**EXPERIMENT: THE CHARGE TO MASS RATIO OF THE ELECTRON**

[Equipment list: Helmholtz Coils, Electron Beam Tube, DC Power Supply (500 Volt, max.), Ruler]

**Overview:**

A charged particle having a mass m and charge q passing through a uniform magnetic field B with a velocity v will experience a force F upon it given by the following equation:

If the velocity is directed perpendicularly to the magnetic field, then the magnitude of the force is equal to:

This force is mutually perpendicular to both the velocity and the magnetic field. Since the force is perpendicular to the velocity the force causes the charged particle to move in a circular path making the force a centripetal force. We can rewrite this centripetal force in terms of the mass m of the particle, the velocity of the particle, and the radius r of the curved path that the particle is moving:

In this experiment the magnetic field is supplied by two coils, each having several equal turns of wire N. Named after Hermann von Helmholtz these two identical coils set apart from each other by a distance equal to the radius R of the coils generate a uniform magnetic field near the center between the two coils when a current I is passed through the coils of:

The permeability of free space, µo, is approximately equal to webers/(amp·meter).

A beam of electrons will pass perpendicularly through this generated magnetic field within a discharge tube. This large, bulbous, tube is placed centrally between the two coils. An electron gun emits a stream of electrons continuously within the tube. The tube is filled with Helium gas at a low pressure. The electrons interact with the Helium gas to generate a visible illuminated path of the electrons. The electron gun consists of a heater coil, a cathode, and an anode. The cathode is warmed and electrons “boil” off. They are then accelerated by a potential difference V between the cathode and anode. The electrons gain kinetic energy as they pass through this region. By the conservation of energy the final velocity of the electrons as they are emitted from the gun may be determined as:

Equations (4) and (5) are then substituted into equation (3), and e is substituted for q, to result in:

where

Helmholtz Coil

Electron Tube

Glass Rod

Electron Beam

Electron Gun

**PROCEDURE:**

1. Measure the radius of the Helmholtz coils with a meter stick. Take five measurements for various diameters and divide each by 2 to get radius. Calculate the average Radius and its associated uncertainty.

2. The number of turns of copper wire per Helmholtz coil is equal to 130 turns.

3. The various radii of the beam in the tube are designated on the Excel worksheet.

4. Make sure all dials are zeroed, and then turn the power on.

5. Adjust current to the first current value on the worksheet (1.8 amps).

6. Do not change I. By adjusting acceleration voltage, the electron beam radius adjusts to strike the different etched markings on the glass rod. Record these voltages on the Excel worksheet.

7. Reduce the D.C. current by 0.1 amps. Repeat steps 6 & 7 until you have enough data with magnetic field in same direction.

8. Find which ring gives the best average value for e/m.

**EQUIPMENT SHUT DOWN:**

1. Zero all controls before turning power supply off.

**Enter data and conduct calculations on the Excel worksheet for this experiment.**

**Calculate the average value for e/m for each radius and the associated uncertainties for these averages on the Excel worksheet.**

The accepted positive value for the charge of the electron (elementary charge) is equal to Coulombs.

The accepted value for the mass of the electron is equal to kilograms.

This results in a “handbook” value for the charge to mass ratio of the electron of:

Coulombs/kilogram.

**Comment on the following in the Results section of your lab report:**

How well do the average values of e/m for each radius agree with the “handbook” value? Is the handbook value within the range of values for each of your average values? Does one radius have a better agreement to the “handbook” value over the others?

Discuss the sources of uncertainty in this experiment. Which of these sources are systematic uncertainties and which of these sources are random uncertainties?

**Further Questions**

1. Why are electrons being used in this experiment? Could we not as easily determine the charge to mass of a proton **using this apparatus**?
2. In which direction should you align the **apparatus’ magnetic field** to minimize the effects of the Earth’s magnetic field on the circling electrons?
3. As you increase the accelerating voltage what happens to the path of the electron beam? Explain why this is happening.
4. When the current is decreased in the Helmholtz coil by 0.1 amps what happens to the path of the electron beam? Explain why this is happening.
5. The electron beam viewed in the tube can be seen to have a particular thickness to it. How does this relate to the amount of energy that each electron receives? What physically was done with the beam to minimize the uncertainty associated with this thickness?
6. What is the advantage of using two sets of coils to generate the magnetic field in this experiment as opposed to using just one coil centered about the electron tube? Make sure that you describe the reasoning why Helmholtz used these coils in a particular way in your answer.