The e/m ratio: Lab Notebook

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Experimental Apparatus

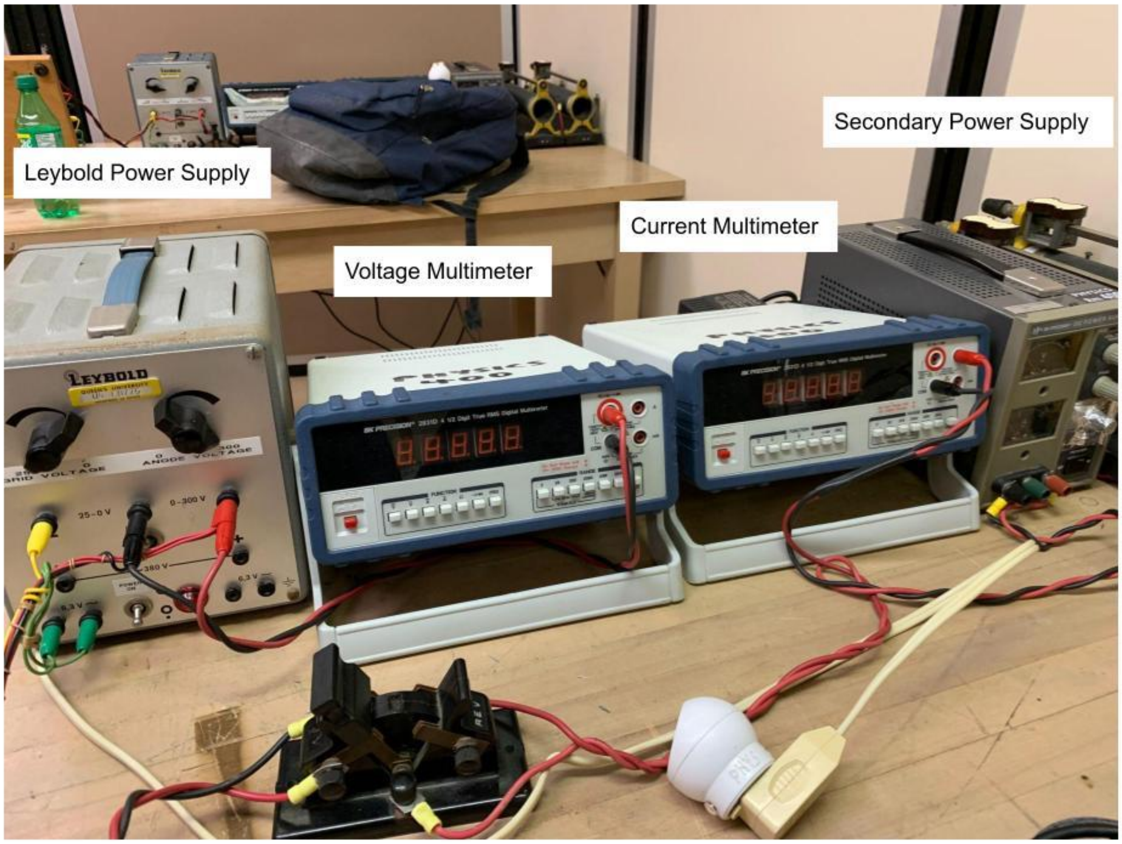

Figure 1: Power supplies and multimeters used during the experiment.

