

# PHYSICS (PHY)

## College of Letters & Science

### PHY 001A – Principles of Physics (3 units)

*Course Description:* Mechanics. Introduction to general principles and analytical methods used in physics with emphasis on applications in applied agricultural and biological sciences and in physical education.

*Prerequisite(s):* Trigonometry or consent of instructor.

*Learning Activities:* Lecture 3 hour(s).

*Credit Limitation(s):* Not open to students who have received credit for PHY 007B or PHY 009A.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

### PHY 001B – Principles of Physics (3 units)

*Course Description:* Continuation of PHY 001A. Heat, optics, electricity, modern physics.

*Prerequisite(s):* PHY 001A or PHY 009A.

*Learning Activities:* Lecture 3 hour(s).

*Credit Limitation(s):* Not open for credit to students who have received credit for PHY 007A, PHY 007B, PHY 007C, PHY 009B, PHY 009C, or PHY 009D.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

### PHY 007A – General Physics (4 units)

*Course Description:* Introduction to general principles and analytical methods used in physics for students majoring in a biological science.

*Prerequisite(s):* MAT 016B (can be concurrent) or MAT 017B (can be concurrent) or MAT 021B (can be concurrent); completion or concurrent enrollment in MAT 016B or MAT 017B or MAT 021B.

*Learning Activities:* Lecture 1.50 hour(s), Discussion/Laboratory 5 hour(s).

*Credit Limitation(s):* Only 2 units of credit allowed to students who have completed PHY 001B or PHY 009B.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

### PHY 007B – General Physics (4 units)

*Course Description:* Continuation of PHY 007A.

*Prerequisite(s):* PHY 007A.

*Learning Activities:* Lecture 1.50 hour(s), Discussion/Laboratory 5 hour(s).

*Credit Limitation(s):* Only 2 units of credit allowed to students who have completed PHY 001A or PHY 009A.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

### PHY 007C – General Physics (4 units)

*Course Description:* Continuation of PHY 007B.

*Prerequisite(s):* PHY 007B.

*Learning Activities:* Lecture 1.50 hour(s), Discussion/Laboratory 5 hour(s).

*Credit Limitation(s):* Only 2 units of credit allowed to students who have completed PHY 009C or PHY 005C.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

### PHY 009A – Classical Physics (5 units)

*Course Description:* Introduction to general principles and analytical methods used in physics for physical science and engineering majors. Classical mechanics.

*Prerequisite(s):* MAT 021B or MAT 021M; or consent of instructor.

*Learning Activities:* Lecture 3 hour(s), Laboratory 2.50 hour(s), Discussion 1 hour(s).

*Credit Limitation(s):* Only 2 units of credit for students who have completed PHY 001A or PHY 007B; not open for credit to students who have completed PHY 009HA.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

### PHY 009B – Classical Physics (5 units)

*Course Description:* Continuation of PHY 009A. Fluid mechanics, thermodynamics, wave phenomena, optics.

*Prerequisite(s):* PHY 009A; MAT 021C; MAT 021D (can be concurrent).

*Learning Activities:* Lecture 3 hour(s), Laboratory 2.50 hour(s), Discussion 1 hour(s).

*Credit Limitation(s):* Only 2 units of credit for students who have completed PHY 007A; not open for credit to students who have completed PHY 009HB, PHY 009HC, or ENG 105.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

### PHY 009C – Classical Physics (5 units)

*Course Description:* Electricity and magnetism including circuits and Maxwell's equations.

*Prerequisite(s):* PHY 009B; MAT 021D; (MAT 022A or MAT 027A (can be concurrent)).

*Learning Activities:* Lecture 3 hour(s), Laboratory 2.50 hour(s), Discussion 1 hour(s).

*Credit Limitation(s):* Only 3 units of credit for students who have completed PHY 007C; not open for credit to students who have completed PHY 009HD.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

### PHY 009D – Modern Physics (4 units)

*Course Description:* Introduction to physics concepts developed since 1900. Special relativity, quantum mechanics, atoms, molecules, condensed matter, nuclear and particle physics.

*Prerequisite(s):* PHY 009C; (MAT 022A or MAT 027A); MAT 022B or MAT 27B recommended (may be taken concurrently).

*Learning Activities:* Lecture 3 hour(s), Discussion 1.50 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

### PHY 009HA – Honors Physics (5 units)

*Course Description:* Classical mechanics. Same material as PHY 009A in greater depth. For students in physical sciences, mathematics, and engineering.

*Prerequisite(s):* MAT 021B (can be concurrent); or consent of instructor.

*Learning Activities:* Lecture 3 hour(s), Discussion/Laboratory 4 hour(s).

*Credit Limitation(s):* Only 2 units of credit for students who have completed PHY 007B; not open for credit to students who have completed PHY 009A.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 009HB – Honors Physics (5 units)**

*Course Description:* Special relativity, thermal physics. Continuation of PHY 009HA.

*Prerequisite(s):* (PHY 009HA or PHY 009A); MAT 021C (can be concurrent).

*Learning Activities:* Lecture 3 hour(s), Discussion/Laboratory 4 hour(s).

*Credit Limitation(s):* Only 2 units of credit for students who have completed PHY 007A; not open for credit to students who have completed PHY 009B or PHY 009D.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 009HC – Honors Physics (5 units)**

*Course Description:* Waves, sound, optics, quantum physics. Continuation of Physics 9HB.

*Prerequisite(s):* PHY 009HB; MAT 021D (can be concurrent).

*Learning Activities:* Lecture 3 hour(s), Discussion/Laboratory 4 hour(s).

*Credit Limitation(s):* Only 2 units of credit for students who have completed PHY 007C; not open for credit to students who have completed PHY 009B or PHY 009D.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 009HD – Honors Physics (5 units)**

*Course Description:* Electricity and magnetism. Continuation of Physics 9HC.

*Prerequisite(s):* PHY 009HC; MAT 021D.

*Learning Activities:* Lecture 3 hour(s), Discussion/Laboratory 4 hour(s).

*Credit Limitation(s):* Not open for credit to students who have completed PHY 009C.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 009HE – Honors Physics (5 units)**

*Course Description:* Application of quantum mechanics.

*Prerequisite(s):* PHY 009HD; (MAT 022B or MAT 027B (can be concurrent)).

*Learning Activities:* Lecture 3 hour(s), Discussion/Laboratory 4 hour(s).

*Credit Limitation(s):* Not open for credit to students who have completed PHY 009D.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 010 – Topics in Physics for Nonscientists (4 units)**

*Course Description:* Emphasis varies: survey of basic principles or a deeper exploration of some particular branch. Past topics included black holes, space time, and relativity; physics of music; history and philosophy; energy and the environment; and natural phenomena.

*Prerequisite(s):* High school algebra.

*Learning Activities:* Lecture 3 hour(s), Discussion 1 hour(s).

*Credit Limitation(s):* No units of credit allowed if taken after any other PHY course.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 010C – Physics of California (3 units)**

*Course Description:* Atmospheric phenomena common in CA, local weather patterns and microclimates. Applications to CA energy, water, and resource management policies. Physics underlying regional sports in CA.

*Learning Activities:* Lecture 3 hour(s).

*Credit Limitation(s):* Not open for credit to students who have completed any quarter of PHY 009 or PHY 009H, or any upper division PHY course.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE); Scientific Literacy (SL); Visual Literacy (VL).

**PHY 010CY – Physics of California (3 units)**

*Course Description:* Conceptual understanding of the physics underlying regional sports in CA. Focus on skiing, surfing, and scuba diving.

Atmospheric phenomena common in CA, local weather patterns and microclimates, applications to CA energy, and water are also discussed.

