Consulting Professors:
Associate Professors:
Assistant Professor:
Mark J. Schnitzer
Chair:
Visiting Professor:
Courses in Physics and Mathematics to overcome deficiencies, consists of the following:
39 units must be graduate-level courses in applied physics, advanced degrees in Applied Physics.
study acquiring the background to meet the requirements for
The MASTER OF SCIENCE IN APPLIED PHYSICS degree. Students entering the program from an engineering include a bachelor’s degree in Physics or an equivalent engineering
GRADUATE PROGRAMS IN APPLIED PHYSICS
optics, space science and astrophysics, synchrotron radiation and
optoelectronics, photonics, quantum
related research fields. Research activities are carried out
laboratories including the Geballe Laboratory for Advanced
Materials, the Edward L. Ginztion Laboratory, the Hansen
Experimental Physics Laboratory, SLAC, the Center for Probing the Nanoscale, and the Stanford Institute for Materials and Energy Science.
The number of graduate students admitted to Applied Physics is limited. Applications should be received by January 6, 2009. Graduate students normally enter the department only in Autumn Quarter.

GRADUATE PROGRAMS IN APPLIED PHYSICS
Admission requirements for graduate work in Applied Physics include a bachelor’s degree in Physics or an equivalent engineering degree. Students entering the program from an engineering curriculum should expect to spend at least an additional quarter of study acquiring the background to meet the requirements for advanced degrees in Applied Physics.

MASTER OF SCIENCE IN APPLIED PHYSICS
The University’s basic requirements for the master’s degree are discussed in the “Graduate Degrees” section of this bulletin. The minimum requirements for the degree are 45 units, of which at least 39 units must be graduate-level courses in applied physics, engineering, mathematics, and physics. The required program consists of the following:
Courses in Physics and Mathematics to overcome deficiencies, if any, in undergraduate preparation.

1. Basic graduate courses (letter grade required):
a. Advanced Mechanics—one quarter, 3 units: PHYSICS 210, or approved substitute 211
b. Electrodynamics—two quarters, 6 units: PHYSICS 220, 221
c. Quantum Mechanics—two quarters, 6 units: PHYSICS 230, 231, or approved substitutes 232, 330, 331, 332, 370
2. 30 units of additional advanced courses in science and/or engineering. 15 of the 30 units may be any combination of advanced courses, Directed Study (APPPHYS 290), and 1-unit seminar courses, to complete the requirement of 45 units. Examples of suitable courses include BIO 217, 232; EE 222, 223, 231, 232, 248, 268, 346; PHYSICS 372, 373.
3. At least 15 of these 30 units must be taken for a letter grade.
4. A final overall grade point average (GPA) of 3.0 (B) is required for courses used to fulfill degree requirements.
There are no department or University examinations, and a thesis is not required. If a student is admitted to the M.S. program only, but later wishes to change to the Ph.D. program, the student must apply to the department’s Admissions Committee.

DOCTOR OF PHILOSOPHY IN APPLIED PHYSICS
The University’s basic requirements for the Ph.D. including residency, dissertation, and examinations are discussed in the “Graduate Degrees” section of this bulletin. The program leading to a Ph.D. in Applied Physics consists of course work, research, qualifying for Ph.D. candidacy, a research progress report, a University oral examination, and a dissertation as follows:

Course Work:
d. Courses in Physics and Mathematics to overcome deficiencies, if any, in undergraduate preparation.
e. Basic graduate courses* (letter grades required):
Advanced Mechanics—one quarter: PHYSICS 210, or approved substitute 211
Statistical Physics—one quarter: PHYSICS 212
Electrodynamics—two quarters: PHYSICS 220, 221
Quantum Mechanics—two quarters: PHYSICS 230, 231, or approved substitutes 232, 330, 331, 332, 370
Laboratory—one quarter: APPPHYS 207, 208, 304, 305; BIO 232; EE 234, 410; MATSCI 171, 172, 173; PHYSICS 301.
f. 18 units of additional advanced courses in science and/or engineering, not including Directed Study (APPPHYS 290), Dissertation Research (APPPHYS 390), and 1-unit seminar courses. Examples of suitable courses include BIO 217, 232; EE 222, 223, 231, 232, 248, 268, 346; PHYSICS 372, 373.
 Only 3 units at the 300 or above level may be taken on a satisfactory/no credit basis.
g. 96 units of additional courses to meet the minimum residency requirement of 135. Directed study and research units as well as 1-unit seminar courses can be included.
h. A final average overall grade point average (GPA) of 3.0 (B) is required for courses used to fulfill degree requirements.
i. Students are normally expected to complete the specified course requirements by the end of their third year of graduate study.

