

# PHYSICS

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Department Chair: Jennifer Klay

## Academic Programs

Program name	Program type
Physics	BA, BS, Minor
Astronomy	Minor
Geology	Minor

The department provides a solid grounding in fundamental physics through theoretical courses in Classical and Modern Physics, Quantum Mechanics, Electromagnetism, and Thermal Physics. These are supported by a comprehensive laboratory program in electronics and quantum physics. Required subjects are complemented by a wide range of elective courses including optics, particle and solid state physics, nonlinear dynamics, astronomy, and geophysics. Facilities include specialized laboratories in electrical measurements, optics, solid state physics, and nuclear and atomic physics. Majors are prepared to attend graduate school, work in technical fields, or pursue a teaching credential. Student activities include a chapter of the national Society of Physics Students and a chapter of the national physics honor society, Sigma Pi Sigma. All physics students are admitted under the BS Program. Beginning in the second quarter of enrollment students may elect to change to the BA program. Consult your academic advisor.

## Undergraduate Programs

### BA Physics

The BA in Physics provides the student with a solid foundation in physics. It is a more flexible major serving students with double majors, nontechnical minors, and students who intend to pursue pre-college teaching. The curriculum has fewer required courses than the BS, which allows students to choose from an extensive list of electives. Tailoring the curriculum to maximize student goals should be done in consultation with an academic advisor. Students considering a career in teaching should consult with their academic advisor early.

### BS Physics

The BS in Physics is the appropriate choice for those students planning a career involving physics in industry or government laboratories, as well as those seeking a strong foundation in physics for graduate study.

### Astronomy Minor

The Astronomy Minor provides students an opportunity to learn about and analyze astronomical phenomena and processes. A minor in astronomy provides a background for graduate-level studies in astronomy or work in related fields. Interested students should see an Astronomy Minor advisor.

## Geology Minor

The Geology Minor is offered in conjunction with the Natural Resources Management and Environmental Sciences Department. It provides a background useful for careers in environmental consulting or geotechnical fields. Interested students should consult with a Geology Minor advisor. Students preparing for the geology minor should take SS 120 and CHEM 124 or CHEM 127, and have credit for MATH 119 or higher to fulfill the prerequisites for the required courses in the minor. Depending on chosen elective courses in the minor additional prerequisites may apply. This minor is not open to students in the Earth Sciences' Geology concentration. For more information about the Geology concentration, please see the Earth Sciences program in the Natural Resources Management and Environmental Sciences Department (<https://catalog.calpoly.edu/collegesandprograms/collegeofagriculturefoodenvironmentalsciences/naturalresourcesmanagementenvironmentalsciences/>).

## Physics Minor

The Physics Minor provides students with the opportunity to build on their introductory physics courses with a coordinated set of electives based on interests and career objectives selected in consultation with a physics advisor.

Students may earn a minor in Physics by completing a course of study consisting of 24 units in physics and astronomy, of which 12 units must be upper division, and no more than 4 units may be from astronomy courses.

## ASTR Courses

### ASTR 101. Introduction to the Solar System. 4 units

Term Typically Offered: F,W,SPSU

2020-21 or later catalog: GE Area B1

2019-20 or earlier catalog: GE Area B3

Descriptive astronomical properties of the Earth, Moon, other planets and their satellites. Comets, asteroids and other members of the Solar System. Theories of the formation of the Solar System. Opportunities for astronomical observations. Intended for non-engineering and non-science majors. Not open to students who have completed or are taking ASTR 301 or ASTR 302. Course may be offered in classroom-based or online format. 4 lectures. Fulfills GE Area B1 (GE Area B3 for students on the 2019-20 or earlier catalogs).

### ASTR 102. Introduction to Stars and Galaxies. 4 units

Term Typically Offered: F, W, SP

2020-21 or later catalog: GE Area B1

2019-20 or earlier catalog: GE Area B3

Descriptive astronomical properties of the Sun, stars, galaxies and interstellar material. Expanding universe and cosmological models. Opportunities for astronomical observations. Not open to students who have completed or are taking ASTR 301, ASTR 302, PHYS 132 or PHYS 142. Course may be offered in classroom-based or online format. 4 lectures. Fulfills GE Area B1 (GE Area B3 for students on the 2019-20 or earlier catalogs).

**ASTR 200. Special Problems for Undergraduates. 1-2 units**

Term Typically Offered: F, W, SP

Prerequisite: Consent of department chair.

Individual investigation, research, studies, or surveys of selected problems. Total credit limited to 4 units, with a maximum of 2 units per quarter.

**ASTR 270. Selected Topics. 1-4 units**

Term Typically Offered: TBD

Prerequisite: Open to undergraduate students and consent of instructor.

Directed group study of selected topics. The Class Schedule will list topic selected. Total credit limited to 8 units. 1 to 4 lectures.

**ASTR 301. Planetary Systems. 3 units**

Term Typically Offered: W

Prerequisite: PHYS 132 or PHYS 142 or PHYS 122, and MATH 141 or MATH 161.

Quantitative and descriptive properties of planetary systems, including our solar system. Physics of planets and their formation, moons, comets, and interplanetary media. Extrasolar planets and astrobiology. 3 lectures.

**ASTR 302. Stars and Galaxies. 3 units**

Term Typically Offered: SP

Prerequisite: PHYS 122 or PHYS 132 or PHYS 142; and MATH 141 or MATH 161.

Quantitative and descriptive properties of stars, galaxies and interstellar material; including stellar structure and evolution, and structure and evolution of galaxies. 3 lectures.

**ASTR 324. Longitude, Navigation, and Timekeeping. 4 units**

Term Typically Offered: W

2020-21 or later: Upper-Div GE Area B

2019-20 or earlier catalog: GE Area B5, B6, or B7

Prerequisite: Junior standing; completion of GE Area A with grades of C- or better; completion of GE Areas B1 through B3; and completion of MATH 119 with a grade of C- or better.

