Cyclotron
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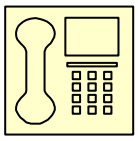
By R. S. Saini

(M.Sc. Physics, M.Ed.)

Kendriya Vidyalaya, Sector 47, Chandigarh



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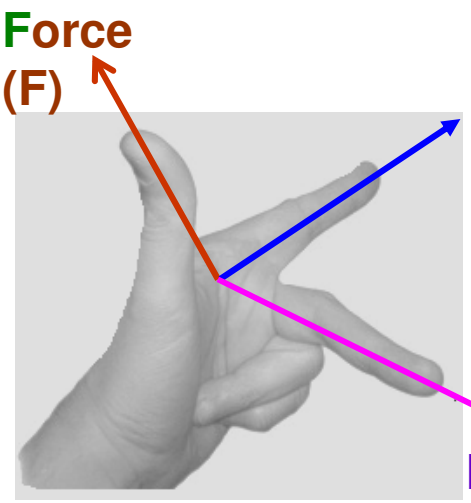
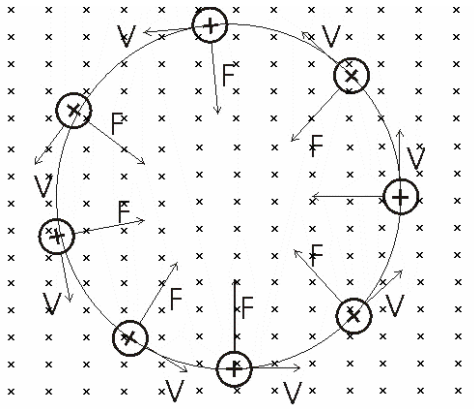
Fleming's Left Hand Rule:



Motion of a charged particle $\perp$ to the magnetic field.



$$\frac{mv^2}{r} = qvB \quad \textbf{or} \quad \boxed{r = \frac{mv}{qB}} \ldots\ldots\ldots (1)$$

Further angular velcocity $\boxed{\omega = \frac{v}{r} = \frac{qB}{m}} \ldots\ldots\ldots (2)$

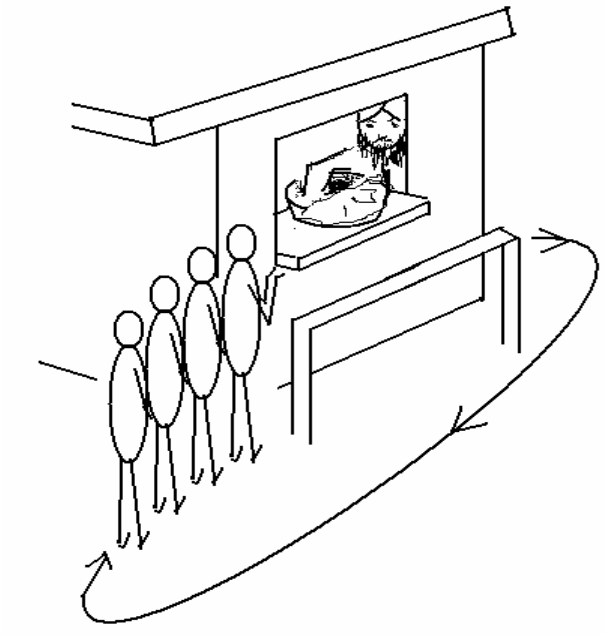
and time period $\boxed{\mathbf{T} = \frac{2\pi}{\omega} = \frac{2\pi m}{qB}} \ldots\ldots\ldots (3)$

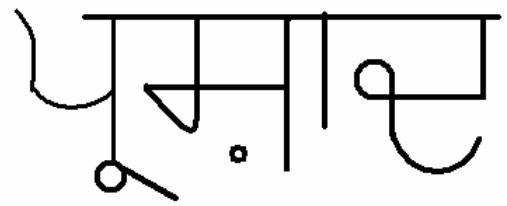
and frequency $\boxed{\upsilon = \frac{1}{T} = \frac{qB}{2\pi n}} \ldots\ldots\ldots (4)$

Cyclotron

A cyclotron accelerates the charged particles like protons, alpha particles etc. using small oscillating electric field.

