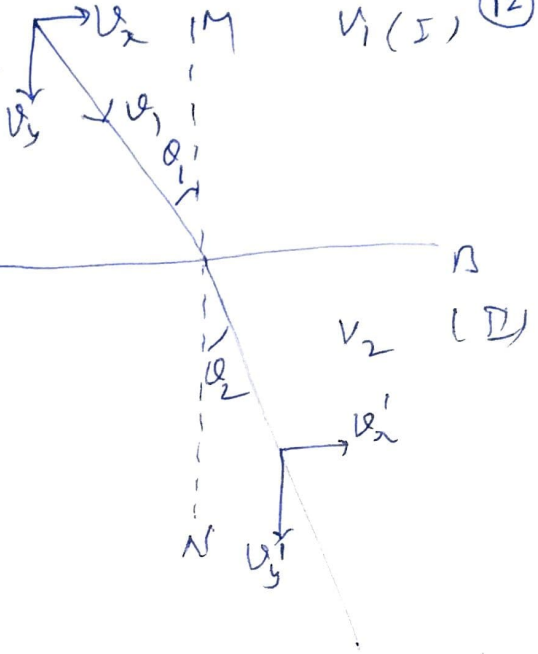
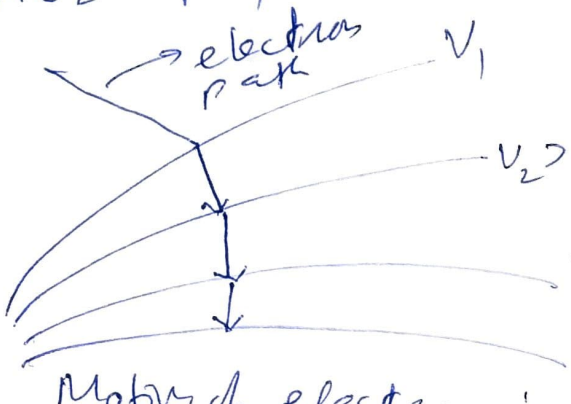
Electron Refraction - Bethe's Law

