Unit IV - **ELECTRON OPTICS**

Basic Definitions:-

Electric field intensity/ strength :- Let a charge Q sets up an electric field in its surrounding space (area) . If a charge q is placed at any point in the region around the charge Q, it experiences a force due to electric field sets up by Q. "Thus, **electric field strength/ intensity is defined as the force per unit charge at that point."**

$$\mathbf{E} = \frac{F}{q}$$

$$F = qE$$

$$F = \frac{q\,Q}{4\pi\epsilon_o\epsilon_r\, r^2}$$

$$\text{Since, } E = \frac{F}{q} = \frac{q\,Q}{4\pi\epsilon_o\epsilon_r\, r^2}$$

Electric field is conventionally represented by lines of force. Field lines indicate the magnitude as well as direction of the field. In uniform electric field, the field lines are straight, parallel and equally spaced shown in fig. 1.

Field lines are curved and spaced non-uniformly in a non-uniform electric field shown in fig. 2.

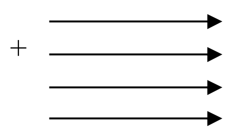


Fig. 1

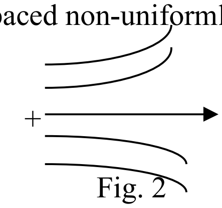


Fig. 2

Direction of electric field lines are always from positive potential to negative potential

Electric Potential(V):- When an electric charge is moved towards like charges or away from an unlike charges then work is done against the force of attraction & repulsion by an external agency. Hence the electric charge acquires the potential energy. If the charge is released work is done by the field.

Definition:- "The electric potential at a certain point P in the field E, is the work done to bring a unit positive charges from infinity upto that point P against the electric lines of force."

$$V = \frac{W}{q} = \frac{Fd}{q} = \frac{qEd}{q} = Ed \qquad \boxed{E = V / d}$$

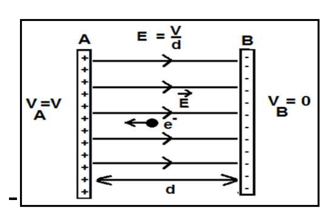
Electron Volt(eV):- It is the unit of measurement of energy. As the amount of kinetic energy acquired by atomic particles is very small compared to Joule, so their energies are expressed in electron volts.

Definition:- It is defined as the energy acquired by an electron accelerated through a potential of one volt.

$$1eV = 1.602 \times 10^{-19} J$$

CASE- I MOTION OF CHARGED PARTICLE IN UNIFORM LONGITUDINAL ELECTRIC FIELD

(i. e. v II E)



Let A & B are two plane parallel metals plates of equal area, separated by distance 'd' and insulated from each other. If a d.c voltage source s applied between two plates, then the plates are charged oppositely and an electric field is produced in the region between the plates. The field lines are directed from +ve to –ve. If the potential difference between A & B is V, then the electric field strength is given by

$$E = V / d \text{ ------(1)}$$

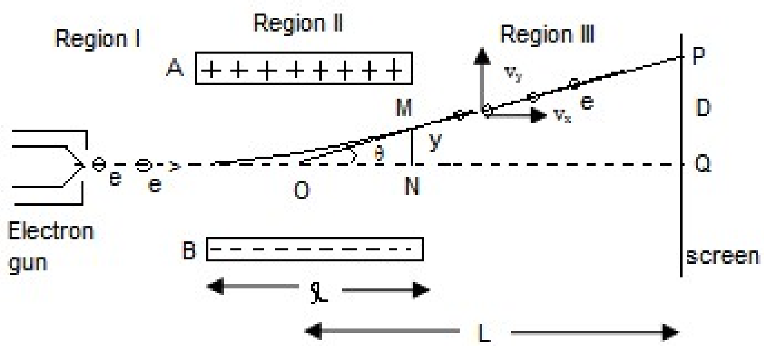
Now assuming that it is a parallel plate capacitor, let an electron of mass 'm' and charge 'e' be placed at rest in uniform electric field and then it is released. This electron experiences a force due to electric field

$$F = -eE \text{ ---------(2)}$$

-ve sign indicates that the force accelerates the electron in a direction opposite to the direction of electric field.

Electron travels in a straight-line path opposite to the direction in which electric field is acting.

CASE II :- Motion of particle perpendicular to uniform electric field (i.e. v ⊥ E)



Consider an electron moving in a uniform perpendicular Electric field intensity $\vec{E}$.

Let, d - distance between two parallel plates.

V - potential difference between two plates.

v_o- initial velocity acquired by the electron moving in x- direction

V_A- Accelerating Potential applied between cathode and anode inside Electron Gun.

The electron moves along a parabolic path in a transverse electric field.

Motion of an electron in a uniform magnetic field

A static magnetic field does not act on an electron which is at rest. However when electron moving with a velocity v enters in a magnetic field, **it experiences a magnetic force** is given by

$$\mathbf{F_L = e(v \times B)}$$

$$\mathbf{F_L = evB\sin\theta} \text{ -------(1)}$$

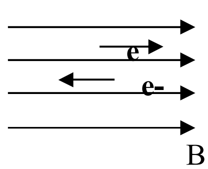
The direction of the force F_L is neither along the direction of v or that of B, but lies along the normal to the plane containing both vectors v & B i.e., Lorentz force is always perpendicular to the displacement of the electron.

The magnetic field does not produce any change in the speed or kinetic energy of an electron.

Kinetic energy of a charged particle remains constant when it moves in a uniform magnetic field. (S-15/3m)

The magnetic field cannot change the speed 'v' and the kinetic energy of the electron.

CASE- I:- Longitudinal uniform magnetic field / magnetic field parallel to initial velocity



If an electron moves parallel to the magnetic field lines the, magnetic force (F_L)on it is zero.

i.e. $F_L = evB\sin\theta = 0$ (since, $\theta = 0$)

similarly, if the electron moves opposite to the field, the magnetic force on it will be zero.

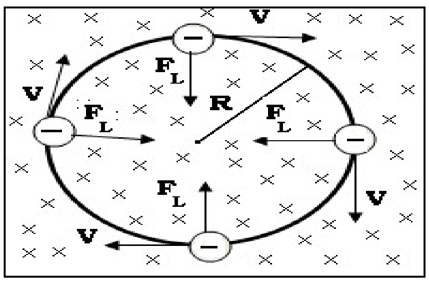
i.e. $F_L = evB\sin\theta = 0$ (since, $\theta = 180^o$)

As the force is zero, the acceleration is zero. Therefore the electron continues to move along the initial direction of motion without suffering any change in its speed or direction of motion.

CASE- II:- Transverse uniform magnetic field / magnetic field perpendicular to direction of electron

Let us now consider the case of an electron moving in a uniform magnetic field(B) with its initial velocity(v) perpendicular to the field. Let θ be an angle between v & B which is 90^o. thus the magnetic force is given by $F_L = evB\sin\theta$

$F_L = evB$ --------(1) (since, $\theta = 90^o$)



(it is assumed that the magnetic field in into the page and indicated by crosses). This force cannot change the magnitude of electron velocity but deflects the electron continuously along a curvilinear path. The force F^L provides the centripetal acceleration which is necessary for the uniform circular motion of the electron. Thus F_L is a centripetal force acting on an electron.

According to Newton's law of motion, the centripetal force is given by,

$$F_C = \frac{mv^2}{r}$$

$$F_L = F_C$$

$$evB = \frac{mv^2}{r}$$

$$r = \frac{mv}{eB} \text{ -----------(2)}$$

$\boxed{r \propto mv}$ (*This eq^n shows that the radius is directly proportional to the momentum)

Since all the parameters in eqn (2) are constant, thus r remains constant. Thus the locus of points at a constant distance from a centre point is a circle. **Therefore an electron describes a <u>circular path</u> in a plane perpendicular to the magnetic field.**

Q. What are the shapes or trajectories of an electron in electric and magnetic field when?

i) v parallel to E ---- straight line path

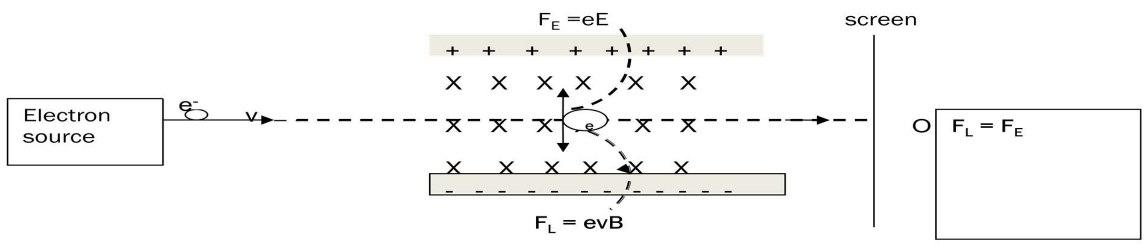
ii) v perpendicular to E ---- parabolic path

iii) v parallel to B ---- straight line path

iv) v perpendicular to B ---- circular path

Electric and magnetic field in cross field configuration

Q.) What is crossed field configuration? Explain. Determine the velocity of the charged particle without any deviation? (S-16/3m)



When uniform electric and magnetic fields are perpendicular to each other and act over the same region, then they are said to be in crossed configuration.

Consider the pair of plane parallel metallic plates A & B which sets up the electric field acting vertically downward. The magnetic field of induction B is applied perpendicular to the electric field and acting into the page.

When an electron passes through the region along a direction normal to both the fields then it experiences electric and magnetic field at the same time.

The electric field deflects the electrons upward whereas the magnetic field deflects the electrons in downward direction.

The force due to the electric field is,

$$F_E = eE$$

And the force due to the magnetic field is,

$$F_L = evB$$

If the magnitudes of the fields E and B are adjusted such that the force exerted by these fields on electron becomes equal to each other, hence the electron will not experience any force.

Thus,

$$F_E = F_L$$

$$eE = evB$$

$$\mathbf{v = E / B}$$

This shows that electrons experience a zero net force as the two forces balance each other and they will not deviate from their original straight line path and travel without change in the velocity v.

Velocity Filter

Q.) Explain the function of velocity filter. (S-13/3m)
Q.) Explain the working of velocity filter. (W-13/3m), (W-15/3m)
Q.) Explain the working of velocity selector with the help of necessary diagram (S-14/3m)
Q.) Explain the working of velocity selector (S-15/3m) (W-16/3m)
Q.) Explain why slower particles and faster particles require the same time for completing one rotation in magnetic field. (S-14/3m)

The velocity filter is an electro-optic device, which uses uniform electric and magnetic fields in crossed field configuration for selecting a stream of charged particles of single velocity from a beam of charged particles having a wide range of velocities(i. e. $\mathbf{v \pm \Delta v}$).

