Exp. 8: Charge to Mass Ratio of Electron

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Abstract

A study was done to determine the charge to mass ratio of an electron. This was done by using an electron gun and an electron beam tube to determine the centripetal force applied to a stream of electrons due to a magnetic field. The charge to mass ratio could be calculated with the formula . Using this formula, the charge to mass ratio was determined to be between the values 1.95E+11 and 2.29E+11.

Introduction

When a force is applied by a magnetic field to a charged particle with a velocity perpendicular to the field, the force can be expressed using the formula , where *q* is the particle’s charge, *v* is its velocity, and *B* is the magnetic field strength. Because the force and velocity vectors are perpendicular to each other, the force is a centripetal force. This means that the previous formula can be expressed as , where *m* is the particle’s mass, and *r* is the radius of the particle’s path. In this experiment, two coils with number of turns *N* are being used to produce the magnetic field. They are set apart from each other at a distance known as *R*. When a current *I* is run through the coils, the magnetic field strength can be expressed as , where is the permeability of free space with value . By equating the kinetic and potential energy of the electrons by the conservation of energy, a formula for the velocity can be expressed as , where *V* is the potential difference between the cathode and anode of the electron gun. By combining these three formulas, the charge to mass ratio of an electron can be expressed as , where *e* replaces *q*, and .

Procedure

In this experiment, the Helmholtz coils were measured five times to determine their average radius. *k2* was then calculated using the formula . A DC power supply was then used to supply a current of 1.8 amps to the electron gun. The accelerating voltage was then adjusted until the arc of electrons reached the 10 cm mark on the ruler inside of the electron beam tube. This voltage was then recorded, and this portion of the experiment was repeated four more times, with the arc reaching the 9, 8, 7, and 6 cm marks on the ruler each successive trial. This procedure was repeated identically three more times, with the current held at 1.7, 1.6, and 1.5 amps for the successive trials. The formula was then used to calculate the charge to mass ratio for an electron for each individual measurement and the average ratio for each set of measurements with matching radius.

Results

The average value for the charge to mass ratio of an electron was determined to be between 1.95E+11 for a radius of 5 cm and 2.29E+11 for a radius of 3 cm, with an uncertainty of 3.77E+9. While the value for a 5 cm radius is closest, these values are all marginally larger than the handbook value of 1.76E+11. This is most likely due to uncertainty in the amount of current supplied to the electron gun, or other uncertainties relating the pressure and quality of the helium in the electron beam tube.

Questions to be Answered

1. Electrons are being used because they are what are being supplied from the DC power supply. Protons cannot be emitted through a power supply.
2. The apparatus’ magnetic field should have its north pole aligned with Earth’s magnetic north pole and vice versa with their south poles.
3. The radius of the electron arc increases. This is due to the increase in centripetal force acting on the electron beam.
4. The radius of the electron arc decreases. This is because the velocity of the electrons decreases, weakening the centripetal force.
5. The thickness of the beam increases as the amount of energy in the electrons increases. A glass rod was used to decrease the thickness of the beam when they came into contact.
6. A singular coil centered around the tube would apply a semi-parabolic vertical force to the beam, making it harder to take accurate measurements. Two coils would apply a singular vertical force to the beam.