PHYSICS AND ASTRONOMY

http://www.pacific.edu/Academics/Schools-and-Colleges/College-of-the-Pacific/Academics/Departments-and-Programs/Physics.html
Phone: (209) 946-2220
Location: Olson Hall, South Campus
Dr. Elisa Toloba, Chair

Degrees Offered

Bachelor of Arts
Bachelor of Science

Majors Offered

Physics (BA)
Physics (BS)

- **Standard Track**
- **Astrophysics**
- **Theoretical Physics**

Engineering Physics (BS)

Minors Offered

Physics

Matter, energy, space and time obey a few general but precise laws, which are fundamental to the structure and behavior we see in our universe. The evolving understanding of this over the centuries has changed our minds, our lives, and our world profoundly.

The Physics and Astronomy Department helps students understand and explore these natural relationships, their meaning, interconnectedness, and their use. The study of physics includes mastering very broad fundamentals which apply to everything from atoms to galaxies, as well as specific studies in topical specializations such as computational and astrophysics. Students are also encouraged to participate in undergraduate research projects both here at Pacific and at other institutions during the summer break.

Degrees in Physics

The degree programs in Physics prepare students to think deeply through questions, to find and connect abstract relationships to new situations, and to be academically confident and broadly knowledgeable scientists and teachers. Bachelor of Science degrees are offered in Physics and Engineering. A Bachelor of Arts degree is also offered in Physics, which is combined with the credential program for secondary school teaching. The department also offers a Physics Minor, intended for students majoring in other disciplines, who have a strong interest in Physics and the underlying principles of science.

Facilities

The Physics and Astronomy Department occupies Olson Hall. Labs are equipped with modern facilities for advanced experiments in quantum optics and condensed matter physics, astrophysics, particle physics, ultra-high vacuum and thin film fabrication, and a 2.3 meter radio telescope for student use. The department has three computer-equipped labs for introductory physics, musical acoustics, and astronomy courses, a scientific computing lab, a machine shop and an electronics shop. Additionally there is ample space for student research projects. Olson Hall features room 120 with 90 seats and state-of-the-art computer displays for large lectures, as well as a number of smaller classrooms.

Recommended High School Preparation

Physics majors should be prepared to take calculus in their first semester at Pacific, and it is highly recommended that they take high school physics. Some experience with computer programming in a language such as C++ or Python is also useful.

Bachelor of Arts - Physics

The Bachelor of Arts degree program requires fewer advanced courses in Physics and Mathematics than are required for the three Bachelor of Science programs. Students complete six courses in Physics and four in Mathematics, which allows time for a student to develop greater breadth in other areas as is appropriate for a high school physical science teaching credential. Thus, this degree is at present limited to students in the secondary school teaching track. (Students interested in teaching credential programs with a physics or physical sciences emphasis can obtain the Teaching Credential Major sheet from the Office of Admissions.)

Bachelor of Science - Physics

The Bachelor of Science in Physics degree program is the standard preparation for professional careers in physics and related physical sciences. Graduates may enter industrial and government positions directly at the BS level or may proceed to graduate study in preparation for higher level research positions.

In addition to the *Standard Track* for the Bachelor of Science in Physics described above, students may choose a focused concentration for their studies, and follow one of the two concentrations below. These concentrations engage the student further in areas where our department has particular expertise and resources.

Astrophysics Concentration

Through coursework and projects that uses the department's astronomical telescopes (optical and radio) and other equipment, students in the Astrophysics Concentration enhance their understanding of the Universe beyond the Earth. Students in this concentration are required to take Astrophysics PHYS 140 and one of Cosmology PHYS 141, Optics PHYS 105, or Special Topics PHYS 093, and their Senior Thesis (PHYS 199) involves either an experimental or theoretical astrophysics project.

Theoretical Physics Concentration

This concentration is for students who are mathematically inclined or intending to double major with Math, focusing on theoretical aspects of physics, deepening the student's expertise through the application of mathematical methods to study physical phenomena. It is satisfied by any two courses from: Mathematical Physics PHYS 137, Particle Physics PHYS 111, Optics PHYS 105, Cosmology PHYS 141, or Special Topics PHYS 093.

Bachelor of Science – Engineering Physics

The Bachelor of Science in Engineering Physics is offered in cooperation with the School of Engineering. The proportions of courses taken in these two areas are roughly equal.