The selection of the particles of same velocity is done by using crossed-field configuration.

Working: As shown in Fig. consider a beam of electrons with different velocities $v \pm dv$ enters the crossed field configuration. The electrons experience both electrostatic force F_E due to the electric field and Lorentz's force F_L due to the presence of magnetic field.

If the magnitude of the fields E and B are adjusted such that the electrostatic force balances the magnetic force, then those electrons having velocity 'v' will not experience any force and continue to travel in a straight path undeviated. Thus,

when $F_E = F_L$

$$qE = qvB \qquad \ldots\ldots\ldots\ldots\ldots\ldots (6.18)$$

$$\therefore v = \frac{E}{B}$$

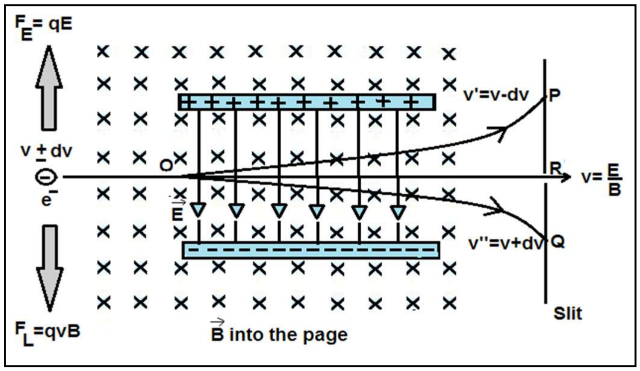


Fig. : Working of velocity filter

The electrons moving with the velocities other than 'v' are deflected upward or downward along OP or OQ. For those electrons which are moving with *higher velocity* (say $v'' = v + dv$), $F_L > F_E$ and they are deflected downward along OQ in circular path. The electrons which are moving with *lower velocity* (say $v' = v - dv$), $F_E > F_L$ hence they are deflected upward along OP in parabolic path.

These electrons which are deflected sideways are absorbed by the slit walls. Thus, a strictly homogeneous **single velocity electron beam travelling along OR is obtained with the help of crossed fields. This arrangement is, therefore, known as a *velocity filter* or *velocity selector.***

The arrangement is therefore known as velocity filter or velocity selector. The velocity filter is used in Bainbridge Mass Spectrograph.

Numericals

1) An electron passes undeviated through velocity selector having E=10^4 V/m and B= 0.02T. Determine the speed of electron. (W-14/2m)

Ans. v = E/B = 10^4/0.02 = 50 x 10^4 m/s

2) An electron beam passes through magnetic field of 2x 10^{-3} Wb/m^2 and electric field of 3.4x 10^4V/m both acting simultaneously at the same point. The path of the electron remains unchanged. Calculate the electron speed. (S-13/3m)

Ans. B=2x 10^{-3} Wb/m^2, E=3.4x 10^4V/m

v = E/B = 3.4x10^4/2x 10^{-3} = 1.7 x 10^7m/s

BETHE'S LAW (ELECTRON REFRACTION)

Q.) What is Bethe's law? Discuss similarities and differences between Bethe's law and snell's law. (S-13/3m)

Q.) Explain Bethe's law. (W-13/3m)

Q.) Explain Bethe,s law with necessary diagram and state its similarities with snell's law. (S-14/3m)

Q.) Explain Bethes law with the help of necessary diagram and discuss the similarities with snell's law. (W-14/4m)

Q.) What is Bethe's law? Discuss the refraction of electron beam across the boundary separating two equipotential regions. (S-15/4m)

Q.) Discuss the refraction of electron beam across an equipotential surface. (W-15/3m)

Q.) Explain Bethe's law of electron refraction. (S-16/3m)

Q.) State the law that governs the reflection of electron. In what way it resembles the snell's law and in what way it differs from it. (W-16/3m)

A nonuniform electric field is a field in which electric intensity varies from point to point. In such a field electric field lines are not straight and also not evenly spaced. On an equipotential surface, the electric potential remains constant and the electric field lines are normal to the surface at any point. Therefore, the normal to the equipotential surface shows the line of action of electric force on the electron.

When a narrow beam of electron travels in a non-uniform electric field, it bends and follows a curved path. This bending of electrons by non-uniform electric fields is called as ***electron refraction****.*

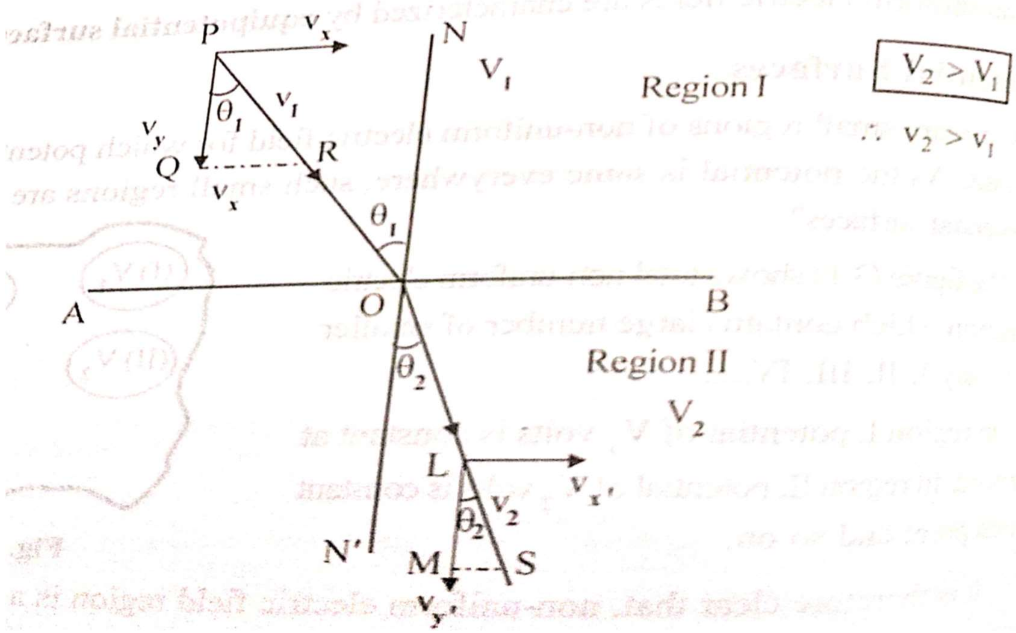


Fig.6.: Refraction of electron beam in non-uniform electric field

Consider an equipotential surface AB. It is considered as the boundary across which the potential V_1 abruptly changes to potential V_2. Let an electron travel through the region I with a uniform velocity v_1 and enter in region II. As the electron passes through the equipotential surface AB, it experiences a force which alters its velocity. **Because the electric field exists only in the vertical direction the y component of electron velocity (normal component of electron velocity) v_y undergoes a change whereas, , the X component of velocity (tangential velocity component) v_x remains constant. The resultant velocity v_2 in region II is different from v_1.**

If $V_2 > V_1$, v_y increases or if $V_2 < V_1$, v_y decreases. Here $V_2 > V_1$ hence v_y increases. The electron path is therefore bent nearer in the surface normal. The electron refraction that occurs at the equipotential surface is similar to the light refraction taking place at the boundary of rarer-to-denser medium. The equipotential surfaces such as AB play the role of refracting boundary in case of charged particles.

As, the X component of velocity (tangential velocity component) remains constant in region-I and in region-II, we write,

$$v_x = v_x'$$

$$v_1 \sin\theta_1 = v_2 \sin\theta_2$$

$$\frac{\sin\theta 1}{\sin\theta} = \frac{v_2}{v_1} \qquad \text{----------} (1)$$

using $v = \sqrt{\frac{2eV}{m}}$ in eq^n (1)

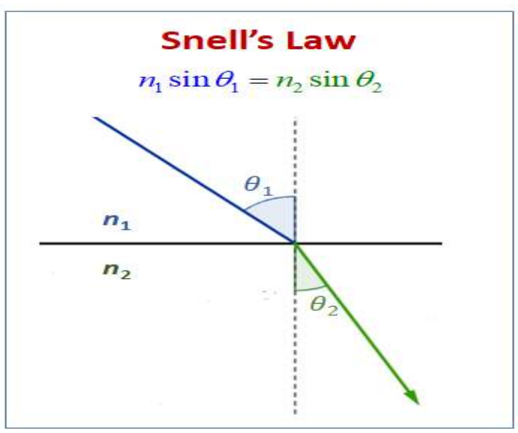
we get, $\frac{\sin\theta 1}{\sin\theta 2} = [\frac{V_2}{V_1}]^{1/2}$

This relation is known as the Bethe's law for electron refraction

Explanation of Snell's Law

When a light ray passes from rarer medium to denser medium, it bends toward the normal.

By snell's law, $\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1} = \frac{c/v_2}{c/v_1} = \frac{v_1}{v_2}$



SIMILARITIES AND DIFFERENCES BETWEEN BETHE'S LAW AND SNELL'S LAW

SIMILARITIES

1) Both laws deal with the phenomenon of refraction.

2) When light ray travels from rarer to denser medium, it bends towards the normal. Similarly, electron beam bends towards the normal when it travels from low potential to high potential region. Therefore, angle of refraction is less than angle of incidence.

3) Velocity of light or that of electron beam changes after refraction.

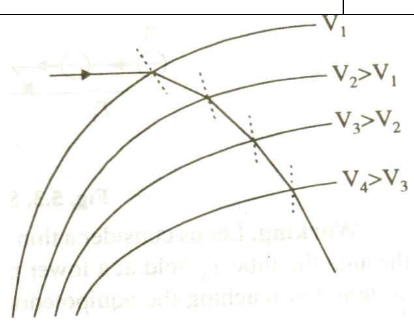
4) Both light ray as well as electron beam follow the law of reversibility.

5) The ratio of refractive index of electrostatic fields is expressed in units of square root of volt.

DIFFERENCES

Table 1: Differences between Bethe's Law and Snell's Law

S.No.	BETHE'S LAW	SNELL'S LAW
1.	When the electron beam travels from a region of lower potential to higher potential, its velocity increases on entering the region of higher potential.	When the light beam enters from rarer to denser medium, its velocity decreases on entering the denser medium
2.	In terms of velocities, Bethe's law can be written as $\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_2}{v_1}$	In terms of velocities, Snell's law can be written as $\frac{\sin i}{\sin r} = \frac{v_1}{v_2}$ Hence the order of velocities is reversed.
3.	Bethe's law deals with refraction of electron beam at the boundary between two regions with different potentials.	Snell's law deals with refraction of light beam at the boundary between two media with different refractive indices.



