

Lab XXI
Measurement of e/m_e
Section 063

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Aim

The purpose of this experiment was to observe how electric and magnetic fields affected the trajectory of electrons. It was also to calculate the e/m_e ratio using the motion of the electron in the fields.

Apparatus

An electron gun was used provide a beam of electrons. Two deflection plates were used to create an electric field, and a screen with a grid was used to visually measure the trajectory of the electrons. A variable power source generator was used to power the electron gun.

Principle

The main idea behind this experiment was that electrons are affected by electric and magnetic fields. Both electric fields and magnetic fields affect the trajectory of a moving electron by providing an accelerating force. This happens because both the electron and the field are charged so there is a resulting the force between the two.

In a transverse electric field, the electron moves in a parabolic path, where as in a magnetic field the electron moves in a circular path.

In a magnetic field the force of the field is always perpendicular to the velocity of the electron. This is what causes the radial motion of the particle. In an electric field, the direction of the force is always in one direction, and this causes a parabolic trajectory.

The e/m_e ratio can be calculated as a relation to the ratio of E/B . The simplified formula for calculating e/m_e is:

$$\frac{e}{m_e} = \frac{125}{128m} \left(\frac{R}{\mu_0 d N} \right)^2$$

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5 Data

Table XXI.3: Anode slit position

$$x_s = 0$$

$$y_s = 0$$

Table XXI.4: Electrostatic deflection of electron beam

x_{grid} [cm]	y_{grid} [cm]	x [m]	y [m]	x_{grid} [cm]	y_{grid} [cm]	x [m]	y [m]
2	.1	.02	.001	3	.1	.03	.001
2.8	.2	.028	.002	4	.2	.04	.002
3.4	.3	.034	.003	4.6	.3	.046	.003
4.0	.4	.04	.004	5.3	.4	.053	.004
4.4	.6	.044	.006	6.0	.5	.060	.005
5.2	.8	.052	.008	6.4	.6	.064	.006
5.4	.9	.054	.009	7.0	.7	.070	.007
5.6	1.0	.056	.01	8.1	1.0	.081	.01
6.2	1.2	.062	.012	9.8	1.2	.088	.012
6.6	1.4	.066	.014	9.5	1.4	.085	.014

Polynomial Fit: $y = f(x) = (C_2)x^2 + (C_1)x + C_0$

$C_2 = 4.1536$

$C_1 = -.0273$

$C_0 = .0007$

$C_2 = 1.8204$

$C_1 = -.0273$

$C_0 = .0003$

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Table XXI.5: Deflection of electron beam in magnetic field

#	x-coordinate [cm]	y-coordinate [cm]	$\frac{x^2+y^2}{2y}$
1	<u>2.0</u>	<u>-.4</u>	<u>-5.2</u>
2	<u>2.4</u>	<u>-.5</u>	<u>-6.01</u>
3	<u>2.8</u>	<u>-.6</u>	<u>-6.93</u>
4	<u>3.0</u>	<u>-.7</u>	<u>-6.78</u>
5	<u>3.1</u>	<u>-.8</u>	<u>-6.41</u>
6	<u>3.8</u>	<u>-1.0</u>	<u>-7.72</u>
7	<u>4.0</u>	<u>-1.1</u>	<u>-7.78</u>
8	<u>4.2</u>	<u>-1.2</u>	<u>-7.95</u>
9	<u>5.0</u>	<u>-1.7</u>	<u>-8.20</u>
10	<u>5.4</u>	<u>-2.0</u>	<u>-8.29</u>

