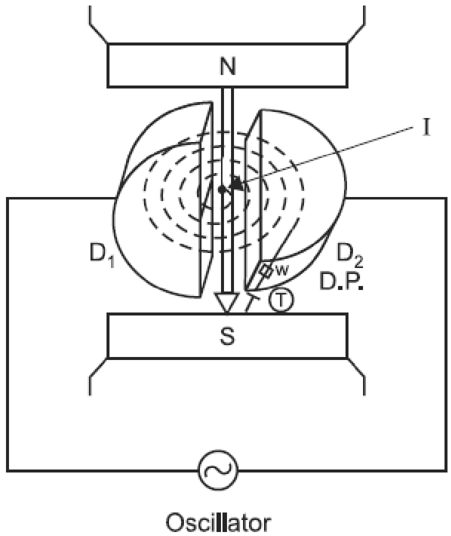
CYLOTRON

(*a*) The essential parts of the cyclotron are as shown in the figure.



NS	:	Magnet
D_1, D_2	:	Dees
D.P.	:	Deflecting plate
T	:	Target
I	:	Ion source
W	:	Window

Principle: A charged particle can be accelerated by repeated application of an oscillating electric field by making it follow a circular path by a transverse magnetic field.

Working: The ion source *I* emitting the charged particles to be accelerated is placed at the centre of the dees. When a particle is emitted, suppose D_1 is positive and D_2 is negative. The particle is accelerated towards D_2 and enters it with a higher speed due to acceleration by electric field.

Once inside D_2 (a hollow conductor); the electric field intensity becomes zero. The particle is under the action of the magnetic field alone and hence follows a circular path. It completes a semicircle inside D_2 and emerges in the gap between the plates.

At this instant; the polarity of the dees is reversed due to the oscillator *i.e.*, D_2 becomes positive and D_1, negative. The particle is again accelerated in the gap, now towards D_1

and is further speeded up before entering D_1. Inside D_1, it follows a semicircle of larger radius. The process is repeated till the particle attains the desired high speed and is deflected out of window *W* by means of deflecting plates (*D.P.*) to hit target *T*.

Role of Crossed Electric and Magnetic fields

The magnetic field acting normal to the plane of motion of the charged particle makes it follow a circular path. It deflects the particle sideways but can't alter its kinetic energy because it does not speed up the particles. It however helps the particle to utilise the same accelerating electric field repeatedly to speed up the particles.

The oscillating electric field increases the speed and hence the kinetic energy of the particle each time it passes the gap between the dees.

We have
$$\frac{mv^2}{r} = q\,v\,B$$
$$v = \frac{q\,B\,r}{m}$$
$$KE = \frac{1}{2}mv^2$$
$$= \frac{1}{2}m\frac{q^2B^2r^2}{m^2}$$
$$= \frac{q^2r^2B^2}{2m}.$$

For maximum K.E; '*r*' should be maximum.

Now
$$r_{\max} = R$$
$$= \text{Radius of dees}$$

$\therefore$
$$K_{\max} = \frac{q^2R^2B^2}{2m}.$$

(*b*) (*i*) Desired frequency of the oscillating electric field is given by

$$\nu = \frac{v}{2\pi r} = \frac{qB}{2\pi m}$$

$\therefore$ ν depends on $\frac{q}{m}$

As $\frac{q}{m}$ is different for α-particle and proton; the particles **cannot be accelerated** using same frequency.

(*ii*) Speed of particle

$$v = \frac{qBr}{m}$$

At the time of exit; $r = R$

$$v_{\alpha} = \frac{q_{\alpha} BR}{m_a} = \left(\frac{2}{4} BR\right) = \frac{1}{2} BR \text{ units}$$

For proton $v_p = \frac{q_p BR}{m_p} = \left(\frac{1}{1} BR\right) = BR$ units

So the two particles emerge with different speeds with proton having a higher velocity.