

Applied Physics

Courses offered by the Department of Applied Physics are listed under the subject code APPPHYS on the (<http://explorecourses.stanford.edu/CourseSearch/search?view=catalog&catalog=&page=0&q=APPPHYS&filter-catalognumber-APPPHYS=on>) Stanford Bulletin's (<http://explorecourses.stanford.edu/CourseSearch/search?view=catalog&catalog=&page=0&q=APPPHYS&filter-catalognumber-APPPHYS=on>) ExploreCourses web site (<http://explorecourses.stanford.edu/CourseSearch/search?view=catalog&catalog=&page=0&q=APPPHYS&filter-catalognumber-APPPHYS=on>).

The Department of Applied Physics offers qualified students with backgrounds in physics or engineering the opportunity to do graduate course work and research in the physics relevant to technical applications and natural phenomena. These areas include accelerator physics, biophysics, condensed matter physics, nanostructured materials, quantum electronics and photonics, quantum optics and quantum information, space science and astrophysics, synchrotron radiation and applications.

Student research is supervised by the faculty members listed above and also by various members of other departments such as Biology, Chemistry, Electrical Engineering, Materials Science and Engineering, Physics, the SLAC National Accelerator Laboratory, and faculty of the Medical School who are engaged in related research fields.

Research activities are carried out in laboratories including the Geballe Laboratory for Advanced Materials, the Edward L. Ginzton Laboratory, the Hansen Experimental Physics Laboratory, the SLAC National Accelerator Laboratory, 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 to the Master of Science and Ph.D. programs should be received by December 15, 2015. M.S. and Ph.D. students normally enter the department only in Autumn Quarter.

Graduate Programs in Applied Physics

The Department of Applied Physics offers three types of advanced degrees:

- the Doctor of Philosophy
- the coterminal Master of Science in Applied and Engineering Physics
- the Master of Science in Applied Physics, either a terminal degree or an en route degree to the Ph.D. for students enrolled in the Applied Physics Department

Admission requirements for graduate work in the Master of Science and Ph.D. programs 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 the M.S. and Ph.D. degrees in Applied Physics.

Learning Outcomes (Graduate)

The purpose of the master's program is to further develop knowledge and skills in Applied Physics and to prepare students for a professional career or doctoral studies. This is achieved through completion of courses, in the primary field as well as related areas, and experience with independent work and specialization.

The Ph.D. is conferred upon candidates who have demonstrated substantial scholarship and the ability to conduct independent research and analysis in Applied Physics. Through completion of advanced course work and

rigorous skills training, the doctoral program prepares students to make original contributions to the knowledge of Applied Physics and to interpret and present the results of such research.

Coterminal Master of Science in Applied and Engineering Physics

Stanford undergraduates, regardless of undergraduate major, who are interested in a M.S. degree at the intersection of applied physics and engineering may choose to apply for the coterminal Master of Science program in Applied and Engineering Physics. The program is designed to be completed in a fifth year at Stanford. Students with accelerated undergraduate programs may be able to complete their B.S. and coterminal M.S. in four years.

Application and Admission

Undergraduates must be admitted to the program and enrolled as a graduate student for at least one quarter prior to B.S. conferral. Applications will be due on the last day of class of the Spring Quarter for Autumn matriculation and at least four weeks before the last day of class in the previous quarter for Winter or Spring matriculation. All application materials must be submitted directly to the Applied Physics department office by the deadlines. To apply for admission to the Applied and Engineering Physics coterminal M.S. program, students must submit the coterminal application which consists of the following:

- Application for Admission to Coterminal Masters' Program (<http://registrar.stanford.edu/pdf/CotermApplic.pdf>)
- Statement of Purpose
- Unofficial Transcript
- Two Letters of Recommendation from members of the Stanford faculty
- Supplemental Form (<http://www.stanford.edu/dept/app-physics/cgi-bin/aep-application-process>)

University Coterminal Requirements

Coterminal master's degree candidates are expected to complete all master's degree requirements as described in this bulletin. University requirements for the coterminal master's degree are described in the "Coterminal Master's Program (<http://exploreddegrees.stanford.edu/cotermdegrees>)" section. University requirements for the master's degree are described in the "Graduate Degrees (<http://exploreddegrees.stanford.edu/graduatedegrees/#masterstext>)" section of this bulletin.

