Physics 115: CONTEMPORARY PHYSICS III
Spring 2009
Prof. Michael S. Vogeley
HOMEWORK 6

Due Friday, May 22 in class

1. Falling magnet

(Review question 26(c) in chapter 22)

A bar magnet is dropped through a vertical copper tube and is observed to fall very slowly, despite the fact that mechanical friction between the magnet and tube is negligible. Explain carefully using equations why this happens and include a diagram to illustrate your explanation.

2. Induced electric field

(Problem 31 in chapter 22 - see diagram on p. 805)

The magnetic field is uniform inside a circle of radius R and the field point out of the circle. The magnetic field is zero outside the circle. The magnitude of the field varies with time, t, as $B = B_0 + bt^3$, where B_0 and b are both positive constants.

(a) What is the direction and magnitude of the induced electric field at location P, at a distance $r_1 < R$ to the left of the center of the circle?

(b) What is the direction and magnitude of the induced electric field at location Q, at a distance $r_2 > R$ to the right of the center of the circle?

3. Rectangular loop

(Problem 39 in chapter 22 - see diagram on p. 807)

A very long, tightly-wound solenoid has radius $r = 3$ cm (with length $L \gg r$). The magnetic field outside the solenoid is negligible. The magnetic field inside the solenoid is uniform, but its magnitude varies with time as $B = 0.07 + 0.03t^2$ tesla. Surrounding the solenoid is a loop of 4 turns of wire in the shape of a rectangle, 10 cm by 15 cm. The total resistance of the wire is 0.1 ohm.

(a) At $t = 2$ seconds, what is the *direction* of the current in the wire rectangle? Explain your answer.

(b) At $t = 2$ seconds, what is the *magnitude* of the current in the wire rectangle? Explain your answer.

4. Electric field of a capacitor

Show that a uniform electric field $\mathbf{E}$ between the plates of a capacitor cannot abruptly jump to zero outside the capacitor as one moves at right angles to the field (see horizontal arrow near location a in the diagram I will sketch). Really big hint: apply Faraday's law to the rectangular path drawn on the figure. (In actual capacitors, this results in "fringing" of the field lines of $\mathbf{E}$, which means that the field strength gradually goes to zero.) Now draw your own version of my diagram, showing more realistic set of field lines.

(Compare to the problem in homework 5 about fringing of the magnetic field of a magnet.)

5. Magnetic field that varies in space and time

A square with sides of length 2.0 cm lies in the $x-y$ plane with one corner at $x = 0, y = 0$, the lower side along the x axis and the left side along the y axis. A magnetic field with magnitude $B = 4(\text{tesla/m s}^2)t^2y$ points in the z direction.

Compute the emf around the square at $t = 2.5$ seconds and give its direction.

6. Sliding bar

A bar of length L, mass m, and resistance R slides along a pair of conducting rails that are connected at one end by another rail. Thus, the sliding bar and rails form a closed rectangle of width L. The bar slides toward the closed end due to gravity, because the plane of the rails is inclined by angle θ from horizontal. A uniform magnetic field $\mathbf{B}$ points vertically throughout the region of the bar and rails.

(a) Solve the equations necessary to show that the steady-state velocity of the bar has magnitude

$$v = \frac{mgR}{B^2L^2}\frac{\sin\theta}{\cos^2\theta}$$

(b) Show that the rate at which the internal energy of the bar is increasing is equal to the rate at which the bar is losing gravitational potential energy.

(c) Discuss what would happen if $\mathbf{B}$ pointed down instead of up.

7. Blow the fuse

An inductor with $L = 5.0$ henry, a resistor with $R = 15$ ohm, an emf$= 10$ volt battery, and a switch are connected in series in a circuit loop. A 3.0 amp fuse is connected to the circuit in parallel with the resistor. The fuse has zero resistance if $I < 3.0$ amp When the current reaches 3.0 amp, the fuse "blows" and has infinite resistance.

The switch is closed and current begins to flow.

(a) Compute the time at which the fuse blows.

(b) Draw a graph of the current I through the inductor as a function of time. Mark the time at which the fuse blows.