Measurement of e/m for the Electron

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Apparatus

Cenco e/m tube and stand
Helmholtz coils
Power supplies, voltmeters, ammeters

Introduction

This experiment is designed to demonstrate the effects of electric and magnetic fields on the motion of charged particles and also to permit the measurement of the charge-to-mass ratio e/m of the electron.

The Cenco e/m tube is a triode in which electrons are emitted by an indirectly heated cathode and accelerated by means of a potential difference between cathode and plate. An electron beam is formed when electrons pass through a small hole in the center of the plate into the experimental region of the tube. Since the beam of electrons would normally diverge, an additional grid electrode is placed between cathode and plate to change the shape of the accelerating field so as to produce a parallel or converging electron beam. A uniform magnetic field B is produced by a pair of circular Helmholtz coils. These coils each have $N = 133$ turns and are separated from each other by a distance that is also equal to the average coil radius R. The current I flows in the same direction in both coils.

A small amount of gas, rather than a high vacuum, is present in the tube. This allows the beam to be made visible due to the emission of light from gas atoms excited in electron-atom collisions.

Procedure

Measurements are to be made of the currents and voltages required to focus the beam on circles of known radii scribed on the upper surface of the plate.

The control panel of the Cenco tube power supply has a rheostat for adjusting the heater current, potentiometers for the grid and plate potentials, and binding posts for metering these potentials. Connect the power supply to the Cenco e/m tube stand. Have the instructor check your wiring. Operate the filament at 0.5 amperes; do not exceed this current. Try to use plate potentials between 70 and 120 volts and grid potentials less than 50 volts. Note: zero plate potential will probably not produce a beam.

A separate dc power supply is used for the Helmholtz coils. These coils are rated up to 5 amperes. However, currents above 3 amperes should be used only during the time that observations are actually being made. Use the reversing switch provided to reverse the direction of the current and the magnetic field.

Since finer control is available on the voltages than on the coil current I, it is suggested that you set I at preselected values and then vary plate and grid potentials until the desired focus is obtained. Repeat the setting several times so as to obtain an estimate of the precision in the values of the plate voltage. Repeat for several combinations of circle radii, coil currents, and B-field direction. Use your results for V(plate), r, and B to determine the e/m ratio for the electron.

Questions

1. Derive the equation $\frac{e}{m} = \frac{2V}{(Br)^2}$.

2. Determine the experimental uncertainties in your results for e/m. Does your result agree with the accepted value of e/m for the electron to within your estimate of the experimental uncertainty?

3. Derive the formula $B = \frac{8\mu_o NI}{\sqrt{125}R}$ for the field at the center of the Helmholtz coils.

4. In a vector diagram showing the directions of the velocity **v**, the magnetic field **B**, and the force **F** in this experiment, demonstrate that the beam of charged particles that you are studying is composed of electrons rather than positrons.

References

Harnwell and Livingood, *Experimental Atomic Physics*, Chapter 4.

Young and Freedman, *University Physics*, Addison Wesley.

Cenco apparatus notes

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