PART –IV ATOMIC AND NUCLEAR PHYSICS

22
EXPERIMENT
Based on

# DETERMINATION OF e/m

## Experiment 22.1

**To measure e/m of electron using helical method.**

### Apparatus Required:

A cathode ray tube, a solenoid, a power supply, commutator, voltmeter (0-1.5 KV), an ammeter (0-1A) etc.

### Theory:

When filament of a cathode ray tube is heated, it eject electrons. When some accelerating potential say V (Volts) is applied to the electrons emitted from cathode. Then, velocity ($v$) acquired by the electron is given as

$$\frac{1}{2}mv^2 = eV \quad \text{or} \quad v = \sqrt{2eV/m} \qquad \text{...(1)}$$

If screen of C.R.O. is at a distance '$l$' from filament of cathode then time taken by the electron to reach to screen

By using equation (1), $$t = \frac{l}{V} = \frac{l}{\sqrt{2eV/m}} \qquad \text{...(2)}$$

If an alternating electric field is applied across the electron beam then electron will experience a transverse alternating force and a line is formed on the screen, whose length depends upon magnitude of transverse electric field. If we apply a longitudinal magnetic field across the beam of electron, it will experience a force on electron which is perpendicular to both transverse motion of electron and applied longitudinal magnetic field, due to which electron describe a circular path with velocity $v'$ in a circle of radius $r'$.

i.e. $$Bev' = \frac{mv'}{r'} \qquad \text{...(3)}$$

or $$\frac{Be}{m} = \frac{v'}{r'}$$

The angular speed $$\omega = \frac{2\pi}{T} = \frac{v'}{r'} = \frac{Be}{m} \qquad \text{...(4)}$$

The period of motion of electron in circular path is given as $T = \frac{2\pi}{\omega} = \frac{2\pi}{Be/m} = \frac{2\pi m}{Be}$

Adjust value of B so that periodic time T becomes equal to '$t$' given in equation (2) so that line will reduce to a point. Further increase B so that time period reduces to T/2, T/3 etc. such that we get number focii with variation of B.

If $B_C$ is the field when $t = T$, then $$T = \frac{2\pi m}{eB_c} \qquad \text{...(5)}$$

From equation (2) and (5), we get

$$\frac{1}{\sqrt{(2eV/m)}} = \frac{2\pi m}{eB_c}$$

$$\frac{l^2 m}{2eV} = \left(\frac{2\pi m}{eB_c}\right)^2$$

$$\frac{l^2 m}{2eV} = \frac{4\pi^2 m^2}{e^2 B_c^2}$$

$$\frac{e}{m} = \frac{8\pi^2 V}{l^2 B_c^2} \text{ coulomb/kg}$$

where $B_c = \mu_0\, n\, i_c \cos\theta$ Wb/m$^2$

$i_c$ = current produced by field $B_c$

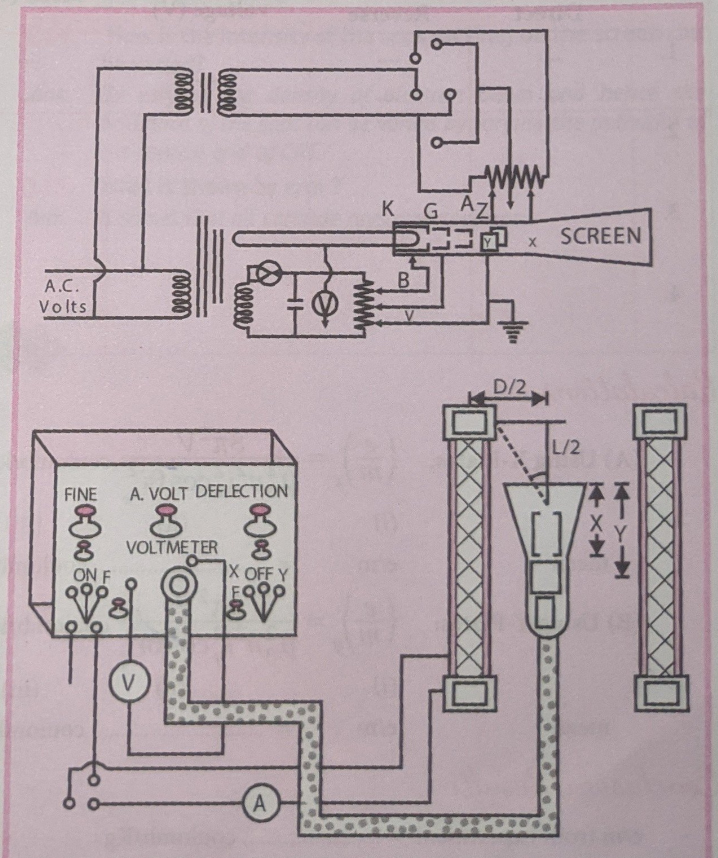


Fig. 22.1.

