XII Physics (Theory) 2016 SET-2

SECTION - A

1) Write the underlying principle of a moving coil galvanometer.

SOL: The principle of a moving coil galvanometer is that a current carrying coil placed in a magnetic field experiences a torque.

In equlb. Deflecting torque = Restoring torque

$BINA \sin\theta = k\phi$

$B \rightarrow$ Magnetic field

$N \rightarrow$ Number of turns in coil (not preferred)

$I \rightarrow$ Current through coil

A $\rightarrow$ Area of coil (not preferred)

$k \rightarrow$ Restoring torque per unit twist.

$\phi \rightarrow$ deflection in the coil.

2) Why are microwaves considered suitable for radar systems used in aircraft navigation ?

SOL: Microwave are of smaller wavelengths hence they can be transmitted as a beam signal in a particular direction much better then radio waves.

Microwave do not bent around the corners of any obstacles coming in their path.

These waves are not absorbed by the atmosphere.

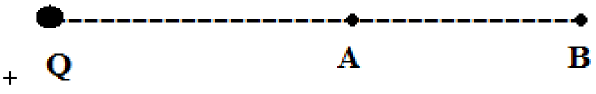
3) Define 'quality factor' of resonance in series LCR circuit. What is its SI unit ?

SOL: The ratio of voltage drop across inductor (V_L) or capacitor (V_C) to the applied voltage (V_R) is called the quality factor of a resonant LCR circuit.

$$Q = \frac{V_L \text{ or } V_C}{V_R} \quad ;$$

No unit.

4) A point charge +Q is placed at point O as shown in the figure. Is the potential difference $V_A - V_B$ positive, negative or zero ?



SOL: Let the distance of points A and B from charge Q be r_A and r_B respectively.

Potential difference between points A and B

$$V_A - V_B = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r_A} - \frac{1}{r_B}\right]$$

As $r_A = OA, r_B = OB$ and $r_A < r_B$

$$\frac{1}{r_A} > \frac{1}{r_B}$$

Therefore $\left(\frac{1}{r_A} - \frac{1}{r_B}\right)$ has positive value.

$V_A - V_B$ depends on the nature of charge Q.

Hence $V_A - V_B$ is positive when Q is positive.

5) How does the *electric* flux due to a point charge enclosed by a spherical Gaussian surface get affected when its radius is increased ?

SOL: No Effect.

6) A nucleus with mass number A = 240 and BE/A = 7.6 MeV breaks into two fragments each of A = 120 with BE/A = 8.5 MeV. Calculate the released energy.

SOL: Initial BE = 240×7.6 = 1824 MeV

Final BE = 120 ×8.5 + 120 ×8.5 = 2040 MeV

Energy released = inc. in B.E. = 2040 – 1824 = 216 MeV

OR

Calculate the energy in fusion reaction :

$_1^2H + _1^2H \longrightarrow _2^4He + n$ **, where BE of** $_1^2H$ **= 2.23 MeV and of** $_2^3$**He = 7.73 MeV.**

SOL: Initial B.E. = 2×2.23 = 4.46 MeV

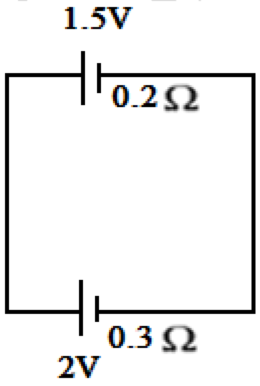
Final B.E. = 7.73 MeV

Energy released = 7.73 – 4.46 = 3.27 MeV.

<u>SECTION-B</u>

7) Two cells of emfs 1.5 V and 2.0 V having internal resistances 0.2Ω and 0.3 Ω respectively are connected in parallel. Calculate the emf and internal resistance of the equivalent cell.

SOL:



$$\frac{1}{r_{net}} = \frac{1}{0.2} + \frac{1}{0.3} = \frac{10}{2} + \frac{10}{3} = 5 + \frac{10}{3} = \frac{15+10}{3}$$

$$\frac{1}{r_{net}} = \frac{25}{3}$$

$$r_{net} = \frac{3}{25} = 0.12\Omega$$

$$E_{net} = \frac{\frac{E_1}{r_1} + \frac{E_2}{r_2}}{\frac{1}{r_1} + \frac{1}{r_2}}$$

$$E_{net} = \frac{\frac{1.5}{0.2} + \frac{2}{0.3}}{\frac{1}{0.2} + \frac{1}{0.3}} = \frac{\frac{15}{2} + \frac{20}{3}}{\frac{10}{2} + \frac{10}{3}} = \frac{\frac{45+40}{6}}{\frac{30+20}{6}} = \frac{85}{50} = 1.7V$$

8) State Brewster's law.

