ENPHYS253

Lab 6: e/m Ratio

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# Results and Analysis

Using Eq. 1, the K­­r for the 4cm and 5cm electron radius was determined to be (771 +/- 4)\*10^(-6) T/A. The BE was experimentally calculated to be (-564 +/- 2)\*10^(-7) T using Eq. 2, which agrees with the accepted range of 54106.7 +/- 152 nT for the latitude and longitude of Ottawa, Ontario [1]. Using Eq. 3, the B­T for the 4cm beam radius was calculated as (1140 +/- 2)\*10^(-6) T and (901 +/- 2)\*10^(-6) T for the 5cm radius. Using these B­T values with Eq. 4, the average e/m value was calculated as (180 +/- 2)\*10^(9) C/kg, which is close to the accepted value of 175.8 \* 10^9 C/kg [2], but it does not overlap. The K for the Helmholtz coil was experimentally calculated to be (77 +/- 2) \* 10^(-5) T/A, which agrees with the manufacturer’s specification of (7.73 ± 0.04) \* 10^-4 T/A.

# Conclusion

Electrons were centripetally accelerated in a vacuum tube filled low pressure hydrogen gas using an electromagnet in the Helmholtz configuration. The electrons were generated by heating a filament and applying a potential difference between the filament and the metal cover surrounding it. By varying the potential difference and the current passing through the filament so that the electron radius always stayed at either 4cm or 8cm the e/m ratio was calculated as (180 +/- 2)\*10^(9) C/kg and. While the e/m value was off from the accepted value of 175.8 \* 10^9 C/kg [2], the BE value was in agreement with the theoretical value of 54106.7 +/- 152 nT [1]. To improve on e/m ratio measurement, a third electron radius should be used to reduce systematic error.

# Appendix

## Equation List

Eq.

Note: For r/R = 0.3, B/Bo = 0.99621 where r is the electron radius and R is the Helmholtz coil radius.

Eq.

Eq.

Eq.

Eq.

## Raw Data

For the following tables, R = 15.4 ± 0.5 cm, 2b = 15.04 ± 0.5 cm, n = 130 turns, and K = (7.73 ± 0.04) \* 10^-4 T/A. Note that the anode voltages had 1% subtracted in the actual calculation to correct for the voltage drop due to the specific experimental setup.

Table : Voltage and Current for r = 4.0 +/- 0.2 cm (CCW Beam)

|  |  |
| --- | --- |
| Anode Voltage [V] +/- 0.1 [V] | Filament Current [A] +/- 0.001[A] |
| 149.5 | 1.226 |
| 169.9 | 1.332 |
| 190.3 | 1.36 |
| 210 | 1.451 |
| 229.9 | 1.517 |
| 250 | 1.597 |

Table : Voltage and Current for r = 4.0 +/- 0.2 cm with reversed current polarization (CW Beam)

|  |  |
| --- | --- |
| Anode Voltage [V] +/- 0.1 [V] | Filament Current [A] +/- 0.001[A] |
| 150.3 | 1.408 |
| 169.7 | 1.472 |
| 189.7 | 1.551 |
| 209.8 | 1.683 |
| 230.2 | 1.645 |
| 250.3 | 1.72 |

Table - Voltage and Current for r = 5.0 +/- 0.2 cm (CCW Beam)

|  |  |
| --- | --- |
| Anode Voltage [V] +/- 0.1 [V] | Filament Current [A] +/- 0.001[A] |
| 150 | 0.984 |
| 169.9 | 1.018 |
| 190 | 1.092 |
| 210.5 | 1.146 |
| 230.5 | 1.2 |
| 249.6 | 1.279 |

Table - Voltage and Current for r = 5.0 +/- 0.2 cm with reversed current polarization (CW Beam)

|  |  |
| --- | --- |
| Anode Voltage [V] +/- 0.1 [V] | Filament Current [A] +/- 0.001[A] |
| 150.1 | 1.093 |
| 170 | 1.16 |
| 190 | 1.227 |
| 209.9 | 1.298 |
| 230.1 | 1.338 |
| 249.8 | 1.394 |

