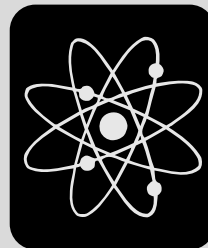


physics and astronomy



bachelor of arts - physics • bachelor of arts - physical science • bachelor of science - physics • minor - physics • minor - astronomy • certificate - scientific instrument development • subject matter program

Program Description

Physics is the most fundamental science and underlies our understanding of nearly all areas of science and technology. In a broad sense, physics is concerned with the study of energy, space, and matter, and with the interactions between matter—and the laws that govern these interactions. More specifically, physicists study mechanics, heat, light, electric and magnetic fields, gravitation, relativity, atomic and nuclear physics, and condensed matter physics.

The Department of Physics and Astronomy at Sacramento State offers three degree programs: the BA in Physics, the BS in Physics, and the BA in Physical Science, and one program for a Single Subject Teaching Credential in Physics; the Department also offers Minor programs in Physics and Astronomy. The BS degree is recommended for students seeking a career in Physics or planning to pursue a graduate degree. The BA degree is recommended for students who are interested in teaching Physics in high school or who want a liberal arts education with an emphasis in Physics. Physics majors are encouraged to take additional mathematics and to develop skills in the use of computers.

Career Possibilities

Research Physicist or Applied Physicist in: Acoustics • Atmospheric Physics • Astrophysics • Astronomy • Atomic and Molecular Physics • Electricity and Magnetism • Electronic Instrumentation • Energy Conservation • Geophysics • Health Physics • Heat • Light • Mechanics • Medical Imaging • Nuclear Medicine • Nuclear Physics • Solar Energy • Solid State Physics • Scientific Computing • Engineer • Science Educator • Technical Writer

Faculty

William DeGraffenreid, Frank Hicks, Sukhbir Mahajan, Zolili Ndlela, Hossein Partovi, Jim Phelps, Randy Phelps, Vassili Sergan, Michael Shea, Gary Shoemaker, John Stevens, Lynn Tashiro, Christopher Taylor, Paul Peter Urone

Contact Information

Gary Shoemaker, *Department Chair* • Rachel Brault, *Administrative Support Coordinator* • Sequoia Hall 230 • (916) 278-6518 • www.sac.edu/physics

Approximately 50 percent of the graduating physics majors from Sacramento State continue on to graduate school earning advanced degrees in Physics, Mathematics, Engineering, Environmental Science, Medicine or Business. Another 40 percent find job opportunities in industrial and government laboratories or agencies. The remaining 10 percent obtain their teaching credential.

Special Features

- In addition to providing a broad academic background and facility in analytic thinking, the study of physics fosters and emphasizes independent study experiences. Physics students at Sacramento State typically spend a year or two working on the design and building of scientific apparatus, assisting a faculty member in a research project, or doing independent study on a topic of special interest to them. These independent projects not only provide a vehicle for applying material learned in class and give students experience in electronics, measurement systems, computers, and machine shop work, but also teach students to work and think on their own. Faculty in the Department have been active in research in acoustics, atomic physics, astrophysics, energy, holography, nuclear physics, optics, quantum mechanics, relativity and solid state physics.
- An advising system has been established by the Department of Physics and Astronomy to help students plan their schedules each semester, to discuss independent project possibilities, and to provide career and current job information. Because of the large number of sequential courses in the degree programs, the Department requires that each student contact his/her advisor before registering for classes each semester. Any student without an advisor should contact Professor Gary Shoemaker in Sequoia Hall 230, or call (916) 278-6518.

Undergraduate Programs

Requirements • Bachelor of Arts Degree – Physics

Units required for Major: 66

Minimum total units required for the BA: 120

Courses in parentheses are prerequisites.