Principle

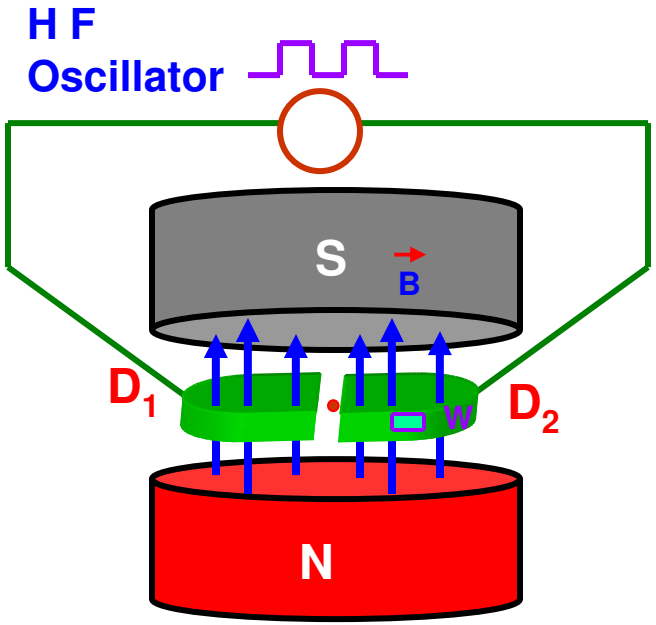


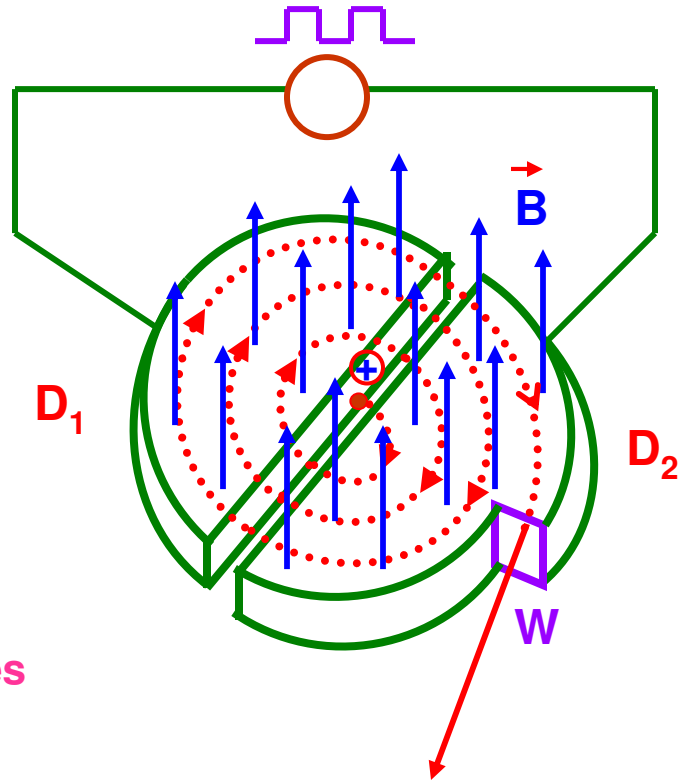


Principle

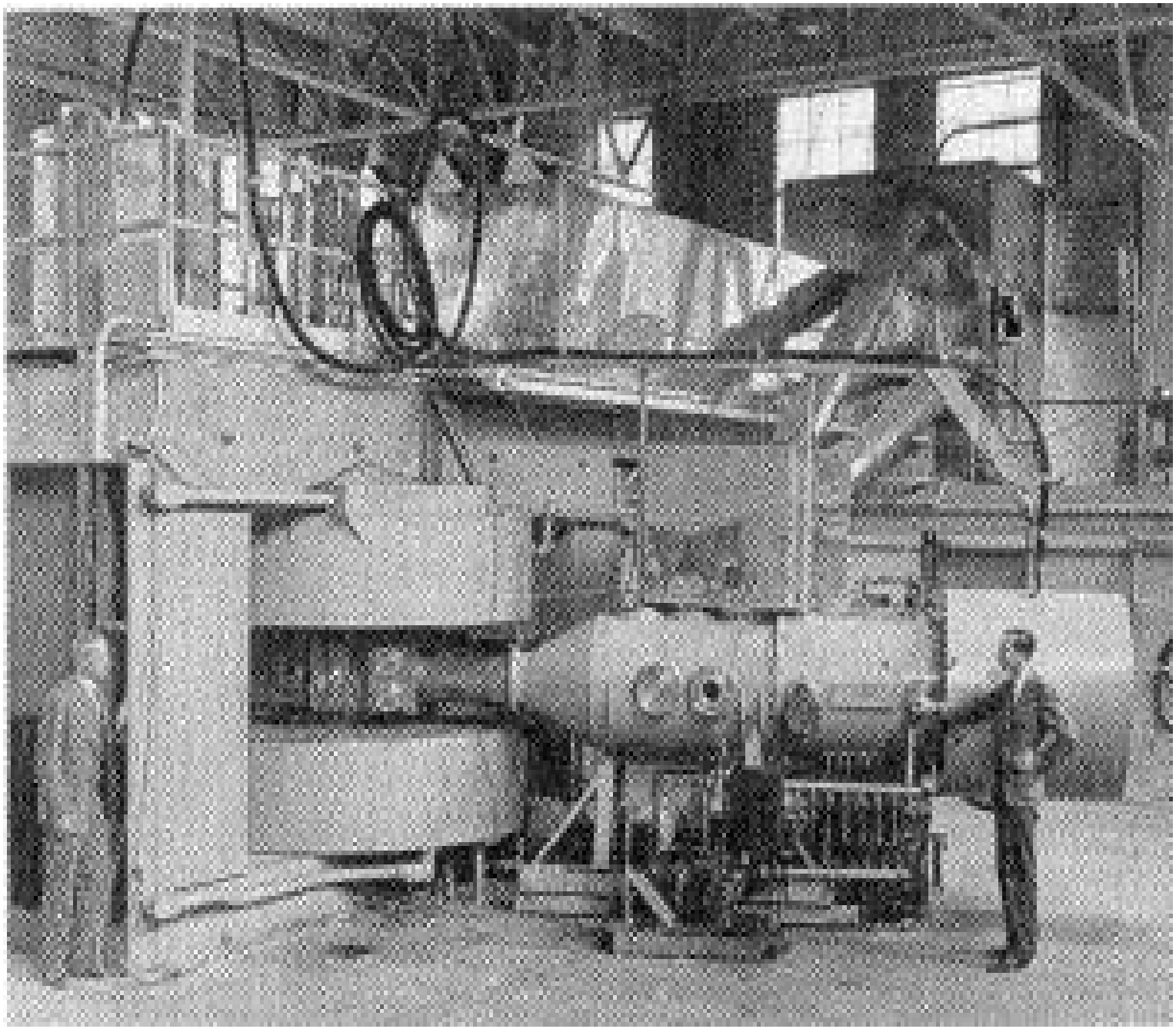
a charged particle can be accelerated to a sufficiently high kinetic energies with the help of smaller oscillating electric potential difference, by making it to cross same electric field again and again

