Physics 115: CONTEMPORARY PHYSICS III
Spring 2007
Prof. Michael S. Vogeley
HOMEWORK 5

Due Friday, May 18 in class

1. Stay in the car!

(Review question 16 in chapter 21)

Explain (using what we learned by applying Gauss's law to chunks of metal) why you are safe and unaffected inside a car that is struck by lightning. Also explain why it might not be safe to step out of the car just after the lightning strike, with one foot in the car and one on the ground.

2. B in the D?

(Problem 25 in chapter 21)

A D-shaped frame is made out of plastic of small square cross section and tightly wrapped uniformly with N turns of wire (see the figure on p. 775), so that the magnetic field has essentially the same magnitude throughout the plastic (radius R of the curved part much larger than cross section width w).

With current I flowing, what is the magnetic field inside the plastic? Draw the "D" and indicate the direction of the field at several locations.

3. Gauss's Law for Gravitation

Gauss's law for gravitation is

$$\frac{1}{4\pi G}\Phi_g = \frac{1}{4\pi G}\int \mathbf{g}\cdot d\mathbf{A} = -m$$

where $\mathbf{g}$ is the gravitational field, m is the enclosed mass, and G is Newton's constant.

Derive Newton's law of gravitation from Gauss's law. What is the significance of the minus sign?

4. Charge on a thin shell

An uncharged, spherical, thin shell has a point charge q at its center. Derive expressions for the electric field

(a) inside the shell and

(b) outside the shell.

(c) Does the shell have any effect on the field due to q?

(d) Does the charge q have any effect on the shell?

If a second charge is held outside the shell,

(e) does this outside charge experience a force?

(f) does the charge q inside the shell a force?

5. Magnetic field fringing

Show that a uniform magnetic field $\mathbf{B}$ cannot abruptly jump to zero as one moves at right angles to it (see horizontal arrow through point a in the diagram I will sketch). Really big hint: apply Ampere's law to the rectangular path drawn on the figure. (In actual magnets, this results in "fringing" of the the field lines of $\mathbf{B}$, 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.

6. Current in a thick wire

The current density insude a particular long, solid, cylindrical wire of radius a is in the direction of the axis. The current strength varies linearly outward from the center of the wire, with current density $J = J_0 r/a$. Solve for the magnetic field inside the wire at some distance r from the center. Express your answer in terms of the total current I carried by the wire.