# Department of Physics

*Professor Emeritus:* William T. Duffy Jr.

*Professors:* Richard P. Barber Jr., Christopher P. Weber, Betty A. Young (Lee and Seymour Graff Professor II)

*Associate Professors:* John T. Birmingham, Philip R. Kesten, Guy Ramon (Department Chair)

*Assistant Professor:* Bachana Lomsadze

*Lecturers:* Kristin Kulas, Nathan Williams

*Senior Lab Instructors:* Omid Ahmadi-Gorgi, Roxana Flacau

The Department of Physics offers major programs of lecture and laboratory instruction leading to the bachelor of science in physics, the bachelor of science in physics with a biophysics emphasis, and the bachelor of science in engineering physics. The department also provides an academic minor in physics and required and elective courses for students majoring in other fields.

Common career goals of physics majors include professional employment in industry, in a government lab, or at a university. It is not uncommon for physics majors to become entrepreneurs, work in the business or finance sector, or teach at the secondary school level. The undergraduate major program in physics is appropriate preparation for graduate study in physics, astronomy and astrophysics, biophysics, environmental science, geological science and geophysics, medical physics and medicine, patent law, oceanography, and other fields.

Popular second majors, or minors for physics majors, include mathematics, computer science, chemistry or areas of engineering .The SCU physics major is offered in two forms. Students can choose between a traditional “physics track” or a “biophysics track”. Both tracks provide a solid preparation for graduate studies and for nearly all of the postgraduate opportunities open to traditional physics majors. Students who complete the biophysics track will have additional opportunities in medicine, the life sciences, and related industries.

The engineering physics major is particularly appropriate for the applied science student who intends to do research and development work in industry, or attend graduate school in physics, applied physics, materials science or various engineering disciplines. The engineering physics major covers a broad spectrum of courses in mathematics, engineering, and physics. This program emphasizes, to a greater extent than the traditional engineering major, the physics fundamentals that are applicable to new technologies as well as to the more established ones.

Research in the department is currently funded by the Department of Energy, National Science Foundation, NASA and private industry. Majors in physics and engineering physics often participate in faculty research projects through PHYS 198 (Undergraduate Physics Research) or external grants, internships or fellowships, including Geoff and Josie Fox Summer Research Fellowships. Students also have opportunities for part-time employment assisting faculty in laboratory and related teaching activities.

A student whose GPA is below a 2.5 must obtain approval from the department chair to declare a Physics or Engineering Physics major.

## Requirements for the Major

The department offers two versions of the physics major (a “physics track” and a “biophysics track”), as well as a separate major in engineering physics. In addition to fulfilling undergraduate Core Curriculum requirements for the bachelor of science degree in physics, students majoring in physics must complete the following departmental requirements:

**Major in Physics**

* CHEM 11 or CHEM 14
* MATH 11, 12, 13, 14
* MATH 22 or MATH 23 or AMTH 106
* PHYS 31, 32 (preferred) or PHYS 11, 12
* PHYS 33, 34, 70, 103, 111, 192
* Completion of either the “physics track” or “biophysics track” course requirements specified below

**Physics Track**

* PHYS 112, 120, 121, 122, 151
* One elective chosen from CSCI 10, COEN 10, COEN 11, COEN 44, COEN 45, MECH 45, CHEM 12
* Three upper-division electives AND one supplemental laboratory chosen from: PHYS 104, 113, 113L, 116, 123, 123L, 161, 162, 171

**Biophysics Track**

* BIOL 1A, 1B, 1C
* CHEM 11, 12, 31, 32, 33 (CHEM 50 recommended) or CHEM 14, 15, 31, 32, 33 (CHEM 50 recommended)
* PHYS 120 (or CHEM 152)
* PHYS 121 (or CHEM 151)
* PHYS 171
* Ten upper-division elective units chosen from: PHYS 112, 113L, 116, 122, 123L, 151(L); BIOL 122(L), 124(L), 175(L); CHEM 141, 143(L), 150, 154(L); BIOE 154, 155, 161(L), 162(L), 163(L), 167, 168, 172(L). (At least one elective must be from PHYS if CHEM 152 or 151 is taken in place of PHYS 120 or 121.)