After accepting admission to this coterminal master's degree program, students may request transfer of courses from the undergraduate to the graduate career to satisfy requirements for the master's degree. Transfer of courses to the graduate career requires review and approval of both the undergraduate and graduate programs on a case by case basis.

In this master's program, courses taken three quarters prior to the first graduate quarter, or later, are eligible for consideration for transfer to the graduate career. No courses taken prior to the first quarter of the sophomore year may be used to meet master's degree requirements.

Course transfers are not possible after the bachelor's degree has been conferred.

The University requires that the graduate adviser be assigned in the student's first graduate quarter even though the undergraduate career may still be open. The University also requires that the Master's Degree Program Proposal be completed by the student and approved by the department by the end of the student's first graduate quarter.

Program Requirements

Coterminal M.S. students are required to take 45 units of course work during their graduate career. Of these 45 units, the following are required.

	Units
Four Breadth Courses (required)	
APPPHYS 201 Electrons and Photons	4
APPPHYS 203 Atoms, Fields and Photons	4
APPPHYS 204 Quantum Materials	4
APPPHYS 205 Introduction to Biophysics	4
Three Engineering Depth Courses	9
At least one must be at the 300 level and the other courses must be at the 200 level or above to provide depth in one area. To be approved by the Applied Physics academic adviser.	
One Laboratory or Methods Course	3-4
APPPHYS 207 Laboratory Electronics	
APPPHYS 208 Laboratory Electronics	
APPPHYS 215 Numerical Methods for Physicists and Engineers	
APPPHYS 217 Estimation and Control Methods for Applied Physics	
APPPHYS 232 Advanced Imaging Lab in Biophysics	
APPPHYS 304 Lasers Laboratory	
APPPHYS 305 Advanced Nonlinear Optics Laboratory	
EE 234 Photonics Laboratory	
EE 251 High-Frequency Circuit Design Laboratory	
EE 410 Integrated Circuit Fabrication Laboratory	
ENGR 341 Micro/Nano Systems Design and Fabrication	
ENGR 342 MEMS Laboratory II	
MATSCI 322 Transmission Electron Microscopy Laboratory	
MATSCI 331 Atom-based computational methods for materials	
Seminar ¹	3
Approved Technical Electives ²	6-12
6 units minimum that brings up the total units to 45	
Total Units	45

¹ The seminar requirement can be fulfilled by either (i) taking one formal seminar course for credit each term, and/or (ii) enrolling in Applied Physics 290 and attending a minimum of 8 informal talks or formal research seminars during each of the three terms. Students enrolling in Applied Physics 290 must submit with their final M.S. program proposal a list of the 8 talks/seminars with a paragraph describing the content, signed by their academic adviser.

² These include APPPHYS, CS, CME, EE, ME, BIOE, MATSCI, PHYSICS courses (see <http://www.stanford.edu/dept/app-physics/cgi-bin/academic-programs/>) as well as those courses that are formally approved by the Applied Physics Graduate Studies Committee through petition.

Any request for a course transfer from the undergraduate career is subject to approval of the undergraduate and graduate departments.

Master of Science in Applied Physics

The University's basic requirements for the master's degree are discussed in the "Graduate Degrees (<http://exploreddegrees.stanford.edu/graduatedegrees/>)" 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:

Advanced Mechanics	3
Select one of the following:	
PHYSICS 210 Advanced Mechanics	
PHYSICS 211 Continuum Mechanics (approved substitute)	
Electrodynamics	3
PHYSICS 220 Classical Electrodynamics	
Quantum Mechanics	6
Select two of the following:	
PHYSICS 230 Graduate Quantum Mechanics I	
PHYSICS 231 Graduate Quantum Mechanics II	
EE 222 Applied Quantum Mechanics I (approved substitute)	
EE 223 Applied Quantum Mechanics II (approved substitute)	
PHYSICS 234 Advanced Topics in Quantum Mechanics (approved substitute)	
PHYSICS 330 Quantum Field Theory I (approved substitute)	
PHYSICS 331 Quantum Field Theory II (approved substitute)	
PHYSICS 332 Quantum Field Theory III (approved substitute)	

