Student ID Number: ________

PRELIMINARY EXAMINATION

DEPARTMENT OF PHYSICS
UNIVERSITY OF FLORIDA
Part A, 12 August 2004, 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 3 level system starts at time $t = 0$ in the state

$$|\psi_0\rangle = \frac{1}{\sqrt{2}} \begin{pmatrix} 1 \\ 1 \\ 0 \end{pmatrix} \quad .$$

The Hamiltonian $\mathcal{H}$ for this sytem is given by

$$\mathcal{H} = 3 \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 1 \\ 0 & 1 & 1 \end{pmatrix} \quad .$$

Let $\hbar = 1$.

(a) (4 points) Find the state $|\psi_t\rangle$ of the system at time $t > 0$.

(b) (3 points) Let

$$A = \begin{pmatrix} 0 & 0 & 1 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \end{pmatrix}$$

be an operator of interest. Determine the variance of A, *i.e.* $\langle A^2 \rangle - \langle A \rangle^2$, in the state $|\psi_t\rangle$ for general t.

(c) (3 points) Determine the probability that $|\psi_t\rangle$ is found in the state of the system that has the least average energy.

A2. A point charge $+Q_2$ is located a distance s from the center of a grounded sphere of radius R.

(a) (2 points) What is the electric potential at every point outside the sphere?

(b) (2 points) What is the surface charge density σ of the induced charge which accumulates on the sphere?

(c) (2 points) Calculate the total charge induced on the sphere.

(d) (2 points) What is the electrostatic force exerted on the point charge $+Q_2$ as a result of the accumulated charge on the grounded sphere?

(e) (2 points) Calculate the total electrostatic energy stored in the electric field outside the sphere.

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A3. Consider the decay of a free neutron at rest into a proton, electron, and an anti-neutrino: $n \rightarrow p + e^- + \overline{\nu}_e$. The rest mass of the particles are: $m_n = 939.6$ MeV/c^2, $m_p = 938.3$ MeV/c^2, $m_e = 0.511$ MeV/c^2, and $m_\nu \approx 0$.

(a) (2 points) Calculate the total kinetic energy of the decay products.

(b) (4 points) Calculate the kinetic energy of the electron assuming that the anti-neutrino carries away negligible momentum and energy (*i.e.* consider only a 2-body decay of the neutron into an electron and proton).

(c) (4 points) Calculate the kinetic energy of the proton assuming that the anti-neutrino carries away negligible momentum and energy.