$$\frac{\sin\theta_1}{\sin\theta_2} = \sqrt{\frac{V_2}{V_1}}$$

$V_2 > V_1$

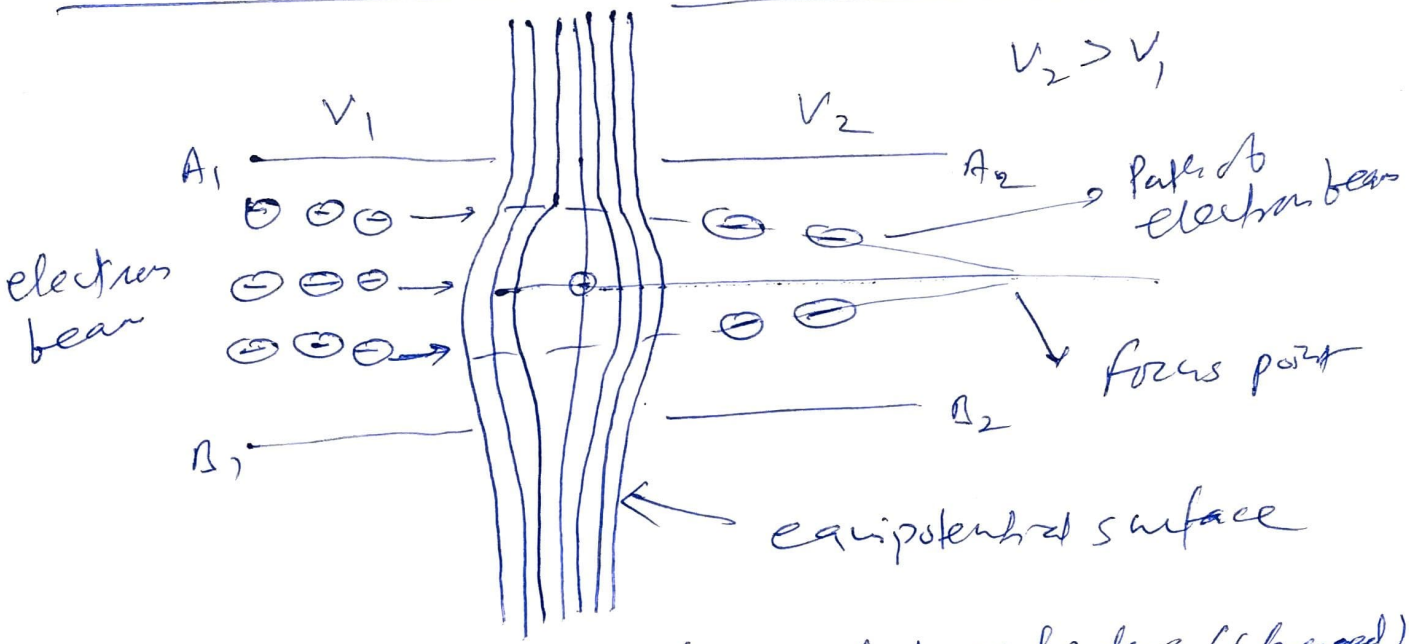
$v_y' > v_y$





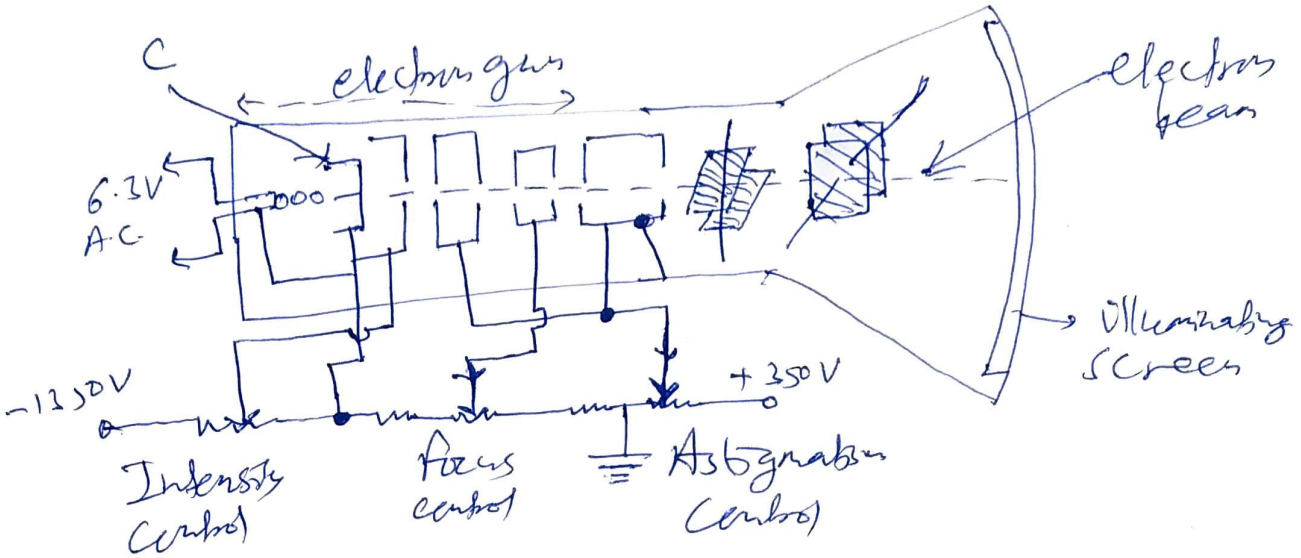
Motion of electron in non-uniform electron field

Electrostatic focussing - Electrostatic Lens



In such arrangement, two metal cylinders (charged) with different potential works as electrostatic lens for electron beam.