	Units
APPPHYS 290 Directed Studies in Applied Physics	
1-unit seminar courses	
Examples of suitable courses include:	
BIO 217 Neuronal Biophysics	
EE 222 Applied Quantum Mechanics I	
EE 223 Applied Quantum Mechanics II	
EE 236A Modern Optics	
EE 236C Lasers	
EE 248 Fundamentals of Noise Processes	
EE 332 Laser Dynamics	
EE 346 Introduction to Nonlinear Optics	
PHYSICS 372 Condensed Matter Theory I	
PHYSICS 373 Condensed Matter Theory II	

1. Courses in Physics and Mathematics to overcome deficiencies, if any, in undergraduate preparation.
2. Basic graduate courses (letter grade required):
 - 33 units of additional advanced courses in science and/or engineering. May be any combination of APPPHYS 290 Directed Studies in Applied Physics, any 1-unit course, and regular courses. At least 18 of these 33 units must be taken for a letter grade.
3. A final overall grade point average (GPA) of 3.0 (B) is required for courses used to fulfill degree requirements.

There are no department nor University examinations. There is no thesis component. 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 (<http://exploreddegrees.stanford.edu/graduatedegrees/>)" 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:

1. Course Work:

	Units
Advanced Mechanics	3
Select one of the following:	
PHYSICS 210 Advanced Mechanics	
PHYSICS 211 Continuum Mechanics (approved substitute)	
Statistical Physics	3-4
Select one of the following:	
APPPHYS 217 Estimation and Control Methods for Applied Physics	
APPPHYS 285 Physics of Disordered Systems	
APPPHYS 315 Methods in Computational Biology	
APPPHYS 387 Quantum Optics and Measurements	
PHYSICS 212 Statistical Mechanics	
Electrodynamics	3
PHYSICS 220 Classical Electrodynamics	
Quantum Mechanics	6
Select two of the following:	
PHYSICS 230 Graduate Quantum Mechanics I	
PHYSICS 231 Graduate Quantum Mechanics II	
PHYSICS 234 Advanced Topics in Quantum Mechanics (approved substitute)	
PHYSICS 330 Quantum Field Theory I (approved substitute)	
PHYSICS 331 Quantum Field Theory II (approved substitute)	
PHYSICS 332 Quantum Field Theory III (approved substitute)	
EE 222 Applied Quantum Mechanics I (approved substitute)	
EE 223 Applied Quantum Mechanics II (approved substitute)	
Laboratory	3-4
Select one of the following:	
APPPHYS 207 Laboratory Electronics	
APPPHYS 208 Laboratory Electronics	
APPPHYS 232 Advanced Imaging Lab in Biophysics	
APPPHYS 304 Lasers Laboratory	
APPPHYS 305 Advanced Nonlinear Optics Laboratory	
BIOE 370 Microfluidic Device Laboratory	
EE 234 Photonics Laboratory	
EE 410 Integrated Circuit Fabrication Laboratory	
MATSCI 171 Nanocharacterization Laboratory	
MATSCI 172 X-Ray Diffraction Laboratory	
MATSCI 173 Mechanical Behavior Laboratory	

PHYSICS Astrophysics Laboratory
301

- Courses in Physics and Mathematics to overcome deficiencies, if any, in undergraduate preparation.
- Basic graduate courses:* These requirements may be totally or partly satisfied with equivalent courses taken elsewhere, pending the approval of the graduate study committee. Letter grades required for all courses:
- 21 units of additional advanced courses in science and/or engineering. Units from APPPHYS 290, APPPHYS 390, and any 1-unit courses do not count towards this requirement. Examples of suitable courses include:

	Units
BIO 217 Neuronal Biophysics	4
EE 222 Applied Quantum Mechanics I	3
EE 223 Applied Quantum Mechanics II	3
EE 236A Modern Optics	3
EE 236C Lasers	3
EE 248 Fundamentals of Noise Processes	3
EE 332 Laser Dynamics	3
EE 346 Introduction to Nonlinear Optics	3
PHYSICS 372 Condensed Matter Theory I	3
PHYSICS 373 Condensed Matter Theory II	3

- Only 3 units at the 300 or above level may be taken on a satisfactory/no credit basis.
 - Additional units of courses as needed to meet the minimum residency requirement of 135. Directed study and research units as well as 1-unit seminar courses can be included.
 - A final average overall grade point average (GPA) of 3.0 (B) is required for courses used to fulfill degree requirements.
 - Students are normally expected to complete the specified course requirements by the end of their third year of graduate study.
- 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.
 - 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 academic adviser (or an approved substitute) and two other members of the faculty selected by the department.
 - 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.
 - 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.
 - Dissertation:* must be approved and signed by the Ph.D. reading committee.

Emeriti: (Professors) Malcolm R. Beasley, Arthur Bienenstock, Alexander L. Fetter, Theodore H. Geballe, Stephen E. Harris, Walter A. Harrison, Peter A. Sturrock, Yoshihisa Yamamoto; (Professors, Research) Calvin F. Quate, Helmut Wiedemann, Herman Winick; (Courtesy) Gordon S. Kino, Douglas D. Osheroff

Chair: Hideo Mabuchi

Professors: Steven M. Block, Philip H. Bucksbaum, Robert L. Byer, Sebastian Doniach, Martin M. Fejer, Daniel S. Fisher, Ian R. Fisher, Tony

F. Heinz, Harold Y. Hwang, Aharon Kapitulnik, Mark A. Kasevich, Young S. Lee, Hideo Mabuchi, Kathryn A. Moler, Vahé Petrosian (on leave Autumn Quarter), Stephen R. Quake, Zhi-Xun Shen, Yuri Suzuki

Associate Professors: David A. Reis, Mark J. Schnitzer (on leave Spring Quarter)

Assistant Professors: Surya Ganguli, Benjamin L. Lev, Amir H. Safavi-Naeini

Professor (Research): Michel J-F. Dignonnet

Courtesy Professors: Mark L. Brongersma, Bruce M. Clemens, Shanhui Fan, David Goldhaber-Gordon, James S. Harris, Lambertus Hesselink, David A. B. Miller, W. E. Moerner, Jelena Vuckovic, Shoucheng Zhang

Courtesy Associate Professors: Zhirong Huang, Andrew J. Spakowitz

Courtesy Assistant Professor: William J. Greenleaf

Consulting Professors: Thomas M. Baer, Raymond G. Beausoleil, John D. Fox, Bernardo A. Huberman, Richard M. Martin, Stuart S. P. Parkin, Daniel Rugar

Courses

APPPHYS 10AX. The Expressive Vessel: An Immersive Introduction to Clay. 2 Units.

Students learn to make and to analyze functional ceramic forms with a focus on wheel-thrown pottery. Studio time dedicated to the acquisition and refinement of shaping, marking/glazing and finishing skills; supplementary lectures and discussions to explore contemporary studio ceramics and major historical traditions. No prior experience necessary; instructors will tailor assignments for students at all levels of ability.

APPPHYS 77N. Functional Materials and Devices. 3 Units.

Preference to freshmen. Exploration via case studies how functional materials have been developed and incorporated into modern devices. Particular emphasis is on magnetic and dielectric materials and devices. Recommended: high school physics course including electricity and magnetism.

APPPHYS 79N. Energy Options for the 21st Century. 3 Units.

Preference to freshmen. Choices for meeting the future energy needs of the U.S. and the world. Basic physics of energy sources, technologies that might be employed, and related public policy issues. Trade-offs and societal impacts of different energy sources. Policy options for making rational choices for a sustainable world energy economy.

APPPHYS 100. The Questions of Clay: Craft, Creativity and Scientific Process. 5 Units.

Students will create individual studio portfolios of ceramic work and pursue technical investigations of clay properties and the firing process using modern scientific equipment. Emphasis on development of creative process; parallels between science and traditional craft; integration of creative expression with scientific method and analysis. Prior ceramics experience desirable but not necessary. Limited enrollment. Prerequisite: any level of background in physics.