## Sample Calculations

# Location of original data

data\_8cm\_normal = \

pd.read\_excel('./data/Data.xlsx', 0).as\_matrix()

data\_8cm\_reverse = \

pd.read\_excel('./data/Data.xlsx', 1).as\_matrix()

data\_10cm\_normal = \

pd.read\_excel('./data/Data.xlsx', 2).as\_matrix()

data\_10cm\_reverse = \

pd.read\_excel('./data/Data.xlsx', 3).as\_matrix()

all\_data = [data\_8cm\_normal, data\_8cm\_reverse, data\_10cm\_normal, data\_10cm\_reverse]

# Normalize Voltage

voltages = []

currents = []

**for** dataset **in** all\_data:

voltage = dataset[:, 0]

voltage -= 0.01 \* voltage

voltages.append(q.MeasurementArray(voltage, 0.1\*np.ones(len(voltage))))

current = dataset[:, 1]

currents.append(q.MeasurementArray(current, 0.001\*np.ones(len(current))))

# Calculating Kr

K = q.Measurement(7.74, 0.04)\*1e-4 # T/A

R = q.Measurement(15.4, 0.5)

r4cm = q.Measurement(8, 0.2)/2

r5cm = q.Measurement(10, 0.2)/2

print("K", K)

print("R", R)

print("r4cm/R", r4cm/R)

B\_Bo4cm = 0.99621

print("r5cm/R", r5cm/R)

B\_Bo5cm = 0.99621

Kr4cm = B\_Bo4cm \* K

Kr5cm = B\_Bo5cm \* K

print("Kr 4cm", Kr4cm)

print("Kr 5cm", Kr5cm)

*K (774 \pm 4)\*10^{-6}*

*R (154 \pm 5)\*10^{-1}*

*r4cm/R (26 \pm 1)\*10^{-2}*

*r5cm/R (32 \pm 1)\*10^{-2}*

*Kr 4cm (771 \pm 4)\*10^{-6}*

*Kr 5cm (771 \pm 4)\*10^{-6}*

# Calculating Bt and Be

Be4cm = Kr4cm/2 \* (currents[0] - currents[1])

print("Be4cm", Be4cm.get\_error\_weighted\_mean())

Be5cm = Kr5cm/2 \* (currents[-2] - currents[-1])

print("Be5cm", Be5cm.get\_error\_weighted\_mean())

Bt4cm = Kr4cm/2 \* (currents[0] + currents[1])

print("Bt4cm", Bt4cm.get\_error\_weighted\_mean())

Bt5cm = Kr5cm/2 \* (currents[-2] + currents[-1])

print("Bt5cm", Bt5cm.get\_error\_weighted\_mean())

Be = (Be4cm.get\_error\_weighted\_mean() + Be5cm.get\_error\_weighted\_mean())/2

print("Be", Be)

*Be4cm (-621 \pm 3)\*10^{-7}*

*Be5cm (-506 \pm 2)\*10^{-7}*

*Bt4cm (1140 \pm 2)\*10^{-6}*

*Bt5cm (901 \pm 2)\*10^{-6}*

*Be (-564 \pm 2)\*10^{-7}*

# em for 4cm

V4cm = (voltages[0] + voltage[1])/2

e\_m4cm = 2\*V4cm / (Bt4cm \* r4cm/100)\*\*2

print(e\_m4cm.get\_error\_weighted\_mean())

*(171 \pm 4)\*10^{9}*

# em for 8cm

V5cm = (voltages[-1] + voltages[-2])/2

e\_m5cm = 2\*V5cm / (Bt5cm \* r5cm/100)\*\*2

print(e\_m5cm.get\_error\_weighted\_mean())

*(188 \pm 3)\*10^{9}*

e\_m = (e\_m4cm.get\_error\_weighted\_mean() + e\_m5cm.get\_error\_weighted\_mean())/2

print(e\_m)

*(180 \pm 2)\*10^{9}*

from numpy import pi

n = 130

b = q.Measurement(15, 0.5)/2

mu = 4\*pi\*1e-7

K = mu\*n\*(R/100)\*\*2/((R/100)\*\*2 + (b/100)\*\*2)\*\*(3/2)

print(K)

*(61 +/- 1)\*10^(-1)*