The value of Brewster angle for a transparent medium is different for light of different colours. Give reason.

Sol: **BREWSTER'S LAW**

It states that *when light is incident at polarising angle at the interface of a refracting medium, the refractive index of the medium is equal to the tangent of the polarising angle.*

If i_p is polarising angle and μ is the refractive index of the refracting medium, then according to Brewster's law,

$$\mu = \tan\ i_p$$

μ is the different for different colours so the Brewster angle for a transparent medium is different for light of different colours.

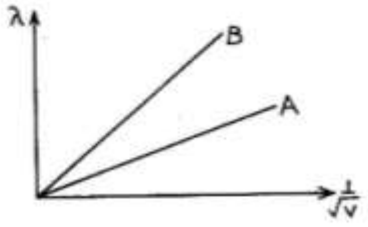
9) Explain the term (i) Attenuation and (ii) Demodulation used in Communication System.

SOL: (i) Attenuation : The loss of strength of a signal while propagating through a medium is known as attenuation.

(ii) Demodulation : The process of retrieval of information from the carrier wave at the receiver end is termed demodulation. This is the reverse process of modulation.

10) Plot a graph showing variation of de-Broglie wavelength λ versus $\frac{1}{\sqrt{V}}$, where V is accelerating potential for two particles A and B carrying same charge but of masses m_1 ,m_2 ($m_1 > m_2$). Which one of the two represents a particle of smaller mass and why ?

SOL:



$$\lambda = \frac{h}{\sqrt{2meV}} \quad \text{or} \quad \lambda = \frac{h}{\sqrt{m}\,\sqrt{2e}} \cdot \frac{1}{\sqrt{V}}$$

$$\frac{1}{\sqrt{m}} = \frac{\sqrt{2}e}{h}\left(\frac{\lambda}{\sqrt{1/\sqrt{V}}}\right)$$

or $$\frac{1}{\sqrt{m}} = \frac{\sqrt{2}e}{h} \times \text{ slope of } \lambda \text{ and } \frac{1}{\sqrt{V}} \text{ graph}$$

since slope of line B is greater than slope of line A

$$\therefore \frac{1}{\sqrt{m_B}} > \frac{1}{\sqrt{m_A}} \quad \text{or} \quad \sqrt{m_B} < \sqrt{m_A}$$

or $$m_B < m_A.$$

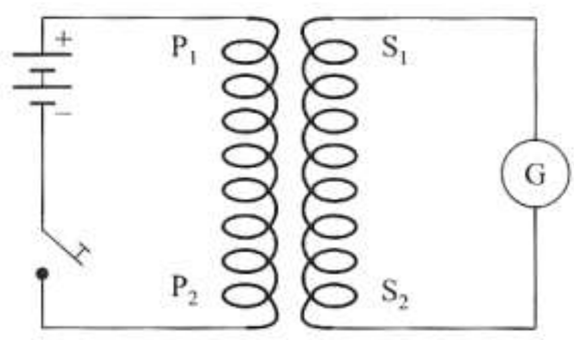
Therefore, line B represents a particle of smaller mass.

SECTION-C

11) Define mutual inductance.

A pair of adjacent coils has a mutual inductance of 1.5 H. If the current in one coil changes from 0 to 20 A in 0.5 s, what is the change of flux linkage with the other coil ?

SOL: <u>MUTUAL INDUCTION</u>



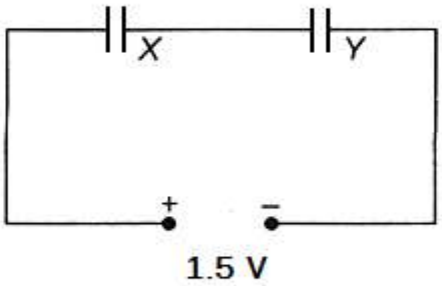
The phenomenon according to which an opposing e.m.f. is produced in a coil as a result of change in current or magnetic flux linked with a neighbouring coil is called mutual induction.

Mutual induction is the property of two coils by virtue of which each opposes any change in the current flowing in the other by developing an induced emf.

