Waves and Fields (PHYS 195): Week 10

Spring 2009 v1.0

Intro:

The effects of magnetic fields will be the first topic for this week. We'll carefully study the torque on a current loop in a magnetic field. This is critical for the design of the motors. The problems are a problem mix on circuits and magnetic fields.

Due Monday, April 13

Reading:

- We are currently in Chapter 28...
- Friday: HRW 29.1-2 (We will skip sections 29.4, Ampère's Law, and on.), 28.9 Motor theory
- Monday: HRW 28.10
- Wednesday: HRW 30.2 "From Faraday to Light" (We will skip the rest of Chapter 30, and Chapters 31-32.)

Physics Topics:

- Magnetic moment
- The $I\ell \times \mathbf{B}$ force
- The Lorentz force $q\mathbf{v} \times \mathbf{B}$

Problems:

(1) HRW 27.6

(2) Find the current in the circuit of the last problem.

(3) HRW 27.11

(4) HRW 27.66

(5) HRW 28.31

(6) **J.J. Thomson discovers the electron!** *"The electrified particle theory has, for purposes of research, a great advantage over the aetherial theory, since it is definite and its consequences can be predicted..."* - J. J. Thomson (1897)

(a) Examine the schematic of the Thomson apparatus. Notice the accelerating potential on the left hand side and the cross section of the capacitor. (We saw this in action two weeks ago and, in a different configuration, in lab this week.) Sketch the electric field lines and equipotentials in the capacitor.

(b) Show that while the particle is between the plates its y position is

$$y(x) = \frac{1}{2}\frac{qE}{m}\frac{x^2}{v_x^2}.$$

(c) Sketch the particle's trajectory. Hint: The position on the screen where the particle lands is given by

$$y(L) = \frac{qE}{m}\frac{b}{v_x^2}\left(L - \frac{b}{2}\right).$$

(d) The cathode beam does not smear out but remains a sharply defined spot. If this beam consists of many particles, what must the host of particles have in common?

(e) The problem with the above equation for position is that it involves *two* unknowns q/m (what Thomson wished to find) and v_x. Ugg. Thomson reduced the number of unknowns by an ingenious way of measuring v_x. He introduced a magnetic field until the spot returned to its initial position on the screen. Find the direction of the magnetic field which restores the beam to its original undeflected position on the screen. Draw a free body diagram and show that the velocity is given by

$$v_x = \frac{E}{B}.$$

Since the spot remains coherent in the magnetic field, what can you infer about the velocities of the particles in the beam?

(f) If you combine all the relevant expressions the ratio of charge to mass is

$$\frac{q}{m} = \frac{y(L)\,\Delta V_p}{\left(L - \frac{b}{2}\right) b\, B^2 d}$$

Suppose that in a given tube b and L are 4.00 cm and 20.00 cm, respectively, and that the spacing between the deflecting plates is 1.50 cm. Under a potential difference of 150 V, the deflection of the spot on the screen is observed to be 2.6 cm. The magnetic field which restores the spot to the center has a strength of 4.5 $\times 10^{-4}$ tesla. Calculate the velocity of the beam particles and the charge-to-mass ratio. (Remember your significant figures.)

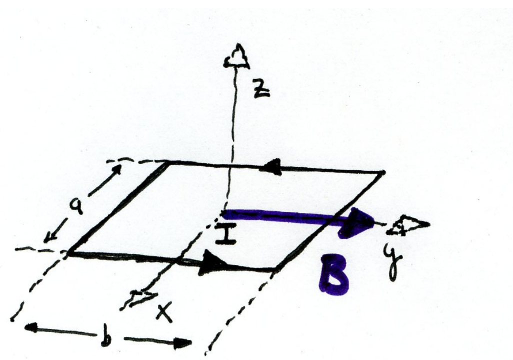
(7) **Magnet testing** You have two identical magnets in your motor kit. Measure the strength of the field of a magnet:

(a) Place a paperclip on a level surface. Holding a ruler perpendicular to the surface, slowly lower the magnet down towards the paperclip. At some point the paper clip "leaps" up to the magnet. Record the heights at which this occurs for the three different orientations of the magnet.

(b) Why does does this happen?

(c) Sketch the magnetic field of your magnet.

(8) **Motor theory**: A rectangular current loop is in a uniform magnetic field pointed along the positive y-axis as shown.



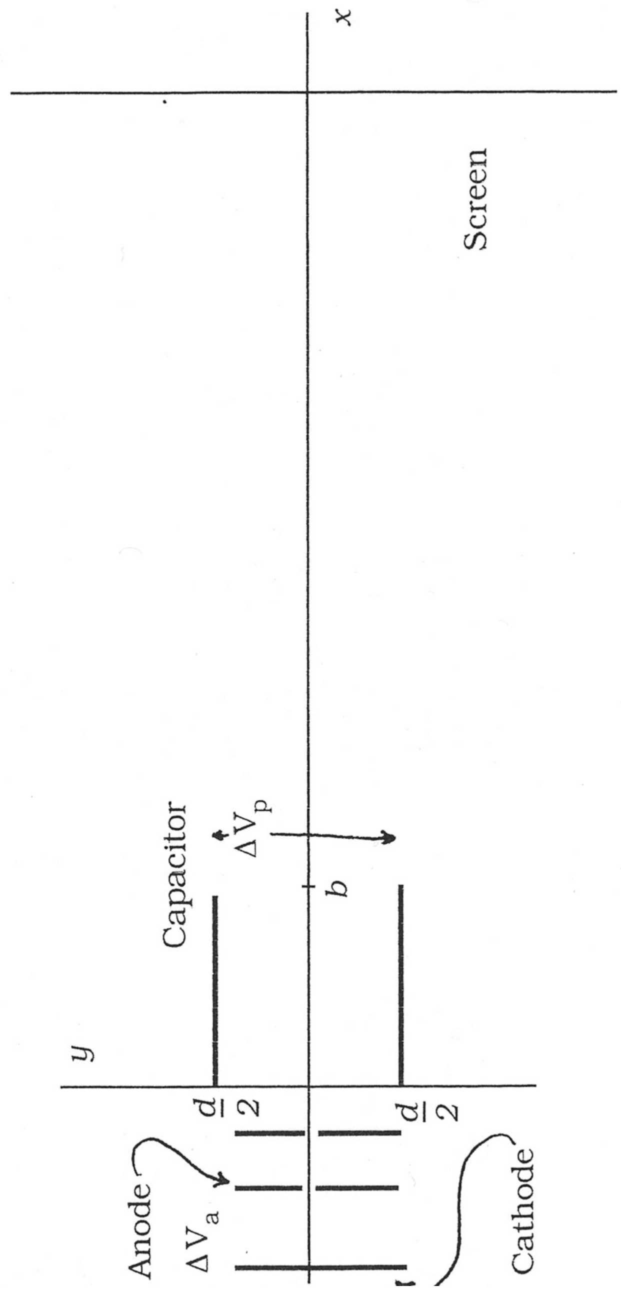
(a) Find the $I\ell \times \mathbf{B}$ force for each side.

(b) What is the total force on the loop?

(c) Find the total torque on the current loop.

(d) Show that the magnetic moment μ is Iab and that you can express your first result as $\tau = \mu \times \mathbf{B}$.

(e) If the magnetic field is 2.0 gauss, $a = 2.1$ cm, $b = 3.5$ cm. and $I = 0.75$ A then what is the torque on the curent loop?



The Thomson Experimental Setup

Lab:
Magnetic field mapping

A look ahead...
Light as a wave! HRW Chapter 33