*Learning Activities:* Web Virtual Lecture 1 hour(s), Web Electronic

Discussion 0.50 hour(s), Discussion 1.50 hour(s).

*Credit Limitation(s):* Not open for credit to students who have completed PHY 010C, any quarter of PHY 009A, PHY 009B, PHY 009C, PHY 009D, PHY 009HA, PHY 009HB, PHY 009HC, PHY 009HD, or PHY 009HE, or any upper division PHY course.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE); Scientific Literacy (SL); Visual Literacy (VL).

**PHY 012 – Visualization in Science (3 units)**

*Course Description:* Production, interpretation, and use of images in physics, astronomy, biology, and chemistry as scientific evidence and for communication of research results.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE); Scientific Literacy (SL); Visual Literacy (VL).

**PHY 030 – Fractals, Chaos & Complexity (3 units)**

This version has ended; see updated course, below.

*Course Description:* Modern ideas about the unifying ideas of fractal geometry, chaos and complexity. Basic theory and applications with examples from physics, earth sciences, mathematics, population dynamics, ecology, history, economics, biology, computer science, art and architecture.

*Prerequisite(s):* MAT 016A or MAT 017A or MAT 021A.

*Learning Activities:* Lecture/Discussion 3 hour(s).

*Cross Listing:* GEL 030.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE); Quantitative Literacy (QL).

**PHY 030 – Fractals, Chaos & Complexity (3 units)**

*Course Description:* Modern ideas about the unifying ideas of fractal geometry, chaos and complexity. Basic theory and applications with examples from physics, earth sciences, mathematics, population dynamics, ecology, history, economics, biology, computer science, art and architecture.

*Prerequisite(s):* MAT 016A or MAT 017A or MAT 019A or MAT 021A.

*Learning Activities:* Lecture/Discussion 3 hour(s).

*Cross Listing:* GEL 030.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE); Quantitative Literacy (QL). This course version is effective from, and including: Fall Quarter 2024.

**PHY 040 – Introduction to Computational Physics (3 units)**

*Course Description:* Introduction to programming with examples from numerical analysis and computational physics. Introduction to modern tools used for scientific analysis and computer algebra.

*Learning Activities:* Lecture 2 hour(s), Laboratory 4 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 045 – Computational Physics (4 units)**

*Course Description:* Algorithms and programming techniques of computational physics with applications from introductory physics.

*Prerequisite(s):* PHY 040; PHY 009C or PHY 009HD.

*Learning Activities:* Lecture 3 hour(s); Laboratory 3 hour(s).

*Credit Limitation(s):* No credit if PHY 104B was taken prior to Fall 2022; 2 units of credit if student has taken PHY 102.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 049 – Supplementary Work in Lower Division Physics (1-3 units)**

*Course Description:* With consent of instructor, students with partial credit in lower division physics courses may complete the credit under this heading.

*Learning Activities:* Variable.

*Repeat Credit:* May be repeated.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 080 – Experimental Techniques (4 units)**

*Course Description:* Experimental techniques. Design of circuits. Data analysis, sources of noise, statistical and systematic uncertainties. Light sources, detection, and measurement in basic optical systems.

*Prerequisite(s):* PHY 009D or PHY 009HD.

*Learning Activities:* Lecture 2 hour(s), Laboratory 5 hour(s).

*Enrollment Restriction(s):* Open to Physics and Applied Physics majors only.

*Grade Mode:* Letter.

**PHY 090X – Lower Division Seminar (2 units)**

*Course Description:* Examination of a special topic in Physics through shared readings, discussions, written assignments, or special activities such as laboratory work.

*Prerequisite(s):* Consent of instructor; lower division standing.

*Learning Activities:* Seminar 2 hour(s).

*Enrollment Restriction(s):* Limited enrollment.

*Repeat Credit:* May be repeated.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 098 – Directed Group Study (1-5 units)**

*Course Description:* Directed group study.

*Prerequisite(s):* Consent of instructor. Primary for lower division students.

*Learning Activities:* Variable.

*Grade Mode:* Pass/No Pass only.

*General Education:* Science & Engineering (SE).

**PHY 099 – Special Study for Undergraduates (1-5 units)**

*Course Description:* Special study for undergraduates.

*Prerequisite(s):* Consent of instructor.

*Learning Activities:* Variable.

*Grade Mode:* Pass/No Pass only.

*General Education:* Science & Engineering (SE).

**PHY 102 – Computational Laboratory in Physics (1 unit)**

*Course Description:* Introduction to computational physics and to the computational resources in the physics department. Preparation for brief programming assignments required in other upper division physics classes.

*Prerequisite(s):* (MAT 021D, (MAT 022A or MAT 027A), (MAT 022B or MAT 027B)), (PHY 009D or PHY 009HD), PHY 040, PHY 104A (can be concurrent).

*Learning Activities:* Laboratory 4 hour(s).

*Credit Limitation(s):* Not open to students who have completed PHY 104B or PHY 105AL.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 104A – Introduction to Mathematical Methods in Physics (4 units)**

*Course Description:* Introduction to mathematics used in upper division physics courses, including applications of vector spaces, Fourier analysis, and partial differential equations.

*Prerequisite(s):* PHY 009C or PHY 009HD; MAT 022B.

*Learning Activities:* Lecture 3 hour(s), Discussion 1 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 104B – Computational Methods of Mathematical Physics (4 units)**

*Course Description:* Introduction to the use of computational techniques to solve the mathematical problems that arise in advanced physics courses, complementing the analytical approaches emphasized in PHY 104A.

*Prerequisite(s):* PHY 104A C- or better; PHY 105AL; or consent of instructor.

*Learning Activities:* Lecture 3 hour(s), Extensive Problem Solving.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 104C – Intermediate Methods of Mathematical Physics (4 units)**

*Course Description:* Applications of complex analysis, conditional probability, integral transformations and other advanced topics.

*Prerequisite(s):* PHY 104A C- or better; or consent of instructor.

*Learning Activities:* Lecture 3 hour(s), Extensive Problem Solving.

*Grade Mode:* Letter.

**PHY 105A – Classical Mechanics (4 units)**

*Course Description:* Principles and applications of Newtonian mechanics. Introduction to Lagrangian and Hamiltonian mechanics.

*Prerequisite(s):* PHY 009C or PHY 009HD; MAT 022A; MAT 022B (can be concurrent).

*Learning Activities:* Lecture 3 hour(s); Discussion 1 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 105B – Analytical Mechanics (4 units)**

*Course Description:* Principles and applications of Newtonian mechanics; introduction to Lagrange's and Hamilton's equations.

*Prerequisite(s):* PHY 104A C or better; PHY 105A C or better; or consent of department for any of the courses.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 105C – Continuum Mechanics (4 units)**

*Course Description:* The continuum hypothesis and limitations, tensors, isotropic constitutive equations, and wave propagation. Applications such as elastic solids, heat flow, aerodynamics, and ocean waves.

*Prerequisite(s):* PHY 104A C- or better; PHY 105A C- or better; or consent of instructor.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 108 – Optics (3 units)**

*Course Description:* The phenomena of diffraction, interference, and polarization of light, with applications to current problems in astrophysics, material science, and atmospheric science. Study of modern optical instrumentation. Open to non-majors.

*Prerequisite(s):* ((PHY 009A, PHY 009B, PHY 009C, PHY 009D) or (PHY 007A, PHY 007B, PHY 007C) or (PHY 009HA, PHY 009HB, PHY 009HC, PHY 009HD, PHY 009HE)); (MAT 021A, MAT 021B, MAT 021C, MAT 021D); or consent of instructor.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 108L – Optics Laboratory (1 unit)**

*Course Description:* The laboratory will consist of one major project pursued throughout the quarter, based on modern applications of optical techniques.