Above fig. shows the motion of an electron in a nonuniform electric field represented by equipotential surface separating equipotential regions of potential V_1,V_2,V_3,V_4 etc. At each surface electron path bends towards or away from the higher or lower potential region. It is observed that the electron motion occurs along a curved path in a non-uniform electric field.

Electrostatic lens (Electron lens):-

Principle:- When a stream of electrons travel through a non-uniform electric field it experience a change in direction. So its path is bent at each equipotential surface in the same way as a light ray is bent at an optical boundary (using optical terminology) .A stream of electrons may be called as an electron ray. Hence non-uniform electric fields can be used to focus a bundle of electron rays just as a convex lens focuses light rays. A non-uniform electric field produced by two coaxial metal tubes maintained at different potential can focus electron rays and therefore, such a system is called as 'electron lens'.

Construction:- An electron lens is made of two coaxial short cylindrical metal tubes T1 and T2 separated by some distance. The tubes are held at different potentials V1 and V2 respectively. V2 and V1 a non-uniform electric field is produced in the gap between the two tubes as shown figure. The equipotential surface are perpendicular to the electric field the electric field within the hallow space of the tube is weak and negligible.

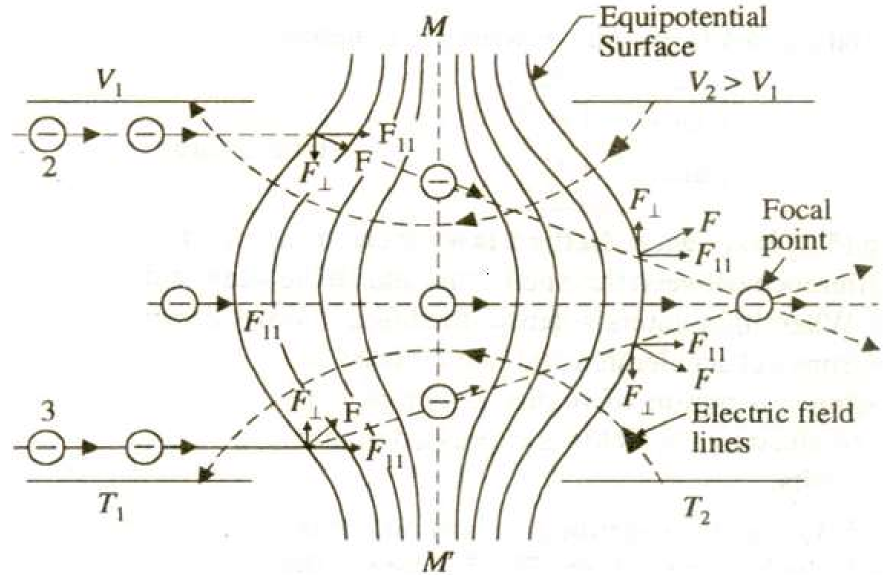


Figure:-

Working :-

Let us consider a bundle of electron rays enters in the double cylinder lens system through the tube T1 which is held at a lower potential V_1.

a) The electrons lablled as (1) move along the axis of the system, When it reached on the equipotential surface in the gap they experience an electric force which acts along the axis in forward direction. Therefore, the electrons gets accelerated towards tube T_2 along axis without any deviation from their initial path of travel.

b) The electrons lablled (2) on reaching the equipotential surface in the gap experience an electric force which acts at an angle to the direction of their motion. The force F experienced by electrons at the converse equipotential surface can be resolved into rectangular components F_{II} and F_I. F_{II} = act parallel to the axis while FI= acts perpendicular to the axis.

Due to the force F_1, the electrons are deflected down towards the axis and because of F_{II} electrons accelerated towards the T_2.

c) Similarly, the electrons lablled (3), are deflected up towards the axis and also accelerated forward, thus all off- the axis electron paths around the axis tends to converge towards the axis.

However, on crossing the midplane MM' of the gap, the converging electron rays encounter equipotential surface of concave shape.

In the second –half of the gap, the normal components of electric force, $F\perp$ is directed always from the axis for all off –axis as shown fig. and the F_{I} components is directed forward. As a result the electrons are accelerated forward but tend to diverge.

Thus the first half of the gap acts like a convex lens where the electrons rays tends to converge and the second half acts like a concave which defocuses the rays.

For every set of values of V_1 and V_2 the conveying action will be stronger than the diverging action. Because the electrons move slower in the lower potential region, they spend a larger in the first half of the gap and the impulse 'F_{11} t' is greater for the convergence interval.

In the second half the electron move faster because of higher potential and the impulse 'F_{11} t' is smaller for divergence interval.

Because of this action, the net result is that electron rays get focused. This double cylinder arrangement is called an electrostatic lens or electron lens.

Comparison with the glass lens:-

1) Light rays are bent only at the two boundaries of a lens but electron rays are refracted continuously through successive equipotential surface.
2) The focal length of a glass lens is fixed, whereas the focal length of an electron lens may be varied by adjusting the potential V_1 and V_2 on the cylinders.

Applications:-

1) Electron lens is the most important components of an electron gun used for producing a narrow intense electron beam.
2) Electron lens action is utilized in particle accelerates to focus charged particles into a narrow beam.

CRO

Q. Draw a schematic of Cathode Ray Tube and show its principle parts. Briefly describe their function. W-01(6m), W-11(3m)

OR Draw the schematic of electrostatic CRT. Describe the role of

(i) Electron gun
(ii) Deflection system
(iii) Fluorescent screen
(iv) Aquadag coating S-07(5m)

OR Which voltage controls the intensity of electron beam on the screen in CRT? What is the function of voltage given to the anode cylinders in it? S-09(3m)

OR What is the use of aquadag coating in CRT? S-09(2m)

OR Give the functions of each block of the CRO. W-02(2m), W-05(5m)

OR State the functions of different blocks of CRO. S-08(3m), W-09(5m)

OR Explain how the true shape of a voltage waveform is displayed on a CRO screen. (5m)

OR Explain in brief the function of the time base circuit. W-06(4m), S-10(2m), S-12(3m)

OR Explain the use of time base circuit in a CRO. W-07(5m)

OR Explain how the actual waveform of the signal is traced on the CRO screen with the help of time-base generator. W-01(5m), S-05(3m)

OR How is CRO used to display A.C. waveform? W-08(3m)

OR Explain the necessity of time base circuit in the CRO. S-03(3m)

OR Is it possible to display the waveform on the CRO screen without the time base generator. Explain. W-10(3m)

Q.) Draw block diagram of CRO and explain how intensity of trace is controlled on screen. (S-13/4m)

Q.) Explain the function of Aquadag coating on the screen of CRT. (S-13/2m)

Q.) Draw block diagram of CRO. Explain function of time base generator. (W-13/4m)

Q.) Draw neat and clean diagram of Cathode ray oscilloscope. Explain function of time base generator in brief. (S-14/4m)

Q.) Draw schematic diagram of CRO and explain the role of aquadag coating in CRT. (W-14/3m)

Q.) Draw block diagram of Cathode ray oscilloscope. (S-15/4m)

Q) Draw block diagram of CRO. How can intensity and focusing of the trace on the screen can be controlled. (W-16/5m)

Q.) Describe the role of Aquadag coating in Cathode ray tube. (S-15/2m)

Q) Explain the role of acquadag coating in cathode ray tube. (W-16/2m)

Q.) Draw block diagram of CRO. Explain the role of electron gun. (W-15/3m)

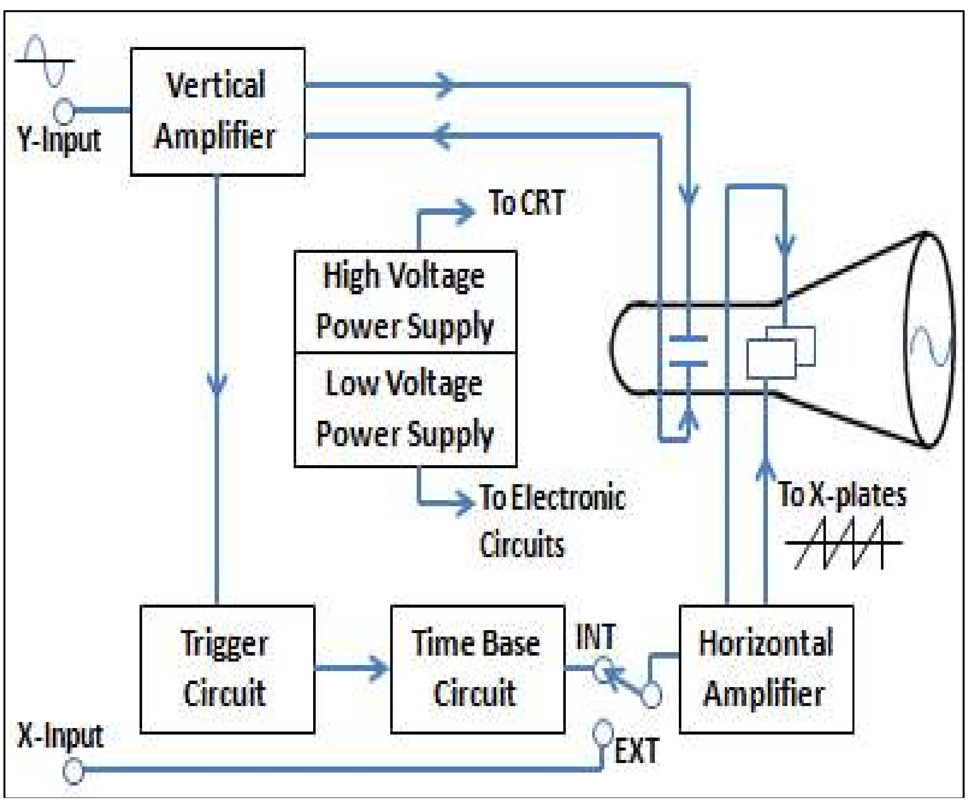
Q. Draw the schematic of an electrostatic CRT, write the function of (i)Electron gun and (ii) Aquadag coating (S-16/2+2m)

Block diagram of CRO

CRO is a very important electronic measuring instrument. It is used to display and measure electrical signals, time interval, phase shift between two electrical signals, voltage and frequency of electrical signals.

