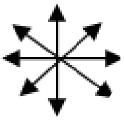
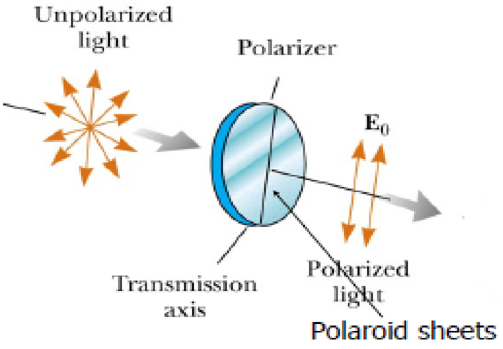
Q. 26. How does an unpolarized light get polarized when passed through a polaroid?
Two polaroids are set in crossed positions. A third polaroid is placed between the two making an angle θ with the pass axis of the first polaroid. Write the expression for the intensity of light transmitted from the second polaroid. In what orientations will the transmitted intensity be (I) minimum and (II) maximum?

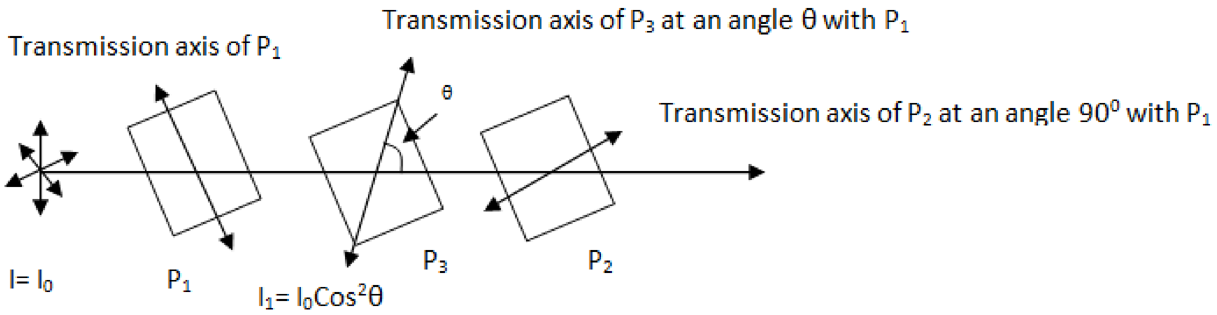
Answer: In unpolarized light electric field has random directions of vibration.



Linearly polarized light electric field has one spatial orientation.



Unpolarized light after passing through polaroid becomes polarized light. When unpolarized light wave pass through Polaroid the light get linearly polarized with the electric vector oscillating along a direction perpendicular to the aligned molecules.



Malus' law states that when a perfect polarizer is placed in a polarized beam of light, the intensity, I, of the light that passes through is given by

$I = I_0 \cos^2\theta_i$

Where I_0 is the initial intensity

θ_i is the angle between the light's initial polarization direction and the axis of the polarizer.

Therefore the intensity of light coming out of the second Polaroid (P_3) which is introduced between two crossed transmission axis Polaroid (P_1 and P_2) = $I_0\text{Cos}^2\theta$

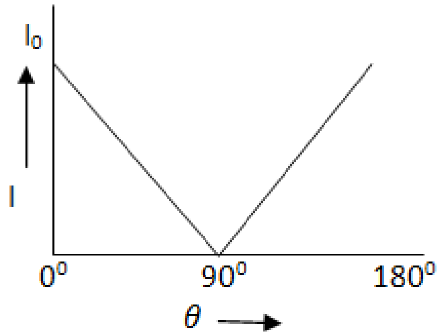
Where I_0 = Intensity of the incident light on the first Polaroid P_1

θ = angle between the transmission axis P_1 and P_3.

If the light from an ordinary source (like a sodium lamp) passes through a polaroid sheet P_1, it is observed that its intensity is reduced by half. Rotating P_1 has no effect on the transmitted beam and transmitted intensity remains constant. Considering polaroid P_2 placed before P_1, though light from the lamp is reduced in intensity on passing through P_2 however on rotating P_1 there is no effect on the light coming from P_2.

