Charge-to-Mass Ratio

In this classic experiment, the goal is to use crossed magnetic and electric fields to measure the charge-to-mass ratio of electrons. By varying the applied voltage, we can control the velocity at which the electrons enter the magnetic field. From conservation of energy we have

$$\frac{1}{2}\mathrm{mv}^2 = eDV \qquad (1)$$

where m is electron mass, v is electron speed, e is electron charge, and ΔV is the voltage drop. Our charge-to-mass ratio is then,

$$\frac{e}{m} = \frac{1}{2} v^2 / DV \ . \qquad (2)$$

In this apparatus there is no convenient measure of the velocity, so we must find a way of eliminating the dependence on velocity. The force on the particle in a magnetic field is given by evB since the velocity and field are perpendicular. Thus we have,

$$\mathrm{evB} = \frac{\mathrm{mv}^2}{r} \ . \qquad (3)$$

We can then solve for velocity in terms of these parameters yielding

$$\mathrm{v} = \frac{\mathrm{eBr}}{m} \ . \qquad (4)$$

Placing this equation into our first expression

$$\frac{e}{m} = \frac{1}{2}\frac{e^2}{m^2} B^2 r^2 \frac{1}{DV} \ , \qquad (5)$$

which simplifies to

$$\frac{e}{m} = \frac{2\mathrm{DV}}{B^2 r^2} \ . \qquad (6)$$

Suggestions:

1. Measure the ratio at various voltage and current settings. Be certain that you adjust the current so that the beam is a circle centered on the center of the scale; otherwise, you may be measuring a chord rather than the radius. *Perform a proper error analysis on these measurements.* Is *e*/*m* constant, independent of voltage?

2. Compare your measurements to known values.

3. Discuss the limiting factors in your measurement—for example, what would you try to improve first to make a better measurement? See the handout on calculating the magnetic field at the center of the two coils. You will need to ascertain the number of turns of wire. Rather than unwrapping the wire from its form, search the Web for the specifications of the apparatus.