Today's engineer must be able to understand and apply new and changing technologies which arise from advances in fundamental science. Pacific engineering physics graduates have a firm understanding of the fundamental physics upon which modern technologies are based. They are able to use advanced mathematical methods and problem solving techniques to relate new ideas and scientific developments to practical problems in engineering. By acquiring skills applicable for lifelong learning, the Pacific engineering physics graduate is well prepared for a competitive career.

Students who pursue a Bachelor of Science in Engineering Physics degree are subject to all of the requirements of an engineering degree student. Among these requirements is a work experience component called the Cooperative Education Program. Students must complete 32 units of full-time work experience in order to graduate. See the Engineering and Computer Science, Cooperative Education for Engineering Programs section of this catalog for more details.

The Physics Minor

A minor in Physics provides the student of any discipline with a very strong understanding of the foundations of science and the workings of the physical world. The study of physics teaches abstract problem solving skills which are both of great benefit to the student, and impressive to prospective employers.

Conceptual and Analytical Capabilities

• Map physical problems into a set of equations and solve them using analytical/numerical methods.
• Identify the relevant physical principles that govern the dynamics of physical problems and obtain solutions for these problems in the areas of (1) classical mechanics, (2) electromagnetism, (3) statistical mechanics, and (4) quantum mechanics/special relativity.

Inquiry and Research Capabilities

• Propose a research project, complete the necessary theoretical background study required for the project, design an experiment or write a computer program for performing necessary calculation/ simulation, and analyze the results to verify/nullify the hypothesis.

Communication Capabilities

• Make clear and effective presentations of research projects in both written and oral form.

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- Bachelor of Science Major in Physics (p. 3)
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- Bachelor of Science in Engineering Physics (p. 4)

Bachelor of Arts Major in Physics

Students must complete a minimum of 120 units with a Pacific cumulative and major/program grade point average of 2.0 in order to earn the bachelor of arts degree with a major in physics.

I. General Education Requirements

For more details, see General Education (https://catalog.pacific.edu/uop/generalinformation/generaleducation/)

Minimum 28 units and 9 courses that include:

A. CORE Seminars (2 courses)

CORE 001	Problem Solving & Oral Comm	3
CORE 002	Writing and Critical Thinking	4

Note: 1) CORE Seminars cannot be taken for Pass/No Credit. ***2)*** Transfer students with 28 or more transfer credits taken after high school are exempt from both CORE seminars.

B. Breadth Requirement (7 courses, at least 3 units each)

At least one course from each of the following areas:

- Artistic Process & Creation
- Civic & Global Responsibility
- Language & Narratives
- Quantitative Reasoning
- Scientific Inquiry
- Social Inquiry
- World Perspectives & Ethics

Note: 1) No more than 2 courses from a single discipline can be used to meet the Breadth Requirement.

C. Diversity and Inclusion Requirement

All students must complete Diversity and Inclusion coursework (at least 3 units)

Note: 1) Diversity and Inclusion courses can also be used to meet the breadth category requirements, or major or minor requirements.

D. Fundamental Skills

Students must demonstrate competence in:

- Writing
- Quantitative Analysis (Math)

Note: 1) Failure to satisfy the fundamental skills requirements by the end of four semesters of full-time study at the University is grounds for academic disqualification.

II. College of the Pacific BA Requirement

Students must complete one year of college instruction or equivalent training in a language other than English.

Note: 1) *Transfer students with sophomore standing are exempt from this requirement.*

III. Breadth Requirements

Students must complete 60 units outside the primary discipline of the first major, regardless of the department who offers the course(s) in that discipline. (Courses include general education courses, transfer courses, CPCE/EXTN units, internships, etc.)

IV. Major Requirements

Minimum 42 units that include:

PHYS 001	Skills for the Physics Major	1
PHYS 053	Principles of Physics I	5
PHYS 055	Principles of Physics II	5

PHYS 057	Modern Physics	4
PHYS 181	Classical Mechanics	4
Two PHYS Electives (Two additional upper division courses)		8
MATH 051	Calculus I	
MATH 053	Calculus II	
MATH 055	Calculus III	
MATH 057	Applied Differential Equations I: ODEs	

Bachelor of Science Major in Physics

Students must complete a minimum of 120 units with a Pacific cumulative and major/program grade point average of 2.0 in order to earn the bachelor of science degree with a major in physics.

