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Cyclotron - HA

1) A proton is accelerated through a potential difference V, subjected to a uniform magnetic field acting normal to the velocity of the proton. If the potential difference is doubled, how will the radius of the circular path described by the proton in the magnetic field change.

ans Change in K.E = qV V - Voltage

$$\Rightarrow \frac{1}{2}mv^2 = qV$$

$$\Rightarrow v^2 = \frac{2qV}{m}$$

$$\Rightarrow \frac{B^2q^2r^2}{m^2} = \frac{2qV}{m}$$

$$\Rightarrow r^2 = \frac{2mV}{qB^2}$$

$$\Rightarrow r = \frac{1}{B}\sqrt{\frac{2mV}{q}}$$

$$\Rightarrow r \propto \sqrt{V}$$

$$\Rightarrow \frac{r_1}{r_2} = \sqrt{\frac{V_1}{V_2}}$$

r_1 - Original radius
r_2 - New radius

$$\frac{r_2}{r_1} = \sqrt{\frac{V_2}{V_1}} \Rightarrow \frac{r_2}{r_1} = \sqrt{\frac{2V}{V}}$$

$$\Rightarrow r_2 = r_1\sqrt{2}$$

2) A deuteron and a proton moving with the same speed enter the same magnetic field region at right angles to the direction of the field. Show the trajectories followed by the two particles in the magnetic field. Find the ratio of the radii of the circular paths which the two particles may describe.

Deutron : $q \rightarrow +e$
$m \rightarrow 2m_p$

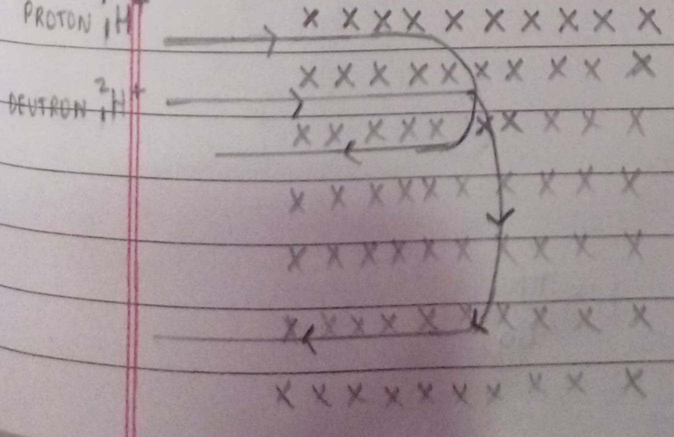
$$R = \frac{mv}{qB}$$

$$R_{proton} = \frac{m_p \times v}{qB}$$

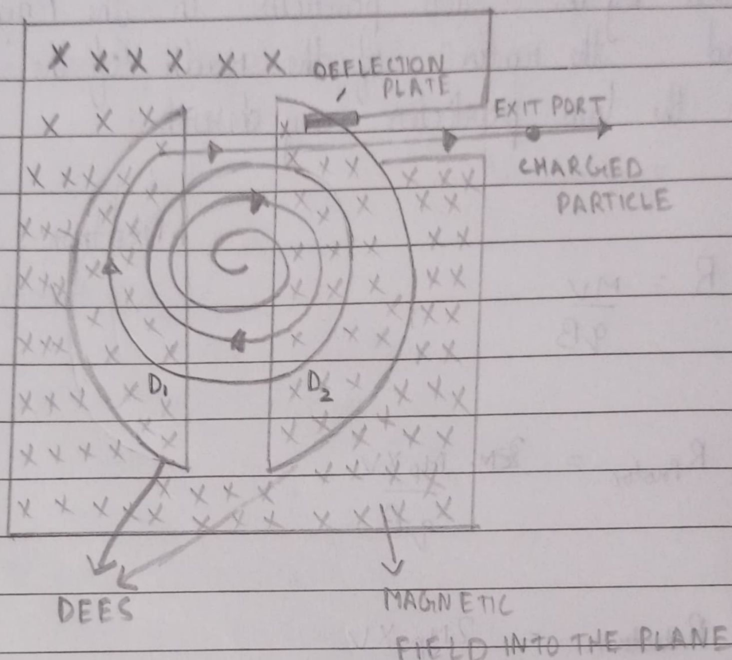
$$R_{deutron} = \frac{2m_p \times v}{qB}$$

Ratio of R_{proton} & $R_{deutron}$ $= \dfrac{\frac{m_p \times v}{qB}}{\frac{2m_p v}{qB}}$

$$= \frac{m_p}{2m_p} = \frac{1}{2} \text{ (Ans)}$$



3) Draw a schematic sketch of the cyclotron. State its working principle. Show that the cyclotron frequency is independent of the velocity of the charged particle.



