis and treatment of diseases, and in biomedical research. Topics include interaction of radiation with living systems; fundamentals of optical and electron microscopy; imaging via X-rays, magnetic resonance and ultrasound; and electrical properties of organs and cells. Prerequisite: Physics 117A–118A or Physics 197–198.
Credit 3 units. Art: NSM BU: SCI EN: BME T, TU

L31 Physics 352 Physics of Biomolecules
This course emphasizes the application of physical laws and concepts in understanding biomolecules and their interactions, and in developing tools to investigate the biological and functional properties and functionalities. Topics include (1) a general introduction to biomolecules and cells, (2) physics of biopolymers as modeled by stochastic analyses, (3) transport processes in biological systems including diffusion, reaction kinetics and "life at low Reynolds number," and (4) the physics of fluorescence and its contemporary applications to dynamics of biomolecules, such as optical tweezers. Prerequisite: Physics 117–118 or Physics 197–198. Some familiarity with thermodynamics; Chem 111A–112A recommended.
Credit 3 units. A&S IQ: NSM, AN

L31 Physics 354 Physics of Living Systems
One of the grand challenges in contemporary biophysics is placing our understanding of cellular systems on a firm quantitative footing. How does the collective activity of molecules enable the cell to sense its environment, make decisions, grow and develop? This course, aimed at physical and life science students, will serve as an introduction to the physical principles and mathematical techniques underlying the analysis of systems and synthetic biology. Topics will include modeling gene and signaling networks, the regulation of intracellular structures, and pattern formation in development. Students in this course can expect to learn both analytical and computer simulation approaches to fundamental problems in biology, biophysics, and biotechnology. Graduate students will explore the subject in more depth. Prerequisites: Physics 117A–118A or Physics 197–198 or Math 217 or Math 309, or permission of instructor.
Credit 3 units. A&S IQ: NSM BU: SCI

L31 Physics 355 Physics of Vision
How do the eyes capture an image and convert it to neural messages that ultimately result in visual experience? This lecture and demonstration course covers the physics of how we see. The course is addressed to physics, premedical and life-sciences students with an interest in biophysics. Topics include physical properties of light, evolution of the eyes, image formation in the eye, image sampling with an array of photoreceptors, transducing light into electrical signals, color coding, retinal organization, computing with nerve cells, compressing the 3-D world into optic nerve signals, inferring the 3-D world from optic nerve signals, biomechanics of eye movement, engineered vision in machines. The functional impact of biophysical mechanisms for visual experience is illustrated with psychophysical demonstrations. Corequisite: Physics 117A, Physics 197 or permission of instructor.
Credit 3 units. A&S IQ: NSM Art: NSM BU: SCI EN: BME T, SU, TU
L31 Physics 360 Biophysics Laboratory
This laboratory course consists of "table-top" experiments in biological physics that are designed to introduce the student to concepts, methods and biological model systems in biophysics. Most experiments combine experimentation with computer simulations. The list of available experiments includes electrophysiology, human bioelectricity, optical tweezers, ultrasonic imaging, mass spectrometer and viscosity measurements. Prerequisites: prior completion of Physics 117A–118A, Physics 197–198 or permission of instructor. Credit 3 units. A&S IQ: NSM, AN Art: NSM

L31 Physics 400 Physical Science in 12 Problems
Exercises related to general chemistry, classical mechanics, quantum mechanics, statistical mechanics, thermodynamics and kinetics, are solved with numerical software. Each exercise is accompanied by a lecture, a software template solving a problem and a related take-home problem. The software allows us to focus on, and treat in a transparent fashion, physical problems without the unworlly idealizations and contrivances found in textbooks. Prerequisites: General Chem, concurrent enrollment with Chem 401 and prior or concurrent enrollment in General Physics. Credit 1 unit. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L31 Physics 411 Mechanics
Motion of a point particle, rotational motion, oscillation, gravitation and central forces, Lagrangian and Hamiltonian formulation. Prerequisites: Physics 117A–118A or Physics 197–198, Math 217 or permission of instructor. Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L31 Physics 421 Electricity and Magnetism
Starting from Coulomb's law, the Biot-Savart law and Faraday's law, the electrical and magnetic fields are defined and applied. Maxwell's equations are derived and their consequences, such as electromagnetic waves and relativity, are explored. Prerequisites: Physics 117A–118A or Physics 197–198, Math 217 or permission of instructor. Credit 3 units. A&S IQ: NSM AN Art: NSM BU: SCI EN: BME T, DU, SU, TU