M = 1.5 H , $\frac{dI}{dt} = \frac{20-0}{0.5} = 40A/s$.

$$d\phi_s = M.dI_S = 1.5(20-0) = 30Wb.$$

12) Two parallel plate capacitors X and Y have the same area of plates and same separation between them. X has air between the plates while Y contains a dielectric medium of ε_r = 4.



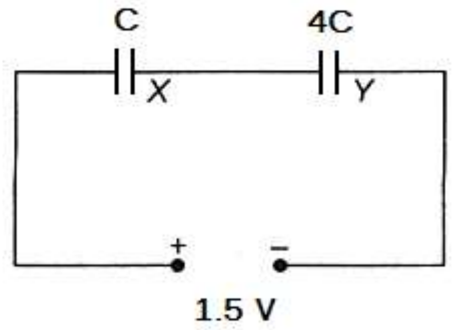
(i) Calculate capacitance of each capacitor if equivalent capacitance of the combination is 4 μF.

(ii) Calculate the potential difference between the plates of X and Y.

(iii) Estimate the ratio of electrostatic energy stored in X and Y.

SOL: (i) $C_y = \frac{4\varepsilon_0 A}{d} = 4C$; $C_x = \frac{\varepsilon_0 A}{d} = C$

$$\frac{C_x}{C_y} = \frac{4C}{C} = \frac{4}{1}$$



$$\frac{1}{C} + \frac{1}{4C} = \frac{1}{4}$$

$$\frac{4+1}{4C} = \frac{1}{4}$$

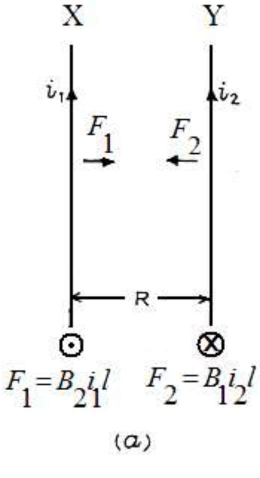
$$\frac{5}{4C} = \frac{1}{4}$$

$$C = 5\mu F$$

$C_X = 5\mu F$; $C_Y = 4 \times 5 = 20\mu F$

$$\frac{U_x}{U_y} = \frac{\left(\frac{q^2}{2C_x}\right)}{\left(\frac{q^2}{2C_y}\right)} = \frac{C_y}{C_x} = \frac{4C}{C} = \frac{4}{1}$$

13) Two long straight parallel conductors carry steady current I_1 and I_2 separated by a distance d. If the currents are flowing in the same direction, show how the magnetic field set up in one produces an attractive force on the other. Obtain the expression for this force. Hence define one ampere.



SOL: Force between two Parallel Current-Carrying Conductors : Definition of Ampere

Let *X* and Y (Fig.) be two long, parallel straight conductors carrying currents $i_1$and i_2 respectively and placed in vacuum (or air) at a distance ***R*** apart. The magnitude of the magnetic field $\vec{B_1}$ at any point on Y due to the current i_1 in *X* is given by $B_1 = \frac{\mu_0}{2\pi}\frac{i_1}{R}$

By right-hand palm rule no. 1 (or Maxwell's right-hand screw rule), $\overrightarrow{B_1}$ is perpendicular to the plane of the page directed downwards.

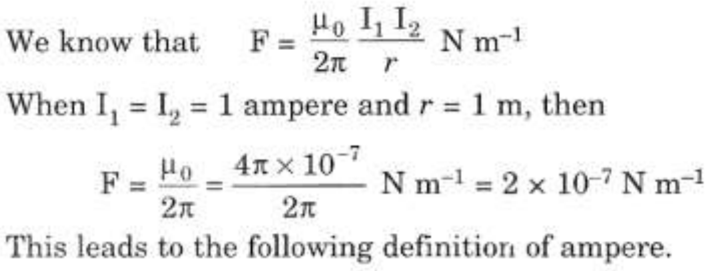
The conductor Y, carrying the current i_2, is thus situated in a magnetic field $\overrightarrow{B_1}$ perpendicular to its length. It therefore experiences a magnetic force. The magnitude of the force acting on a length l of Y is given by

$F_2 = i_2 \overrightarrow{B_1} l = i_2 \left(\frac{\mu_0}{2\pi} \frac{i_1}{R} \right) l$ and similarly

$$F_1 = i_1 \overrightarrow{B_2} l = i_1 \left(\frac{\mu_0}{2\pi} \frac{i_2}{R} \right) l$$

$$\frac{F_1}{l} = \frac{F_2}{l} = \frac{F}{l} = \frac{\mu_0}{2\pi} \frac{i_1 i_2}{R}$$

<u>Definition of one Ampere</u>



We know that $\quad F = \frac{\mu_0}{2\pi} \frac{I_1 I_2}{r}$ N m^{-1}

When $I_1 = I_2 = 1$ ampere and $r = 1$ m, then

$$F = \frac{\mu_0}{2\pi} = \frac{4\pi \times 10^{-7}}{2\pi} \text{ N m}^{-1} = 2 \times 10^{-7} \text{ N m}^{-1}$$

This leads to the following definition of ampere.

