PHYS 104 Lab 7 ELECTRON CHARGE TO MASS RATIO

Introduction

In this lab you will measure a fundamental property of the electron i.e. the ratio of its *charge* to its *mass*. You will use a special **e/m apparatus** and two **power supplies**: one providing low *voltage* for the **Helmholtz coils** and the **heater** and one providing a high *voltage* for the **electrodes** of the electric gun. You will tabulate your results using **Excel**.

Theory

In this experiment a beam of electrons is accelerated from rest by a known *potential difference*, and thus its *velocity* is known. The beam is then bent into a circular path by a uniform *magnetic field* perpendicular to the electron beam produced by a pair of **Helmholtz coils**. The beam travels through a rarefied gas of a fluorescent molecule contained in a glass bulb. Some of the electrons in the beam collide with the molecules of the gas which results in the emission of light. This process produces a visible track corresponding to the electron beam, so the *radius* of the electron beam’s circular path may be measured by eye. By measuring the accelerating *potential V*, the *current* to the **Helmholtz coils** *I*, and the *radius* of the circular path of the electron beam *r*, electrons *charge* to *mass* ratio can be determined.

The magnitude of the *magnetic force* acting on the charged particle moving in a magnetic field is given by

, (1)

where *q* is the electric *charge* of the particle, *v* is the *velocity* of the charged particle, and *B* is the *magnetic field strength*. If the *magnetic field* is uniform and the *velocity* vector is perpendicular to the *magnetic field* vector, then the *force* acts so that the particle moves in a circle as shown in figure 1 (you can check it using right hand rule).

***r***

.

### *F*

***v***

**Figure 1. A negatively charged particle moving in a uniform magnetic field that is directed out of the page.**

Using the expression for *centripetal force*,

 (2)

equation (1) can be re-written as

*m* = *e v B*, (3)

where *r* is the *radius* of the circular orbit, *e* is the electron’s *charge*,and *m* is its *mass*. This can be solved for *e/m*

 = . (4)

or if we want it solved for *r*:

*r* =  . (5)

Now we need to determine the electron’s *speed v*, and the magnitude of the *magnetic field* *B*. The electron’s *speed v* can be determined from the accelerating *voltage* Δ*V*, using the *conservation of energy*. Since Δ*PE* = *e* Δ*V* and Δ*KE* = *m* *v*2 / 2 (if particle started at rest), we have:

*v* = ( 2 *e* Δ*V* / *m* )1/ 2 . (6)

The *magnetic field* produced inside the **Helmholtz coils** is given by equation:

*B* =, (7)

where *μ* 0 is the *permeability* constant equal to 4π×10-7 T m /A, *N* is the number of turns in each of the **Helmholtz coils**, *a* is the *radius* of the **Helmholtz coils**, and *I* is the *current* through the **Helmholtz coils**.

Combining equations (4), (6), and (7), we get

 = = , (8)

or

 = *w* , (9)

with

*w* = = const. (10)

for a particular set of **Helmholtz coils**.

The set of Helmholtz coils you’ll use has the *radius* *a* of 15 cm and the number of turns in each of the is **Helmholtz coils** is *N* = 130.

Procedure

1. Make sure that all the **power supplies** are **TURNED OFF** and the **dials** are at the LOWEST SETTING, and that the **toggle switch** is up in the **e/m measure** position. Turn the **current adjust knob** for the **Helmholtz coils** to the **OFF** position.

Electron Gun

Toggle switch

Focus knob

Current adjust knob

Helmholtz coils

Electrodes

**+**

Heater

**+**

**-**

**-**

**LOW VOLTAGE AC/DC POWER** **SUPPLY**

power supply power supply

for Helmholtz coils for the electron

6 to9 V DC, gun heater

<1% ripple 6 V, AC

**HIGH VOLTAGE POWER SUPPLY**

for the accelerating electrodes

150 to 250 V, DC

**Figure 2. e/m apparatus.**

2. Connect the apparatus as shown in figure 2. Make sure the DC **power supplies** are connected with correct polarity.

3. The power supplies can be adjusted over the ranges listed below:

**HELMHOLZ COILS : 6-9 V, DC**

**ELECTRODES: 150-250 V, DC**

#### ELECTRON GUN HEATER: 6 V, AC

#### CAUTION: The accelerating voltage is sufficiently high to result in a potentially lethal shock. It is important that you follow directions carefully. The wires should be connected before turning on the voltage. Make sure your instructor checks your circuitry before you turn it on.

#### 4. Turn on the Low Voltage Power Supply and adjust the settings according to the specifications listed above.

#### 5. Turn on the High Voltage Power Supply and adjust the accelerating *voltage* to 150 V. Wait several minutes for the cathode to heat up. When it does you will see the electron beam emerge from the electron gun in form of a horizontal blue-green beam.

#### 6. Focus the beam using the focus knob.

#### 7. Slowly turn clockwise the current adjust knob for the Helmholtz coils. Watch the ammeter on the Low Voltage Power Supply and take care that the *current* does not exceed 2A. As the *magnetic field* strength increases, the electron beam will bend into a circle.

8. Check that the electron beam is parallel to the **Helmholtz coils**. If not, turn the bulb until it is. Do not take the bulb out of the socket; as you rotate the bulb the socket will turn as well.

9. Measure the *radius* *r* of the electron beam. To do this you need to look through the bulb at the electron beam and the scale on the mirror behind it. To avoid parallax errors, move your head to align the electron beam with its reflection on the mirrored scale. Measure the *radius* of the beam as you see it on both sides of the scale. If the numbers are far apart, it means the beam is not is parallel to the **Helmholtz coils** and needs further adjustment. You’ll get better results if the circle is fairly large with the *radius* of the order of 4-4.5 cm. If the circle is very small you may want to readjust the *current* for the **Helmholtz coils**. On the other hand, make sure that the beam forms a full circle and is clearly visible.

10. Enter the two results for the *radius* of the electron beam into an **Excel** table. Then find their average.

11. Record the accelerating *voltage*Δ*V* (from **High Voltage Power Supply**) and the *current I* in the **Helmholtz coils** (from **Low Voltage Power Supply**) in the **Excel** table.

12. Using equation (9) calculate *e/m*.

13. Repeat the procedure for accelerating *voltages* of 175V, 200V, 225V, and 250 V. Find the average value of your measurements of *e/m*.

14. Compare your averaged value of your measurements of *e/m* with the accepted value by finding % difference. Discuss the outcome.

15. How does the radius of the circle change if you change accelerating *voltage*? Explain why. (Hint: consider equation (5). What quantities in that equation do change in this case?)

16. How does the radius of the circle change if you change adjust the *current* for the **Helmholtz coils**? Explain why (Hint: consider equation (5). What quantities in that equation do change in this case?)

17. Use the right hand rule to determine the direction of the *magnetic field* inside the **Helmholtz coils**. Discuss.

18. Use the other right hand rule to determine the direction of the *current* flowing through the **Helmholtz coils**. Discuss

**19. Turn off the equipment and turn the dials down**

**Save your data once you acquired it.**

**Print tables and graphs you have made and attach them to your report.**

**SAVE PAPER.**

**Delete your files from the computer when finished.**

**Disconnect all equipment, close all applications, and log off your PC.**

**lab 7 Report** Name……………………………...

Introduction:

Data Presentation:

14.

15.

16.

17.

18.

**REMINDERS:** Include units.

Make sure to attach all your data and graphs. No data = No credit

Please do not hand in the manual, just the report.

conclusion: