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?
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.
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.

Home Assignment

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?

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.

11/7/21

Cyclotron

Home assignment (for 12-7-21)

1) 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

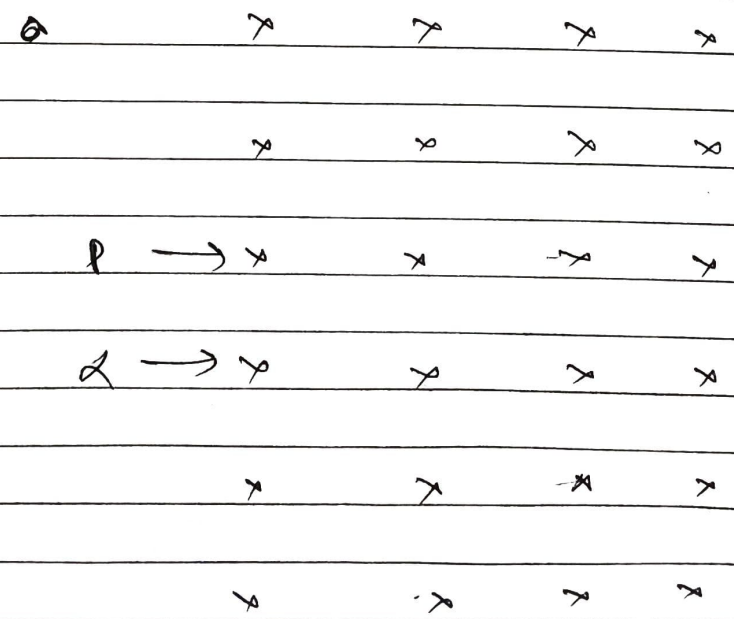
$\therefore r \propto \sqrt{V}$.

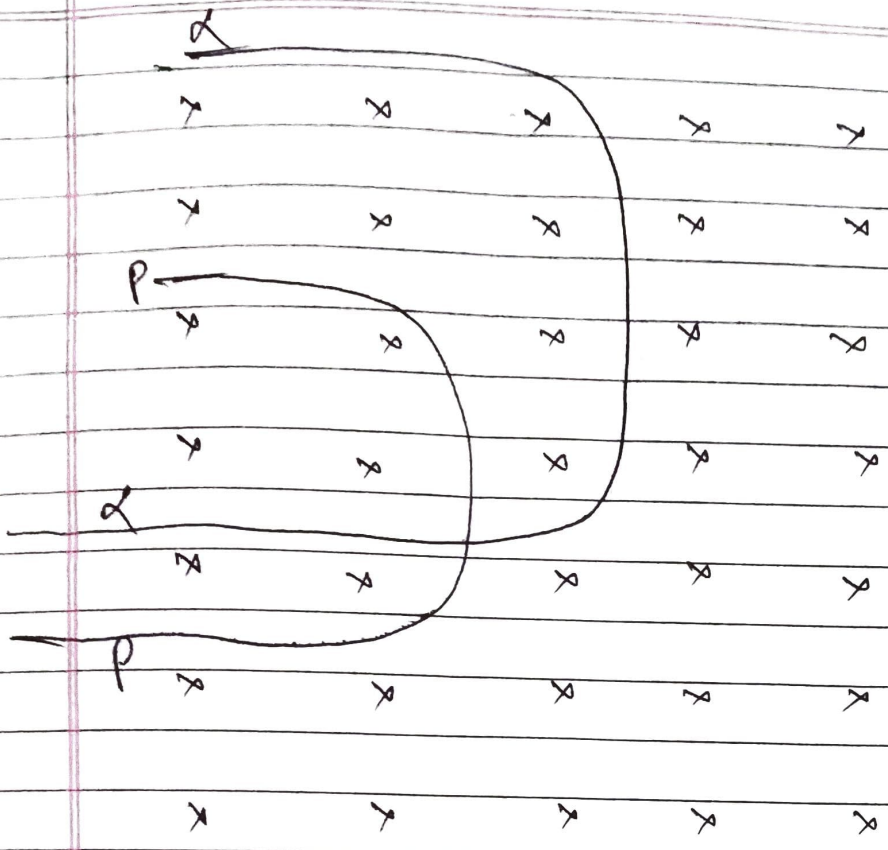
let r be the radius when the potential difference is V & r' be the radius when the potential difference is 2V.

