Concepts of Physics
Lab 6: Moving Charges

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Activity 1: Deflecting electrons

A moving charged particle will feel a force in an electric field, and it will feel a force in a magnetic field. In this experiment you will observe both of these effects. The beam of electrons which comprise the moving charges will be visible because they will strike a screen that glows when struck—similar to a TV screen. You will control the speed of the electrons by controlling the accelerating voltage, V_a, which speeds them up. You will control the electric field E by controlling another voltage, V_d, the deflecting voltage. The magnetic field B will be created by two coils of wire with a current I in them—you will control I.

Play with the controls, and see how apllying both electric and magnetic fields deflects moving charges, in different ways.

Warning: This expensive equipment can be damaged easily. Don't turn anything on or up unless you are sure it is set up correctly.

To hand in for activity 1

Your observations: how does the electron beam deflect (in what direction, in a tighter or less tight curve) as you change the voltages and curents you control?

Activity 2: Charge to mass ratio

It is possible to set up an electric field and magetic field in your apparatus in such a way that the effects of both cancel each other out, leading to no deflection. We then can take note of what the voltages and currents you control happen to be for when there is no deflection, and figure out q/m, the charge to mass ratio of the electron.

To do this, say you ask for the help of a physics senior who is supposed to know how to calculate such things. She works for a bit, and presents you with an equation:

$$\frac{q}{m} = \frac{V_d^2 a^2}{2kd^2 V_a N^2 I^2}$$

She then explains that

- V_d: The deflecting voltage you set,
- a: The radius of the coils generating the magnetic field,
- k: A constant depending on the geometry, which in this case she guesses is about $k = 9.0 \times 10^{-7}$ N/A^2
- d: The distance V_d is applied across,
- V_a: The accelerating voltage you set,
- N: The number of coils; $N = 320$.
- I: The current you set through the coils.

Using the method I will show you, adjust everything so that the path of the electron is a straight line, and measure and write down values for V_d, V_a, d, a, and I. Do this for at least two different sets of values—more if you have time.

Using these data, calculate an experimental value of q/m for an electron for two or more trials, and average those values for a final experimental result.

Then, using accepted values for the electron charge and mass,

$$q = 1.60 \times 10^{-19} \text{ C}$$

$$m = 9.11 \times 10^{-31} \text{ kg}$$

calculate the accepted value of the ratio q/m for an electron to two significant digits.

To hand in for activity 2

All measured values for each trial, experimental q/m for each trial, your final result for experimental q/m, the accepted value of q/m, and comparison with the accepted value.

Comment on how far off the physics senior's prediction was. What do you think might be the biggest problem with it?