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Table XXI.6: Crossed E and B fields: Energy vs. coil current for undeflected trajectory

$$N = 320 \text{ turns}$$

$$R = 0.068 \text{ m turns}$$

$V_C = V_D$ [V]	I [A]	I^2 [A ²]	E [V/m]	B [T]	$v = E/B$ [m/s]
2000	<u>.27</u>	<u>.0729</u>	<u>40000</u>	<u>1.14×10^{-3}</u>	<u>3.5×10^7</u>
2500	<u>.29</u>	<u>.0841</u>	<u>50000</u>	<u>1.23×10^{-3}</u>	<u>4.07×10^7</u>
3000	<u>.33</u>	<u>.1089</u>	<u>60000</u>	<u>1.40×10^{-3}</u>	<u>4.30×10^7</u>
3500	<u>.35</u>	<u>.1225</u>	<u>70000</u>	<u>1.48×10^{-3}</u>	<u>4.73×10^7</u>
4000	<u>.37</u>	<u>.1369</u>	<u>80000</u>	<u>1.57×10^{-3}</u>	<u>5.1×10^7</u>
4500	<u>.39</u>	<u>.1521</u>	<u>90000</u>	<u>1.65×10^{-3}</u>	<u>5.45×10^7</u>
5000	<u>.42</u>	<u>.1764</u>	<u>100000</u>	<u>1.78×10^{-3}</u>	<u>5.63×10^7</u>

Table XXI.7: Calculation of e/m_e

Slope of I^2 vs. $V_D^2/V_C =$

3.39×10^{-5}

Experimental value of $e/m_e =$

3.30×10^{-11}

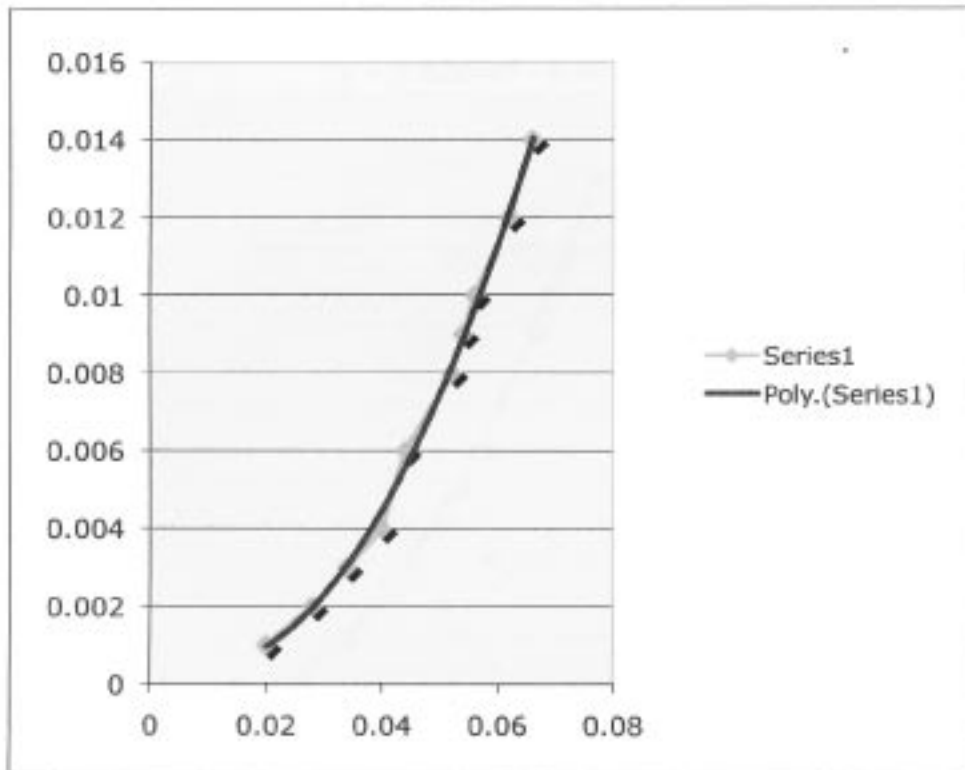
Accepted value of $e/m_e =$

1.76×10^{-11}

$$\% \text{ difference} = \frac{(\text{Experimental Value}) - (\text{Accepted Value})}{(\text{Accepted Value})} \times 100\% =$$