*Prerequisite(s):* PHY 108 (can be concurrent); PHY 108 required concurrently.

*Learning Activities:* Laboratory 3 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 110A – Electricity & Magnetism (4 units)**

*Course Description:* Theory of electrostatics, electromagnetism, Maxwell's equations, electromagnetic waves.

*Prerequisite(s):* (PHY 009B C- or better, PHY 009C C- or better, PHY 009D C- or better) or (PHY 009HB C- or better, PHY 009HC C- or better, PHY 009HD C- or better, PHY 009HE C- or better); MAT 021D C- or better; (MAT 022A C- or better or MAT 027A C- or better); (MAT 022B C- or better or MAT 027B C- or better); PHY 104A; PHY 105A; or consent of department.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 110B – Electricity & Magnetism (4 units)**

*Course Description:* Theory of electrostatics, electromagnetism, Maxwell's equations, electromagnetic waves.

*Prerequisite(s):* PHY 110A C- or better; PHY 104A C- or better; or consent of department.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 110C – Electricity & Magnetism (4 units)**

*Course Description:* Theory of electrostatics, electromagnetism, Maxwell's equations, electromagnetic waves.

*Prerequisite(s):* PHY 110B C- or better; or consent of department.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 110L – Computational Physics Lab for Electricity & Magnetism (1 unit)**

*Course Description:* Applications of computational physics to problems from electricity and magnetism.

*Prerequisite(s):* PHY 045 or ECS 036B; PHY 110B (can be concurrent).

*Learning Activities:* Lecture/Lab 1 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 112 – Thermodynamics & Statistical Mechanics (4 units)**

*Course Description:* Introduction to classical and quantum statistical mechanics and their connections with thermodynamics. Theory is developed for the ideal gas model and simple magnetic models and then extended to studies of solids, quantum fluids, and chemical equilibria.

*Prerequisite(s):* PHY 115A; or the equivalent.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 112L – Computational Physics Lab for Statistical Mechanics (1 unit)**

*Course Description:* Applications of computational physics to problems from statistical mechanics.

*Prerequisite(s):* PHY 045 or ECS 036B; PHY 112 (can be concurrent).

*Learning Activities:* Lecture/Lab 1 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 115A – Foundation of Quantum Mechanics (4 units)**

*Course Description:* Introduction to the methods of quantum mechanics with applications to atomic, molecular, solid state, nuclear and elementary particle physics. Extensive problem solving.

*Prerequisite(s):* PHY 104A C- or better; PHY 105A C- or better; or consent of department.

*Learning Activities:* Lecture 3 hour(s), Extensive Problem Solving.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

### PHY 115B – Applications of Quantum Mechanics (4 units)

*Course Description:* Angular momentum and spin; hydrogen atom and atomic spectra; perturbation theory; scattering theory.

*Prerequisite(s):* PHY 115A C- or better; or consent of department.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

### PHY 115L – Computational Physics Lab for Quantum Mechanics (1 unit)

*Course Description:* Applications of computational physics to problems from Classical and Quantum Mechanics.

*Prerequisite(s):* PHY 045 or ECS 036B; PHY 115A.

*Learning Activities:* Lecture/Lab 1 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

### PHY 116A – Electronic Instrumentation (4 units)

*Course Description:* Experimental and theoretical study of important analog electronic circuits. Linear circuits, transmission lines, input impedance, feedback, amplifiers, oscillators, noise.

*Prerequisite(s):* (PHY 009C or PHY 009HD); (MAT 022B or MAT 027B); or consent of instructor.

*Learning Activities:* Lecture 3 hour(s), Laboratory 3 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE); Visual Literacy (VL).

### PHY 116B – Electronic Instrumentation (4 units)

*Course Description:* Continuation of PHY 116A. Introduction to the use of digital electronics and microcomputers in experimental physics. Nonlinear electronics, integrated circuits, analog-to-digital and digital-to-analog converters, transducers, actuators.

*Prerequisite(s):* PHY 009C or PHY 009HD; or consent of instructor.

*Learning Activities:* Lecture 3 hour(s), Laboratory 3 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

### PHY 116C – Introduction to Computer-Based Experiments in Physics (4 units)

*Course Description:* Introduction to techniques for making physical measurements using computer-based instrumentation.

*Prerequisite(s):* (PHY 009D or PHY 009HD); PHY 116B; MAT 022B; or consent of instructor.

*Learning Activities:* Lecture 3 hour(s), Laboratory 3 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE); Writing Experience (WE).

### PHY 117 – Physics Instrumentation with Analog & Digital Electronics (4 units)

*Course Description:* Experimental and theoretical study of important electronic circuits involving analog and digital components. Feedback, amplifiers, oscillators, noise, integrated circuits, digital logic, timers, analog-to-digital and digital-to-analog converters.

*Prerequisite(s):* PHY 080.

*Learning Activities:* Lecture 3 hour(s); Laboratory 3 hour(s).

*Credit Limitation(s):* 2 units of credit if student has taken PHY 116A; no credit if student has taken PHY 116B.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

### PHY 118 – Physics Instrumentation for Data Acquisition (4 units)

*Course Description:* Experimental application of modern high-density integrated circuits. Automated data acquisition, microprocessors, field programmable gate arrays.

*Prerequisite(s):* PHY 080; PHY 045 or ECS 036B.

*Learning Activities:* Lecture 3 hour(s); Laboratory 3 hour(s).

*Credit Limitation(s):* 2 units of credit if student has taken PHY 116B; no credit if student has taken PHY 116C.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

### PHY 122A – Advanced Laboratory in Condensed Matter Physics (4 units)

*Course Description:* Experimental techniques and measurements in solid-state physics. Three-six experiments performed depending on difficulty. Individual work is stressed. Thorough write-ups of the experiments are required.

*Prerequisite(s):* PHY 104A; PHY 105A; PHY 110B; PHY 115A; PHY 112 (can be concurrent); PHY 080; or consent of the department.

*Learning Activities:* Laboratory 8 hour(s).

*Enrollment Restriction(s):* Registration by Permission to Add (PTA) number only; priority given to graduating PHY and APP majors.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE); Writing Experience (WE).

### PHY 122B – Advanced Laboratory in Particle Physics (4 units)

*Course Description:* Experimental techniques and measurements in nuclear and particle physics. Students perform three to six experiments depending on difficulty. Individual work is stressed. Thorough write-ups of the experiments are required.

*Prerequisite(s):* PHY 104A; PHY 105A; PHY 110B; PHY 115A; PHY 112 (can be concurrent); PHY 080; or consent of the department.

*Learning Activities:* Laboratory 8 hour(s).

*Enrollment Restriction(s):* Registration by Permission to Add (PTA) number only; priority given to graduating PHY and APP majors.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE); Writing Experience (WE).

### PHY 123 – Signals & Noise in Physics (4 units)

*Course Description:* Techniques of measurement and analysis designed to avoid systematic error and maximize signal/noise ratio. Illustrative examples of optimal filters ranging from condensed matter to cosmology.

*Prerequisite(s):* (PHY 009A, PHY 009B, PHY 009C, PHY 009D) or (PHY 009HA, PHY 009HB, PHY 009HC, PHY 009HD, PHY 009HE); PHY 104A; or consent of instructor.

*Learning Activities:* Lecture 3 hour(s), Project 1 hour(s).

*Enrollment Restriction(s):* Not open to students who have taken this course previously as PHY 198 with the Signals & Noise in Physics topic.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 129A – Introduction to Nuclear Physics (4 units)**

*Course Description:* Survey of basic nuclear properties and concepts requiring introductory knowledge of quantum mechanics: nuclear models and forces, radioactive decay and detecting nuclear radiation and nuclear reaction products, alpha, beta and gamma decay.