**Major in Engineering Physics**

* CHEM 11 or CHEM 14
* MATH 11, 12, 13, 14
* AMTH 106 or MATH 22 or MATH 23
* One course chosen from CSCI 10, COEN 10, COEN 11, COEN 44, COEN 45, or MECH 45
* PHYS 31, 32, 33, 34, 70, 103, 111, 112, 121, 192
* One upper-division physics elective chosen from PHYS 104 -171
* PHYS 120 (preferred) or MECH 121
* At least four courses chosen from MECH 10, MECH 11, MECH 15, MECH 122, MECH 143or ELEN 123, CENG 41, CENG 43, COEN 11 or CSCI 60, ELEN 21 or COEN 21, ELEN 100, ELEN 110, ELEN 115, ELEN 118, ELEN 144
* An approved cluster of five additional technical courses focused in a specific area chosen by the student and subject to advisor consent. A few of the many possible course cluster areas include: computational, electronics, materials science, solid state, and mechanical. See the engineering physics program coordinator for additional information or go to the [Physics Department website](https://www.scu.edu/cas/physics/).

## Requirements for the Minor

Students must fulfill the following requirements for a minor in physics:

* PHYS 31, 32, 33, 34, 192
* Four additional and approved physics courses numbered 70–171

## Lower-Division Courses

### 1. Hands-On Physics!

How do scientists know what they “know?” The course is taught in a “Workshop Physics” style emphasizing hands-on experimentation and timely topics in today’s world. Instrumentation and “learning by doing” are emphasized. Includes student-designed, peer-reviewed group projects. (4 units)

### 2. Introduction to Astronomy: The Solar System

An introduction to astronomy with a particular focus on the origin and evolution of the solar system, planets, and their satellites. Topics include a brief history of the science of astronomy, telescopes and observational methods, gravitation, spectra and the sun, asteroids, comets, astrobiology, searches for new planetary bodies, and Earth science. Students should be familiar with arithmetic and basic algebra. Evening observational lab meets five times during the quarter. (4 units)

### 3. Introduction to Astronomy: The Universe

An introduction to astronomy with a particular focus on the origin and evolution of the universe, galaxies, and stars. Topics include a brief history of the science of astronomy, understanding the night sky and phases of the moon, telescopes and observational methods, gravitation, spectra and the sun, the big bang, and the expansion and ultimate fate of the universe. Special emphasis is given to stellar evolution, from the birth of stars to their ultimate demise, and stellar remnants such as neutron stars and black holes. Students should be familiar with arithmetic and basic algebra. Evening observational lab meets five times during the quarter. (4 units)

### 4. The Physics of Dance

An exploration of the connection between the art of dance and the science of motion with both lecture/discussion sessions and movement laboratories. Topics include mass, force, equilibrium, acceleration, energy, momentum, torque, rotation, and angular momentum. Movement laboratory combines personal experience of movement with scientific measurements and analysis, in other words: “dance it” and “measure it.” This is a lab science course, not a dance technique course. Also listed as DANC 4. (4 units)

### 5. Physics and Technology for Future Leaders

Examples of how science and technology impact daily life are ubiquitous. Each day brings new comforts and challenges to communities around the world. Leaders in government, industry, finance, and elsewhere are expected to make important and impactful decisions every day on issues related to power consumption, new materials technology, transportation, terrorism, global resources, radiation, climate change, energy sources, conservation, and more. To make the best decisions, leaders must be literate in modern science and technology. This course aims to help students understand the need-to-know physics behind many of the debates impacting our world today. Most importantly, the course aims to give students, the future leaders of our world, the basic tools needed to independently and critically analyze technologically relevant material presented in the media everyday. Assumes basic algebra only. (4 units)

### 7. Physics of Music

The course explores the physical foundations underlying the production, propagation, and perception of music. No prior knowledge of either physics or music is expected, and math will be restricted to basic algebra. At the end of this course, students should possess a basic understanding of the nature of sound; the basic workings of string, wind, and brass instruments, as well as the human voice and ear; knowledge of basic musical notation; and a familiarity with some acoustical problems and their solutions. Through laboratory investigations, students will become familiar with methods of scientific exploration and gain an appreciation of the experimental method. (4 units)

### 8. Introduction to Space Sciences

An introduction to space exploration and how observations from space have influenced our knowledge of Earth and of the other planets in our solar system. This is synthesized within the context of the field of astrobiology, an interdisciplinary study of the origin of the universe, and the evolution and future of life on Earth. (4 units)