L31 Physics 422 Electricity and Magnetism II
The second course in a two-part series covering the classical theory of electricity and magnetism leading to the derivation and application of Maxwell's equation. Topics in electrodynamics including Faraday's law, the displacement current and Maxwell's equations in vacuum and in matter are covered. Electromagnetic waves and radiation, special relativity and relativistic electrodynamics also are discussed. Prerequisite: Physics 421 or permission of instructor. Credit 3 units. A&S IQ: NSM AN Arch: NSM Art: NSM BU: SCI EN: BME T, DU, SU, TU

L31 Physics 427 Introduction to Computational Physics
What does it mean to solve a research problem using a computer? What is the difference between "someone ran a simulation" and an interesting research result? What skills are needed? Familiarity with a programming language is, of course, essential, but that is only the beginning. This course will focus on the methodology of computational research, touching also on topics in numerical analysis, statistics, and visualization. The format will combine lectures and hands-on experience with an emphasis on research-style small-group projects. Prerequisites: Physics 197/198, calculus, and familiarity with a programming language. Credit 3 units. A&S IQ: NSM Art: NSM

L31 Physics 435 Nuclear and Radiochemistry Lab
Application of radiochemical techniques to problems in chemistry, physics, and nuclear medicine. Prerequisites: 3 units of physical chemistry and permission of instructor. One lecture hour and five hours of laboratory a week. Same as L07 Chem 435 Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L31 Physics 436 Introduction to the Atomic Nucleus
Introduction to the production and decay of radioactive nuclides, the structure and properties of nuclei, and the applications of nuclear and radiochemical techniques to current scientific problems. Prerequisites: one year of chemistry, mathematics and physics. Same as L07 Chem 436 Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L31 Physics 441 Selected Topics in Physics IV
Topics of special interest (e.g., holography, relativity, nuclear power, computer applications in physics, etc.) may be studied under the supervision of a faculty member, variously by lectures, seminars or individual study or research. Students hoping to arrange such a course must prepare a proposal and secure the instructor's consent to undertake direction of the course from a faculty member and finally secure approval of the department chair. Credit variable, maximum 3 units. A&S IQ: NSM Art: NSM BU: SCI

L31 Physics 442 Selected Topics in Physics IV
Topics of special interest (e.g., holography, relativity, nuclear power, computer applications in physics, etc.) may be studied under the supervision of a faculty member, variously by lectures, seminars or individual study or research. Students hoping to arrange such a course must prepare a proposal and secure the instructor's consent to undertake direction of the course from a faculty member and finally secure approval of the department chair. Credit variable, maximum 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L31 Physics 446 Galactic Astrophysics
In these lectures, the focus is on the dynamics and statistical mechanics of a collection of stars, which is treated as a collisionless system. The course begins with a discussion of potential theory and proceeds to discuss the density and phase distributions of stars in star clusters and galaxies, thus leading to an understanding of the equilibria and stability of these systems. Topics such as Chandrasekhar's dynamical friction, galaxy formation, and dark matter will constitute the final topics of discussion. Credit 3 units. A&S IQ: NSM BU: SCI

L31 Physics 450 Physics of the Brain
Contents are the same as Physics 350. Also intended for graduate students. Includes a more sophisticated term project
L31 Physics 454 Physics of Living Systems
Contents are the same as Physics 354. Graduate students will enjoy the subject in more depth. Prerequisites: Physics 117A–118A or Physics 197 or permission of instructor.
Credit 3 units. A&S IQ: NSM

L31 Physics 455 Physics of Vision
Contents are the same as Physics 355. Also intended for graduate students. Includes a more sophisticated term project than Physics 355. Corequisite: Physics 117A , Physics 197 or permission of instructor.
Credit 3 units. A&S IQ: NSM

L31 Physics 456 Stellar Astrophysics
The course Stellar Astrophysics discusses the physical processes that play a role inside stars. Relevant physical processes include emissions and absorption processes, radiation transfer, convective transfer, the weak and strong interactions, nuclear processes and nuclear burning, and the thermodynamics of equilibrium and non-equilibrium processes in stellar interiors. Subsequently, these processes are used to explain the structure and evolution of stars of different mass ranges. Finally, the course discusses endpoints of stellar evolution including white dwarfs, neutron stars, black holes, supernova explosions and gamma-ray burst. Prerequisites: Physics 312, Physics 318, or permission of instructor.
Same as L31 Physics 556.
Credit 3 units.