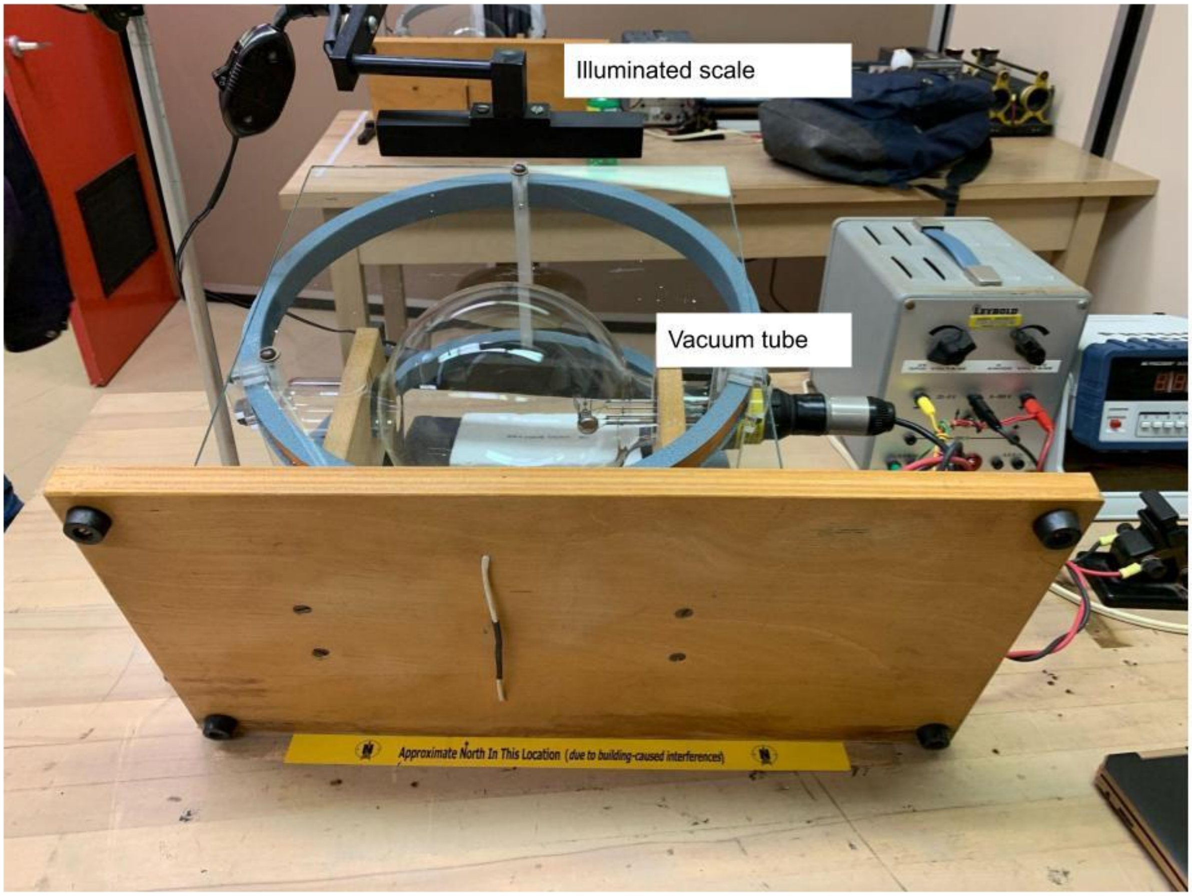

Figure 2: Setup used to perform the experiment

Procedure

- The Leybold power supply was turned on and allowed to heat up.
- The illuminated scale was positioned parallel to the glass plate.
- Once the filament was warm, the vacuum tube was rotated until the plane of the beam was parallel with the illuminated scale.
- The DC power supply shown in Figure 1 was increased from 150 V to 250 V in increments of 20 V. At each voltage, the current was increased using a secondary power supply to create a circular beam with a diameter of 8.00 ± 0.05 cm. The current and voltage were recorded using the digital multimeters shown in Figure 1. The measurements were recorded in Table 1.
- The uncertainty of the diameter was taken to be half of the smallest division of the scale. For both digital multimeters, the uncertainty was taken to be ± 1 digit, as was recommended in the lab manual.

Table 1: Clockwise electron beam data collected for D = (8.00 ± 0.05) cm.