### 11. General Physics I

One-dimensional motion. Vectors. Two-dimensional motion. Newtonian laws of motion. Law of gravitation. Planetary motion. Work. Kinetic and potential energy. Linear momentum and impulse. Torque and rotational motion. Rotational energy and momentum. Equilibrium. Elastic deformation of solids. Density and pressure of fluids. Bernoulli’s principle. Buoyant forces. Surface tension. Includes weekly laboratory. Prerequisite: MATH 11, 12, 13, 14, 35, or 36, or permission of the instructor. The PHYS 31/32/33 sequence and the PHYS 11/12/13 sequence cannot both be taken for credit. (5 units)

### 12. General Physics II

Temperature. Thermal expansion of solids and liquids. Thermal energy. Heat transfer. Specific heat. Mechanical equivalent of heat. Work and heat. Laws of thermodynamics. Kinetic theory of gases. Ideal gas law. Entropy. Vibration and wave motion. Hooke’s Law. Sound. Electric charges, fields, and potential. Gauss’s Law. Ohm’s Law. Potential difference. Electric potential. Capacitors. Electric current. Resistance and resistivity. Electric energy and power. Kirchhoff’s Rules. RC circuits. Magnetic fields and forces. Ampere’s Law. Induced EMF. Faraday’s Law. Lenz’s Law. Self-inductance. Includes weekly laboratory. Prerequisite: PHYS 11. The PHYS 31/32/33 sequence and the PHYS 11/12/13 sequence cannot both be taken for credit. (5 units)

### 13. General Physics III

RCL series circuit. Power in an AC circuit. Resonance. Transformers. Optics: reflection, refraction, mirrors, and lenses. Total internal reflection. Diffraction. Young’s double slit interference. Polarization. Optical Instruments. Relativity. Wave-particle duality. Photoelectric effect. X-rays. Pair production and annihilation. Bohr Atom. Spectra. Uncertainty principle. Quantum numbers. Radioactivity. Nuclear particles and reactions. Subnuclear particles. Includes weekly laboratory. Prerequisite: PHYS 12. The PHYS 31/32/33 sequence and the PHYS 11/12/13 sequence cannot both be taken for credit. (5 units)

### 31. Physics for Scientists and Engineers I

Measurement. Vectors. Straight-line kinematics. Kinematics in two dimensions. Laws of inertia, mass conservation, and momentum conservation. Center-of-mass and reference frames. Force. Newtonian mechanics and its applications. Work and kinetic energy. Potential energy and energy conservation. Rotational dynamics. Statics. Includes weekly laboratory. The PHYS 31/32/33 sequence and the PHYS 11/12/13 sequence cannot both be taken for credit. Prerequisite: MATH 11 or by permission of instructor. Knowledge of basic calculus is expected. Students who have been given special permission to enroll in PHYS 31 and who will be concurrently enrolled in MATH 11 must also enroll in the recitation class, PHYS 31R. (5 units)

### 31H. Physics 31H Honors Supplement

Weekly seminar for 15–20 students that extends the treatment of PHYS 31 topics to more challenging/thought-provoking problems. The seminar is being offered so that PHYS 31 can count for Honors credit. Students who are not in the Honors Program but who have a strong math background and some physics experience, and who want the added fun of working on intriguing problems and solutions techniques, may also enroll. (1 unit).

### 31R. Physics 31R Recitation Supplement

Weekly, 1-hour recitation supplement for Physics 31. Highly recommended for students who are new to physics or who need a refresher for the math used in Physics 31. Required for students who have not yet completed MATH 11. (1 unit)

### 32. Physics for Scientists and Engineers II

Simple harmonic motion. Gravitation. Kepler’s Laws. Fluids. Waves. Sound. Interference, diffraction, and polarization. Thermodynamics. Includes weekly laboratory. The PHYS 31/32/33 sequence and the PHYS 11/12/13 sequence cannot both be taken for credit. Prerequisites: PHYS 31 and MATH 12 or by permission of instructor. (5 units)

### 32H. Physics 32H Honors Supplement

Weekly seminar for 15–20 students that extends the treatment of PHYS 32 topics to more challenging/thought-provoking problems. The seminar is being offered so that PHYS 32 can count for Honors credit. Students who are not in the SCU Honors Program but have a strong interest in physics or math, and who want the added fun of working on intriguing problems and solutions techniques, may also enroll. (1 unit)

