Introduction

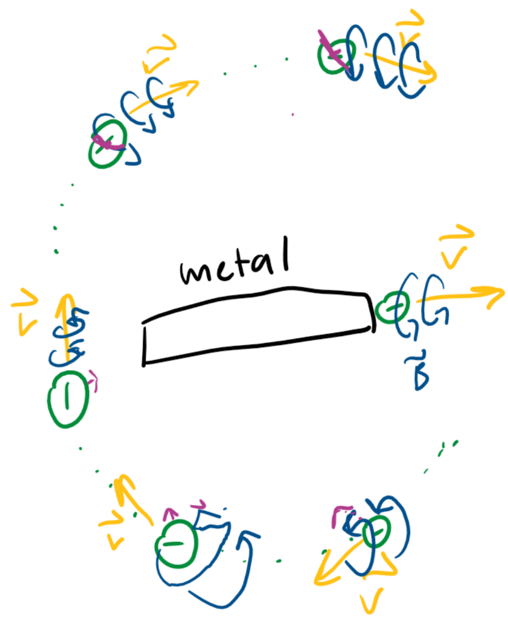
In this lab, the ratio of q/m will be examined using a Novel Prize winning experiment.

Theory

2) The specific goal of this lab is to simulate JJ Thomson's cathode ray experiment and walk step by step through his experimental process to better understand how he developed his theory surrounding the electron.

3) Observe the current's effect on the diameter of the electron beam, record the measurements of the current and voltage supplied to the apparatus.

4)



5)

a) Electrical force

b) Magnetic force

6) final velocity

a)

$$\Delta U = q\Delta V$$

$$\Delta K + \Delta U = 0$$

$$\Delta E_k + \Delta E_p = 0$$

$$\frac{1}{2} m \Delta v + q\Delta V = 0$$

$$v_1 = 0$$

$$\frac{1}{2} m v_2 + q\Delta V = 0$$

$$\frac{1}{2} m v_2 = -q\Delta V$$

$$\frac{1}{2} m v_2 = -(-e)\Delta V$$

$$\frac{1}{2} m v_2 = e\Delta V$$

b)

$$v = \sqrt{\frac{2e\Delta V}{m}}$$

7) There is centripetal acceleration due to the magnetic field.

8)

$$|\vec{F}_M| = |qv \sin\theta|$$

$$= |qv \sin 90|$$

$$|\vec{F}_m| = |qv|$$

9)

$$r = \frac{m|\vec{v}|}{q|\vec{B}|}$$

10)

$$r^2 = \frac{\left[2\left(\frac{m}{e}\right)\Delta V\right]}{|\vec{B}|^2}$$

11) By plotting r^2 and $1/B^2$ on the y and x axis, the slope can be used to divide 2*voltage to obtain e/m.

Procedure

Helmholtz coils oriented 15◦ east were used in this lab. The machine was

1. Turn on all power. The filament should start glowing red after 30 seconds.
2. Slowly increase the accelerating voltage until a voltage of 250V is reached or a strong blue green beam emits from the anode.
3. Slowly increase the current supplied to the coils. If the beam doesn't bend in a circular path there might be an issue with your equipment or setup. If the beam doesn't complete a circular path, increase the accelerating voltage by 50V. If the beam bend in the opposite direction desired, reverse the direction of the magnetic field. Voltage might need to be adjusted to obtain a visible beam.
4. Change the radius of the beam by adjusting the coil current. Record the current, voltage, and diameter of the beam. Repeat this step for at least 10 unique diameters.

Results and Calculation

Voltage of 296V. The coils had a diameter of 15 cm. Uncertainty of r^2 = 0.000921109. Uncertainty of $1/b^2$=84729.82439.

Current	Diameter (cm)	v beam	B
2.62	10	14.4	0.00204173
2.44	11	13.5	0.001901458
2.11	12	11.6	0.001644294
2.05	13	11.2	0.001597537
1.88	14	10.3	0.001465058
1.3	20	7.1	0.001013072
1.78	15	0.97	0.001387129
1.68	16	0.92	0.001309201
1.61	17	8.8	0.001254651
1.51	18	8.3	0.001176722
1.41	19	7.7	0.001098793
1.28	21	7.1	0.000997486