*Prerequisite(s):* PHY 115A C- or better; or consent of instructor.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 129B – Nuclear Physics, Extensions & Applications (4 units)**

*Course Description:* Continuation of PHY 129A. Nuclear reactions, neutrons, fission, fusion accelerators, introduction to meson and particle physics, nuclear astrophysics, and applications of nuclear physics and techniques to mass spectrometry, nuclear medicine, trace element analysis.

*Prerequisite(s):* PHY 129A.

*Learning Activities:* Lecture 3 hour(s), Term Paper.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 130A – Elementary Particle Physics (4 units)**

*Course Description:* Properties and classification of elementary particles and their interactions. Experimental techniques. Conservation laws and symmetries. Strong, electromagnetic, and weak interactions. Introduction to Feynman calculus.

*Prerequisite(s):* PHY 115A C- or better; or consent of instructor.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 130B – Elementary Particle Physics (4 units)**

*Course Description:* Properties and classification of elementary particles and their interactions. Experimental techniques. Conservation laws and symmetries. Strong, electromagnetic, and weak interactions. Introduction to Feynman calculus.

*Prerequisite(s):* PHY 115A C- or better; or consent of instructor.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 140A – Introduction to Solid State Physics (4 units)**

*Course Description:* Survey of fundamental ideas in the physics of solids, with selected device applications. Crystal structure, x-ray and neutron diffraction, phonons, simple metals, energy bands and Fermi surfaces, semiconductors, optical properties, magnetism, superconductivity.

*Prerequisite(s):* PHY 115A C- or better; or equivalent course passed with C- or better, or consent of instructor.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 140B – Introduction to Solid State Physics (4 units)**

*Course Description:* Survey of fundamental ideas in the physics of solids, with selected device applications. Crystal structure, x-ray and neutron diffraction, phonons, simple metals, energy bands and Fermi surfaces, semiconductors, optical properties, magnetism, superconductivity.

*Prerequisite(s):* PHY 115A C- or better; or equivalent course passed with C- or better, or consent of instructor.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 150 – Special Topics in Physics (4 units)**

*Course Description:* Topics vary, covering areas of contemporary research in physics.

*Prerequisite(s):* (PHY 009A, PHY 009B, PHY 009C, PHY 009D) or (PHY 009HA, PHY 009HB, PHY 009HC, PHY 009HD, PHY 009HE); or consent of instructor.

*Learning Activities:* Lecture 3 hour(s), Extensive Problem Solving.

*Repeat Credit:* May be repeated.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 151 – Stellar Structure & Evolution (4 units)**

*Course Description:* Chemical composition, structure, energy sources and evolutionary history of stars, with equal emphasis on both the observational data and theoretical models, including black holes, neutron stars and white dwarfs and the formation of substellar masses.

*Prerequisite(s):* (PHY 009A, PHY 009B, PHY 009C, PHY 009D) or (PHY 009HA, PHY 009HB, PHY 009HC, PHY 009HD, PHY 009HE); or consent of instructor.

*Learning Activities:* Lecture 3 hour(s), Project.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 152 – Galactic Structure & the Interstellar Medium (4 units)**

*Course Description:* Structure, contents, and formation of our Milky Way galaxy, viz. its shape and size, the nature of the interstellar medium, stellar populations, rotation curves, mass determination and evidence of dark matter.

*Prerequisite(s):* ((PHY 009A, PHY 009B, PHY 009C, PHY 009D) or (PHY 009HA, PHY 009HB, PHY 009HC, PHY 009HD, PHY 009HE)); PHY 105A (can be concurrent); or consent of instructor.

*Learning Activities:* Lecture 3 hour(s), Project.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 153 – Extragalactic Astrophysics (4 units)**

*Course Description:* Structure and evolution of galaxies and clusters of galaxies, including distance and mass determination, galaxy types and environments, active galactic nuclei and quasars, gravitational lensing and dark matter, global cosmological properties.

*Prerequisite(s):* ((PHY 009A, PHY 009B, PHY 009C, PHY 009D) or (PHY 009HA, PHY 009HB, PHY 009HC, PHY 009HD, PHY 009HE)); PHY 104A; PHY 105A; or consent of instructor.

*Learning Activities:* Lecture 3 hour(s), Project.

*Credit Limitation(s):* Not open to students who have taken PHY 127.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

### PHY 154 – Astrophysical Applications of Physics (4 units)

*Course Description:* Applications of classical and quantum mechanics, thermodynamics, statistical mechanics, and electricity and magnetism to astrophysical settings such as the Big Bang, degenerate white dwarf and neutron stars, and solar neutrinos.

*Prerequisite(s):* PHY 105A; PHY 105B; PHY 110B (can be concurrent); PHY 115A (can be concurrent); PHY 112; PHY 112 or consent of instructor; PHY 110B and PHY 115A required concurrently.

*Learning Activities:* Lecture 3 hour(s), Project.

*Enrollment Restriction(s):* Not open to students who have taken this course previously as PHY 198.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

### PHY 155 – General Relativity (4 units)

*Course Description:* Definition of the mathematical frame work for the description of the gravitational field, introduction of the dynamical equations of Einstein governing its evolution and review of the key solutions, including black holes and expanding universes.

*Prerequisite(s):* PHY 104A; PHY 105A; PHY 105B; PHY 110A; PHY 105B and PHY 110A or consent of instructor.

*Learning Activities:* Lecture 3 hour(s), Project.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

### PHY 156 – Introduction to Cosmology (4 units)

*Course Description:* Contemporary knowledge regarding the origin of the universe, including the Big Bang and nucleosynthesis, microwave background radiation, formation of cosmic structure, cosmic inflation, cosmic acceleration and dark energy.

*Prerequisite(s):* ((PHY 009A, PHY 009B, PHY 009C, PHY 009D) or (PHY 009HA, PHY 009HB, PHY 009HC, PHY 009HD, PHY 009HE)); PHY 105A (can be concurrent); or consent of instructor.

*Learning Activities:* Lecture 3 hour(s), Project.

*Credit Limitation(s):* Not open to students who have completed PHY 126.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

### PHY 157 – Astronomy Instrumentation & Data Analysis Laboratory (4 units)

*Course Description:* Experimental techniques, data acquisition and analysis involving laboratory astrophysics plus stellar, nebular and galaxy digital imaging, photometry and/or spectroscopy. Students perform three experiments. Individual work stressed. Minimum 10-15 page journal style articles of two experiments are required.

*Prerequisite(s):* PHY 080; PHY 104A; PHY 105A; PHY 110A; PHY 110B (can be concurrent); PHY 115A (can be concurrent); and consent of department.

*Learning Activities:* Laboratory 8 hour(s).

*Enrollment Restriction(s):* Registration by Permission to Add (PTA) number only; priority given to graduating PHY astrophysics emphasis seniors.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE); Writing Experience (WE).

### PHY 158 – Formation of Galaxies & Cosmic Structures (4 units)

*Course Description:* Formation of the cosmic web, including dark-matter halos and galaxies within them. Components of the Universe (dark matter, gas, stars) and their dynamical evolution. Gravitational collapse and virialization. Gas dynamics, heating, and cooling. Galactic star formation and stellar dynamics. Emphasis on theoretical concepts, computational methods, and simulations.

*Prerequisite(s):* (PHY 009A or PHY 009HA C- or better); (PHY 009B or PHY 009HB C- or better); (PHY 009C or PHY 009HC C- or better); (PHY 009D or PHY 009HD C- or better); PHY 104A C- or better; PHY 105A C- or better; or consent of instructor.