Evolution of navigational science from 1700 to today, covering the 'longitude problem' to the Global Positioning System. Emphasizes relevant concerns with navigation and timekeeping, including celestial navigation, clocks, and the use of technology, mathematics, and science to address societal problems. 4 lectures. Fulfills GE Area Upper-Division B (GE Areas B5, B6, or B7 for students on the 2019-20 catalog).

**ASTR 326. Cosmology. 3 units**

Term Typically Offered: F

Prerequisite: PHYS 211 (may be taken concurrently).

Introduction to the basic ideas of modern observational cosmology from the Big Bang to the ultimate fate of the universe. Topics include: special and general relativity, curvature of space, dark matter, dark energy, cosmic microwave background, type Ia supernovae. 3 lectures.

**ASTR 400. Special Problems for Advanced Undergraduates. 1-2 units**

Term Typically Offered: F, W, SP

Prerequisite: Consent of department chair.

Individual investigation, research, studies, or surveys of selected problems. Total credit limited to 4 units, with a maximum of 2 units per quarter.

**ASTR 404. Research Experience for Advanced Undergraduates. 1-2 units**

Term Typically Offered: F, W, SP

CR/NC

Prerequisite: Consent of department chair.

Individual investigations, research, studies, or surveys of selected problems. Credit/No Credit grading only. Total credit limited to 4 units, with a maximum of 2 units per quarter.

**ASTR 444. Observational Astronomy. 4 units**

Term Typically Offered: F

Prerequisite: ASTR 301 or ASTR 302.

Introduction to observational astronomy. Coordinate systems, telescopes and observational instruments (CCDs, filters, spectrographs), observational methods and techniques, data reduction and analysis. Laboratory activities include use of a telescope, CCD camera for data acquisition, data reduction and analysis, and presentation of results. 3 lectures, 1 laboratory.

**ASTR 470. Selected Advanced Topics. 1-4 units**

Term Typically Offered: TBD

Prerequisite: Consent of instructor.

Directed group study of selected topics for advanced students. The Class Schedule will list topic selected. Total credit limited to 8 units. 1 to 4 lectures.

**ASTR 471. Selected Advanced Laboratory. 1-2 units**

Term Typically Offered: TBD

Prerequisite: Consent of instructor.

Directed group laboratory study of selected topics for advanced students. The Class Schedule will list topic selected. Total credit limited to 8 units. 1 to 2 laboratories.

**GEOL Courses****GEOL 102. Introduction to Geology. 4 units**

Term Typically Offered: W

2020-21 or later catalog: GE Area B1

2019-20 or earlier catalog: GE Area B3

Processes responsible for the Earth's minerals, rocks, structure, and surface features. Volcanism; mountain building; plate tectonics; weathering. Erosion and deposition by streams, glaciers, wind and waves. Geological resources, earth hazards, and interaction of humanity with global processes. 3 lectures, 1 discussion. Fulfills GE Area B1 (GE Area B3 for students on the 2019-20 or earlier catalogs).

**GEOL 200. Special Problems for Undergraduates. 1-2 units**

Term Typically Offered: F, W, SP

Prerequisite: Consent of department chair.

Individual investigation, research, studies, or surveys of selected problems. Total credit limited to 4 units, with a maximum of 2 units per quarter.

**GEOL 201. Physical Geology. 3 units**

Term Typically Offered: F, W, SP

Prerequisite: MATH 119.

Processes responsible for the Earth's rocks, structural surface features, geologic hazards, and natural resources, with emphasis on interactions with human activities. 3 lectures.

**GEOL 203. The Geologic Record: Fossils and the History of Life. 4 units**

Term Typically Offered: W

2020-21 or later catalog: GE Area B1

2019-20 or earlier catalog: GE Area B5

A historical account of life on Earth interpreted from the fossil record. Paleoenvironmental controls on the rise and decline of lineages of organisms deduced from stratigraphy, and from the composition, character, and geochemistry of sedimentary rocks. Identification of fossils. 3 lectures, 1 discussion. Fulfills GE Area B1 (GE Area B5 for students on the 2019-20 or earlier catalogs).

**GEOL 206. Geologic Excursions. 1 unit**

Term Typically Offered: F, SP

CR/NC

Field trips to places of geologic interest. The Class Schedule will indicate destinations. Students must provide their own transportation, food, and camping equipment. May be repeated for a maximum of 3 units provided field trips are taken to different locations. Credit/No Credit grading only. 1 laboratory.

**GEOL 241. Physical Geology Laboratory. 1 unit**

Term Typically Offered: F, W, SP

Corequisite: GEOL 102 or GEOL 201.

Properties and identification of minerals and rocks. Topographic maps and landform analysis. Geologic maps and interpretation of rock structure. 1 laboratory.

**GEOL 270. Selected Topics. 1-4 units**

Term Typically Offered: TBD

Prerequisite: Consent of instructor.

Directed group study of selected topics. The Class Schedule will list topic selected. Total credit limited to 8 units. 1 to 4 lectures.

**GEOL 301. Physical Models in the Geosciences. 4 units**

Term Typically Offered: F

Prerequisite: MATH 142; PHYS 141; and GEOL 201.

Development and analysis of geodynamical models. Stress and strain, flexure, heat flow, faulting, and elastic waves in the solid earth. Additional topics may include fluid flow, flow of natural materials, geochronology, and equations of state in high pressure mineral physics. 4 lectures.

**GEOL 303. Computation and Visualization in the Geosciences. 3 units**

Term Typically Offered: W

Prerequisite: GEOL 301 and one of the following: STAT 217, STAT 218, STAT 301, STAT 312, or STAT 321.

Introduction to scientific programming and data visualization for solving problems in the geosciences. Import and export of data, plotting data and maps, time series analysis, statistical description of data, and numerical approximations of equations. 2 lectures, 1 laboratory.

**GEOL 305. Seismology and Earth Structure. 4 units**

Term Typically Offered: SP

2020-21 or later: Upper-Div GE Area B

2019-20 or earlier catalog: GE Area B5, B6, or B7

Prerequisite: Junior standing; completion of GE Area A with grades of C- or better; one course in GE Area B4 with a grade of C- or better (GE Area B1 for students on the 2019-20 or earlier catalogs); GEOL 303; or PHYS 132 or PHYS 142 and MATH 242 or MATH 244.

