Prelim Exam info

CUA Physics Department
Preliminary Examination for Graduate Students

Friday, August 27, 2010 from 1:00 PM to 5:00 PM in Room 133 Hannan Hall

The Preliminary Examination ("Prelim") must be taken by

- all incoming graduate students
- all returning graduate students who have not yet passed the Preliminary Examination

Beginning in 2009, the exam was changed to have a slightly different format from previous years, consisting of a larger number of shorter questions.

Further details:

- General information about the Preliminary Examination (pdf file) (html file)
- Sample questions in the new format (pdf file)
- Previous Preliminary Examinations
  - 2009 (pdf file) (first year of new format)
  - 2008 (pdf file)
  - 2007 (pdf file)
  - 2006 (pdf file)
- Concepts and topics in undergraduate physics (pdf file)

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Some sample questions in the new Preliminary Examination format 29 May 2009

1. A point mass m slides frictionlessly on the inside of a vertical circular track of radius R. The speed of the mass at the bottom of the track is v_0.
   a) Assuming that the mass makes it to the top of the track, what is its speed at the top?
   b) What is the minimum value of v_0 which assures that the mass will actually reach the top of the circle? (Careful: If the "speed at the top" is 0, the mass will have lost contact with the track before it gets to the top. Let v_{top} be the speed at the top, and consider the forces on the mass and its acceleration at the top of the circle.)

2. Write Maxwell's equations in integral form, and define the quantities that appear in them.

3. A mass M is suspended from a massless rigid rod of length L and swings as a simple pendulum. Let θ be the angle between the rod and the vertical. In terms of the given quantities, write
   a) the kinetic energy of the pendulum.
   b) the potential energy of the pendulum.
   c) the Lagrangian of the system.
   d) the Lagrange equation of motion for the variable θ.

4. In the Bohr model of the hydrogen atom, an electron (mass m, charge $-e$) orbits an infinitely massive fixed proton of charge $+e$ in a circular path of radius r, and the angular momentum l of the electron is quantized in integer multiples of Planck's constant $\hbar$ ($l = n\hbar$).
   a) Express the velocity of the electron in terms of m, r, $\hbar$ and n.
   b) Noting that the centripetal acceleration of the electron is due to the Coulomb attraction of the proton, find the radius of the circular orbit in terms of m, r, $\hbar$ and n.
   c) Find the total energy of the electron in terms of m, r, $\hbar$ and n.

5. The first two stationary states of a given quantum mechanical system are described by the time-independent normalized wave functions $\psi_1(x)$ and $\psi_2(x)$, corresponding to energy eigenvalues E_1 and E_2 respectively.
   A given physical state consists of an equal mixture of these two states.
   b) In terms of the given quantities, write the form of the time-dependent wave function $\Psi(x,t)$ for this state.
   c) Write the probability density corresponding to this wave function, and find the frequency of its time dependence.

6. a) What are Einstein's two postulates of special relativity?
   b) Event 1 occurs at position x_1 and time t_1, and event 2 occurs at position x_2 and time t_2, both as measured in the xyz reference frame. An observer (Sam) is moving at velocity u in the $+x$ direction. What is the time interval between the two events as seen in Sam's reference frame? Define all symbols which appear in your answer.

Concepts and Topics Expected to be Covered in Undergraduate Physics
(Revised 13 May 2009)

Mechanics (elementary)

Typical textbooks:

Young and Freedman, *University Physics*
Halliday, Resnick and Walker, *Fundamentals of Physics*
Ohanian and Markert, *Physics for Engineers and Scientists*

vectors
Newton's laws of motion
work and energy
conservative forces (gravity: uniform and $1/r^2$, ideal spring)
conservation of energy
motion of center of mass
conservation of momentum
kinematics of rotation
rigid body rotation
conservation of angular momentum
equilibrium: force and torque equations
Newton's law of gravitation
oscillations (simple harmonic motion)
waves on a string: wavelength, frequency, velocity

Mechanics (intermediate)

Typical textbooks:

Taylor, *Classical Mechanics*
Hamill, *Intermediate Dynamics*
Fowles and Cassiday, *Analytical Mechanics*

Above topics in greater depth, plus

using differential equations
velocity and acceleration in polar and spherical coordinates
damped and driven harmonic oscillator
coupled harmonic oscillators
- normal modes

Lagrange equations of motion (one or more dimensions)
rocket motion
central force motion
- effective potential energy
- planetary motion: Kepler's laws

rigid body motion
- rotational equation of motion
- parallel-axis theorem
- precession of gyroscope

accelerated coordinate systems

fictitious forces
principal axes
free symmetric top

gravitation

Newton's spherical shell theorem
tides

Electricity and magnetism (elementary)

Typical textbooks: see list for elementary mechanics

Coulomb's law
electric field
Gauss's law and applications
electrostatic potential
energy of a system of charges
electrical energy density
capacitance
current and current density
resistivity and resistance
power in circuit elements
Kirchhoff rules: voltage (loop) and current (node)
RC circuits
magnetic force and magnetic field
Biot-Savart law
Ampere's law and applications
torque on a current loop
Faraday's law and motional emf
self-inductance
magnetic energy density
RL circuits
AC circuits
LC and RLC oscillations
Maxwell's equations (integral form)
plane electromagnetic waves
light
laws of reflection and refraction
total internal reflection
lenses and mirrors
two-slit interference
diffraction grating

Electricity and magnetism (intermediate)

Typical textbook: Griffiths, *Introduction to Electrodynamics*

Above topics in greater depth, plus

vector operators: gradient, divergence, curl, Laplacian

Maxwell's equations in differential form
solutions of Laplace's equation (in rectangular, spherical, cylindrical coordinates)
multipole expansion of V: monopole and dipole terms
image charges in an infinite conducting plane
E, D and ***P*** in a dielectric
boundary conditions on ***E*** and ***D***
using Biot-Savart law
divergence and curl of ***B***
magnetic vector potential
B, H and ***M*** in a magnetic material
boundary conditions on ***B*** and ***H***
wave equation using complex wave functions
reflection and refraction at a boundary
reflection and transmission (Fresnel coefficients)

Modern physics

Typical textbook: Bernstein, Fishbane and Gasiorowicz, *Modern Physics*

special relativity
- postulates
- Lorentz transformation
- time dilation and length contraction
- relativistic energy and momentum conservation

photoelectric effect
Compton scattering
DeBroglie wavelength
X-ray diffraction
electron diffraction
Bohr model of the H atom
uncertainty principle
Schrödinger equation
- wave function and probability
- stationary states and time-independent Schrödinger equation
- solutions for square well
- barrier penetration

Angular momentum rules (qualitative)
Quantum numbers of the Hydrogen atom

Quantum mechanics

Typical textbook: Griffiths, *Introduction to Quantum Mechanics*

Schrödinger equation
probability
normalization
momentum operator
stationary states and time-independent Schrödinger equation
barriers and wells

square well (infinite and finite)
harmonic oscillator
free particle and wave packets
Hermitian operators and observables
Dirac notation
Schrödinger equation in spherical coordinates
spherical harmonics
hydrogen atom
angular momentum operators and eigenvalues
spin and Pauli spin matrices
addition of angular momentum
bosons and fermions
two-particle systems and exchange forces
atoms and periodic table
quantum statistical mechanics
- Maxwell-Boltzmann
- Fermi-Dirac
- Bose-Einstein

time-independent perturbation theory
hydrogen fine structure
Zeeman effect
time-dependent perturbation theory
absorption, emission and stimulated emission (Einstein coefficients)

Thermodynamics and statistical physics

Typical textbook: Adkins, *Equilibrium Thermodynamics*

thermodynamic variables
temperature
thermodynamic equilibrium
zeroth law
work, heat and internal energy
first law
heat capacities
ideal gases
second law
refrigerators and heat pumps
heat engines
entropy
Carnot cycle
thermodynamic potentials
Maxwell relationships
irreversibility
phase transitions