*Learning Activities:* Lecture 3 hour(s), Extensive Problem Solving.

*Grade Mode:* Letter.

### PHY 160 – Environmental Physics & Society (3 units)

*Course Description:* Impact of humankind on the environment are discussed from the point of view of the physical sciences. Calculations based on physical principles will be made, and the resulting policy implications are considered.

*Prerequisite(s):* (PHY 009D or PHY 007C); (PHY 010 or PHY 001B); MAT 016B; or the equivalent.

*Learning Activities:* Lecture 3 hour(s).

*Cross Listing:* ENG 160.

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE); Scientific Literacy (SL).

### PHY 185 – Alumni Seminar Series (1 unit)

*Course Description:* Weekly guest speakers (usually a physics alumnus or alumna) tell students about their careers. Speakers use their experience to give students valuable perspectives on life after a degree in physics.

*Learning Activities:* Seminar 1 hour(s).

*Repeat Credit:* May be repeated 2 time(s).

*Grade Mode:* Pass/No Pass only.

*General Education:* Science & Engineering (SE).

### PHY 190 – Careers in Physics (1 unit)

*Course Description:* Overview of important research areas in physics, discussions of research opportunities and internships, strategies for graduate school and industrial careers, the fellowship and assistantship selection process, preparation of resumes, personal statements, and letters of recommendation.

*Learning Activities:* Seminar 2 hour(s).

*Enrollment Restriction(s):* Restricted to Physics and Applied Physics majors only.

*Repeat Credit:* May be repeated.

*Grade Mode:* Pass/No Pass only.

*General Education:* Science & Engineering (SE).

### PHY 192 – Internship in Physics (1-12 units)

*Course Description:* Supervised work experience requiring the application of physics principles and techniques in a professional setting, including but not limited to industry and national laboratories.

*Prerequisite(s):* Consent of instructor/Physics Internship Director.

*Learning Activities:* Internship 3-36 hour(s).

*Enrollment Restriction(s):* Enrollment dependent on availability of intern positions; open to Physics majors only.

*Repeat Credit:* May be repeated 12 unit(s).

*Grade Mode:* Pass/No Pass only.

**PHY 194HA – Special Study for Honors Students (4 units)**

*Course Description:* Open only to Physics and Applied Physics majors who satisfy the College of Letters and Science requirements for entrance into the Honors Program. Independent research project at a level significantly beyond that defined by the normal physics curriculum.

*Prerequisite(s):* Consent of instructor.

*Learning Activities:* Independent Study 12 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 194HB – Special Study for Honors Students (4 units)**

*Course Description:* Open only to Physics and Applied Physics majors who satisfy the College of Letters and Science requirements for entrance into the Honors Program. Independent research project at a level significantly beyond that defined by the normal physics curriculum.

*Prerequisite(s):* Consent of instructor.

*Learning Activities:* Independent Study 12 hour(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 195 – Senior Thesis (5 units)**

*Course Description:* Open only to Physics and Applied Physics majors with senior standing. Preparation of a senior thesis on a topic selected by the student with approval of the department.

*Prerequisite(s):* Consent of instructor.

*Learning Activities:* Independent Study 15 hour(s).

*Repeat Credit:* May be repeated 15 unit(s).

*Grade Mode:* Letter.

*General Education:* Science & Engineering (SE).

**PHY 197T – Tutoring in Physics & Astronomy (1-5 units)**

*Course Description:* Tutoring of students in lower division courses. Leading of small voluntary discussion groups affiliated with one of the department's regular courses. Weekly meeting with instructor.

*Learning Activities:* Tutorial.

*Grade Mode:* Pass/No Pass only.

*General Education:* Science & Engineering (SE).

**PHY 198 – Directed Group Study (1-5 units)**

*Course Description:* Directed group study.

*Prerequisite(s):* Consent of instructor.

*Learning Activities:* Variable.

*Grade Mode:* Pass/No Pass only.

*General Education:* Science & Engineering (SE).

**PHY 199 – Special Study for Advanced Undergraduates (1-5 units)**

*Course Description:* Special study for advanced undergraduates.

*Learning Activities:* Variable.

*Grade Mode:* Pass/No Pass only.

*General Education:* Science & Engineering (SE).

**PHY 200A – Theory of Mechanics & Electromagnetics (4 units)**

*Course Description:* Theoretical approaches in classical mechanics including the use of generalized coordinates and virtual work; variational calculus; Lagrange equations; symmetries, conservation laws, and Noether theorem; Lagrangian density; Hamilton formalism; canonical transformations; Poisson brackets; and Hamilton-Jacobi equations.

*Prerequisite(s):* PHY 204A (can be concurrent); PHY 104B; PHY 105B; PHY 110C; or equivalent to PHY 110C; PHY 204A required concurrently.

*Learning Activities:* Lecture 3 hour(s), Independent Study 1 hour(s).

*Grade Mode:* Letter.

**PHY 200B – Theory of Mechanics & Electromagnetics (4 units)**

*Course Description:* Theoretical approaches in electromagnetics including static electromagnetic fields; Maxwell's equations; plane waves in various media; magnetohydrodynamics; diffraction theory; radiating systems; and special relativity.

*Prerequisite(s):* PHY 200A; PHY 204B (can be concurrent); PHY 204B concurrently.

*Learning Activities:* Lecture 3 hour(s), Independent Study 1 hour(s).

*Grade Mode:* Letter.

**PHY 200C – Theory of Mechanics & Electromagnetics (4 units)**

*Course Description:* Theoretical approaches in electromagnetics including static electromagnetic fields; Maxwell's equations; plane waves in various media; magnetohydrodynamics; diffraction theory; radiating systems; and special relativity.

*Prerequisite(s):* PHY 200A; PHY 204B (can be concurrent); PHY 204B concurrently.

*Learning Activities:* Lecture 3 hour(s), Independent Study 1 hour(s).

*Grade Mode:* Letter.

**PHY 204A – Methods of Mathematical Physics (4 units)**

*Course Description:* Linear vector spaces, operators and their spectral analysis, complete sets of functions, complex variables, functional analysis, Greens functions, calculus of variations, introduction to numerical analysis.

*Prerequisite(s):* PHY 104A; or the equivalent.

*Learning Activities:* Lecture 3 hour(s), Extensive Problem Solving.

*Grade Mode:* Letter.

**PHY 204B – Methods of Mathematical Physics (4 units)**

*Course Description:* Linear vector spaces, operators and their spectral analysis, complete sets of functions, complex variables, functional analysis, Green's functions, calculus of variations, introduction to numerical analysis.

*Prerequisite(s):* PHY 104A; PHY 104B; or the equivalent.

*Learning Activities:* Lecture 3 hour(s), Independent Study 1 hour(s).

*Grade Mode:* Letter.

**PHY 210 – Computational Physics (3 units)**

*Course Description:* Analytic techniques to solve differential equations and eigenvalue problems. Physics content of course will be self-contained, and adjusted according to background of students.

*Prerequisite(s):* Knowledge of Fortran or C.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.



**PHY 215A – Quantum Mechanics (4 units)**

*Course Description:* Formal development and interpretation of non-relativistic quantum mechanics; its application to atomic, nuclear, molecular, and solid-state problems; brief introduction to relativistic quantum mechanics and the Dirac equation.

*Prerequisite(s):* PHY 115B; or the equivalent.

*Learning Activities:* Lecture 3 hour(s), Independent Study 1 hour(s).

*Grade Mode:* Letter.

**PHY 215B – Quantum Mechanics (4 units)**

*Course Description:* Formal development and interpretation of non-relativistic quantum mechanics; its application to atomic, nuclear, molecular, and solid-state problems; brief introduction to relativistic quantum mechanics and the Dirac equation.

