Lab 213: Measurement of E/M of an Electron

**Name: Arsh Bhamla, Kevin Gettler,
Stephanie Herrera-Chavez, Yosif Ismail** **Group: G**

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Course: PHYS 121A 016 **Instructor: Subodh Dahal**

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1. INTRODUCTION

1.1 OBJECTIVES

To get and measure the charge to mass ratio e/m for an electron. via the acceleration and circular motion of the electrons in a direction perpendicular to the uniform magnetic field generated by the Helmholtz coils. Using the magnetic field's voltage, radius, and intensity, we will calculate e/m.

1.2 THEORETICAL BACKGROUND

In this lab we begin a discussion on the second half of Physics 2, magnetism, and how it interacts with the electric forces that we introduced in the past several chapters. Reviewing our past formulas, we are familiar with:

$$Fe = \frac{kq1q2}{r^2}$$

$$E = \frac{Fe}{q} \rightarrow Fe = Eq$$

Then there is the force of a magnetic field, which is defined by the following:

$$Fb = q(v \times B) = |q|vBsin(\Theta)$$

We were then introduced to “Lorentz force”, a combined force which adds the force of an electric field and the force of the magnetic field. Its formula is:

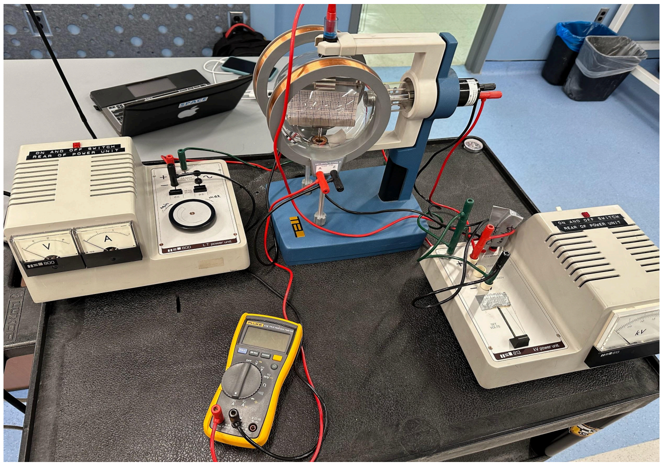
$$F = Eq + q(v \times B)$$

We can see that this formula is the combination of Fe, which is the force of the electric field, and Fb, which is the force of the magnetic field. Assuming that the magnetic field is at a 90 degree angle, we can make a substitution without the cross product. Another change is using the charge of an electron, which will be put in as e, but has a value of 1.6×10^{-19}. These substitutions create the following formula below:

$$eE = evB$$

The charges e would cancel out, giving us the formula for velocity, which can simply be expressed as the value of the electric field,

2. EXPERIMENTAL PROCEDURE



1. Assemble the CRT and attach the power supply to it.

2. Set the accelerating voltage to 3000 Volts.

3. Encircle the CRT with the Helmholtz coils and attach them to a power source.

4-Use the Gauss Meter to gauge the magnetic field's strength.

5. To strengthen the magnetic field, gradually increase the current flowing through the Helmholtz coils. The current has zero deflection.

6. Examine the electron beam's circular trajectory within the CRT.

7. Calculate the circular path's radius at various magnetic field intensities. Measure 6 points for X and Y on the path of the beam.

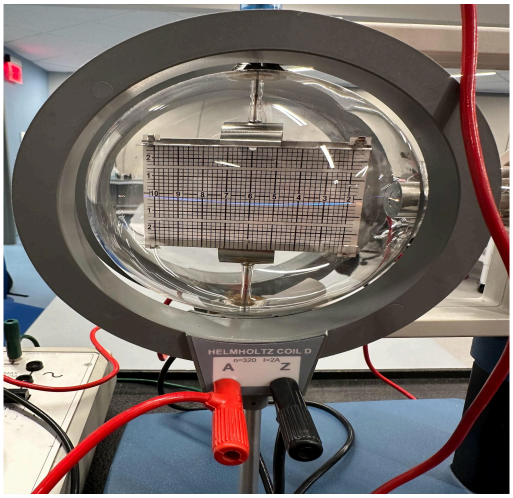
8. Note the electron beam's radius, magnetic field intensity, and accelerating voltage.

