Name:

Physics 115: CONTEMPORARY PHYSICS III
Spring 2008
Prof. Michael S. Vogeley
MIDTERM EXAM

INSTRUCTIONS

Write your name at the top of EVERY SHEET (do this now).

You have two hours to complete the exam.

For the "quantitative" questions, you may use the equation sheet provided. You may also use a calculator.

You must show your work for all problems. Correct answers (guesses?) without justification will receive zero credit.

READ THE PROBLEMS CAREFULLY BEFORE BEGINNING. A few moments of thought may save you lots of time.

Write your answers on these exam pages. Use the back of each sheet, if necessary. Ask for more paper if you run out of space.

Name:

1. Current and Resistance (5 pts)

Mark each of the following as TRUE or FALSE.

(a) Electron current flows in the direction opposite conventional current.

(b) The speed of electrons in a wire is very small compared to the speed of light.

(c) Lowering the temperature of a wire increases the conductivity.

(d) Doubling the cross-sectional area of a wire doubles the voltage.

(e) Resistance in a wire is caused by the Coulomb force between electrons.

2. Dot Cross Fun (5 pts)

See figure below.

(a) Compute the dot product $\mathbf{A} \cdot \mathbf{B}$ of these two vectors.

(b) Compute the cross product $\mathbf{A} \times \mathbf{B}$ (magnitude and direction – into or out of the paper) of these two vectors.

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3. Loop and Torque (10 pts)

See figure below.

A long straight wire carries current I. There is a loop in the wire with radius R. At first, the loop axis is perpendicular to the wire (so the loop lies in the same plane as the wire).

(a) What is the magnetic dipole moment of the loop?

(b) What is the magnitude and direction of the magnetic field $\mathbf{B}$ at the center of loop? (THIS WAS A HOMEWORK PROBLEM!)

Now assume that the loop is rigid, but can swivel around an axis that is in the plane of the loop and is perpendicular to the long wire. The loop is swiveled until the loop axis makes an angle θ with the wire. We then let go of the loop.

(c) What is the magnetic torque on the loop? (Be specific: In which direction does it turn?)

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4. Bypassed Current (10 pts)

See Figure below.

A long wire carrying current I has a "bypass" in it - parallel paths that form semi-circles with radius R.

(a) What are the magnitude and direction of the magnetic field $\mathbf{B}$ at the center of the loop?

(b) How does your answer change if we put a resistor R in the upper path? Be specific about the effect on both the magnitude and direction of the magnetic field. (Assume that the wire has small but finite internal resistance, such that the internal resistance of each semi-circle of wire is R_{int}.)

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5. Current, Potential, and Electric Field (10 pts)
See the circuit in the figure below.

(a) Draw arrows to indicate the direction of current flow along each segment of the circuit (a "segment" is region between two lettered points, e.g., A and B)

(b) Draw arrows to indicate the direction of electric field along each segment of the circuit

(c) Fill in the graphs of current I, potential V, and electric field E at the different points around the circuit (A, B, C, D, E, F, G, H – note that there are two paths through the parallel piece, so you need to draw two sets of lines! And you must show your work to explain how you solved for the currents.)

(d) Where possible, put numerical labels on the y axis of each graph. If you do not believe there is enough information to give correct units to one of the graphs, explain why, and describe what you would need to complete the graph.

6. Varying the Resistance (5 pts)

A current I_0 runs through a resistor that consists of a wire of length L and cross-section A. The wire is made of material with electron mobility u and density n of charge carriers q.

In terms of the original current I_0, solve for the new current I through the resistor if we

(a) double the length of the wire

(b) halve the cross-section of the wire

(c) replace the resistor with one with identical geometry but twice the electron mobility

(d) place a second, identical resistor in *parallel* with the first resistor (careful - what is the current through the original resistor, not the battery?)

(e) place a second, identical resistor in *series* with the first resistor

7. RC Circuit (15 pts)

See figure below.

Initial condition: At time $t = 0$, the capacitor C has no charge on it.

The following four questions concern the circuit behavior at $t = 0$.

(a) What is the current I?

(b) What is the voltage ΔV across the resistor?

(c) What is the power being dissipated by the resistor?

(d) What is the voltage ΔV across the capacitor?

Now examine the behavior at $t > 0$.

(e) Apply the loop rule to this circuit to write an equation for the charge on the capacitor, Q.

(f) Rewrite the previous answer to write down the differential equation that describes the time rate of change of the charge on the capacitor, dQ/dt.

(g) Draw a qualitatively correct graph that shows how the charge Q varies with time (Q on the y axis). Explain how/why this graph agrees with the equations above in the limits $t = 0$ and $t = \infty$. You must label $t = 0$ and $t = \infty$ on the graph.

(h) Draw a qualitatively correct graph that shows how the current I varies with time (I on the y axis). Explain how/why this graph agrees with the equations above in the limits $t = 0$ and $t = \infty$. You must label $t = 0$ and $t = \infty$ on the graph.

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8. Dueling Capacitors (10 pts)

In the circuit diagram below, with both switches open, capacitors $C_1 = 1.16\mu$F and $C_2 = 3.22\mu$F are each charged to $\Delta V = 96.6$V, but with opposite polarity. Then we close both switches and let the system reach equilibrium.

(a) What is the potential difference between points A and B?

(b) What is the charge on C_1?

(c) What is the charge on C_2?

Name:

9. Sliding Wire (10 pts)

A metal wire of mass m slides without friction on two horizontal conducting rails a distance d apart. A generator provides constant current I that flows down one rail, across, the wire, back down the other rail to the generator. The entire apparatus is placed in a constant magnetic field $\mathbf{B}$ that is perpendicular to the current loop.

Find the velocity and direction of motion of the wire as a function of time, assuming that $v = 0$ at $t = 0$.

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10. E or B Field? (10 pts)

In the diagram below, a long wire carries current I and an electron with velocity v (as measured in the frame of rest of the wire) travels parallel to the wire. Measurements are made of the electric and magnetic fields at distance d from the wire.

(a) In the rest frame of the wire, what are the components of the electric and magnetic fields $E_x, E_y, E_z, B_x, B_y, B_z$ due to the wire at the location of the electron

(b) In the rest frame of the wire, what is the direction and magnitude of the total force on the electron?

(c) In the rest frame of the electron, what are the components of the electric and magnetic fields $E_x, E_y, E_z, B_x, B_y, B_z$ due to the wire at the location of the electron? (Careful, I have intentionally not put any primes on the components or coordinates in either frame. It's up to you to use the transformation equations correctly.)

(d) In the rest frame of the electron, what are the magnitude and direction of the total force on the electron?