Elastic waves in layered media. Principle of the seismometer. Magnitude, seismic moment and energy calculations. Source mechanics. Major California faults and paleoseismology. Theory of plate tectonics. Seismic properties, structure, and composition of the Earth. Field trip required. 3 lectures, 1 laboratory. Fulfills GE Area Upper-Division B (GE Areas B5, B6, or B7 for students on the 2019-20 catalog).

**GEOL 309. Igneous Petrology. 3 units**

Term Typically Offered: W

Prerequisite: GEOL 102 or GEOL 201; and ERSC 223.

Processes associated with melt generation and igneous crystallization with special attention to relationships with tectonic setting. Field trip required. Not open to students with credit in GEOL 310. 2 lectures, 1 laboratory.

**GEOL 311. Metamorphic Petrology. 3 units**

Term Typically Offered: SP

Prerequisite: GEOL 309.

Textures and minerals associated with the metamorphism of igneous and sedimentary rocks. Principles of metamorphic reactions and thermobarometry. Special attention to metamorphic processes in the context of plate tectonics. Field trip required. Not open to students with credit in GEOL 310. 2 lectures, 1 laboratory.

**GEOL 330. Principles of Stratigraphy. 4 units**

Term Typically Offered: SP

Prerequisite: GEOL 102 or GEOL 201, and GEOL 241.

Description and analysis of stratified rock and sediment. Sedimentology, diagenesis, transgressive/regressive sequences, bedform interpretation, marine and terrestrial sediment and sedimentary-rock sequence interpretation, and sequence stratigraphy. Required field trips. 3 lectures, 1 laboratory.

**GEOL 400. Special Problems for Advanced Undergraduates. 1-2 units**

Term Typically Offered: F, W, SP

Prerequisite: Consent of department chair.

Individual investigations, research, studies, or surveys of selected problems. Total credit limited to 4 units, with a maximum of 2 units per quarter.

**GEOL 404. Research Experience for Advanced Undergraduates. 1-2 units**

Term Typically Offered: F, W, SP

CR/NC

Prerequisite: Consent of department chair.

Individual investigations, research, studies, or surveys of selected problems. Credit/No Credit grading only. Total credit limited to 4 units, with a maximum of 2 units per quarter.

**GEOL 415. Structural Geology. 4 units**

Term Typically Offered: F

Prerequisite: GEOL 241 and ERSC 223.

Recognition, interpretation, and depiction of geological structures. Understanding rock deformation through the study of faults and folds. 3 lectures, 1 laboratory. Required weekend field trips.

**GEOL 416. Field-Geology Methods. 4 units**

Term Typically Offered: W

Prerequisite: GEOL 102 or GEOL 201; and GEOL 415.

Collecting and interpreting field-geologic data. Description of sedimentary rocks and construction of stratigraphic columns. Mapping geologic structures in the field. Surficial geologic stratigraphy and surficial geologic mapping. Understanding geologic processes through field study. Communicating results of field study. 1 lecture, 3 activities. Crosslisted as ERSC/GEOL 416. Formerly ERSC/GEOL 401.

**GEOL 417. Geologic Mapping. 4 units**

Term Typically Offered: SP

Prerequisite: ERSC/GEOL 401 or ERSC/GEOL 416.

Bedrock geologic mapping on topographic maps and aerial photos. Surficial geologic mapping on topographic maps and aerial photos. Correlating and defining surficial geologic map units on the basis of soil development. Understanding landscape evolution using soil development. 4 activities. Crosslisted as ERSC/GEOL 417. Formerly ERSC/GEOL 402.

**GEOL 420. Applied Geophysics. 3 units**

Term Typically Offered: F

Prerequisite: GEOL 201 and PHYS 141.

Introduction to geophysical exploration of the shallow subsurface: seismic refraction, seismic reflection, electrical resistivity, magnetic and gravity methods. Application to determination of subsurface structure, groundwater and mineral resources. Field trip required. 2 lectures, 1 laboratory.

**GEOL 470. Selected Advanced Topics. 1-4 units**

Term Typically Offered: TBD

Prerequisite: Consent of instructor.

Directed group study of selected topics for advanced students. Open to undergraduate and graduate students. The Class Schedule will list topic selected. Total credit limited to 8 units. 1 to 4 lectures.

**GEOL 471. Selected Advanced Laboratory. 1-4 units**

Term Typically Offered: TBD

Prerequisite: Consent of instructor.

Directed group laboratory study of selected topics for advanced students. Open to undergraduate and graduate students. The Class Schedule will list topic selected. Total credit limited to 8 units. 1 to 4 laboratories.

**PHYS Courses****PHYS 100. Introduction to the Physics Major. 1 unit**

Term Typically Offered: F

CR/NC

Introduction to the skills, tools, and habits-of-mind physicists use to approach and investigate physical phenomena. Exploration of possible careers for physics majors and issues of diversity and representation in physics. Includes community building activities. Designed for new physics majors. 1 activity. Credit/No credit grading only.

**PHYS 104. Introductory Physics. 4 units**

Term Typically Offered: F

2020-21 or later catalog: GE Area B1

2019-20 or earlier catalog: GE Area B3

Prerequisite: Appropriate Math Placement Level; or MATH 115; or MATH 116; or MATH 118.

Elementary introduction to mechanics, gases, liquids and solids, heat, vibrations and waves, light, electricity and magnetism. Intended to provide non-science students with an understanding of basic physical concepts. Not open to students who have credit in a college physics course. 4 lectures. Fulfills GE Area B1 (GE Area B3 for students on the 2019-20 or earlier catalogs).

**PHYS 111. Contemporary Physics for Nonscientists. 4 units**

Term Typically Offered: F

2020-21 or later catalog: GE Area B1

2019-20 or earlier catalog: GE Area B3

Qualitative exploration of the key concepts of quantum mechanics and Einstein's special and general theories of relativity. Particle-wave duality, Heisenberg's uncertainty principle, Schrodinger's cat, warped spacetime, black holes. 4 lectures. Not open to students with credit in PHYS 211. Fulfills GE Area B1 (GE Area B3 for students on the 2019-20 or earlier catalogs).

