Measuring the Mass of the Electron, Part II

Objective: To measure the mass of the electron.

Part II: Mass of the Electron

1. See the diagram below. Connect the wires from the 6AF6 tube as shown in the diagram. Turn on the potentials to obtain an undeflected electron beam pattern. Place the tube inside the solenoid. Increase the current in the solenoid from zero to five amperes and watch the curving pattern appear.

2. Set the accelerating potential between 90 and 250 volts with a 4-ampere current through the solenoid. You then need to obtain a value for the radius of curvature for the electrons’ deflected path (see diagram). To help you do this, obtain a set of four different sized round dowel rods. Adjust the accelerating potential so that the curved pattern matches the size of a medium-sized dowel as exactly as possible. Then use a Vernier caliper to measure the diameter of the dowel, and thus the radius of curvature. Record all values in a table that records $V$, $I_S$, and $r$.

3. Vary the accelerating potential so that the curved pattern matches a different dowel. Then vary the coil current (and thus the $B$-field strength) and match two more different dowels. You will therefore have four different measurements for $V$, $I_S$, and $r$ which will yield values for the mass of the electron.

Data Analysis

1. In the 6AF6 tube, the electrons moving in the magnetic field of the solenoid experience a force equal to $F = e v B$. The electron experiences this force perpendicularly to its direction of motion, so it moves in a circle, the radius of which is related to the magnetic force by the centripetal force equation, $F = \frac{m v^2}{r}$.

2. To find the speed of the electron, we note that it was accelerated through a potential $V$ giving it an amount of energy $W = Ve = \frac{1}{2} m v^2$.

3. Using these relations and the solenoid calibration relation $B = \alpha I_S$, derive an expression to find the mass of the electron (as a function of $e$, $\alpha$, $I_S$, $V$ and $r$) for the four different measurements you took. Report the four values in a new column on your table and calculate their average and a percent different with the accepted value, $m_e = 9.1 \times 10^{-31}$ kg.

Questions

1. What are the major sources of error in this experiment? Which measurements do you think were the least trustworthy?
2. Suppose that protons were emitted in the vacuum tube instead of electrons. How would this affect the experiment?
3. For our solenoid, we used the relation $B = \alpha I_S$, and we know from Chapter 22 that $B = \mu_0 I_S n$, where $n$ is the turn density of the solenoid. Calculate the turn density of your solenoid.