

# Physics

College of Science and Mathematics

## Department of Physics

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**B.S. in Physics**

**M.S. in Physics**

**Minor in Physics**

**Minor in Physical Science**

**Single Subject Teaching Credential  
in the Sciences**

## Physics

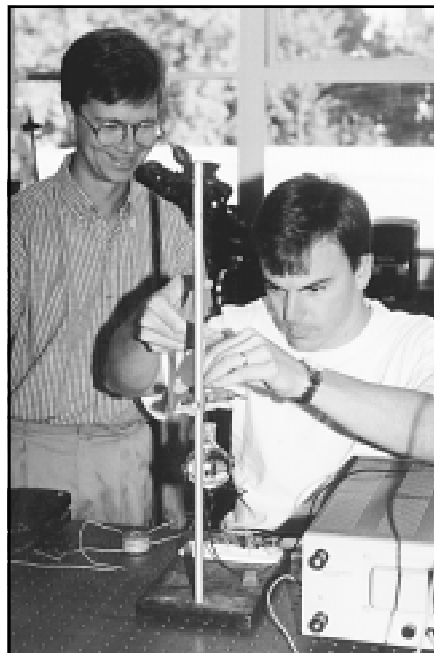
The fascination of physics is that it is so fundamental: the continuing attempt to understand how things work. It combines observational and experimental grappling with nature to get the facts of behavior, with the creative synthesis of these facts into theories and laws of nature, often beautiful in their simplicity and universality.

Albert Einstein said, "They [the laws of theoretical physics] should form the basis from which a picture of all processes of nature can be derived by thoughtful deduction — and these include also the processes of life." He also said, "The deeper we search, the more we find there is to know, and as long as human life exists, I believe it will always be so."

More specifically, physics includes the study of the fundamental particles that make up nuclear particles, of electromagnetic, gravitational, atomic and nuclear forces, of energy, of light and heat, of electronics and the structure of materials, of the interiors of the earth and the stars.

## Faculty and Facilities

Our faculty came here to teach and do research. Several faculty members have research projects involving students.



Classes are small; our upper-division and graduate classes run from two to 15 in enrollment. Physics majors get to know each other very well. They develop friendships with peers, faculty, and staff, which extend beyond graduation.

We have two medium-power lasers, which enhance our capabilities in modern optical studies, including Raman spectroscopy and nonlinear optics. The department has well-equipped research laboratories with laminar flow hoods, evaporative and ion beam sputtering chambers, and high temperature ovens for thin film research. We also have a fully-equipped scanning probe microscope with low current scanning tunneling, lateral force and intermittent contact atomic force imaging capabilities — contained in an environmentally controlled chamber for research involving the self assembly of biomolecules. A dedicated networked computer houses an SPM image library for K-12 education purposes.

Another ongoing research project involves fullerenes, the cage-like molecules formed entirely from carbon. We are able to produce gram quantities of fullerenes in our computer-controlled plasma generator. Current fullerene projects include the measurement of the polarizability and electric dipole moments of metal-doped fullerenes.

High energy particle physics experiments and semiconductor research dealing with solar cells and optical fibers are also part of our current experimental efforts. Two faculty members do theoretical work in particle physics and field theory and several are interested in physics pedagogy.

In addition, our physical facilities have just undergone a multimillion dollar renovation. The renovation project substantially improves both our research and teaching capabilities.

**The Downing Planetarium.** The Downing Planetarium, which is operated by the Physics Department, was completed during the 2000 spring semester. The planetarium features a computer-controlled Spitz A3P star projector and a main theater which seats 74 in reclining seats under a thirty-foot dome. The facility includes a teacher resource center and presents multimedia shows on a daily basis. Physics students have the opportunity to participate in presenting the shows and to assist in planetarium operation.

A remote robotic observatory (which will be situated in the nearby foothills) is in the planning stage. Students interested in astronomy will be able to perform observation projects using a computer-controlled 16" Schmidt-Cassegrain telescope and a CCD camera. The telescope will be controlled from campus and students will be able to electronically download images on campus without having to go to the telescope site.