In one position, the intensity transmitted by P_2 followed by P_1 is nearly zero. When turned by 90^0 from this position, P_1 transmits nearly the full intensity emerging from P_2 as shown in the figure.

Graphical representation: Intensity of light taken along Y axis and the angle between polariser and analyser taken along X-axis following graph obtained

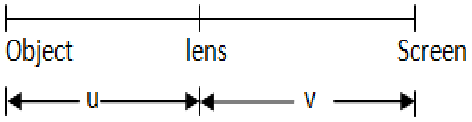


Maximum Intensity: When the Polaroid is rotated in the path of plane Polaroid light, its intensity will be maximum when the vibrations of the plane polarized light are parallel to the axis of the Polaroid.

Minimum Intensity: When the direction of vibrations become perpendicular to the axis of the crystal.

Q. 27. An illuminated object and a screen are placed 90 cm apart. Determine the focal length and nature of the lens required to produce a clear image on the screen, twice the size of the object.

Answer:



Given: $\therefore u + v = 90 \ldots\ldots\ldots\ldots\ldots\ldots (I)$

$m = \frac{v}{u} \Rightarrow 2 = \frac{v}{u} \Rightarrow v = 2u \ldots\ldots (II)$

Putting the value of v in (I), we get

$u + 2u = 90 \Rightarrow u = \frac{90}{3} = 30$

$\therefore v = 2 \times 30 = 60$

Using Lens formula

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{f} = \frac{1}{60} - \frac{1}{-30}$$

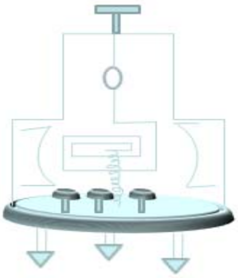
$$\Rightarrow \frac{1}{f} = \frac{1}{60} + \frac{1}{30} = \frac{3}{60}$$

$$\Rightarrow f = \frac{60}{3} = 20 \text{ cm.}$$

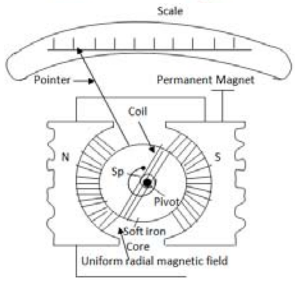
Q. 28.

- **a.** With the help of a diagram, explain the principle and working of a moving coil galvanometer.
- **b.** What is the importance of a radial magnetic field and how is it produced?
- **c.** Why is it that while using a moving coil galvanometer as a voltmeter a high resistance in series is required whereas in an ammeter a shunt is used?

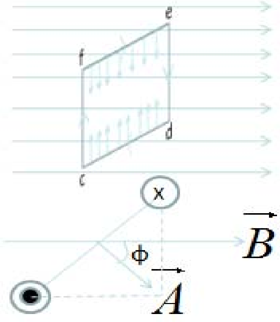
Answer :(a) Moving **coil galvanometer:** It is a device used for the detection and measurement of small electric current.



Principle :(Based on the principle of the force of interaction between the current carrying conductor and a magnetic field) A coil is suspended in a magnetic field. The current to be measured is passed through the coil. The current through the coil produces a magnetic field which interacts with the given magnetic field in which the coil is suspended. Due to the interaction the coil gets deflected and measuring the angle of rotation current can be calculated.



A circular or rectangular coil of about 10 to 15 turns of a fine insulated copper or aluminium wire is suspended from a torsion head T, by means of quartz fibre in between the concave pole pieces of a strong magnet. The lower end of the coil is attached to a light springs which brings the coil back to its original position when the current is stopped. The suspension wire and the spring are connected with two terminal screws at the base which acts as the leads of current. The whole thing is enclosed in a metal box provided with glass face and is supported on levelling screws. The angle of rotation of the coil is measured by lamp & scale arrangement, reflection takes place from the tiny mirror M attached with the suspension wire.