**PHYS 121. College Physics I. 4 units**

Term Typically Offered: F,W,SP,SU

2020-21 or later catalog: GE Area B1

2019-20 or earlier catalog: GE Area B3

Prerequisite: Appropriate Math Placement Level; or MATH 118 and high school trigonometry; or MATH 119.

Introductory course in mechanics emphasizing motion, force, and energy. Not open to students having a grade of C- or better in PHYS 141. Course may be offered in classroom-based or online format. 4 lectures. Fulfills GE Area B1 (GE Area B3 for students on the 2019-20 or earlier catalogs).

**PHYS 122. College Physics II. 4 units**

Term Typically Offered: F,W,SP,SU

2020-21 or later catalog: GE Area B1

2020-21 or later catalog: GE Area B3

2019-20 or earlier catalog: GE Area B3

2019-20 or earlier catalog: GE Area B4

Prerequisite: PHYS 121 or PHYS 141.

Continuation of PHYS 121. Topics include properties of materials, fluids, waves and vibrations, sound, heat, light and optics. Not open for credit to students having a grade of C- or better in PHYS 132. 3 lectures, 1 laboratory. Fulfills GE Areas B1 and B3 (GE Areas B3 and B4 for students on the 2019-20 or earlier catalogs).

**PHYS 123. College Physics III. 4 units**

Term Typically Offered: F, W, SP

Prerequisite: PHYS 118, PHYS 121, PHYS 131, or PHYS 141.

Recommended: PHYS 122.

Continuation of PHYS 121 and 122. Electrostatics, electric current, magnetic fields and induction. Elements of modern physics. Not open for credit to students having a grade of C- or better in PHYS 133 or PHYS 143. 3 lectures, 1 laboratory.

**PHYS 125. College Physics I Laboratory. 1 unit**

Term Typically Offered: F, W, SP

Prerequisite: Consent of the College of Science and Mathematics Advising Center. Co-requisite: PHYS 121.

Laboratory experiments to complement introductory course in mechanics, emphasizing experiments on motion, force, and energy. Not open to students with a grade of C- or better in PHYS 131 or PHYS 141. 1 laboratory.

**PHYS 141. General Physics I. 4 units**

Term Typically Offered: F,W,SP,SU

2020-21 or later catalog: GE Area B1

2019-20 or earlier catalog: GE Area B3

Prerequisite: MATH 141 with grade C- or better. Corequisite: MATH 142 or MATH 182. Recommended: High School Physics.

Fundamental principles of mechanics. Vectors, particle kinematics. Equilibrium of a rigid body. Work and energy, linear momentum, rotational kinematics and dynamics. Primarily for engineering and science students. Course may be offered in classroom-based or online format. 4 lectures. Crosslisted as HNRS 134/PHYS 141. Fulfills GE Area B1 (GE Area B3 for students on the 2019-20 or earlier catalogs).

**PHYS 142. General Physics II. 4 units**

Term Typically Offered: F,W,SP,SU

2020-21 or later catalog: GE Area B1

2020-21 or later catalog: GE Area B3

2019-20 or earlier catalog: GE Area B3

2019-20 or earlier catalog: GE Area B4

Prerequisite: PHYS 141; and MATH 142 or MATH 182.

Oscillations, waves in elastic media, sound waves. Temperature, heat and the first law of thermodynamics. Kinetic theory of matter, second law of thermodynamics. Geometrical and physical optics. 3 lectures, 1 laboratory. Crosslisted as HNRS 132/PHYS 142. Fulfills GE Areas B1 and B3 (GE Areas B3 and B4 for students on the 2019-20 or earlier catalogs). Formerly PHYS 132.

**PHYS 143. General Physics III. 4 units**

Term Typically Offered: F,W,SP,SU

2020-21 or later catalog: GE Area B1

2020-21 or later catalog: GE Area B3

2019-20 or earlier catalog: GE Area B3

2019-20 or earlier catalog: GE Area B4

Prerequisite: MATH 142 and PHYS 141. Recommended: MATH 241.

Charge and matter, electric field, electric potential, dielectrics, capacitance, current and resistance, electromotive force and circuits, magnetic fields, magnetic field of a moving charge, induced emf. 3 lectures, 1 laboratory. Fulfills GE Areas B1 and B3 (GE Areas B3 and B4 for students on the 2019-20 or earlier catalogs). Formerly PHYS 133.

**PHYS 200. Special Problems for Undergraduates. 1-2 units**

Term Typically Offered: F, W, SP

Prerequisite: Consent of department chair.

Individual investigation, research, studies, or surveys of selected problems. Total credit limited to 4 units, with a maximum of 2 units per quarter.

**PHYS 202. Physics on the Computer. 4 units**

Term Typically Offered: SP

Prerequisite: PHYS 133 or PHYS 143; and MATH 241 or MATH 244.

Introduction to using computers for solving problems in physics: differential equations, matrix manipulations, simulations and numerical techniques, nonlinear dynamics. 4 lectures.

**PHYS 206. Electronics and Instrumentation. 4 units**

Term Typically Offered: W

Prerequisite: PHYS 133 or PHYS 143 and MATH 143.

L-R-C circuits and electronic circuit elements emphasizing the applications of analog and digital electronics to instrumentation in modern physics. 3 lectures, 1 laboratory.

**PHYS 211. Modern Physics I. 4 units**

Term Typically Offered: F, W, SP

Prerequisite: PHYS 132 or PHYS 142; PHYS 133 or PHYS 143; and MATH 241. Recommended: MATH 242 or MATH 244.

Special relativity, fundamental principles of quantum mechanics, emphasizing the modern description of atomic phenomena. Wave-particle duality, Bohr theory, Schrodinger equation, elementary atomic structure. Course may be offered in classroom-based or online format. 4 lectures.

**PHYS 212. Modern Physics II. 4 units**

Term Typically Offered: SP

Prerequisite: PHYS 211.

