Date 09/07/21

Chapter - 4

Moving Charges & Magnetism

Home Assignment - 4

Q.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 ~~cha~~ change?

Ans- Given,
Proton is accelerated by potential difference = V.
Here,
The direction velocity of the proton is normal to the direction of magnetic field so,

$$F_m = Bvq \sin\theta$$
$$= Bvq \sin 90^\circ = Bvq$$

As, the velocity is $\perp$ar to magnetic field and magnetic force, ~~it~~ the proton will have a circular path.
$\therefore$ The force on the ~~part~~ porton will also be a centripetal force.
Hence,
Magnetic force = Centripetal force

$$\Rightarrow F_m = F_c$$
$$\Rightarrow Bvq = \frac{mv^2}{r}$$
$$\Rightarrow Bq = \frac{mv}{r} \quad \Rightarrow r = \frac{mv}{Bq}$$

Here,
$r \rightarrow$ is the radius of circular path followed by the proton due to magnetic field.
$v \Rightarrow$ is the velocity of the proton.

Now,
As per the work energy theorem.
Work done = change in kinetic energy

$$\Rightarrow W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$

$$\Rightarrow qV = \frac{1}{2}m(v^2 - u^2) \qquad [W = q(V)]$$

$$\Rightarrow qV = \frac{1}{2}mv^2 \qquad [u = 0]$$

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

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

Now,
Putting value of v in the radius.

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

$$\Rightarrow r = \left(\frac{m}{Bq}\right) \cdot \sqrt{\frac{2qV}{m}}$$

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

$$= \sqrt{\frac{2mV}{B^2q}}$$

Now,
If the potential difference is doubled then.

$$r_1 = \sqrt{\frac{2m(2V)}{B^2q}}$$

$$= \left(\sqrt{\frac{2mV}{B^2q}}\right)\sqrt{2}$$

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

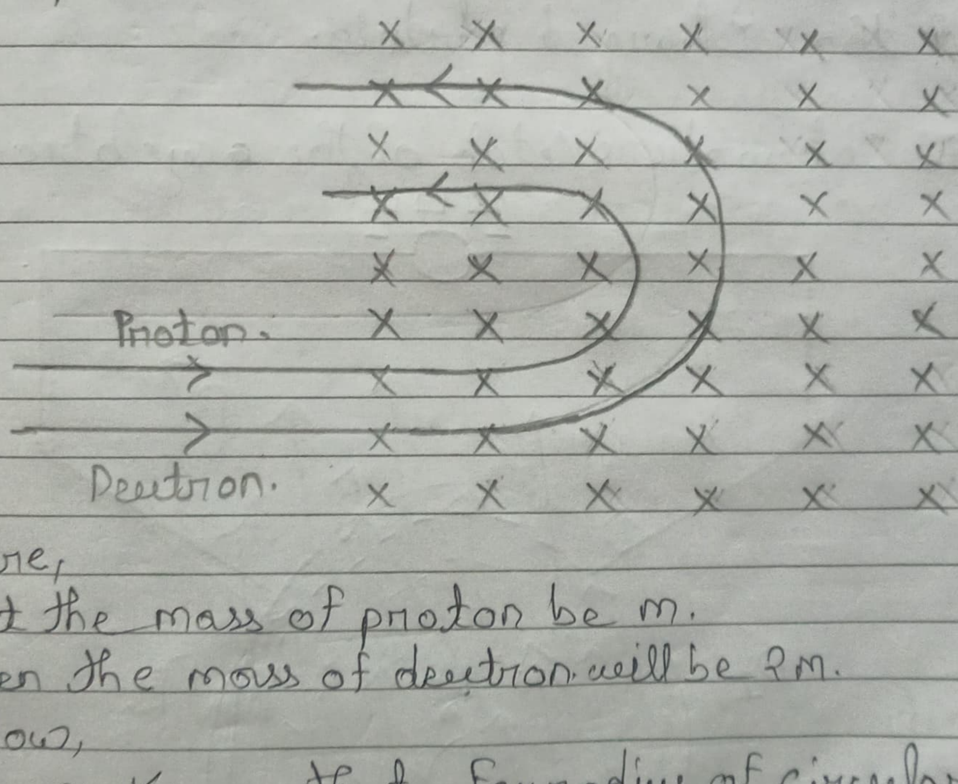
$$\Rightarrow r_1 = \sqrt{2}\, r$$

Hence, the radius of the circular path will increase.

by $\sqrt{2}$ times that of the initial radius of the circular path of proton.