Basically CRO consists of seven major blocks

a) Cathode ray tube
b) Time base circuit
c) Trigger circuit
d) Vertical circuit
e) Horizontal circuit
f) High voltage power supply
g) Low voltage power supply

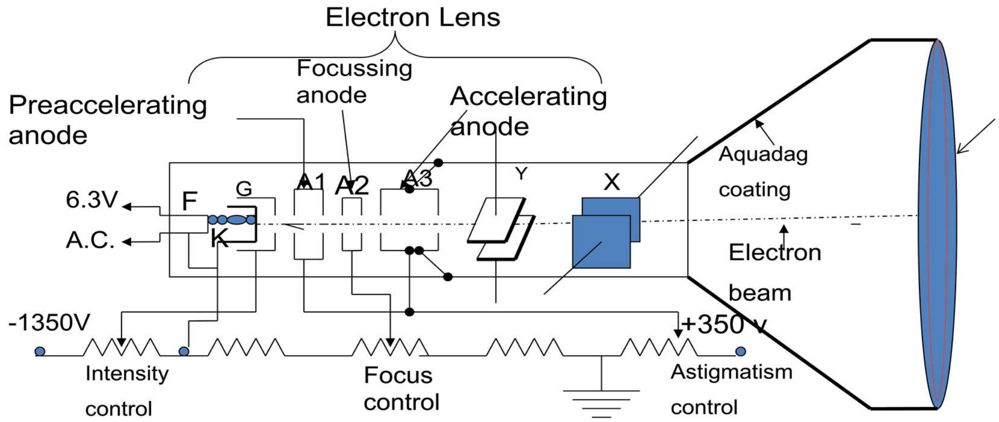


Working of various blocks:

I) CRT: A cathode ray tube is a specially constructed vacuum tube in which an electron beam is controlled by electric and magnetic field which generated a visual display of input electrical signals on fluorescent screen.It consists of three main parts electron gun, deflection system and fluorescent screen.

The CRT is like a conical flask, placed horizontally and sealed at its one end. The electron gun contains several electrodes mounted at one end of the tube. All electrodes are connected by using basepins. The deflection system consists of two pairs of parallel metal plates. These plates are oriented in such a way that the orientation is perpendicular to the axis of the CRT.

The screen consists of a thin coating of phosphors deposited on the surface of curve of envelope. The inner surface of two side ends contains coating of graphite material which is known as acquadag coating.



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a) Electron gun: An electron gun is a device which is used to produce a narrow electron beam of high intensity.

Principle: It is based on the principle of non uniform electric field that cause bending of electronic paths.

Construction: the electron gun consists of a cathode (K), a filament heater (F), control grid (G) and three anodes A_1, A_2 and A_3.

The cathode K is a short hollow cylinder made up of nickel. The front face of cathode is coated with thoriated tungsten or barium and strontium oxide that helps for thermionic emission to occur at moderate temperature 700o to 900oC. The cathode surrounded by the control grid having a small opening in its front face to pass the electrons. Anode A_1, A_2 and A_3 are coaxially situated beyond the cathode.

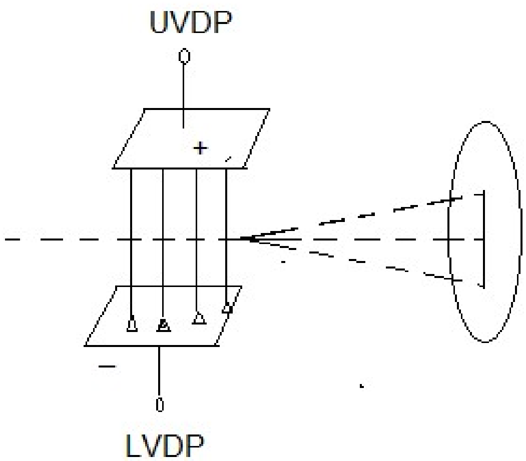
Working:

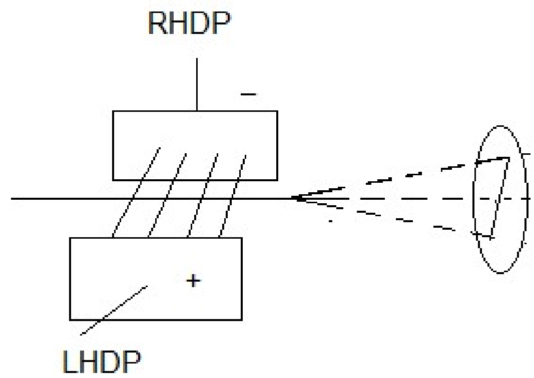
When power is switched on, the filament heats up the cathode. The electrons are emitted from the cathode and pass through the control grid. The control grid is held at negative potential. When the grid is at less negative potential then more number of electrons pass through it and intensity of the luminous spot on the screen is high. Similarly, when the grid is held at high negative potential then less number of electrons pass through it and intensity of the luminous spot on the screen is less. Thus, the grid acts as a gate and regulates the passage of electrons through it. **Thus control grid is used to control the intensity of the luminous spot on the screen.** Anode A1 accelerates the beam of electrons. The grid G and A2 forms the first lens which is used to prefocusses the electron beam and known as **prefocussing** lens. A2 and A3 forms the second lens which focuses the electron beam and convert it into s fine spot which is seen on the screen.

b) Deflection System: After emerging from the electron gun, a narrow and accelerated electron beam passes toward the fluorescent screen, but before striking, theses beam passes through the deflection system. The deflection system consists of two pairs of metals plates, aligned parallel to each other. These two pairs are perpendicular to each other and also to the axis of CRT.

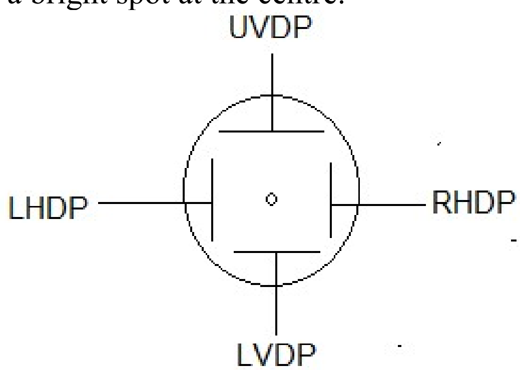
When a potential difference is applied to the horizontal plate, a uniform electric field is produced in vertical direction. This plate causes a vertical deflection and hence the set of deflection plates are called vertical deflection plates (VDP) also called Y-plates.

Similarly, when potential difference is applied to the vertical plate, the uniform electric field is produced horizontally and causes a horizontal deflection of the beam, hence the set of plates are called horizontal deflection plates (HDP) and are called X-plates.

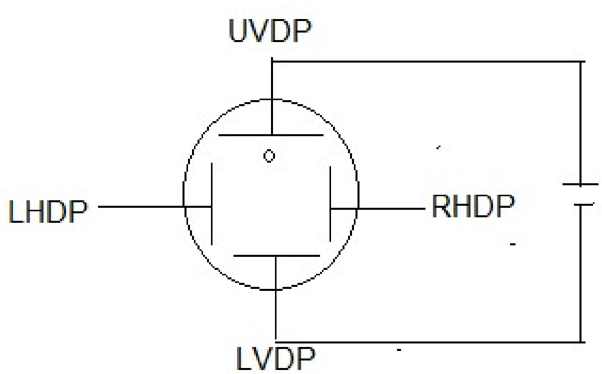




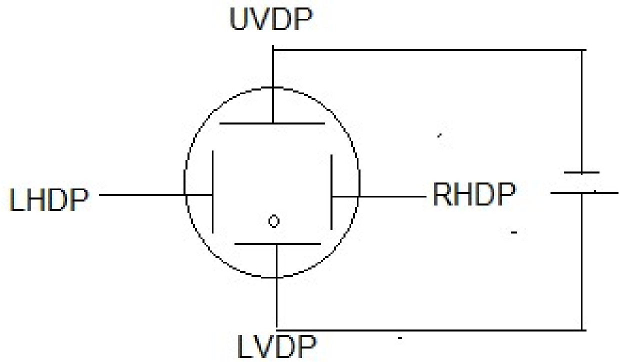
1) When voltages are not applied to X and Y plates, the electron beam travels straight and strikes on the screen producing a bright spot at the centre.



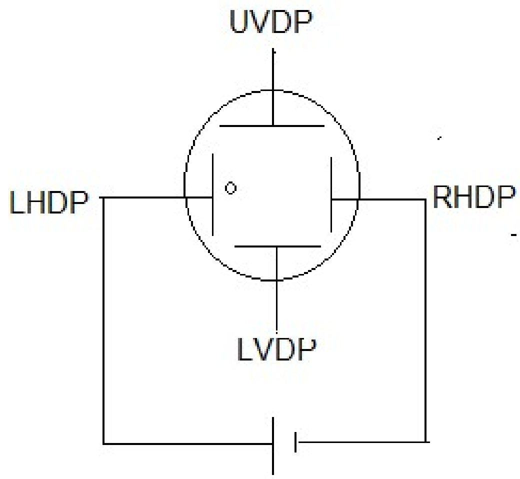
2) When dc voltage is applied to Y plate in such a way that upper plate is at positive potential and lower plate is at negative potential then electron beam is attracted toward upper plate and the spot moves upward.



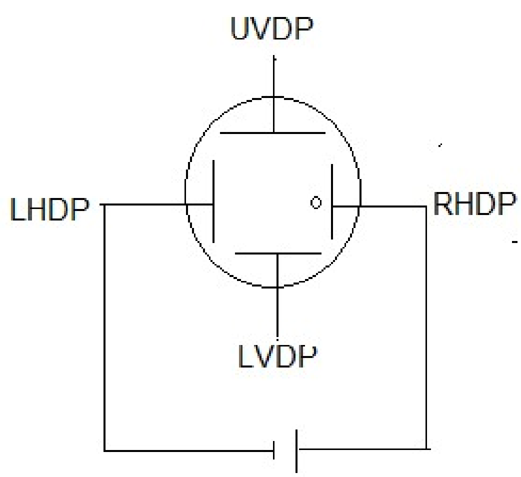
3) When lower plate is made positive and upper plate is negative then bright spot will move downward on the screen.



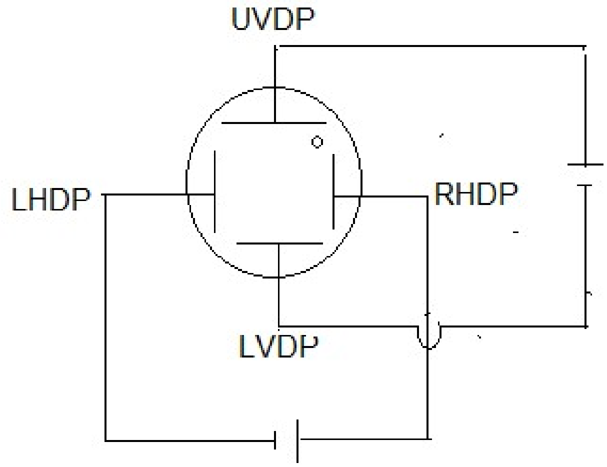
4) When a dc voltage is applied to X-plate in such a way that left plate is +ve and right plate is –ve then spot moves toward left plate.



5) When left plate is –ve and right plate is +ve, the spot moves toward right plate.



6) When dc voltages are applied to both X and Y plates, the electron beam gets deflected along the directions of their resultant.



c) Fluorescent Screen: The interior surface of circular front face is coated with thin layer of phosphor. The spot on the screen continues to glow for a short period of time even after the electron beam moves away. This coating is made thin to allow thw light to pass through the screen and viewed from outside the CRT.

Aquadag Coating :

1) When electrons strikes the screen, they tends to charge the screen negatively and repels the electrons arriving afterwards. It will reduce the number of electrons reaching the screen and also the brightness of the glow.

2) Similarly, as electrons emitted from the cathode are in large number, the cathode assumes gradually a +ve charge and again intensity of the glow on the screen reduces. Hence **the cathode is to be replenished with electrons. The acquadag coating is the conducting coating of aqueous solution of graphite which is used to complete the electrical circuit from screen to cathode. The electrons striking the fluorescent screen not only cause emission of light but produces secondary emission of electrons. The secondary electrons are attracted by the anode A3 and the electrons are returned to cathode through the ground.**

Note:

When ac signal voltage is applied to the Y plate the beam moves up and down along vertical line in steps with varying voltages. The successive position of the spot cannot be displayed when signal frequencies are greater than 20Hz. The phosphor continue to glow for a short time after the electron beam passes, due to persistence of vision and the path of the beam across the screen is seen as a vertical line. It is called trace, the length of the trace corresponds to the peak to peak voltage Vp-p of the applied signal.

Similarly horizontal motion of the electron beam is produced when an ac voltage is applied to X-plate.

II) Vertical circuit: the signal is applied to Y input. It goes through ac-dc-gnd switch. When the switch is set in ac position then a capacitor is in series with the switch which allows ac signals to pass and blocks the dc components. When the switch is set in dc, the signals is directly coupled. When the switch is set in gnd, the signal containing ac and dc components is isolated and hence no deflection is obtained on the screen.

The signal amplitude can be increased or decreased to obtain an adequate deflection on the screen by the volt/cm control (to get proper deflection on the screen).

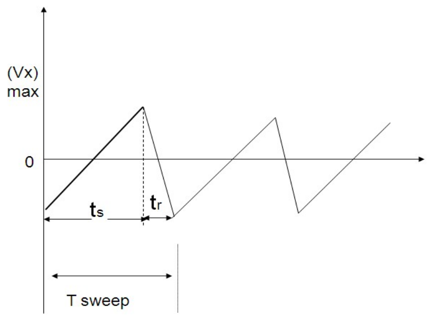
III) Horizontal circuit: The voltage to X plate can be applied form internal source or external source. When the switch is kept in external mode, the X plates are disconnected from the internal source. A signal connected to X input passes to the X plate through an attenuator, preamplifier and horizontal amplifier. The output of horizontal amplifier is fed to X plate. When the switch is kept in INT position a ramp voltage produced by an internal time base circuit is applied to the horizontal amplifier.

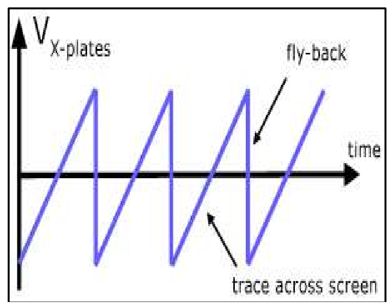
IV) Low voltage power supply: Low voltage power supply provides power to all the electronic circuits such as trigger circuit, time base generator etc. it gives an output of the order of 400V.

V) High voltage power supply: The high voltage power supply provides power to circuit i.e. the electrodes in the electron gun. It supplies voltage of the order of 1600 to 2200 volts.

VI) Time base circuit: It consists of time base generator. In the signal the voltage varies as a function of time which requires the beam to move horizontally that covers equal distances in equal interval of time.
1) When the voltage is applied to X plate it rises through equal amount of voltage per unit time.
2) Secondly at the end of horizontal motion, the beam should return to the starting point after completing one rotation, which is known as ramp voltage.
" Ramp voltage is the voltage varies linearly with time."

The time base generator is a variable frequency oscillator that produces an output voltage of sawtooth shape known as sawtooth voltage.
[If a harmonic voltage is applied to X plates, voltage is applied to X plates, the voltage varies through different amount in equal interval of time.]

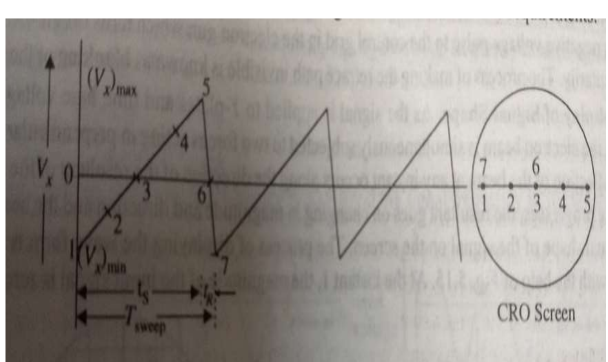




- **Time base generator is a variable frequency oscillator that produces time base voltage/ or sweep voltage. This voltage is fed internally to X-plates of CRT to produce true shape of the signal on the screen of CRO.**
- **True shape of the input signal voltage cannot be observed through vertical motion of the beam.**
- **It can be displayed on the screen only if the beam is made to move simultaneously in a horizontal direction by equal distances in equal interval of time. This is done by Time base circuit.**
- **The sweep voltage starts from some initial value $(V)_{-max}$, increases linearly with time to $(V)_{+max}$. This time is known as *sweep time* t_{s}, as it is sweeping from negative to positive maxima, then it suddenly returns to its value $(V)_{-max}$ again, this time is known as *retrace time* t_r.**

- **The time taken by the electron beam to start from $(V)_{-max}$ and reach $(V)_{+max}$ is called sweep time t_s.**
- **The time taken by the electron beam to drop from $(V)_{+max}$ to $(V)_{-max}$ is called retrace time or fly back time t_r.**
- **The sum of sweep time (t_s) and retrace time (t_r) is called sweep period (T_S).**

$$T_S = t_s + t_r$$



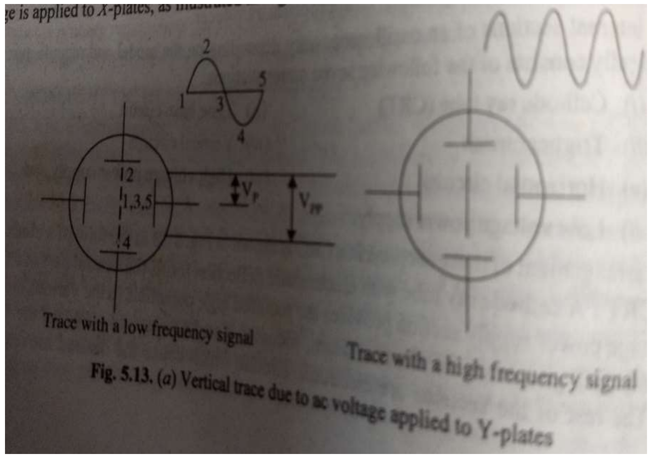


Fig. 5.13. (a) Vertical trace due to ac voltage applied to Y-plates

At t = 0, the ramp voltage is at its –ve max on the RHDP, the voltage rises uniformly with time and the beam moves towards the right side on the screen. When ramp voltage reaches to zero, the beam will come to the centre and when voltage increases the beam continues to move toward right end of the screen. When the voltage drops instantaneously to a minimum value the spot is whipped (sweep) back across the screen to its starting point on left edge from where it repeat the next cycle. Hence ramp voltage is also called as sweep voltage or sawtooth voltage.

X-axis of the screen not only denotes amount of horizontal deflection but also the time covered therefore it is called time base voltage.

The time taken by the sweep voltage to rise from its maximum negative voltage to its maximum +ve voltage is known as sweep time or trace time (ts). the time taken by the sweep voltage to dip from its positive maximum to negative maximum value is called fly-back time or retrace time (tr).

$$T_{sweep} = ts + tr = ts$$

Q) Why ramp voltage is necessary? OR What are the conditions that must be fulfilled by the horizontal voltage in order to trace the true wave shape of signal on the CRO screen?

CRO is used to measure the signal as a function of time. Signal which is to be tested is applied to y-input of CRO. If ac signal voltage is given to y-plates, it makes the electron beam to move up and down along vertical line so to reproduce faithful display of wave shape of signal on CRO screen it is essential.

1) To spread the deflected electron beam horizontal through equal distances in equal interval of time and
2) After completing one cycle, the beam should return to the starting point to repeat the next motion (cycle).

The ramp voltage fulfils both these condition.

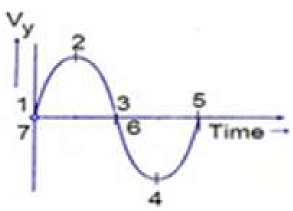
Q) What is Blanking? How is it achieved?

Blanking is the method of making retrace path of electron beam invisible during flyback time. Retrace path can be made invisible by applying a high negative voltage pulse to the control grid in electron gun which turns off electron beam momentarily.

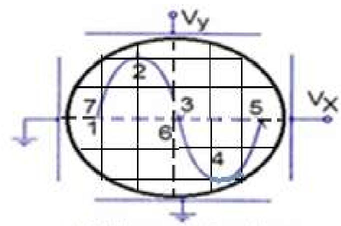
Display of true shape of signal

- As the signal is applied to Y-plates and sweep voltage to the X-plates, the electron beam is subjected to two forces acting in perpendicular direction to each other.

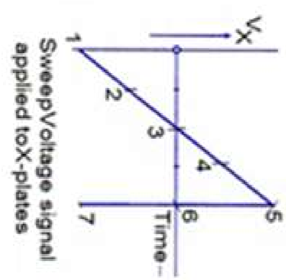
- The deflection of the beam at any instant occurs along the direction of the resultant of the two forces.
- As time progresses, the resultant change in magnitude and direction and the beam displays the actual shape of the signal on the screen.



