128A. Intermediate Scuba Diving (4)
Lecture—3 hours; laboratory—3 hours; fieldwork—2 hours. Prerequisite: course 29 and consent of instructor. Lectures and practice in diver safety, rescue, accident management and patient care. Pool and open water sessions required for certification. (P/NP grading only.)—II. (II.) Fastenau

128B. Research Diving Techniques (4)
Lecture—3 hours; laboratory—3 hours; fieldwork—3 hours. Prerequisite: course 128A; consent of instructor. Lectures and application on search and light salvage, night diving, research techniques, cold-water, low visibility diving, blue water, deep and altitude diving. Pool and open water sessions required for certification. (P/NP grading only.)—III. (III.) Fastenau

131. Physical Activity and the Disabled (4)
Lecture—3 hours; laboratory—3 hours. The study of the diverse and complex nature of individuals with disabilities and how they adapt to their disabilities in daily living. Integration of individuals with disabilities into the community, schools, and physical activity and recreational programs. Not open for credit to students who have completed Exercise Biology 131. Vochatzer

133. Prevention and Care of Sports Injuries (3)
Lecture—2 hours; laboratory—3 hours. Prerequisite: Cell Biology and Human Anatomy 101 (may be taken concurrently). Prevention, care, and rehabilitation of injuries incurred by athletes. Laboratory on anatomy, emergency care, physical therapy methods, and taping techniques. Not open for credit to students who have completed Exercise Biology 133.—II. (III.)

135. Advanced Procedures in Evaluation and Management of Athletic Injuries (3)
Lecture—3 hours. Prerequisite: course 133 or Exercise Biology 133, Cell Biology and Human Anatomy 101, consent of instructor. Advanced study of the evaluation and management of athletic injuries, including mechanism of injury, biomechanics and pathophysiology. Current topics in athletic training. Not open for credit to students who have completed Exercise Biology 135.—III.

142. Physical Education in the Public Schools (3)
Lecture—3 hours. Analysis and study of the principles and methods basic to teaching physical education at the elementary and secondary levels.—II. (II.) S. Williams

143. Coaching Effectiveness (3)
Lecture—3 hours. Prerequisite: upper division standing; 3 units of courses 1 and 6 combined. Synthesis and application of basic components of sport psychology, sport pedagogy, and sport physiology and basic management and administration of athletics in public high schools. (P/NP grading only.)—II. (II.) Bronzan

144. Principles of Health Education (2)
Lecture—2 hours. Prerequisite: course 44 and upper division standing or consent of instructor. Principles of teaching health education in the public schools. (P/NP grading only.)

150. Recreation in the Community (3)
Lecture—2 hours; discussion—1 hour; two Saturday field trips—8 hours. The nature and scope of community recreation programs in California emphasizing low income, highly populated areas, and poor rural communities.

192. Physical Education Internship (1-12)
Internship—3-36 hours; written project proposal and evaluation. Prerequisite: upper division standing and consent of instructor; enrollment dependent on availability of intern positions, with priority given to Exercise Science majors. Work experience in the application of physical activity programs to teaching, recreational, clinical or research situations under department faculty supervision. May be repeated for a total of 12 units (including course 92) but no internship units will be counted toward Exercise Science major. (P/NP grading only.)—I, II, III. (I, II, III.)

197T. Tutoring in Physical Education (1-5)
Tutorial—1-5 hours. Prerequisite: consent of chairperson. Tutoring of students in lower division physical activity courses. Written reports on methods and materials required. May be repeated once for credit. (P/NP grading only.)

197TC. Tutoring in the Community (1-5)
Tutorial—2-15 hours; discussion—1 hour. Prerequisite: upper division standing and consent of Department Chairperson. Tutoring in the community in physical education related projects under the guidance of the Physical Education faculty. Regular meet ings with instructor in charge and written report required. May be repeated once for credit. (P/NP grading only

198. Directed Group Study (1-5)
Prerequisite: consent of instructor and Department Chairperson. (P/NP grading only.)

199. Special Study for Advanced Undergraduates (1-5)
Prerequisite: consent of instructor. (P/NP grading only.)

Professional Courses

300. The Elementary Physical Education Program (2)
Lecture—1 hour; laboratory—2 hours; field trips to selected programs. Prerequisite: senior standing or credential student. Introduction to principles, theories, material, and practices of elementary school physical education program.—III. (III.)

380. Methods of Teaching Physical Education (3)
Lecture—1 hour; laboratory—6 hours. Prerequisite: course 142 and six units of course 7; or consent of instructor. The methods of teaching group and individual activities for grades K-12; program planning, class management, organization, and evaluation. (P/NP grading only.)—S. Williams

Physical Medicine and Rehabilitation

See Medicine, School of, on page 345.

