Physics 5C – Practice Final Exam – Spring 2008

Final Instructions:

- You have 3 hours for the exam.
- You are allowed to use both sides of one sheet of (standard letter size) paper that you have brought with you, for reference.
- You may also use calculators *for arithmetic operations only.*
- You will receive 11 points for putting your name on the paper, accurately following directions, etc. Failure in any of these thing will lead to a partial or total loss of your 11 points.
- The exam is worth 200 points total. Partial credit will be given *if* your thought process is clear to the grader, and you are being graded not just on the final answer but also your thought process, so *show all work* as clearly as possible. (It might even help to throw a few words in to your solution here and there.) If you change your mind in the middle of a problem, please indicate the line of thought and answers that you wish us to consider.

Section A (40 points): Multiple choice: choose the best answer. You will get 5 points for each correct answer.

1. An electric dipole lies in a uniform electric field, and the dipole moment points perpendicular to the field. Which one of the following is FALSE?

   (a) ____ The dipole will continue to point in that direction if no other forces act on it.

   (b) ____ The net force on the dipole is zero.

   (c) ____ The electrostatic potential energy of the dipole is zero.

   (d) ____ The net charge of the dipole is zero.

2. Einstein's theory of relativity states that $E = mc^2$, i.e. that adding energy to a system makes it more massive. Imagine a conducting sphere on a scale (but insulated from it). Now imagine adding a charge q to the sphere. Neglecting the mass of the charge carriers you use to add the charge, the mass reading on the scale will:

   (a) ____ Decrease if $q < 0$ and decrease if $q > 0$.

   (b) ____ Decrease if $q < 0$ and increase if $q > 0$.

   (c) ____ Increase if $q < 0$ and increase if $q > 0$.

   (d) ____ Increase if $q < 0$ and decrease if $q > 0$.

3. A lightning bolt hits the ground, and creates a point of very high voltage on the ground, which is at zero potential far away from the strike. A physics 5C student and a cow are both 10 m away from the strike, *and facing toward it.* Assume that both have the same resistance to current passing through them.

(a) ____ The cow is in greater danger than the 5C student.

(b) ____ 5C student is in greater danger than the cow.

(c) ____ The student and the cow are in equal danger.

4. If i, R, C, B, and L are current, resistance, capacitance, B-field strength, and inductance, then the quantity $iRCB/L$ has units:

   (a) ____ Cs/V

   (b) ____ mC^2/s

   (c) ____ $C^2/(m^2 s)$

   (d) ____ Vm/Cs

5. Consider a magnetic dipole $\vec{u}$ in a magnetic field $\vec{B}$. Which of the following is FALSE?

   (a) ____ There is no net force on the dipole if B is uniform.

   (b) ____ There is a torque on the dipole unless $\vec{u} \parallel \vec{B}$.

   (c) ____ If $\vec{u} \parallel \vec{B}$, then the field due to the dipole will tend to cancel the field B.

   (d) ____ If the dipole points out of the page, it could be due to an electron circling in a clockwise fashion.

6. To get a device with a high capacitance, it should have

   (a) ____ Large area, small plate separation, and small dielectric constant.

   (b) ____ Large area, large plate separation, and small dielectric constant.

   (c) ____ Large area, large plate separation, and large dielectric constant.

   (d) ____ Large area, small plate separation, and large dielectric constant.

7. The diplacement current is defined as $\epsilon_0 d\Phi_E/dt$. If I was charging a capacitor with dielectric κ, then to have the displacement current between the plates equal to the current flowing into (or out of) the capactitor, I should define it as:

   (a) ____ $\epsilon_0 \kappa d\Phi_E/dt$

   (b) ____ $\epsilon_0 \kappa^{-1} d\Phi_E/dt$

   (c) ____ $\epsilon_0 d\Phi_E/dt$

8. If I have a transformer with a primary coil of 1000 turns and a secondary coil of 500 turns, then

   (a) ____ The primary voltage will be twice the secondary voltage and the primary current will be half the secondary current.