*Prerequisite(s):* PHY 115B; or the equivalent.

*Learning Activities:* Lecture 3 hour(s), Independent Study 1 hour(s).

*Grade Mode:* Letter.

**PHY 215C – Quantum Mechanics (4 units)**

*Course Description:* Formal development and interpretation of non-relativistic quantum mechanics; its application to atomic, nuclear, molecular, and solid-state problems; brief introduction to relativistic quantum mechanics and the Dirac equation.

*Prerequisite(s):* PHY 115B; or the equivalent.

*Learning Activities:* Lecture 3 hour(s), Independent Study 1 hour(s).

*Grade Mode:* Letter.

**PHY 219A – Statistical Mechanics (4 units)**

*Course Description:* Foundations of thermodynamics and classical and quantum statistical mechanics with simple applications to properties of solids, real gases, nuclear matter, etc. and a brief introduction to phase transitions.

*Prerequisite(s):* PHY 215B; or equivalent.

*Learning Activities:* Lecture 3 hour(s), Extensive Problem Solving 1 hour(s).

*Grade Mode:* Letter.

**PHY 219B – Statistical Mechanics (4 units)**

*Course Description:* Further applications of thermodynamics and classical and quantum statistical mechanics. The modern theory of fluctuations about the equilibrium state, phase transitions and critical phenomena.

*Prerequisite(s):* PHY 219A.

*Learning Activities:* Lecture 3 hour(s), Extensive Problem Solving 1 hour(s).

*Grade Mode:* Letter.

**PHY 223A – Group Theoretical Methods of Physics-Condensed Matter (3 units)**

*Course Description:* Theory of groups and their representations with applications in condensed matter.

*Prerequisite(s):* PHY 215A; PHY 215B; PHY 215C (can be concurrent); or consent of instructor. PHY 215C required concurrently.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 223B – Group Theoretical Methods of Physics-Elementary Particles (3 units)**

*Course Description:* Theory of groups and their representations with applications in elementary particle physics.

*Prerequisite(s):* PHY 215A; PHY 215B; PHY 215C (can be concurrent); or consent of instructor. PHY 215C required concurrently.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 224A – Nuclear Physics (3 units)**

*Course Description:* Comprehensive study of the nucleon-nucleon interaction including the deuteron, nucleon-nucleon scattering, polarization, determination of real parameters of S-matrix, and related topics.

*Prerequisite(s):* PHY 215B.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 224B – Nuclear Physics (3 units)**

*Course Description:* Study of nuclear models, including shell model, collective model, unified model. Energy level spectra, static momenta, and electromagnetic transition rates.

*Prerequisite(s):* PHY 224A.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 224C – Nuclear Physics (3 units)**

*Course Description:* Study of nuclear scattering and reactions including the optical model and direct interactions. Beta decay and an introduction to weak interactions.

*Prerequisite(s):* PHY 224B.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 229A – Advanced Nuclear Theory (3 units)**

*Course Description:* Advanced topics in nuclear theory; theory of quantum-mechanical scattering processes. Exact formal theory and models for two-body scattering.

*Prerequisite(s):* PHY 224C.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 229B – Advanced Nuclear Theory (3 units)**

*Course Description:* Advanced topics in nuclear theory; theory of quantum-mechanical scattering processes. Exact formal theory and models for three-body scattering.

*Prerequisite(s):* PHY 229A.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 230A – Quantum Theory of Fields (3 units)**

*Course Description:* Relativistic quantum mechanics of particles; techniques and applications of second quantization; Feynman diagrams; renormalization.

*Prerequisite(s):* PHY 215C.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 230B – Quantum Theory of Fields (3 units)**

*Course Description:* Continuation of 230A, with selected advanced topics, such as S-matrix theory, dispersion relations, axiomatic formulations.

*Prerequisite(s):* PHY 230A.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 230C – Quantum Theory of Fields (3 units)**

*Course Description:* Renormalization theory and applications, including dimensional regularization, Ward identities, renormalization group equations, coupling constant unification, and precision electroweak calculations.

*Prerequisite(s):* PHY 230A; PHY 230B; or consent of instructor.

*Learning Activities:* Lecture 3 hour(s).

*Repeat Credit:* May be repeated with consent of instructor.

*Grade Mode:* Letter.

**PHY 232 – Topics in String Theory (3 units)**

*Course Description:* Current research trends in string theory, with topics ranging from perturbative worldsheet methods, nonperturbative aspects and dualities, AdS/CFT correspondence, string field theory, etc.

*Prerequisite(s):* Graduate standing in Physics or consent of instructor; PHY 230A, PHY 230B, PHY 230C PHY 260 or equivalent are strongly recommended.

*Learning Activities:* Lecture 3 hour(s).

*Repeat Credit:* May be repeated when topic differs.

*Grade Mode:* Letter.

**PHY 233 – Advanced Topics in Geometry & Physics (3 units)**

*Course Description:* Modern geometric methods in theoretical physics, with topics ranging from pseudo-Riemannian differential geometry and topology with application to general relativity, black holes, and string theory.

*Prerequisite(s):* PHY 230A, PHY 230B, PHY 230C, PHY 260 or equivalent strongly recommended.

*Learning Activities:* Lecture 3 hour(s).

*Enrollment Restriction(s):* Graduate standing in Physics or consent of instructor required.

*Repeat Credit:* May be repeated when topic differs.

*Grade Mode:* Letter.

**PHY 240A – Condensed Matter Physics A (3 units)**

*Course Description:* Topics in condensed matter physics: Crystal structure; one-electron theory; transport and optical properties of semiconductors; phonons, electron-phonon scattering.

*Prerequisite(s):* PHY 215C; PHY 219A; PHY 140A PHY 140B or equivalent recommended.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 240B – Condensed Matter Physics B (3 units)**

*Course Description:* Topics in condensed matter physics: transport and optical properties of metals and quantum structures; experimental measurement the Fermi surface and of phonon spectra.

*Prerequisite(s):* PHY 240A.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 240C – Condensed Matter Physics (3 units)**

*Course Description:* Review of second quantization. Interacting electron gas, electron-phonon interaction and effects, including instabilities of electronic systems. Topics in the theory of superconductivity and magnetism.

*Prerequisite(s):* PHY 240A; PHY 240B.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 241 – Advanced Topics in Magnetism (3 units)**

*Course Description:* Topics chosen from areas of current research interest.

*Prerequisite(s):* PHY 240A; PHY 240B; PHY 240C; PHY 240D; or consent of instructor.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 242 – Advanced Topics in Superconductivity (3 units)**

*Course Description:* Topics chosen from areas of current research interest.

*Prerequisite(s):* PHY 240A; PHY 240B; PHY 240C; PHY 240D; or consent of instructor.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 243A – Surface Physics of Materials (3 units)**

*Course Description:* Experimental and theoretical fundamentals of surface and interface physics and chemistry, including electronic and magnetic structure, thermodynamics, adsorption kinetics, epitaxial growth, and a discussion of various spectroscopic and structural probes based on photons, electrons, ions, and scanning probes.

*Prerequisite(s):* PHY 140A; PHY 140B; PHY 115A; PHY 115B; or the equivalent to any; PHY 215A, PHY 240A, or the equivalents recommended.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 243B – Surface Physics of Materials (3 units)**

*Course Description:* Experimental and theoretical fundamentals of surface and interface physics and chemistry, including electronic and magnetic structure, thermodynamics, adsorption kinetics, epitaxial growth, and a discussion of various spectroscopic and structural probes based on photons, electrons, ions, and scanning probes.