Voltage signal applied toY-plates



Pattern of signal on CRO screen



Q) What is synchronization ? How it is achieved in a CRO? S-11(3m)
OR Mention the function of a trigger circuit. S-01, 10(2m)
Q.) What are Lissajous patterns? Define synchronization. How the intensity of the trace on the screen is controlled? (S-16/1+1+1m)
Q.) What is synchronization? (S-14/2m)

To get the steady and stable wave pattern on the CRO screen, horizontal deflection of electron beam should start at the same point of the input signal in each sweep cycle. When it occurs it is said that horizontal sweep voltage is synchronized with input signal.
"Synchronization is the method of locking of frequencies of both time base generator (x plate) to the frequency of the input signal (y plate)", to get a stationary display of wave pattern on CRO screen.
Signal is synchronized only when the following conditions are satisfied.

$$F_{signal} = nf_{sweep}$$
$$1/T_{signal} = n(1/T_{sweep})$$
$$T_{sweep} = n\,T_{signal}$$

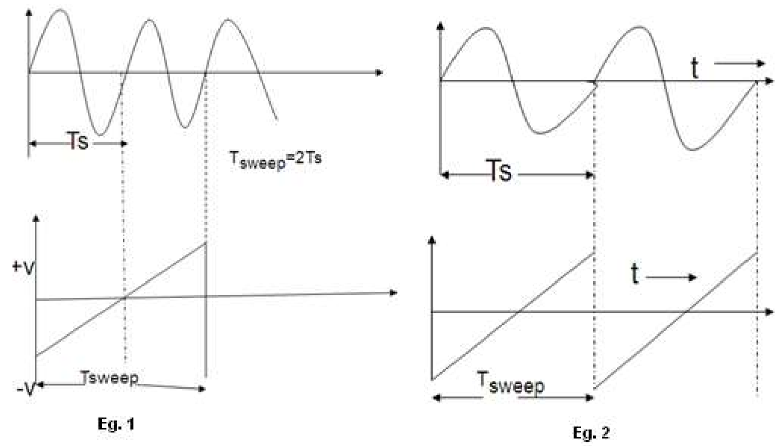
Eg. 1. If signal frequency is 50Hz and sweep frequency is 50Hz

$$F_{signal} = nf_{sweep}$$
$$50 = n\,50$$
$$n = 1$$
$$T_{sweep} = T_{signal}$$

Eg. 2. If signal frequency is 100Hz and sweep frequency is 50Hz

$$F_{signal} = nf_{sweep}$$
$$100 = n\,50$$
$$n = 2$$

Tsweep = 2 Tsignal



VII) Trigger Circuit: Synchronization of sweep and input signal voltage can be achieved by triggering method. The role of trigger circuit is to make ensure that the horizontal sweep begins at its specific time in the period of the vertical input signal.

Trigger Circuit produces trigger pulse which triggers the time base circuit to produce time base voltage.It Synchronizes sweep voltage and input signal voltage.
Synchronization is the method of locking of frequency of time base generator (x- plate) with the frequency of the input signal (y- plate) to get a stationary display of wave pattern on CRO screen".
i.e., $f_{signal}=nf_{sweep}$

or

$T_{sweep}=nT_{signal}$

To achieve the condition of Synchronization, a portion of input signal is fed to the trigger circuit of the time base circuit

Q) What is function of delay line?

During the generation of trigger pulse, ramp voltage, the input signal is being fed through a delay line that delays the input signal before it is further amplified and fed to y-plates. So delay line gives enough time for developing trigger and the starting of ramp voltage.

Q. Explain how intensity and sharpness of the trace on the screen are controlled.

W-04(3m), S-11(2m), W-11(3m)

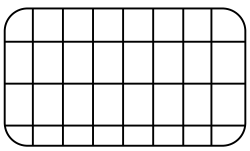
Ans**. Intensity control:**
The intensity of the display depends on the number of electrons striking the screen. Grid voltage regulates the number of electrons coming out of the aperture and hence grid voltage regulates the intensity of the display. When the grid is at less negative potential then more number of electrons pass through it and intensity of the luminous spot on the screen is high. Similarly when the grid is held at high negative potential then less number of electrons pass through it and intensity of the luminous spot on the screen is less. Thus the grid acts as a gate and regulates the passage of electrons through it. **Thus control grid is used to control the intensity of the luminous spot on the screen.**

Sharpness/ Focussing control: The three anodes A1, A2 and A3 are kept at different potentials from the electrostatic lens which focuses the beam to a single spot on the screen. Hence, the potential on these anodes, controls the sharpness of the display on the screen.

Applications of CRO

CRO is used to measure variety of electrical parameters, some of quantities measured with its help are described as follows.

1) **Study of waveform**: The signal under study is applied at the y-input terminal and the sweep voltage is internally applied to x-plates. The waveform of the signal is displayed on the screen.
2) **Measurement of dc-voltages**: Initially the trace is adjusted to the center of the screen. The dc-voltages under study is applied at y-input. The trace gets deflected upward or downward depending upon the polarity of the applied voltage. The deflection is read on the graticule and by multiplying it with deflection factor (volt/cm), the magnitude of the unknown voltage is obtained.

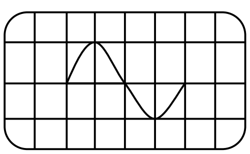


Displacement = 1cm

Position of vertical amplifier = 1V/div

Applied voltage = 1x1 = 1V

3) **Measurement of ac-voltages**: The trace is adjusted at the centre of the screen and ac-voltage under study is applied to y-input. The peak distance is measured and on multiplying it by deflection factor Vp-p is obtained. The values of Vrms & Vavg are then calculated by using formulae.



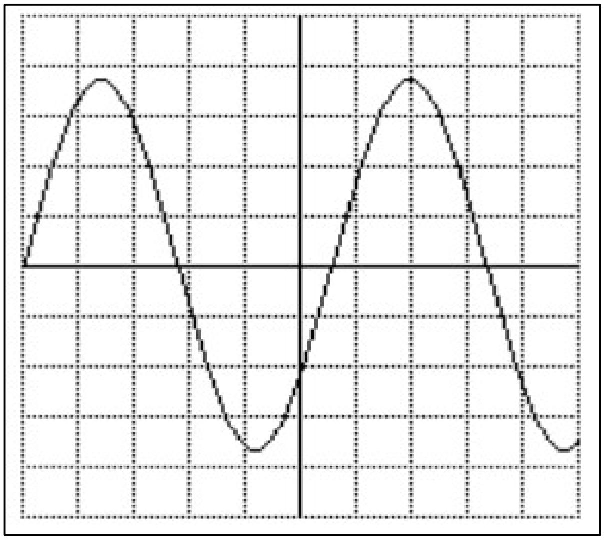
Vp = $\frac{V_{p-p}}{2}$ and Vrms = $\frac{V_p}{\sqrt{2}}$ = 0.707 Vp

Vavg = 0.636 Vp

4) **Measurement of frequency**: Method I: A sinusoidal signal whose frequency is to be determined is applied to y-input. The time base control is adjusted to obtained 2 or 3 cycles of the signal on screen. The horizontal spread of one cycle is noted. By multiplying it with time-base sensitivity, the time period of the signal is obtained. Then the reciprocal of the time period gives the frequency of the signal.

   T = (horizontal spread of 1 cycle) x (position of time-base sensitivity)

   F = 1/T



-
- **Time base sensitivity (x) =2 ms/cm**
  - **Spread of wave (l) = 5.6 cm**
  - **Time period T = 2x5.6 =11.2 ms**
  - **Frequency f = 1/T**

    = 1/11.2ms

    = 1000/11.2

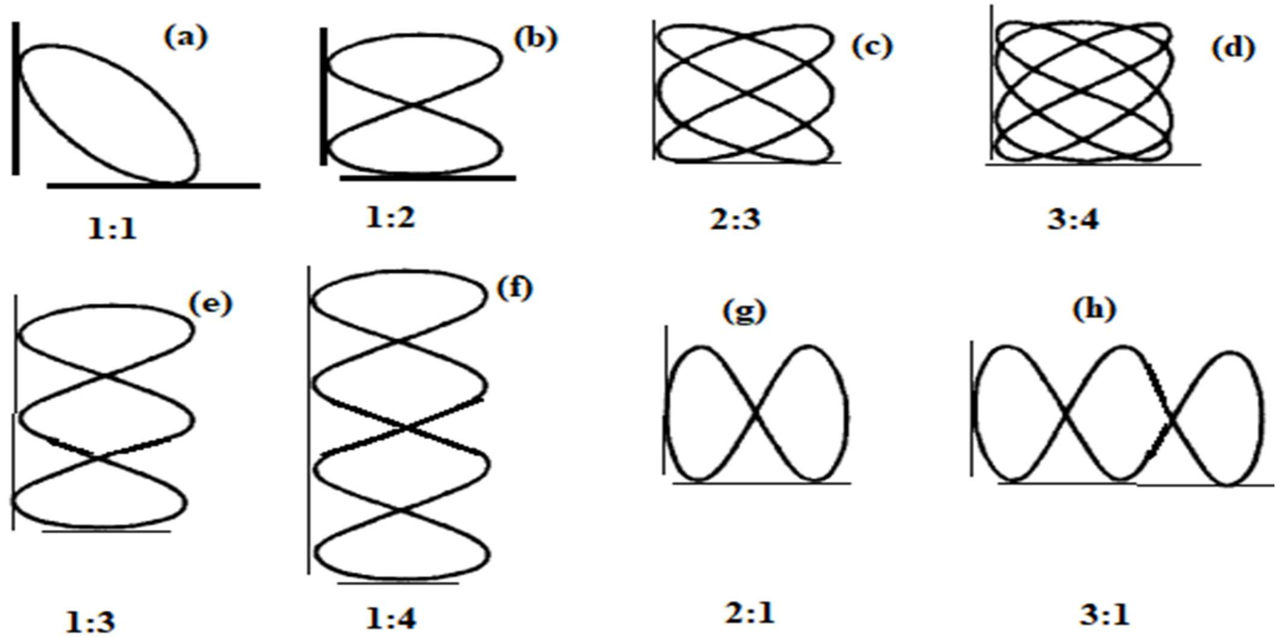
    = 89.28Hz.

5) **Alternative method using Lissajou's pattern**: frequency of test signal can be measured using lissajou's pattern. When two sine waves oscillating in mutually perpendicular planes are combined, different types of closed loop patterns are obtained. They are called as lissajou's pattern. If two sine waves of different frequencies are applied to x & y plates of a CRO then closed loop pattern are displayed on the screen. A stable pattern is obtained when ratio of the frequencies is an integer.

   The number of points at which the loops are touching the horizontal and the vertical tangents i.e. L_H and L_V are noted.

   The unknown frequency is given by

$$F_Y = \frac{L_H}{L_V} F_X$$

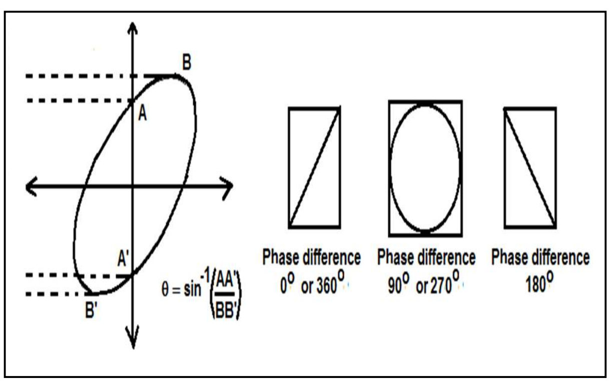


Eg. When two voltages are applied to x & y plates and ratio of frequency 2:1 (fig. g)

i.e. $\frac{f_y}{f_x} = \frac{2}{1}$

let the known and unknown signal source are connected to x & y plates respectively, by varying frequency of the known source a stable loop pattern is displayed.

6) **Measurement of phase difference or phase angle**: when two sine waves oscillating in mutually perpendicular planes are of the same frequency, the lissajou's pattern takes the form of an ellipse. The phase angle Ø can be calculated by using formula $Ø = \sin^{-1} (\frac{AA'}{BB'})$



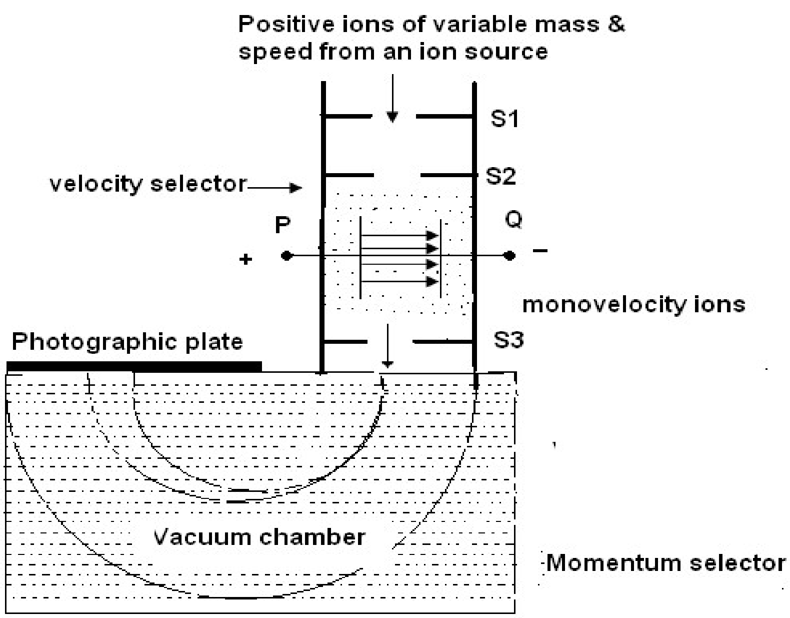
BAINBRIDGE MASS SPECTROGRAPH

Q.) Explain construction and working of Bainbridge Mass spectrograph. (W-13/5m)(W-15/4m) (S-16/3m)
Q.)Describe the working principle of a Bainbridge mass spectrograph with neat sketch. (S-13/5m)
Q.) Discuss the construction and working of velocity selector to produce the mono-velocity beam of charged particle. (W-14/3m)

It is an instrument which, by using electric field and magnetic fields, separates isotopes from a stream of positive ions of an element and measures their individual masses. This instrument separates ions of different masses, hence called a mass spectrograph. It was designed by K. T. Bainbridge in 1933.

Principle:

Bainbridge mass spectrograph is based on the principle that a uniform magnetic field acting normal to the path of ions having the same velocity deflects the ions of different masses along several circular paths of different radii. The radius of each circular path is linearly related to the mass of the ion. Velocity selector is used to produce monovelocity ion beam.



Construction:

It mainly consist of 1) Velocity selector 2) Analysing chamber or momentum selector. Bainbridge mass spectrograph is vacuum chamber placed in a uniform magnetic field, acting perpendicular to its larger surface. Positive ions of variable speed coming from ion-source are collimated by the slits S_1 and S_2. Deflection plates P and Q are placed next to the slits. These are charged and produce electric field. Electric field and transverse magnetic fields constitute a velocity selector/ filter. Slits S_3 is arranged to collimate the narrow monovelocity ion beam and allows it to pass through the analyzing chamber. A photographic plate is mounted in the analyzing chamber in line with slit S_3.

Working:

An element under study is taken in the form of gas. The gas is ionized when the potential difference across the electrodes. Positive ions are accelerated and conducted into the mass spectrograph through the slits S_1 and S_2. These ions are of variable speed/velocity and of variable mass. They pass through the velocity filter, after collimation through S_1 and S_2. The electric field strength is adjusted such that ions having a velocity v = E/B merge out of the filter without deflection and pass through the slits S_3. (ions having a velocity v=E/B i.e. FE = FL for ions). Ions having velocities different form v get deflected away and are absorbed by the walls of the chamber. Monovelocity ions after passing through the slit S_3 enter the transverse uniform magnetic field B. this transverse field B deflect these ions in a circular path. Monovelocity ions having same values get focused at the same point on the photographic plates mounted in line with field acting on the chamber constitutes a momentum selector and separates out ions of different masses. Different isotopes produce multiple vertical lines.

The visual record of ions in the form of vertical lines on the photographic plates is called **mass-spectrum**.

Q. Show that mass-scale is linear in Bainbridge mass-spectrograph?

Ans. Isotopes positions are recorded as vertical lines on photographic plates held in the analyzing chamber of Bainbridge mass spectrograph. The distance of any line is measured from the centre of the slit S_3 through which the isotopes enter the evacuated analyzing chamber. Let 'x' be the distance of a line marked by a singly ionized ion of mass M with velocity v, 'R' be the radius of its circular path.

$$X = 2R = \text{diameter of circular path of ion}$$

$$X = 2\left(\frac{Mv}{qB}\right) \quad (\text{since } v = E/B)$$

$$X = \frac{2ME}{qB^2} \text{ ----------(1)}$$

$$\therefore \quad M = \frac{qx}{2E}^{2} \text{ --------(2)}$$

$$\Rightarrow \quad \boxed{M \,\alpha\, x} \text{ -----------(3)} \quad (\text{since } \frac{qB^2}{2E} \text{ is constant for given E \& B})$$

Eq^n (3) is the equation of straight line. Thus mass scale is linear.

Derivation of line separation:

Let M_1 and M_2 be the masses of two isotopes and if x_1 and x_2 respectively are the distance from the centre of the slit S_3, then by using equation (1)

$$x_1 = \frac{2EM_1}{qB^2}, \qquad x_2 = \frac{2EM_2}{qB^2}$$

The line separation is given by,

$$\Delta x = (x_2 - x_1) = \frac{2E}{qB^2}(M_2 - M_1)$$

. LIST OF FORMULAE

MAGNETIC FIELD:

TRANSVERSE MAGNETIC FIELD:

- Lorentz force F_L= q ($\vec{v} \times \vec{B}$) = q v B sinθ = qvB when $\vec{v}$ is perpendicular to $\vec{B}$
  for electron, F_L= e($\vec{v} \times \vec{B}$) = evBsinθ = evB
- Radius R of circular path = $\frac{mv}{qB}$
  for electron, R of circular path = $\frac{mv}{eB}$

CROSSED ELECTRIC AND MAGNETIC FIELD CONFIGURATION

- $F_E = F_L$
- $v = \frac{E}{B}$

BETHE LAW OF ELECTRON REFRACTION

- Bethe's law in terms of potential $\frac{Sin\theta_1}{Sin\theta_2} = \sqrt{\frac{V_2}{V_1}}$
- Bethe's law in terms of velocity of an electron $\frac{\text{Sin}\theta_1}{\text{Sin}\theta_2} = \frac{v_2}{v_1}$

BAINBRIDGEMASS SPECTROGRAPH

- The line separation between the isotopic masses $(x_2 - x_1) = \frac{2E}{qB^2}(M_2 - M_1)$
- To find unknown mass of an element $(M_2 - M_1) = \frac{qB^2}{2E}(x_2 - x_1)$

SOLVED NUMERICALS

1. **An electron beam passes through a magnetic field 2×10^{-3}Wb/m^2 and an electric field of 3.4×10^4V/m, both fields being normal to each other and acting simultaneously in the same region. The path of electrons remains unchanged. Calculate the electron speed? (3M)[Summer-13&17]**

Ans. Given: B = 2×10^{-3}Wb/m^2,
E = 3.4×10^4V/m
Solution: $v = \frac{E}{B}$
$=\frac{3.4\text{x}10^4}{2X10^{-3}} = 1.7 \times 10^7\text{m/s}$

2. **Determine the velocity of ions that pass undeflected through crossed E and B fields for which E=7.7 kV/m and B=0.14T. (3M)[Winter-17]**

Ans. Given: B = 0.14T,
E = 7.7kV/m= 7.7×10^3 V/m

Solution: $v = \frac{E}{B}$

$=\frac{7.7\text{x}10^3}{0.14} = 5.5 \times 10^4\text{m/s}$

3. **An electron passes undeviated through a velocity selector having E=10^4V/m and B=0.02T. Determine the speed of electron. (2M)[Winter-09,14& 19]**

Ans. Given: B = 0.02T,
E = 10^4V/m

Solution: $\mathbf{v} = \frac{E}{B}$

$=\frac{10^4}{0.02} = 50 \times 10^4 \text{m/s}$

4. **A positive ion beam moving along the x-axis enters a region of uniform electric field of 3kV/m along Y-axis and magnetic field of 1 KG along z-axis. Calculate the speed of those ions, which pass undeviated. What will happen to ions, which are moving (i) Faster, (ii) slower than these ions? (4M)[Winter-00 &02]**

Ans. Given: $B = 1\text{KG} = 10^3\,\text{G} = 10^3\times10^{-4}\text{Wb/m}^2 = 0.1\text{T}$,

$E= 3\text{kV/m} = 3\times10^3\text{V/m}$

Solution: Speed $v = \frac{E}{B}$

$=\frac{3\text{x}10^3}{0.1} = 3 \times 10^4 \text{m/s}$ -------- for un-deviated ions.

Ions moving faster than these ions will be deflected towards magnetic field along circular path and slower ions will be deflected towards electric field along parabolic path. Both deviated ions will be absorbed by slit walls of velocity filter.

5.Electrons accelerated under a potential of 250V enters the electric field at an angle of incidence of 50^0 and gets refracted through an angle of 30^0. Find the potential of second region. **Find the potential difference between the two.**

Ans. Given: V_1=250V

$\theta_1=50^0$

$\theta_2=30^0$

V_2=?

