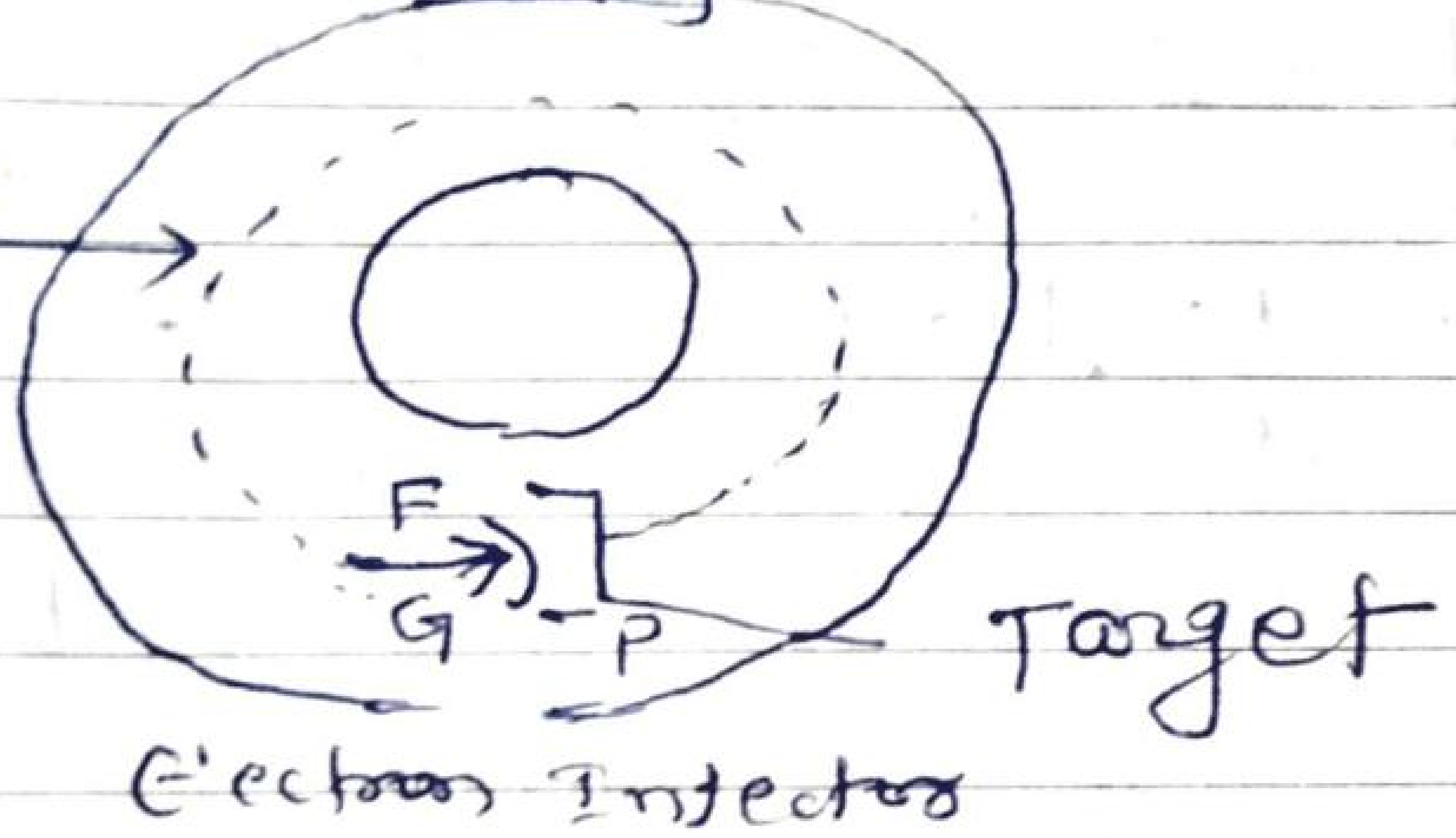
Betatron

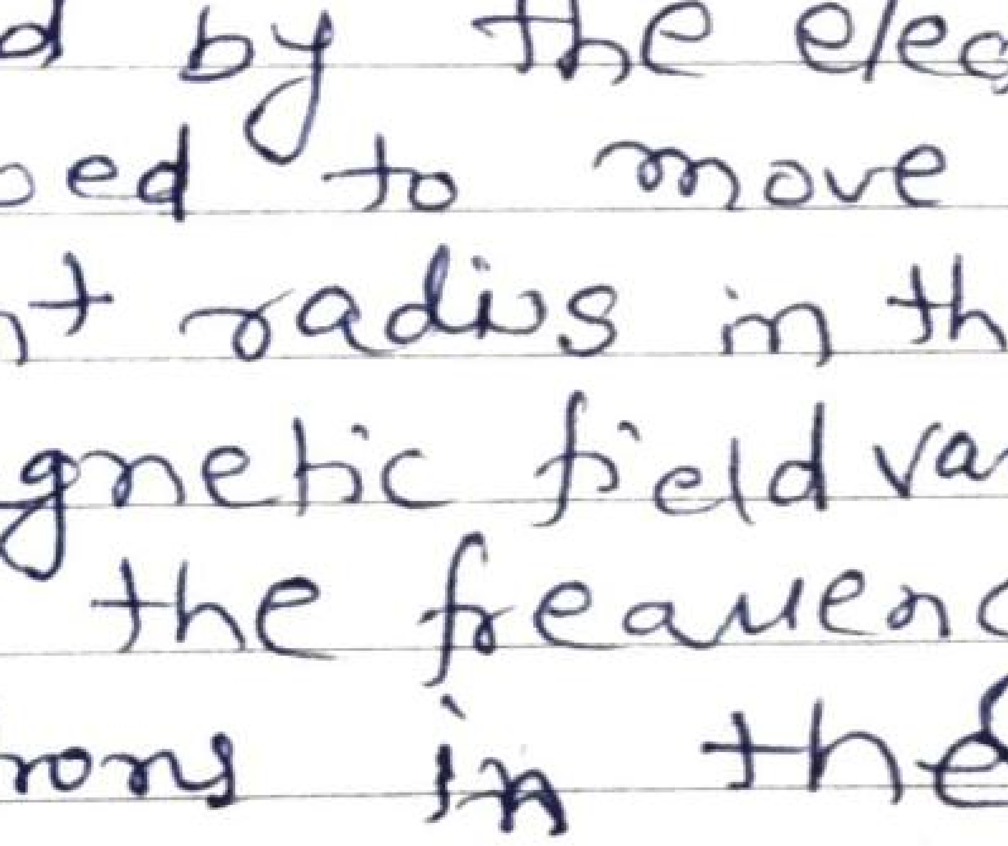
Betatron is a device to accelerate electrons (beta particles) to very high energy. The action of this device depends on the principle of transformer.

Construction → It consists of a doughnut-shaped vacuum chamber placed between the pole-pieces of an electromagnet.



The electromagnet is energised by an alternating current. The magnet produces a strong magnetic field in the doughnut. The electrons are produced by the electron gun (FG) and are allowed to move in a circular orbit of constant radius in the vacuum chamber. The magnetic field varies very slowly compared with the frequency of revolution of the electrons in the equilibrium orbit.

The varying magnetic field acting parallel in the axis of the vacuum tube produces two effects on the electrons viz.



(i) The changing flux due to the electromagnet produces the induced emf which is resposible for the acceleration of the electrons.

(ii) The field of the magnet serves at the same time to bend the electrons in a circular path in the chamber and confine them to the rigion of the changing flux.

Theory → If the electron moving in an orbit of radius r,

flux linked with orbit : ϕ

The rate of change of flux = $d\phi/dt$

The induced emf in the orbit

$$E = -d\phi/dt$$

The electronic charge - e

The work done on an electron of charge e in one revolution $= Ee$

$$= -e\frac{d\phi}{dt}$$

The tangential electric force acting on the orbiting electron - F

The path length in one revolution $= 2\pi r$

The work done on the electron in one revolution $\} = F \times 2\pi r$

$$\therefore F \times 2\pi r = -e\, d\phi/dt$$

$$\therefore \boxed{F = -\frac{e}{2\pi r} d\phi/dt} \rightarrow (A)$$

 When the velocity (v) of the electron

increases due to this force,

The electron experience a radial force inward = centripetal force mv^2/r

In presence of the magnetic flux perpendicular to the plance of the orbit then

$$Bev = mv^2/r$$

B = magnetic flux.

