09.07.21

Home Assignment:

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?

A- V = Potential difference

angle between motion & B = 90°

1st case:

$$\frac{1}{2} m v_1^2 = qV$$

2nd case:

$$\frac{1}{2} m v_2^2 = q(2V)$$

$$\frac{v_1}{v_2} = \frac{1}{\sqrt{2}} \Rightarrow v_2 = v_1 \sqrt{2}$$

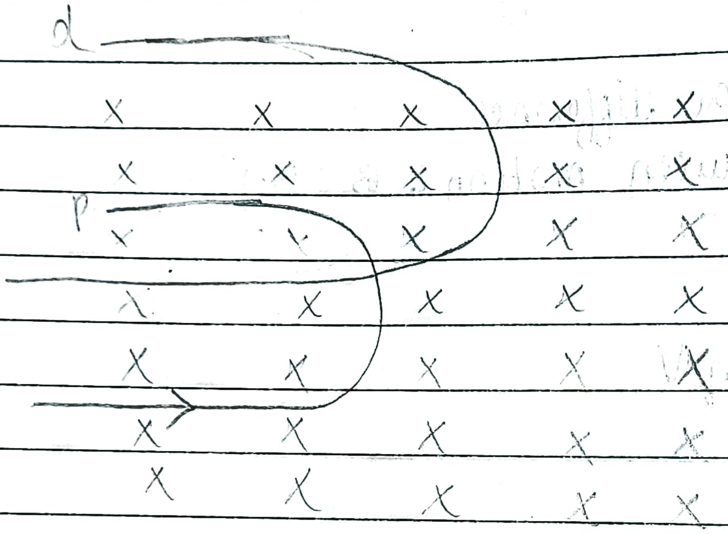
$$r_1 = \frac{m v_1}{qB}$$

$$r_2 = \frac{m v_2}{qB} = \frac{m v_1 \sqrt{2}}{qB}$$

$$\frac{r_1}{r_2} = \frac{1}{\sqrt{2}}$$

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.

A-



Radius of charged particle in magnetic field is given by the relation,

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

For same v and B,

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

So, $\frac{r_p}{r_d} = \frac{(M/q)_p}{(M/q)_d} = \frac{M_p/e}{2M_p/e} = \frac{1}{2}$

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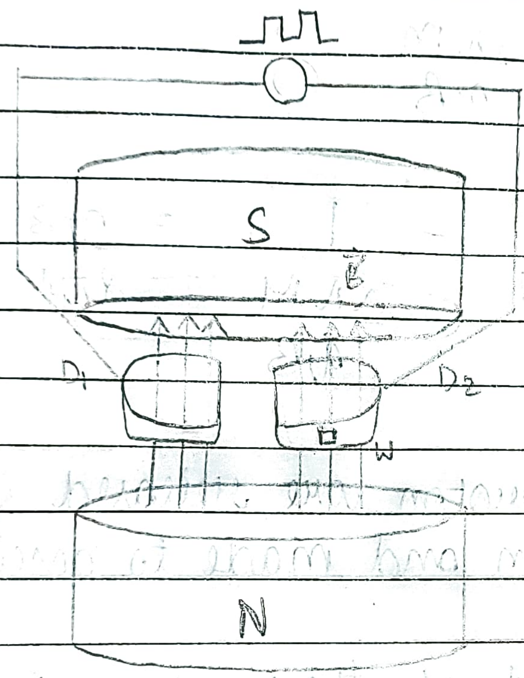
$\Rightarrow r_p : r_d = 1:2$

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

A-



Here, D_1, D_2 - Dees
N, S - Magnetic Pole Pieces
W - Window
B - Magnetic Field

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 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 orbital.

Consider a particle of charge q revolving in the path of radius r with a velocity v.

Centripetal force = Lorentz force due to magnetic field B.

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$$\frac{mv^2}{r} = qvB \Rightarrow \frac{v}{r} = \frac{qB}{M}$$

Angular velocity, $\omega = \frac{v}{r} = \frac{qB}{M}$

Time Period $= \frac{2\pi}{\omega} = \frac{2\pi m}{qB}$

Frequency $= \frac{1}{\text{Time period}} = \frac{1}{\frac{2\pi M}{qB}} = \frac{qB}{2\pi M}$

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 will have higher velocity at the exit slit of the dees?

A- a) Let us consider : Mass of proton = m, charge of proton = q, mass of alpha particle = 4M

Charge of alpha particle = 2q

Cyclotron frequency, $v = \frac{Bq}{2\pi m} \Rightarrow v \propto \frac{q}{m}$

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For proton : Frequency, $v_p = \frac{q}{M}$

For alpha particle : Frequency, $v_\alpha \propto \frac{2q}{4m}$ or $\frac{q}{2m}$

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

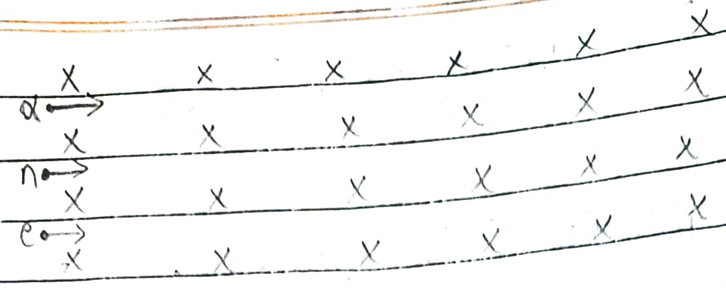
(b) Velocity, $v = \frac{Bqr}{M} \Rightarrow v \propto \frac{q}{M}$

For proton : Velocity, $v_p \propto \frac{q}{M}$

For alpha particle : Velocity, $v_\alpha \propto \frac{2q}{4m}$ or $\frac{q}{2m}$

Thus, particles will not the dees with same velocity. The velocity of proton is 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.



A- We know that a charged particle will experience a force when it enters a magnetic field. The magnetic field will move the charged particle in a circular path, as the force is perpendicular to the velocity of the particle. The radius of the circular path will be given by

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

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

As B and v are constant, we can write

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

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

The electron will inscribe a circle of radius smaller than that of the alpha particle as the mass to charge ratio of the alpha particle is more than that of the electron.

So, the alpha particle will move in the clockwise direction and the electron will move in the anticlockwise direction according to right hand rule.