The *ampere* is the value of that steady current which, when maintained in each of the two very long, straight, parallel conductors of negligible cross-section, and placed one metre apart in vacuum, would produce on each of these conductors a force equal to 2×10^{-7} Newtons per metre of length.

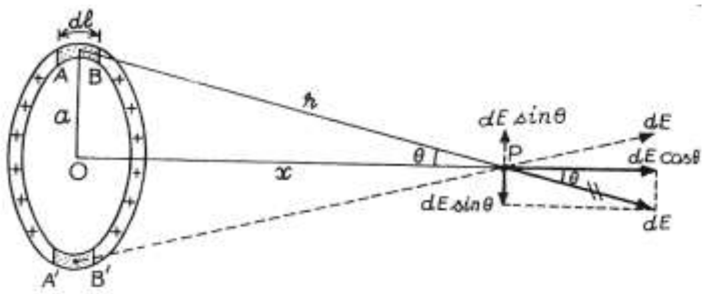
14) A charge is distributed uniformly over a ring of radius 'a'. Obtain an expression for the electric intensity E at a point on the axis of the ring. Hence show that for points at large distances from the ring, it behaves like a point charge.

SOL: <u>Electric Field due to a Circular Loop of Charge (Charged Ring):</u>

Let ***O*** be the centre of a circular ring of radius ***a,*** and having a charge ***q*** (say, positive) uniformly distributed over it. Its circumference is $2\pi a$ **,** so that the charge per unit length of the ring is $\frac{q}{2\pi a}$ **.**

Let ***P*** be a point on the axis of the ring at which the electric intensity is required. Let ***OP = x .***

Let us consider an infinitesimally small ring-element ***AB*** of length ***dl.*** It carries a charge given by



$$dq = \frac{q}{2\pi a}\, dl\,.$$

Let the distance of the element AB from P be r. The magnitude of the electric intensity dE at P due to this element is given by

$$dE = \frac{1}{4\pi\varepsilon_0}\frac{dq}{r^2}\,.$$

But $dq = \frac{q}{2\pi a}\, dl$ and $r^2 = (a^2 + x^2)$.

$$\therefore\ dE = \frac{1}{4\pi\varepsilon_0}\frac{q\, dl}{2\pi a\,(a^2+x^2)}\,. \qquad \text{...(i)}$$

$$E_{net} = E_x = \int dE\cos\theta$$

And it is direction along the axis OP(away from the center O)

Substituting the value of dE from eq. (i) and noting that $\cos\theta = \frac{x}{r} = \frac{x}{(a^2+x^2)^{1/2}}$, the last integral becomes

$$E = \int \frac{1}{4\pi\varepsilon_0}\frac{q\,dl}{2\pi a\,(a^2+x^2)}\frac{x}{(a^2+x^2)^{1/2}} = \frac{1}{4\pi\varepsilon_0}\frac{q\,x}{2\pi a\,(a^2+x^2)^{3/2}}\int dl\,.$$

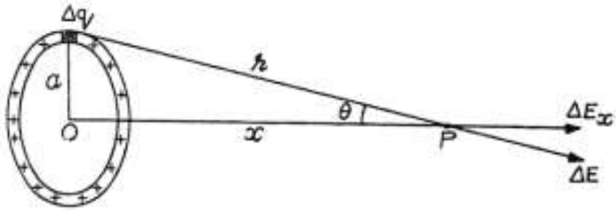
Now, $\int dl = 2\pi a$ (total length of the ring).

$$\therefore\ \boxed{E = \frac{1}{4\pi\varepsilon_0}\frac{q\,x}{(a^2+x^2)^{3/2}}} \quad \text{along } OP.$$

Special Cases :

If the point ***P*** is at a *large* distance from the ring *(x > > a),* then a^2 can be ignored compared to $\mathbf{x^2}$ in the above expression. Then, we have $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{x^2}$

points on the axis at distances much larger than the radius of the ring, the ring behaves like a point-charge.



15) Write three characteristic features in photoelectric effect which cannot be explained on the basis of wave theory of light, but can be explained only using Einstein's equation.

SOL: The wave nature of light shows up in the phenomena of interference, diffraction and polarisation. On the other hand, in photoelectric effect and Compton effect which involve energy and momentum transfer, radiation behaves as if it is made up of a bunch of particles – the photons.

Failure of Wave Theory:

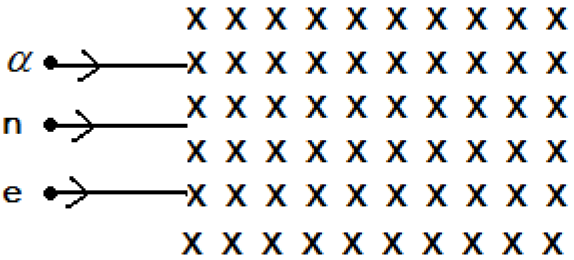
i) According to wave picture of light, the greater the intensity, the greater should be the energy absorbed by each electron and hence the max. *KE* of photoelectrons is expected to increase with increase in intensity. But according to photoelectric effect, *KE* is independent of intensity.

ii) According to wave theory, photoelectric emission is possible by light waves of all frequencies if the intensity is sufficient to impart enough energy to electrons needed to escape from the metal surface. But it is against the experimental fact which states that the emission is not possible below threshold frequency.

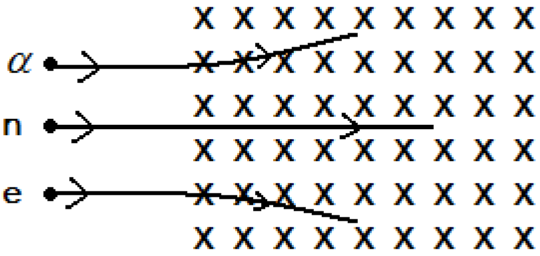
iii) In the wave picture, since the energy is distributed uniformly, therefore electrons will take some time to accumulate the energy required for the emission of electron from the metal surface. But photoelectric effect is an instantaneous process.

16) (a)Write the expression for the magnetic force acting on a charged particle moving with velocity v in the presence of magnetic field B.

(b) A neutron, an electron and an alpha particle moving with equal velocities, enter a uniform magnetic field going into the plane of the paper as shown. Trace their paths in the field and justify your answer.



SOL: (b)



17) Calculate the distance of an object of height h from a concave mirror of radius of curvature 20 cm, so as to obtain a real image of magnification 2. Find the location of image also.

(b) Using mirror formula, explain why does a convex mirror always produce a virtual image.

SOL: (a) m = 2 , u= ? , $f = -20$ cm ,

$$m = -\frac{v}{u}$$

$$u = -\frac{v}{m} = -\frac{v}{2}$$

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{v} + \frac{1}{\left(-\frac{v}{2}\right)} = \frac{1}{-20}$$

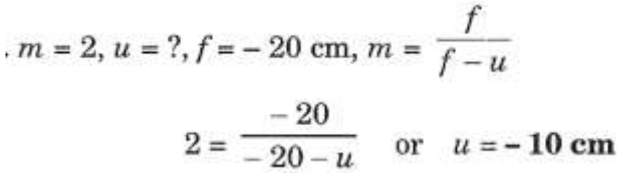
$$\frac{1}{v} - \frac{2}{v} = -\frac{1}{20}$$

$$-\frac{1}{v} = -\frac{1}{20}$$

$$v = 20$$

$$now\ u = -\frac{v}{2} = -\frac{20}{2} = -10cm$$

OR



$m = 2, u = ?, f = -20$ cm, $m = \frac{f}{f-u}$

$$2 = \frac{-20}{-20-u} \quad \text{or} \quad u = \mathbf{-10\ cm}$$

Negative sign indicates that the image is formed in front of the mirror.

(b) For a convex mirror, *f is* positive while *u* is always negative (for all real objects). Therefore v is 'positive', that is, the image is formed behind the minor, irrespective of the position of the object.

The magnification is

$$m = \frac{f}{f-u}$$

$$\frac{1}{m} = \frac{f-u}{f} = 1 - \frac{u}{f} > 1$$

because *u* is always negative while *f* is positive. *m* < 1 ,

that is, the image is virtual (because *m* is positive) and smaller in size than the object.