   (b) ____ The primary voltage will be half the secondary voltage and the primary current will be half the secondary current.

   (c) ____ The primary voltage will be twice the secondary voltage and the primary current will be twice the secondary current.

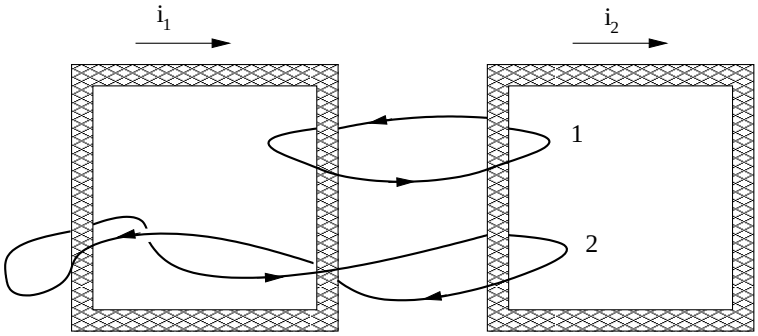

FIG. 1:

(d) ____ The primary voltage will be half the secondary voltage and the primary current will be twice the secondary current.

Section B: Problems

1. (14 points) Figure 1 shows two closed paths wrapped around two conducting loops carrying currents $i_1 = 5.0\,\mathrm{A}$ and $i_2 = 3.0\,\mathrm{A}$. What is the value of the integral $\oint \vec{B} \cdot d\vec{l}$ for

   (a) Path 1?

   (b) Path 2?

2. (14 points) A long, straight wire of length l carries current i. A right-angle bend formed at the middle of the wire is in the shape of a circular arc of radius $r \ll l$, as shown in Fig. 2 (the wire is the bent line).

   Determine the approximate magnetic field (magnitude and direction) at the center of the arc, using $r \ll l$.

3. (16 points) Scientists working on the SETI program have just detected a signal from another star. It is a radio wave of intensity $10^{-22} W/m^2$ (near Arecibo's sensitivity limit), and appears to come from a star ~ 20 light-years (2×10^{17} m) away.

   (a) What are the maximum E and B fields at the SETI antenna due to this signal?

   (b) What is the power, in Watts, of the Alien emitter, if it beams signals equally in all directions? How does this compare to the $10^{13}\,W$ used (on average) by all of humanity?

4. (18 points) Figure 3 shows a portion of a circuit through which there is a curernt $I = 6\,\mathrm{A}$. The resistances are $R_1 = R_2 = 2.00R_3 = 2.00R_4 = 4.00\,\Omega$. What is the current i_1 through resistor 1?

5. (18 points) The voltage in a power outlet is about 110V rms, at 60Hz in the US and Canada.

   (a) What is the maximum voltage that comes out of the wall socket at any instant of time?

   (b) What is the resistance of a 4-slice, 1600W toaster?

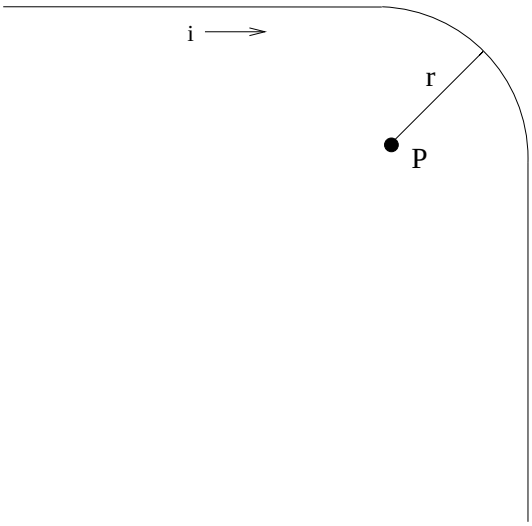

FIG. 2:

(c) What is the capacitance that (with no resistor present) will allow the same amplitude current to flow when plugged into the wall socket?