## Career Opportunities

Approximately half of our bachelor's and master's degree graduates have gone directly into graduate school at various institutions, pursuing master's or doctoral degrees in physics or related fields. The other half have found employment in teaching, in industry, in government, and in the medical professions. We have also observed a recent increase in the demand for high school physics teachers.

Physics graduates have the versatility, knowledge, and analytical skills necessary to adapt quickly to the opportunities which arise in the dynamic world of modern science and high technology. Our graduates report interesting, exciting careers with increasing levels of responsibility and satisfaction.

**Faculty**

Michael J. Zender, *Chair*  
 Vanvilai Katkanant,  
*Undergraduate Adviser*  
 Manfred Bucher, *Graduate Adviser*  
 Parameswar Hari, *Preoptometry Adviser*  
 Gerardo Munoz, *Premedical Adviser*  
 Steven J. White,  
*Downing Planetarium Director*  
 Raymond Hall      Douglas Singleton  
 Floyd L. Judd      James P. Vesenka  
 Brandt Kehoe

**Bachelor of Science in Physics**

The B.S. in Physics offers preparation appropriate to employment in government and industry involving a range of activities from laboratory work to technical sales. It also offers appropriate background preparation for graduate study in physics and a large number of other fields. With an appropriate choice of electives, it provides a very strong premedical, pre dental, or preoptometry program.

Beyond professional goals, the study of physics provides a deep understanding of fundamental processes which underlie our physical world and fosters methods of inquiry which promote intelligent analysis generally.

**Bachelor of Science Degree Requirements**

<i>Physics Major</i>	<i>Units</i>
<b>Physics requirements</b> .....	<b>47</b>
<i>(see note 1)</i>	
Physics core .....	(30)
PHYS 4A, 4AL, 4B, 4BL, 4C, 102, 104, 105A, 105B, 107A, 110	
Upper-division electives .....	(17)
Includes courses in physics and, with approval, in related fields. Students planning to pursue graduate study in physics are strongly encouraged to take PHYS 107B, 115, 130, 140, 162, and 170A (see note 2)	
<b>Additional requirements</b> .....	<b>31-33</b>
<i>(see notes 1 and 4)</i>	
MATH 75, 76, 77, 81; CHEM 1A, 1B; IT 53; C SCI 15 or 40 or ECE 70	
<b>General Education</b> .....	<b>51</b>
<i>(see note 3)</i>	
<b>Electives</b> .....	<b>0-1</b>
<i>(see notes 3 and 4)</i>	
<b>Total</b> .....	<b>124-125</b>

**Advising Notes**

1. *CR/NC* grading is not permitted in the physics major. Additional requirements, however, may be taken *CR/NC* (see *Credit/No Credit Grading*).
2. Courses outside the Department of Physics may be substituted for physics upper-division electives with prior approval of the department chair.
3. It is anticipated that 6 units of course-work required for the major will count toward General Education requirements.
4. Students should be sure to take sufficient upper-division units in their General Education courses and electives to satisfy the university requirement of 40 upper-division units for graduation.

**Suggested Sequence of Courses for the B.S. in Physics**

The list below is a suggested schedule of courses for the major for students planning to complete the suggested pregraduate study sequence in four years.

In addition to the specific courses listed below, General Education requirements and electives should be included to bring the total to 15-17 units per semester. A total of 124 units must be completed for the Bachelor of Science degree. (See *Degree Requirements*.)

1st Year:	PHYS 4A, 4AL; CHEM 1A, 1B; MATH 75, 76; Computer Programming
2nd Year:	PHYS 4B, 4BL, 4C; IT 53; MATH 77, 81
3rd Year:	PHYS 102, 104, 105A, 105B, 110, 150, 170A
4th Year:	PHYS 107A, 107B, 115, 130, 140, 162; plus upper-division electives

**Physics Minor**

	<i>Units</i>
PHYS 4A, 4AL, 4B, 4BL, 4C .....	<b>11</b>
PHYS 102 .....	<b>3</b>
Other upper-division physics .....	<b>6</b>
<b>Total</b> .....	<b>20</b>

**Bachelor of Arts in Natural Sciences**

*Physics Emphasis*

The B.A. in Natural Sciences is designed primarily to meet the needs of students interested in pursuing a teaching career in the sciences at the secondary level. Students interested in satisfying the waiver program in the natural sciences should consult an appropriate adviser early in their academic program. Contact either the Department of Physics or the Office of the Dean, College of Science and Mathematics.