Theory : Given n = the number of turns in the coil

l & b = the length of each vertical & horizontal side of the coil respectively (assuming) the coil to be rectangular

i = the current flowing through the coil.

B = the induction vector of the magnetic field in which the coil is suspended.

We know that the force experienced by the current carrying conductor placed in a magnetic field is

$\vec{F} = i\left(\vec{l} \times \vec{B}\right) \rightarrow (1)$

Force on each wire 'de' and 'fc'

$\left|\vec{F}\right| = ibB\sin(90 - \phi) = ibB\sin\phi$

where ϕ = angle between the normal to the plane of the coil and the direction of the magnetic field.

The direction of the force on the wires 'de' & 'fc' are in the plane of the coil along the downward and upward direction respectively and hence cancel out.

The force on the two vertical wires ‘cd’ and ‘ef’ by using equation(1) are found to have magnitude

$\mathrm{F} = il\mathrm{B}\sin 90^0 = il\mathrm{b}$

Applying the right hand curl rule for vector product the directions of the force are as shown in the figure. These two forces being equal in magnitude, opposite in direction parallel and non co-planer constitute a couple.

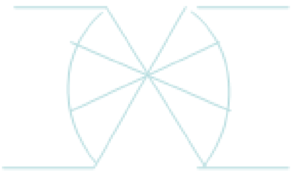
Moment of the couple $\Gamma = ilB \times OC$

$\Gamma = ilBb\sin\phi = i(lb)B\sin\phi = iAB\sin\phi$

Since there are n turns in the coil the total torque experienced by the current carrying coil in the magnetic field

$\Gamma = \mathrm{niABsin}\phi$

Due to this torque the coil rotates a restoring couple due to the torsion rigidity sets in and when the restoring couple equals to the deflecting couple the coil comes to equilibrium



Let c = torsional couple per unit twist of the suspension wire

θ = the angle through which the coil rotate in the position of equilibrium

Restoring couple $= c\theta \rightarrow (1)$

From equation(2) and (3): $\mathrm{nAiBsin}\phi = c\theta$

$$i = \frac{c}{nAB}\frac{\theta}{\sin\phi} \rightarrow (4)$$

By using concave pole pieces the magnetic field is made

radial so that for any position of coil ϕ is always 90^0.

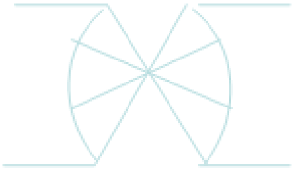
$\sin\phi = \sin 90^0 = 1$

$$\therefore i = \frac{c}{nAB}\theta \rightarrow (5)$$

Since c, n, A & B are all constant

$i \propto \theta$

b) **Radial magnetic field:** The plane of the coil always lies in the direction of the magnetic field. A radial magnetic field is produced by (A) properly cutting the magnetic pole pieces in the shape of



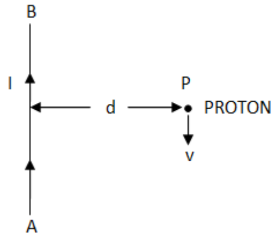
concave faces and (B) using a soft iron core within the coil (shown in the above figure)

c) A galvanometer can be converted into a voltmeter by connecting a high resistance in series with galvanometer to draw a very small current.

A galvanometer can be converted into an ammeter by connecting a low resistance shunt in parallel with galvanometer to draw large value of current. This low resistance is called Shunt.

Or,

a) Derive an expression for the force between two long parallel current carrying conductors.
b) Use this expression to define SI unit of current.
c) A long straight wire AB carries a current I. A proton P travels with a speed v1 parallel to the wire, at a distance d from it in a direction opposite to the current as shown in the figure. What is the force experienced by the proton and what is its direction?

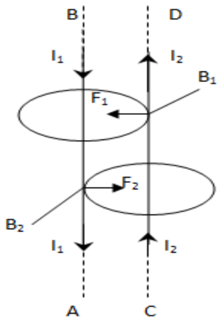


Answer: (a) Force between two parallel current carrying wires

Given: AB and CD are two infinitely long conductors, placed parallel to each other

r= distance of separation between two wires.