Physics

(College of Letters and Science)

Shirley Chiang, Ph.D., Chairperson of the Department

Lori Lubin, Ph.D., Vice Chairperson of the Department (Administration and Undergraduate Matters

Steven Carlip, Ph.D., Vice Chairperson of the Department (Graduate Matters)

Department Office. 225 Physics/Geology Building
(530) 752-1500; *http://www.physics.ucdavis.edu*

Faculty

Andreas J. Albrecht, Ph.D., Professor
Robert H. Becker, Ph.D., Professor
Patricia C. Boeshaar, Ph.D., Senior Lecturer
Manuel Calderon de la Barca Sanchez, Ph.D., Assistant Professor
Steven Carlip, Ph.D., Professor
Daniel A. Cebra, Ph.D., Professor
Ling-Lie Chau, Ph.D., Professor
Hsin-Chia Cheng, Ph.D., Assistant Professor
Maxwell B. Chertok, Ph.D., Associate Professor
Shirley Chiang, Ph.D., Professor, *Academic Senate Distinguished Teaching Award*
Lawrence B. Coleman, Ph.D., Professor, *Academic Senate Distinguished Teaching Award*
John Conway, Ph.D., Professor
Linton R. Corruccini, Ph.D., Professor
Daniel L. Cox, Ph.D., Professor
James Crutchfield, Ph.D., Professor
Charles S. Fadley, Ph.D., Professor
Robin Erbacher, Ph.D., Assistant Professor
Christopher D. Fassnacht, Ph.D., Assistant Professor
Daniel Ferenc, Ph.D., Associate Professor
Ching-Yao Fong, Ph.D., Professor
John F. Gunion, Ph.D., Professor
Nemanja Kaloper, Ph.D., Professor
Joseph E. Kiskis, Ph.D., Professor
Barry M. Klein, Ph.D., Professor
Lloyd E. Knox, Ph.D., Professor
Winston T. Ko, Ph.D., Professor
Richard L. Lander, Ph.D., Professor
Kai Liu, Ph.D., Associate Professor
Lori Lubin, Ph.D., Associate Professor
David E. Pellett, Ph.D., Professor
Warren E. Pickett, Ph.D., Professor
David Pines, Ph.D., Professor
John B. Rundle, Ph.D., Professor
Sergey Savrasov, Ph.D., Associate Professor
Richard T. Scalettar, Ph.D., Professor
Rajiv R.P. Singh, Ph.D., Professor
John Terning, Ph.D., Associate Professor
S. Mani Tripathi, Ph.D., Professor
J. Anthony Tyson, Ph.D., Professor
David J. Webb, Ph.D., Associate Professor
Philip M. Yager, Ph.D., Professor
Xiangdong Zhu, Ph.D., Professor
Rena J. Zieve, Ph.D., Associate Professor
Gergely Zimanyi, Ph.D., Professor

Emeriti Faculty

Franklin P. Brady, Ph.D., Professor Emeritus
Thomas A. Cahill, Ph.D., Professor Emeritus
James E. Draper, Ph.D., Professor Emeritus
Glen W. Erickson, Ph.D., Professor Emeritus
Claude Garrod, Ph.D., Professor Emeritus
James P. Hurley, Ph.D., Professor Emeritus
John A. Jungerman, Ph.D., Professor Emeritus
William J. Knox, Ph.D., Professor Emeritus
Douglas W. McColm, Ph.D., Senior Lecturer Emeritus, *Academic Senate Distinguished Teaching Award*
Neal Peek, Ph.D., Senior Lecturer Emeritus
Wendell H. Potter, Ph.D., Senior Lecturer Emeritus, *Academic Senate Distinguished Teaching Award*
Roderick V. Reid, Jr., Ph.D., Professor Emeritus

Affiliated Faculty

Rodney W. Cole, Ph.D., Lecturer, *Academic Federation Excellence in Teaching Award*
Randy R. Harris, Ph.D., Lecturer, *Academic Federation Excellence in Teaching Award*
Eckart Lorenz, Ph.D., Adjunct Professor
Michael McElfresh, Ph.D., Adjunct Professor
Randy Phelps, Ph.D., Associate Adjunct Professor
Harry B. Radousky, Ph.D., Adjunct Professor
Michael Van Hove, Ph.D., Adjunct Professor
Ramona Vogt, Ph.D., Associate Adjunct Professor

The Major Program

From the smallest subatomic particles to atoms, molecules, stars, and galaxies, the study of physics is the study of what makes the universe work. Information learned from high-energy particle atomic-scale microscopes and high-energy particle accelerators and nuclear reactors teaches us not only what holds the nucleus atom and the atom nucleus together but also how proteins function and why stars shine.

The Program. The Department of Physics offers three degree programs: the Bachelor of Arts in Physics, and the Bachelor of Science in Physics and in Applied Physics. The A.B. degree provides a broad coverage of classical and modern physics while permitting a broader liberal arts education than is possible with the other two programs. The B.S. degree in either Physics or Applied Physics should be followed by the student who plans to enter physics as a profession. The B.S. in Applied Physics provides the student with a solid introduction to a particular applied physics specialty. For the student who plans to enter the job market on completing a B.S. degree, the

applied physics orientation would be an asset. Either B.S. program provides a solid foundation in physics for the student interested in graduate work in either pure or applied physics.

Career Alternatives. Careers in physics and applied physics include research and development, either in universities, government laboratories, or industry; teaching in high schools, junior colleges, and universities; management and administration in industrial laboratories and in government agencies; and in production and sales in industry. A major in physics also provides a strong base for graduate-level work in such interdisciplinary areas as chemical physics, biophysics and medical physics, geophysics and environmental physics, astrophysics and astronomy, computer science, and materials science.