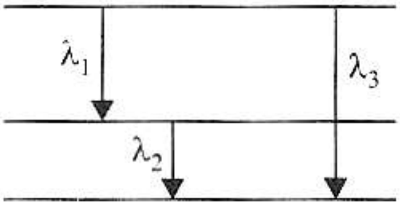
$$further \qquad m = \frac{f-v}{f} \qquad or \qquad v = (1-m)f$$

But m < 1, therefore v < *f* , that is, the image is formed between pole and focus.

Thus, *a convex mirror always forms a virtual, erect and smaller (than the object) image behind it between the pole and the focus, irrespective of the position of the object*

18) State Bohr's quantization condition for defining stationary orbits. How does de Broglie hypothesis explain the stationary orbits ?

Find the relation between the three wavelengths λ_1 , λ_2 and λ_3 from the energy level diagram shown below.



SOL:

$$\Delta E_3 = \Delta E_1 + \Delta E_2$$

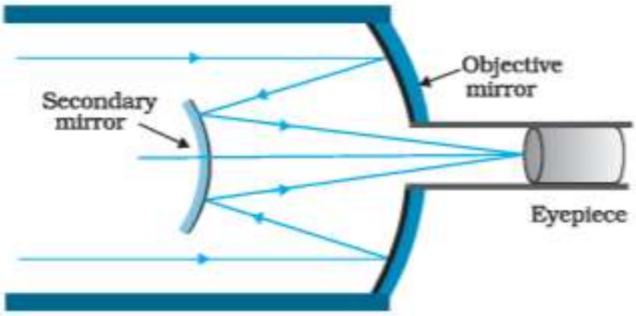
$$\frac{hc}{\lambda_3} = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2}$$

$$\frac{1}{\lambda_3} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$$

$$\frac{1}{\lambda_3} = \frac{\lambda_2 + \lambda_1}{\lambda_1 \lambda_2}$$

$$\lambda_3 = \frac{\lambda_1 \lambda_2}{\lambda_1 + \lambda_2}$$

19) Draw a schematic ray diagram of reflecting telescope showing how rays coming from a distant object are received at the eye-piece. Write its two important advantages over a refracting telescope.



SOL: **Reflecting telescope (Cassegrain):**

The main considerations with an astronomical telescope are its light gathering power and its resolution or resolving power. The former clearly depends on the area of the objective. With larger diameters, fainter objects can be observed. The resolving power, or the ability to observe two objects distinctly, which are in very nearly the same direction, also depends on the diameter of the objective. So, the desirable aim in optical telescopes is to make them with objective of large diameter. Such big lenses tend to be very heavy and therefore, difficult to make and support by their edges. Further, it is rather difficult and expensive to make such large sized lenses which form images that are free from any kind of chromatic aberration and distortions.

Modern telescopes use a concave mirror rather than a lens for the objective. Telescopes with mirror objectives are called *reflecting* telescopes. They have several advantages. First, there is no chromatic aberration in a mirror. Second, if a parabolic reflecting surface is chosen, spherical aberration is also removed. Mechanical support is much less of a problem since a mirror weighs much less than a lens of equivalent optical quality, and can be supported over its entire back surface, not just over its rim. One obvious problem with a reflecting telescope is that the objective mirror focusses light inside the telescope tube. One must have an eyepiece and the observer right there, obstructing some light (depending on the size of the observer cage).

The viewer sits near the focal point of the mirror, in a small cage. Another solution to the problem is to deflect the light being focussed by another mirror. One such arrangement using a convex secondary mirror to focus the incident light, which now passes through a hole in the objective primary mirror. It has the advantages of a large focal length in a short telescope.

Merits (any two) :

(i) In modern reflecting telescopes with the use of paraboloidal mirror the image may also be made free from spherical aberration.

(ii) The image formed by a reflecting telescope is brighter than that formed by a refracting telescope of equivalent size because in the latter the intensity of light is partially lost due to reflection and absorption by the objective lens glass.

(iii) Further, in reflecting telescope the image is free from chromatic aberration, because only reflection is involved, while this defect persists in the image formed by a refracting telescope.

(iv) The objective of the telescope should have a large aperture. It is difficult to construct lenses of large aperture because the glass becomes distorted during the manufacturing process. The image formed by such a lens becomes distorted. On the other hand, the image produced by a mirror is not affected by any distortion in the interior of the glass.

