{ B.Sc Part II Physics (Hons)
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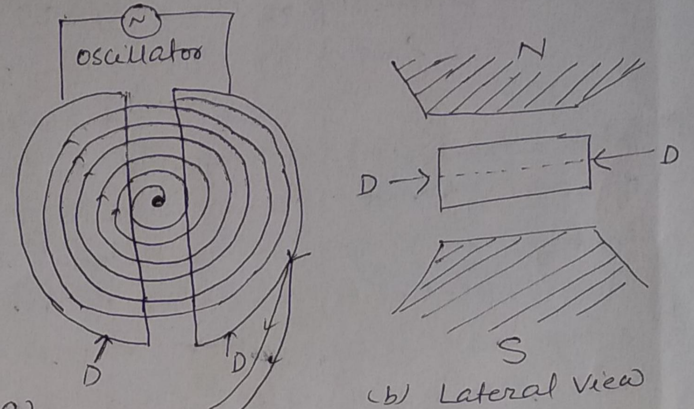
**Q** Describe the construction and working of a cyclotron. Obtain an expression for the energy of a particle accelerated by it. What are the limitations of this instrument.

**Ans** <u>Cyclotron:-</u>




(a) Vertical view (b) Lateral view cyclotron

Cyclotron is that type of accelerator in which the energy of a charged particle is increased by subjecting it to periodic potential while it moves in circular orbits. It is developed by Lawrence. In this machine the function of a large number of drift tubes of a linear accelerator is acheived by a pair of hollow metallic electrodes called dees as shown in figure. The dees (D, D) are connected to the two terminals of high frequency oscillator and are kept in between the pole pieces of a large electromagnet, while the electric field acts over the charged particle moving in the hollow dees only. when they are in the interdee gap region, the magnetic field acts on them everywhere and as such they move in circular orbits. They are accelerated by the electric field only when they come in interdee gap region and their motion is synchoronized with the oscillator frequency. For charged particles of mass 'm' charge 'e', velocity 'v' in their circular orbit of radius r, we get

$$Hev = \frac{mv^2}{r} \quad \text{But } v = r\omega \quad \text{--- (I)}$$

$$\omega = \frac{He}{m} = 2\pi f \quad \text{--- (II)}$$

$$\text{or } f = \frac{He}{2\pi m}$$

Here H = intensity of the magnetic field and 'f' is the frequency of the oscillator. The equation (I) shows that the charged particle will move with constant angular velocity and synchronization for accl$^n$ will be acheived, if the oscillator frequency satisfies the eq$^n$ (II), then the maximum energy of the charged particle depends on the radius R of the dees.

Let the velocity in the outermost orbit be $V_R$, then

$$HeV_R = \frac{mV_R^2}{R}$$

or $mV_R = HeR$

$$\therefore E = \frac{1}{2}mV_R^2 = \frac{1}{2m}(HeR)^2 = \frac{H^2e^2R^2}{2m} \quad \text{------ (III)}$$

This shows that maximum energy E depends on the intensity of the magnetic field H.

from eq (II) & (III) $E = 2\pi^2 f^2 R^2 m$

This shows that the maximum energy also depends on the frequency of the oscillator. After the completion of a few ~~found~~ rounds inside the dees, the energy of a charged particle increases so much that the eqn (II) does not hold correctly due to relativistic variation of m. This puts a limit to the maximum energy and just by increasing the intensity of the magnetic field and the size of pole faces of the electromagnet the limit can not be exceeded. This difficulty has been overcome by two methods. In one method the increasing m of equation (II) is compensated by decrease in oscillator frequency f. The accelerator in which this type of arrangement is made is called synchrocyclotron. In this ~~acceler~~ ~~accelet~~ accelerator frequency starts from its maximum value $f_{max}$ when the charged particles are injected for acceleration and goes on decreasing during the time, the particles are accelerated till its minimum value $f_{min}$ is reached and the particles have reached the outermost orbit in the dees. The change in f and m during the period of accleration is such that eqn (II) holds good. This condition can be made also by increasing H so that $\left(\frac{H}{m}\right)$ remain constant during the period of acceleration. This is done in Synchroton. The value of H is minimum when the particles are injected for acceleration and goes on increasing during the period of acceleration till its maximum value is reached and the particles have reached their outermost orbit