APPPHYS 201. Electrons and Photons. 4 Units.

Applied Physics Core course appropriate for graduate students and advanced undergraduate students with prior knowledge of elementary quantum mechanics, electricity and magnetism, and special relativity. Interaction of electrons with intense electromagnetic fields from microwaves to x-ray, including electron accelerators, x-ray lasers and synchrotron light sources, attosecond laser-atom interactions, and x-ray matter interactions. Mechanisms of radiation, free-electron lasing, and advanced techniques for generating ultrashort brilliant pulses. Characterization of electronic properties of advanced materials, prospects for single-molecule structure determination using x-ray lasers, and imaging attosecond molecular dynamics.

Same as: PHOTON 201

APPPHYS 203. Atoms, Fields and Photons. 4 Units.

Applied Physics Core course appropriate for graduate students and advanced undergraduate students with prior knowledge of elementary quantum mechanics, electricity and magnetism, and ordinary differential equations. Structure of single- and multi-electron atoms and molecules, and cold collisions. Phenomenology and quantitative modeling of atoms in strong fields, with modern applications. Introduction to quantum optical theory of atom-photon interactions, including quantum trajectory theory, mechanical effects of light on atoms, and fundamentals of laser spectroscopy and coherent control.

APPPHYS 204. Quantum Materials. 4 Units.

Applied Physics Core course appropriate for graduate students and advanced undergraduate students with prior knowledge of elementary quantum mechanics. Introduction to materials and topics of current interest. Topics include superconductivity, magnetism, charge and spin density waves, frustration, classical and quantum phase transitions, multiferroics, and interfaces. Prerequisite: elementary course in quantum mechanics.

APPPHYS 205. Introduction to Biophysics. 3-4 Units.

Core course appropriate for advanced undergraduate students and graduate students with prior knowledge of calculus and a college physics course. Introduction to how physical principles offer insights into modern biology, with regard to the structural, dynamical, and functional organization of biological systems. Topics include the roles of free energy, diffusion, electromotive forces, non-equilibrium dynamics, and information in fundamental biological processes. Same as: BIO 126, BIO 226

APPPHYS 206. Dynamical Systems: Linear, Non-Linear, and Stochastic. 4 Units.

Introduction to dynamical systems including linear, nonlinear, stochastic and spatiotemporal models. Emphasis on asymptotic and multi-scale analysis as well as fundamental concepts of stability, bifurcation and oscillation. Prerequisites: linear algebra and unfamiliarity with ordinary and partial differential equations; basic probability.

APPPHYS 207. Laboratory Electronics. 4 Units.

Lecture/lab emphasizing analog and digital electronics for lab research. RC and diode circuits. Transistors. Feedback and operational amplifiers. Active filters and circuits. Pulsed circuits, voltage regulators, and power circuits. Precision circuits, low-noise measurement, and noise reduction techniques. Circuit simulation tools. Analog signal processing techniques and modulation/demodulation. Principles of synchronous detection and applications of lock-in amplifiers. Common laboratory measurements and techniques illustrated via topical applications. Prerequisites: undergraduate device and circuit exposure.

APPPHYS 208. Laboratory Electronics. 4 Units.

Lecture/lab emphasizing analog and digital electronics for lab research. Continuation of APPPHYS 207 with emphasis on applications of digital techniques. Combinatorial and synchronous digital circuits. Design using programmable logic. Analog/digital conversion. Microprocessors and real time programming, concepts and methods of digital signal processing techniques. Current lab interface protocols. Techniques commonly used for lab measurements. Development of student lab projects during the last three weeks. Prerequisites: undergraduate device and circuit exposure. Recommended: previous enrollment in APPPHYS 207.

APPPHYS 215. Numerical Methods for Physicists and Engineers. 4 Units.

Fundamentals of numerical methods applied to physical systems. Derivatives and integrals; interpolation; quadrature; FFT; singular value decomposition; optimization; linear and nonlinear least squares fitting; error estimation; deterministic and stochastic differential equations; Monte Carlo methods. Lectures will be accompanied by guided project work enabling each student to make rapid progress on a project of relevance to their interests.

