Measurement e/m for Electron

Lab Report 008

Professor Todd R. Gelbord
Report Written By Galib F. Rahman
PHYS 1442 Section D783
November 17, 2017

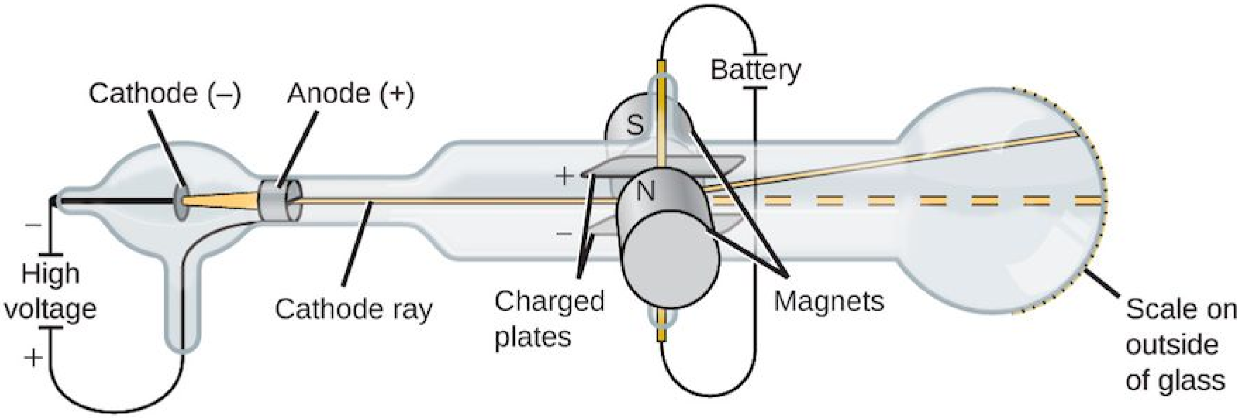
Table of Contents

Objective

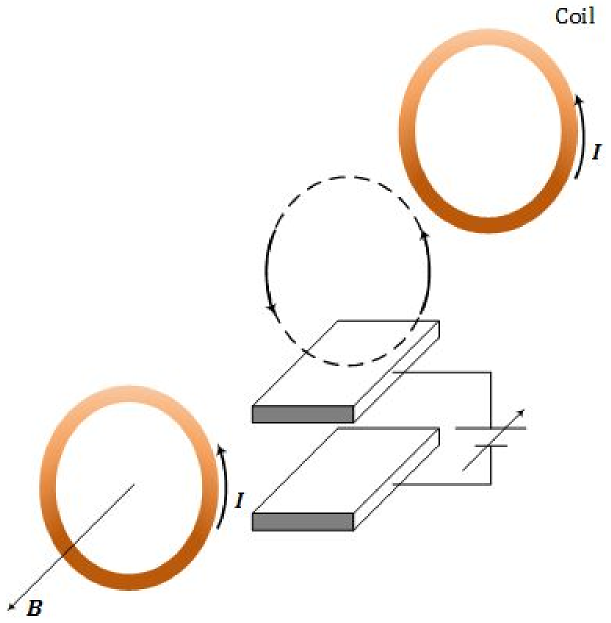
The purpose of this laboratory exercise is to determine the electron's charge to mass ratio (e/m), via observation of an electron beam's trajectory influenced by the electric and magnetic fields of a simplified version of Thomson's apparatus.

Theory

Joseph John Thomson performed an experiment, in which he successfully measured the ratio, e/m for an electron (in 1897). This experiment demonstrated that atoms contained charged particles, which we now call electrons. This was contrary to the ideas of his time, where it was believed that atoms were the only "*fundamental building blocks of matter*". Eventually, as people studied the characteristics of atoms in the presence of large electric fields, further evidence was discovered dissproving such an assumption.



In the 19th century physicists discovered that if a glass tube with a wire inserted, in both ends of said tube, and expelled of as much air as possible, an electric charge would travel across the tube and emit a fluorescent glow. Many debated whether or not the rays were waves or particles, which led to J.J. Thomson's three cathode ray experiments. In the first two cathode ray experiments Thomson proved that the negative charge and cathode ray were inseparable and that these rays consisted of negatively charged particles. In his third and final cathode ray experiment, he deduced the e/m ratio from the amount of particles that bent by various electrical currents. In his experimental findings, he discovered that the charge to mass ratio was 1.75881962 x 10^{11} C/kg.



In this laboratory exercise we use a similar apparatus to that of J.J. Thomson's. In the rear end of the evacuated tube, electrons are emitted by a hot filament, which are accelerated by the high voltage source. Upon passage through the narrow slit, the electrons form a narrow beam, which then passes through a uniform magnetic field *B*, perpendicular to the velocity of said electrons. Due to the magnetic field's deflection of electrons and their velocity, they follow a circular path, visible to the naked eye. (Left)

Materials

Adjustable High Voltage DC Power Supply

Digital DC Voltmeter

Adjustable Low Voltage DC Power Supply

Wire Conductors

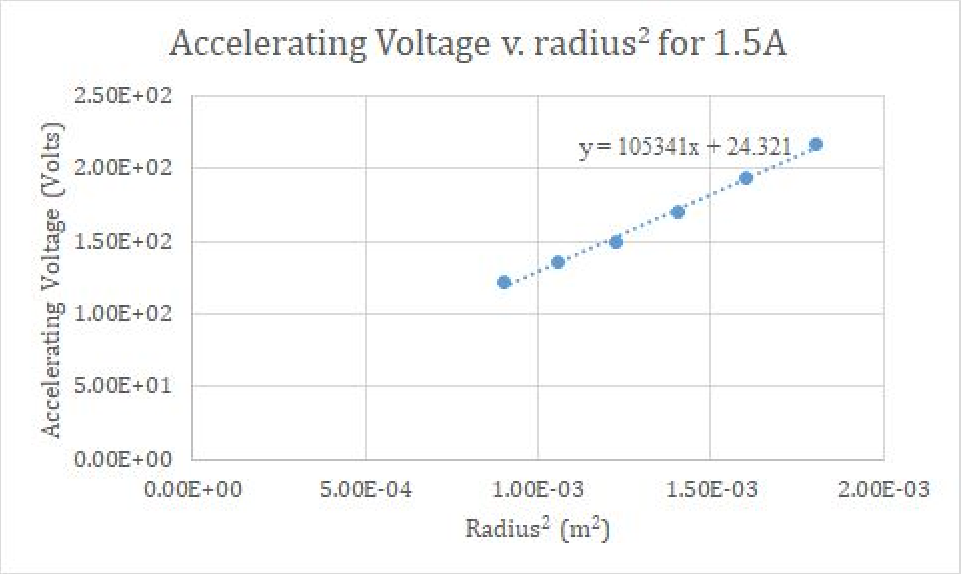
e/m Apparatus
[consisting electron tube & Helmholtz coils]

Procedure

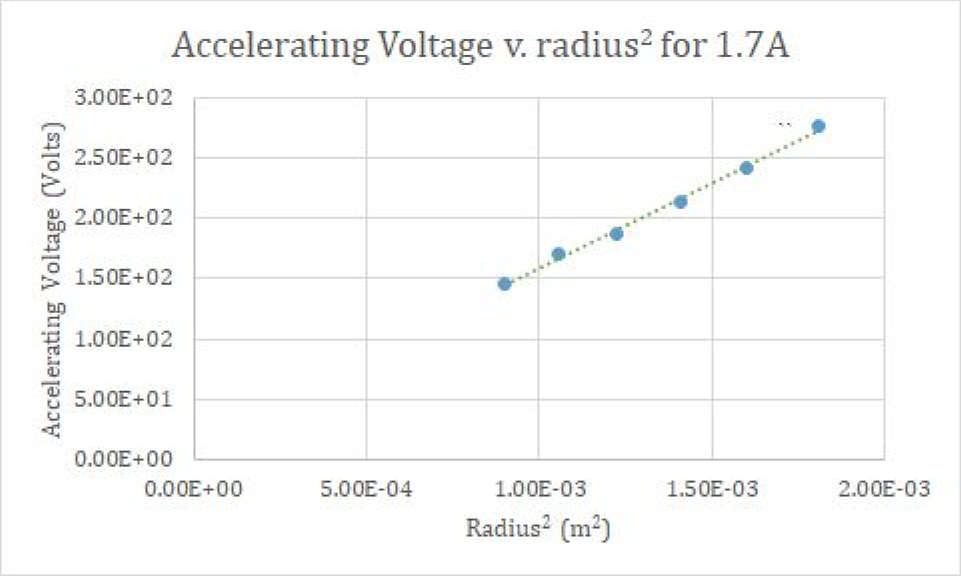
1. Record the number of turns and radius of the Helmholtz coil as displayed on the apparatus
2. Gradually turn the voltage knob gradually and turn on the power supply to 200 Volts
3. Supply 200 Volts from the power supply and notice a green trajectory in the tube.
4. Slowly turn the voltage knob that is connected to the Helmholtz coils to a potential of 12 volts and ensure the current does not exceed 1.3 Amps.
5. Turn the “coil adjustment current knob” clockwise and adjust the current within the range of 1.82 to 1.85 Amps and record.
6. Adjust the high voltage knob and until the circular beam illuminates the 6.5cm or 7cm diameter mark. Record the diameter observed and the voltage displayed by the power supply.
7. Increase the accelerating voltage slowly such that the diameter increases in increments of 0.5 cm . Record the diameters and the voltages displayed until the 9 to 9.5 cm mark
8. Repeat steps 6-7 with a different current value.

Data

Graphs



Accelerating Voltage v. radius^2 for 1.5A



Accelerating Voltage v. radius^2 for 1.7A

Computations & Source of Error

[All graphical computations were performed on Excel]

Sample Computations

$$B = \frac{8(1.26x10^{-6})(130)(1.5)}{\sqrt{125}\,(150 \times 10^{-3})} = 1.17 \times 10^{-3}\,T \;\; \rightarrow \;\; B^2 = (1.17 \times 10^{-3}\,T)^2 = 1.37\; \times 10^{-6}\,T^2$$

$$d = 6.0 \times 10^{-2}\,m$$

$$r = \frac{d}{2} = \frac{6.0x10^{-2}m}{2} = 3.0 \times 10^{-2}\,m$$

$$r^2 = \;(3.0x10^{-2}\,m)^2 = 9 \times 10^{-4}m$$

Questions

1. Using your experimental data for e/m and equation (4) compute the velocity of the electrons for each value of the accelerating voltage *V*. Discuss the range of the velocities and the electrons acquired in this experiment.

Velocity (m/s)	Voltage (V)	Velocity (m/s)	Voltage (V)
6.551E+25	1.22E+02	7.17E+25	1.46E+02
6.917E+25	1.36E+02	7.73E+25	1.70E+02
7.264E+25	1.50E+02	8.11E+25	1.87E+02
7.733E+25	1.70E+02	8.66E+25	2.13E+02
8.24E+25	1.93E+02	9.21E+25	2.41E+02
8.737E+25	2.17E+02	9.85E+25	2.76E+02

2. What would be the theoretical slope of the graph of *V* as a function of r^2?

   The theoretical slope of the graph of V as a function of r^2 would be close to e/m value, which is $1.76x10^{11}$ C/kg.

3. An electron at point A in Fig. 11.5 has a speed of $v = 6 \text{ x } 10^6$ m/s. Find the magnitude and the direction of the magnetic field that will cause the electron follow the circular trajectory. The diameter of the trajectory is 2 cm.

$$B = \frac{\frac{mv^2}{r}}{ev} = \frac{\frac{(9x10^{-31})(6x10^6)^2}{(\frac{2x10^{-2}}{2})}}{(1.6x10^{-19})(6x10^6)} = 3.375x10^{-3}T$$

Conclusion

In this laboratory experiment, we utilized a simplified version of Thomson's apparatus to measure the charge to mass ratio of an electron. Using the apparatus and data collected from the apparatus, we were able to deduce the e/m from the slope of the graph (multiplied by $2/B^2$) , Accelerating Voltage vs radius^2, up to a percent error of 10.7%.