Student ID Number: __________

PRELIMINARY EXAMINATION

Department of Physics
University of Florida
Part A, 17 August 2006, 09:00–12:00

Instructions

1. You may use a calculator and CRC Math tables or equivalent. No other tables or aids are allowed or required. You may **NOT** use programmable calculators to store formulae.
2. All of the problems will be graded and will be tabulated to generate a final score. Therefore, you should submit work for all of the problems.
3. For convenience in grading please write legibly, use only one side of each sheet of paper, and work different problems on separate sheets of paper. The sheets for each problem will be stapled together but separately from the other two problems.
4. Your assigned student **ID Number**, the **Problem Number**, and the **Page Number** should appear in the upper right hand corner of each sheet. Do **NOT** use your name anywhere on the Exam.
5. All work must be shown to receive full credit. Work must be clear and unambiguous. Be sure that you hand your completed work to the Proctor.
6. Each problem is worth 10 points.
7. Following the UF Honor Code, your work on this examination must reflect your own independent effort, and you must not have given, nor received, any unauthorized help or assistance. If you have any questions, ask the Proctor.

University of Florida Honor Code: We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honesty and integrity. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: *"On my honor, I have neither given nor received unauthorized aid in doing this assignment."*

DO NOT OPEN EXAM UNTIL INSTRUCTED

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A1. Let Ψ_{nlm} denote the hydrogen atom eigenstate with quantum numbers n, l, m in the usual notation. Assume that Ψ_{nlm} is normalized to unit probability. Suppose that an atom is in the state

$$\Psi = C\left[\Psi_{100} + \frac{1}{3}\Psi_{21-1} + \frac{1}{2}\Psi_{322}\right].$$

(a) (1 point) What is the value of the constant C?

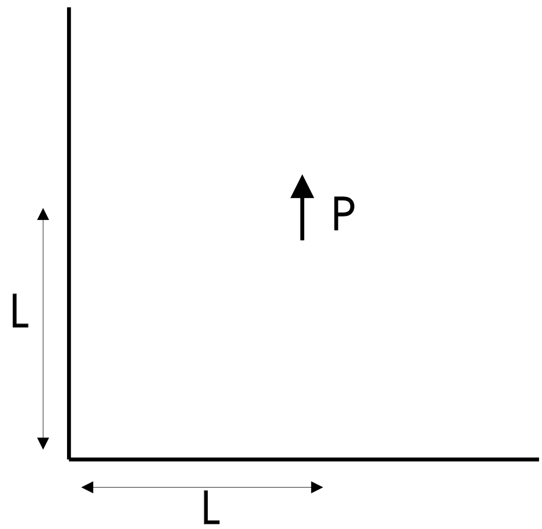
(b) (1 point) What is the probability that a measurement will find the atom in the state (322)?

(c) (2 points) Work out the expectation value of the operator $\mathbf{L}^2$ for the state Ψ given above, where $\mathbf{L}$ is the orbital angular momentum operator.

(d) (4 points) Work out the expectation value of the operator $\mathbf{L_z}^2\mathbf{L_x}^2$ for the state Ψ given above.

(e) (2 points) Work out the expectation value of the operator $\mathbf{L_x}^3$ for the state Ψ given above.

A2. A vertically oriented dipole with dipole moment P is placed close to two (semi-infinite) metal sheets forming a 90^{O} angle, as shown in the figure below. The center of the dipole is fixed to be a distance L away from each of the metal sheets, but the dipole is free to rotate in the two-dimensional plane shown in the figure.



(a) (4 points) Construct all images of the dipole from the two metal surfaces shown in the figure.

(b) (1 point) If the dipole is slightly rotated in a counter clockwise direction, indicate the direction of rotation of all the images.

(c) (2 points) Obtain the total electrostatic energy of the system as a function of the rotation angle. [Hint: Use the formula for the energy of interaction between two dipoles.]

(d) (3 points) Determine the direction and the magnitude of the rotational torque acting on the dipole.

A3. A beam of neutrons of kinetic energy 0.29 eV, and intensity $10^5\mathrm{s}^{-1}$ traverses (at right angles) a foil of $^{235}_{92}\mathrm{U}$, "thickness" $10^{-1}\mathrm{kg}\cdot\mathrm{m}^{-2}$. Any nucleon-nucleus collision can have one of three possible results:

(1) Elastic scattering of neutrons: $\sigma_e = 2\times 10^{-30}\mathrm{m}^2$.

(2) Capture of the neutron, followed by the emission of a γ ray by the nucleus: $\sigma_c = 7\times 10^{-27}\mathrm{m}^2$.

(3) Capture of the neutron followed by the splitting of the nucleus into two, almost equal, parts (fission) $\sigma_f = 2\times 10^{-26}\mathrm{m}^2$.

Calculate,

(a) (3 points) The attenuation of the neutron beam by the foil, that is, the fraction of the beam that survives without a collision.

(b) (3 points) The number of fission reactions occurring per second in the foil, caused by the incident beam.

(c) (4 points) The flux of elastically scattered neutrons, at a point 10 m from the foil and out of the incident beam, assuming isotropic distribution of the scattered neutrons.

Note that 1 atomic mass unit is 1.66×10^{-27} kg.