Physics

A.B. Major Requirements:

UNITS

Preparatory Subject Matter.....41-47

Physics 9A, 9B, 9C, 9D or 9HA, 9HB, 9HC, 9HD, 9HE 19-25
Mathematics 21A, 21B, 21C, 21D, 22A, 22B 22

Depth Subject Matter 35-37

Physics 104A, 105A, 110A, 110B, 112, 115A, 122 28
At least one course from 127, 140A, 129A, or 130A 4
Physics 102 (1 unit) waived if 104B taken 0-1
At least one additional fixed-unit upper division Physics course excluding 137 and 160..... 3-4

Total Units for the Major 76-84

B.S. Major Requirements:

UNITS

Preparatory Subject Matter.....50-56

Physics 9A, 9B, 9C, 9D or 9HA, 9HB, 9HC, 9HD, 9HE 19-25
Mathematics 21A, 21B, 21C, 21D, 22A, 22B 22
Computer Science Engineering 30 (or equivalent programming course) 4
Chemistry 2A or 2HA (2B-2C or 2HB-2HC highly recommended) 5

Depth Subject Matter 59-62

Physics 104A, 105A, 105B, 110A, 110B, 110C, 112, 115A, 115B,.....36

Physics 102 (1 unit) or 104B 1-4
Physics 122 or 116A,B and C 4-12
Two courses from one specialty (Astrophysics/Cosmology, Condensed Matter, or Nuclear/Particle Physics) and one course from a different specialty. Lists of courses in each specialty are available from the department..... 12
Additional upper division Physics courses excluding 137 and 160, for a total of 15 upper division Physics courses of 3 or more units each. With prior departmental approval, one course from mathematics, engineering, or natural science may be used to meet this requirement. May include only one course from 194H, 195, 198, 199 0-9

Total Units for the Major 109-118

Applied Physics

B.S. Major Requirements:

UNITS

Preparatory Subject Matter.....49-56

Physics 9A, 9B, 9C, 9D or 9HA, 9HB, 9HC, 9HD, 9HE 19-25
Mathematics 21A, 21B, 21C, 21D, 22A, 22B 22
Computer Science Engineering 30 (or equivalent programming course) 4
Depending on area of concentration:
Chemistry 2A or 2HA (2B-2C or 2HB-2HC highly recommended)
or
Computer Science Engineering 40
or
Mathematics 22AL 14-5

Depth Subject Matter 57-65

Physics 104A, 105A, 110A, 110B, 112, 115A, 116A, 116B, ... 32
Physics 102 (1 unit) or 104B 1-4
Physics 122 or 116 C 4
Further courses from approved lists within one of the following concentrations chosen in consultation with a major adviser, to bring total number of three-five unit Depth courses to 15 20-24
Lists of approved courses for concentrations in atmospheric physics, chemical physics, computational physics, geophysics, materials science, physical electronics, and physical oceanography are available from the Physics Department.

Total Units for the Major 106-121

Recommended Electives

Astronomy: Astronomy 2
Computer and numerical analysis: Mathematics 128A or Applied Science Engineering 115
Statistics: Statistics 131A
Advanced mathematics: Mathematics 108, 118AB, 119AB 127ABC 185AB

Program Variance. Courses from other departments may be submitted for courses in the depth subject matter requirements by obtaining written permission from the Undergraduate Curriculum Committee Chairperson, as approved by the Department.

Major Advisers. Contact Departmental Undergraduate Majors office in 225 Physics/Geology Building, for adviser assignment.

Minor Program Requirements:

All courses in the minor have prerequisites equivalent to Mathematics 21A-21B-21C-21D and 22A-22B and Physics 9A-9B-9C-9D. Students considering the possibility of a minor should consult with a Physics major advisor before beginning course work in the minor program.

UNITS

Physics 24

At least 6 upper division courses in Physics (excluding Physics 137, 160, 197T and 199) 24

Graduate Study. The Department of Physics offers programs of study and research leading to the M.S. and Ph.D. degrees. Further information regarding requirements for these three degrees, graduate research, teaching assistantships, and research assistantships may be obtained by writing to the Chairperson, Department of Physics, One Shields Avenue, University of California, Davis, CA 95616.

Astronomy. In addition to the introductory Astronomy courses listed, Upper Division and graduate courses in Astronomy, Astrophysics and Cosmology are listed under Physics.

Courses in Astronomy (AST)

Lower Division Courses

2. Introduction to Modern Astronomy and Astrophysics (4)

Lecture—3 hours; laboratory/discussion—2 hours. Prerequisite: good facility in high school physics and mathematics (algebra and trigonometry). Description and interpretation of astronomical phenomena using the laws of modern physics. Modern astronomical instrumentation. Gravitation, relativity, electromagnetic radiation, atomic and nuclear processes in relation to the structure and evolution of stars, the solar system, galaxies, and the Universe. Not open to students who have received credit for course 10.—I, III. (I, III.) Becker, Fassnacht, Knox, Lubin

10G. Introduction to Stars, Galaxies, and the Universe (3)

Lecture—3 hours. Non-mathematical introduction to astrophysics of the Universe beyond our solar system using concepts of modern physics. Not open for credit to students who have completed course 2, 10, or any physics course (except 10, 137 or 160). GE credit: SciEng.—I, III. (I, III.)

10L. Observational Astronomy Laboratory (1)

Laboratory—2.5 hours. Prerequisite: course 10G or 10S (may be taken concurrently). Introduction to observations of the night sky using small telescopes in nighttime laboratory. Not open for credit to students who have completed course 2 or 10.—I, II, III. (I, II, III.)

10S. Introduction to the Solar System (3)

Lecture—3 hours. Non-mathematical introduction to the astrophysics of the solar system using concepts of modern physics. Not open for credit to students who have taken course 2 or any Physics course, except 10, 137, or 160. GE credit: SciEng.—II, III. (II, III.)

Courses in Physics (PHY)

Physics 10 is primarily a concept-oriented one-quarter lecture/discussion course requiring relatively little mathematical background.