APPPHYS 217. Estimation and Control Methods for Applied Physics. 4 Units.

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.

APPPHYS 219. Solid State Physics Problems in Energy Technology. 3 Units.

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.

APPPHYS 220. Applied Electrodynamics. 3 Units.

Techniques for general electrodynamics, illustrated by examples from geophysics, microwave engineering, optical devices, accelerators, antennas, and plasma physics. RF/microwave structure representations, scattering matrices, treatments for periodic systems. Perturbation and variational techniques applied to approximate solutions, fundamentals of numerical techniques. Analysis methods via expansions in terms of natural modes. Introduction to finite element methods via the application of variational techniques. Laboratory experiments including time domain and frequency domain methods. Solutions of inverse electrodynamic problems via perturbation techniques coupled with lab measurements (such as estimation of a physical structure via experimental measurements and formal models). Prerequisites: PHYSICS 121, MATH 106 and MATH 132, or equivalent experience.

APPPHYS 223B. Nonlinear Dynamics: This Side of Chaos. 3 Units.

Linear dynamics, periodic systems, Hamiltonian motion and phase space. The physics of nonlinear motion: thinking in phase space. Perturbation theory, periodic orbits, resonances, stability and instability. Integrability and symplectic integration. The KAM theorem and renormalization description of the transition to chaos. Dissipation and bifurcation. Application of methods to nanoscience, lasers and accelerators, condensed matter physics and biophysics. Prerequisites: differential equations and classical mechanics.

APPPHYS 225. Probability and Quantum Mechanics. 3 Units.

Structure of quantum theory emphasizing states, measurements, and probabilistic modeling. Generalized quantum measurement theory; parallels between classical and quantum probability; conditional expectation in the Schroumldinger and Heisenberg pictures; covariance with respect to symmetry groups; reference frames and super-selection 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.

APPPHYS 232. Advanced Imaging Lab in Biophysics. 4 Units.

Laboratory and lectures. Advanced microscopy and imaging, emphasizing hands-on experience with state-of-the-art techniques. Students construct and operate working apparatus. Topics include microscope optics, Koehler illumination, contrast-generating mechanisms (bright/dark field, fluorescence, phase contrast, differential interference contrast), and resolution limits. Laboratory topics vary by year, but include single-molecule fluorescence, fluorescence resonance energy transfer, confocal microscopy, two-photon microscopy, microendoscopy, and optical trapping. Limited enrollment. Recommended: basic physics, Biology core or equivalent, and consent of instructor.

Same as: BIO 132, BIO 232, BIOPHYS 232, GENE 232

APPPHYS 236. Biology by the Numbers. 3 Units.

For PhD students and advanced undergraduates. Students will develop skills in quantitative reasoning over a wide range of biological problems. Topics: biological size scales ranging from proteins to ecosystems; biological times time scales ranging from enzymatic catalysis and DNA replication to evolution; biological energy, motion and force from molecular to organismic scales; mechanisms of environmental sensing ranging from bacterial chemotaxis to vision.

Same as: BIOC 236

APPPHYS 240. From Atom Smashers to X-ray Lasers. 3 Units.

Physics and impact of particle beams and accelerators from their origins up to the present state of the art. Accelerator fundamentals, special topic lectures by expert scientists, laboratory accelerator experiment using state of the art accelerators at SLAC. Prerequisites: Advanced undergraduate courses in Maxwell's equations, special relativity, mathematical physics, and introductory quantum mechanics.

Same as: PHOTON 240

APPPHYS 270. Magnetism and Long Range Order in Solids. 3 Units.

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 209, or equivalent introductory condensed matter physics course.

APPPHYS 272. Solid State Physics. 3 Units.

Introduction to the properties of solids. Crystal structures and bonding in materials. Momentum-space analysis and diffraction probes. Lattice dynamics, phonon theory and measurements, thermal properties. Electronic structure theory, classical and quantum; free, nearly-free, and tight-binding limits. Electron dynamics and basic transport properties; quantum oscillations. Properties and applications of semiconductors. Reduced-dimensional systems. Undergraduates should register for PHYSICS 172 and graduate students for APPPHYS 272. Prerequisites: PHYSICS 170 and PHYSICS 171, or equivalents.