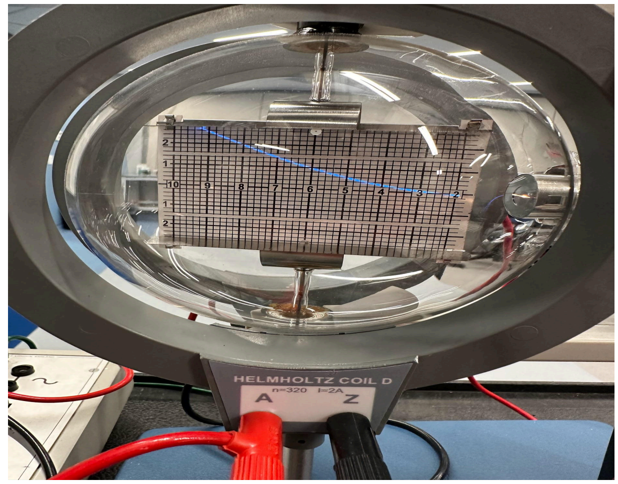
3. **RESULTS**

3.1 **EXPERIMENTAL DATA**

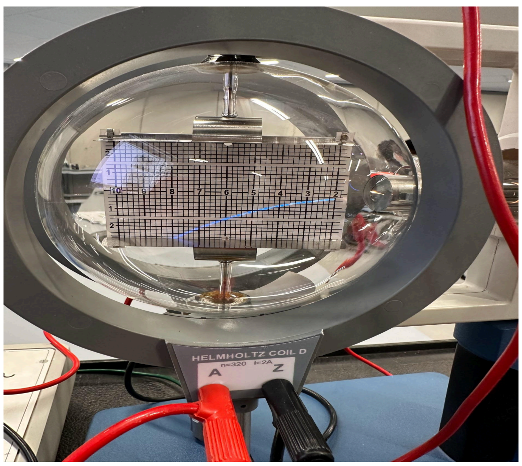
The expression for the charge-to-mass ratio (e/m) of the electron may be obtained by applying the centripetal and Lorentz force formula: eE=evB

<u>Case One</u>





Case Two



3.2 **CALCULATION**

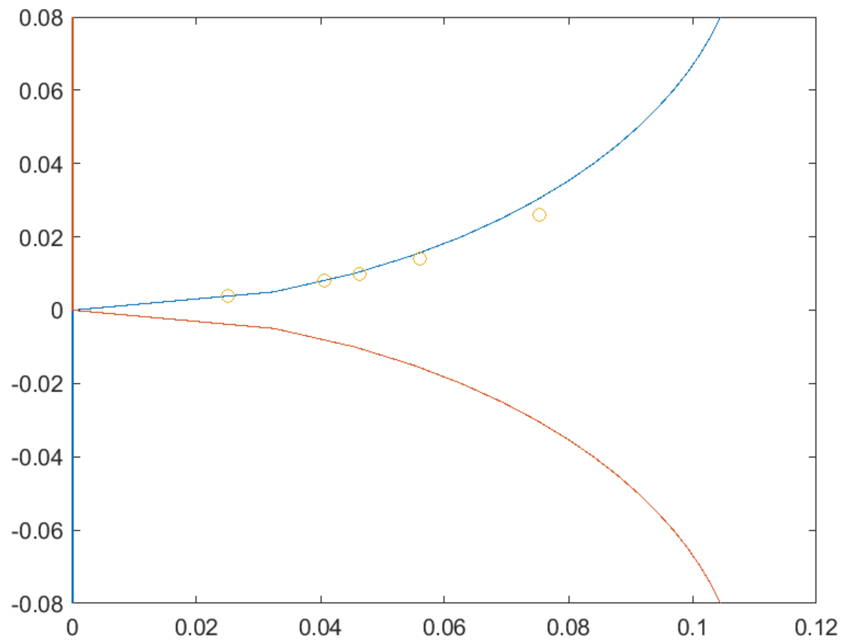
MatLab Code;

```
Xexp = [0.026 0.042 0.048 0.058 0.078]*cosd(15);
Yexp = [0.004 0.008 0.010 0.014 0.026];
Rexp = (Xexp.^2 + Yexp.^2)./(2*Yexp);
Rmean = mean(Rexp) ;
e = 1.6*10^-19;
me= 9.11*10^-31;
N = 320;
R = 0.068;
I = 0.376;
d = 5.2*10^-2;
Vp = 3.1*10^3;
B = 8.992*10^-7*N*I/R;
```

```
E = 0.77*Vp/d;
v = E/B;
x = 0.02:0.002:0.1;
y = -0.08:0.005:0.08;
x = sqrt(2*y.*Rmean - y.^2);
plot (x, y, x, -y, Xexp, Yexp, 'o')
Rexp
Rmean
ratio_theory =  e / me
ratio_exper = v/(Rmean*B)
percent_error = (ratio_exper - ratio_theory)/ratio_theory*100
e_over_m = 2*v^2*Yexp./(E*(Xexp.^2+Yexp.^2));
```