The degree is also a suitable choice for students with a general interest in physics and interest in pursuing a career in law, medicine, dentistry, optometry, and other areas for which the breadth of scientific coverage of this degree is advantageous.

A full description of the degree, including all of the emphases available, can be found in the *Natural Sciences Interdisciplinary Courses* section in this catalog. The B.A. in Natural Sciences with the Physics Emphasis is as follows:

**Bachelor of Arts Degree Requirements**

<i>Natural Sciences Major</i>	<i>Units</i>
<b>Core requirements</b> .....	<b>37-38</b>
<i>Biology</i> <sup>1</sup> .....	(12-13)
BIOSC 1A or BIOL 15 <sup>1</sup> , BIOSC 1B, BIOSC 130	
<i>Chemistry</i> .....	(10)
CHEM 1A, 1B	
<i>Geology</i> <sup>1</sup> .....	(8)
GEOL 1 and 3 (or 15) <sup>1</sup> , GEOL 168	
<i>Natural Science</i> .....	(3)
N SCI 106	
<i>Physical Science</i> .....	(4)
P SCI 21	
<b>Physics Emphasis</b> .....	<b>45</b>
CHEM 128A .....	(3)
P SCI 168 .....	(3)
MATH 75, 76, 77, 81 .....	(16)
PHYS 4A, 4AL, 4B, 4BL, 4C .....	(11)
PHYS 102, 105A, 107A, 140 .....	(12)
<b>General Education</b> .....	<b>51</b>
<b>Electives and remaining degree requirements</b> <sup>3,4</sup> .....	<b>2-3</b>
<b>Total</b> .....	<b>124</b>

See *Advising Notes* on next page.

## Advising Notes for the Natural Sciences Major

- BIOL 15 and GEOL 15 are part of the Humans and the Natural Environment Cluster. See the *Natural Sciences Interdisciplinary Courses* section in this catalog. GEOL 15 is equivalent to GEOL 1 and 3.
- Substitutions may be made with the permission of the appropriate department chair. PHYS 4A-B-C with labs 4AL, 4BL is recommended instead of PHYS 2A-B for those students well-prepared for physics.
- This figure takes into account that 12 units required for the major are expected to count toward General Education as follows: CHEM 1A (3 units), BIOSC 1A or BIOL 15 (3 units), GEOL 168 (3 units), and MATH 75 (3 units). Consult your major adviser for details.
- Students should be sure to take sufficient upper-division units in their General Education courses and electives to satisfy the university requirement of 40 upper-division units for graduation.

## Waiver Program for the Single Subject Credential in the Sciences

Students interested in satisfying the waiver program in the Natural Sciences should consult an appropriate adviser early in their academic program.

## Physical Science Minor

The Physical Science Minor offers an opportunity for both nonscience and science majors to diversify into important and interesting fields. It consists of 21 units of courses selected according to one of the patterns listed in the copy that follows:

	<i>Units</i>
A. CHEM 3A and 3B* .....	7
PHYS 2A and 2B* .....	8
Upper-division electives** .....	6
	21
B. CHEM 10 .....	3
PHYS 2A and 2B* .....	8
GEOL 1 .....	4
Upper-division electives** .....	6
	21
C. CHEM 3A and 3B* .....	7
PHYS 10 .....	4
GEOL 1 .....	4
Upper-division electives** .....	6
	21

For chemistry, geology or physics majors, all courses must be outside the major department. The revised program must be approved by the chair of the major department.

\* CHEM 1A may be substituted for CHEM 3A, and CHEM 1B may be substituted for CHEM 3B. PHYS 4A and 4AL may be substituted for PHYS 2A, and PHYS 4B and 4BL may be substituted for PHYS 2B.

\*\* The upper-division electives may be any upper-division courses for which the student is qualified, from the three departments. Courses with very few prerequisites are CHEM 139; GEOL 105, 114, 154, 168, 169; PHYS 100, 145; P SCI 106, 131, 168.

## Graduate Program

The Department of Physics offers graduate instruction and research leading to the Master of Science degree.