I_1 and I_2 = current flowing through AB and CD respectively (direction of current taken same).



Magnetic field produced by current I_1 at any point on CD is

$$B_1 = \frac{\mu_0 I_1}{2\pi r}$$

This field acts perpendicular to CD and into the plane of paper. It exerts a force on wire CD carrying current I_2 is

$$F = B_1\, I_2\, l$$

$$F = \frac{\mu_0}{2\pi r} \times I_1 \,.\, I_2\, l$$

$$F = \frac{\mu_0}{2\pi} \,.\, \frac{I_1 I_2}{r} \,.\, l$$

$\therefore$ Force per unit length is

$$F = \frac{\mu_0}{2\pi} \,.\, \frac{I_1 I_2}{r}$$

$$\therefore F = \frac{\mu_0}{4\pi} \,.\, \frac{2 I_1 I_2}{r}$$

By Fleming’s left hand rule, this force will be attractive.

(b) Definition of ampere:

Let I1 = I2 = 1 A, r = 1 m then

$\mathrm{F}=\frac{4\pi\times10^{-7}\times2\times1\times1}{4\pi\times1}\ [\because \mu_0=4\pi\times10^{-7}]$

$\mathrm{F}=2\times10^{-7}\ \mathrm{Nm}^{-1}$

Thus, one ampere can be defined as the amount of current which when flows through each of the two parallel uniform long linear conductors placed in free space at a distance of one metre from each other will attract or repel each other with a force of 2×10^{-7} N per metre of their length.

(c)Magnetic field induction at the point P is

$$\mathrm{B}=\frac{\mu_0}{4\pi}\cdot\frac{2\mathrm{I}}{\mathrm{r}}$$

The direction of $\vec{B}$ is perpendicular to the plane of paper directed inwards

(According to Right Hand Thumb Rule).

The force on moving proton of charge q due to magnetic field B is

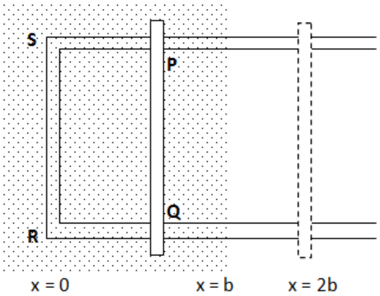
$\mathrm{F}=\mathrm{q\ vB}\sin 90°=\mathrm{q\ vB}\ \ (\mathit{Since}\ \vec{F}=q(\vec{V}\times\vec{B})$

$\text{Given: Charge of proton }\ \mathrm{q}=1.6\times10^{-9}\ \mathrm{C}$

$\therefore \mathrm{F}=1.6\times10^{-9}\times\mathrm{vB}\ \ \ \mathrm{N}$

The direction of force on proton, according to Fleming’s Left Hand Rule acts in the plane of paper towards right.

Q. 29. State Faraday's law of electromagnetic induction. Figure shows a rectangular conductor PQRS in which the conductor PQ is free to move in a uniform magnetic field B perpendicular to the plane of the paper. The field extends from x = 0 to x = b and is zero for x > b. Assume that only the arm PQ possesses resistance r. When the arm PQ is pulled outward from x = 0 with constant speed v, obtain the expressions for the flux and the induced emf. Sketch the variations of these quantities with distance $0 \le x \le 2b$.



Answer: Faraday's law of induction:

First law: The induced emf is proportional to the number of turns in the coil.

$e \propto N \rightarrow (1)$ where N = number of turns in the coil.

Second law: The emf induced across the coil is proportional to the rate of change of flux through the coil.