6. (18 points) Figure 4 shows, in cross-section, two solid spheres with uniformly distributed charge throughout their volumes. Each has radius R. Point P lies on a line connecting the centers of the spheres, at radial distance $R/2.00$ from the center of sphere 1. If the net electric field at point P is zero, what is the ratio q_2/q_1 of the total charge q_2 in sphere 2 to the total charge q_1 in sphere 1?

7. (25 points) A perfectly conducting rod of length l moves on two horizontal, frictionless, resistanceless rails as shown in Fig. 5. Connecting the rails are a capacitor C and resistor R. At time $t = 0$, the capacitor is uncharged and the bar is moving at a constant speed

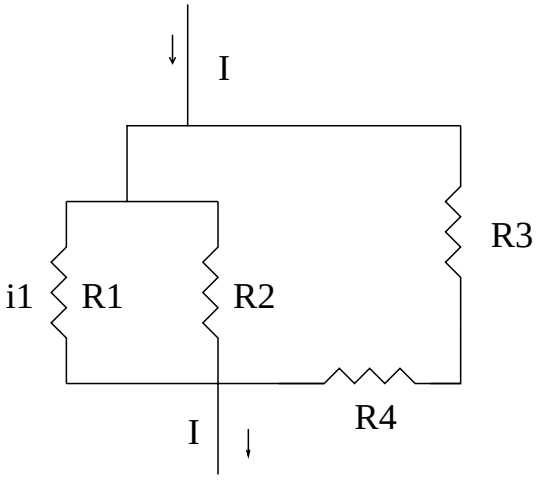

FIG. 3:

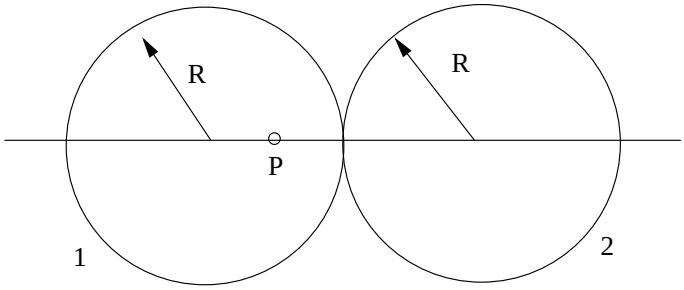

FIG. 4:

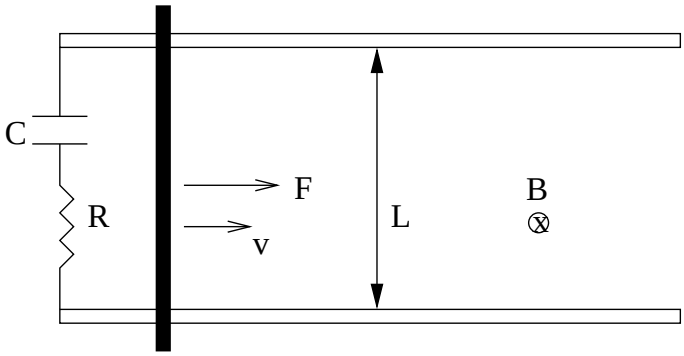

FIG. 5:

v through a magnetic field $\vec{B}$ that is directed into the page. It is kept at this speed by an external force F.

(a) What is the current i through the resistor an instant after $t = 0$?

(b) What is the charge on the capacitor a very long time after $t = 0$?

(c) What is the current i through the resistor when the capacitor has attained half its final charge?

(d) What is the total work done after $t = 0$ by the agent exerting the external force F?

8. (25 points) A Sith Lord is able to fry a Jedi Knight at a distance of $L \approx 5\,m$ with electric lightning shooting from his fingertips. See Figure 6. Assess the following.

(Note that you can answer later parts in terms of the variables given in earlier parts, so don't stop if you get stuck.)

(a) For a lightning bolt to shoot, the electric field must ionize the air. This requires a field of $\approx 3.0 \times 10^6\,\mathrm{V/m}$ where the bolt is going to start (after that it tends to ionize the rest of the path automatically). Consider the Sith to be an isolated charged conducting sphere of radius $r = 0.5\,m$. What is the charge Q_{sith} of the Sith when the sparks start to fly?