This arrangement is used in electron beam of Cathode ray tube or Cathode ray oscillograph



Cathode Ray Tube

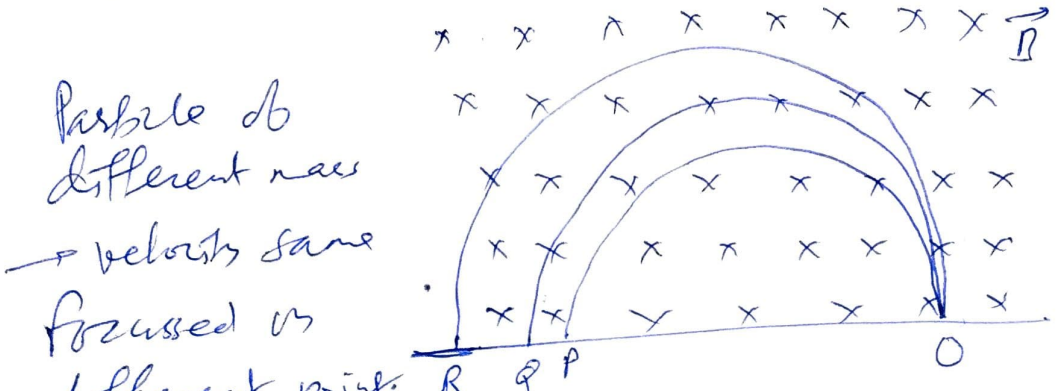
electron gun has many high potential cylinders with continuously increasing potential with anodes A_1, A_2, A_3 --- etc.

The electron beam emitted from electric source C is focussed on screen as fine beam.

Magnetic focussing

Electron beam can also be focussed using magnetic field.

(i) Longitudinal Magnetic field focussing
(ii) Transverse Magnetic field focussing



→ Principle of Mass spectrograph

Magnetic focussing used in cyclotron

Cyclotron :- device to accelerate charged particles.

It is a cyclic accelerator. Charged particles can be accelerated at low potential.

Working Principle

When a charged particle enters a transverse uniform magnetic field, its motion in magnetic field B circular and its time period is

$$T = \frac{2\pi m}{qB} \quad \text{and frequency} \quad \nu = \frac{qB}{2\pi m}$$

⇒ Rotation frequency or angular frequency does not depend on particle velocity.

In transverse magnetic field, particle of different velocity, travels in circular path of different radius with same time period.

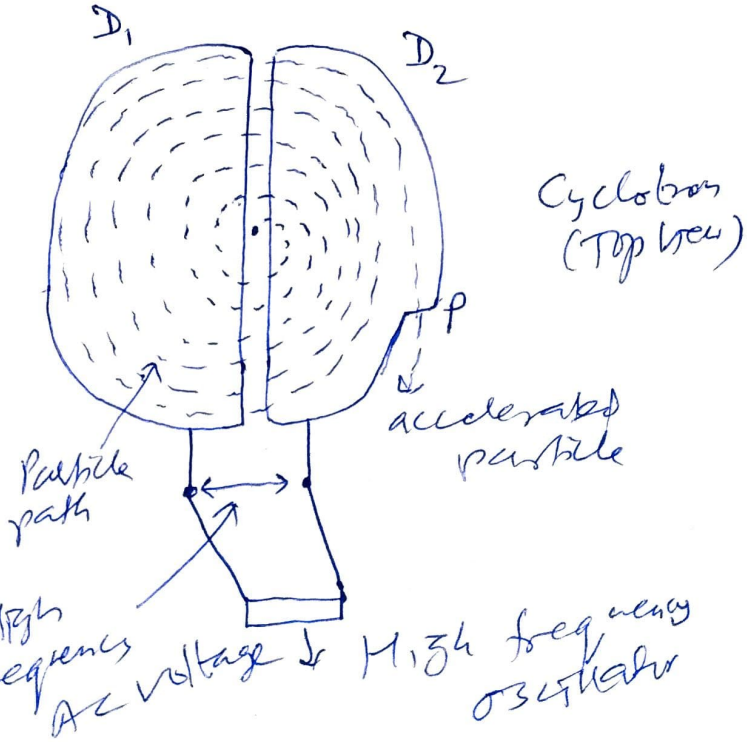
Particles are continuously accelerated and energy increases after each cycle.