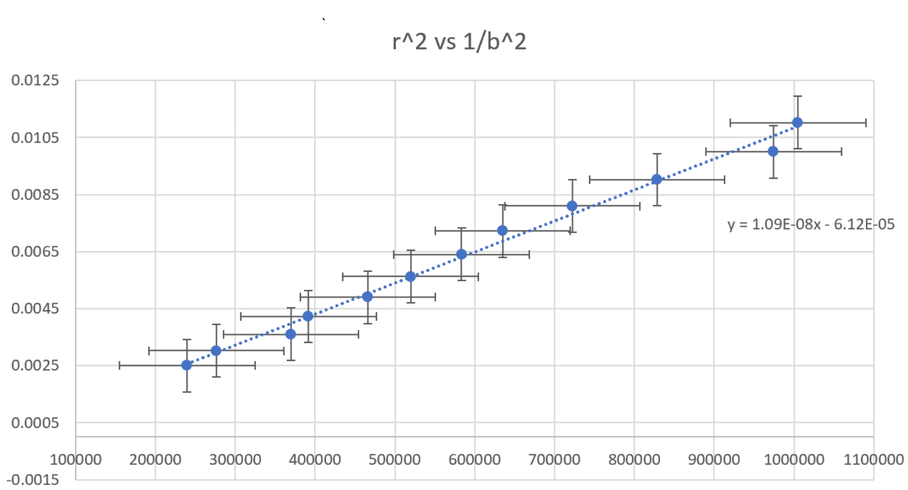
$$\frac{e}{m} = \frac{2\Delta V}{\text{slope}}$$

$$= \frac{2(296)}{1.09\times10^{-8}}$$

$$\frac{e}{m} = 5.4312\times10^{10}$$

$$\% = \frac{|T-E|}{T}\times100$$

$$\% = 69.12\%\ \text{error}$$



Discussion and Conclusion

1. Bring a magnet close to the electron beam. Does the beam show a deflection as a result of the bar magnet? Does it move in the way you expected it to? Record your observations.
   a. The brightness of the beam appeared to increase as the magnet was brought closer to the bulb.
2. What is the direction of the magnetic field in your experiment? Explain your reasoning using Figure 1, assuming the electron is traveling in a counter clockwise circle in the plane of the page
   a. If the election is travelling in a counter clockwise circle, using the right hand rule, the direction of magnetic field should be towards from the viewer.
3. Suppose ΔV is kept fixed so that the speed of the electrons is constant. Which electron has a larger acceleration: one traveling in a tight circle (small r), or one traveling in a big circle (larger r)? Explain your reasoning. Which electron has a larger force acting on it: one traveling in a tight circle (small r), or one traveling in a big circle (larger r)? Explain your reasoning. Is this consistent with the results you observed in the experiment? Explain.
   a. The electron travelling in the tighter circle has the higher acceleration. The acceleration the electron experiences is essentially centripetal acceleration, which has the formula v^2/r. Therefore, a larger radius should yield a lower acceleration.
   b. This generally seems to be true. As the radius increased, the velocity of the particle decreased. If velocity decreases, so will acceleration. Therefore this is accurate.
4. Imagine you are J.J. Thomson performing this experiment for the first time. The only known particle at the time (the proton) has mass 1.67×10^{27} kg and charge $q_p = 1.602\times10^{-19}$C. Based only on your observations, could the beam of particles you observe be protons, or could you claim the discovery of another particle? Explain your reasoning.
   a. Based on the observation, the discovery of another particle could be claimed. The e/m ratio of a proton based on these measurements would 1.04244×10^{46}, however the calculated e/m is several times smaller than this value. Therefore, this couldn't be the same particle, and must be a new object.
5. Suppose you had your accelerating voltage at ΔV1 and the Helmholtz coil current was set so that the diameter of the electron path is 6.0cm. If you changed the accelerating voltage to ΔV2 (see Table 1), what would you predict would be the new path diameter? Make a concrete prediction including uncertainty.
   a. I predict that the new path diameter will increase to 8.0 cm. The more power supplied to the electron means the faster it can move, and therefore the larger radius it can cover using the same amount of current.
6. When you are ready with your prediction, use the apparatus to test it. Turn back on the apparatus with the accelerating voltage at ΔV1 (see Table 1) and a path diameter of 6.0 cm. Then, keeping the magnetic field fixed, increase the accelerating voltage to ΔV2 (see Table 1) and measure the new path diameter. Record your result with uncertainty and compare with your prediction.
   a. The new diameter was around 10.0 cm(+-0.05cm). My prediction was correct, but the numerical values were incorrect.