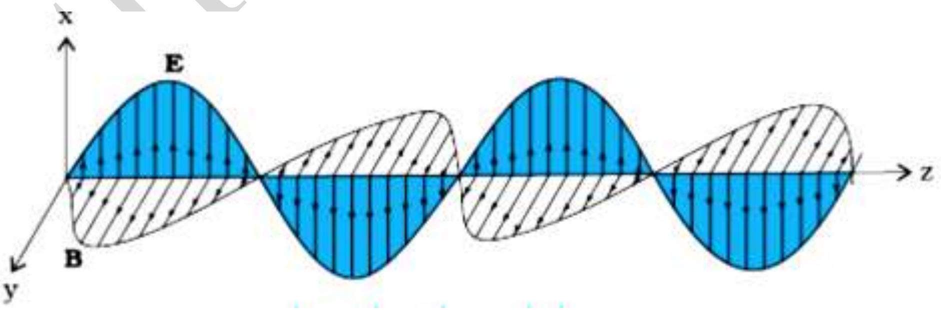
(v) High resolution is achieved by using a minor of large aperture which is easier to support than a lens of equal aperture.

20) How are em waves produced by oscillating charges ?

Draw a sketch of linearly polarized em waves propagating in the Z-direction. Indicate the directions of the oscillating electric and magnetic fields.

SOL: SOL: (a) An oscillating charge produces an oscillating electric field in space, which produces an oscillating magnetic field. The oscillating electric and magnetic fields regenerate each other, and this results in the production of e-m waves in space.

b)



OR

Write Maxwell's generalization of Ampere's Circuital Law. Show that in the process of charging a capacitor, the current produced within the plates of the capacitor is

$$i = \varepsilon_0 \frac{d\phi_E}{dt}$$

where ϕ_E is the electric flux produced during charging of the capacitor plates.

SOL: <u>Generalisation Made by Maxwell :</u>

The source of magnetic field is not just the conduction electric current due to flowing charges, but also the time rate of change of electric field

Total current = conduction current + displacement current

i = i_C + i_D

$$= i_C + \varepsilon_0 \left(\frac{d\phi_E}{dt} \right)$$

Outside the capacitor plates, we have only conduction current i.e. $i = i_C$, and $i_D = 0$

Inside the capacitor, there is no conduction current i.e. $i_c = 0$ and there is only displacement current i.e. $i = i_D$

Time - dependent electric and magnetic fields give rise to each other.

<u>Ampere Maxwell's Law</u>:

$\oint_C \vec{B} \cdot \vec{dl} = \mu_0 \left(I + \varepsilon_0 \frac{d\phi_E}{dt} \right) = \mu_0 (I + I_D)$ where $I_D = \varepsilon_0 \frac{d\phi_E}{dt}$ is displacement and

ϕ_E is the electric flux across the loop C.

during the charging of capacitor, direction of E is from positive plate to the negative plate whereas the direction of B at a point S between the two plates of capacitor, is perpendicular to the plane of the paper.

<u>The current produced within the plates of the capacitor is (Displacement Current)</u> : Current due to changing electric field.

The electric flux ϕ_E through the surface b/w and parallel to the plates of the parallel plate capacitor through which a time dependent current flows is given by :

$\phi_E = |\mathrm{E}|\,\mathrm{A} = \left(\frac{1}{\varepsilon_0} \frac{Q}{A} \right) A = \frac{Q}{\varepsilon_0}$ (E: Electric field between the plates)

Now if the charge Q on the capacitor plate charges with time, there is a current $\left(i = \frac{dQ}{dt} \right)$

We have, $\frac{d\phi_E}{dt} = \frac{d}{dt} \left(\frac{Q}{\varepsilon_0} \right) = \frac{1}{\varepsilon_0} \frac{dQ}{dt}$.

$i = \varepsilon_0 \left[\frac{d}{dt} (\phi_E) \right]$ (i = displacement current)

21) (a)Explain any two factors which justify the need of modulating a low frequency signal.

(b) Write two advantages of frequency modulation over amplitude modulation.

SOL: (a) The needs of modulation for transmission of a signal are -

(1) The transmission of low frequency signal need antenna of height 4-5 km which is impossible to construct. So there is need to modulate the wave in order to reduce the height of antenna to a reasonable height.

(2) Effective power radiated by antenna for low wavelength or high frequency wave as $P \propto \frac{l^2}{\lambda^2}$

So, for effective radiation by antenna, there is need to modulate the wave.