4. Research: may be conducted in a science/engineering field under the supervision of a member of the Applied Physics faculty or appropriate faculty from other departments.
5. Ph.D. Candidacy: satisfactory progress in academic and research work, together with passing the Ph.D. candidacy qualifying examination, qualifies the student to apply for Ph.D. candidacy, and must be completed before the third year of graduate registration. The examination consists of a seminar on a suitable subject delivered by the student before the faculty advisory committee (or an approved substitute) and two other members of the faculty selected by the department.
6. Research Progress Report: normally before the end of the Winter Quarter of the fourth year of enrollment in graduate study at Stanford, the student arranges to give an oral research progress report of approximately 45 minutes, of which a minimum of 15 minutes should be devoted to questions from the Ph.D. reading committee.
2. University Ph.D., Oral Examination: consists of a public seminar in defense of the dissertation, followed by private questioning of the candidate by the University examining committee.

3. Dissertation: must be approved and signed by the Ph.D. reading committee.

* Requirements for item ‘1b’ may be totally or partly satisfied with equivalent courses taken elsewhere, pending approval of the graduate study committee.

# APPLIED PHYSICS (APPPHYS) COURSES

For information on graduate programs in the Department of Applied Physics see the “Applied Physics” section of this bulletin.

## UNDERGRADUATE COURSES IN APPLIED PHYSICS

### APPPHYS 68N. Lasers and Photons

3 units, Aut (Bucksbaum, P)

### APPPHYS 79N. Energy Choices for the 21st Century

3 units, Aut (Fox, J; Geballe, T)

### APPPHYS 136. Biology by the Numbers
(Same as BIOC 236.) Skillbuilding in biological quantitative reasoning. Topics include: biological size scales from proteins to ecosystems; biological time scales from enzymatic catalysis and DNA replication to evolution; biological energy, motion, and force from molecular to organismic scales; mechanisms of environmental sensing from bacterial chemotaxis to vision. Prerequisite: Physics 21, 41, or consent of instructor.

3 units, Win (Theriot, J; Fisher, D)

### APPPHYS 192. Introductory Biophysics
(Same as APPPHYS 292.) For advanced undergraduates or beginning graduate students. Quantitative models used in molecular biophysics. The relation of structure to function. Chemical equilibria, cooperativity, and control: elementary statistical mechanics, affinity plots, allosteric, models of hemoglobin-oxygen binding, bacterial chemotaxis. Macromolecular conformations; polymer chain models, protein folding, taxonomy of globular proteins, general principles of selection. Chemical kinetics. Multiple barriers: CO-myoglobin kinetics, ion diffusion through channels and ion selectivity, spectroscopy of ion channels-acetylcholine receptor. Supramolecular kinetics; conversion of chemical energy to mechanical force, myosin and kinesin, actin polymers. Nerve impulse propagation: membrane potentials, voltage sensitive ion gates, Hodgkin-Huxley equations, propagation of the nerve impulse.

3 units, alternate years, not given this year

# GRADUATE COURSES IN APPLIED PHYSICS

Primarily for graduate students; undergraduates may enroll with consent of instructor.

### APPPHYS 207. Laboratory Electronics

3 units, Win (Fox, J)

### APPPHYS 208. Laboratory Electronics

3 units, Spr (Fox, J), alternate years, not given next year

### APPPHYS 214. Randomness in the Physical World
(Same as STATS 214.) Topics include: random numbers, and their generation and applications; random systems and quenching, and annealing; percolation and fractal structures; universality, the renormalization group, and limit theorems; path integrals, partition functions, and Wiener measure; random matrices; and optical estimation. Prerequisite: introductory course in statistical mechanics or analysis.