*Prerequisite(s):* PHY 140A; PHY 140B; PHY 115A; PHY 115B; or the equivalent to any; PHY 215A, PHY 240A, or the equivalents recommended.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 243C – Surface Physics of Materials (3 units)**

*Course Description:* Experimental and theoretical fundamentals of surface and interface physics and chemistry, including electronic and magnetic structure, thermodynamics, adsorption kinetics, epitaxial growth, and a discussion of various spectroscopic and structural probes based on photons, electrons, ions, and scanning probes.

*Prerequisite(s):* PHY 140A; PHY 140B; PHY 115A; PHY 115B; or the equivalent to any; PHY 215A, PHY 240A, or equivalents recommended.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 245A – High-Energy Physics (3 units)**

*Course Description:* Phenomenology and systematics of strong, electromagnetic, and weak interactions of hadrons and leptons; determination of quantum numbers; quarks and quarkonia; deep inelastic scattering; the quark parton model; experiments at hadron colliders and electron-positron colliders.

*Prerequisite(s):* PHY 230A.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 245B – High-Energy Physics (3 units)**

*Course Description:* Electroweak interactions; phenomenology of the Standard Model of SU(2) $\times$ U(1); weak interaction experiments; properties of and experiments with W and Z vector bosons; Glashow-Weinberg-Salam model and the Higgs boson; introduction to supersymmetry and other speculations.

*Prerequisite(s):* PHY 245A.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 245C – Collider Physics (3 units)**

*Course Description:* Collider physics. Topics include quark and gluon distribution functions and the computation of cross sections; Large Hadron Collider and International Linear Collider phenomenology; collider and detector characteristics; extracting models from data; software tools for analyzing experimental data.

*Prerequisite(s):* PHY 245A; PHY 252B (can be concurrent); or consent of instructor; PHY 252B taken previously or concurrently.

*Learning Activities:* Lecture 3 hour(s).

*Repeat Credit:* May be repeated with consent of instructor.

*Grade Mode:* Letter.

**PHY 246 – Supersymmetry: Theory & Phenomenology (3 units)**

*Course Description:* Construction of supersymmetric models of particle physics; superfields; supersymmetry breaking the minimal supersymmetric standard model; supergravity. Collider phenomenology of supersymmetry. Dark matter phenomenology.

*Prerequisite(s):* PHY 230A, PHY 230B, PHY 245A, PHY 245B recommended, or consent of instructor.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 246A – Supersymmetry: Theory & Phenomenology (3 units)**

*Course Description:* Construction of supersymmetric models of particle physics; superfields; supersymmetry breaking the minimal supersymmetric standard model; supergravity. Collider phenomenology of supersymmetry. Dark matter phenomenology. Not offered every year.

*Prerequisite(s):* PHY 230A; PHY 230B; PHY 245A, PHY 245B recommended or consent of instructor.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 246B – Advanced Supersymmetry (3 units)**

*Course Description:* Advanced topics in supersymmetry. Topics include holomorphy, the Affleck-Dine-Seiberg superpotential, Seiberg duality for SUSY QCD, dynamical SUSY breaking, Seiberg-Witten theory, superconformal field theories, supergravity, anomaly and gaugino mediation, and the AdS/CFT correspondence.

*Prerequisite(s):* PHY 246A.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 250 – Special Topics in Physics (3 units)**

*Course Description:* Topic varies.

*Prerequisite(s):* Consent of instructor.

*Learning Activities:* Lecture 3 hour(s).

*Repeat Credit:* May be repeated.

*Grade Mode:* Letter.

**PHY 252A – Techniques of Experimental Physics (3 units)**

*Course Description:* Introduction to techniques and methods of designing and executing experiments. Problems and examples from condensed matter research will be utilized.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 252B – Techniques of Experimental Physics (3 units)**

*Course Description:* Introduction to techniques and methods of designing and executing experiments. Problems and examples from nuclear and particle research will be utilized.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 252C – Statistics & Data Analysis for Particle Physics (3 units)**

*Course Description:* Introduction to statistical data analysis methods in particle physics. Theoretical lectures combined with practical computer laboratory work.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 253 – Signals & Noise in Physics (3 units)**

*Course Description:* Techniques for extracting signals from noise, systematic error.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 255 – Econophysics (4 units)**

*Course Description:* Application of ideas from statistical mechanics to the financial markets. Market dynamics from a physics and systems perspective, including the statistical distributions of returns, the dynamics of prices, and models for the markets.

*Prerequisite(s):* Knowledge of Python, R, Excel, Matlab, or consent of instructor.

*Learning Activities:* Lecture/Discussion 3 hour(s), Project.

*Grade Mode:* Letter.

**PHY 256A – Physics of Information (4 units)**

*Course Description:* Nonlinear dynamics, deterministic chaos, bifurcations, pattern formation, symbolic dynamics, measurement theory, stochastic processes, elementary information theory, information in complex systems, computational laboratory.

*Prerequisite(s):* Consent of instructor; advanced undergraduate or introductory graduate differential equations, applied linear algebra, and probability theory; e.g., MAT 119A/MAT 119B or MAT 207A, MAT 167 or MAT 226A, and MAT 135A/MAT 135B or MAT 235A, respectively; or in PHY 104A/PHY 104B/PHY 104C or PHY 204A/PHY 204B.

*Learning Activities:* Lecture 3 hour(s), Extensive Problem Solving.

*Enrollment Restriction(s):* Limited to 30 students.

*Grade Mode:* Letter.

**PHY 256B – Physics of Computation (4 units)**

*Course Description:* Structural complexity, computational mechanics, information measures, causal inference, applications to complex materials, quantum dynamics, and nonequilibrium thermodynamics, computational laboratory.

*Prerequisite(s):* PHY 256A; consent of instructor; advanced undergraduate or introductory graduate differential equations, applied linear algebra, and probability theory; e.g., MAT 119A/MAT 119B or MAT 207A, MAT 167 or MAT 226A, and MAT 135A/MAT 135B or MAT 235A, respectively; or in PHY 104A/PHY 104B/PHY 104C or PHY 204A/PHY 204B.

*Learning Activities:* Lecture 3 hour(s), Extensive Problem Solving.

*Enrollment Restriction(s):* Limited to 30 students.

*Grade Mode:* Letter.

**PHY 260 – Introduction to General Relativity (3 units)**

*Course Description:* An introduction to general relativity. Differential geometry and curved spacetime; the Einstein field equations; gravitational fields of stars and black holes; weak fields and gravitational radiation; experimental tests; Big Bang cosmology.

*Prerequisite(s):* PHY 200A; PHY 200B.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 262 – Early Universe Cosmology (3 units)**

*Course Description:* Introduction to early universe cosmology: the Big Bang, inflation, primordial nucleosynthesis, dark matter, dark energy, and other topics of current interest.

*Prerequisite(s):* Second year standing in Physics Graduate Program or consent of instructor.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 263 – Cosmic Structure Formation (3 units)**

*Course Description:* Growth of structure from small density inhomogeneities in the early universe to the diverse structures observable today. Use of observable properties (cosmic microwave background, gravitational lensing, peculiar velocities, number density, etc.) to constrain models of structure formation and fundamental physics.

*Prerequisite(s):* PHY 260.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 265 – High Energy Astrophysics & Radiative Processes (3 units)**

*Course Description:* Survey covering galactic and extragalactic X-ray and gamma-ray astronomy, radiative processes, and techniques of high-energy astrophysics.

*Prerequisite(s):* Graduate standing in Physics or consent of instructor.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 266 – Data Analysis for Astrophysics (3 units)**

*Course Description:* Survey covering measurement and signal analysis techniques for astrophysics and cosmology throughout the electromagnetic spectrum.