For general information, read the *Graduate Studies* section in this catalog, and in particular, the sections on *Admission to Graduate Standing, Advancement to Candidacy, and Program Requirements*. The minimum entrance requirements are a GPA of 2.5 over the last 60 units, satisfactory scores on the GRE General Examination, and good references. Although the GRE scores are not the only, or most important, criteria used in the admission process, we generally look for scores above 600 on the quantitative portion of the exam or for a total above 1,000 on the combined quantitative and verbal portions. The GRE General Examination must be taken before applying for admission.

It is important to achieve classified standing quickly, before completion of 10 units. The next step is advancement to candidacy, after completion of at least 9 units of graduate study with a minimum GPA of 3.0 and satisfaction of the writing proficiency requirement. Advancement is dependent upon achieving a satisfactory score on the Advanced Physics GRE Subject Examination.

Teaching assistantships are usually available, as is general financial aid. For some forms of financial aid, application must be completed before the end of February.

For specific questions, consult the chair of the department or the graduate adviser.

## Master of Science in Physics

The objective of our M.S. program is to build a firm basis for subsequent Ph.D.

study in physics or in related fields, for positions in industry, and for teaching at the community college level. We offer a broad-based academic program with the opportunity for specialized theoretical or experimental research. Students completing degrees have successfully pursued all three of these career goals — with roughly equal numbers going to doctoral programs and industry, and a smaller number directly into teaching.

Areas of research in which our current faculty are active include condensed matter theory and experiment, dipolar magnetism, Fullerene research, laser Raman spectroscopy, classical and quantum field theory, particle physics theory and experiment, scanning probe microscopies, the biophysics of self-assembled biomolecules, and physics pedagogy.

Under the direction of the graduate adviser and the graduate faculty, a coherent program, directed toward the student's goal in graduate study and designed within the framework outlined in the copy that follows, is prepared and submitted to the department. There is a standard core of classical mechanics (PHYS 203), classical electrodynamics (PHYS 220A, B) and quantum mechanics (PHYS 222A, B) which is strongly recommended for students planning to pursue further graduate study — and, at least in part, for all students. Other courses, both from within and from outside the department, can be used to complete the 30 unit master's program. A culminating experience, consisting of either a project (PHYS 298) plus a competency examination or a thesis (PHYS 299), is required.

Undergraduate education equivalent to a physics major at California State University, Fresno is necessary for admission. Note the other requirements under *Graduate Program*.

	<i>Units</i>
Physics graduate courses .....	21
PHYS 298 or 299 (minimum) ..	(3)
Additional graduate courses in physics .....	(18)
Students planning further graduate study should include PHYS 203, 220A-B, 222A, and 222B.	
Upper-division or graduate electives in physics or related fields .....	9
<b>Total</b> .....	<b>30</b>

## COURSES

**Physics (PHYS)****2A. General Physics (4)**

Prerequisite: completion of General Education Quantitative Reasoning requirement. Topics and concepts in Newtonian mechanics of point particles and rigid bodies, energy, properties of fluids, heat and thermodynamics, waves and sound. G.E. Breadth B1. (3 lecture, 3 lab hours) (CAN PHYS 2)

**2B. General Physics (4)**

Prerequisite: PHYS 2A. Topics and concepts in light, electricity, magnetism, atomic structure, relativity, quantum nature of light and matter, nuclear structure and radiation. (3 lecture, 3 lab hours) (CAN PHYS 4)

**4A. Mechanics and Wave Motion (3)**

Prerequisite: MATH 76 (may be taken concurrently). Topics in classical Newtonian mechanics including linear and circular motion; energy; linear and angular momentum; systems of particles; rigid body motion; wave motion and sound. G.E. Breadth B1.

**4AL. Laboratory in Mechanics and Wave Motion (1)**

Corequisite: PHYS 4A. Introduction to laboratory methods. Experiments in mechanics, waves, and sound. G.E. Breadth B1. (3 lab hours)

**4B. Electricity, Magnetism, and Heat (3)**

Prerequisites: PHYS 4A; MATH 77 (may be taken concurrently). Topics in classical physics including heat and thermodynamics, electrostatics, electric fields and potential, currents and AC and DC electric circuits, magnetic fields, electromagnetic induction.

**4BL. Laboratory in Electricity, Magnetism, and Heat (1)**

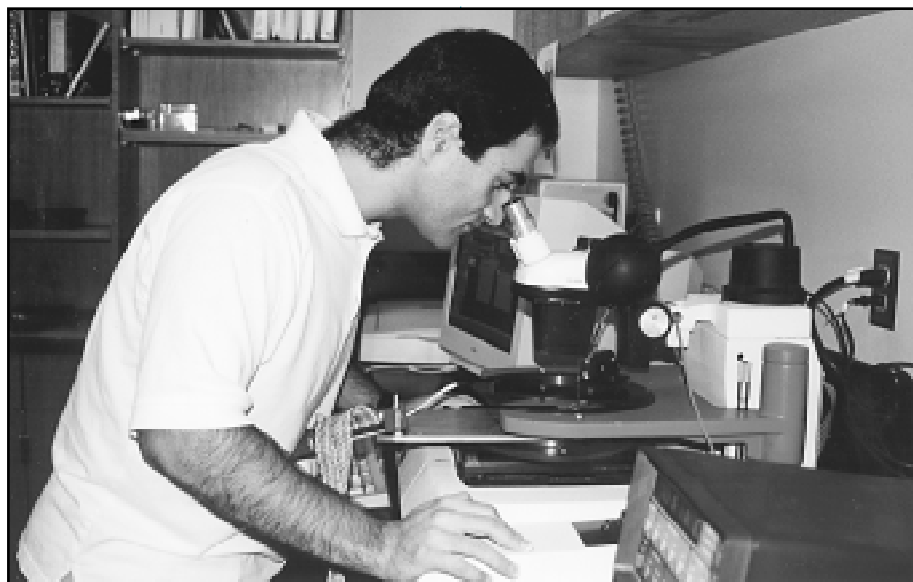
Corequisite: PHYS 4B. Experiments in electricity, magnetism, heat, and thermodynamics. (3 lab hours)

**4C. Light and Modern Physics (3)**

Prerequisites: PHYS 4B; MATH 77. Maxwell's Equations, geometrical optics; electromagnetic radiation; physical optics; introduction to special relativity; quantum physics; and the physics of atoms, nuclei, and the solid state.

**10. Conceptual Physics (4)**

Prerequisite: MATH 45 (may be taken concurrently). Basic ideas of physics and their relationship to the everyday environ-



ment. Physical phenomena, misconceptions, terminology, scientific method, and metric system. Memorable demonstrations in lectures; household-related experiments in the lab. G.E. Breadth B1. (3 lecture, 2 lab hours)

**90. Directed Study (1-2; max total 3)**

Prerequisite: any university-level physics course. Individually arranged course of study in some limited area of physics, either to remove a deficiency or to investigate in more depth. (1-2 hours to be arranged)

**100. Concepts of Modern Physics (3)**

Prerequisite: General Education Quantitative Reasoning and Area B Breadth requirements. Conceptual development of relativity and quantum theory. Demonstration of abstract concepts with mechanical analogues; visualization with diagrams. G.E. Integration IB. (3 lecture hours)

**102. Modern Physics (3)**

Prerequisite: PHYS 4C. Fundamental concepts of atomic and nuclear structure, transitions and radiation. Includes discussions of relativistic mechanics, quantum mechanics, solid state physics. Special topics as they pertain to modern developments in physics, engineering, and chemistry.

**104. Experimental Techniques in Condensed Matter Physics (4)**

Prerequisite: PHYS 4C. Shop techniques and safety instructions. Basic concepts in condensed matter physics. Measurements of conductivity, energy gap in semiconductors, drift mobility, Hall coefficients, photoconductivity, magnetic susceptibilities, exci-

ton spectra, dielectric loss. Experience in X-ray diffraction, vacuum technology, thin-film deposition, and low temperature techniques. (1 lecture, 9 lab hours)

**105A-B. Analytical Mechanics (3-3)**

Prerequisite: PHYS 4C. (A) Analytical and vector treatment of the fundamental principles of statics, kinematics, and dynamics. (B) Advanced dynamics; harmonic motion, central force fields, and Lagrange's equations.