A. Required Lower Division Courses (37 units)

- (4) PHYS 011A General Physics: Mechanics (MATH 030, MATH 031; or equivalent certificated high school courses. MATH 031 may be taken concurrently)
- (4) PHYS 011B General Physics: Heat, Light, Sound (MATH 031, PHYS 011A)
- (4) PHYS 011C General Physics: Electricity and Magnetism, Modern Physics (MATH 031, PHYS 011A)
- (4) MATH 030 Calculus I (MATH 029 or four years of high school mathematics which includes two years of algebra, one year of geometry, and one year of mathematical analysis; completion of ELM requirement and Pre-Calculus Diagnostic Test)
- (4) MATH 031 Calculus II (MATH 030 or appropriate high school based AP credit)
- (4) MATH 032 Calculus III (MATH 031)
- (3) MATH 045 Differential Equations for Science and Engineering (MATH 031)
- (5) CHEM 001A General Chemistry I (High school algebra [two years] and high school chemistry; or equivalent)
- (5) CHEM 001B General Chemistry II (CHEM 001A)

B. Required Upper Division Courses (23 units)

- (3) PHYS 105 Mathematical Methods in Physics (MATH 032; PHYS 011A, PHYS 011B, PHYS 011C or PHYS 005A, PHYS 005B)
- (3) PHYS 106 Introduction to Modern Physics (MATH 031; PHYS 011A, PHYS 011B, PHYS 011C or PHYS 005A, PHYS 005B)
- (3) PHYS 110 Classical Mechanics (MATH 032; MATH 045, PHYS 011C, PHYS 105)
- (4) PHYS 115 Electronics and Instrumentation (PHYS 011C or PHYS 005B with instructor permission) **OR**
- (3) PHYS 145 Optics (MATH 045, PHYS 011A, PHYS 011B, PHYS 011C)
- (3) PHYS 124 Thermodynamics and Statistical Mechanics (MATH 032, MATH 045, PHYS 011A, PHYS 011B, PHYS 011C)
- (3) PHYS 135 Electricity and Magnetism (MATH 032, MATH 045, PHYS 011C, PHYS 105)
- (2) PHYS 175 Advanced Physics Laboratory (6 units of upper division physics)
- (2) PHYS 191 Senior Project

C. Elective Upper Division Requirements (6 units)

Six elective units in Physics selected in consultation with an advisor.

- (3) PHYS 116 Advanced Electronics and Instrumentation (PHYS 115)
- (3) PHYS 130 Acoustics (MATH 045, PHYS 011A, PHYS 011B, PHYS 011C)
- (3) PHYS 136 Electrodynamics of Waves, Radiation, and Materials (PHYS 135)

- (3) PHYS 142 Applied Solid State Physics (MATH 045, PHYS 106)
- (3) PHYS 150 Quantum Mechanics (MATH 045, PHYS 106, PHYS 110)
- (3) PHYS 151 Advanced Modern Physics (PHYS 150)
- (3) PHYS 162 Computational Physics (two semesters of calculus: PHYS 005A and PHYS 005B or two of the following: (PHYS 011A, PHYS 011B, or PHYS 011C. Ability to program in a language such as BASIC, PASCAL, FORTRAN or C)
- PHYS 196 Experimental Offerings in Physics (1-3 units per semester; 4 unit maximum)
- PHYS 198 Co-curricular Activities (1-3 units per semester; 4 unit maximum)
- PHYS 199 Special Problems (1-3 units per semester; 4 unit maximum)

And whichever of the courses below not previously used to fulfill the upper division requirement:

- (4) PHYS 115 Electronics and Instrumentation (PHYS 011C)
- (3) PHYS 145 Optics (MATH 032, MATH 045, PHYS 106, PHYS 110)

Requirements • Bachelor of Science Degree – Physics

Units required for Major: 75

Minimum total units required for the BS: 120

Courses in parentheses are prerequisites.

A. Required Lower Division Courses (37 units)

Same as Section A for BA in Physics.