*Prerequisite(s):* Graduate standing in Physics or consent of instructor.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 267 – Observational Extragalactic Astronomy & Cosmology (3 units)**

*Course Description:* Survey covering current areas of research on extragalactic objects, their physical properties, origin, evolution, and distribution in space.

*Prerequisite(s):* Graduate standing in Physics or consent of instructor.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 268 – Research Methods in Astrophysics (3 units)**

*Course Description:* Introduction to research methods in astrophysics and cosmology. Problems and examples from observational and theoretical work will be included.

*Prerequisite(s):* PHY 204A, PHY 204B and PHY 215A recommended.

*Learning Activities:* Lecture 3 hour(s).

*Enrollment Restriction(s):* Graduate standing in Physics or consent of instructor.

*Grade Mode:* Letter.

**PHY 269 – Stellar Structure & Evolution (3 units)**

*Course Description:* Underlying physics of stars as the building blocks of the Universe. Reasons for their existence, mechanisms behind their function, their evolution and ultimate fate. Structure of self-gravitating objects, energy transport in stars, nuclear fusion in stars, stellar evolution, and the birth of compact objects.

*Prerequisite(s):* PHY 200A, PHY 200B, and PHY 215A recommended; graduate standing in Physics; or consent of instructor.

*Learning Activities:* Lecture 3 hour(s).

*Grade Mode:* Letter.

**PHY 270 – Current Topics in Physics Research (3 units)**

*Course Description:* Reading and discussion to help physics graduate students develop and maintain familiarity with the current and past literature in their immediate field of research and related areas.

*Prerequisite(s):* Graduate standing in Physics or consent of instructor.

*Learning Activities:* Lecture/Discussion 3 hour(s).

*Repeat Credit:* May be repeated.

*Grade Mode:* Satisfactory/Unsatisfactory only.

**PHY 285 – Careers in Physics (1 unit)**

*Course Description:* Designed to give Physics graduate students an in-depth appreciation of career opportunities with a graduate degree in physics. Professional physicists, mainly from outside academia, will give seminars describing both research and career insights.

*Prerequisite(s):* Graduate standing in Physics.

*Learning Activities:* Seminar 1.50 hour(s).

*Repeat Credit:* May be repeated.

*Grade Mode:* Satisfactory/Unsatisfactory only.

**PHY 290 – Seminar in Physics (1 unit)**

*Course Description:* Presentation and discussion of topics of current research interest in physics. Topics will vary weekly and will cover a broad spectrum of the active fields of physics research at a level accessible to all physics graduate students.

*Prerequisite(s):* Graduate standing in Physics or consent of instructor.

*Learning Activities:* Seminar.

*Repeat Credit:* May be repeated.

*Grade Mode:* Satisfactory/Unsatisfactory only.

**PHY 291 – Seminar in Nuclear Physics (1 unit)**

*Course Description:* Presentation and discussion of topics of current research interest in nuclear physics.

*Prerequisite(s):* Graduate standing in Physics or consent of instructor.

*Learning Activities:* Seminar 1 hour(s).

*Repeat Credit:* May be repeated.

*Grade Mode:* Satisfactory/Unsatisfactory only.

**PHY 292A – Seminar in Elementary Particle Physics (1 unit)**

*Course Description:* Presentation and discussion of topics of current research interest in elementary particle physics.

*Prerequisite(s):* Graduate standing in Physics or consent of instructor.

*Learning Activities:* Seminar 1 hour(s).

*Repeat Credit:* May be repeated.

*Grade Mode:* Satisfactory/Unsatisfactory only.

**PHY 292B – High Energy Frontier Initiative & Cosmology Theory Seminar (1 unit)**

*Course Description:* Weekly seminar on current issues in Particle physics and Cosmology.

*Prerequisite(s):* Physics graduate students.

*Learning Activities:* Seminar 1 hour(s).

*Repeat Credit:* May be repeated 5 time(s).

*Grade Mode:* Satisfactory/Unsatisfactory only.

**PHY 293 – Seminar in Condensed Matter Physics (1 unit)**

*Course Description:* Presentation and discussion of topics of current research interest in condensed matter physics.

*Prerequisite(s):* Graduate standing in Physics or consent of instructor.

*Learning Activities:* Seminar 1 hour(s).

*Repeat Credit:* May be repeated.

*Grade Mode:* Satisfactory/Unsatisfactory only.

**PHY 294 – Seminar in Cosmology (1 unit)**

*Course Description:* Presentation and discussion of topics of current research interest in Cosmology.

*Prerequisite(s):* Graduate standing in Physics or consent of instructor.

*Learning Activities:* Seminar 1 hour(s).

*Repeat Credit:* May be repeated.

*Grade Mode:* Satisfactory/Unsatisfactory only.

**PHY 295 – Introduction to Departmental Research (1 unit)**

*Course Description:* Seminar to introduce first- and second-year physics graduate students to the fields of specialty and research of the Physics staff.

*Learning Activities:* Seminar 1 hour(s).

*Grade Mode:* Satisfactory/Unsatisfactory only.

**PHY 296 – Field, Strings, & Gravity Seminar (1 unit)**

*Course Description:* Presentation and discussion of topics of current research interest in the areas of quantum field theory, string theory and gravity.

*Prerequisite(s):* Consent of instructor.

*Learning Activities:* Lecture 1.50 hour(s).

*Repeat Credit:* May be repeated.

*Grade Mode:* Satisfactory/Unsatisfactory only.

**PHY 297 – Research on the Teaching & Learning of Physics (3 units)**

*Course Description:* Discussion and analysis of recent research in how students construct understanding of physics and other science concepts and the implications of this research for instruction.

*Prerequisite(s):* Graduate standing in Physics or consent of instructor.

*Learning Activities:* Seminar 3 hour(s).

*Repeat Credit:* May be repeated.

*Grade Mode:* Letter.

**PHY 298 – Group Study (1-5 units)**

*Course Description:* Group study.

*Prerequisite(s):* Consent of instructor.

*Learning Activities:* Variable.

*Grade Mode:* Satisfactory/Unsatisfactory only.

**PHY 299 – Research (1-12 units)**

*Course Description:* Research.

*Learning Activities:* Variable.

*Grade Mode:* Satisfactory/Unsatisfactory only.

**PHY 371 – Teaching in an Active-Engagement Physics Discussion/Lab Setting (1 unit)**

*Course Description:* Analysis of recent research on science/physics teaching and learning and its implications for teaching labs, discussions, and discussion/labs with an emphasis on differences between conventional and active-engagement instructional settings. The appropriate role of the instructor in specific instructional settings.

*Prerequisite(s):* PHY 009D; or equivalent.

*Learning Activities:* Lecture/Discussion 1 hour(s).

*Enrollment Restriction(s):* Open to graduate students only.

*Repeat Credit:* May be repeated 2 time(s).

*Grade Mode:* Letter.

**PHY 390 – Methods of Teaching Physics (1 unit)**

*Course Description:* Practical experience in methods and problems related to teaching physics laboratories at the university level, including discussion of teaching techniques, analysis of quizzes and laboratory reports and related topics. Required of all Physics Teaching Assistants.

*Prerequisite(s):* Consent of instructor; graduate standing in Physics.

*Learning Activities:* Lecture/Discussion 1 hour(s).

*Repeat Credit:* May be repeated.

*Grade Mode:* Satisfactory/Unsatisfactory only.

**PHY 396 – Teaching Assistant Training Practicum (1-4 units)**

*Course Description:* Teaching assistant training.

*Prerequisite(s):* Graduate standing.

*Learning Activities:* Variable.

*Repeat Credit:* May be repeated.

*Grade Mode:* Pass/No Pass only.