$\mathrm{e} \propto \frac{\mathrm{d}\phi}{\mathrm{dt}}$ where $\frac{\mathrm{d}\phi}{\mathrm{dt}}$ is rate of change of flux at an instant t

Combining first and second law : $\mathrm{e} \propto \mathrm{N}\frac{\mathrm{d}\phi}{\mathrm{dt}}$

$$e = KN\frac{\mathrm{d}\phi}{\mathrm{dt}}$$

Where K = constant of proportionality, by proper choice of unit

i.e. if e is in volt and flux in tesla - m^2 then constant K = 1

$$\mathrm{e} = \mathrm{N}\frac{\mathrm{d}\phi}{\mathrm{dt}}$$

Equation can be more correctly written as

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

The negative sign indicates that the direction of the induced emf is opposite to that of the cause.

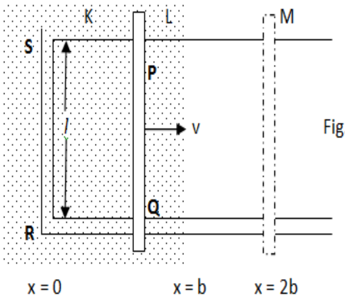


Fig. (a)

Considering the forward motion from x = 0 to x = 2b. The flux ϕ_B linked with the circuit SPQR is

$$\phi_B = Blx \qquad 0 \le x < b$$

$$= Blb \qquad b \le x < 2b$$

The induced emf is, $\varepsilon = -\frac{d\phi_B}{dt}$ (as number of turns N=1)

$$= -B\,lv \qquad 0 \le x < b$$

$$= 0 \qquad b \le x < 2b$$

When the induced emf is non-zero, the current I is (in magnitude) $I = \frac{B\,lv}{r}$

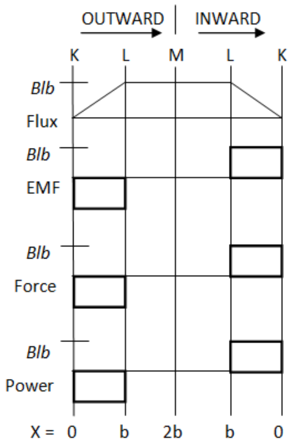


Fig. (b)

The force required to keep the arm PQ in constant motion is I 1B. Its direction is to the left. In magnitude

$$F = \frac{B^2 l^2 v}{r} \qquad 0 \le x < b$$

$$= 0 \qquad b \le x < 2b$$

The Joule heating loss is

$$P_J = I^2\,r$$

$$= \frac{B^2 l^2 v^2}{r} \qquad 0 \le x < b$$

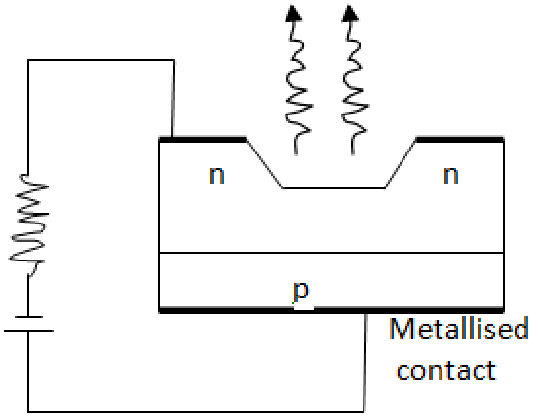
$$= 0 \qquad b \le x < 2b$$

Q. 30. Part I: **Being repeat question not answered in this answer sheet.**

Part II: What **is** a light emitting diode (LED)? Mention two important advantages of LEDs over conventional lamps.

Answer:

b) **Light Emitting Diode (LED)**
These are forward biased p –n junction diode which emits spontaneous radiations. When electron falls from the higher to lower energy level containing holes, the energy is released in the form of light radiations.



It is a basic pn-junction diode, which emits light when activated. When a fitting voltage is applied to the leads, electrons are able to recombine with electron holes within the device, that is when electron falls from higher to lower energy level containing holes the difference of energy is released in the form of photons (light). This effect is called electroluminescence, and the colour of the light (corresponding to the energy of the photon) is determined by the energy band gap of the semiconductor.

Advantages of LED: Two advantages over conventional incandescent lamps

I. Low operational voltage and less power consumption.
II. Fast action and no warm up time required.