Description of the Preliminary Examination

The faculty feels that, in order to most benefit from graduate work, incoming students need to have a solid foundation in undergraduate physics, including upper-division mechanics, electricity and magnetism, thermal physics and quantum physics. These are the topics typically included, and at the level usually taught, within a Bachelor's degree program in Physics at most universities. As a part of this foundation, the students should also have formed a well-integrated overall picture of the fields studied. The preliminary exam is meant to assess the students' background, so that any missing pieces can be made up as soon as possible.

The preliminary exam is a written examination, divided into four sections, three hours for each section: (1) classical mechanics, (2) electromagnetism and optics, and special relativity, (3) thermodynamics and statistical physics, and (4) quantum mechanics. All sections of the exam are administered twice a year on two successive Saturdays at the beginning of each semester. *Note that these divisions do not preclude the possibility of questions on one section that draw from subject material emphasized in a different section.* (e.g. a question that touches on thermodynamics in the quantum mechanics section.)

Detailed description of the schedule for passing the preliminary exam, exceptions to this schedule, and the faculty review process are in the **Policy on the Preliminary Examination**. A student who has passed any section of the written exam need not take that section again.

The preliminary exam covers material learned in an undergraduate physics major, as outlined below. However, it requires a deeper level of understanding than the minimum required to pass undergraduate courses. Each section of the exam will cover traditional, textbook style problems, as well as more comprehensive questions that specifically test physical and numerical insight (e.g., order-of-magnitude estimates including physical constants, analyzing physical situation by application of general principles instead of complex calculations, etc.).

Below is a specific description of the material covered in the examinations, with a list of recommended texts. There is in addition a set of supplemental problems designed to more broadly test physical and numerical insight that are often not part of homework problems in textbooks; these will be provided to you by the department. Each part of the written exam will assign at least ~80% of total points to problems based closely on problems or examples from the recommended texts and the supplementary example problems; we note that the textbook-based problems and examples may have added parts designed to test physical and numerical insight, and problems similar to the supplementary problems may be augmented by asking for derivation of the underlying principles.

Units and Physical Constants (All Sections)

Problems may be worked in either SI or cgs units or other specialized units where appropriate (*e.g.* electron volts). If physical constants are required they will be supplied in both sets of units (*except in comprehensive questions designed to test physical and numerical insight*).

Basic Physics (All Sections)

Lower division physics corresponding to the Physics 7 series at Berkeley or to most calculus-based introductory texts, such as Giancoli, *Physics for Scientists & Engineers*, or Resnick, Halliday & Krane, *Physics.*

Section 1: Classical Mechanics

Newtonian mechanics, motion of a particle in one, two and three dimensions, central force motion, oscillations and normal modes, Lagrangian mechanics, rudiments of Hamiltonian mechanics and phase space, rigid body dynamics. Rudiments of the mechanics of continuous media. Elementary vector and tensor analysis. Note: some elementary applications of Thermal Physics and Special Relativity may be required in the Classical Mechanics section.

This corresponds to Physics 105 at Berkeley. Recommended texts:
Taylor, *Classical Mechanics*
Hand & Finch, *Analytical Mechanics*
Thornton & Marion, *Classical Dynamics of Particles & Systems*

Section 2: Electromagnetism and Optics, and Special Relativity

Electromagnetism and Optics: Electrostatics and magnetostatics, quasi-static phenomena. Conductors, dielectric media, magnetic properties of matter, conduction in plasmas, phenomenological superconductivity, basic circuit theory. Maxwell's equations in differential and integrated forms, Gauss' and Stokes' theorems, stress-energy tensor, formulations in terms of spherical and cylindrical coordinates. Wave guides, radiation phenomena, dipole radiation, Huygens' principle, wave propagation in media, scattering, interference and diffraction. Applications to optics: dispersion and physical optics, Fourier spectroscopy, ray optics.

This corresponds to Physics 110 at Berkeley. Recommended texts:
Griffiths, *Introduction to Electrodynamics*
Pedrotti, Pedrotti & Pedrotti, *Introduction to Optics*
Pollack and Stump, *Electromagnetism*

Special Relativity: Principles of special relativity, Minkowski space-time, Lorentz transformation and four-vector formulation. Elementary relativistic collision kinematics. The Lorentz transformation of the electromagnetic field, motion of charged particles, relativistic invariance of electrodynamics.

