8.02X Electricity and Magnetism

Problem Set 8

Issued: **Sat, Apr 2**
Due: **Fri, Apr 8 , 4PM <- note Date + Time!**

Note that the exp MF write-up from <u>both </u>lab partners is also due on 4/8 4PM!

Reading suggestions (from Young & Freedman)

Mon: Electromagnetic Induction I
Wed: Electromagnetic Induction II
Fri: Quiz 3 Review

Homework Problems (30 points total)

Problem 1 (10 points) Two parallel wires carrying currents in the same direction are found to attract each other.
   (a) Give a step-by-step explanation of why the wires attract each other, due to the field created by moving electric charges and the forces on moving charges. Use pictures and words, but not equations
   (b) Again using pictures and words show that you get repulsion if the currents in the two wires run anti-parallel.

Problem 2 (10 points) You have a horizontal cathode ray tube (CRT) in a lab room which has been adjusted such that the electron beam should produce a single spot in the center of the front screen. However, you find that the spot is offset to the right, when viewed from the front.
   (a) You realize that the offset could be caused by an electric or magnetic field or by a misalignment of the cathode. How can you determine the cause of the problem without any instruments to detect electric or magnetic fields and without removing the CRT from the room?
   (b) If the cause was an magnetic field, what direction would the field have, relative to the original direction of the electron beam?

Problem 3 (10 points) The Large Hadron Collider at CERN, Geneva, will accelerate lead nuclei to an energy of 2.8 TeV/nucleon. The nuclei will follow a circular trajectory of 27km circumference
   (a) What is the momentum of each nucleus [note: The relativistic relationship between energy and momentum is $E = \sqrt{p^2 c^2 + m_0^2\ c^4}$]?
   (b) How big is the magnetic field of the dipole magnets that hold the nuclei on their trajectory?

(c) Would it be possible to build a linear accelerator of 100m length that achieves the same final energy of the particles? What electric field would be necessary for this and how does it compare to the typical fields inside atoms?

Experiment MF (Magnetic Force)
(20 points total)

Note that check-off and experiment write-up for experiment 'Magnetic Force (MF)' are due on Fri, 4/8. There will be 2 bonus points for MF check-off on 4/4 and 1 bonus point on 4/5.

The lab hours are Mon 3-5, Tue. 7:30-9:30 pm, Wed 7:30-9:30 pm, Thu 3-5, Fri 12-3.

You will be graded according to the following criteria:
1. Your Experiment: Magnetic Force apparatus works (you will need to demonstrate a trial run during the check-off).
2. Your understanding of the underlining physical principles involved in the experiment.
3. **You may be asked a question during the check-off about how to calculate the magnetic permeability constant** $\mu_0 = \dfrac{1}{slope}(\dfrac{\rho Atgd}{n_1 n_2 r})$.

Problem 1 (10 points)

In your experiment, depending upon the winding direction of the coils, the current through them will generate magnetic forces such that the coils will either attract or repel each other causing them to move.

a) Is your apparatus set up to repel or attract? Briefly explain how you intend to measure the current that flows through the coil that will produce a magnetic force that will just balance the weight of the foil.

b) What is the radius r of your coils? What is the distance d between your coils?

c) You will measure the current that will produce a magnetic force that will just balance one, two, and three squares of the foil. Suitable weights are 2 cm by 2 cm squares of foil. For each number of weights, n, make several measurements of the current that balances the weight. Average your values.

d) Make a table of your data with columns for weight (in terms of the number of weights, n), the current (in A), and the current squared (in A^2).

e) Make a plot of the current squared (in A^2) vertically vs. the weight (in terms of the number of weights, n) horizontally. If no weights were on your balance, and it balanced at zero current, then origin is also a point.

f) Use a linear regression to find the slope and intercept of a straight-line fit of your plot. (You may also find the best fit straight-line by eye.)

g) Estimate the error on the slope. This can be done by taking the extremal (maximum and minimum) values of the slope and computing the difference with the best fit slope.

h) Then from the best straight-line fit of your data, calculate the magnetic permeability of space using

$$\mu_0 = \frac{1}{slope}(\frac{\rho Atgd}{n_1 n_2 r}),$$

where $g = 9.8 m/s^2$, A is the area of your foil, $\rho = 2.7 \times 10^3 kg/m^3$ is the density of aluminum, $t = 1.8 \times 10^{-5} m$ is the thickness of the aluminum, $n_1 = 38$, $n_2 = 10$, r is the radius of your coils, and d is the separation between your coils.

i) Consider the uncertainties in the measurements of slope, g, ρ, A, t, d, and r. Which error contributes the most? Which errors can you safely ignore?

Problem 2 (10 points)

In the magnetic force experiment, a current $I = 0.5A$ is passed in series through a 38 turn coil taped to a table and a 10 turn coil which is taped to a balance directly above the 38 turn coil. The distance between the 10 turn coil and the 38 turn coil is $d = 0.5cm$. Each coil has a radius of $r = 6.0cm$.

a) Calculate the magnitude of the magnetic field originating from the 38 turn coil at any point on the 10 turn coil. Clearly indicate any approximations you make.

b) Calculate the magnitude of the magnetic field originating from both coils along the central axis at a height $z = 0.5cm$ above the plane of the 38 turn coil. You may take this point as the center of the 10 turn coil.