**107A-B. Intermediate Electricity and Magnetism (3-3)**

Prerequisites: PHYS 105A, MATH 81. (A) Mathematical analysis of electrostatics and magnetostatics, Gauss' law, solutions of Laplace's equation, images, theory of conduction, magnetic potentials. (B) Motion of ions in electric and magnetic fields, electromagnetic induction, Maxwell's equations and wave propagation, electron theory, and magnetic properties.

**110. Physical Optics (3)**

Prerequisites: PHYS 4C, MATH 81. Theory of optical phenomena; wave theory of light with applications to optical instruments; interference and diffraction phenomena, dispersion, polarization, coherence, and laser phenomena. Practical experience in using lasers and optical instruments. (2 lecture, 3 lab hours)

**115. Quantum Mechanics (3)**

Prerequisites: PHYS 102, 105A, 170A (may be taken concurrently), MATH 81. Historical background, postulates, meaning, and methods of quantum mechanics; applications to atomic phenomena.

## 130. Advanced Laboratory (2)

Prerequisite: PHYS 102. Advanced experiments in atomic and nuclear physics. Radiation safety. Gamma ray, X-ray, and particle detection and spectroscopy. X-ray fluorescence analysis, Mossbauer, coincidence, Compton scattering and radiation attenuation experiments. Statistics, error analysis. Projects. (6 lab hours)

## 136. Radiation Physics (3)

Prerequisite: PHYS 102. The interaction of radiation with matter: photoelectric, Compton and pair production processes, neutron and charged particle interactions, linear energy transfer, quality factor, attenuation coefficients, shielding. Biological effects, RBE, internal dose, permissible exposures, beneficial application. Instrumentation.

## 140. Thermodynamics and Kinetic Theory (3)

Prerequisite: MATH 81. Fundamental concepts and laws of classical thermodynamics. Rudiments of kinetic theory and statistical thermodynamics with application to physical and chemical systems.

## 145. Geophysics (3)

Prerequisites: PHYS 2A, 2B or 4A, MATH 75. Basic principles of physics applied to the solution of geological problems, rotation and figure of the earth, the gravity field, seismology and the earth's interior, geomagnetism, and the thermal history of the earth.

## 150. Astrophysics (3)

Prerequisites: MATH 75 and PHYS 2A, 2B or PHYS 4A, 4B and 4C. Introduction to celestial mechanics, spectral classification, stellar atmospheres and interiors, star formation and evolution, variable stars, neutron stars, pulsars, black holes, the nature of galaxies, and the expansion of the universe. (Formerly PHYS 175T)

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## 162. Condensed Matter Physics (3)

Prerequisites: PHYS 102, or CHEM 110B and permission of instructor, or CHEM 215. Classification of solids; crystalline state and lattice vibrations; properties of metallic lattices and dielectrics; magnetic properties of solids; free electron theory and band theory of metals; semiconductors; imperfections.

## 170A. Mathematical Physics (3)

Prerequisite: MATH 81. Application of mathematical methods to the solution of problems in physics.

## 175T. Topics in Contemporary Physics (1-4; max total 12)

Designed to provide students with special work in such areas of physics as biophysics, modern optics, plasmas, high energy physics, solid state, chaos theory, nuclear structure, astrophysics, low temperature phenomena. Some topics may have labs.

## 180. Seminar in Physics (1; max total 3)

Prerequisite: senior or graduate physics major or permission of department chair.

## 190. Independent Study (1-3; max total 6)

See *Academic Placement — Independent Study*. Approved for *SP* grading.

## GRADUATE COURSES

(See *Course Numbering System*.)

### **Physics (PHYS)**

## 203. Classical Mechanics (4)

Advanced treatment of classical analytical mechanics including Lagrange's and Hamilton's formulation of the laws of motion, special relativity, small oscillation theory, hydrodynamics. (Formerly PHYS 203A-B)

## 220A-B. Advanced Electricity and Magnetism (3-3)

Electromagnetic theory and its applications: electrostatics, boundary-value problems in electrostatics, dielectrics, multipoles, magnetostatics, Maxwell's equations, electromagnetic radiation, optical properties of materials, wave guides and resonant cavities.

