Student ID Number: ________

PRELIMINARY EXAMINATION

DEPARTMENT OF PHYSICS
UNIVERSITY OF FLORIDA
Part A, 15 August 2002, 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. Consider the lower atmosphere, known as the troposphere. The air can be taken to be an ideal gas, and you may recall that gas constant $R = 8.314$ J K^{-1} mol^{-1}. For a thin layer, force balance suggests that

$$\frac{\mathrm{d}P}{\mathrm{d}z} = -\rho g \quad ,$$

where P is the pressure, z is a distance measured positive upwards from the surface, ρ is the mass density (kg/m^3) of air, and g is the acceleration due to gravity. For this problem, you may approximate g as a constant equal to 10 m/s^2.

(a) (3 points) Show that if the atmosphere is isothermal, the pressure decreases exponentially as

$$P(z) = P_0 \, e^{-z/h} \quad , \quad \text{where } h = \frac{RT}{\mu g} \quad .$$

If $T = 250$ K and $\mu = 29$ g/mole, how large is h?

(b) (3 points) If the atmosphere is adiabatic, P and ρ are related by $P = B\rho^\gamma$, where B is a constant and γ is the ratio of the specific heat at constant pressure to the specific heat at constant volume, *i.e.* $\gamma = c_P/c_V$. Show that the density $\rho(z)$ is given by

$$\rho(z) = \left[\frac{g(\gamma-1)}{\gamma B}(\kappa - z)\right]^{1/(\gamma-1)} \quad ,$$

where the density at the surface is

$$\rho_0 = \left[\frac{g(\gamma-1)}{\gamma B}\kappa\right]^{1/(\gamma-1)} \quad .$$

(c) (4 points) In an adiabatic atmosphere, the easiest quantity to calculate is the temperature gradient. Show that $\frac{\partial T}{\partial z}$ is about 10 K/km. You may wish to recall that $\gamma = \frac{7}{5}$ for air.

A2. Consider a one dimensional, nonrelativistic particle of mass m which moves in the potential,

$$V(x) = Ax^6 - 3\hbar\sqrt{\frac{A}{2m}}x^2 \quad ,$$

where A is a positive constant.

(a) (3 points) Prove that the Hamiltonian is a positive semi-definite operator.

(b) (3 points) This system has a state of zero energy. Find the normalized wave function.

(c) (4 points) Prove that $E = 0$ is the ground state energy.

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A3. Two particles with equal charge $Q = 1\ \mu$C are at rest in the O′-frame (particle frame) a distance $\Delta y' = d = 1$ m apart as shown in the figure. The two particles are moving with a constant speed $v = 0.8c$ in the x-direction of the O-frame (lab frame). Note: this problem needs to be performed with relativistic corrections, if appropriate.

(a) (1 point) What is the magnitude and direction of the electric force that particle 1 exerts on particle 2 in the particle frame?

(b) (1 point) What is the magnitude and direction of the magnetic force that particle 1 exerts on particle 2 in the particle frame?

(c) (2 points) What is the magnitude and direction of the electric force that particle 1 exerts on particle 2 in the lab frame?

(d) (2 points) What is the magnitude and direction of the magnetic force that particle 1 exerts on particle 2 in the lab frame?

(e) (2 points) What is the magnitude and direction of the total electromagnetic force (electric plus magnetic) that particle 1 exerts on particle 2 in the lab frame?

(f) (2 points) Let $R = F/F'$. In words, R is the ratio of the magnitude of the total force that particle 1 exerts on particle 2 in the lab frame to the magnitude of the total force that particle 1 exerts on particle 2 in the particle frame. Let $\beta = v/c$, which is a common notation for relativistic problems. Sketch a graph of R versus β as β varies from 0 to 1. Label the R-axis correctly.