Result:

Rexp	0.0808 0.1069 0.1125 0.1191 0.1222
Rmean	0.1083
ratio_theory	1.7563e+11
percent_error	-4.6561



4. **ANALYSIS and DISCUSSION**

This lab was a visual way to understand how electric speed works and Electric voltage. Before we could input the code into MATLAB and make changes, we had to understand its purpose and the desired result. Furthermore, we had to understand how MATLAB works in order to properly create, edit, and print the figures. The physics concepts and formulas for the electric and magnetic fields, along with the centripetal force formulas from Physics I: Mechanics, were applied in all experimental parts of this Measurement of e/m for an Electron Lab 212 to arrive at a reasonable experimental value for the e/m ratio of the electron. The first part of the experiment measured the electron's velocity in relation to the electric field's strength divided by the magnetic field's strength. A formula for the electron's velocity was then derived using the physics law or principle that states that the electric field's magnitude is equal to the magnetic field's magnitude. the centripetal force, electric field, and magnetic field formulae and concepts from Physics I: To determine an appropriate experimental result for the electron's e/m ratio, mechanics were used to all experimental components of this Measurement of e/m for an Electron Lab 212.Using the physics law, or principle, that the strength of the electric field equals the strength of the magnetic field, the first part of the experiment focused on calculating the electron's velocity in relation to the electric field's strength divided by the magnetic field's strength. This allowed for the calculation of the electron's velocity. The assessment of this formula resulted in the following expression for the electron's velocity in terms of the intensity of the magnetic field and the electric field. 4 % was our deviation error percentage. Several factors contributed to the experimental inaccuracy, including incorrectly calibrating the voltmeter and ammeter and adjusting the electric and magnetic field strengths. Therefore, while employing the laboratory apparatus, the precise magnetic field value and electric field value would not have been measured. The error might be from human error because small mistakes could lead to errors.

5. **CONCLUSIONS**

In this experiment, we saw that an electron beam moving in a circular orbit of radius r was affected by both an electric and magnetic field. The accelerating voltage determines the radius, r. The circular orbit's radius, r, grows as the accelerating voltage rises. We can see a straight line on the graph of the accelerating voltage against the square of the radius. Overall, this experiment enhanced our understanding of fundamental electrical principles and also demonstrated the relationship between voltage and velocity in a real-world scenario. By employing a cathode ray tube and magnetic deflection, the experiment was able to accurately determine the charge-to-mass ratio (e/m) of an electron. Electron behavior in a magnetic field and the fundamentals of electromagnetic theory are validated by the near match between the calculated and accepted values. The key that can assist us in determining the voltage and velocity is the magnetic and electric fields. Even if the charge to mass ratio has nothing to do with the idea of a magnetic field, it is nevertheless a useful transformation to have a deeper understanding of it.

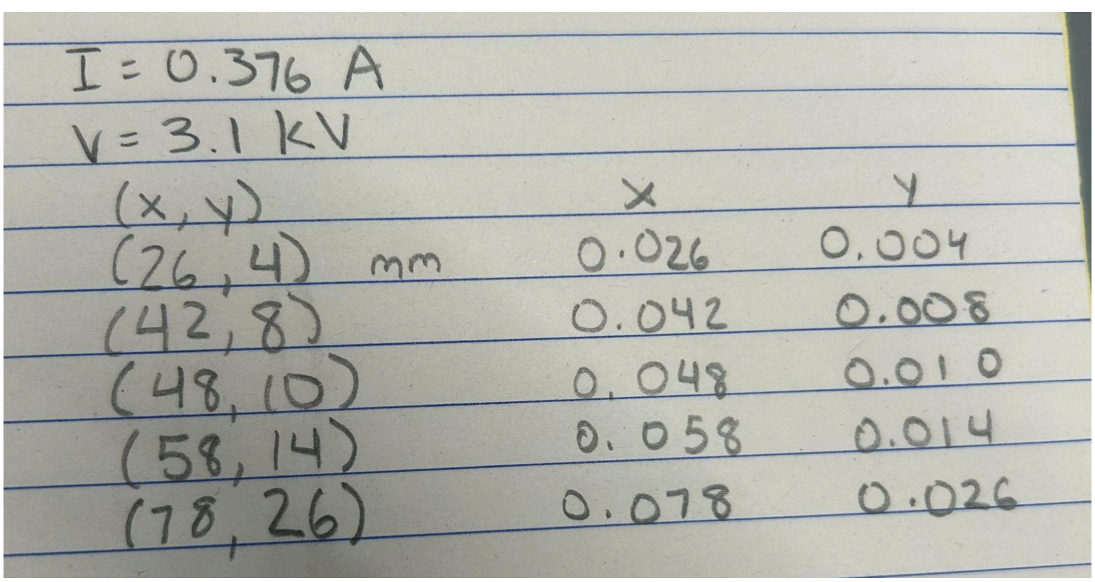
Questions:

1- 4 % was our deviation error percentage. Several factors contributed to the experimental inaccuracy, including incorrectly calibrating the voltmeter and ammeter and adjusting the electric and magnetic field strengths.

2- While employing the laboratory apparatus, the precise magnetic field value and electric field value would not have been measured.

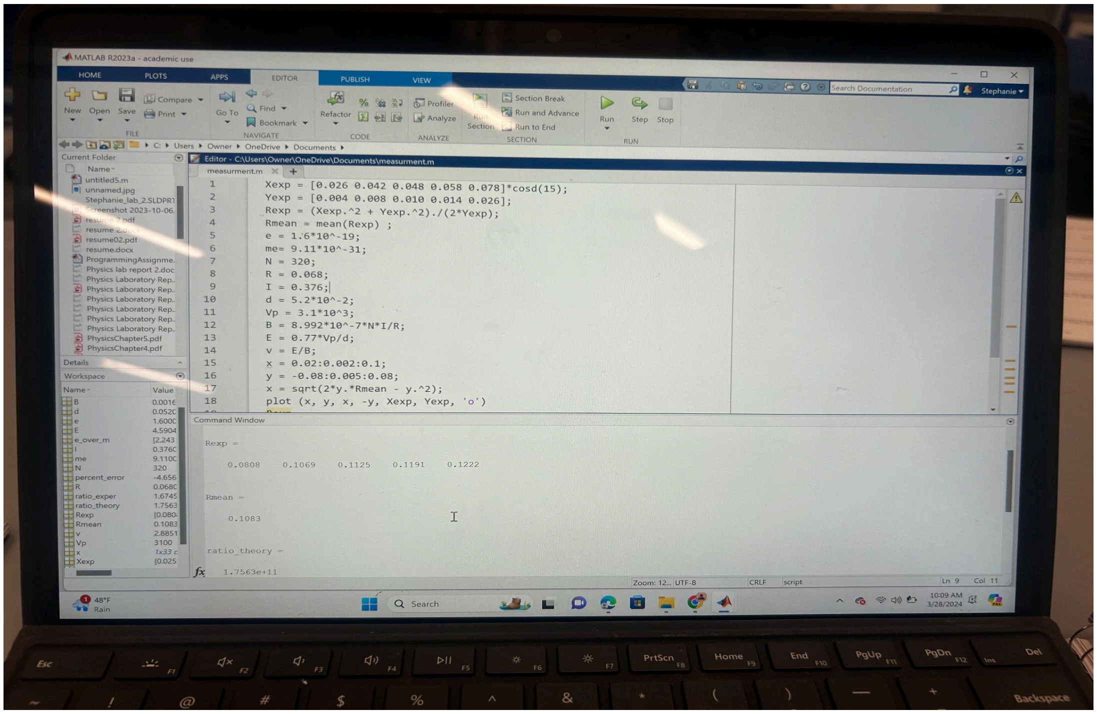
3- The error might be from human error because small mistakes could lead to errors.

6. **RAW DATA**



I = 0.376 A
V = 3.1 kV

(x, y)	x	y
(26, 4) mm	0.026	0.004
(42, 8)	0.042	0.008
(48, 10)	0.048	0.010
(58, 14)	0.058	0.014
(78, 26)	0.078	0.026


MATLAB R2023a - academic use
Editor - C:\Users\Owner\OneDrive\Documents\measurment.m
measurment.m
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Command Window
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