I. General Education Requirements

For more details, see General Education (https://catalog.pacific.edu/uop/generalinformation/generaleducation/)

Minimum 28 units and 9 courses that include:

A. CORE Seminars (2 courses)

CORE 001	Problem Solving & Oral Comm	3
CORE 002	Writing and Critical Thinking	4

Note: 1) CORE Seminars cannot be taken for Pass/No Credit. ***2)*** Transfer students with 28 or more transfer credits taken after high school are exempt from both CORE seminars.

B. Breadth Requirement (7 courses, at least 3 units each)

At least one course from each of the following areas:

Artistic Process & Creation
Civic & Global Responsibility
Language & Narratives
Quantitative Reasoning
Scientific Inquiry
Social Inquiry
World Perspectives & Ethics

Note: 1) No more than 2 courses from a single discipline can be used to meet the Breadth Requirement.

C. Diversity and Inclusion Requirement

All students must complete Diversity and Inclusion coursework (at least 3 units)

Note: 1) Diversity and Inclusion courses can also be used to meet the breadth category requirements, or major or minor requirements.

D. Fundamental Skills

Students must demonstrate competence in:

Writing
Quantitative Analysis (Math)

Note: 1) Failure to satisfy the fundamental skills requirements by the end of four semesters of full-time study at the University is grounds for academic disqualification.

II. Breadth Requirements

Students must complete 60 units outside the primary discipline of the first major, regardless of the department who offers the course(s) in that discipline. (Courses include general education courses, transfer courses, CPCE/EXTN units, internships, etc.)

III. Major Requirements

Minimum 71 units that include:

PHYS 001	Skills for the Physics Major	1
PHYS 053	Principles of Physics I	5
PHYS 055	Principles of Physics II	5
PHYS 057	Modern Physics	4
PHYS 101	Electricity and Magnetism	4
PHYS 102	Electrodynamics	4
PHYS 151	Advanced Physics Laboratory	4
PHYS 161	Thermal Physics	4
PHYS 181	Classical Mechanics	4
PHYS 183	Quantum Mechanics	4
MATH 051	Calculus I	4
MATH 053	Calculus II	4
MATH 055	Calculus III	4
MATH 057	Applied Differential Equations I: ODEs *	4
One of the following COMP Courses		4
COMP 051	Introduction to Computer Science	
COMP 061	Introduction to Programming for Data Science	
Select one of the following courses: **		4
CHEM 024	Fundamentals of Chem	
PHYS 127	Computational Physics	
MATH 075	Introduction to Linear Algebra	
MATH 110	Numerical Analysis	
Select one of the following concentrations:		
Standard Track		
Two PHYS Electives (Two additional upper division courses)		8
Astrophysics Concentration		
PHYS 140	Astrophysics	4
Select one of the following:		4
PHYS 141	Cosmology	
PHYS 105	Optics	
PHYS 093	Special Topics	
Theoretical Physics Concentration		
Select two of the following:		8
PHYS 137	Mathematical Physics	
PHYS 111	Particle Physics	
PHYS 105	Optics	
PHYS 141	Cosmology	
PHYS 093	Special Topics	
MATH or PHYS course as approved by Department Chair		

* An upper level vector calculus or complex analysis course is recommended, such as MATH 152

** Students take the Chemistry Placement Exam during orientation to determine which course is appropriate.

Bachelor of Science Major in Physics with Departmental Honors

To be awarded a degree in Physics with Honors at graduation, you must accomplish three learning outcomes: 1) A minimum overall GPA of 3.3.

2) A minimum GPA of 3.5 for courses within the major. 3) Senior Thesis Physics 199.

Students must complete a minimum of 120 units with a Pacific cumulative and major/program grade point average of 2.0 in order to earn the bachelor of science degree with a major in physics.

I. General Education Requirements

For more details, see General Education (https://catalog.pacific.edu/uop/generalinformation/generaleducation/)

Minimum 28 units and 9 courses that include:

A. CORE Seminars (2 courses)

CORE 001	Problem Solving & Oral Comm	3
CORE 002	Writing and Critical Thinking	4

Note: 1) CORE Seminars cannot be taken for Pass/No Credit. ***2)*** Transfer students with 28 or more transfer credits taken after high school are exempt from both CORE seminars.

