Student ID Number: ___________

PRELIMINARY EXAMINATION

Department of Physics
University of Florida
Part A, 5 January 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. A certain quantum-mechanical system can exist in just two states. The Hamiltonian for this system can be written in a particular basis as

$$H = \begin{pmatrix} \epsilon & \Delta \\ \Delta & \epsilon \end{pmatrix}.$$

This problem will also deal with a physical quantity ω, associated with the operator Ω that can be written (in the same basis as above)

$$\Omega = \begin{pmatrix} \omega_1 & 0 \\ 0 & \omega_2 \end{pmatrix},$$

where $\omega_2 > \omega_1$.

(a) (3 points) Find the eigenvalues and normalized eigenstates of H.

(b) (3 points) Suppose that at time $t = 0$, the system is in the state

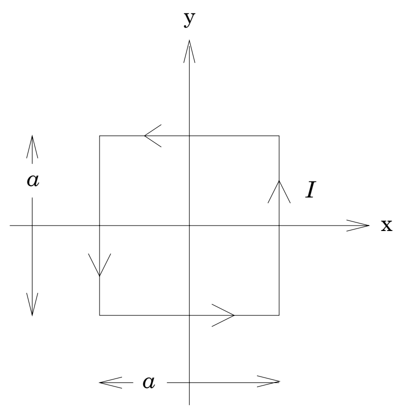
$$|\psi(t = 0)\rangle = \begin{pmatrix} 1 \\ 0 \end{pmatrix}.$$

Write down the state $|\psi(t)\rangle$ describing the system at an arbitrary time $t > 0$.

(c) (2 points) Suppose that at some time $t > 0$, a measurement of ω is performed on the system from part (b). List the possible results of this measurement and their respective probabilities.

(d) (2 points) At what time(s) is the expectation value of ω greatest?

A2. The interaction between magnetic dipoles is important for magnetic materials. To understand this interaction, consider the following simple model for a magnetic dipole. Let there be a square loop of wire with sides a in the x-y plane with current I flowing counterclockwise, as shown below.



(a) (2 points) What is the magnetic moment of this loop? (Give both magnitude and direction.)

(b) (3 points) If the loop is placed in an arbitrary external magnetic field, $\vec{B}$, obtain an expression for the torque on the loop starting from the force on each side due to the field $\vec{B}$. From the expression for the torque find if the torque tends to align or anti-align the magnetic moment with the external magnetic field.

(c) (3 points) The loop also creates a magnetic field. Starting from the Biot-Savart law, obtain an expression for the magnetic field due to this loop, in terms of its magnetic moment, for distances $r \gg a$.

(d) (2 points) Now suppose that you have many magnetic moments placed in a plane and that they are all pointing in the same direction (ferromagnetism). Using the results of parts (b) and (c), find if the magnetic moments tend to align in the plane or out of the plane.

A3. An elementary particle called a neutral pion (or π^0 meson) is moving in the x-direction when it spontaneously decays into two massless photons. One of the photons travels in the x-direction and the other travels in the negative x-direction. The difference in energy between these two photons is equal to the rest mass energy of the pion. Calculate the speed of the pion (in units of the speed of light) just before its decay.