## 222A. Quantum Mechanics I (3)

Prerequisite: PHYS 115. Quantum Dynamics: representations and pictures, path integrals, evolution operator, propagators. Angular Momentum: orbital and spin, addition. Perturbation Theory: time-independent and time-dependent problems, sudden and adiabatic approximations. Scattering: Lippman-Schwinger equations, scattering matrix, Born approximation, partial waves.

## 222B. Quantum Mechanics II (3)

Prerequisite: PHYS 222A. Identical Particles: fermions and bosons, second quantization. Electromagnetic Fields: radiation field, photons, coherent states, vacuum state and Casimir effect, interactions with charged particles. Relativistic Quantum Mechanics: Klein-Gordon and Dirac equations, relativistic hydrogen atom, perturbation theory and Feynman diagrams.

## 262. Advanced Condensed Matter Physics (3)

Binding and crystal structure, crystal electron theories, elementary excitations, transport theories, crystal defects, superconductivity.

**270. Advanced****Mathematical Physics (3)**

Prerequisite: PHYS 170A. Covers three topics: group theory, including continuous (Lie) groups, Lie algebras, and an introduction to the theory of representations, Green's functions and their applications to physical problems, and integral equations including diagrammatic methods of solution.

**272. General Relativity (3)**

Prerequisite: PHYS 203. The principle of equivalence, tensor calculus in curved spacetimes, the Einstein-Hilbert equations, the Schwarzschild solution tests of general relativity, gravitational radiation, introduction to cosmology.

**275T. Topics in Contemporary Physics (1-3; max total 6)**

Advanced topics in such areas as modern optics, plasma physics, high energy physics, astrophysics, nuclear physics, biophysics. Some topics may have labs.

**290. Independent Study (1-3; max total 6)**

See *Academic Placement — Independent Study*. Approved for *SP* grading.

**298. Project (2-6; max total 6)**

Prerequisite: permission of instructor. Scholarly investigation by the advanced graduate student as a culminating experience for the master's degree, including a written project report and an oral defense, and followed by a competency exam. Approved for *SP* grading.

**299. Thesis (2-6; max total 6)**

Prerequisite: See *Criteria for Thesis and Project*. Preparation, completion, and submission of an acceptable thesis for the master's degree. Approved for *SP* grading.

**PHYSICAL SCIENCE COURSES*****Physical Science (PSCI)*****ASTRONOMY****21. Elementary Astronomy (4)**

Prerequisite: MATH 45 (may be taken concurrently) or second-year high school algebra. Concepts, theories, important physical principles, and history of astronomy. Stellar properties, distances, and evolution. Three field trips for observing with telescopes. G.E. Breadth B1. (3 lecture, 2 lab hours)

**OTHER****106. History of Physical Science (3)**

The development of our understanding of the physical world from ancient times to the 20th century with an emphasis on astronomy, mechanics, thermodynamics, and the nature of matter. An exploration of the evolution of ideas.

**131. Concepts of Classical Physics from Babylon to Maxwell (3)**

Prerequisites: General Education Quantitative Reasoning and Area B Breadth requirements. Concepts, theories, and laws of classical physics. Mathematics, astronomy, mechanics, light, electricity, magnetism, thermodynamics, chemistry, and the atom. G.E. Integration IB.

**168. Environmental Impact of Energy Demands by Society (3)**

Analysis of energy crisis; introduction to various forms of energy, energy conversion processes and environmental effects; present energy supply and energy projections; future energy demands and ways of evaluating alternatives.

**180T. Topics in Physical Science (1-3; max total 9)**

Detailed discussion of special topics within the realm of physical science.

**IN-SERVICE COURSES**

(See *Course Numbering System*.)

***Physical Science (PSCI)*****305. Physical Science for Secondary School Teachers (3; max total 6 in any one field)**

Prerequisites: secondary credential and two years of teaching experience. Objectives, content, and instructional materials for the physical sciences; fundamental principles and recent developments. Emphasis may be on chemistry, geology, or physics.

**350. Physical Science for Elementary School Teachers (3-6; max total 6 in any one field)**

Maximum total credit 12 units; not more than 6 units in one field. Prerequisite: elementary credential. Selection of source materials and aids available for illustration of fundamental concepts and principles in physical science; laboratory work in construction, operation, and use of demonstrations and experiments in the elementary school.