Q.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 trajectories following ~~the~~ 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- The trajectories of the two particles deuteron and proton are :-



Here,
Let the mass of proton be m.
then the mass of deutron will be 2m.
Now,
As we know that, For radius of circular path.

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

So, For proton, $r_p = \frac{mv}{Bq}$

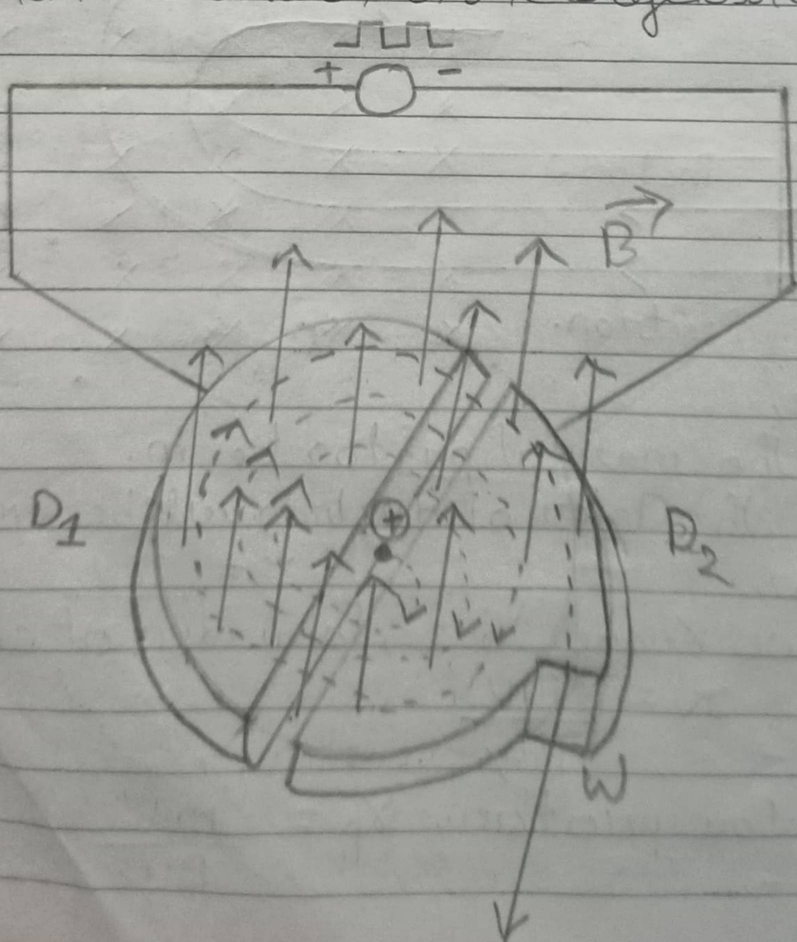
& For deutron, $r_d = \frac{2mV}{Bq}$.

Hence,
The ratio of the radius of the circular path followed by proton & deutron is

$$\frac{r_p}{r_d} = \frac{\frac{mV}{Bq_p}}{\frac{2mV}{Bq_p}} = \frac{1}{2} = 1:2$$

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

Ans- The schematic sketch of the cyclotron is,



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~~The Working principle of a cyclotron.~~
~~Imag~~
Now,
Working Principle:-
A charged particle can be accelerated to very high energies by making it pass through a moderate electric field a number of times. This can be done with the help of a perpendicular magnetic field which throws the ~~chaged~~ charged particle into a circular motion, the frequency of which does not depend on the speed of the particle and the radius of the circular orbit.
Now,
In this cyclotron,
The magnetic force experienced by the charge particle provides the centripetal force required to decribe its circular path.

$$F_c = F_m$$

$$\Rightarrow \frac{mv^2}{r} = Bvq \sin 90^\circ$$

$$\Rightarrow \frac{mv}{r} = Bq.$$

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

Now,
The time taken by the charged particle to complete semicircular path of cyclotron.