Design

There is a hollow cylindrical box of metal in cyclotron.

This box is splitted in two parts along the diameter

Two parts called D_1 and D_2

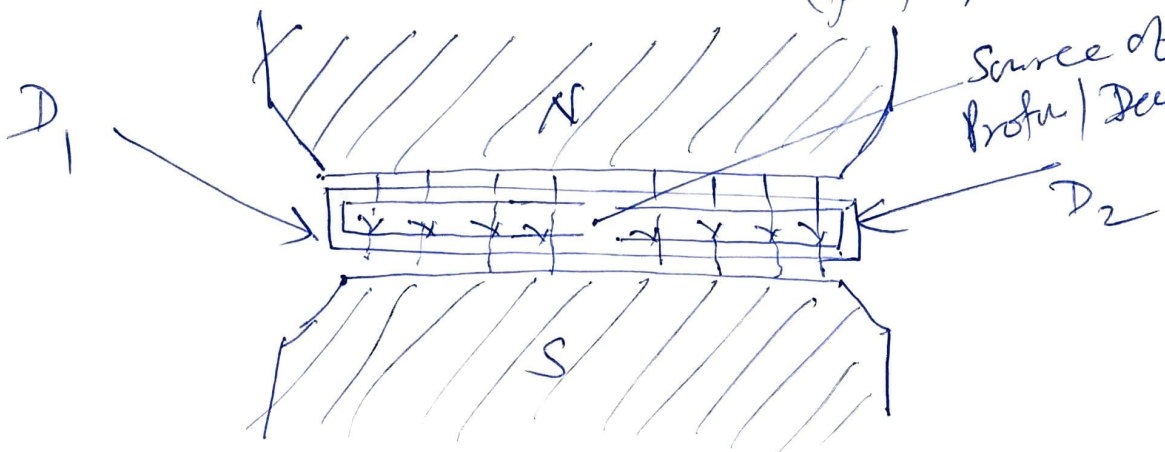


Cyclotron (Top view)

Two D are connected with high frequency oscillator, A.C. voltage difference and Electric field (E) is established in between D.

Strong magnetic field (B) is established perpendicular to the plane of D. On one side of D plane North pole (N) and other side South pole (S) is placed. Whole setup is placed in vacuum and source of charged particle is kept in the center of D.

(proton, deuteron)



Cyclotron (Back view)
Side view)

The condition required for acceleration of particle is → The frequency of AC. Electric field E, ν_0 should be reciprocal of the particle time period $T = \frac{2\pi m}{qB}$

$$\therefore \nu_0 = \frac{1}{T} = \frac{qB}{2\pi m}$$

Condition of resonance

ν_0 → Resonance frequency or Cyclotron frequency

Final energy of particle

If particle completes N cycles before coming out of D.

In each half cycle particle is accelerated by potential V.

Energy in one complete cycle = $(2qV)$

Energy after N cycle = $N(2qV)$

If v_{max} is maximum velocity after N cycle

$$E_{max} = \frac{1}{2} m v_{max}^2$$

$$\Rightarrow \frac{1}{2} m v_{max}^2 = 2NqV$$

$$R_{max} = \frac{m v_{max}}{qB}$$

$$E_{max} = \frac{1}{2} m \left[\frac{qBR_{max}}{m}\right]^2$$

$$= \left[\frac{1}{2} B^2 R_{max}^2\right]\left[\frac{q^2}{m}\right]$$

$$\therefore E_{max} \propto \frac{q^2}{m}$$

B = Constant

R = Constant

Energy of protons $\simeq 25$ MeV