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

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

2)

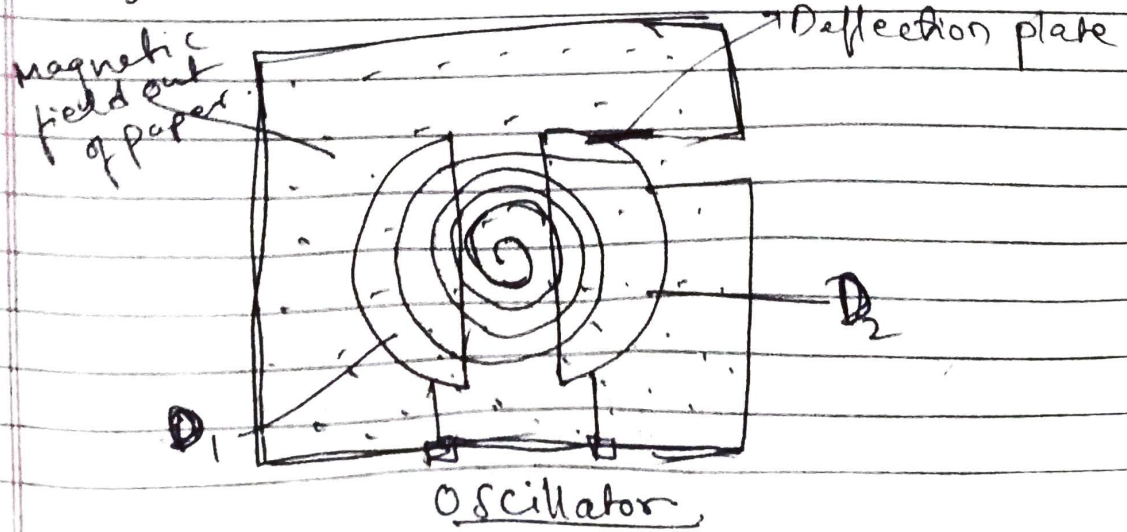




$$r = \frac{mv}{qB} \propto \frac{m}{q} \text{ for some } v \text{ & } B.$$

$$\frac{r_p}{r_\alpha} = \frac{(m/q)_p}{(m/q)_\alpha} = \frac{(mp/e)}{((4mp)/2e)} = \frac{1}{2}$$

3. Diagram of Cyclotron.



Principle :- The charged particle can be accelerated to very high energies by making it pass through moderate electric field by a number of times. This can be done with the help of a ⊥ magnetic field which throws the charged particle into a circular motion, the frequency of which doesn't depend on the speed of the particle & the radius of the circular orbit.

Cyclotron frequency is independent of the velocity of charged particle.

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.

4) α-particle and a proton are released from the centre.

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 $\Rightarrow$ $\boxed{\nu_p \propto \frac{q}{m}}$

For alpha particle: frequency,

$$\nu_\alpha \propto \frac{2q}{4m} \text{ or } \nu_\alpha \propto \frac{q}{2m}$$

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

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

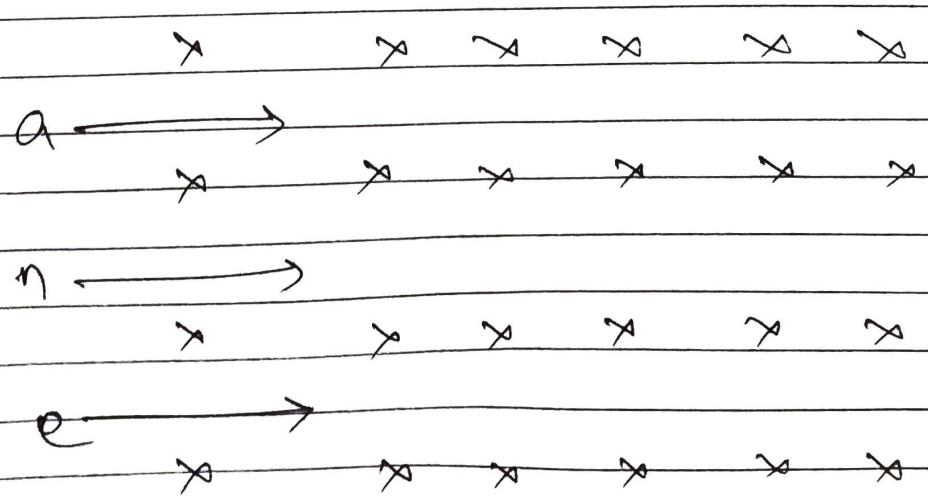
for proton: velocity, $v_p \propto \frac{q}{m}$.

for alpha particle: velocity,

$$v_\alpha \propto \frac{2q}{4m} \text{ or } v_\alpha \propto \frac{q}{2m}$$

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

5)



α particle will trace circular path in clockwise direction as it's deviation will be ⊥ in the direction $(\vec{v} \times \vec{B})$, ie ⊥ to the velocity of particle. Neutron will pass without any deviation as magnetic field doesn't 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 $\left(r = \frac{mv}{qB}\right)$.