### 33. Physics for Scientists and Engineers III

Electrostatics. Gauss’s Law. Potential. Capacitance. Electric current. Resistance. Kirchhoff’s rules. DC circuits. AC circuits. Magnetic force. Ampere’s Law. Electromagnetic induction. Includes weekly laboratory. The PHYS 31/32/33 sequence and the PHYS 11/12/13 sequence cannot both be taken for credit. Prerequisites: PHYS 32 and MATH 13 or by permission of instructor. (5 units)

### 34. Physics for Scientists and Engineers IV

Special relativity. Historical development of modern physics: black body radiation, photoelectric effect, Compton scattering, X-rays, Bohr atom, DeBroglie wavelength, Heisenberg uncertainty principle. Quantum waves and particles. Schrödinger equation. Nuclear structure and decay. Particle physics. Introduction to semiconductors. Includes weekly laboratory. Prerequisite: PHYS 33. (5 units)

### 70. Electronic Circuits for Scientists

Linear electric circuits. DC analysis, network theorems, phasor AC analysis. Diode circuits. Physics of p-n junction. Junction diodes, field-effect devices, bipolar junction transistors. Elementary amplifiers. Small-signal device models. Logic gates, digital integrated circuits, Boolean algebra, registers, counters, memory. Operational amplifier circuits. Linear amplifier bias circuits. Includes weekly laboratory. Prerequisite: PHYS 33. (5 units)

## Upper-Division Courses

### 103. Numerical Methods in Physics

Basic elements of programming in MATLAB. Ordinary and partial differential equations. Fourier transforms and spectral analysis. Linear regression and curve fitting. Numerical integration. Stochastic methods. Selected applications include planetary motion, diffusion, Laplace and Poisson equations, and waves. Weekly computer lab. Prior exposure to basic linear algebra will be helpful but is not required. Prerequisite: MATH 22 or MATH 23 or AMTH 106. Strongly recommended prerequisite: CSCI 10 or COEN 10 or COEN 44 or COEN 45 or MECH 45. (5 units)

### 104. Analytical Mechanics

Calculus of variations. Hamilton’s principle. Lagrangian and Hamiltonian approaches to classical dynamics. Central force motion. Noninertial reference frames. Dynamics of rigid bodies. Selected topics in classical dynamics such as coupled oscillators, special relativity, and chaos theory. Prerequisites: PHYS 31 and MATH 22 or MATH 23 or AMTH 106. (5 units)

### 111. Electromagnetic Theory I

Review of vector calculus. Dirac delta function. Electrostatic fields. Work and energy. Laplace and Poisson equations. Separation of variables. Fourier’s trick. Legendre equation. Multipole expansion. Computational problems. Prerequisites: PHYS 33 and MATH 22 or MATH 23 or AMTH 106. Co-requisite: PHYS 103. (5 units)

### 112. Electromagnetic Theory II

Magnetostatics. Induced electromotive forces. Maxwell’s equations. Energy and momentum in electrodynamics. Electromagnetic stress tensor. Electromagnetic waves. Potential formulation. Computational problems. Dipole radiation. Prerequisite: PHYS 111 or ELEN 104. (5 units)

### 113. Advanced Electromagnetism and Optics

Geometric optics. Polarization and optically active media. Interferometry. Optical signal and noise in detection and communication. Interaction of light with metals, dielectrics, and atoms. Thermal radiation. Laser operation. Most students will take 113 and 113L simultaneously. Prerequisite: PHYS 112 or consent of instructor. Also listed without lab as ELEN 725. (4 units)

### 113L. Advanced Electromagnetism and Optics Lab

Weekly lab to accompany PHYS 113. Most students will take PHYS 113 and PHYS 113L simultaneously. Corequisite: PHYS 113 OR consent of instructor. (1 unit)

### 116. Physics of Solids

Crystal structure. Phonons. Free electron theory of metals. Band theory of solids. Semiconductors. Electrical and thermal transport properties of materials. Magnetism. Superconductivity. Topics from current research literature. PHYS 116 is taught as a capstone course. Prerequisites: PHYS 120, 121, and senior standing. (5 units)