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

So, Time taken by the charged particle to complete one circular motion.

$$T = \frac{2\pi r}{v} = \frac{2\pi m}{Bq}$$

Now,
The frequency of the cyclotron will be

$$f = \frac{1}{T}$$

$$= \frac{1}{\frac{2\pi m}{Bq}} = \frac{Bq}{2\pi m}.$$

Hence, it is proved that the cyclotron frequency is independent of the velocity of the charged particle.

Q.4. 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.
b) When they are accelerated in turn, which of the ~~two~~ ~~be~~ will ~~be~~ have higher velocity at the exist slit of the dees?

Ans-a) Here,
Let's consider the mass of proton to be m and charge of proton to be q.
then,
the mass of α-particle will be 4m,
and chage on ~~proton~~ it will be 2q.
Now,
Both α-particle and proton will accelerate

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at the same time due to Electric field.

Now,

Cyclotron frequency of proton.

$$f_p = \frac{Bq}{2\pi m}$$

$$= \left(\frac{B}{2\pi}\right)\frac{q}{m} \qquad \left[\because \frac{B}{2\pi} = \text{constant}\right]$$

$$\Rightarrow f_p \propto \frac{q}{m}.$$

Cyclotron frequency of α-particle.

$$f_\alpha = \frac{B \times 2q}{2\pi \times 4m}$$

$$= \left(\frac{B}{2\pi}\right)\cdot\frac{q}{2m}. \qquad \left[\frac{B}{2\pi} = \text{constant}\right]$$

$$\Rightarrow f_\alpha \propto \frac{q}{2m}$$

From this, by taking ratio of both ~~for~~ frequency we get,

$$\frac{f_p}{f_\alpha} = \left(\frac{B}{2\pi}\right)\frac{q}{m} \times \left(\frac{2\pi}{B}\right)\cdot \frac{2m}{q}$$

$$\Rightarrow \frac{f_p}{f_\alpha} = 2$$

$$\Rightarrow f_p = 2 f_\alpha$$

Hence,

They both cannot accelerate with same cyclotron frequency as cyclotron frequency of proton is twice that of α-particle as & mass of ~~prot~~ α-particle is twice of proton.

b) Now,

For velocity of particle, $v = \frac{Bqr}{m}.$

Now,
Velocity of proton will be

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

$$= (Br)\frac{q}{m} \qquad [Br = \text{constant}]$$

$$\Rightarrow V_p \propto \frac{q}{m}$$

Velocity of α-particle will be

$$V_\alpha = \frac{B \times 2q \times r}{4m}$$

$$= (Br)\frac{q}{2m} \qquad [Br = \text{constant}]$$

$$\Rightarrow V_\alpha \propto \frac{q}{2m}$$

Now,
Taking the ratio of both the velocities

$$\frac{V_p}{V_\alpha} = \frac{Brq}{m} \times \frac{2m}{Brq}$$

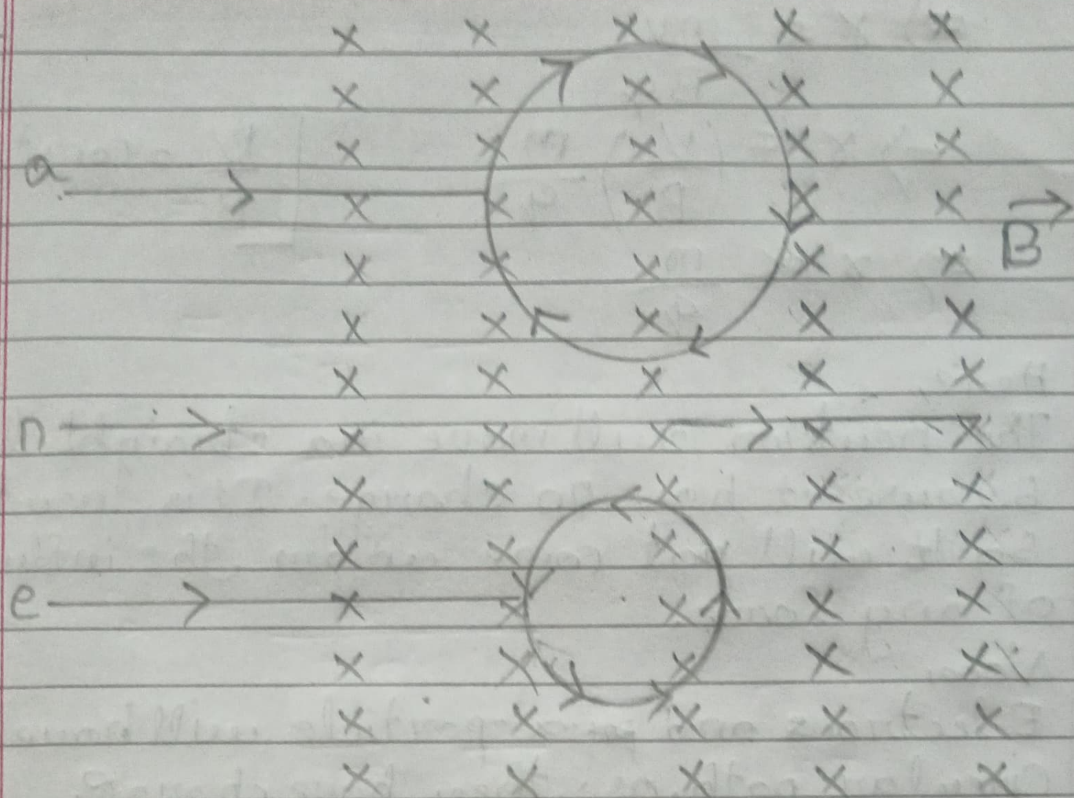
$$\Rightarrow \frac{V_p}{V_\alpha} = 2$$

$$\Rightarrow V_p = 2V_\alpha$$

Hence,
The ~~vel~~ proton will have the higher velocity than the α-particle.

Q.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.

Ans:-



Here,

~~The expression for~~

As the motion of charge particles are perpend-icular to the magnetic force, the particle will move in a circular path and will experices centipetal force.

So, the expression for ~~velocity is~~ radius is.

$$\frac{mv^2}{r} = Bvq$$

$$\Rightarrow \frac{mv}{r} = Bq$$

$$\cancel{\Rightarrow r = \frac{Bq}{mV}} \quad \cancel{\Rightarrow r \propto \frac{q}{m}}$$

Here

→ ~~The neutron will move in the straight line~~

$$\Rightarrow r = \frac{mv}{Bq}$$

$$\Rightarrow r = \left(\frac{V}{B}\right)\frac{m}{q} \qquad \left[\frac{V}{B} = \text{constant}\right]$$

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

Here,

→ The neutron will move in a straight line because it has no charge. It is neutral. So, it will not come under the influence of any force.

Now,

→ Electrons and ~~p~~ α-particle will have a circular path as they have charge.

And.

~~For electron, r_e = mv~~

The radius of the circular path followed by the electron will be less than that of the α-particle as the mass of electron is less than α-particle.

And

as $r \propto m$, so, with more mass the radius of the particle's circular path will increase.

Now,

→ The electron will move in the anticlockwise direction as the direction of current is opposite to the direction of motion of electron

And,

the α-particle will move in the clockwise direction as the current and its velocity are in the same direction.