Voltage ±0.1 [V]	Current ±0.001 [A]
149.6	1.277
170.4	1.359
190.1	1.449

209.4	1.534
230.0	1.614
250.2	1.688

- Next, the vacuum tube was rotated 180 degrees and the polarity of the current was reversed. The previous process was followed again to collect the data shown in Table 2.

Table 2: Counter-clockwise electron beam data collected for D = (8.00 ± 0.05) cm.

Voltage ±0.1 [V]	Current ±0.001 [A]
150.3	1.124
170.0	1.226
189.6	1.320
209.9	1.400
229.4	1.472
249.9	1.556

- This process was repeated again, this time adjusting the current to get a diameter of 10.00 ± 0.05 cm.

Table 3: Clockwise electron beam data collected for D = (10.00 ± 0.05) cm.

Voltage ±0.1 [V]	Current ±0.001 [A]
149.9	1.004
170.0	1.09
189.8	1.166
210.0	1.235
230.0	1.289
249.7	1.350

Table 4: Counter-clockwise electron beam data collected for D = (10.00 ± 0.05) cm.

Voltage ±0.1 [V]	Current ±0.001 [A]
149.8	0.888
170.3	0.961
189.9	1.032
209.9	1.102
229.8	1.163
250.3	1.224

- The magnetic field in Kingston was found to have a magnitude of 53337.5 nT [1].

Preliminary Calculations

Using the data for the D = 8 cm beam, the magnetic field of the Earth B_E and the charge to mass ratio e/m were estimated.

Table 5: Values used in preliminary calculations.

Variable	Value
r	4.00 cm
r/R	0.2

B/B_0	0.99928
K	7.73x10^{-4} T/A

$$B_T = \frac{K_r}{2}(I_l + I_s) \tag{1}$$

$$B_E = \frac{K_r}{2}(I_l - I_s) \tag{2}$$

$$K_r = \frac{B}{B_0}K \tag{3}$$

$$\frac{e}{m} = \frac{2V}{B_T^2 r^2} \tag{4}$$

Using equation (3) with $B/B_0 = 0.99928$, and $K = 7.73 \times 10^{-4}\ \mathrm{T/A}$:

$$K_r = \frac{B}{B_0}K = (0.99928)(7.73 \times 10^{-4}\ \mathrm{T/A})$$

$$K_r = 7.7244 \times 10^{-4}\ \mathrm{T/A}$$

Using this value in equation (1) with $I_l = 1.6880\ \mathrm{A}$, and $I_s = 1.5560\ \mathrm{A}$:

$$B_T = \frac{K_r}{2}(I_l + I_s) = \frac{(7.7244 \times 10^{-4}\ \mathrm{T/A})}{2}(1.6880\ \mathrm{A} + 1.5560\ \mathrm{A})$$

$$B_T = 0.00125\ \mathrm{T}$$

Equation (4) can than be used to estimate the charge to mass ratio by taking $V = 250\ \mathrm{V}$:

$$\frac{e}{m} = \frac{2V}{B_T^2 r^2} = \frac{2(250\ \mathrm{V})}{(0.00125\ \mathrm{T})^2(0.04\ \mathrm{m})^2}$$

$$\frac{e}{m} = 1.99 \times 10^{11}\ \mathrm{C/kg}$$

Based on the accepted charge to mass ratio of $1.75882 \times 10^{11}\ \mathrm{C/kg}$, the experimental value is within 14%.

The magnetic field in Kingston was calculated using equation (2):

$$B_E = \frac{K_r}{2}(I_l - I_s) = \frac{(7.7244 \times 10^{-4}\ \mathrm{T/A})}{2}(1.6880\ \mathrm{A} - 1.5560\ \mathrm{A})$$

$$B_E = 5.0981 \times 10^{-5}\ \mathrm{T}$$

Thus, the estimated magnetic field is within 5% of the actual value on the day.

References

[1] https://www.magnetic-declination.com/Canada/Kingston/335755.html#:~:text=Answer%3A%20%2D12.13%C2%B0%20(%2D12%C2%B07')]