### 120. Thermal Physics

Laws of thermodynamics with applications to ideal and non-ideal systems. Kinetic theory of gases. Entropy. Classical and quantum statistical mechanics. Bose and Fermi systems. Selected topics from magnetism, materials, and low-temperature physics. Prerequisites: PHYS 34 and PHYS 103 or AMTH 118. Recommended: PHYS 121. (5 units)

### 121. Quantum Mechanics I

The Schrödinger equation. The wave-function and its interpretation. One dimensional potentials. Harmonic oscillator. Methods in linear algebra including matrix operations, unitary transformations and rotations, eigenvalue problems and diagonalization. Hilbert space, observables, operators, and Dirac notation. The hydrogen atom. Angular momentum. Prerequisites: PHYS 34 and PHYS 103 or AMTH 118. Recommended prerequisite: MATH 53. (5 units)

### 122. Quantum Mechanics II

Angular momentum and spin. Electrons in EM field. Addition of angular momenta. Identical particles. Time-independent perturbation theory. Fine and hyperfine structure. Time-dependent perturbation theory and its application to light-matter interaction. Fermi’s golden rule. Prerequisite: PHYS 121. (5 units)

### 123. Quantum Mechanics III

Variational principle. WKB approximation. Scattering theory. Single-particle relativistic quantum theories. Quantum paradoxes. Introduction to quantum electrodynamics and/or quantum computation: qubits, quantum gates and circuits, quantum teleportation, quantum algorithms, error correction codes. Quantum computer implementations. Most students will take PHYS 123 and PHYS 123L simultaneously. Prerequisite: PHYS 122. (4 units)

### 123L. Quantum Mechanics III Lab

Weekly lab to accompany PHYS 123. Most students will take PHYS 123 and PHYS 123L simultaneously. Prerequisite: PHYS 121 and consent of instructor. (1 unit)

### 141. Modern Topics in Physics

A course focused on a topic in current physics research selected by junior and senior Physics majors in consultation with department faculty. Recent topics have included quantum information and quantum computation, quantum paradoxes, and high-energy physics. May be repeated for credit. (4–5 units)

### 151. Advanced Laboratory

Students conduct intensive laboratory-based experiments in the areas of atomic, nuclear, quantum and condensed matter physics, RF detection, signal processing and more. Emphasis on in-depth understanding of underlying physics, experimental techniques, data analysis, and dissemination of results. Additional design and implementation of independent table-top project also required. Introduction to LabVIEW programming and LaTeX. Written and oral presentations. Prerequisite: Senior standing in physics or consent of instructor. (5 units)

### 161. Introduction to Astrophysics

A survey of astronomy for science majors focused on the physics and mathematics that astronomers use to interpret observations of planets, stars, and galaxies. Topics include the kinematics of objects in the solar system, the nature of stars and their evolution, and the evolution and formation of galaxies. Prerequisite: PHYS 33. PHYS 34 recommended but not required. (5 units)

### 162. Cosmology

A survey of cosmology for science majors. Much of the course will focus on the properties of an idealized, perfectly smooth, model universe. Topics include the formation of galaxies and clusters in an evolving universe, the Benchmark Model of the universe, dark matter and dark energy, the cosmic microwave background and its fluctuation spectrum, recent results from such experiments as WMAP and Planck, Big Bang nucleosynthesis, and problems with the standard Big Bang models and inflation theory. Prerequisites: PHYS 34 or PHYS 161. Knowledge of calculus through differential equations is assumed. (5 units)

### 171. Biophysics

Diffusion and dissipation in cells. Friction and inertia in biological systems. Entropic and chemical forces. Macromolecules. Molecular machines. Ion pumps. Nerve impulses. Prerequisite: PHYS 33 or consent of instructor. (5 units)

### 190. Senior Seminar

Advanced topics in selected areas of physics. Enrollment by permission of instructor. (2 units)

### 192. Physics and Society

Colloquium course that focuses on Physics research topics with significant societal impact. Weekly speakers come from academia, the private sector, industry, non-profits, and government laboratories. Students participate in weekly discussions and write short reflection papers. Prerequisite: PHYS 34. (1 unit)

### 198. Undergraduate Physics Research

Departmental work under close professorial direction on research in progress. Permission of the professor directing the research must be secured before registering for this course. (1–5 units)

### 199. Directed Reading in Physics

Detailed investigation of some area or topic in physics not covered in the regular courses; supervised by a faculty member. Permission of the professor directing the study must be secured before registering for this course. (1–5 units)