Same as: PHYSICS 172

APPPHYS 273. Solid State Physics II. 3 Units.

Introduction to the many-body aspects of crystalline solids. Second quantization of phonons, anharmonic effects, polaritons, and scattering theory. Second quantization of Fermi fields. Electrons in the Hartree-Fock and random phase approximation; electron screening and plasmons. Magnetic exchange interactions. Electron-phonon interaction in ionic/covalent semiconductors and metals; effective attractive electron-electron interactions, Cooper pairing, and BCS description of the superconducting state. Prerequisite: APPPHYS 272 or PHYSICS 172.

APPPHYS 280. Phenomenology of Superconductors. 3 Units.

Phenomenology of superconductivity viewed as a macroscopic quantum phenomenon. Topics include the superconducting pair wave function, London and Ginzburg-Landau theories, the Josephson effect, type I type II superconductivity, and the response of superconductors to currents, magnetic fields, and RF electromagnetic radiation. Introduction to thermal fluctuation effects in superconductors and quantum superconductivity.

APPPHYS 285. Physics of Disordered Systems. 3 Units.

Topics include types of disorder, percolation, localization, glasses and spin glasses, fractals, self-organized criticality, aggregation, gelation, and other random processes leading to disordered media.

APPPHYS 290. Directed Studies in Applied Physics. 1-15 Unit.

Special studies under the direction of a faculty member for which academic credit may properly be allowed. May include lab work or directed reading.

APPPHYS 291. Practical Training. 3 Units.

Opportunity for practical training in industrial labs. Arranged by student with research adviser's approval. Summary of activities required.

APPPHYS 293. Theoretical Neuroscience. 3 Units.

Introduction to fundamental theoretical ideas that provide conceptual insights into how networks of neurons cooperatively mediate important brain functions. Topics include basic mathematical models of single neurons, neuronal computation through feedforward and recurrent network dynamics, principles of associative memory, applications of information theory to early sensory systems, correlations and neural population coding, network plasticity and the self-organization of stimulus selectivity, and supervised and unsupervised learning through multiple mechanisms of synaptic plasticity. Emphasis on developing mathematical and computational skills to analyze complex neural systems. Prerequisites: calculus, linear algebra, and basic probability theory, or consent of instructor.

APPPHYS 294. Cellular Biophysics. 3 Units.

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.

Same as: BIO 294, BIOPHYS 294

APPPHYS 302. Experimental Techniques in Condensed Matter Physics. 4 Units.

Cryogenics; low signal measurements and noise analysis; data collection and analysis; examples of current experiments. Prerequisites: PHYSICS 170, PHYSICS 171, and PHYSICS 172, or equivalents.

APPPHYS 304. Lasers Laboratory. 4 Units.

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 236C and EE 332, or consent of instructor.

APPPHYS 305. Advanced Nonlinear Optics Laboratory. 4 Units.

Core concepts and experiments in the nonlinear interaction of laser light with matter. Experiments on second harmonic generation and optical parametric oscillation culminate with assembly and use of an optical frequency comb for student-defined, open-ended experiments. Supercontinuum light generation, carrier-envelope phase stabilization, and metrology and spectroscopy. Prerequisites: APPPHYS 304, or consent of instructor.

APPPHYS 315. Methods in Computational Biology. 3 Units.

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.

APPPHYS 324. Introduction to Accelerator Physics. 3 Units.

Physics of particle beams in linear and circular accelerators. Transverse and longitudinal beam dynamics, equilibrium emittances in electron storage rings, high-brightness electron sources, RF acceleration and emittance preservation, bunch compression and associated collective effects, accelerator physics design for x-ray FELs, advanced accelerator concepts.

APPPHYS 325. X-rays: Past, Present and Future. 3 Units.

Introduction to the physics of bright x-ray sources. Topics include: physics and basic properties of short wavelength radiation, X-ray generation via incoherent Compton scattering and High Harmonic Generation (HHG), applications and impact of insertion devices in synchrotron radiation facilities and the development of x-ray free electron lasers. Includes selected laboratory tours of the Linac Coherent Light Source and/or measurements at SLAC. Prerequisite: graduate-level electrodynamics, or consent of instructor.

Same as: PHOTON 325

APPPHYS 345. Advanced Numerical Methods for Data Analysis and Simulation. 3 Units.

Gaussian and unit sphere quadrature, singular value decomposition and principal component analysis, Krylov methods, non-linear fitting and super-resolution, independent component analysis, 3d reconstruction, "shrink-wrap", hidden Markov methods, support vector machines, simulated annealing, molecular dynamics and parallel tempering, Markov state methods, Monte Carlo methods for constrained systems.

APPPHYS 376. Literature of Ultracold Atomic Physics. 3 Units.

Ultracold atomic gases in modern quantum optics, metrology, quantum information science, and quantum many-body physics. Review of basic concepts and survey of key literature in seminar format.

APPPHYS 383. Introduction to Atomic Processes. 3 Units.

Atomic spectroscopy, matrix elements using the Coulomb approximation, summary of Racah algebra, oscillator and line strengths, Einstein A coefficients. Radiative processes, Hamiltonian for two- and three-state systems, single- and multi-photon processes, linear and nonlinear susceptibilities, density matrix, brightness, detailed balance, and electromagnetically induced transparency. Inelastic collisions in the impact approximation, interaction potentials, Landau-Zener formulation. Continuum processes, Saha equilibrium, autoionization, and recombination.

APPPHYS 387. Quantum Optics and Measurements. 3 Units.

Basic concerns and fundamental postulates in quantum theory of measurements. Quantum non-demolition measurements, nonlinear measurements and continuous measurements. Non-local quantum correlation and Bell's inequality. Generation, detection, and application of single photons and entangled photon-pairs. Reservoir theory of an open dissipative system. Laser phase transition versus BCS transition in microcavities.

APPPHYS 390. Dissertation Research. 1-15 Unit.

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APPPHYS 392. Topics in Molecular Biophysics: Biophysics of Functional RNA. 3 Units.

Survey of methods used to relate RNA sequences to the structure and function of transcribed RNA molecules. Computation of contributions of the counter-ion cloud to the dependence of free energy on conformation of the folded RNA. The relation of structure to function of riboswitches and ribozymes.

Same as: BIOPHYS 392

APPPHYS 393. Biophysics of Solvation. 3 Units.

Statistical mechanics of water-protein or water-DNA (or RNA) interactions; effects of coulomb forces on molecular hydration shells and ion clouds; limitations of the Poisson-Boltzmann equations; DNA collapse, DNA-protein interactions; structure-function relationships in ion channels.

Same as: BIOPHYS 393

APPPHYS 453A. Collective Instabilities in Accelerators. 3 Units.

A beam in an accelerator can become unstable if its intensity is too high. Topics include the physical mechanism causing these instabilities; establishing the framework by introducing the concepts of wakefield and impedance; various instability mechanisms with a special emphasis on the underlying physical principles; new types of instabilities encountered in modern high performance accelerators such as the fast ion and the electron cloud instabilities. Course may be repeated when a different course is offered as a Special Topics.

Same as: PHOTON 453A

APPPHYS 470. Condensed Matter Seminar. 1 Unit.

Current research and literature; offered by faculty, students, and outside specialists. May be repeated for credit.

APPPHYS 473B. Topics in Condensed Matter Physics: Quantum Matter Meets Quantum Optics. 3 Units.

Graduate seminar to survey the contemporary literature on emerging topics in light-matter interactions, including novel optical spectroscopy approaches to the study of material properties and exotic optical properties of novel materials.

APPPHYS 483. Optics and Electronics Seminar. 1 Unit.

Current research topics in lasers, quantum electronics, optics, and photonics by faculty, students, and invited outside speakers. May be repeated for credit.

APPPHYS 801. TGR Master's Project. 0 Units.

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APPPHYS 802. TGR PhD Dissertation. 0 Units.

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