University of California, Berkeley  
Physics H7C Spring 2013 (Yury Kolomensky)  

PRACTICE PROBLEMS FOR THE FINAL EXAM  

Maximum score: 200 points

The Final Exam will contain 5-6 problems for a total of 200 points, covering the material from the entire course. A larger emphasis will be placed on the material from the Quantum Physics part of the course, although you should expect some problems similar to the Midterm. Below is a sample of problems and their rough point values. One the actual exam, you would be expected to be spend about 30 minutes per problem.

During the exam, you will be allowed three 8-1/2" × 11" sheets of paper containing any information you wish on both sides. Calculators are also allowed, but answers to the problems should be given in an analytical form, before plugging in the numbers. Partial credit will be given, with more credit given for the conceptual understanding of the problem than for the numerical answer.

Please bring a Blue Book (or two) to the exam.

Good luck!

1. (20 points)  
This is a little blitz problem to warm you up. This problem consists of four questions, 5 points each. Circle correct answer for each part. (FYI: questions like these are frequently found on a Physics GRE exam)

1. A scientist wants to take a picture of a distant yellow object using a pinhole camera such that the picture is of maximum sharpness. Let \( \lambda \) be the wavelength of yellow light, \( d \) be the diameter of the pinhole, and \( D \) be the distance from pinhole to film. Find \( d \).

   (a) \( \sqrt{2.44\lambda D} \)
   (b) \( 1.22\lambda^2/D \)
   (c) \( 2.44\lambda^2/D \)
   (d) \( \sqrt{\lambda D} \)
   (e) \( \sqrt{1.22\lambda D} \)

2. Consider a Young double-slit experiment where two slits are spaced \( d = 0.1 \text{ mm} \) apart. When a screen is at distance \( \ell = 2 \text{ m} \), the first bright maximum is displaced by \( y = 1 \text{ cm} \) from the central maximum. Find the wavelength of light.

   (a) 400 nm
   (b) 500 nm
   (c) 800 nm
   (d) 1000 nm
   (e) \( 5 \times 10^{-7} \text{ nm} \)

3. In the Zeeman effect, a spectral line splits in a magnetic field. What is the amount of energy difference between the lines in the Zeeman splitting (in SI units) ?

   (a) \( eB/2m_e c \)
   (b) \( e\hbar B/2m_e \)
   (c) \( e\hbar B/m_e \)
   (d) \( eB/m_e \)
   (e) \( 2e\hbar B/m_e \)

4. Time dilation may be observed in a jet airplane using an atomic clock. Suppose that the plane moves at 900 km/h. If the laboratory time is \( \Delta t = 1 \text{ s} \), what is the dilated time ?

   (a) \( (1 - 3.5 \times 10^{-13}) \text{ s} \)
2. (40 points)
Neutral meson $\eta$, rest mass $548 \text{ MeV}/c^2$, decays into a pair of equal-energy photons: $\eta \rightarrow \gamma \gamma$. The energy of each photon in the laboratory is 300 MeV.

(a) Find the initial momentum of the meson $p_\eta$ and its velocity $v_\eta$.
(b) Find the angle between the two photons in the lab frame.

3. (30 points)
A flux of monochromatic electrons impinges on a pair of long narrow slits, as shown in the picture. When slit 1 is open and slit 2 is closed, a detector at point P registers the rate of $n_1 = 100$ electrons/sec. When slit 2 is open and slit 1 is closed, the rate at $P$ is $n_2 = 25$ electrons/sec. The distance between the slits is $d = 25 \mu m$, the distance from the slits to the screen is $\ell = 1 \text{ m}$, and the distance from the center of the screen to $P$ is $x = 50 \mu m$. Find the rate at $P$ with both slits open for electrons of kinetic energy of

(a) $K = 1.0 \text{ eV}$
(b) $K = 2.3 \text{ eV}$

4. (35 points)
A particle of mass $m$ is moving in a central force field $\mathbf{F}(r) = -kr$ (where $k > 0$ is a constant). Using Bohr quantization of angular momentum, find expressions for

(a) Possible values $r_n$ of the stable orbits
(b) Possible values $E_n$ of the full energy of the particle.

Express $E_n$ in terms of the classical oscillation frequency $\omega = \sqrt{k/m}$.

5. (35 points)
The wavefunction of the ground state of the hydrogen atom has the form $\psi(r) = A \exp(-r/a_0)$, where $a_0$ is the Bohr radius. Find

(a) Value of the constant $A$
(b) Probability density $f(r) = dP/dr$ to find the electron in an interval $[r..r + dr]$ from the nucleus.
(c) Most probable value of the radius $r_{\text{max}}$ (i.e., the radius at which $f(r_{\text{max}}) = \text{max}$).
(d) Average distance $\langle r \rangle$
(e) Average potential energy $\langle U \rangle$

6. (40 points)
An atom is in a multi-electron state characterized by the total spin $S = 3/2\hbar$ and angular momentum $L = 2\hbar$.

(a) What values of the total angular momentum $J$ are possible?
(b) What is the value of $J$ for a state with zero magnetic moment?
**Answer Key:**

1. (a), (b), (b), (a)

2. $p_\eta = 244 \text{ MeV}/c, v_\eta = 0.41c, \Theta = 132^\circ$

3. (a): 125 electrons/sec; (b): 75 electrons/sec

4. $r_n = \sqrt{n\hbar/m\omega}, E_n = n\hbar\omega$

5. $A = 1/\sqrt{\pi a_0^3}, dP/dr = (4r^2/a_0^2) \exp(-2r/a_0), r_{\text{max}} = a_0, \langle r \rangle = 3a_0/2, \langle U \rangle = -e^2/(4\pi \epsilon a_0)$

6. (a): $J = 1/2\hbar, 3/2\hbar, 5/2\hbar, 7/2\hbar$; (b): $J = 1/2\hbar$. 