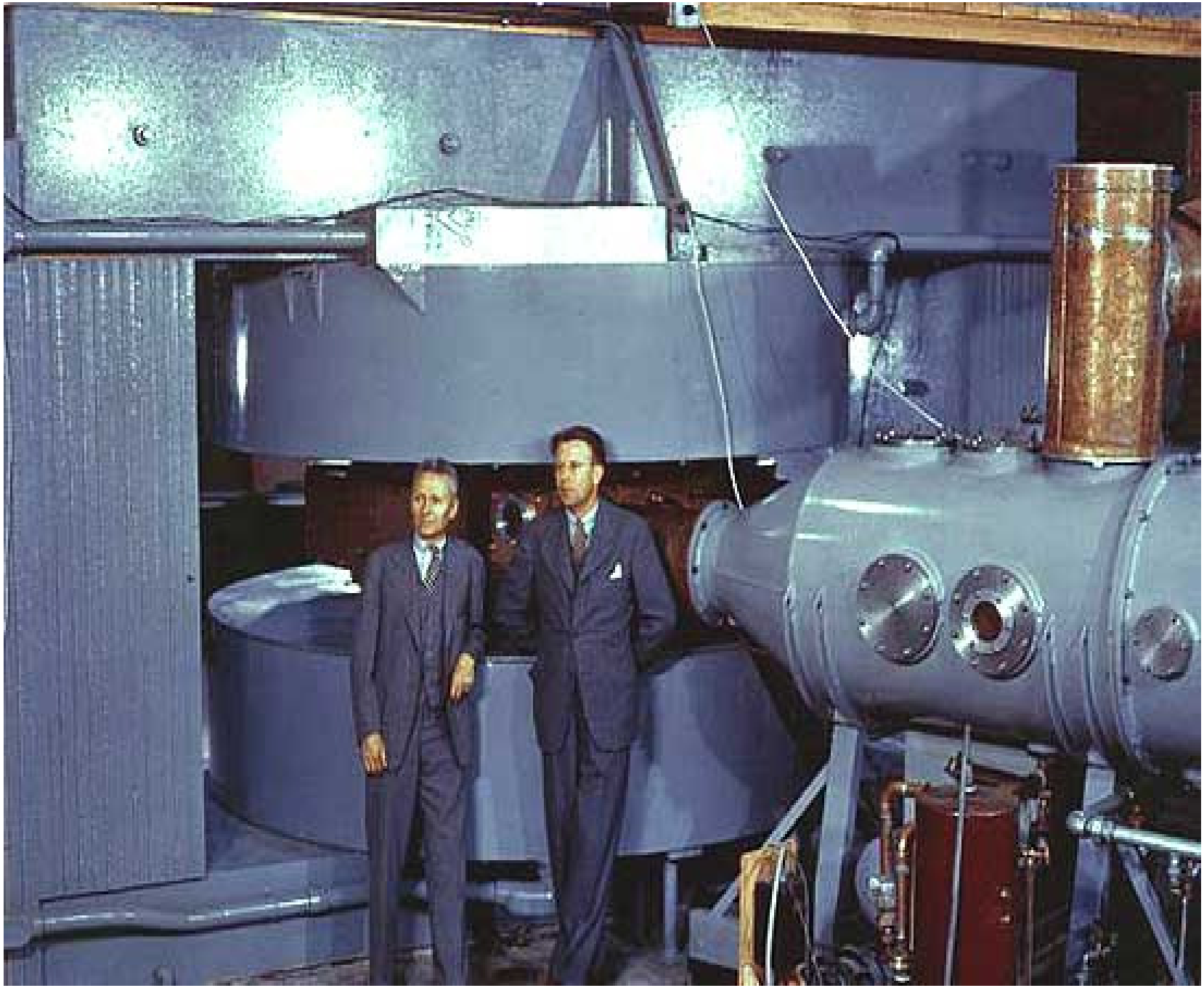
Cyclotron:





D_1, D_2 – Dees N, S – Magnetic Pole Pieces
W – Window B - Magnetic Field





Theory:

The magnetic force experienced by the charge provides centripetal force required to describe circular path.

$\therefore \quad mv^2 / r = qvB \sin 90°$

$$v = \frac{B\,q\,r}{m}$$

(where m – mass of the charged particle, q – charge, v – velocity on the path of radius – r, B is magnetic field and 90° is the angle b/n v and B)

If t is the time taken by the charge to describe the semi-circular path inside the dee, then

$$t = \frac{\pi\ r}{v} \quad \text{or} \quad t = \frac{\pi\ m}{B\ q}$$

Time taken inside the dee depends only on the magnetic field and m/q ratio and not on the speed of the charge or the radius of the path.

If T is the time period of the high frequency oscillator, then for resonance,

$$T = 2\ t \quad \text{or} \quad T = \frac{2\pi m}{B\ q}$$

If f is the frequency of the high frequency oscillator (Cyclotron Frequency), then

$$f = \frac{B\ q}{2\pi m}$$

Maximum Energy of the Particle:

Kinetic Energy of the charged particle is

$$K.E. = \tfrac{1}{2} m v^2 = \tfrac{1}{2} m \left(\frac{B q r}{m}\right)^2 = \tfrac{1}{2} \frac{B^2 q^2 r^2}{m}$$

Maximum Kinetic Energy of the charged particle is when r = R (radius of the D's).

$$K.E._{max} = \tfrac{1}{2} \frac{B^2 q^2 R^2}{m}$$

m varies with v according to Einstein's Relativistic Principle as per

$$m = \frac{m_0}{[1 - (v^2 / c^2)]^{1/2}}$$

NOTE: Cyclotron can not be used for accelerating neutral particles. Electrons can not be accelerated because they gain speed very quickly due to their lighter mass and go out of phase with alternating e.m.f. and get lost within the dees.