B. Required Upper Division Courses (32 units)

Same as Section B for BA in Physics plus the following:

- (3) PHYS 136 Electrodynamics of Waves, Radiation, and Materials (PHYS 135)
- (3) PHYS 150 Quantum Mechanics (MATH 045, PHYS 106, PHYS 110)
- (3) PHYS 151 Advanced Modern Physics (PHYS 150)

C. Elective Upper Division Requirements (6 units)

Six elective units in Physics selected from the following in consultation with an advisor:

- (3) PHYS 116 Advanced Electronics and Instrumentation (PHYS 115)
- (3) PHYS 130 Acoustics (MATH 045, PHYS 011A, PHYS 011B, PHYS 011C)
- (3) PHYS 142 Applied Solid State Physics (MATH 045, PHYS 106)
- (3) PHYS 162 Computational Physics (two semesters of calculus: PHYS 005A and PHYS 005B or two of the following: (PHYS 011A, PHYS 011B, or PHYS 011C. Ability to program in a language such as BASIC, PASCAL, FORTRAN or C)
- PHYS 196 Experimental Offerings in Physics (1-3 units per semester; 4 unit maximum)
- PHYS 198 Co-curricular Activities (1-3 units per semester; 4 unit maximum)
- PHYS 199 Special Problems (1-3 units per semester; 4 unit maximum)

And whichever of the courses below not previously used to fulfill the upper division requirement:

- (4) PHYS 115 Electronics and Instrumentation (PHYS 011C)
- (3) PHYS 145 Optics (MATH 032, MATH 045, PHYS 106, PHYS 110)

Notes:

- In addition to the course requirements listed above, both the BA and BS degree programs in Physics require the fulfillment of a minimum attendance of Department colloquia. Students should consult with the Department Chair on how to fulfill this requirement.
- For the BS degree PHYS 199 may be substituted for PHYS 175, if approved by the department.
- Students with an interest in theoretical physics are encouraged to consider a minor in Mathematics.
- For students intending to pursue a graduate degree, the study of one foreign language is recommended. Development of computer skills and the acquisition of various machine shop skills are also recommended. Although a minor is not required for the Physics major, a minor in another science or mathematics is recommended.

Requirements • Bachelor of Arts Degree – Physical Science

Units required for Major: 76

Minimum total units required for the BA: 121

Note: Additional units may be required to meet the Sacramento State foreign language requirement.

Courses in parentheses are prerequisites.

The Physical Science major offers a greater diversity than is possible with a major in a single science. Course work is taken in each of the three physical sciences—Physics, Chemistry and the Earth Sciences.

A. Required Lower Division Courses (46 units)

- (4) MATH 030 Calculus I (MATH 029 or four years of high school mathematics which includes two years of algebra, one year of geometry, and one year of mathematical analysis; completion of ELM requirement and Pre-Calculus Diagnostic Test)
- (4) MATH 031 Calculus II (MATH 030 or appropriate high school based AP credit)
- (3) MATH 045 Differential Equations for Science and Engineering (MATH 031)
- (4) PHYS 011A General Physics: Mechanics (MATH 030, MATH 031; or equivalent certificated high school courses. MATH 031 may be taken concurrently)
- (4) PHYS 011B General Physics: Heat, Light, Sound (MATH 031, PHYS 011A)
- (4) PHYS 011C General Physics: Electricity and Magnetism, Modern Physics (MATH 031, PHYS 011A)
- (5) CHEM 001A General Chemistry I (High school algebra [two years] and high school chemistry; or equivalent)
- (5) CHEM 001B General Chemistry II (CHEM 001A)
- (3) CHEM 020 Organic Chemistry Lecture—Brief Course (CHEM 001B)

- (3) ASTR 004 Introduction to Astronomy (One year of high school geometry or instructor permission)
- (1) ASTR 006 Astronomical Observation Laboratory (ASTR 004, may be taken concurrently)
- (3) GEOL 010 Physical Geology
- (3) BIO 010 Basic Biological Concepts

