Student ID Number: ________

PRELIMINARY EXAMINATION

DEPARTMENT OF PHYSICS
UNIVERSITY OF FLORIDA
Part C, 16 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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C1. The fact that electrons are indistinguishable Fermions has consequences for the quantum mechanics of many-electron atoms. The simplest such system is Helium, an atom with nuclear charge +2 containing *two* electrons. For simplicity, we will *totally neglect* the Coulomb interaction between the electrons. We will also assume that the nucleus is so heavy that it defines the center of mass, and neglect coupling of spin and orbital degrees of freedom.

(a) (2 points) Write down the Hamiltonian for the electrons in this system. Use center-of-mass coordinates.

(b) (2 points) Show that the Schrödinger equation separates into equations for each electron. What does this mean for the electronic wavefunction? Assume that you have found the spatial eigenfunctions for each electron, and call them $\psi_{nlm}(1)$ and $\psi_{nlm}(2)$, where n, l, and m are the conventional quantum numbers. The electron spin is either up or down, so may be represented either by a spinor like $\begin{pmatrix} 1 \\ 0 \end{pmatrix}_1$ or by a ket like $|\uparrow(1)\rangle$ for the case where electron 1 has up spin.

(c) (2 points) Take both electrons to be in the ground ($n = 1$) state. Write a valid wavefunction for the electrons. Include the electron spin. What is the expectation value of the total spin operator $S^2 = (s_1 + s_2)^2$? (Hint: remember that S is a vector.)

(d) (2 points) Write down a valid wavefunction if one electron is in a 1s state and the other is in a 2p state and the spins of the electrons are pointing in the *same direction.* What is the expectation value of the total spin operator $S^2 = (s_1 + s_2)^2$?

(e) (2 points) Write down a valid wavefunction if one electron is in a 1s state and the other is in a 2p state and the spins are the same as they were in part (c).

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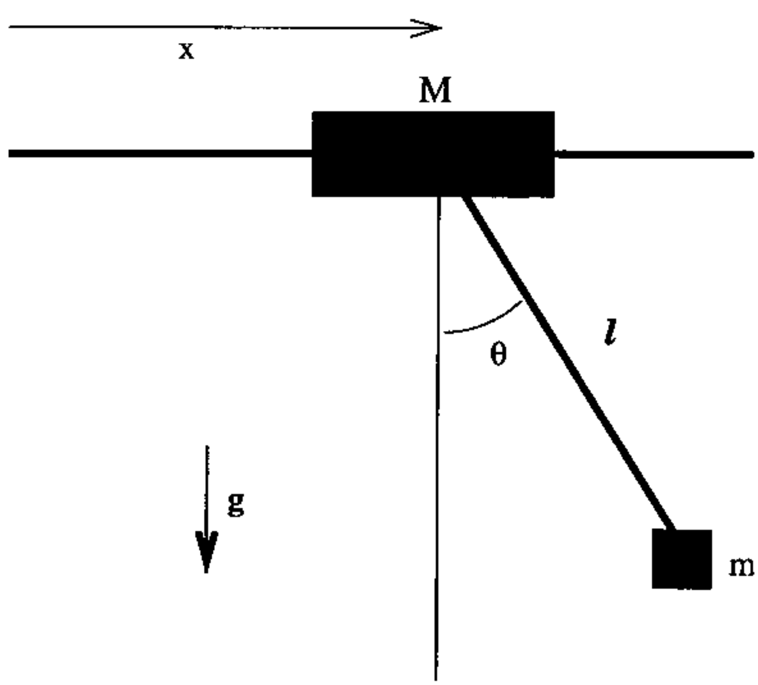
C2. A large bead of mass M slides on a horizontal wire and supports a second small bead of mass m on the end of a massless strut of length ℓ. The lower bead is constrained to move in the same plane as the wire. Assume that this system is near the surface of the Earth and that there is no friction.

(a) (2 points) Find the Lagrangian of this system using the generalized coordinates x and θ described in the diagram.

(b) (3 points) What are the equations of motion for x and θ?

(c) (3 points) Find two independent conserved quantities, and express these in terms of x, θ, $\dot{x}$ and $\dot{\theta}$. The dot denotes a derivative with respect to time.

(d) (2 points) What is the frequency of small oscillations of this system?



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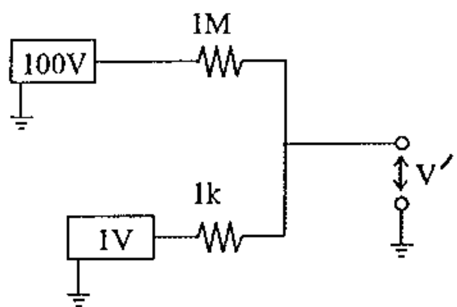
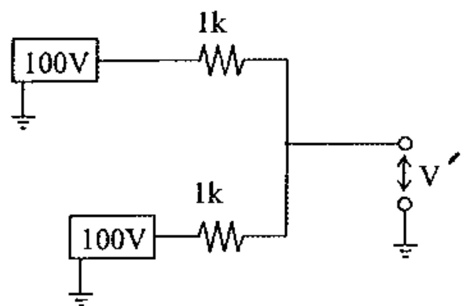
C3. Consider the following circuit diagrams. For 2 points each, find the value V′ for each circuit. The voltages that are shown are all positive. The values of all the resistors are given in ohms, where $M \equiv 10^6$ and $k \equiv 10^3$. Remember that you must justify your answer for full credit.

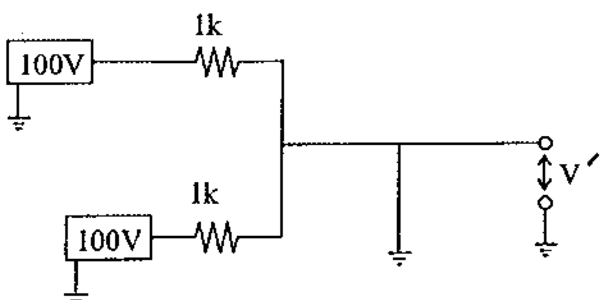
a)



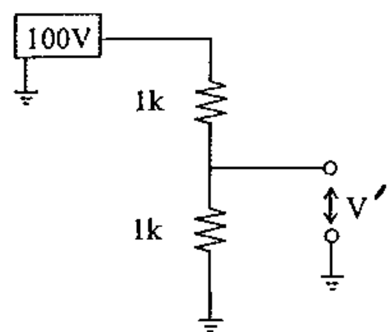
b)



c)



d)



e)