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 the electron. By varying the applied voltage, we can control the velocity at which the electrons enter the magnetic field. From conservation of energy we have

$$\frac{1}{2}mv^2 = e\Delta V \qquad (1)$$

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

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

In this apparatus there is no convenient way to measure the velocity directly, 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

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

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

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

Substituting for v in Eq. (2), we find

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

and

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

Suggestions:

1. Measure the ratio *e/m* at various voltage and current settings. Make sure that *e*/*m* is constant, independent of voltage or current Be certain that you adjust the current and voltage 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 uncertainty analysis on these measurements.* You may look up the specifications of the power supplies and the digital multimeters, but it is probably safe to assume that the largest probable error is about 3 % off the full scale reading (as opposed to 3 % of the measured value).

2. Compare your measurements to the known value of *e/m*. Does the known value lie within your 95 % confidence interval?

3. Discuss the limiting factors in your measurement—for example, what would you try to improve first to make a better measurement?

For information on the e/m apparatus, Google "pasco e/m" and follow a link to the manufacturer, Pasco Scientific. Read the manual!