B. Required Upper Division Courses (30 units)

- (3) GEOG 111 Elements of Meteorology (GEOG 001 or instructor permission)
- (3) GEOL 130 Oceanography
- (3) GEOL 121 Geology of California (GEOL 010 or equivalent) **OR**
- GEOL 140 Geology and the Environment
- (2) GEOL 184 Geological Field Trip
- (3) PHSC 107 History of the Physical Sciences
- (3) PHYS 106 Introduction to Modern Physics (MATH 031; PHYS 011A, PHYS 011B, PHYS 011C or PHYS 005A, PHYS 005B)
- (7) Select two of the following:
- (4) PHYS 115 Electronics and Instrumentation (PHYS 011C or PHYS 005B with instructor permission.)
- (3) PHYS 130 Acoustics (MATH 045, PHYS 011A, PHYS 011B, PHYS 011C)
- (3) PHYS 145 Optics (MATH 045, PHYS 011A, PHYS 011B, PHYS 011C)
- (6) Select two of the following:
- (3) CHEM 124 Organic Chemistry Lecture II (CHEM 024, or instructor permission; concurrent enrollment in CHEM 025 recommended.)
- (3) CHEM 125 Organic Chemistry Laboratory II (CHEM 025, CHEM 124, ENGL 020 or an equivalent second semester composition course)
- (3) CHEM 140A Physical Chemistry Lecture I (CHEM 001B, CHEM 024, CHEM 031, MATH 032; PHYS 005A, PHYS 005B or PHYS 011A, PHYS 011B, PHYS 011C; PHYS 011C may be taken concurrently)
- (3) CHEM 140B Physical Chemistry Lecture II (CHEM 140A)
- (3) CHEM 161 General Biochemistry (CHEM 020 or CHEM 124)

Requirements • Minor – Physics

Units required for Minor: 21, all of which must be taken in Physics.

A minimum of 9 upper division units is required.

Written approval from a Physics faculty advisor is required.

A. Required Lower Division Courses (12 units)

- (4) PHYS 011A General Physics: Mechanics (MATH 030, MATH 031; or equivalent certificated high school courses. MATH 031 may be taken concurrently)
- (4) PHYS 011B General Physics: Heat, Light, Sound (MATH 031, PHYS 011A)
- (4) PHYS 011C General Physics: Electricity and Magnetism, Modern Physics (MATH 031, PHYS 011A)

B. Required Upper Division Courses (3 units)

- (3) PHYS 106 Introduction to Modern Physics (MATH 031; PHYS 011A, PHYS 011B, PHYS 011C or PHYS 005A, PHYS 005B)

C. Additional Upper Division Requirements (6 units)

Six elective units in Physics selected in consultation with an advisor:

- (3) PHYS 105 Mathematical Methods (MATH 032; PHYS 011A, PHYS 011B, PHYS 011C or PHYS 005A, PHYS 005B)
- (3) PHYS 110 Classical Mechanics (MATH 045, PHYS 105)
- (4) PHYS 115 Electronics and Instrumentation (PHYS 011C)
- (3) PHYS 124 Thermodynamics and Statistical Mechanics (MATH 045, PHYS 011A, PHYS 011B, PHYS 011C)
- (3) PHYS 130 Acoustics (MATH 045, PHYS 011A, PHYS 011B, PHYS 011C)
- (3) PHYS 135 Electricity and Magnetism (MATH 045, PHYS 011C, PHYS 105)
- (3) PHYS 136 Electrodynamics of Waves, Radiation, and Materials (PHYS 135)
- (3) PHYS 142 Applied Solid State Physics (MATH 045, PHYS 106)
- (3) PHYS 145 Optics (MATH 045, PHYS 011A, PHYS 011B, PHYS 011C)
- (3) PHYS 150 Quantum Mechanics (MATH 045, PHYS 106, PHYS 110)
- (3) PHYS 151 Advanced Modern Physics (PHYS 150)
- (3) PHYS 162 Computational Physics (two semesters of calculus; PHYS 005A and PHYS 005B or two of the following: PHYS 011A, PHYS 011B or PHYS 011C. Ability to program in a language such as BASIC, PASCAL, FORTRAN or C)
- (2) PHYS 175 Advanced Physics Laboratory (6 units of upper division physics)

Note: PHYS 005A, PHYS 005B may be substituted for PHYS 011A, PHYS 011C, but the 21-unit minimum must be met by additional courses in one of two ways:

- PHYS 106 plus three other upper division Physics courses
OR
 PHYS 106 plus PHYS 011B plus two other upper division Physics courses.

Requirements • Minor – Astronomy

Please refer to the Astronomy section within this catalog.