B. Breadth Requirement (7 courses, at least 3 units each)

At least one course from each of the following areas:

- Artistic Process & Creation
- Civic & Global Responsibility
- Language & Narratives
- Quantitative Reasoning
- Scientific Inquiry
- Social Inquiry
- World Perspectives & Ethics

Note: 1) No more than 2 courses from a single discipline can be used to meet the Breadth Requirement.

C. Diversity and Inclusion Requirement

All students must complete Diversity and Inclusion coursework (at least 3 units)

Note: 1) Diversity and Inclusion courses can also be used to meet the breadth category requirements, or major or minor requirements.

D. Fundamental Skills

Students must demonstrate competence in:

- Writing
- Quantitative Analysis (Math)

Note: 1) Failure to satisfy the fundamental skills requirements by the end of four semesters of full-time study at the University is grounds for academic disqualification.

II. Breadth Requirements

Students must complete 60 units outside the primary discipline of the first major, regardless of the department who offers the course(s) in that discipline. (Courses include general education courses, transfer courses, CPCE/EXTN units, internships, etc.)

III. Major Requirements

Minimum 75 units that include:

PHYS 001	Skills for the Physics Major	1
PHYS 053	Principles of Physics I	5
PHYS 055	Principles of Physics II	5
PHYS 057	Modern Physics	4
PHYS 101	Electricity and Magnetism	4
PHYS 102	Electrodynamics	4
PHYS 151	Advanced Physics Laboratory	4
PHYS 161	Thermal Physics	4
PHYS 181	Classical Mechanics	4
PHYS 183	Quantum Mechanics	4
PHYS 199	Senior Thesis	4
MATH 051	Calculus I	4
MATH 053	Calculus II	4
MATH 055	Calculus III	4
MATH 057	Applied Differential Equations I: ODEs *	4
One of the following COMP Courses		4
COMP 051	Introduction to Computer Science	
COMP 061	Introduction to Programming for Data Science	
Select one of the following courses: **		4
CHEM 024	Fundamentals of Chem	
PHYS 127	Computational Physics	
MATH 075	Introduction to Linear Algebra	
MATH 110	Numerical Analysis	
Select one of the following concentrations:		
Standard Track		
Two PHYS Electives (Two additional upper division courses)		8
Astrophysics Concentration		
PHYS 140	Astrophysics	4
Select one of the following:		4
PHYS 141	Cosmology	
PHYS 105	Optics	
PHYS 093	Special Topics	
Theoretical Physics Concentration		
Select two of the following:		8
PHYS 137	Mathematical Physics	
PHYS 111	Particle Physics	
PHYS 105	Optics	
PHYS 141	Cosmology	
PHYS 093	Special Topics	
MATH or PHYS course as approved by Department Chair		

* An upper level vector calculus or complex analysis course is recommended, such as MATH 152

** Students take the Chemistry Placement Exam during orientation to determine which course is appropriate.

Bachelor of Science in Engineering Physics

For information and program requirements for the bachelor of science degree with a major in engineering physics, please see the School of Engineering and Computer Science, Department of Engineering Physics (http://catalog.pacific.edu/stocktongeneral/schoolofengineeringandcomputerscience/engineeringphysics/) portion of the general catalog.

Physics Courses

PHYS 001. Skills for the Physics Major. 1 Unit.
This course familiarizes students with the Physics program, where they will learn about the physics curriculum, meet the faculty, develop beginning computing skills, find out about research opportunities, and look ahead to career planning and discover what Physics graduates do. This class is for beginning Physics majors only. Prerequisites: Physics major.

PHYS 017. Concepts of Physics. 4 Units.
This course is a descriptive, general education course for students who have not had high school physics. Topics include motion, heat, energy, light, sound and other wave phenomena, electricity and magnetism, and atomic structure. Practical applications are emphasized. The course includes laboratory work. Prerequisite: a passing score on the Intermediate Algebra placement test or MATH 005 or MATH 033 or MATH 037 or MATH 039 or MATH 041 or MATH 051 or MATH 053. **(GE3A, GESI)**

PHYS 021. Energy for Global Citizens. 4 Units.
This lab course empowers the students to make informed energy decisions in their everyday life as they become global citizens. The students learn basic practical knowledge about energy use and production, and the impact of their personal decisions on energy conservation, environmental protection, and the global community. Prerequisite: a passing score on the Intermediate Algebra placement test or MATH 005 or MATH 033 or MATH 037 or MATH 039 or MATH 041 or MATH 051 or MATH 053.