Applications of quantum physics to atoms, molecules, solid state systems, nuclei, and elementary particles including angular momentum and spin. Topics may include applications of statistical mechanics, principles of the laser, cooling and trapping of atoms, Bose-Einstein condensates, semiconductors, superconductors, heavy ion physics, and other topics of current interest. 4 lectures.

**PHYS 220. Introduction to Physics Research. 1 unit**

Term Typically Offered: F

CR/NC

Prerequisite: PHYS 132 or PHYS 133 or PHYS 142 or PHYS 143.

Introduction to the research programs of faculty in the department and opportunities for research. Survey of departmental facilities and procedures related to research. Overview of external research programs/ internships. Credit/No Credit grading. 1 lecture.

**PHYS 270. Selected Topics. 1-4 units**

Term Typically Offered: TBD

Prerequisite: Consent of instructor.

Directed group study of selected topics. The Class Schedule will list topic selected. Total credit limited to 8 units. 1 to 4 lectures.

**PHYS 301. Thermal Physics I. 4 units**

Term Typically Offered: W

Prerequisite: PHYS 211.

Thermodynamics and statistical mechanics. Entropy, temperature, ensembles, partition functions, chemical potential, free energy. Selected applications including paramagnetism, ideal gas, Fermi-Dirac and Bose-Einstein distributions. 4 lectures.



**PHYS 305. Classical Mechanics I. 4 units**

Term Typically Offered: F

2020-21 or later: Upper-Div GE Area B

Prerequisite: Junior standing; completion of GE Area A with grades of C- or better; and one course in GE Area B4 with a grade of C- or better (GE Area B1 for students on the 2019-20 or earlier catalogs); PHYS 141; MATH 241; and MATH 242 or MATH 244.

Laws of motion, kinematics and dynamics of a particle. Oscillations. Work and energy. Linear and angular momentum. Lagrange's and Hamilton's equations and the calculus of variations. Newton's Law of gravity, Kepler's laws of orbital motion, and central force problems. Use of numerical methods for solving problems. Not open to students with credit in PHYS 302. 4 lectures. Fulfills GE Area Upper-Division B (GE Areas B5, B6, or B7 for students on the 2019-20 catalog).

**PHYS 306. Classical Mechanics II. 3 units**

Term Typically Offered: W

Prerequisite: PHYS 305.

Mechanics in non-inertial reference frames. Dynamics of a rigid bodies. Coupled oscillators and normal modes. Use of numerical methods for solving problems. 3 lectures. Formerly PHYS 303.

**PHYS 310. Physics of Energy. 3 units**

Term Typically Offered: SP

Sustainability Focused

Prerequisite: PHYS 132 or PHYS 142.

Physics and mathematics applied to broad energy topics. Efficient usage, transportation, solar energy, nuclear fission and fusion. Plasma, hydrogen economy, fuel cells, wind wave, tidal, and geothermal energy. Transmission, storage, fossils. National planning, and energy economics. 3 lectures.

**PHYS 313. Introduction to Atmospheric Physics. 3 units**

Term Typically Offered: SP

Prerequisite: PHYS 132 or PHYS 142 or PHYS 122, and MATH 241.

Recommended: MATH 304.

Properties of the atmosphere, atmospheric motions, solar and terrestrial radiation. Emphasis on conservation laws of momentum, energy and mass applied to understanding the Earth's atmospheric motions. 3 lectures.

**PHYS 314. Ocean Dynamics. 3 units**

Term Typically Offered: SP

Sustainability Focused

Prerequisite: PHYS 122 or PHYS 132 or PHYS 142; and MATH 241.

Recommended: MATH 304 or PHYS 320.

Physics governing ocean circulation and transport processes. Physical environment, dynamics of fluid motion in the presence of rotation and stratification, balanced flows, heat budgets, ocean waves, mixing/transport, and applications to climate processes and the biological environment. 3 lectures.

**PHYS 315. Lasers. 3 units**

Term Typically Offered: SP

Prerequisite: PHYS 211 and MATH 143.

Interaction of light with matter, theory of laser action, characteristics and modification of laser output, types of lasers. Laser applications. Topics may include interferometry, fiber optics, holography. 3 lectures.

**PHYS 318. Special Theory of Relativity. 3 units**

Term Typically Offered: W

Prerequisite: PHYS 211.

Fundamental experiments and basic postulates of special relativity. Simultaneity, length and time measurements. Lorentz transformations. Four-Vectors. Space-time diagrams. Relativistic mechanics and electromagnetism. 3 lectures.

**PHYS 320. Methods of Theoretical Physics I. 4 units**

Term Typically Offered: F

Prerequisite: PHYS 211; MATH 242 or MATH 244; and Physics major.

Introduction to the mathematical techniques of theoretical physics with applications from classical mechanics, optics, electromagnetism and quantum mechanics. Maxwell's equations and vector calculus. Waves, the wave equation and Fourier analysis. Green's functions. Physics applications of complex contour integration and series. Not open to students with credit in PHYS 322 or PHYS 424. 4 lectures.

**PHYS 321. Methods of Theoretical Physics II. 4 units**

Term Typically Offered: W

Prerequisite: PHYS 320; and Physics major.

Continuing study of the mathematical techniques of theoretical physics. Methods for solving differential equations in classical mechanics, electromagnetism and quantum mechanics. Problems involving the heat equation, the wave equation and the Schrodinger equation in one, two and three dimensions. 4 lectures.

**PHYS 323. Optics. 4 units**

Term Typically Offered: W

Prerequisite: MATH 241; PHYS 133 or PHYS 143; and one of the following: PHYS 320, PHYS 322, EE 228, EE 201, or ME 318.

Ray optics, lens systems, optical instruments, wave optics, and polarization of light. 3 lectures, 1 laboratory.

**PHYS 330. Teaching Physics. 4 units**

Term Typically Offered: SP

Prerequisite: one of the following: PHYS 122, PHYS 123, PHYS 132, PHYS 133, PHYS 142, PHYS 143, PSC 102, or PSC 103.

