9th July

Ch-4 – Moving Charges and Magnetism

Cyclotron

Home Assignment:

Q1. 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 1.
$$r = \frac{mv}{qB}$$
$$= \frac{\sqrt{2mqV}}{qB}$$

$$r' = \frac{\sqrt{2mq2V}}{qB}$$

$$\frac{r'}{r} = \frac{\sqrt{2mq2V}}{qB} \times \frac{qB}{\sqrt{2mqV}}$$

$$\frac{r'}{r} = \sqrt{\frac{2x}{x}} = \sqrt{2}$$

$$r' = \sqrt{2}r$$

Q2. 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

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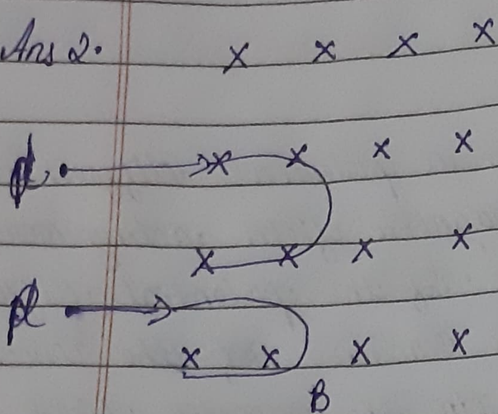
trajectories followed by the two particles in the magnetic field. Find the ratio of the radii of the circular paths which the two particles may describe.

Ans 2.



d → deuteron ; p → proton

mass of d = 2m (1 proton + 1 neutron)

mass of p = m (1 proton)

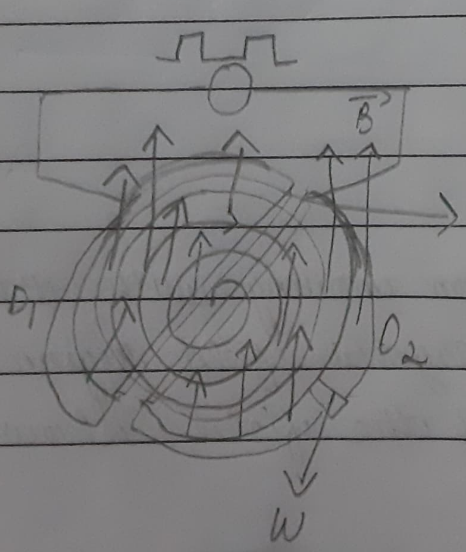
∴ radius of p = $\frac{mv}{qB}$

and radius of d = $\frac{2mv}{qB}$

Ratio → $\frac{r_p}{r_d} = \frac{mv}{qB} \times \frac{qB}{2mv} = \frac{1}{2}$

Q3. 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.

Ans 3.



D_1, D_2 → Dees

W → Window

B → Magnetic field

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Working Principle: Cyclotron works on the principle that a positively charged particle can be accelerated by making it to cross the same electric field repeatedly with the help of a magnetic field.

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

Time Period of revolution → $T = \frac{2\pi r}{V} = \frac{2\pi}{v} \frac{mv}{qB}$

$$T = \frac{2\pi m}{qB}$$

Frequency of revolution → $f = \frac{1}{T} = \frac{qB}{2\pi m}$
cyclotron

Hence, frequency is independent of the velocity of the charged particle.

Q4. An α-particle and a proton are released from the centre of the cyclotron and made to accelerate.

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

Ans a) mass of α-particle = 4m   mass of proton = m
charge of α-particle = 2q   charge of proton = q

cyclotron frequency $(v) = \frac{qB}{2\pi m}$

$v \propto \frac{q}{m}$

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$V_\alpha \propto \frac{2q}{4m}$ $\quad$ $V_\alpha \propto \frac{q}{2m}$

∴ particles will not accelerate with same cyclotron frequency. The frequency of proton is twice than the frequency of alpha particles

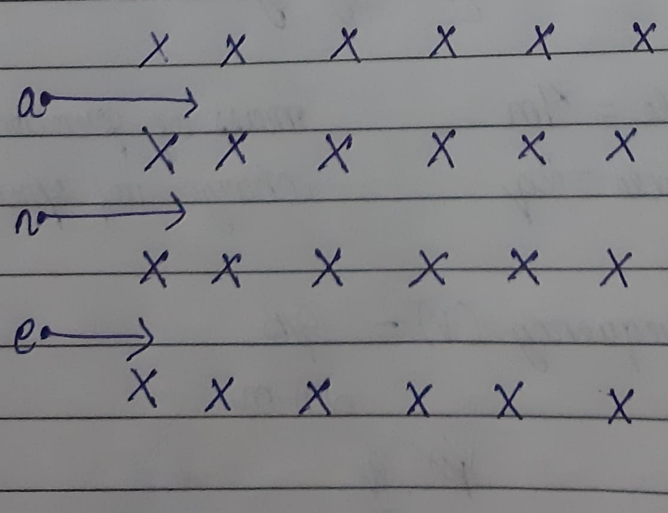
b) When they are accelerated in turn, which of the two will have higher velocity at the exit slit of the dees?

Ans b) As $V_p \propto \frac{q}{m}$ and $V_\alpha \propto \frac{q}{2m}$

∴ The particles will not exit the dees with same velocity. The velocity of proton is twice than the velocity of alpha particle.

Q5. 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.

~~Ans 5~~



Ans 5. $r = \frac{mv}{Bq}$

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

The neutron will move along the straight line as it has no charge.

The electron will move in a circle smaller than that of the alpha particle.

α-particle will move in the clockwise direction and electron will move in the anticlockwise direction according to the right-hand rule.