Working Principle: Cyclotron uses the fact that the frequency of revolution of the charged particle in a magnetic field is independent of its energy.

Inside the dees, the particle is acted upon only by magnetic field which makes it go round in a circular path. Every time, the particle moves from one D to another it comes electric field acts upon it to increase its energy & its radius.

$$v = \frac{Bqr}{m}$$

$$t = \frac{\pi r}{v} \quad \text{or} \quad t = \frac{\pi m}{Bq}$$

$T = 2t$ or $T = \frac{2\pi m}{Bq}$

$f_c = \frac{1}{T} = \frac{Bq}{2\pi m}$ (Thus it is independent of velocity)

Q4)

a) Can both be accelerated at the same cyclotron frequency? Give reason to justify your answer.

ans Mass of proton = M, Charge = q

Mass of alpha particle = 4M, Charge = 2q

Cyclotron frequency,

$\nu = \frac{Bq}{2\pi M} \Rightarrow \nu \propto \frac{q}{M}$

$\nu_p = \frac{Bq}{2\pi M}$

$\nu_\alpha = \frac{B2q}{2\pi 4M}$

$= \frac{Bq}{4\pi M}$

$\frac{\nu_p}{\nu_\alpha} = \frac{Bq/2\pi m}{Bq/4\pi M} = \frac{4}{2} = 2:1$

$\nu_p = 2\nu_\alpha$

∴ frequency of proton is double of α-particle

(ii) Velocity

$v = \frac{Bqr}{M}$

$\Rightarrow V_p = \frac{Bqr}{M}$

$\Rightarrow V_\alpha = \frac{B2qr}{4M} = \frac{Bqr}{2M}$

$\therefore \frac{V_p}{V_\alpha} = \frac{2}{1} = V_p = 2V_\alpha$

∴ the proton will exit with twice the velocity of alpha particle.

5) A neutron, an electron and an alpha particle moving with equal velocities, enter a uniform magnetic field going into the plane of the paper as shown in the figure. Trace their paths in the field and justify your answer.

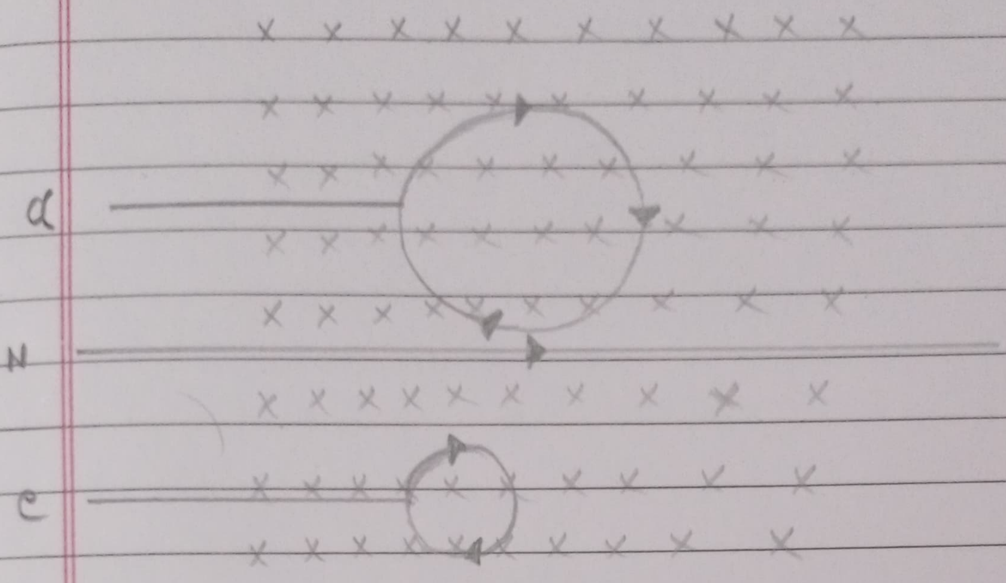
Charge

$\alpha \rightarrow 2q$

$r = \frac{MV}{Bq}$ $\quad N \rightarrow 0$

$e \rightarrow -q$

$r \propto \frac{M}{q}$


α
N
e