(b) What is the Sith's potential V_{sith} at the same time, where $V = 0$ at infinity?

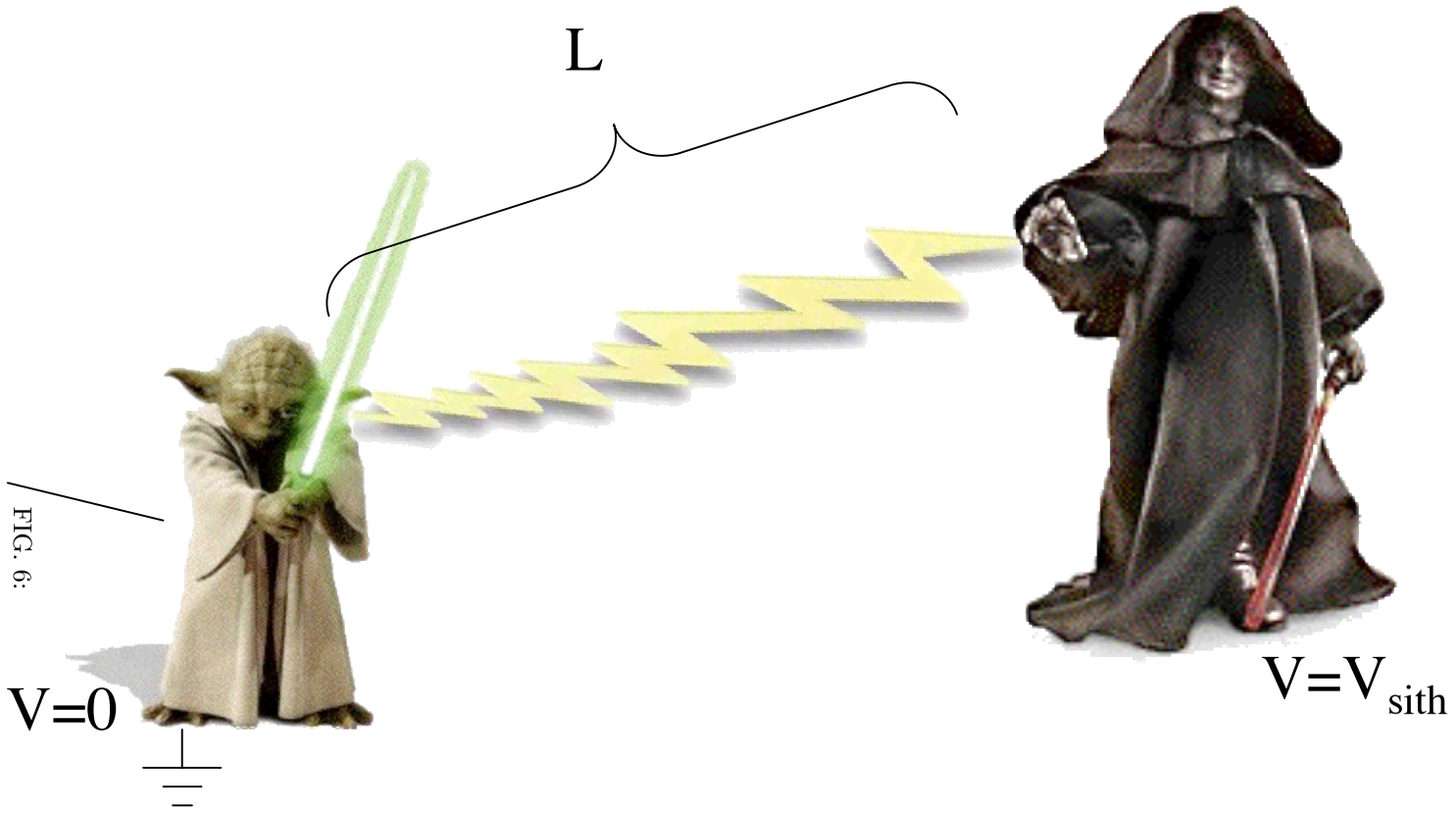

FIG. 6: