Full Formal Report, Lab 2A: Charge to Mass Ratio

Andrew Rippy,[*] Caleb Powell, and Will Lillis
Department of Physics, Wabash College, Crawfordsville, IN 47933
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The goal of this lab was to measure the charge to mass ratio of an electron, using a glass apparatus filled with helium, and accelerating electrons through a potential. We measured the diameter of the circle and then given the strength of the magnetic field and the speed of the electron, we found the charge to mass ratio to be $1.9672810 \times 10^{11} \pm 0.0000093$ which did not match the expected value of 1.75^{11}

I. INTRODUCTION

In this lab, we will a glass apparatus full of helium in order to see the electrons (since they excite the gas). They will be accelerated through a potential, then their path will be bent into a circle with a magnetic field of known magnitude, created from two solenoids. The diameter of this circle will be directly related to the current through the solenoids, and the accelerating potential, V. From this, we can find the charge to mass ratio by plugging in the known constants, as well as the differing voltages and currents.

II. THEORETICAL MODEL

First, we must find an equation for the charge to mass ratio of the electron. We have:

$$\frac{e}{m} = \frac{8\Delta V}{B^2 D^2}$$

We know that the strength, B, of the magnetic field is:

$$(\frac{4}{5})^{\frac{3}{2}} \frac{\mu_0 N I}{R}$$

Substituting in B, we now have

$$\frac{e}{m} = \alpha \frac{\Delta V}{I^2 D^2}$$

Where α is

$$\alpha = \frac{8}{\left((\frac{4}{5})^{\frac{3}{2}} \frac{\mu_0 N}{R} \right)^2}$$

III. EXPERIMENT

A. Procedure

Two power supplies were connected to high accuracy voltmeters and ammeters. From the meters, they were connected to the apparatus. A dial controlled the accelerating potential, and another dial controlled the current for the solenoids. A third power supply gave power to the filament, and kept constant to avoid burning it out.

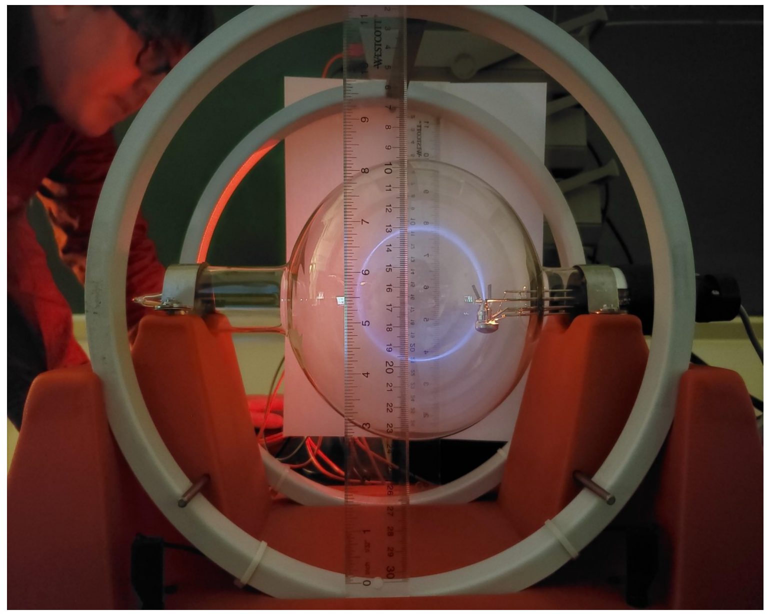

FIG. 1. A photo of the setup for the lab. There is a glass apparatus, connected to power supplies and meters. Two rulers are used to measure the diameter.

Two rulers, one behind the apparatus, and one in front of the apparatus, were used to measure the diameter of the resulting electron circle. Using the average of the two distances, we were able to find the diameter of the circle in the center. A picture was taken for each trial, the voltage and current were varied for each trial, and from the photo, the diameters were recorded.

B. Data

Originally, it was noted that the charge to mass ratio was off further than expected, so it was thought the curvature of the glass apparatus was a contributor. We went back and counted the ratio of front ruler centimeters to back ruler centimeters, if there was no impact, the ratio would be constant. However, this was not the case. Through the center of the sphere, the ratio was 1:1.6 (Front:Back) however near the edges it became 1:1.7 and 1:1.8. This would have an impact on the measured diameter, so based on how far the measurement went into

Diameter (m)	Voltage	Current	charge/mass ($\times 10^{11}$)
0.10695	294.9	1.3175	1.94
0.0905	209.87	1.3162	1.94
0.1107	209.86	1.0507	2.02
0.1004	261.87	1.315	1.97
0.10445	194.44	1.1377	1.81
0.1102	241.63	1.1494	1.98
0.0889	179.09	1.2168	2.01
0.1012	275.05	1.3395	1.96
0.10005	162.29	1.0243	2.03
0.0933	217.17	1.2751	2.02

TABLE I. Data with corrected Diameter based on ratios in ratio table

Front cm mark	ratio
$22 \rightarrow 21$	1.8
$21 \rightarrow 20$	1.7
$20 \rightarrow 13$	1.6
$13 \rightarrow 12$	1.8
$12 \rightarrow 11$	1.8

TABLE II. The ratio for the front cm measurement to the back cm measurement. Higher numbers than 1.6 indicate curvature at the edges

these edges, the corrections were made accordingly. To find the corrected back length, we use this equation:

$$b_c = b - \left(1 - \frac{1.6}{1.8}\right)a_1 - \left(1 - \frac{1.7}{1.8}\right)a_2$$

Where b is the uncorrected back length, a_1 is the length of the ruler that falls inside refraction zones with a ratio of 1.8, and a_2 is the length of the ruler that falls inside refraction zones with a ratio of 1.7.

IV. CONCLUSION

There still remained some error after the curvature corrections were added, which could be attributed to possible parallax of the phone camera, as well as the fact the phone was not in the exact same place each time for every picture, since each photo was checked to make sure it was readable. Also, the magnetic field may have not been exactly the calculated value, a fix to this would have been to use a magnetic field probe to find the exact magnetic field the electron was in. Also, the data wasn't saved correctly, so I had to look in my notebook, and only had the first 10 data points written down before they were put into excel. Overall, the measured value for the charge to mass ratio of $1.9672810 \times 10^{11} \pm 0.0000093$ within reasonable uncertainty did not match the expected value of 1.75×10^{11}.

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* anrippy22@wabash.edu