PHYS 023. General Physics I. 5 Units.
Students study the physics of mechanics and motion, rotation fluids, and thermodynamics. The course includes laboratory work. Prerequisite: a passing score on the Pre-Calculus placement test or MATH 039 or MATH 041 or MATH 045 or MATH 051 or MATH 053 or MATH 055. **(GE3A, GESI)**

PHYS 025. General Physics II. 5 Units.
Students study acoustics and waves, electricity and magnetism, quantum mechanics and relativity. The course includes laboratory work. Prerequisite: PHYS 023 or PHYS 053. **(GE3A, GESI)**

PHYS 027. Scientific Computing Tutorial. 1 Unit.
This course meets weekly and provides students with an introduction to the department's computer facilities and their use. After an introduction to unix, students learn basic programming in C++. The course then covers scientific software and libraries for data analysis and visualization. Prerequisite: a passing score on the Intermediate Algebra placement test or MATH 005 or MATH 033 or MATH 037 or MATH 039 or MATH 041 or MATH 045 or MATH 051 or MATH 053 or MATH 055.

PHYS 039. Physics of Music. 3 Units.
This liberal arts lab-science course is designed to enhance students' enjoyment and appreciation of music by developing an understanding of the basic physics involved. Topics include: the physics of motion, vibration, waves and sound; some aspects of hearing, harmony and musical scales; the physical behavior of the various families of musical instruments; electronic sound systems; architectural acoustics. Prerequisite: a passing score on the Intermediate Algebra placement test or MATH 005 or MATH 033 or MATH 037 or MATH 039 or MATH 041 or MATH 045 or MATH 051 or MATH 053 or MATH 055. **(GE3A, GESI)**

PHYS 041. Astronomy. 4 Units.
Students examine a broad overview of modern astronomy, with emphasis on conceptual understanding. Topics include motions of stars and planets, the solar system, stellar evolution, pulsars, black holes, quasars, galaxies and cosmology. The course includes some outdoor observing activities and laboratory work. Prerequisite: a passing score on the Intermediate Algebra placement test or MATH 005 or MATH 033 or MATH 037 or MATH 039 or MATH 041 or MATH 045 or MATH 051 or MATH 053 or MATH 055. **(GE3A, GESI)**

PHYS 053. Principles of Physics I. 5 Units.
Students investigate kinematics, dynamics, oscillations, wave motion and fluids. This course includes laboratory work. Prerequisite: MATH 053 (or concurrent enrollment) or MATH 055 or MATH 057. Recommended: High school physics or PHYS 023. **(GE3A, GESI)**

PHYS 055. Principles of Physics II. 5 Units.
Students study thermodynamics, electricity, magnetism, light and optics, atomic and nuclear physics, particle physics and cosmology. This course includes laboratory work. Prerequisite: PHYS 053. **(GE3A, GESI)**

PHYS 057. Modern Physics. 4 Units.
This course covers special relativity, quantization, wave/particle duality and the uncertainty principle, solution and interpretation of simple Schroedinger equations, atomic structure, as well as an introduction to nuclear and elementary particle physics. Laboratory work is included. Prerequisites: PHYS 055 and MATH 055. Prerequisite, may be taken concurrently: MATH 057.

PHYS 093. Special Topics. 4 Units.

PHYS 101. Electricity and Magnetism. 4 Units.
This course examines the theory of electrostatic and electromagnetic fields and their interaction with matter with practical applications. Studies also examine the development of Maxwell's equations. Prerequisites: PHYS 055 and MATH 055. Prerequisite, may be taken concurrently: MATH 057.

PHYS 102. Electrodynamics. 4 Units.
Students examine Maxwell's equations, progagation of electromagnetic radiation, transmission lines, wave guides, antennas as well as their applications. Prerequisites: PHYS 057, PHYS 101, MATH 057.

PHYS 105. Optics. 4 Units.
This course is a modern introduction to optics. Topics include geometrical optics, optical instrumentation, the wave nature of light, polarization, diffraction, lasers and fiber-optics and it includes laboratory. Prerequisites: PHYS 055; MATH 055 and MATH 057 (or concurrent enrollment).