Requirements • Certificate – Scientific Instrument Development

Units required for the Certificate: 11 minimum

A certificate in Scientific Instrument Development is available through the Department of Physics and Astronomy. The Scientific Instrument Development certificate program focuses not only on using scientific instruments, but also will teach the fundamentals of electronics, computer interfacing, and machining. Students that earn this certificate will be prepared to design, prototype, and construct instruments for a wide range of scientific applications. A minimum of 11 units is required.

Specific course requirements are:

- (2) PHSC 075 Introduction to Machine Shop Practices
- (4) PHYS 115 Electronics and Instrumentation (PHYS 011C or PHYS 005B, instructor permission)
- (3) PHYS 116 Advanced Electronics and Instrumentation (PHYS 115)
- (2-4) Select one of the following:
- (2) PHYS 175 Advanced Physics Laboratory (6 units of upper division physics)
- (4) CHEM 133 Chemical Instrumentation (CHEM 031, CHEM 140B, or CHEM 142, instructor permission, ENGL 020 or an equivalent second semester composition course)
- (3) CHEM 141 Physical Chemistry Laboratory (ENGL 020 or an equivalent second semester composition course, CHEM 140A, CHEM 140B or CHEM 142, instructor permission; CHEM 140B may be taken concurrently)
- (2-3) GEOL 197 Advanced Laboratory Techniques in Geology (appropriate upper division courses and instructor permission)

To receive the certificate in Scientific Instrument Development, students must

- achieve a 2.5 GPA in the certificate program courses;
- must be working towards a degree at Sacramento State or have special approval from the Chair of the Department of Physics and Astronomy.

Requirements • Subject Matter Program (pre-credential preparation)

Physics majors who intend to pursue a single subject teaching credential must complete a BA in Physics including courses in the Science Subject Matter Program which is described in more detail under the heading “Science Subject Matter Program” in this catalog. Upon successful completion, this program fulfills the subject matter competence requirement and qualifies students to enter the Teaching Credential Program in the School of Education. The science teaching credential with a concentration in Physics allows candidates to teach all four of the natural sciences (Biology, Chemistry, Geoscience, and Physics) at the general science level and Physics at an advanced level in high school.

Currently there is a serious need in public school education for well-educated science teachers. Physics majors who have an interest in teaching should see the credential advisor in the Department (Dr. Gary Shoemaker,

shoemaker@csus.edu) to plan an academic program and to explore ways to get involved in teaching-related activities such as tutoring, grading, and working in the schools.

Note: Due to policy changes from the California Commission on Teacher Credentialing and the federal No Child Left Behind mandate, the Subject Matter program was under review at the time of this 2006-2008 catalog printing and is subject to revision. As a result it is important to consult a credential advisor for current details.

Lower Division Courses

Physical Science

PHSC 075. Introduction to Machine Shop Practices. Safe machine operation techniques on common fabrication equipment. Study of materials and methods used to build testing and measuring equipment. Reading and calibrating measuring devices, gauging and optical gauging. Study of measuring conventions and understanding of precision. Interpretation of drawings, tolerances and tactics for maintaining tolerances. Jigs and mounts for dynamic data collection equipment. Prototype manufacturing. Students completing this course qualify to perform work in the shop with minimum supervision. Lecture one hour; Laboratory three hours. 2 units.

Physics

PHYS 001. Physical Reasoning and Calculation. Introduction to the analytical skills needed for the study of Physics. The focus is to prepare students to take PHYS 011A, however, PHYS 001 is also suitable as preparation for PHYS 005A. Emphasis is on reasoning and problem-solving, including conceptualization, visualization, and interpretation of written descriptions of physical situations, and on the connection of physical laws to the mathematical techniques used in their solution. 2 units.

PHYS 002. Topics in Elementary Physics. One semester introductory physics course including a laboratory. Covers the fundamental concepts of physics with an emphasis on everyday life situations and applications. The range of material includes mechanics, waves, electricity and optics. One hour lecture, two hour discussion, and a three hour laboratory session. **Prerequisite:** A recent one year course in high school algebra and one year of plane geometry or a college course in algebra (MATH 009). 4 units.