3 units, Spr (Diaconis, P; Fisher, D; Holmes, S), alternate years, not given next year

### APPPHYS 216. X-Ray and VUV Physics

3 units, alternate years, not given this year

### APPPHYS 217. Estimation and Control Methods for Applied Physics
Recursive filtering, parameter estimation, and feedback control methods based on linear and nonlinear state-space modeling. Topics in: dynamical systems theory; practical overview of stochastic differential equations; model reduction; and tradeoffs among performance, complexity, and robustness. Numerical implementations in MATLAB. Contemporary applications in systems biology and quantum precision measurement. Prerequisites: linear algebra and ordinary differential equations.

3 units, not given this year
APPHYS 218. X-Ray and Neutron Scattering in the 21st Century
Interaction of x-rays and neutrons with matter. Modern sources of radiation: synchrotrons, x-ray free electron lasers, and spallation neutron sources. Scattering formulae. Determination of molecular, crystal, and magnetic structures, and their associated charge, lattice, and magnetic excitations. Applications from condensed matter physics, materials science, biophysics, medicine, and the arts. Examples include thermal and quantum phase transitions, excitations and competing phases in high-temperature superconductors, materials under extreme pressure, structure of nanoparticles, proteins and water, computer-aided tomography, and nondestructive testing of art objects. 3 units, alternate years, not given this year

APPHYS 219. Solid State Physics and the Energy Challenge
Technology issues for a secure energy future; role of solid state physics in energy technologies. Topics include the physics principles behind future technologies related to solar energy and solar cells, solid state lighting, superconductivity, solid state fuel cells and batteries, electrical energy storage, materials under extreme condition, nanomaterials. 3 units, Win (Shen, Z), alternate years, not given next year

APPHYS 223. Stochastic and Nonlinear Dynamics
(Same as BME 229.) Theoretical and dynamical processes: dynamical systems, stochastic processes, and spatiotemporal dynamics. Motivations and applications from biology and physics. Emphasis is on methods including qualitative approaches, asymptotics, and multiple scale analysis. Prerequisites: ordinary and partial differential equations, complex analysis, and probability or statistical physics. 3 units, alternate years, not given this year

APPHYS 225. Probability and Quantum Mechanics
Structure of quantum theory emphasizing states, measurements, and probabilistic modeling. Generalized quantum measurement theory; parallels between classical and quantum probability; conditional expectation in the Schrödinger and Heisenberg pictures; covariance with respect to symmetry groups; reference frames and superselection rules. Classical versus quantum correlations; nonlocal aspects of quantum probability; axiomatic approaches to interpretation. Prerequisites: undergraduate quantum mechanics, linear algebra, and basic probability and statistics. 3 units, Aut (Mabuchi, H)

APPHYS 226. Physics of Quantum Information
Laws and concepts of quantum information science. Postulates of quantum mechanics: symmetrization postulate, quantum indistinguishability and multi-particle interference, commutation relations, and quantum measurement, reduction postulate and impossibility of measuring, cloning and deleting a single wavefunction. Quantum information theory: von Neumann entropy, Holevo information and Schumacher data compression. Decoherence: Lindbladian, quantum error correction, and purification of entanglement. 3 units, Win (Yamamoto, Y), alternate years, not given next year

APPHYS 227. Applications of Quantum Information
Concepts and constituent technologies of quantum information systems. Quantum cryptography: single photon and entangled photon-pair-based quantum key distributions, quantum teleportation, quantum repeater. Quantum computer: Deutsch-Josza algorithm, Grover algorithm, Shor algorithm, quantum simulation, quantum circuits. Quantum hardwares: atomic physics, nuclear magnetic resonance, spintronics and quantum optics. 3 units, Spr (Mabuchi, H; Yamamoto, Y), alternate years, not given next year

APPHYS 270. Magnetism and Long Range Order in Solids
Cooperative effects in solids. Topics include the origin of magnetism in solids, crystal electric field effects and anisotropy, exchange, phase transitions and long-range order, ferromagnetism, antiferromagnetism, metamagnetism, density waves and superconductivity. Emphasis is on archetypal materials. Prerequisite: PHYSICS 172 or MATSCI 291, or equivalent introductory condensed matter physics course. 3 units, Aut (Fisher, I), alternate years, not given next year