Inquiry approaches to teaching physics incorporating insights from physics education research and the use of computer technology. Emphasis on pedagogical approaches and assessment that engage learners in scientific discourse and the development of basic models of physics phenomena such as motion, forces, energy, and momentum through experimentation. 2 lectures, 2 activities.

**PHYS 340. Quantum Physics Laboratory I. 2 units**

Term Typically Offered: F

Prerequisite: PHYS 206; PHYS 212; and one of the following: PHYS 202, CSC 101, CSC 231, or CSC 234.

Experimental studies of the quantum properties of atoms and nuclei. Measurements of fundamental constants. Statistics and data analysis. 1 lecture, 1 laboratory.

**PHYS 341. Quantum Physics Laboratory II. 2 units**

Term Typically Offered: W

Prerequisite: PHYS 340.

Experimental studies of quantum properties of atoms and nuclei. Interactions of radiation, particles and fields. 2 laboratories.

**PHYS 342. Quantum Physics Laboratory III. 1 unit**

Term Typically Offered: SP

Prerequisite: PHYS 341.

Advanced experimental studies of quantum properties of atoms and nuclei. Interactions of radiation, particles and fields emphasizing spectroscopic techniques. 1 laboratory.

**PHYS 345. Quantum Computing. 4 units**

Term Typically Offered: SP

Prerequisites: MATH 206 or MATH 244; and CHEM 353 or PHYS 211.

Quantum mechanical wave functions. Principle of superposition and entanglement. States of one or more quantum bits. Quantum gates and circuits. Application of quantum gates on simulators and quantum computers. Quantum computer architectures. Quantum algorithms. Ethics of quantum computing. 3 lectures, 1 activity. Crosslisted as CPE/PHYS 345.

**PHYS 357. Advanced Instrumentation in Experimental Physics. 3 units**

Term Typically Offered: SP

Prerequisite: PHYS 206.

Advanced analog and digital electronics, computer interfacing to experiments, robotics. 2 lectures, 1 laboratory.

**PHYS 400. Special Problems for Advanced Undergraduates. 1-2 units**

Term Typically Offered: F, W, SP

Prerequisite: Consent of department chair.

Individual investigations, research, studies, or surveys of selected problems. Total credit limited to 4 units, with a maximum of 2 units per quarter.

**PHYS 401. Thermal Physics II. 3 units**

Term Typically Offered: SP

Prerequisite: PHYS 301.

Additional topics in thermodynamics and statistical physics, including chemical equilibrium, phase transitions, transport processes, and cryogenics. 3 lectures.

**PHYS 403. Particle and Nuclear Physics. 3 units**

Term Typically Offered: SP

Prerequisite: PHYS 212 and PHYS 405.

Elementary particles and their interactions, fundamental forces, the Standard Model of particle physics. Symmetries and conservation laws including parity, charge conjugation, and time reversal invariance, as well as charge-parity violation. Dirac equation, quantum electrodynamics, and Feynman diagrams. Advanced nuclear physics. Topics may include decays, symmetries of the quark model, neutrinos, nucleosynthesis, and the quark-gluon plasma. 3 lectures.

**PHYS 404. Research Experience for Advanced Undergraduates. 1-2 units**

Term Typically Offered: F, W, SP

CR/NC

Prerequisite: Consent of department chair.

Individual investigations, research, studies, or surveys of selected problems. Credit/No Credit grading only. Total credit limited to 4 units, with a maximum of 2 units per quarter.

**PHYS 405. Quantum Mechanics I. 4 units**

Term Typically Offered: SP

Prerequisite: PHYS 212; PHYS 302 or PHYS 305; PHYS 320 or PHYS 322; MATH 241; and MATH 242 or MATH 244. Recommended: MATH 344 or PHYS 321.

Wave nature of matter and the basic postulates of quantum mechanics. The wave function, operators, and their interpretation. Schrodinger's equation and its solutions in one and more dimensions. The hydrogen atom and the periodic table. 4 lectures.

**PHYS 406. Quantum Mechanics II. 3 units**

Term Typically Offered: F

Prerequisite: PHYS 405.

Angular momentum operators and problems in three dimensions including the hydrogen atom. Elements of matrix mechanics and properties of spin state vectors. Time-independent and time-dependent perturbation theory. Topics may include variational principle, WKB approximation. 3 lectures.

**PHYS 408. Electromagnetic Fields and Waves I. 4 units**

Term Typically Offered: F

Prerequisite: PHYS 133 or PHYS 143; and MATH 304 or PHYS 320.

Electric and magnetic field theory using vector analysis. Electric fields, dielectric materials, magnetic fields, induced emf, magnetic materials, Maxwell's equations, wave equation. 4 lectures.

**PHYS 409. Electromagnetic Fields and Waves II. 3 units**

Term Typically Offered: W

Prerequisite: PHYS 408. Recommended: PHYS 320 or PHYS 322.

Wave equation, plane electromagnetic waves, guided waves. Dipole radiation, radiation from an accelerated charge. Special relativity. 3 lectures.

**PHYS 410. Physics of Solid Earth. 3 units**

Term Typically Offered: W

Prerequisite: PHYS 133 or PHYS 143; MATH 241; and MATH 242 or MATH 244.

Gravity and the figure of the Earth. Body wave seismology, structure and composition of the Earth, heat flow and heat sources, Earth tides, rotational dynamics, the geomagnetic field and its source, paleomagnetism. 3 lectures.

**PHYS 418. Introduction to General Relativity. 3 units**

Term Typically Offered: SP

Prerequisite: PHYS 211; and PHYS 302 or PHYS 305.

Introduction to Einstein's theory of gravity: general relativity. Geometric description of special relativity as flat spacetime. Extension to curved spacetimes and description of gravity. Topics include solar system tests of relativity, black holes, gravitational waves, and applications to astronomy and cosmology. 3 lectures.

**PHYS 422. Polymer Electronics Laboratory. 1 unit**

Term Typically Offered: SP

Prerequisite: EE 347 or MATE 340 or CHEM 319 or PHYS 340.

Experimental procedures in polymer electronics. Investigation of the characteristics of a polymer electronic device. 1 laboratory. Crosslisted as EE/PHYS 422.

**PHYS 423. Advanced Optics. 4 units**

Term Typically Offered: SP

Prerequisite: PHYS 323.

Advanced topics of modern optics. May include: fiber optics, Fourier optics, quantum optics, lasers, holography, non-linear optics. 3 lectures, 1 laboratory.

**PHYS 425. Solid State Physics. 3 units**

Term Typically Offered: F

Prerequisite: PHYS 211; and MATH 242 or MATH 244.

Physics of solids including the structural, mechanical, thermal, and electronic properties, energy band theory and the properties of metals and semiconductors. 3 lectures.

**PHYS 426. Solid State Physics Laboratory. 1 unit**

Term Typically Offered: SP

Prerequisite or concurrent: PHYS 412 or PHYS 425.

Selected experiments on X-ray diffraction, Hall effect, optical absorption, thermo-electric effect, photovoltaic cells, diode characteristics, and superconductivity. 1 laboratory.

**PHYS 427. Advanced Topics in Solid State Physics. 3 units**

Term Typically Offered: SP

Prerequisite: PHYS 412 or PHYS 425.

Semiconducting devices, including junction and field-effect transistors, LED's, and diode lasers. Magnetic properties of solids. Superconductivity, including discussion of high-temperature superconductors. Other topics of current interest in solid state physics. 3 lectures. Formerly PHYS 413.

**PHYS 428. Nonlinear Dynamical Systems. 4 units**

Term Typically Offered: SP

Prerequisite: PHYS 122, PHYS 132, or PHYS 142; and PHYS 123, PHYS 133, or PHYS 143; and MATH 241; and MATH 242 or MATH 244.

Recommended: Junior standing.

Analysis of linear and nonlinear dynamical systems with emphasis on geometrical methods and visualization techniques. Fixed points, phase plane analysis, bifurcations and limit cycles. Laboratory component includes data acquisition and analysis using computers, numerical simulations of dynamical systems, and analysis of discrete systems. 3 lectures, 1 laboratory.

**PHYS 461. Senior Project I. 2 units**

Term Typically Offered: F,W,SP,SU

Prerequisite: Consent of instructor.

Selection and completion of a project under faculty supervision. Projects typical of problems which graduates must solve in their fields of employment. Project results are presented in a formal report. Minimum 60 hours total time.

**PHYS 462. Senior Project II. 2 units**

Term Typically Offered: F,W,SP,SU

Prerequisite: Consent of instructor.

Selection and completion of a project under faculty supervision. Projects typical of problems which graduates must solve in their fields of employment. Project results are presented in a formal report. Minimum 60 hours total time.

**PHYS 470. Selected Advanced Topics. 1-4 units**

Term Typically Offered: TBD

Prerequisite: Consent of instructor.

Directed group study of selected topics for advanced students. Open to undergraduate and graduate students. The Class Schedule will list topic selected. Total credit limited to 8 units. 1 to 4 lectures.

**PHYS 471. Selected Advanced Laboratory. 1-4 units**

Term Typically Offered: TBD

Prerequisite: Consent of instructor.

Directed group laboratory study of selected topics for advanced students. Open to undergraduate and graduate students. The Class Schedule will list topic selected. Total credit limited to 8 units. 1 to 4 laboratories.

**PHYS 485. Cooperative Education Experience. 6 units**

Term Typically Offered: TBD

CR/NC

Prerequisite: Sophomore standing and consent of instructor.

Part-time work experience in business, industry, government, and other areas of student career interest. Positions are paid and usually require relocation and registration in course for two consecutive quarters. Formal report and evaluation by work supervisor required. Total credit limited to 12 units; major credit limited to 2 units. Credit/No Credit grading only.

**PHYS 495. Cooperative Education Experience. 12 units**

Term Typically Offered: TBD

CR/NC

Prerequisite: Sophomore standing and consent of instructor.

Full-time work experience in business, industry, government, and other areas of student career interest. Positions are paid and usually require relocation and registration in course for two consecutive quarters. Formal report and evaluation by work supervisor required. Total credit limited to 12 units; major credit limited to 2 units. Credit/No Credit grading only.

**PSC Courses****PSC 101. Matter and Energy. 4 units**

Term Typically Offered: F, W, SP

2020-21 or later catalog: GE Area B1

2020-21 or later catalog: GE Area B3

2019-20 or earlier catalog: GE Area B3

2019-20 or earlier catalog: GE Area B4

Introduction to the basic principles of physical science, including observation, description, modeling, and the application of physical phenomena. Emphasis on interactions as described by energy, forces, and fields for mechanical, thermal, electric, and magnetic systems. 3 lectures, 1 laboratory. Fulfills GE Areas B1 and B3 (GE Areas B3 and B4 for students on the 2019-20 or earlier catalogs).

**PSC 102. Atoms and Molecules. 4 units**

Term Typically Offered: W

Prerequisite: PHYS 121 or PHYS 131 or PHYS 141 or PSC 101.

Introduction to the basic principles of physical science (observation, description, modeling of physical phenomena) with an emphasis on interactions at the molecular level. Interactions and the behavior of gases, physical change, and chemical change (including chemical reactions, chemical bonding, and solutions). 3 lectures, 1 laboratory.



**PSC 103. The Physical Environment: Earth. 4 units**

Term Typically Offered: SP

Prerequisite: PSC 101 or PHYS 121 or PHYS 131 or PHYS 141.

Recommended: PSC 102.

Introduction to the basic principles of the earth sciences, and applications of these principles in modern society. Structure and formation of the Earth, earthquakes, weather, and oceanography. 3 lectures, 1 laboratory.

**PSC 201. Physical Oceanography. 4 units**

Term Typically Offered: F, W, SP

2020-21 or later catalog: GE Area B1

2019-20 or earlier catalog: GE Area B3

Sustainability Focused

Introduction to the motions of the ocean. Physical environment and sea floor features; seawater properties; atmosphere and ocean interactions; ocean currents and circulation; waves and tides; the El Nino cycle; coastal ocean processes; climate change and ocean stressors; ocean resources and marine life. 4 lectures. Fulfills GE Area B1 (GE Area B3 for students on the 2019-20 or earlier catalogs).