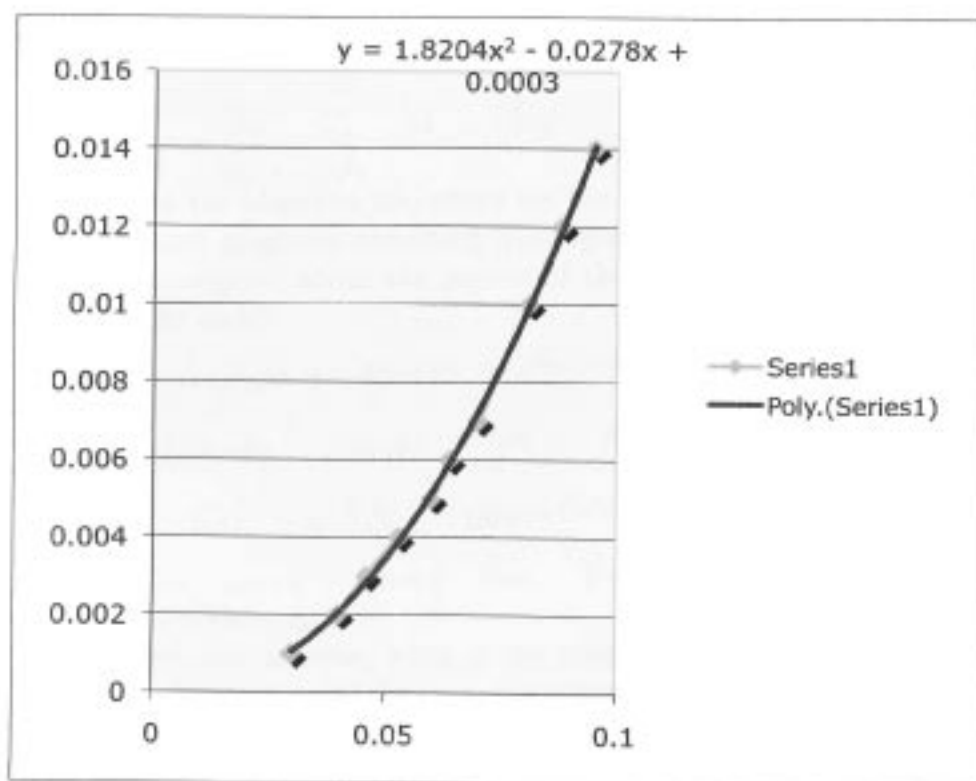
87.5%

2	0.1	0.02	0.001
2.8	0.2	0.028	0.002
3.4	0.3	0.034	0.003
4	0.4	0.04	0.004
4.4	0.6	0.044	0.006
5.2	0.8	0.052	0.008
5.4	0.9	0.054	0.009
5.6	1	0.056	0.01
6.2	1.2	0.062	0.012
6.6	1.4	0.066	0.014



BE SURE TO LABEL ALL OF YOUR GRAPHS!!!

0.03	0.001
0.04	0.002
0.046	0.003
0.053	0.004
0.06	0.005
0.064	0.006
0.07	0.007
0.081	0.01
0.088	0.012
0.095	0.014



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6 Conclusions

1. How does the observed trajectory for the motion of an electron beam through a transverse electrostatic deflecting field agree with theory? What is the significance of the coefficient C_2 for the trajectory? Compare C_2 for the cases where $V_D = V_C$ and $V_D = 0.5V_C$.

It agrees with the theory because the beam is deflected and has a curved trajectory because of the electrostatic field. The C_2 indicates the acceleration caused by the field. The C_2 is 4x greater when $V_D = V_C$ than when $V_D = 0.5V_C$.

2. How does the observed trajectory for the motion of an electron beam through a transverse magnetic deflecting field agree with theory? Is r constant? What does this suggest about the nature of the field inhomogeneity away from the axis of the coils?

The trajectory agrees with the theory by moving in a relatively circular shape. R is very close to constant, but still has a little variation. This suggests that as you move away from the axis, the field becomes more inhomogeneous.

3. In the velocity selector, what is the observed relationship of $V_D = V_C$ to the current, I , in the coils? From a theoretical viewpoint, why is this so?

As the V increases, the I increases. This is because the resistance does not increase so I has to increase to account for the increase in V since $V = IR$.

4. What is the percent deviation of the measured value of e/m_e from the accepted value? What effects or experimental limitations have led to that deviation?

87% deviation. One limitation that affected the experiment was that the measurements were made by eye.