

Lab 3 e/m Ratio Tasks

First **full** report due Monday, October 5th at 6pm

Read the remainder of Ch. 1, Secs. 1.7-12 in your Lyons text (pp 21-39)

Safety/Equipment note: Adjust the high voltage and magnet current slowly. Make sure the current meter is connected to the 10A setting and the voltage to DC. Always turn the high voltage all the way down before turning off and make sure it is turned all the way down before turning on. Do not exceed 250V.

If a particle with charge q and mass m starting at rest is accelerated through a voltage V , it will have kinetic energy $\frac{1}{2}mv^2 = qV$. Subjected to a magnetic field B , it will start traveling in a circular orbit of radius R . From Newton's second law, the Lorentz force law, and the acceleration needed for a circular orbit: $F = qvB = ma = mv^2/R$. Solving these two equations yields $q/m = 2V/(BR)^2$. The voltage V can be measured with a multimeter, and the radius R with a ruler. The magnetic field B will be proportional to the measurable current I we run through the electromagnet. To get a precise value, we must know something about the geometry of the magnet. In our case we use Helmholtz coils to create the field, these coils are distinguished by the fact that their radii r are equal to the spacing between them. Integrating the Biot-Savart law, as you did in your introduction to electricity and magnetism, to find the field along their axis yields $B = (8\mu_0NI)/(5\sqrt{5}r)$ (see the Wikipedia article on Helmholtz coils for a derivation). For the coils in the experiment there are $N = 130$ turns.

Because the setup is enclosed in glass, measuring R with a ruler turns out to be a bit tricky. Instead, use a digital camera to take pictures of the circulating electrons. Write a module in *Mathematica* that extracts the radius of the circle for each photograph using three points that lie on this circle. You will need to be sure to take one photograph that has a known length scale in it to convert your measured radii in pixels into physical distances.

Find the ratio e/m for at least 20 different combinations of V , B , and R . Find the mean and standard deviation of your measurements. Next, plot $2V$ vs. $(BR)^2$ for your measurements, fit the plot to a straight line, and use this fit to find e/m . Address sources of error and discuss which method of finding e/m you think is best.