L31 Physics 457 Stellar Astrophysics II
The course Stellar Astrophysics II discusses the physical processes that play a role inside stars. Relevant physical processes include emissions and absorption processes, radiation transfer, convective transfer, the weak and strong interactions, nuclear processes and nuclear burning, and the thermodynamics of equilibrium and non-equilibrium processes in stellar interiors. Subsequently, these processes are used to explain the structure and evolution of stars of different mass ranges. Finally, the course discusses endpoints of stellar evolution including white dwarfs, neutron stars, black holes, supernova explosions and gamma-ray burst. Prerequisites: Physics 312, Physics 318, or permission of instructor.
Same as L31 Physics 556.
Credit 3 units.

L31 Physics 460 X-Ray & Gamma-Ray Astrophysics
Observers started to use X-ray and gamma-rays in the ‘60s and ’70s to explore the cosmos with high-energy photons. The sky looks dramatically different at these energies with bright flares from mass accreting black holes and gamma-ray bursts and large diffuse emission from supernova remnants and cosmic rays interacting with galactic matter and magnetic fields dominating the emission. This course gives a comprehensive overview of the underlying physics and observable phenomenology. Topics covered include the history of X-ray and gamma-ray astronomy, high-energy radiation processes, particle heating and acceleration, accretion physics, blast waves and shocks, black holes, neutron stars, supernova remnants, gamma-ray bursts, and galaxy clusters. Prerequisite: L31 Physics 312.
Credit 3 units. A&S IQ: NSM

L31 Physics 463 Statistical Mechanics and Thermodynamics
Basic methods of classical and quantum statistical mechanics, thermodynamics and transport theory. Prerequisite: Physics 217 or permission of instructor.
Credit 3 units. A&S IQ: NSM

L31 Physics 471 Quantum Mechanics
Origins of quantum theory, wave packets and uncertainty relations, Schrodinger's equation in one dimension, step potentials and harmonic oscillators, eigenfunctions and eigenvalues, Schrodinger's equation in three dimensions, the hydrogen atom, symmetry, spin and the periodic table, approximation methods for time independent problems, quantum statistics. Prerequisite: Math 217, Physics 217, or permission of instructor.
Credit 3 units. A&S IQ: NSM

L31 Physics 472 Solid State Physics
Crystal structures, binding energies, thermal properties, dielectrics, magnetism, free electron theory of metals, band theory, semiconductors, defects in solids. Prerequisite: Physics 471.
Credit 3 units. A&S IQ: NSM

L31 Physics 473 Introduction to Particle Physics
Introduction to the standard model of particle physics, including symmetries, conservation laws, the weak interaction, the strong interaction, quark confinement and some more exotic ideas such as grand unified theories. Prerequisite: Physics 471.
Credit 3 units. A&S IQ: NSM

L31 Physics 474 Astrophysics
This Astrophysics course focuses on cosmic rays. Victor Hess discovered in 1912 that ionizing radiation impinges on the top of Earth’s atmosphere. Even though physicists have been studying cosmic rays (the ionizing radiation) for more than 100 years now with a fantastic repertoire of experimental and theoretical tools, cosmic rays never stop to surprise us, and cosmic ray physicists are still pushing the frontier of cosmic exploration in many ways. This course gives an introduction into this exciting topic covering historical and recent cosmic ray measurements at all energies, particle and antiparticle observations, and neutrino observations. The presently favored models of cosmic ray acceleration and transport are discussed in detail, and some topics of current interest are highlighted (including the production of particles and antiparticles by dark matter). The course also covers radio astronomy and highlights the clues about the origin of the cosmic rays that can be obtained from radio observations. Prerequisite: Physics 312 or permission of instructor.
Credit 3 units. A&S IQ: NSM

L31 Physics 475 Physics of Finite and Infinite Nuclear Systems
Credit 3 units. A&S IQ: NSM

L31 Physics 476 From Black Holes to the Big Bang
An introduction to general relativity. The goal is to illustrate important features of general relativity without the full-blown mathematics of Einstein's equations by restricting attention to
spherically symmetric spacetimes. Topics include: principle of equivalence; curved spacetime; spherical stars and black holes; the Big Bang model, observational cosmology. Prerequisite: Physics 411 or permission of instructor.
Credit 3 units. A&S IQ: NSM Art: NSM

L31 Physics 482 Research Seminar
Designed to introduce students to current developments in physics and to research carried out by faculty. Topics vary each year. Each member of the department addresses their particular specialty. Interested undergraduates may take this seminar in their junior or senior year. Must be taken pass/fail.
Credit 1 unit. A&S IQ: NSM Art: NSM

L31 Physics 499 Honors Program
Prerequisites: junior standing, an average grade of B or better, and permission of the chair of the department. Program and credit to be determined; maximum 6 units.
Credit variable, maximum 3 units. Art: NSM