PHYS 005A. General Physics: Mechanics, Heat, Sound. Physics 005A-B sequence is a two-semester course in introductory physics in which fundamental concepts are emphasized including some physiological applications. These courses satisfy the requirement for pre-medical and pre-dental students and biology majors. Lecture one hour; quiz two hours; laboratory three hours. **Prerequisite:** Recently completed three years of high school algebra and geometry; and a college course in algebra and trigonometry (MATH 009 recommended) for those having an inadequate mathematics background. 4 units. (CAN PHYS 002)

PHYS 005B. General Physics: Light, Electricity and Magnetism, Modern Physics. Lecture one hour; quiz two hours; laboratory three hours. **Prerequisite:** PHYS 005A or instructor permission. 4 units. (CAN PHYS 004)

PHYS 010. Physics in Our World. Introductory course designed for non-science students completing general education requirements. Students will be introduced to basic concepts in Physics through the study of astronomy, atomic nature of matter, electromagnetic waves, energy, sound and earthquake waves, current electricity, magnetism, and nuclear processes. Development of reasoning and quantitative skills and applying them to scientific and technological topics of current importance will be emphasized. 3 units.

PHYS 010L. Physics in Our World Laboratory. Laboratory course complements PHYS 010 and satisfies the general education science lab requirement. Emphasis is placed on the nature of scientific observation and measurement and their relationship to general physical concepts. Students will be given a concrete, hands-

on sense of observing and interpreting data from a variety of experimental environments. **Prerequisite:** PHYS 010; may be taken concurrently. 1 unit.

PHYS 011A. General Physics: Mechanics. PHYS 011A, 011B, 011C sequence is a three semester course in introductory physics requiring elementary calculus. This sequence satisfies the lower division physics requirement for a major in physics, physical science, chemistry, geology, or engineering. Lecture two hours; quiz two hours; laboratory three hours. **Prerequisite:** MATH 030, MATH 031; or equivalent certificated high school courses. MATH 031 may be taken concurrently. 4 units. (CAN PHYS 008)

PHYS 011B. General Physics: Heat, Light, Sound. Lecture one hour; quiz two hours; laboratory three hours. **Prerequisite:** MATH 031, PHYS 011A. 4 units. (PHYS 011A + 011B + 011C = CAN PHYS SEQ. B)

PHYS 011C. General Physics: Electricity and Magnetism, Modern Physics. Lecture one hour; quiz two hours; laboratory three hours. **Prerequisite:** MATH 031, PHYS 011A. 4 units. (PHYS 011A + 011B + 011C = CAN PHYS SEQ. B)

PHYS 030. Science and Pseudoscience. Examination of the methodology of science. Comparison of legitimate investigations with others that do not meet high scientific standards, including both science poorly done and nonsense posing as science. Examples will be drawn primarily from the physical sciences. Analyzes will require study of basic skills of reasoning, types of logical argument, structure and validity of arguments, common reasoning fallacies, critical evaluation of evidence, and understanding of the scientific thinking process. 3 units.

PHYS 099. Special Problems. Individual projects or directed reading. **Note:** Open only to students who appear competent to assume individual work on the approval of the instructor. For students with lower division status. Up to 4 units may be taken for grade. 1-3 units.

Upper Division Courses

Physical Science

PHSC 107. History of the Physical Sciences. Study of the development of the major physical laws presently used in describing our physical world. Some considerations of the influences of these developments on other areas of knowledge and on society in general. Cross-listed as HIST 107; only one may be counted for credit. 3 units.

PHSC 196. Experimental Offerings in Physical Science. When a sufficient number of qualified students apply, one of the staff will conduct a seminar in some topic in one of the physical sciences. 1-3 units.

PHSC 199. Special Problems. Individual projects or directed reading. **Note:** Open only to students who appear competent to assume individual work on the approval of the instructor. Up to 4 units may be taken for grade. 1-3 units.

Physics

PHYS 105. Mathematical Methods in Physics. Linear algebra and linear vector spaces, linear transformations and eigenvectors, differential and integral vector calculus, with applications to physical problems. **Prerequisite:** MATH 032; PHYS 011A, PHYS 011B, PHYS 011C or PHYS 005A, PHYS 005B. Fall only. 3 units.

