The goal of this lab is to measure the ratio of the charge of the electron to its mass . We did this by shooting a beam of electrons at a known voltage perpendicular to a uniform magnetic field of a known strength ). This causes the beam of electrons to move in a circle due to the Lorentz force. By modeling the motion of the beam as due to a *centripetal* force, we can derive an expression for the ratio . Overlaying a coordinate system on a phosphorescent card allows us to measure the radius of the motion caused by the imaginary centripetal force and calculate explicit values for .

The force of a magnetic field of strength () on a charge moving at velocity throughout the field is represented by the equation

For our setup, we used Helmholtz coils (figure A) to create a magnetic field that is perpendicular to the duty of the electron beam. A Helmholtz coil consists of two identically oriented solenoids connected in series that are set apart from each other distance equal to their radius that are connected in series. The magnetic field moves perpendicular to the flow of current through the wires, and because the current flows the same way in each solenoid, the magnetic field near the geometric edge of each solenoid cancels out to create a uniform magnetic field perpendicular to the symmetrical plane of the solenoids.

We shoot the election beam perpendicular to the uniform magnetic field, so by the definition of the cross product [[1]](#footnote-1), the force the magnetic field exerts on the electron beam is

The direction of this force can be determines using the right-hand rule (see figure A).

This force, called the Lorentz force, causes the beam of electrons to move in a circle. In this instance, we can model the Lorentz force as a *centripetal* force, that is, the force that causes the electron of mass *m* to move at a speed in the motion of a circle with radius *r*. Such a force is expressed by

Our Lorentz force () and centripetal force () are equal, so

An electron shot out of an electron gun has a certain kinetic energy given by the equation

This energy is equal to the product of the electric potential (*voltage*) and charge of the electron (*q*), and this physical interaction is what causes the electron to move at velocity . This relationship is represented by the equation

Solving equation (1) for yields

Solving equation (2) for yields

Squaring (3) and setting it equal to (2),

The setup is depicted in figure B. A high voltage power supply is connected to an electron gun, which consists of a filament, two accelerator plates, and two deflector plates all housed in an evacuated tube. The Helmholtz coil is connected to another power supply, and the electron gun is housed in a glass ball between the solenoids of the Helmholtz coil. A phosphorescent card 8cm x 8cm with hash marks 1cm from the edge following the edge of the card is in the glass ball in which the electron gun is housed. When the electron beam hits the card, excites electrons in phosphorus which release photons when they return to their base energy level. This allows us to trace the path of the electron beam and determine the radius of the circle. We set up our coordinate system such that is at the corner of the card next to the accelerator plates (corner A) and ( is at the corner opposite (corner B), so the center of the circle has coordinates depending on the direction of the current. The equation of a circle with center is

If the beam intersects the hash marks at point distance from corner B, then the coordinates of are

Given that , where is the current and , and plugging equations (5), (6) into (4) yields

Which is the final expression we used to get the ration q/m

Using the final expression derived for q/m, we calculated a value of 1.49E+11 C/kg with a standard deviation of 1.33E+10. Our experimental mean was within 2 standard deviations of the literature value[[2]](#footnote-2) of ~-1.76E+11 C/kg, which is expected to occur 95% of the time[[3]](#footnote-3). I believe that there are several things that attribute to this expected but extremely high (10 orders of magnitude!) standard deviation. First, one of the solenoids on the Helmholtz coil my group used was bent. We also could not get the solenoids to be parallel, and these two things could have altered the path of the magnetic field, throwing off the path of the electron beam leading to inaccurate calculations of radii. Second, the instrumentation we used did not have the capacity to measure to the orders of magnitude of an electrons mass nor it’s charge, let alone the ratio of the two. Our ammeter only read to 3 decimal points, and our variable power supply was set via an analog dial. We did not have nearly enough precision to perform this calculation. Third, the phosphorescent card was knocked around multiple times during adjustments mid experiment, which would have thrown off our readings for the distance between corner B and the electron beam.

1. , where is the internal angle between vectors and . [↑](#footnote-ref-1)
2. “CODATA Value: Electron Charge to Mass Quotient.” Accessed September 3, 2017. <https://physics.nist.gov/cgi-bin/cuu/Value?esme>. [↑](#footnote-ref-2)
3. Lab sheet [↑](#footnote-ref-3)