$$\cos\theta = \frac{\frac{L}{2}}{\sqrt{\left\{\left(\frac{D^2}{4}\right)+\left(\frac{L^2}{4}\right)\right\}}} = \frac{L}{\sqrt{(D^2+L^2)}}$$

where L = Length of solenoid, D = diameter of solenoid.

$$\frac{e}{m} = \frac{8\pi^2 V}{\mu_0^2 n^2 i_c^2 \cos\theta l^2} = \text{coulomb/kg}$$

If N is total no. of turns and L is length of solenoid then

$$\frac{e}{m} = \frac{8\pi^2 V L^2}{\mu_0^2 n^2 i_c^2 \cos\theta l^2} \text{ coulomb/kg}$$

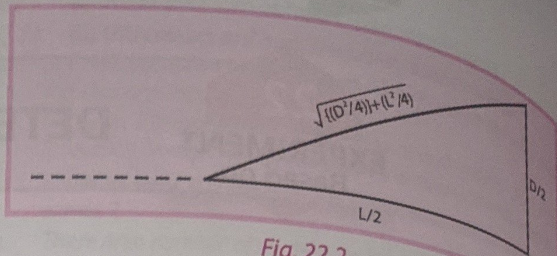


Fig. 22.2.

## Procedure:

Step 1. Place a solenoid in east-west direction and mount cathode ray tube carefully inside the solenoid.

Step 2. Make connection as shown in figure and switch on power supply unit. Give desired accelerating potential and make fine and clear spot on the screen of cathode ray tube.

Step 3. Apply *a.c.* deflecting potential to one set at plates say $x - x$ plates. Adjust value of *a.c.* deflecting potential so that a line of 2 cm is formed.

Step 4. Switch on the solenoid current and adjust its value so that line reduces to a point. Reverse solenoid current and again make a fine point on screen. Average of these two values gives current in amp. ($i_c$)

Step 5. Repeat the step 3 & 4 for $y - y$ set of plates and find $i_c$.

Step 6. Repeat whole procedure from step 2 to step 5 for different values of accelerating voltage.

## Observations:

Distance between the edge of *x*-plate and the screen $l_A$ = ....... *m.*

Distance between in edge of *y*-plate and the screen $l_B$ = ....... *m.*

Number of turns of solenoid, N = ....... .

Diameter of solenoid, D = ....... *m.*

Length of solenoid L = ....... *m.*

$$\cos\theta = \frac{L}{\sqrt{(D^2+L^2)}}$$

**Table 22.1.**

| S. No. | Using X-Plates | | | | Using Y-Plates | | | |
|---|---|---|---|---|---|---|---|---|
| | Current I (Amp.) | | Accelerating voltage (V) | Mean ($I_A$) | Current I (Amp.) | | Accelerating voltage (V) | Mean ($I_B$) |
| | Direct | Reverse | | | Direct | Reverse | | |
| 1. | .... <br> .... | .... <br> .... | ....... | .... <br> .... | .... <br> .... | .... <br> .... | ....... | .... <br> .... |
| 2. | | | | | | | | |
| 3. | | | | | | | | |
| 4. | | | | | | | | |

## Calculations:

**(A) Using X-Plates:** $\left(\frac{e}{m}\right)_x = \frac{8\pi^2 V}{\mu_0^2 n^2 i_x^2 \cos\theta i_{c_x}^2}$ coulomb/kg

(i) (ii) (iii)

mean e/m = ............................ coulomb/Kg

**(B) Using Y-Plates:** $\left(\frac{e}{m}\right)_y = \frac{8\pi^2 V}{\mu_0^2 n^2 i_y^2 \cos\theta i_{c_y}^2}$ coulomb/kg

(i) (ii) (iii)

mean e/m = ............................ coulomb/Kg

## Conclusion/Result:

*e/m* from experiment = ...................... coulomb/Kg

Standard value of *e/m* = 1.758 × 10⁴ Coul/Kg

$$\text{Percentage error} = \frac{\text{standard value} - \text{observed value}}{\text{standard value}} \times 100 = \text{..........\%}$$

**Precautions:**

(i) C.R.O. tube should be placed symmetrically within the solenoid.
(ii) Factor $\cos\theta$ should be applied for finding $B_c$ if solenoid is of finite size.
(iii) Accelerating voltage should be applied carefully.
(iv) Length of line formed on screen should be 2-3 cm.
(v) If potential applied is very high then relativistic correction for mass of electron should be applied.