PHYS 106. Introduction to Modern Physics. Basic concepts of special relativity and quantum theory of matter. Phenomenological study of atomic and molecular energy states and spectra. Elements of solid-state and nuclear physics. **Prerequisite:** MATH 031; PHYS 011A, PHYS 011B, PHYS 011C or PHYS 005A, PHYS 005B. 3 units.

PHYS 107. Conceptual Physics and Scientific Inquiry. Concepts include matter, waves and energy, force and motion, electricity and magnetism, and scientific inquiry. Emphasizes hands on cooperative learning engaging students in scientific inquiry by posing testable scientific questions, conducting experiments, and analyzing and presenting findings to their peers. Appropriate for Liberal Studies and Blended Multiple Subject Credential students. Two activity sessions per week. **Prerequisite:** BIO 007, CHEM 106, GEOL 008, MATH 017. 4 units.

PHYS 110. Classical Mechanics. Fundamental principles of statics and dynamics, including Newton's equations and conservation laws, damped and forced oscillations, central force motion, accelerated coordinate systems, coupled oscillations, normal modes, Lagrangian and Hamiltonian methods, introduction to nonlinear systems and chaos theory.

Prerequisite: MATH 045, PHYS 11C, PHYS 105. Spring only. 3 units.

PHYS 115. Electronics and Instrumentation. Linear and nonlinear circuits, operational amplifiers, transducers, basics of digital circuitry, and an introduction to computerized data acquisition.

Lecture two hours; laboratory six hours. **Prerequisite:** PHYS 011C or PHYS 005B with instructor permission. Fall only. 4 units.

PHYS 116. Advanced Electronics and Instrumentation. Noise reduction techniques, signal recovery, frequency analysis, computerized instrument control, and instrument development. Lecture one hour; laboratory six hours. **Prerequisite:** PHYS 115. Spring only. 3 units.

PHYS 124. Thermodynamics and Statistical Mechanics. Basic concepts and laws of thermodynamics and thermal properties of matter; kinetic theory of gases; use of distribution functions and ensembles in statistical mechanics; connection of probability and entropy; quantum statistics; applications to various systems. **Prerequisite:** MATH 045, PHYS 011A, PHYS 011B, PHYS 011C. Fall only. 3 units.

PHYS 130. Acoustics. Theoretical and experimental study of sound sources, sound waves and sound measurement. Basic properties of waves in continuous media; spectral analysis of vibrations; use of acoustic impedance and circuit analogies; applications to environmental noise analysis, room acoustics, and loudspeaker and microphone design and use; experience with acoustic instrumentation. Lecture two hours; laboratory three hours. **Prerequisite:** MATH 045, PHYS 011A, PHYS 011B, PHYS 011C. 3 units.

PHYS 135. Electricity and Magnetism. Development of electromagnetic theory from basic experimental laws; electrostatics, electric currents, magnetostatics, electric and magnetic properties of matter, induction, Maxwell's equations, conservation laws, introduction to electromagnetic waves. **Prerequisite:** MATH 045, PHYS 011C, PHYS 105. Spring only. 3 units.

PHYS 136. Electrodynamics of Waves, Radiation, and Materials. Electromagnetic waves, wave propagation in material media, reflection and refraction, polarization, cavities and waveguides, optical fibers, simple radiating systems, radiation from an accelerated charge and special relativity. Introduction to plasma physics and electromagnetic properties of superconductors. **Prerequisite:** PHYS 135. 3 units.

PHYS 142. Applied Solid State Physics. Elementary treatment of crystal structure and lattice and electron dynamics. Physics of semiconductor junctions, diodes, transistors and MOSFETS, solar cells, lasers, electro-optic and acousto-optic devices. Introduction to basic physical properties such as electrical conduction of selected amorphous solids and their applications. Laboratory experience. **Prerequisite:** MATH 045, PHYS 106. 3 units.

PHYS 145. Optics. Theoretical and experimental treatment of wave optics; interference, diffraction, absorption, scattering, dispersion, polarization. Selected topics from contemporary optics: Fourier optics, coherence theory, lasers, holography. Lecture two hours; laboratory three hours. **Prerequisite:** MATH 045, PHYS 011A, PHYS 011B, PHYS 011C. Fall only. 3 units.

PHYS 150. Quantum Mechanics. Foundations of wave mechanics, including wave packets, superposition, and the uncertainty principle. The Schroedinger equation and its relation to operators and eigenstates. Symmetric systems and conserved quantities. Introduction to matrix mechanics, spin, scattering, and perturbation theory. **Prerequisite:** MATH 045, PHYS 106, PHYS 110. Fall only. 3 units.

PHYS 151. Advanced Modern Physics. Structure of matter including basic elements of atomics, molecular, solid state, nuclear and particle physics. Topics will also include photon and electron gases, lasers, superconductivity, Bose-Einstein condensation and superfluidity. **Prerequisite:** PHYS 150. Spring only. 3 units.

PHYS 156. Advanced Classical Physics. Topics from classical field theory, including wave propagation in material media, reflection and refraction, polarization, cavities, waveguides, optical fibers, simple radiating systems, dipole radiation, radiation from an accelerated

charge, and special relativity. Advanced formulations of mechanics, including Lagrange's equations and applications, rigid body motion, introduction to Hamiltonian methods, small vibrations and normal modes, and introduction to nonlinear dynamics and chaos.

Prerequisite: PHYS 110, PHYS 135. Fall only. 3 units.

PHYS 162. Computational Physics. Study of methods and development of skills for application of computers in solution of physical problems. Calculation techniques, modeling and simulation, data acquisition and manipulation, and use of programming resources. Practical experience in methods. **Prerequisite:** Two semesters of calculus; PHYS 005A and PHYS 005B or two of the following: PHYS 011A, PHYS 011B, or PHYS 011C. Ability to program in a language such as BASIC, PASCAL, FORTRAN or C. Fall only. 3 units.

PHYS 175. Advanced Physics Laboratory. Advanced experiments chosen from several of the major areas of physics, performed usually on an individual basis. Laboratory six hours. **Note:** May be repeated once with permission of advisor. **Prerequisite:** 6 units of upper division physics. Spring only. 2 units.

PHYS 186. Musical Acoustics: Science and Sound. Physical principles of vibration and wave motion, with illustrations involving musical instruments and concert hall acoustics; principles of electronic synthesis, recording, and reproduction of sound; operation of the human ear and brain in receiving and analyzing sound; relation of the harmonic series to sound quality, harmony and scales; proper roles for science in explaining music as an artistic activity. **Note:** No technical background required; course cannot be used to meet Physics BS program requirements. Cross-listed as MUSC 186; only one may be counted for credit. 3 units.

PHYS 190. Physics Seminar. Special lecture series on announced topics by local and visiting speakers, emphasizing current research developments, with related reading assignments. May be taken twice for credit. 1-2 units.

PHYS 191. Senior Project. Research Project under faculty supervision. Project may consist of laboratory or theoretical research project, instrumentation/demonstration development, or literature research project. Projects require written and oral reports. **Note:** May be taken twice for credit in sequential semesters for a maximum of two units total. Grade assigned upon completion of the project. **Prerequisite:** Department chair permission. 1-2 units.

PHYS 194. Physics Related Work Experience. Supervised employment in a physics or astronomy related company or agency. Placement is arranged through the department and the Cooperative Education Program office. Requires completion of a three-to-six month work assignment and a written report. **Note:** PHYS 194 may not be used to meet major requirements in Physics. **Prerequisite:** Upper-division status and Department Chair permission. Graded Credit/No Credit. 6-12 units.

PHYS 196. Experimental Offerings in Physics. To be offered in the various fields of physics in response to student demand. **Prerequisite:** Appropriate upper division course work and instructor permission. 1-3 units.

PHYS 198. Co-Curricular Activities. Students may provide special tutoring to students taking physics courses, participate in community oriented projects, assist in activity sessions for teacher training courses, or engage in activities related to the subject matter and concerns of the Physics and Astronomy Department. Up to 4 units may be taken. Graded Credit/No Credit. 1-3 units.

PHYS 199. Special Problems. Individual projects or directed reading. Open only to students who appear competent to assume individual work on the approval of the instructor. Up to 4 units may be taken for grade. 1-3 units.