Electron Charge to Mass Ratio

Theory (1/2)

- Hypothesis: given an electron beam in a constant magnetic field, the charge to mass ratio will be a constant
- We know the kinetic energy of an electron

$$\frac{1}{2} m v^2 \Rightarrow v = \sqrt{\frac{2 e U_{acc}}{m}}$$

- We also know that magnetic and centripetal force are equal

$$F_C = \frac{m v^2}{r} = F_B = e v B$$

- Solve for e/m, substitute

Theory (2/2)

- B is known for Helmholtz coils

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

- N = 130 and a = 0.158m for the lab equipment

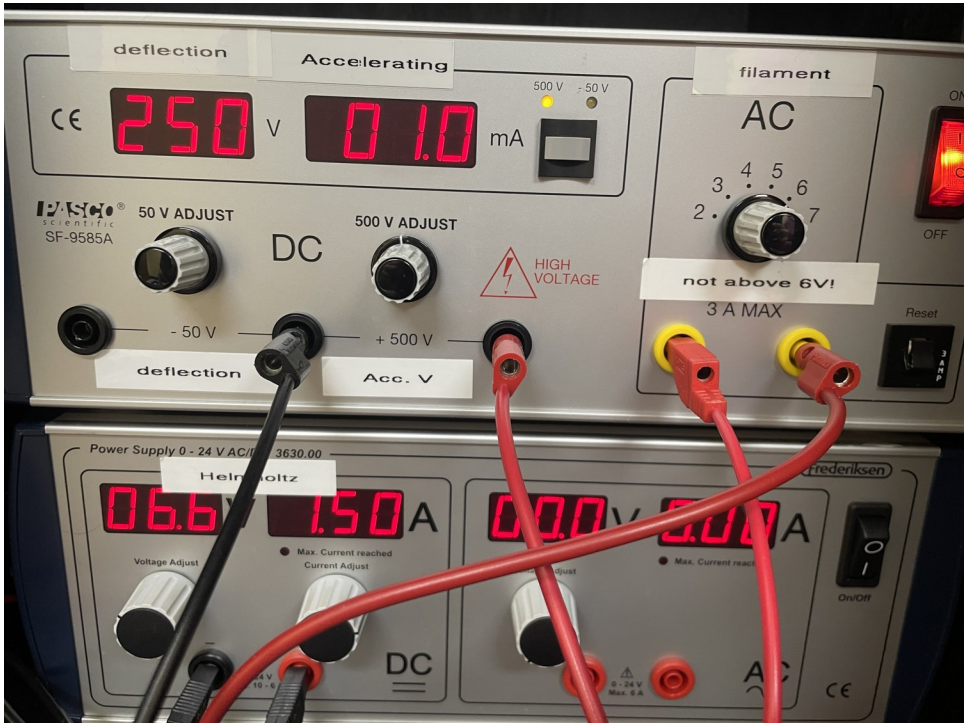
$$\frac{e}{m} = \frac{2 U_{acc} \left(\frac{5}{4}\right)^3 a^2}{N \mu_0 I r^2}$$

The accepted value is approximately 1.6e-19 / 9.1e-31

Setup Procedure (1/5)

- This lab works with **high voltage** (500V), **electron beams**
- This lab is in the secondary lab room
- Turn off all power supplies
- Connect the high-voltage DC power to the accelerating voltage
- Connect the low-voltage DC power supply to the Helmholtz coils
  - Ensure current flows through both coils, not just one
- Connect the low-voltage AC power supply to the filament
- Verify connections are in-place with instructor before energizing

Setup Procedure (2/5)



- Proper terminals to use seen to the side
- Your power supplies should not be on at this state

Setup Procedure (3/5)

- Cover lab with hood if needed
- When energizing and controlling voltage, increment voltage slowly
- When energizing and controlling both voltage and current, increment current slightly, then voltage slightly, and continue alternating
  - Failure to do so will lead to surges

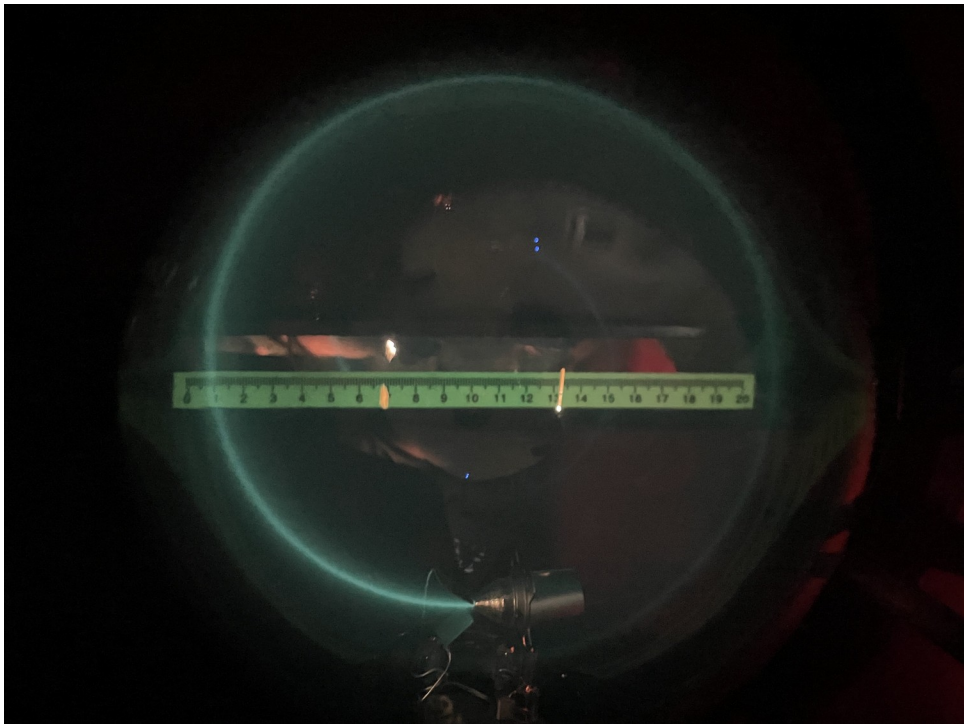
Setup Procedure (4/5)

- Energize filament to 6ADC (do not exceed at risk of equipment damage)
- Energize accelerating voltage to 150-250VDC
  - The specific power supply must be toggled between the 50/500V readout using the small button
- Energize the Helmholtz coils to 4-7VDC (max 2A)
  - Limit current to ¾ of the full range. Ensure you are using the leftmost outputs of the power supply.
  - Exceeding or approaching 2A will lead to the beam nearing the edge of the tube and diffracting or reflecting

Setup Procedure (5/5)

- Wait several minutes for the filament and tube to heat up
  - Safety: **Do not touch the glass** (risk of thermal burns and electrocution)
- The electron beam will appear and be curved by the coils. If it fails to do so, gently curve the base.
  - Turn the lights off and close the door
- Output variables are U_acc, I and r
  - Accelerating voltage, current through the coils, and radius of the beam

Electron Beam



- Dark room required to see

Measurement Procedure

- Suggested starting parameters for measurement are U_acc = 200V, I_coil = 1.2A
- Rotate the tube to obtain a straight circular path
- Read and record I_coil (current to Helmholtz coils)
- Measure the radius of the electron beam and estimated error
- Take at least ten measurements for U_acc in 150-250VAC and constant current I_1
- Repeat the same measurements for the chosen U_acc for a second current I_2

Cleanup

- Reduce all voltages to zero
  - Ensure this is done gradually to avoid sharp cutoffs, reverse EMF, back-current, or other issues
- Turn off all power supplies
- Disconnect all wires