APPHYS 272. Solid State Physics I
The properties of solids. Theory of free electrons, classical and quantum. Crystal structure and methods of determination. Electron energy levels in a crystal: weak potential and tight-binding limits. Classification of solids: metals, semiconductors, and insulators. Types of bonding and cohesion in crystals. Lattice dynamics, phonon spectra, and thermal properties of harmonic crystals. Pre- or corequisites: PHYSICS 120 and 121; and PHYSICS 130 and 131, or equivalents. 3 units, Win (Kivelson, S)

APPHYS 273. Solid State Physics II

APPHYS 275. Probing the Nanoscale
Theory, operation, and applications of nanoprobes of interest in physics and materials science. Lectures by experts. Topics include scanning tunneling microscopy, spectroscopy, and potentiometry; atomic manipulation; scanning magnetic sensors and magnetic resonance; scanning field-effect gates; scanning force probes; and ultra-near-field optical scanning. 3 units, alternate years, not given this year

APPHYS 280. Phenomenology of Superconductors
Applications based on superconductivity as a phase-coherent macroscopic quantum phenomena. Topics include the superconducting pair wave function, London and Ginzburg-Landau theories, their physical content, the Josephson effect and superconducting quantum interference devices, s- and d-wave superconductivity, the response of superconductors to currents, magnetic fields, and RF electromagnetic radiation. 3 units, alternate years, not given this year

APPHYS 291. Practical Training
Practical training in industrial labs. Arranged by student with research advisor’s approval. Summary of activities required. 3 units, Sum (Staff)

APPHYS 292. Introductory Biophysics
(Same as APPPHYS 192.) Quantitative models used in molecular biophysics. The relation of structure to function. Chemical equilibria, cooperativity, and control: elementary statistical mechanics, affinity plots, allosteroy, models of hemoglobin-oxygen binding, bacterial chemotaxis. Macromolecular conformational changes: polymer chain models, protein folding, taxonomy of globular proteins, general principles of sequence selection. Chemical kinetics. Multiple barriers: CO-myoglobin kinetics, ion diffusion through channels and ion selectivity, spectroscopy of ion channels-acetylcholine receptor. Supramolecular kinetics: conversion of chemical energy to mechanical force, myosin and kinesin, actin polymers. Nerve impulse propagation: membrane potentials, voltage sensitive ion gates, Hodgkin-Huxley equations, propagation of the nerve impulse. 3 units, alternate years, not given this year

APPHYS 294. Cellular Biophysics
(Same as BIO 294.) Physical biology of dynamical and mechanical processes in cells. Emphasis is on qualitative understanding of biological functions through quantitative analysis and simple mathematical models. Sensory transduction, signaling, adaptation, switches, molecular motors, actin and microtubules, motility, and circadian clocks. Prerequisites: differential equations and introductory statistical mechanics. 3 units, alternate years, not given this year
Prerequisites: PHYSICS 170, 171, and 172, or equivalents.

Matter Physics
Cryogenics; low signal measurements and noise analysis; data collection and analysis; examples of current experiments.

Cryogenics; low signal measurements and noise analysis; data

APPPHYS 302. Experimental Techniques in Condensed Matter Physics
Theory and practice. Theoretical and descriptive background for lab experiments, detectors and noise, and lasers (helium neon, beams and resonators, argon ion, cw dye, titanium sapphire, semiconductor diode, and the Nd:YAG). Measurements of laser threshold, gain, saturation, and output power levels. Laser transverse and axial modes, linewidth and tuning, Q-switching and modelocking. Limited enrollment. Prerequisites: EE 231 and 232, or consent of instructor.

3 units, alternate years, not given this year

APPPHYS 304. Lasers Laboratory
Laser interaction with matter. Laser devices provide radiation to explore the linear and nonlinear properties of matter. Experiments on modulation, harmonic generation, parametric oscillators, modelocking, stimulated Raman and Brillouin scattering, coherent anti-Stokes scattering, other four-wave mixing interactions such as wavefront conjugation and optical bistability. Optical pumping and spectroscopy of atomic and molecular species. Limited enrollment. Prerequisites: EE 231 and 232, or consent of instructor.

3 units, not given this year

APPPHYS 305. Nonlinear Optics Laboratory
Methods of bioinformatics and biomolecular modeling from the standpoint of biophysical chemistry. Methods of genome analysis; cluster analysis, phylogenetic trees, microarrays; protein, RNA and DNA structure and dynamics, structural and functional homology; protein-protein interactions and cellular networks; molecular dynamics methods using massively parallel algorithms. Topics of current research in accelerator physics.

3 units, not given this year

APPPHYS 315. Methods in Computational Biology
Theory and practice. Theoretical and descriptive background for lab experiments, detectors and noise, and lasers (helium neon, beams and resonators, argon ion, cw dye, titanium sapphire, semiconductor diode, and the Nd:YAG). Measurements of laser threshold, gain, saturation, and output power levels. Laser transverse and axial modes, linewidth and tuning, Q-switching and modelocking. Limited enrollment. Prerequisites: EE 231 and 232, or consent of instructor.

3 units, alternate years, not given this year

APPPHYS 316. Methods in Computational Biology
Methods of bioinformatics and biomolecular modeling from the standpoint of biophysical chemistry. Methods of genome analysis; cluster analysis, phylogenetic trees, microarrays; protein, RNA and DNA structure and dynamics, structural and functional homology; protein-protein interactions and cellular networks; molecular dynamics methods using massively parallel algorithms. Topics of current research in accelerator physics.

3 units, Win (Bucksbaum, P), alternate years, not given next year

APPPHYS 324. Introduction to Accelerator Physics
Physics of particle beams in linear and circular accelerators. Transverse beam dynamics, acceleration, longitudinal beam dynamics, synchrotron radiation, collective instabilities, and nonlinear effects. Topics of current research in accelerator physics.

3 units, Win (Ruth, R), alternate years, not given next year

APPPHYS 376. Literature of Cavity Quantum Electrodynamics
Historical development and contemporary frontiers of cavity quantum electrodynamics in the optical and microwave domains. Topics include effects of boundary conditions on spontaneous emission, development of strong coupling in experimental systems, fundamental theoretical models, linear and nonlinear phenomenology in the strong coupling regime, optical bistability, input-output theory, photon statistics and single-photon sources, and modern developments in circuit QED. Journal club format; student presentations.

3 units, Win (Mabuchi, H)

APPPHYS 377. Literature of Condensed Matter Physics
Discoveries and experiments in condensed matter physics in the past 15 years. Topics: sliding charge density waves in layer compounds, the first pressure-induced Mott transition and organic superconductor, discovery of superfluid 3He, quasicrystals, the Shrinov effect, the quantum Hall effect, and reentrant superconductivity. Journal club format; student presentations.

3 units, Win (Beasley, M), alternate years, not given next year

APPPHYS 383. Introduction to Atomic Processes

3 units, Win (Bucksbaum, P), alternate years, not given next year

APPPHYS 387. Quantum Optics and Measurements

3 units, alternate years, not given this year

APPPHYS 388. Mesoscopic Physics and Nanostructures

3 units, alternate years, not given this year

APPPHYS 390. Dissertation Research
To do original research. May be repeated for credit. Corequisite: 387.

1-15 units, Aut (Staff), Win (Staff), Spr (Staff)

APPPHYS 392. Topics in Molecular Biophysics
Concepts from statistical mechanics applied to contemporary molecular biology: allosteric transitions; protein folding; molecular recognition; actin polymers and gels; molecular motors; lipids and membrane proteins; ion channels. Some of the basic models used to quantitate fundamental biomolecular functions. Prerequisites: elementary statistical mechanics and chemical kinetics.

3 units, alternate years, not given this year

APPPHYS 470. Condensed Matter Seminar
Current research and literature; offered by faculty, students, and outside specialists. May be repeated for credit.

1 unit, Aut (Beasley, M), Win (Beasley, M), Spr (Beasley, M)

APPPHYS 473A. Condensed Matter Physics
Students undertake background study prior to each weekly seminar offered through 470 as an introduction to topics of contemporary interest in condensed matter physics, critique each seminar for success in oral communication, and present a one-hour seminar on a contemporary topic for critique by the class. May be repeated for credit. Corequisite: 470.

2 units, Aut (Beasley, M), Win (Beasley, M), Spr (Beasley, M)

APPPHYS 483. Optics and Electronics Seminar
Current research topics in lasers, quantum electronics, optics, and photonics by faculty, students, and invited speakers. May be repeated for credit.

1 unit, Aut (Mabuchi, H), Win (Byer, R), Spr (Harris, S)