**PSC 307. Nuclear Energy and Weapons in the Modern World. 4 units**

Term Typically Offered: SP

2020-21 or later: Upper-Div GE Area B

2019-20 or earlier catalog: GE Area B5, B6, or B7

Prerequisite: Junior standing; completion of GE Area A with grades of C- or better; and completion of GE Areas B1 through B4, with a grade of C- or better in one course in GE Area B4 (GE Area B1 for students on the 2019-20 or earlier catalogs).

Technology and basic science of fission/fusion weapons, uranium/plutonium, nuclear reactors, offensive/defensive missile systems, command/control, verification, weapon effects, nuclear testing. Historical context of Cold War and proliferation, recent events, global norms, arms control treaties. 3 lectures, 1 seminar. Fulfills GE Area Upper-Division B (GE Areas B5, B6, or B7 for students on the 2019-20 catalog).

**PSC 320. Energy, Society and the Environment. 4 units**

Term Typically Offered: W

2020-21 or later: Upper-Div GE Area B

2019-20 or earlier catalog: GE Area B5, B6, or B7

Sustainability Focused

Prerequisite: Junior standing; completion of GE Area A with grades of C- or better; and completion of GE Areas B1 through B4, with a grade of C- or better in one course in GE Area B4 (GE Area B1 for students on the 2019-20 or earlier catalogs).

Science and technology of current and future energy sources along with associated environmental problems and societal response. Energy production, consumption, efficient usage, fossil fuels, nuclear, solar, other renewables. Risks, benefits, planning, economics. 3 lectures, 1 activity. Fulfills GE Area Upper-Division B (GE Areas B5, B6, or B7 for students on the 2019-20 catalog).

**PSC 391. Appropriate Technology for the World's People: Development. 4 units**

Term Typically Offered: F

2020-21 or later: Upper-Div GE Area D

2019-20 or earlier catalog: GE Area D5

Sustainability Focused

Prerequisite: Junior standing; completion of GE Area A with grades of C- or better; one course in GE Area B4 with a grade of C- or better (GE Area B1 for students on the 2019-20 or earlier catalogs); and two lower-division courses in GE Area D.

A broad overview of international development and appropriate design for sustainability. Besides traditional classroom work, students work in teams to address problems with technical solutions. Collaboration with mentors from the university, private sector, and nonprofits serves to provide diverse background and project mentorship. 4 lectures. Crosslisted as HNRS/PSC/UNIV 391. Fulfills GE Upper-Division D (GE Area D5 for students on the 2019-20 or earlier catalogs).

**PSC 392. Appropriate Technology for the World's People: Design. 4 units**

Term Typically Offered: SP

2020-21 or later: Upper-Div GE Area B

2019-20 or earlier catalog: GE Area B5, B6, or B7

Sustainability Focused

Prerequisite: Junior standing; completion of GE Area A with grades of C- or better; and completion of GE Areas B1 through B4, with a grade of C- or better in one course in GE Area B4 (GE Area B1 for students on the 2019-20 or earlier catalogs). Recommended: UNIV 391 and completion of GE Area D2.

Addresses the needs of international impoverished communities with technological solutions, which are inexpensive, ecologically sustainable, and socially appropriate. Group study of target communities, and design and construction of an appropriate technology prototype. Not open to students with credit in PSC/UNIV/HNRS 492. 3 lectures, 1 laboratory. Crosslisted as HNRS/PSC/UNIV 392. Fulfills GE Area Upper-Division B (GE Areas B5, B6, or B7 for students on the 2019-20 catalog).

**PSC 424. Organizing and Teaching Science. 4 units**

Term Typically Offered: F

Prerequisite: Admission to the Single Subject Credential Program.

Techniques, aims and objectives in the teaching of physical and life sciences at the secondary level. Selection and organization of teaching material, including strategies for English language learners (ELL) and special needs students. Evaluation of results. 3 lectures, 1 activity. Crosslisted as BIO/PSC 424.

**PSC 425. Clinical Experience in Teaching Science Seminar. 2 units**

Term Typically Offered: W, SP

CR/NC

Prerequisite: Acceptance into the Single Subject Credential Program in Science. Concurrent: EDUC 469 or EDUC 479.

Principles and practices in effective teaching of science at the middle and high school level, learning theories, curriculum content and structure, classroom issues, and the teaching profession. Credit/No Credit grading only. Total credit limited to 4 units. 2 seminars. Crosslisted as BIO/PSC 425.

**PSC 491. Appropriate Technology for the World's People: Development. 4 units**

Term Typically Offered: F

Prerequisite: Consent of instructor, and senior or graduate standing.

Corequisite: GE Area D5.

A broad overview of international development and appropriate design for sustainability. Besides traditional classroom work, students work in teams to address problems with technical solutions. Collaboration with mentors from the university, private sector, and nonprofits serves to provide diverse background and mentorship. Seminar paper required. Not open to students with credit in PSC/UNIV/HNRS 391. 4 lectures. Crosslisted as PSC/UNIV 491.

**PSC 492. Appropriate Technology for the World's People: Design. 4 units**

Term Typically Offered: SP

Prerequisite: Junior standing and completion of GE Areas B1 through B4, with a grade of C- or better in one course in GE Area B4 (GE Area B1 for students on the 2019-20 or earlier catalogs); or graduate standing.

Recommended: UNIV 391 and two lower-division courses in GE Area D2 (or in GE Area D3 for students on the 2019-20 or earlier catalogs).

Addresses the needs of international impoverished communities with techno-logical solutions, which are inexpensive, ecologically sustainable, and socially appropriate. Group study of target communities, and design and construction of an appropriate technology prototype. Seminar paper required. Not open to students with credit in PSC/UNIV/HNRS 392. 3 lectures, 1 laboratory. Crosslisted as PSC/UNIV 492.