Physics 1 is a two-quarter sequence requiring some mathematics (trigonometry). Either 1A alone or both quarters may be taken. The sequence is not intended to satisfy entrance requirements of a year of physics for professional schools, but will satisfy requirements of 3 or 6 units of physics.

Physics 7 is a one-year (three-quarter) introductory physics course with laboratory intended for students majoring in the biological sciences. It has a calculus prerequisite. If you don't need a full year of introductory physics, you should take one or two quarters of Physics 1 instead. Read the following information carefully if you are using Physics 7 to complete an introductory course you have already begun.

The sequence of material in Physics 7 is different from that in most traditionally taught introductory physics courses. Physics 7B is most like the first quarter or semester of traditionally taught courses which treat classical mechanics. Physics 7C is most like the last quarter or semester which, in traditionally taught courses, treats optics, electricity and magnetism, and modern physics. The content and sequence of Physics 7A is unlike that of most other traditionally taught courses.

If you have completed one introductory quarter or semester of a traditionally taught physics course and want to continue with Physics 7, you should first take (and will receive full credit for) Physics 7A.Then, either skip 7B, but self-study the last three weeks of material, or take 7B and receive reduced credit. Next, take 7C for full credit.

If you have taken two quarters of a year-long introductory physics course and have not had extensive work in optics, electricity and magnetism, and modern physics, you should take Physics 7C. In no case should you take Physics 7B without first taking Physics 7A. All other situations should be discussed directly with a Physics 7 instructor.

Students not intending to take the entire sequence should take Physics 1.

Physics 9 is a four-quarter sequence using calculus throughout and including laboratory work as an integral part. The course is primarily for students in the physical sciences and engineering.

Physics 9H is a five-quarter honors physics sequence, which may be taken instead of Physics 9. It is intended primarily for first-year students with a strong interest in physics and with advanced placement in mathematics. In course requirements and prerequisites, Physics 9HA–9HE can be substituted for Physics 9A–9D.

Lower Division Courses

1A. Principles of Physics (3)
Lecture—3 hours. Prerequisite: trigonometry or consent of instructor. 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. Not open to students who have received credit for course 7B, or 9A.—I. (I.)

1B. Principles of Physics (3)
Lecture—3 hours. Prerequisite: course 1A or 9A. Continuation of course 1A. Heat, optics, electricity, modern physics. Not open for credit to students who have received credit for course 7A, 7B, 7C, 9B, 9C, or 9D.—II. (II.)

7A. General Physics (4)
Lecture—1.5 hours; discussion/laboratory—5 hours. Prerequisite: Mathematics 16B (may be taken concurrently). Introduction to general principles and analytical methods used in physics for students majoring in a biological science. Only two units of credit allowed to students who have completed course 9B, or 1B.—I, II, III. (I, II, III.)

7B. General Physics (4)
Lecture—1.5 hours; discussion/laboratory—5 hours. Prerequisite: course 7A. Continuation of course 7A. Only two units of credit allowed to students who have completed course 9A, or 1A.—I, II, III. (I, II, III.)

7C. General Physics (4)
Lecture—1.5 hours; discussion/laboratory—5 hours. Prerequisite: course 7B. Continuation of course 7B. Only two units of credit allowed to students who have completed course 9C or 5C.—I, II, III. (I, II, III.)

9A. Classical Physics (5)
Lecture—3 hours; laboratory—2.5 hours; discussion—1 hour. Prerequisite: Mathematics 21B. Introduction to general principles and analytical methods used in physics for physical science and engineering majors. Classical mechanics. Only 2 units of credit to students who have completed course 1A or 7B. Not open for credit to students who have completed course 9HA.—I,III. (I,III.)

9B. Classical Physics (5)
Lecture—3 hours; laboratory—2.5 hours; discussion—1 hour. Prerequisite: course 9A, Mathematics 21C, 21D (may be taken concurrently). Continuation of course 9A. Fluid mechanics, thermodynamics, wave phenomena, optics. Only 2 units of credit to students who have completed course 7A. Not open for credit to students who have completed course 9HB, 9HC, or Engineering 105.—I,II. (I,II.)

9C. Classical Physics (5)
Lecture—3 hours; laboratory—2.5 hours; discussion—1 hour. Prerequisite; course 9B, Mathematics 21D, 22A (may be taken concurrently). Electricity and magnetism including circuits and Maxwell's equations. Only 3 units of credit to students who have completed course 7C. Not open for credit to students who have completed course 9HD.—II,III. (II,III.)

9D. Modern Physics (4)
Lecture—3 hours; discussion—1.5 hours. Prerequisite: course 9C and Mathematics 22A; Mathematics 22B recommended (may be taken concurrently). Introduction to physics concepts developed since 1900. Special relativity, quantum mechanics, atoms, molecules, condensed matter, nuclear and particle physics. Not open for credit to students who have completed course 9HB, 9HC, or 9HE.—I,III. (I,III.)

9HA. Honors Physics (5)
Lecture—3 hours; discussion/laboratory—4 hours. Prerequisite: Mathematics 21B (may be taken concurrently) or consent of instructor. Classical mechanics. Same material as course 9A in greater depth. For students in physical sciences, mathematics, and engineering. Only 2 units of credit to students who have completed course 7B. Not open for credit to students who have completed course 9A.—I. (I.)

9HB. Honors Physics (5)
Lecture—3 hours; discussion/laboratory—4 hours. Prerequisite: Physics 9HA or 9A, Mathematics 21C (may be taken concurrently). Special relativity, thermal physics. Continuation of course 9HA. Only 2 units of credit to students who have completed course 7A. Not open for credit to students who have completed course 9B or 9D.—II. (II.)

9HC. Honors Physics (5)
Lecture—3 hours; discussion/laboratory—4 hours. Prerequisite: course 9HB and Mathematics 21D (may be taken concurrently). Waves, sound, optics, quantum physics. Continuation of Physics 9HB. Only 2 units of credit to students who have completed course 7C. Not open for credit to students who have completed course 9B or 9D.—III. (III.)

9HD. Honors Physics (5)
Lecture—3 hours; discussion/laboratory—4 hours. Prerequisite: course 9HC and Mathematics 21D. Electricity and magnetism. Continuation of Physics 9HC. Not open for credit to students who have completed course 9C.—I. (I.)

9HE. Honors Physics (5)
Lecture—3 hours; discussion/laboratory—4 hours. Prerequisite: course 9HD and Mathematics 22B (may be taken concurrently). Application of quantum mechanics. Not open for credit to students who have completed course 9D.—II. (II.)

10. Topics in Physics for Nonscientists (4)
Lecture—3 hours; discussion—1 hour. Prerequisite: high school algebra. 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. Check with the Department office for the current emphasis. No units of credit allowed if taken after any other physics course. GE credit: SciEng, Wrt.

49. Supplementary Work in Lower Division Physics (1-3)
Students with partial credit in lower division physics courses may, with consent of instructor, complete the credit under this heading. May be repeated for credit.—I, II, III. (I, II, III.)

90X. Lower Division Seminar (2)
Seminar—2 hours. Prerequisite: lower division standing and consent of instructor. Examination of a special topic in Physics through shared readings, discussions, written assignments, or special activities such as laboratory work. May be repeated for credit. Limited enrollment.

98. Directed Group Study (1-5)
Prerequisite: consent of instructor; primarily for lower division students. (P/NP grading only.)

99. Special Study for Undergraduates (1-5)
Prerequisite: consent of instructor. (P/NP grading only.)

Upper Division Courses

102. Computational Laboratory in Physics (1)
Laboratory—3 hours. Prerequisite: Mathematics 21D, 22A, 22B, Computer Science Engineering 30, course 9D or 9HD, course 104A concurrently. 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. Not open for credit to students who have completed course 104B or 105AL.—I. (I.)

104A. Introductory Methods of Mathematical Physics (4)
Lecture—3 hours; extensive problem solving. Prerequisite: courses 9B, 9C, 9D and Mathematics 21D, 22A, and 22B with grade C- or better or consent of instructor. Introduction to the mathematics used in upper-division physics courses, including applications of vector spaces, Fourier analysis, partial differential equations.—I. (I.)

104B. Computational Methods of Mathematical Physics (4)
Lecture—3 hours; extensive problem solving. Prerequisite: course 104A with grade C- or better and course 105AL or consent of instructor. Introduction to the use of computational techniques to solve the mathematical problems that arise in advanced physics courses, complementing the analytical approaches emphasized in course 104A.—II. (II.)

104C. Intermediate Methods of Mathematical Physics (4)
Lecture—3 hours; extensive problem solving. Prerequisite: course 104A with grade C- or better or consent of instructor. Applications of complex analysis, conditional probability, integral transformations and other advanced topics. Not offered every year.—(III.)

105A-105B. Analytical Mechanics (4-4)
Lecture—3 hours; extensive problem solving. Prerequisite: courses 9B, 9C, 9D and Mathematics 21D, 22A, and 22B passed with grade C– or better; or consent of department; course 104A and 105A passed with a grade C– or better or consent of department required for 105B. Principles and applications of Newtonian mechanics; introduction to Lagrange's and Hamilton's equations.—I-II. (I-II.)

105C. Continuum Mechanics (4)
Lecture—3 hours; extensive problem solving. Prerequisite: courses 104B and 105A passed with a grade of C– or better, or consent of department. The continuum hypothesis and limitations. Tensor methods develop stress-strain relations for linear isotropic solids/fluids and field equations to study wave propagation in solids/fluids, heat flow, potential flow and ocean waves.—III. (III.)

108. Optics (3)
Lecture—3 hours. Prerequisite: course 9 or 7 sequence and Mathematics 21 sequence or consent of instructor. 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.—III. (III.)

108L. Optics Laboratory (1)
Laboratory—3 hours. Prerequisite: course 108 concurrently. The laboratory will consist of one major project pursued throughout the quarter, based on modern applications of optical techniques.—III. (III.)

110A-110B-110C. Electricity and Magnetism (4-4-4)
Lecture—3 hours; extensive problem solving. Prerequisite: courses 9B, 9C, 9D and Mathematics 21D, 22A, and 22B passed with grade C– or better, or consent of department; prerequisite for 110B is courses 110A and 104A passed with a grade of C– or better or consent of department; prerequisite for course 110C is courses 110B and 104B passed with a grade of C– or better, or consent of department. Theory of electrostatics, electromagnetism, Maxwell's equations, electromagnetic waves.—II-III-I. (II-III-I.)

112. Thermodynamics and Statistical Mechanics (4)
Lecture—3 hours; extensive problem solving. Prerequisite: course 115A or the equivalent. Introduction to classical and quantum statistical mechanics and their connections with thermodynamics. The theory is developed for the ideal gas model and simple magnetic models and then extended to studies of solids, quantum fluids, and chemical equilibria.—I. (I.)

115A. Foundation of Quantum Mechanics (4)
Lecture—3 hours; extensive problem solving. Prerequisite: courses 104A and 105B with grade C- of better, or consent of instructor. Introduction to the methods of quantum mechanics with applications to atomic, molecular, solid state, nuclear and elementary particle physics.—III. (III.)

115B. Applications of Quantum Mechanics (4)
Lecture—3 hours; extensive problem solving. Prerequisite: course 115A passed with a grade of C– of better, or consent of department. Angular momentum and spin; hydrogen atom and atomic spectra; perturbation theory; scattering theory.—I. (I.)

116A. Electronic Instrumentation (4)
Lecture—3 hours; laboratory—3 hours. Prerequisite: course 9C, Mathematics 22B. An experimental and theoretical study of important electronic circuits commonly used in physics.—I. (I.)

116B. Electronic Instrumentation (4)
Lecture—3 hours; laboratory—3 hours. Prerequisite: courses 9D, 116A. Continuation of course 116A. Introduction to the use of digital electronics and microcomputers in experimental physics.—II. (II.)

116C. Introduction to Computer-Based Experiments in Physics (4)
Lecture—3 hours; laboratory—3 hours. Prerequisite: course 9D or 9HD, 116B, Mathematics 22B or consent of instructor. Introduction to techniques for making physical measurements using computer-based instrumentation.—III. (III.) Pellett

121. Atomic Physics (4)
Lecture—3 hours; term paper. Prerequisite: course 9D. The phenomena of atomic physics including contemporary work: fine-and hyperfine-structure, quantum electrodynamics, laser spectroscopy, beam foil experiments and trapped atoms.—I. (I.)

122. Advanced Physics Laboratory (4)
Laboratory—8 hours; extensive problem solving. Prerequisite: course 9D with grade C- or better or consent of instructor. Experimental techniques and measurements in atomic, condensed matter, nuclear and high energy physics. Student performs three to six experiments depending on difficulty. Individual work is stressed. May be repeated for credit.—II, III. (II, III.)

126. Introduction to Cosmology (4)
Lecture—3 hours; discussion—1 hour. Prerequisite: course 105A or consent of instructor. Introduction to cosmology.—III. (III.)

127. Introduction to Astrophysics (4)
Lecture—3 hours; extensive problem solving. Prerequisite: course 105A passed with grade C- or better, or consent of instructor. Celestial mechanics, radiation, astrophysical measurements, electromagnetic processes, the sun, binary and variable stars, stellar structure and evolution, galaxies, cosmology.—II. (II.)

129A. Introduction to Nuclear Physics (4)
Lecture—3 hours; extensive problem solving. Prerequisite: course 115A passed with a grade of C- or better or consent of instructor. 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.—III. (III.)

129B. Nuclear Physics, Extensions and Applications (4)
Lecture—3 hours; term paper. Prerequisite: course 129A. Continuation of course 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. Not offered every year.

130A-130B. Elementary Particle Physics (4-4)
Lecture—3 hours; extensive problem solving. Prerequisite: course 115A passed with a grade of C- or better or consent of instructor. Properties and classification of elementary particles and their interactions. Experimental techniques. Conservation laws and symmetries. Strong, electromagnetic, and weak interactions. Introduction to Feynman calculus. Not offered every year.—II,III. (II,III.)

137. Weapons of Mass Destruction, the Cold War, and Modern Terrorism (4)
Lecture—3 hours; discussion—1 hour. Prerequisite: upper division standing, one course from 1B, 7C, 9C, or 10. Science of nuclear, biological, and chemical weapons related to the Cold War and terrorism. Order of magnitude calculations and modern quandaries of mass destruction. (Same course as Applied Science Engineering 137.) GE credit: SciEng, Wrt.—I. Cox

140A-140B. Introduction to Solid State Physics (4-4)
Lecture—3 hours; extensive problem solving. Prerequisite: course 115A or the equivalent passed with a grade of C- or better or consent of instructor. 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.—II-III. (II-III.)

160. Environmental Physics and Society (3)
Lecture—3 hours. Prerequisite: course 9D or 7C; or course 10 or 1B and Mathematics 16B or the equivalent. Impact of humankind on the environment will be discussed from the point of view of the physical sciences. Calculations based on physical principles will be made, and the resulting policy implications will be considered. (Same course as Engineering 160.) GE credit: SciEng or SocSci.—III. (III.)

194HA-194HB. Special Study for Honors Students (4-4)
Independent study—12 hours. Prerequisite: consent of instructor required. 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. (Deferred grading only, pending completion of sequence).

195. Senior Thesis (5)
Independent study—15 hours. Prerequisite: consent of instructor required. 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. May be repeated for a total of 15 units.—I, II, III. (I, II, III.)

197T. Tutoring in Physics and Astronomy (1-5)
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. (P/NP grading only.)—I, II, III. (I, II, III.)

198. Directed Group Study (1-5)
Prerequisite: consent of instructor. (P/NP grading only.)

199. Special Study for Advanced Undergraduates (1-5)
(P/NP grading only.)

Graduate Courses

200A. Theory of Mechanics and Electromagnetics (4)
Lecture—3 hours; independent study—1 hour. Prerequisite: courses 104B, 105B, and 110C or the equivalent; course 204A concurrently. 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.—I. (I.)

200B-200C. Theory of Mechanics and Electromagnetics (4-4)
Lecture—3 hours; independent study—1 hour. Prerequisite: course 200A, and course 204B concurrently. Theoretical approaches in electromagnetics including static electromagnetic fields; Maxwell's equations; plane waves in various media; magnetohydrodynamics; diffraction theory; radiating systems; and special relativity.—II-III. (II-III.)

204A-204B. Methods of Mathematical Physics (4-4)
Lecture—3 hours; independent study—1 hour. Prerequisite: courses 104A and 104B or the equivalent. 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.—I-II. (I-II.)

210. Computational Physics (3)
Lecture—3 hours. Prerequisite: knowledge of Fortran or C. Analytic techniques to solve differential equations and eignevalue problems. Physics content of course will be self-contained, and adjusted according to background of students.—II. (II.)

215A-215B-215C. Quantum Mechanics (4-4-4)
Lecture—3 hours; independent study—1 hour. Prerequisite: course 115B or the equivalent. 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.—I-II-III. (I-II-III.)

219A. Statistical Mechanics (4)
Lecture—3 hours; extensive problem solving. Prerequisite: course 215B or the equivalent. 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.—III. (III.)

219B. Statistical Mechanics (4)
Lecture—3 hours; extensive problem solving. Prerequisite: course 219A. Further applications of thermodynamics and classical and quantum statistical mechanics. The modern theory of fluctuations about the equilibrium state, phase transitions and critical phenomena.—I. (I.)

223A. Group Theoretical Methods of Physics—Condensed Matter (3)
Lecture—3 hours. Prerequisite: courses 215A, 215B (215C is corequisite) or consent of instructor. Theory of groups and their representations with applications in condensed matter. Not offered every year.—I. (I.)

223B. Group Theoretical Methods of Physics—Elementary Particles (3)
Lecture—3 hours. Prerequisite: courses 215A, 215B (215C is corequisite) or consent of instructor. Theory of groups and their representations with applications in elementary particle physics. Not offered every year.

224A. Nuclear Physics (3)
Lecture—3 hours. Prerequisite: course 215B. Comprehensive study of the nucleon-nucleon interaction including the deuteron, nucleon-nucleon scattering, polarization, determination of real parameters of S-matrix, and related topics. Not offered every year.

224B. Nuclear Physics (3)
Lecture—3 hours. Prerequisite: course 224A. Study of nuclear models, including shell model, collective model, unified model. Energy level spectra, static momenta, and electromagnetic transition rates. Not offered every year.

224C. Nuclear Physics (3)
Lecture—3 hours. Prerequisite: course 224B. Study of nuclear scattering and reactions including the optical model and direct interactions. Beta decay and an introduction to weak interactions. Not offered every year.

229A. Advanced Nuclear Theory (3)
Lecture—3 hours. Prerequisite: course 224C. Advanced topics in nuclear theory; theory of quantum-mechanical scattering processes. Exact formal theory and models for two-body scattering. Not offered every year.

229B. Advanced Nuclear Theory (3)
Lecture—3 hours. Prerequisite: course 229A. Advanced topics in nuclear theory; theory of quantum-mechanical scattering processes. Exact formal theory and models for three-body scattering. Not offered every year.

230A. Quantum Theory of Fields (3)
Lecture—3 hours. Prerequisite: course 215C. Relativistic quantum mechanics of particles; techniques and applications of second quantization; Feynman diagrams; renormalization.—I. (I.)

230B. Quantum Theory of Fields (3)
Lecture—3 hours. Prerequisite: course 230A. Continuation of 230A, with selected advanced topics, such as S-matrix theory, dispersion relations, axiomatic formulations.—II. (II.)

240A-240B. Solid State Physics (3-3)
Lecture—3 hours. Prerequisite: courses 215A-215B-215C; courses 140A-140B recommended. Introduction to the phenomena and theory of the solid state. Periodic structures, lattice structures, electron states, static properties, electron-electron interaction, electron dynamics, transport properties, optical properties, the Fermi surface, magnetism, superconductivity.—III. (I-III.)

240C. Condensed Matter Physics (3)
Lecture—3 hours. Prerequisite: course 240AB. 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.—III (III.)

241. Advanced Topics in Magnetism (3)
Lecture—3 hours. Prerequisite: courses 240A-240B and 240C-240D, or consent of instructor. Topics chosen from areas of current research interest. Not offered every year.

242. Advanced Topics in Superconductivity (3)
Lecture—3 hours. Prerequisite: courses 240A-240B and 240C-240D, or consent of instructor. Topics chosen from areas of current research interest. Not offered every year.

243A-243B-243C. Surface Physics of Materials (3-3-3)
Lecture—3 hours. Prerequisite: courses 140A-140B, 115A-115B or the equivalents; courses 215A, 240A, or the equivalents recommended. 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. Offered in alternate years—(I, II, III.)

245A. High-Energy Physics (3)
Lecture—3 hours. Prerequisite: course 230A. 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.—II. (II.)

245B. High-Energy Physics (3)
Lecture—3 hours. Prerequisite: course 245A. Electroweak interactions; phenomenology of the Standard Model of $SU(2)_L xU(1)$; 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.—III. (III.)

245C. High-Energy Physics (3)
Lecture—3 hours. Prerequisite: course 245A. Strong interaction: quantum chromodynamics phenomenology; jets and other experimental tests; quark and gluon distribution functions; quark and gluon scattering; applications of the renormalization group. Not offered every year.—III. (III.)

