E&M Problem Set 11
Due ***Friday***, April 18 at 4pm

1. **Griffiths Problem 7.01:** Two concentric metal spherical shells, of radius a and b, respectively, are separated by weakly conducting material of conductivity σ (see Figure 7.41a below).

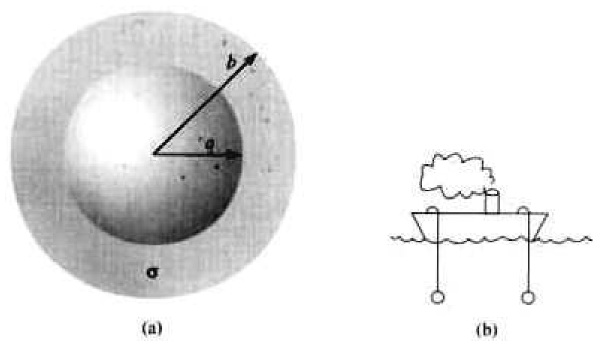

Figure 7.4

   (a) If they are maintained at a potential difference V, what current flows from one to the other? **HINT:** Start by defining current in terms of volume current density $\vec{J}$ and solve for current using equation 7.3 for Ohm's Law.

   (b) What is the resistance between the shells?

   (c) Notice that if $b \gg a$ the outer radius (b) is irrelevant. How do you account for that? Exploit this observation to determine the current flowing between two metal spheres, each of radius a, immersed deep in the sea and held quite far apart (As shown in Figure 7.4b above), if the potential difference between them is V. (This arrangement can be used to measure the conductivity of sea water.)

2. **Griffiths Problem 7.06:** A rectangular loop of wire is situated so that one end (height h) is between the plates of a parallel-plate capacitor (see Figure 7.9 below), oriented parallel to the field $\vec{E}$. The other end is way outside, where the field is essentially zero. What is the emf in this loop? If the total resistance is R, what current flows? Explain. [*Warning:* this is a trick question, so be careful; if you have invented a perpetual motion machine, theres probably something wrong with it. As an added hint, very little math is involved if you understand the math involved.]

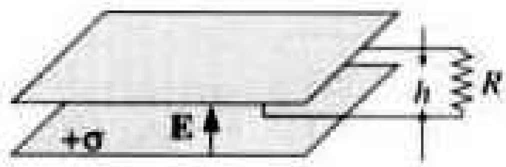

Figure 7.9

3. **Griffiths Problem 7.08:** A square loop of wire (side a) lies on a table, a distance s from a very long straight wire, which carries current I, as shown in Figure 7.17 (below).

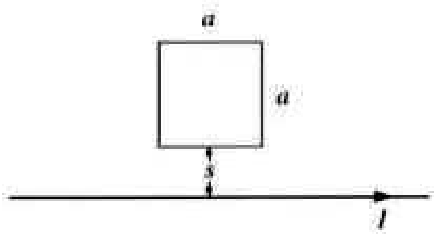

Figure 7.17

(a) Find the flux of $\vec{B}$ through the loop? **HINT:** This will involve you working out an integral, because the strength of $\vec{B}$ varries within the loop.

(b) If someone now pulls the loop directly away from the wire, at speed v, what is the emf generated? In what direction (clockwise or counterclockwise) does the current flow?

(c) What if the loop is pulled to the *right* at speed v, instead of away?

4. **Griffiths Problem 7.09:** An infinite number of different surfaces can be fit to a given boundary line, and yet, in defining the magnetic flux through a loop $\Phi = \int \vec{B} \cdot d\vec{a}$, I never specified the particular surface to be used. Justify this apparent oversight. **HINT:** What Griffiths is getting at is justify that *any* surface, as long as it is bound by a given boundary, will have the same Φ. You should exploit the properties of $\vec{B}$ and Helmholtz's Theorems. This is conceptual problem.

5. **Griffiths Problem 7.11 tweaked:** A square loop is cut out of a thick sheet of aluminum. It is then placed so that the top portion is in a uniform magnetic field $\vec{B}$, and allowed to fall under gravity (as shown in Figure 7.19 below). (In the diagram, shading indicates the field region; $\vec{B}$ points into the page.)

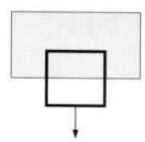

Figure 7.19

   (a) Recall that a current carrying wire will feel a force from a magnetic force. Compute the induced emf in this situation, use that to compute the induced current in the square loop, then use that to figure out the magnetic force acting on the loop. Use that information and the meaning of terminal velocity to find an expression for the terminal velocity, v_t.

   (b) If the magnetic field is 1 T (a pretty standard laboratory field), find the terminal velocity of the loop (in m/s). **Note:** It may be helpful to know that to solve this problem you will need to find an expression for the resistance R of the aluminum loop given some cross sectional area A and its resistivity, ρ. To work out the numbers, you need to know the resistivity of aluminum is $\rho = 2.82 \times 10^{-8}\Omega \cdot m$ and the mass density of aluminum is $\eta = 2.7 \times 10^{3} kg\ m^{-3}$, where I am using η to indicate mass density, because ρ is being used for resistivity. The geometrical parameters of the loop will cancel if everything works out well.

   (c) If fully immersed in the magnetic field, what would the loop's acceleration be? **HINT:** No computations necessary if you are clever.

(d) What would happen if you cut a tiny slit in the ring, breaking the circuit?

6. **Griffiths Problem 7.12:** A long solenoid, of radius a, is driven by an alternating current, so that the field inside is sinusoidal: $\vec{B}(t) = B_0 cos(\omega t)\hat{z}$. A circular loop of wire, of radius $a/2$ and resistance R, is placed inside the solenoid, and is coaxial with it. Find the current induced in the loop, as a function of time.

7. **Griffiths Problem 7.14:** As a lecture demonstration a short cylindrical bar magnet is dropped down a vertical aluminum pipe of slightly larger diameter, about 2 meters long. It takes several seconds to to emerge at the bottom, whereas an otherwise identical piece of *unmagnetized* iron makes the trip in a fraction of a second. Explain why the magnet falls more slowly. **HINT:** What would be the directions of any induced currents and where would they be located? What effect would they have?

8. **Griffiths Problem 7.15:** A long solenoid with a radius a and n turns per unit length carries a time-dependent current $I(t)$ in the $\hat{\phi}$ direction. Find the electric field (magnitude and direction) at a distance s from the axis (both inside and outside the solenoid), in the quasistatic approximation. **NOTE:** By quasistatic approximation, what we mean is you can compute the magnetic field assuming steady current in the solenoid to get an expresion for $\vec{B}$, and then assume that $\vec{B}$ has the same dependence on current when current is allowed to vary with time.