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Home Assignment : Cyclotron

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 ~~pass~~ described by the proton in the magnetic field change?

Soln The radius of the circular path by the proton in the magnetic field change can be described as :

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

where B is the magnetic field
V is the potential difference

Therefore

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

Let r be the radius when the potential difference is V and r' be the radius when the potential difference is

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

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

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.

Soln Mass of deuteron = 2m (1 proton + 1 neutron)

Mass of proton = m (1 proton)

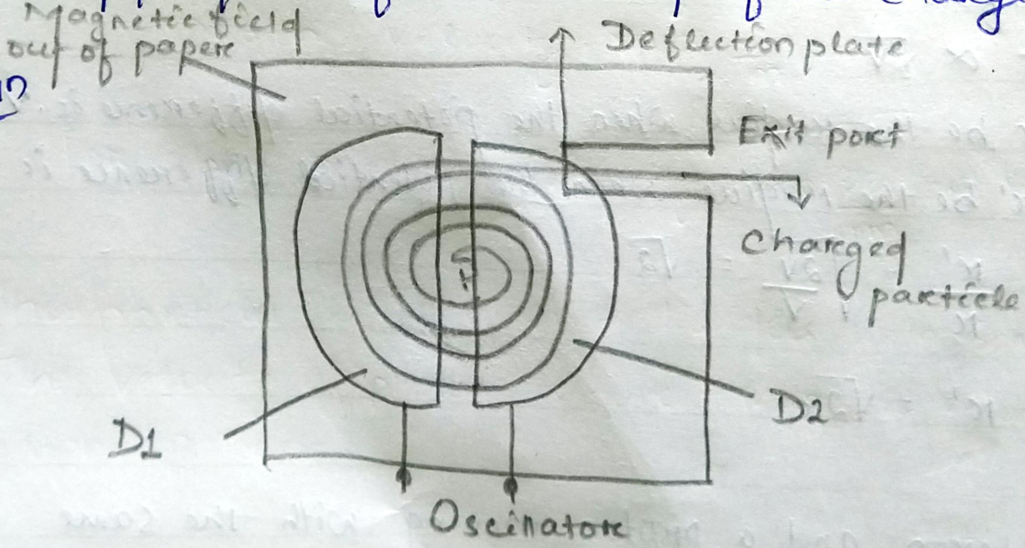
$\therefore$ $R(\text{proton}) = \dfrac{mv}{qB}$

$R(\text{deuteron}) = \dfrac{2m \times v}{qB}$

$\therefore$ Ratio $\left(\dfrac{\text{proton}}{\text{deuteron}}\right) = \dfrac{1}{2}$.

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.

Soln



Working Principle of ~~cyclotron~~ Cyclotron:

The Cyclotron uses crossed electric and magnetic fields

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which increases the kinetic energy of a charged particle without changing its frequency of revolution.

Such that,

$$F_c = F_m$$

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

$$\frac{v}{r} = \frac{qB}{m}$$

$$\omega = \frac{qB}{m}$$

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

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

The frequency is independent of velocity of the charged particle.

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

a) ~~b~~ Can both be ~~acc~~ 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?

Soln (i) Let us Consider : Mass of proton = m, charge of proton = q, Mass of alpha particle = 4m.
Charge of alpha particle = 2q.
Cyclotron frequency, $\nu = \frac{Bq}{2\pi m} \Rightarrow \nu \propto \frac{q}{m}$

For proton : Frequency, $\nu_p \propto \frac{q}{m}$

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

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

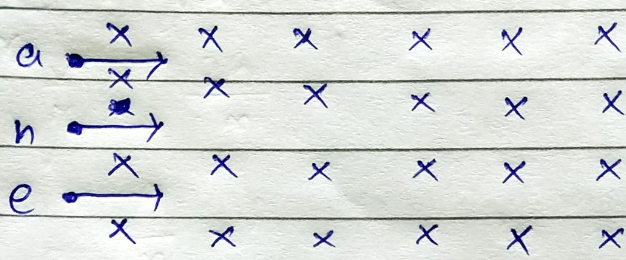
(ii) velocity, $v = \frac{Bqr}{m} \Rightarrow v \propto \frac{q}{m}$

For proton : velocity, $v_p \propto \frac{q}{m}$

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

Thus particles will not exist the dees with same velocity. The velocity of proton is twice than 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 fig. Trace their paths in the field & justify your answer.



Soln α - particle will trace circular path in clockwise direction as it's deviation will be in the direction $(\vec{v} \times \vec{B})$
i.e, perpendicular to the velocity of particle. neutron will pass without any deviation as magnetic field does not exert neutral particle.
Electron will trace circular path in anticlockwise direction as its deviation will be in the direction opposite to $(\vec{v} \times \vec{B})$ with a smaller radius due to large charge / mass ratio as $r = mv/qB$.

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