246. Supersymmetry: Theory and Phenomenology (3)
Lecture—3 hours. Prerequisite: courses 230A-230B, 245A-245B recommended, or consent of instructor. 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.

250. Special Topics in Physics (3)
Lecture—3 hours. Prerequisite: consent of instructor. Topic varies. May be repeated for credit. Not offered every quarter.—I, II, III. (I, II, III.)

252A. Techniques of Experimental Physics (3)
Lecture—3 hours. Introduction to techniques and methods of designing and executing experiments. Problems and examples from condensed matter research will be utilized. Not offered every year.

252B. Techniques of Experimental Physics (3)
Lecture—3 hours. Introduction to techniques and methods of designing and executing experiments. Problems and examples from nuclear and particle research will be utilized.—III. (III.)

260. Introduction to General Relativity (3)
Lecture—3 hours. Prerequisite: courses 200A, 200B. 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.—I. (I.)

262. Early Universe Cosmology (3)
Lecture—3 hours. Prerequisite: second year standing in Physics graduate program or consent of instructor. Introduction to early universe cosmology: the Big Bang, inflation, primordial nucleosynthesis, dark matter, dark energy, and other topics of current interest.—I. (I.)

263. Cosmic Structure Formation (3)
Lecture—3 hours. Prerequisite: course 260. 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.—III. (III.)

265. High Energy Astrophysics and Radiative Processes (3)
Lecture—3 hours. Prerequisite: graduate standing in physics or consent of instructor. Survey course covering galactic and extragalactic X-ray and gamma-ray astronomy, radiative processes, and techniques of high-energy astrophysics.—I. (I.)

266. Data Analysis for Astrophysics (3)
Lecture—3 hours. Prerequisite: graduate standing in physics or consent of instructor. Survey course covering measurement and signal analysis techniques for astrophysics and cosmology throughout the electromagnetic spectrum.—II. (II.)

267. Observational Extragalactic Astronomy & Cosmology (3)
Lecture—3 hours. Prerequisite: graduate standing in physics or consent of the instructor. Survey course covering current areas of research on extragalactic objects, their physical properties, origin, evolution, and distribution in space.—III. (III.)

270. Current Topics in Physics Research (2)
Lecture/discussion—2 hours. Prerequisite: graduate standing in physics or consent of instructor. 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. May be repeated for credit when topics differ. (S/U grading only.)—I, II, III. (I, II, III.)

280. Seminar in Ethics for Scientists (2)
Seminar—2 hours. Prerequisite: graduate standing in any department of Science or Engineering. Studies of topical and historical issues in the ethics of science, possibly including issues such as proper authorship, peer review, fraud, plagiarism, responsible collaboration, and conflict of interest. Limited enrollment. (Same course as Chemical Engineering and Materials Science 280 and Chemisitry 280.) (S/U grading only.)—III. (III.)

290. Seminar in Physics (1)
Seminar—1 hour. Prerequisite: graduate standing in Physics or consent of instructor. 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. May be repeated for credit. (S/U grading only.)—I, II, III. (I, II, III.)

291. Seminar in Nuclear Physics (1)
Seminar—1 hour. Prerequisite: graduate standing in Physics or consent of instructor. Presentation and discussion of topics of current research interest in nuclear physics. May be repeated for credit. (S/U grading only.)—I, II, III. (I, II, III.)

292. Seminar in Elementary Particle Physics (1)
Seminar—1 hour. Prerequisite: graduate standing in Physics or consent of instructor. Presentation and discussion of topics of current research interest in elementary particle physics. May be repeated for credit. (S/U grading only.)—I, II, III. (I, II, III.)

293. Seminar in Condensed Matter Physics (1)
Seminar—1 hour. Prerequisite: graduate standing in Physics or consent of instructor. Presentation and discussion of topics of current research interest in condensed matter physics. May be repeated for credit. (S/U grading only.)—I, II, III. (I, II, III.)

294. Seminar in Cosmology (1)
Seminar—1 hour. Prerequisite: graduate standing in Physics or consent of instructor. Presentation and discussion of topics of current research interest in Cosmology. May be repeated for credit. (S/U grading only.)—I, II, III. (I, II, III.)

295. Introduction to Departmental Research (1)
Seminar—1 hour. Seminar to introduce first- and second-year physics graduate students to the fields of specialty and research of the Physics staff. (S/U grading only.)—II.

297. Research on the Teaching and Learning of Physics (3)
Seminar—3 hours. Prerequisite: graduate standing in Physics or consent of instructor. 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.—III. (III.) Potter

298. Group Study (1-5)
Prerequisite: consent of instructor. (S/U grading only.)

299. Research (1-12)
(S/U grading only.)

Professional Courses

371. Teaching in an Active-Engagement Physics Discussion/Lab Setting (1)
Lecture/discussion—1 hour. Prerequisite: course 9D or equivalent; consent of instructor; open to graduate students only. Analysis of recent research on science/physics teaching and learning and its implications for teaching labs, discussions, and discussion/labs with an emphasis on the differences between conventional and active-engagement instructional settings. The appropriate role of the instructor in specific instructional settings. III. (III.)

390. Methods of Teaching Physics (1)
Lecture/discussion—1 hour. Prerequisite: graduate standing in Physics; consent of instructor. 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. May be repeated for credit. (S/U grading only.)—I, II, III. (I, II, III.)

396. Teaching Assistant Training Practicum (1-4)
Prerequisite: graduate standing. May be repeated for credit. (S/U grading only.)—I, II, III. (I, II, III.)