This material is usually included in Physics 110 at Berkeley, and sometimes partly in 105, as well as in Physics 7. Recommended texts:
Hartle, *Gravity: An Introduction to Einstein's General Relativity (chapters on special relativity only)*
Griffiths, *Introduction to Electrodynamics (chapter on electrodynamics and special relativity)*

Section 3: Thermodynamics and Statistical Physics

The fundamental concepts of microscopic quantum statistical physics, Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac distributions. Applications to ideal and actual gases, heat engines, absolute temperature, entropy, Maxwell's equations, Clausius-Clapeyron equation, phase transitions, irreversibility. Basic concepts of statistical mechanics, statistical ensembles, microscopic basis of thermodynamics, Maxwell-Boltzmann distribution. Applications to macroscopic phenomena. Classical Thermodynamics. Elementary kinetic theory of transport phenomena. Various aspects of condensed matter physics, low-temperature phenomena, Black Body radiation. Note: some elementary applications of Quantum Physics and Classical Mechanics may be required in the Thermal Physics section.

This corresponds to Physics 112 at Berkeley. Recommended texts:
Kittel & Kroemer, *Thermal Physics*
Reif, *Fundamentals of Statistical & Thermal Physics*

Section 4: Quantum Mechanics

Basic non-relativistic quantum mechanics, the Schrodinger equation, matrix mechanics. Simple one, two, and three-dimensional problems. Elementary theory of angular momentum. Electron spin, identical particles and the Pauli Principle. Time-independent perturbation theory, elementary time-dependent perturbation theory, scattering theory, the Born approximation and the method of partial waves. Miscellaneous applications: atomic spectra, atomic structure and the periodic system, molecular binding, Born-Oppenheimer approximation and molecular excitations, elementary band theory, radiative transitions and the Golden Rule, selection rules and symmetry principles, radioactivity, X-rays and X-ray diffraction. The most basic properties of nuclei. Note: some elementary applications of Thermal Physics and Special Relativity may be required in the Quantum Mechanics section.

This corresponds to Physics 137 at Berkeley. Recommended texts:
Bransden & Joachain, *Quantum Mechanics*
Griffiths, *Introduction to Quantum Mechanics*
Liboff, *Introductory Quantum Mechanics*

Advice

Though nearly all students ultimately pass the exam, it is a tough exam and quite a few students need to repeat sections of the exam before passing.

How to prepare for the exam? Undergraduate institutions all have their own way of teaching physics, and Berkeley is no exception. You will probably discover differences between the content of your training and the topics covered in these texts, previous prelim exams, and supplementary problem examples. Practice doing problems in the recommended textbooks, and previous prelim exams and example problems (provided by student affairs office). The department offers practice sessions during a one-week period before each set of exams led by one of our advanced graduate students, and a summer review course recommended for continuing students who do not pass in their first attempts at the exam.

Before you arrive at Berkeley, we ask that you correspond with your assigned Berkeley faculty mentor to discuss your undergraduate background and identify possible weaknesses where an undergraduate course(s) in your first year would be the best course of action, in which case deferring that section of the written exams will be recommended (see prelim policy for more details). Taking an undergraduate course in your first year is not only acceptable, it is often the best thing to do if there is an area that you feel unsure about, so you should feel comfortable in suggesting/discussing this option with your mentor and/or the Head Grad Advisor. We also recommend that for exam sections where an undergrad course is not specifically recommended, you take the prelim exam when you first arrive, primarily as a diagnostic tool. Any sections that are passed, you will not be asked to re-take, and failed sections may suggest taking an undergraduate course the first year. In either case, your performance in this first exam (at the start of your 1st semester here) will *not* be held against you in any way. Your subsequent exams will be used to determine that you have the necessary command of a broad spectrum of undergraduate physics. Once this is determined to be true, any early poor performance is not important. In fact, most faculty members pay very little attention to your prelim scores. Preliminary exam scores are not recorded on your university transcript. Once passed, the exam is truly history.