Solution: $\frac{\text{Sin}\theta_1}{\text{Sin}\theta_2} = \sqrt{\frac{V_2}{V_1}}$

$$\frac{\text{Sin}\theta_1}{\text{Sin}\theta_2} = \sqrt{\frac{V_2}{250}}$$

$$\Rightarrow V_2 = 586.8\text{V}$$

$$\therefore \quad \text{Potential difference} = V_2 - V_1 = 586.8 - 250 = 336.8\text{V}$$

5. **An electron beam enters from a region of potential 75 V into a region of potential 100V, making an angle of 45^0 with the direction of electric filed. Find the angle through which the beam refracts. (3M)[Summer-13](3M)[Winter-19]**

Ans: Given: V_1=75V

$\theta_1=45^0$

V_2=100V

θ_2=?

Solution: $\frac{\text{Sin}\,\theta_1}{\text{Sin}\,\theta_2} = \sqrt{\frac{V_2}{V_1}}$

$$\Rightarrow \frac{\text{Sin } 45}{\text{Sin}\,\theta_2} = \sqrt{\frac{100}{75}}$$

$$\frac{\text{Sin}\,\theta_2}{\text{Sin } 45} = \sqrt{\frac{75}{100}}$$

$$\frac{\text{Sin}\,\theta_2}{} = \text{Sin } 45\sqrt{\frac{75}{100}}$$

$$\Rightarrow \theta_2 = 38°$$

6. **A. In a[a] Bainbridge mass spectrograph, singly ionized atoms of Ne^{20}passes into deflection chamber with velocity of 10^5 m/sec. if they are deflected by a magnetic field of flux density of 8 x 10^{-2} Wb/m^2, Calculate radius of the path of singly ionized Ne^{20}atom.**

Ans: Given: v=10^5 m/sec

B=8 × 10^{-2} Wb/m^2

M=20 a.m.u. = 20 $\times 1.67\text{x}10^{-27}$Kg

q=1.602 $\times$ 10^{-19}C

r=?

Solution:$r = \frac{Mv}{qB}$

$$r = \frac{20 \times 1.67 \times 10^{-27} \times 10^5}{1.602 \times 10^{-19} \times 8 \times 10^{-2}}$$

$$= 0.26\text{m} = 26\text{cm}.$$

Q.6.B. In a Bainbridge mass spectrograph, singly ionized atom of Ne^{20} passes into deflection chamber with the velocity 10^3 m/sec. If they are deflected by a magnetic field of flux density 0.07Wb/m^2.Calculate the radius of path of singly ionized Ne^{20} atom.

(3)S-18

Ans. **Given:** B= 0.07 wb/m^2

v= 10^3 m/sec

M= 20 amu= 20 x 1.67 x 10^{-27} kg = 3.34X10^{-26} kg, q = 1.602 x 10^{-19} C, R=?

Solution: $R = \frac{Mv}{qB}$ $= \frac{3.34X10^{-2}\ X10^3}{1.602X10^{-19}X0.07}$= 2.978 x$10^{-3}$m

7. **The electric field between the plates of a velocity selector is 150V/cm and the magnetic field common to both the velocity selector and the analyzing chamber is 0.5T. If the source contains two isotopes of magnesium Mg ^{24},Mg^{25} which are single charged, then find the distance between the lines formed by these isotopes on photographic plate.** **(4M)[Winter-15&16]**

Ans: Given:E=150 V/cm= 150$\times10^2$ V/cm

B=0.5T

M_1=24$\times$1.67$\times10^{-27}$Kg

M_2=25$\times$1.67$\times10^{-27}$Kg

q =1.602$\times10^{-19}$C

Δx=?

Solution:

$$\Delta x = \frac{2E(M_2 - M_1)}{B^2 q}$$

$$\Delta x = \frac{2\times150\times10^2(25-24)\times1.67X10^{-27}}{(0.5)^2\times1.602x\ 10^{-19}} = 1.245 \text{ mm}$$

8. A. In a Bainbridge mass spectrograph, the electric field used is 8 x 10^{14} V/m ,the magnetic field common to both places is 0.2 Wb/m^2. If the ion source consists of singly ionized neon isotopes of atomic masses 20 and 22, calculate linear separation of lines formed on photographic plate. **(3M)[Summer-19,Winter-13]**

Ans. Given: E=8 $\times$ 10^{14} V/m

B=0.2 Wb/m^2

M_1=20 $\times$1.67 x10^{-27}Kg

M_2=22 $\times$1.67 x10^{-27}Kg

q =1.609 $\times$ 10^{-19}C

Δx=?

Solution:$\Delta x = \frac{2E(M_2-M_1)}{B^2 q}$

$$= \frac{2\times8\times10^{14}\times(22-20)\times1.67X10^{-27}}{(0.2)^2\times1.609x\ 10^{-19}} = 8.3\times10^{8}\, m$$

Q.8.B. In a Bainbridge mass spectrograph, the electric field used is 8 x 10^4V/m, the magnetic field common to both places is 0.55 wb/m^2. If the ion source consists of singly ionized neon isotopes of atomic masses 20 and 22, calculate linear separation of lines formed on photographic plate. **(3) W-12**

Ans.Given:

M_1= 20 a.m.u = 20x 1.67 x 10^{-27}Kg

M_2= 22 a.m.u =22 x 1.67 x 10^{-27} Kg

B= 0.55 wb/m^2, E= 8 x 10^4V/m, q=1.602x10^{-19}c

Δx =?

Solution: Linear Separation$\Delta x = \frac{2E}{qB^2}(M_2 - M_1)$ meters

$$= \frac{\mathbf{2X8X10^4(22-20)X1.67X10^{-27}}}{\mathbf{1.602X10^{-19}X(0.55)^2}}$$

= 11x10^{-3}m

9. A. In a Bainbridge mass spectrograph, the magnetic field in the velocity filter is 1Tesla and the ions having a speed of 4 x 10^6 m/s pass through it undeflected. (a)What should be the electric field between the plates? (b)If the separation of plates is 0.5 cm, what is the potential difference between the plates?

Ans. Given: B=1Tesla

v=4 $\times 10^6$m/sec.

d=0.5cm=0.5$\times 10^{-2}$m.

E=?

V=?

Solution: (a)$v = \frac{E}{B}$

$$\Rightarrow E = vB$$

$$= 4\times10^6 \times 1 = 4\times10^6 V/m$$

(b) $E = \frac{V}{d}$

$$\Rightarrow V = E.d$$

$$= 4 \times 10^6 \times 0.5 \times 10^{-2} = 2 \times 10^4 V$$

9. B. In Bainbridge mass spectrograph a potential difference of 1000 V is applied between two plates separated by 1 cm and magnetic field B= 1T. Then the velocity of undeflected positive ions in m/s from the velocity selector is____

Ans. Given: B=1Tesla

v=?.

d=1cm=1$\times 10^{-2}$m.

E=?

V=1000V

Solution:

$$E = \frac{V}{d} = \frac{1000}{10^{-2}} = 10^5 \text{V/m}$$

$$v = \frac{E}{B} = \frac{10^5}{1} = 10^5 m/s$$

10. The electric field between the plates or velocity selector in Bainbridge mass spectrometer is 1.2 x 10^5 V/m and magnetic field in both regions is 0.6T. A stream of singly charged neon ions moves in a circular path of radius 7.28 cm in magnetic field. Determine mass number of neon isotope. (3M)[Summer-15,17]

Ans. Given: E = 1.2 $\times 10^5$ V/m

B = 0.6T

R = 7.28 cm = 7.28 $\times$ 10^{-2} m

Solution:

$$R = \frac{ME}{qB^2}$$

$$\Rightarrow M = \frac{RqB^2}{E}$$

$$= \frac{7.28 \times 10^{-2} \times 1.602 \times 10^{-19} \times 0.6^2}{1.2 \times 10^5} = 3.49 \times 10^{-2}\ \text{kg}$$

$$= \frac{3.49 \times 10^{-26}}{1.67 \times 10^{-27}} = 20.89\text{amu} = 21$$

11. In a Bainbridge mass spectrograph, the electric field used is 8 x 10^4 V/m, the magnetic field common to both places is 0.2 Wb/m^2. If the ion singly ionized atom of Mg^{26} passes into analyzing chamber with velocity 10^4 m/s. Calculate the radius of path of singly ionized Mg^{26} atom. **(3M)[Winter-15]**

Ans. Given: $E = 8 \times 10^4$ V/m

$B = 0.2$ Wb/m^2

$M = 26 \times 1.67 \times 10^{-27}$Kg

R = ?

Solution: $R = \frac{Mv}{qB}$

$$= \frac{26 \text{ x } 1.67 \text{ x} 10^{-27} \text{ x } 10^4}{0.2 \times 1.602\text{x } 10^{-19}} = 0.013m$$

12. The element Tin is being analysed in Bainbridge Mass Spectrograph amongst the isotopes present of masses 116 and 120. The electric and magnetic fields are 30 KV/m and 0.3 Wb/m^2 at both the places respectively. Find linear separation between the lines produced on the photographic plate by singly charged ions of Tin 116 and 120. **(3M)[Summer-18]**

Ans. Given: E = 30 KV/m

$B = 0.3$ Wb/m^2

$M_1 = 116 \times 1.67 \times 10^{-27}$Kg

$M_2 = 120 \times 1.67 \times 10^{-27}$Kg

$q = 1.609 \times 10^{-19}$C

Δx=?

Solution: $\Delta x = \frac{2E(M_2 - M_1)}{B^2 q}$

$$= \frac{2 \times 30 \times 10^3 \times (120 - 116) \times 1.67\text{X}10^{-27}}{(0.3)^2 \times 1.602\text{x } 10^{-19}} = 0.027\text{m}$$

13. In a Bainbridge mass spectrograph, the electric field used is 25 KV/m, the magnetic field is 0.2 Wb/m^2. The element Tin is being analyzed having isotopes of masses 116 and 120. Find linear separation between the lines produced on the photographic plate by singly charged ions of Tin 116 and 120. **(3M)[Winter-18]**

Ans. Given: E = 25 KV/m

$B = 0.2$ Wb/m^2

$M_1 = 116 \times 1.67 \times 10^{-27}$Kg

$M_2 = 120 \times 1.67 \times 10^{-27}$Kg

$q = 1.609 \times 10^{-19}$C

Δx=?

Solution: $\Delta x = \frac{2E(M_2 - M_1)}{B^2 q}$

$$= \frac{2 \times 25 \times 10^3 \times (120 - 116) \times 1.67\text{X}10^{-27}}{(0.2)^2 \times 1.602\text{x } 10^{-19}} = 0.052\text{m}$$