Lab 3 e/m Ratio Tasks

Lab report due Saturday, October 10th at 5pm

Read the whole of Ch. 1 in your Lyons text again (pp 1-39)

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 $B = (8\mu_o NI)/(5\sqrt{5}r)$ (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 functions in `Python` that extract the radius of the circle for each photograph using three points that lie on the circles. You will need to be sure to take photographs that have a known length scale in them 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 uncertainty and discuss which method of finding e/m you think is best.