# PHYS 3650L - Modern Physics Laboratory

1. Objectives. The objective of this laboratory is to measure the charge to mass ratio of an electron.

2. Theory.

a. As a charged particle enters the magnetic field directed perpendicularly to the velocity of the particle, it starts to rotate with a radius of orbit

$$r = \frac{mV}{qB} \tag{1}$$

where

$m$ is the mass of the particle,

$V$ is the speed of the particle,

$q$ is the magnitude of the particle's charge, and

$B$ is the strength of the magnetic field.

b. For an electron, the equation (1) becomes

$$r = \frac{mV}{eB} \tag{2}$$

where

$e$ is the magnitude of the charge of an electron.

c. The magnetic field produced near the axis of a pair of Helmholtz coils is given by the equation:

$$B = \frac{N\mu_0 I}{(5/4)^{3/2}a}$$ **(3)**

where

*N* is the number of turns on each Helmholtz coil (130),
$\mu_0$ is the permiability of free space, and
*a* is the radius of the Helmholtz coils (15.0 cm).

d. After the electrons are accelerated through the accelerating potential difference, $\Delta V$, gaining kinetic energy, their speed become:

$$V = \sqrt{\frac{2e\Delta V}{m}}$$ **(4)**

Combining equations (2), (3), and (4) produces the final formula for e/m ratio:

$$e/m = \frac{2\Delta V(5/4)^3 a^2}{(N\mu_0 Ir)^2}$$ **(5)**

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3. <u>Apparatus and experimental procedures</u>.

a. Equipment.

1) e/m apparatus.

2) Power supplies (3).

3) Multimeters (2).

b. Experimental setup. To be provided by the student.

c. Capabilities. To be provided by the student.

d. Procedures. Detailed instructions are provided in paragraph 4 below.

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4. <u>Requirements</u>.

a. In the laboratory.

1) Your instructor will introduce you to the equipment to be used in the experiment.

2) Measure the current to the Helmholtz coils and accelerating voltage.

3) Measure the radii of the electron beam on the right and on the left side of the orbit.

4) Repeat steps 2 and 3 for two more values of the current in Helmholtz coils.

b. After the laboratory. The items listed below will be turned in at the beginning of the next laboratory period. A complete laboratory report is **not** required for this experiment.

**Para 3. Apparatus and experimental procedures**.

1) Provide a figure of the experimental apparatus (para 3b).

2) Provide descriptions of the capabilities of equipment used in the experiment (para 3c).

**Para 4. Data**. Data tables are included at Annex A for recording measurements taken in the laboratory. A copy of these tables must be included with the lab report. Provide the items listed below in your report in the form a Microsoft Excel$^{TM}$ spreadsheet showing data, calculations and graphs. The spreadsheet will include:

1) A table including measured value of the current to the Helmholtz coils, measured value of the accelerating voltage, and measured value of the orbital radii for each of the tree trials.

2) Calculation of the mean radius of the orbit for each trial.

3) Calculation of the value of e/m ratio for each trial.

4) Calculation of the mean value of e/m ratio.

5) Calculation of the percent discrepancy in the e/m ratio. Your instructor will provide the actual value.

**Para 5. Results and Conclusions**.

**a. Results**.

1) A statement of the measured value for the e/m ratio.

2) A statement of the percent discrepancy in the e/m ratio.

**b. Conclusions.**

1) Assess the accuracy of your experiment.

2) Describe the sources of random and systematic error in the experiment.

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**Annex A**
**Data**

| Trial | $I$ (A) | $\Delta V$ (V) | $r_r$ (m) | $r_l$ (m) |
|-------|---------|----------------|-----------|-----------|
| 1 |  |  |  |  |
| 2 |  |  |  |  |
| 3 |  |  |  |  |