Student ID Number: ________

PRELIMINARY EXAMINATION
Department of Physics
University of Florida
Part A, January, 2012, 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 point charge q of mass m is released from rest at a distance d from an infinite grounded conducting plane. How long Δt will it take for the charge to hit the plane, neglecting the force of gravity?

(a) **(3 points)** Dimensional analysis gives you how the time Δt depends upon the parameters q, m, d and ϵ_0, up to an overall constant. What is this form?

(b) **(3 points)** Suppose the charge q is at height z. Use the Method of Images to find the force exerted upon it by the conducting plane.

(c) **(4 points)**What is the exact formula for Δt?

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A2. Consider one dimensional infinite square well of width $2L$ with a particle of mass m moving in it ($-L < x < L$). The particle is in the lowest-energy state. Assume now that at $t = 0$ the walls of the well move instantaneously so that its width doubles ($-2L < x < 2L$). This change does not affect the state of the particle, which is the same before and immediately after the change.

(a) Find the wave function for the lowest-energy state and its energy at time $t < 0$.

(b) Find the eigenvalues and eigenfunctions of the modified system at time $t > 0$.

(c) Write down the wave function of the particle at times $t > 0$.

(d) Calculate the probability of finding the particle in an arbitrary eigenstate of the modified system.

(e) What is the probability of finding the particle in odd eigenstate?

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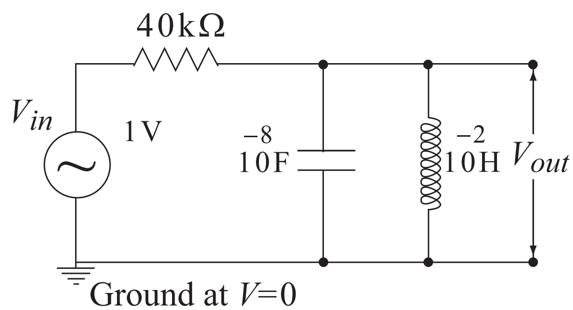
A3. A band pass filter that passes voltage signals over a narrow frequency range can be made from the combination of passive circuit elements (R, L, C) arranged as shown in the figure. The ac input voltage source V_{in} has a negligible output impedance and produces a sinusoidal signal $V_0 \sin(\omega t)$ with amplitude of $V_0 = 1$ volt that can be tuned over a wide range of frequencies $f = \omega/2\pi$. The output voltage detector V_{out} has high input impedance and can measure the amplitude $|V_{out}(\omega)|$ and phase $\phi(\omega)$ of the voltage at the dividing point between the resistance R and the complex impedance $Z_{LC}(\omega)$ of the parallel combination of the capacitance C and inductance L.



(a) **(2 points)** Calculate an expression for $Z_{LC}(\omega)$ and find the resonant frequency f_R in Hz where $Z_{LC}(\omega)$ is maximum. In the following sections leave all your answers in terms of the variables R, L and C.

(b) **(2 points)** Calculate the complex response $\frac{V_{out}(\omega)}{V_{in}(\omega)} = \left|\frac{V_{out}(\omega)}{V_{in}(\omega)}\right| \exp(i\phi(\omega))$ by separately calculating $\left|\frac{V_{out}(\omega)}{V_{in}(\omega)}\right|$ and $\phi(\omega)$ and then identify the resonant frequency where $\left|\frac{V_{out}(\omega)}{V_{in}(\omega)}\right|$ is maximum.

(c) **(2 points)** Sketch $\left|\frac{V_{out}(\omega)}{V_{in}(\omega)}\right|$ versus ω. In your sketch label all axes and locate the point where the maximum response occurs. Find the respective values of ϕ in the low and high frequency limits and at resonance.

(d) **(2 points)** By flipping a switch on the voltage source, a square wave with Fourier transform $V(t) = \frac{4}{\pi} V_0 \left[\sin(\omega t) + \frac{1}{3}\sin(3\omega t) + \frac{1}{5}\sin(5\omega t) + ...\right]$ is generated. Briefly describe how you (the experimentalist) can vary ω to check the values (1/3, 1/5, etc.) of the harmonic coefficients. You will want to use frequencies that give you maximum sensitivity as determined above.

(e) **(1 point)** Describe how you might obtain an experimental value for π. Remember that your voltage source can output both sinusoidal and square wave signals.

(f) **(1 point)** Rearrange the circuit elements in the figure and draw a sketch of a band reject filter, *i.e.*, a filter that rejects rather than accepts input voltages over a narrow frequency range.