Student ID Number: _____

PRELIMINARY EXAMINATION

DEPARTMENT OF PHYSICS
UNIVERSITY OF FLORIDA
Part D, 5 January 2007, 14:00–17:00

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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D1. A symmetrical top with moment of intertia I_0 about its symmetry axis rotates "rapidly" about this axis with angular frequency ω_0. The earth's gravitational field $\vec{g}$ is directed vertically downwards, and the center of mass of the top is a distance R from the point of contact with the table. It is observed that when the axis makes an angle θ with the vertical, the top precesses slowly and uniformly, with frequency ω_p.

(a) (2 *points*) What is the direction of the precession as seen from above? Does it depend on the direction the top is spinning?

(b) (5 *points*) What is the precession frequency ω_p? Is it faster for θ near vertical or near horizontal?

(c) (3 *points*) How large must ω_0 be for the rotation to be considered as "rapid"?

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D2. An electron in a magnetic field B has an energy $\pm\mu_B B$ according to whether the spin magnetic moment is parallel or anti-parallel to the field. For a system of free electrons at temperature $T = 0$ where the degeneracy is complete:

(a) (5 *points*) What are the number of spin up and down electrons without the B-field in terms of Fermi energy (E_F), mass, and volume?

(b) (3 *points*) Calculate the total magnetic moment.

(c) (2 *points*) Assuming $E_F \gg \mu_B B$, calculate the spin paramagnetic susceptibility of the system.

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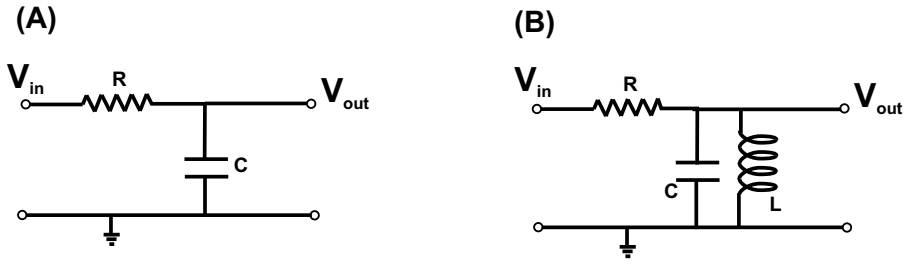
D3. Resistors, capacitors, and inductors can be used to build simple frequency filters in electronics circuits. In this question, you will consider and derive some of their properties. The circuit shown in Figure (A) consists of input and output terminals V_{in} and V_{out} connected by a resistor R with a capacitor C connected to ground.



(a) (*3 points*) Assume that the input voltage is of the form $\tilde{V}_{in} = V_0 e^{i\omega t}$. You can compute the individual impedances $\tilde{Z}_R, \tilde{Z}_C$ of the resistor and capacitor by noting that Ohm's Law still holds, $\tilde{V} = \tilde{I}\tilde{Z}$ where $\tilde{V}, \tilde{I}$, and $\tilde{Z}$ are complex quantities. Compute $\tilde{Z}_R$ and $\tilde{Z}_C$. From this, write down the total impedance of the RC circuit, using the fact that impedances can be treated as generalized resistors.

(b) (*4 points*) This circuit can be thought of as a frequency-dependent voltage divider in which the output V_{out} is attenuated with respect to V_{in} by the divider formed by R and C. Compute $\tilde{V}_{out}/\tilde{V}_{in}$ for the RC circuit (both in magnitude and phase), and state how the circuit behaves in the limit of high and low frequencies. Is this a high pass or a low pass filter? What is f_{3dB} for this circuit, i.e., the frequency where $|\tilde{V}_{out}/\tilde{V}_{in}| = 1/\sqrt{2}$?

(c) (*3 points*) A band pass filter can be constructed by adding an inductor L in parallel with the capacitor as shown in Figure (B). Compute $\tilde{V}_{out}/\tilde{V}_{in}$ for this circuit and find its resonant frequency.