PHYS 111. Particle Physics. 4 Units.
Students are introduced to the concepts of particle physics, connecting quantum physics (what happens at very small distances) and special relativity (what happens at very high speeds) to learn how the presently known particles interact with one another and how various phenomena can be predicted by an underlying theory, the Standard Model. The course leads up to the latest experimental discovery, the Higgs boson, and future directions in particle physics. Prerequisites: PHYS 057 & MATH 057.

PHYS 127. Computational Physics. 4 Units.
This course provides an introduction to the main computational and simulation techniques used in modern physics. Topics include numerical solution of ordinary and partial differential equations, matrix and linear algebra, Monte Carlo and random variable methods, and computer algebra. Prerequisites: PHYS 055, MATH 057, COMP 051 or permission of instructor for other programming experience.

PHYS 137. Mathematical Physics. 4 Units.
This course covers infinite series and sequences, complex analysis, techniques of solving differential equations (ODEs and partial diff. eqs.), linear operators in Hilbert space, special functions, symmetry and group theory. Prerequisites: PHYS 055 and MATH 057.

PHYS 140. Astrophysics. 4 Units.
This course is an introduction to the physics of stars. Topics include: celestial coordinate systems, observational properties of stars, stellar structure, stellar evolution, close binary stars, white dwarfs, neutron stars and black holes. Prerequisite: PHYS 055.

PHYS 141. Cosmology. 4 Units.
Students are introduced to the physics of stars, galaxies and the universe. Topics include: observational properties of stars, stellar structure, star formation, stellar evolution, close binary stars, white dwarfs, neutron stars and black holes, observational properties of galaxies, galactic dynamics, interstellar and intergalactic medium, expansion of the universe and cosmology. Prerequisite: PHYS 055. Prerequisite, may be taken concurrently: MATH 057.

PHYS 151. Advanced Physics Laboratory. 4 Units.
Students examine experimental studies in modern physics, especially ones that require the design, construction and use of special apparatus. the course includes experiments in atomic, nuclear, and particle, optics, solid state physics and astrophysics are possible. Prerequisite: PHYS 057.

PHYS 161. Thermal Physics. 4 Units.
This course covers the general laws of thermodynamics with applications to heat engines and thermal properties of solids. Students are also introduced statistical mechanics with applications to molecules, solids, thermoelectric phenomena and radiation. Prerequisites: PHYS 055 and MATH 055.

PHYS 170. Solid State Devices. 4 Units.
This course introduces concepts related to the crystal structure of semiconductors and electronic, optical, and magnetic properties of semiconductors. Dynamics of carriers under equilibrium and non-equilibrium conditions are presented as a frame work for understanding the behavior of a number of devices including Metal-Oxide-Semiconductor (MOS) and Hetero-junction Bipolar (HBT) devices. On such a background, the course builds an understanding of the latest advances in the field. This course is cross listed with ECPE 133 and EPHY 133. Prerequisite: MATH 057, PHYS 055 with a "C-" or better.

PHYS 181. Classical Mechanics. 4 Units.
Students examine Newtonian mechanics, Hamilton's principle, Lagrangian and Hamiltonian dynamics. Oscillations, central force motion, waves, nonlinear systems and chaos are also covered. Prerequisites: PHYS 055 and MATH 057.

PHYS 183. Quantum Mechanics. 4 Units.
This course is an introduction to quantum mechanics as it contrasts with classical physics. Topics include the Wave Particle Duality, Dirac Formalism, Postulates of Quantum Mechanics, Two Level Systems in Spin 1/2, The Harmonic Oscillator, Angular Momentum, and The Hydrogen Atom. Prerequisites: PHYS 057 and MATH 057.

PHYS 191. Independent Study. 2-4 Units.

PHYS 197. Undergraduate Research. 1-4 Units.

PHYS 199. Senior Thesis. 4 Units.

PHYS 204. Statistical Mechanics. 4 Units.

PHYS 211. Quantum Mechanics, First Semester. 4 Units.

PHYS 213. Quantum Mechanics, Second Semester. 4 Units.

PHYS 219. Science Teaching and Leadership. 3 Units.

PHYS 251. Advanced Physics Laboratory. 4 Units.

PHYS 291. Graduate Independent Study. 2-4 Units.

PHYS 293. Special Topics. 4 Units.

PHYS 297. Graduate Research. 2-4 Units.

PHYS 299. Thesis. 2 or 4 Units.