m = mass of electron.

$$mv = Ber$$

From newton's second law of motion

$$F = \frac{dp}{dt} = \frac{d}{dt}(mv)$$

$$= \frac{d}{dt}(Ber) = er\, dB/dt$$

$$\boxed{F = er\, dB/dt} \quad \text{— (B)}$$

Equating eqn (A) & B for constant radius of the orbit

$$\frac{e}{2\pi r}\, d\phi/dt = er\, dB/dt$$

$$d\phi = 2\pi r^2 dB$$

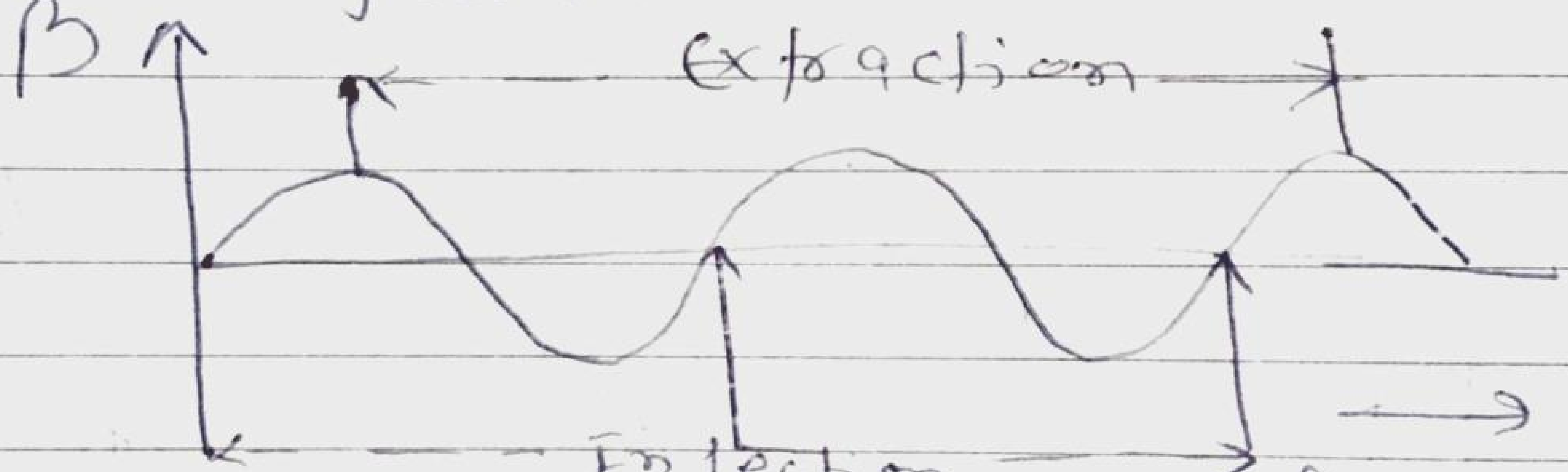
integrating it

$$\int_0^{\phi} d\phi = 2\pi r^2 \int_0^{B} dB$$

$$\boxed{\phi = 2\pi r^2 dB}$$ Betatron condition

If the uniform magnetic field B acts over an area πr^2
The magnetic flux $\phi' = \pi r^2 B$.
Therefore the flux through the orbit is twice the flux enclosed by the orbit, if the magnetic field were to be uniform over the area.

This distribution of magnetic flux is obtained by the special pole-pieces where the magnetic field is greater at the centre of the orbit than at its circumference.



Variation of magnetic field with time.

Electrons are Ejected into the chamber when magnetic field just begins to rise. The electrons are then accelerated by the increasing magnetic flux linked with the electron orbit. During the time the magnetic field reaches its peak value the electrons make several revolutions and get accelerated. If they are allowed to revolve any more, the decreasing magnetic field would retard the electrons. Hence, the electrons are expacted at this

Stage by using an auxiliary
9 magnetic field to deflect them from
their normal Course. The high energy
10 electron beam can be made to strike
the target, generating X-rays. lastly the
11 electrons can be made to emerge
out of the apparatus and used to
12 transmutation work.

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