(b) The frequency modulation has higher bandwidth and quality compared to that of amplitude modulation. Since the information is transmitted in the form of frequency variation, the changes occurring to the amplitude of the signal do not affect the information transmitted whereas it becomes a problem in amplitude modulation. Therefore, frequency modulation is preferred over amplitude modulation for transmission of music.

22) (i) Write the functions of three segments of a transistor.

(ii) Draw the circuit diagram for studying the input and output characteristics of n-p-n transistor in common emitter configuration. Using the circuit, explain how input, output characteristics are obtained.

SOL: <u>The three segments of a transistor are:</u>

<u>Emitter :</u> *It* is of moderate size and heavily doped. It supplies a large number of majority carriers for the current flow through the transistor.

<u>Base</u> : This is the central segment. It is very thin and lightly doped.

<u>Collector :</u> This segment collects of a major portion of the majority carriers supplied by the emitter. The collector side is moderately doped and larger in size as compared to the emitter.

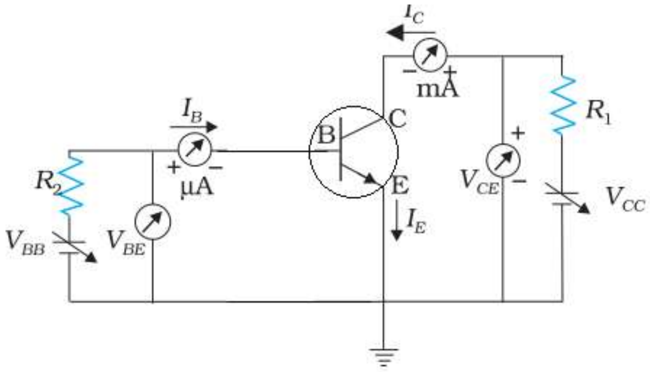
(ii) <u>Common emitter transistor characteristics</u>

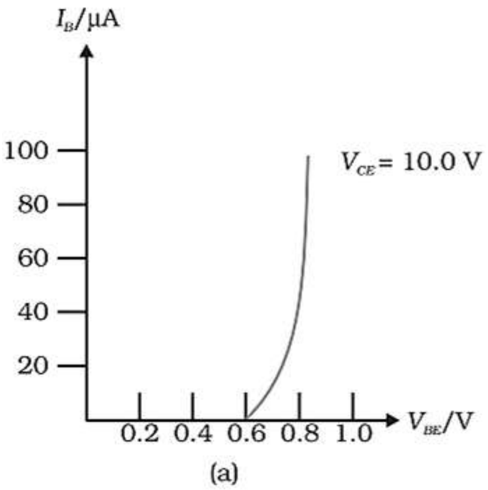
When a transistor is used in CE configuration, the input is between the base and the emitter and the output is between the collector and the emitter.

<u>Input characterstics:</u>

The variation of the base current I_B with the base-emitter voltage V_{BE} is called the ***input characteristic*.**

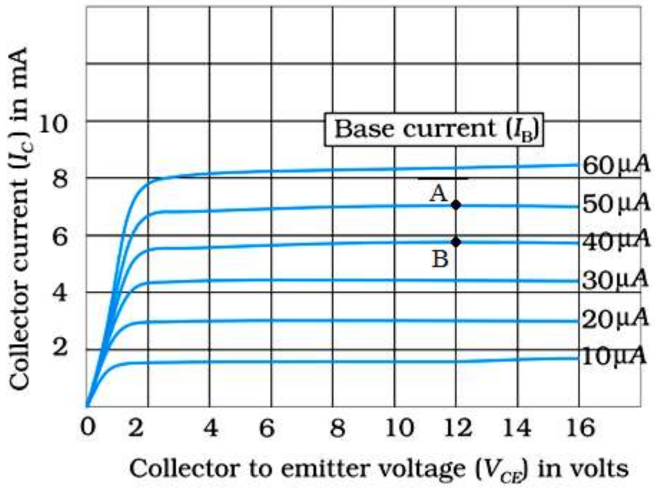
- To study the input characteristics of the transistor in CE configuration, a curve is plotted between the base current I_B against the base-emitter voltage V_{BE} . The collector-emitter voltage V_{CE} is kept fixed while studying the dependence of I_B on V_{BE} when the transistor is in active state.





Output characteristic

- The variation of the collector current I_C with the collector-emitter voltage V_{CE} at constant I_B is called the **output characteristic.**
- If V_{BE} is increased by a small amount, both hole current from the emitter region and the electron current from the base region will increase. As a consequence, both I_B and I_C will increase proportionately. This shows that when I_B increase, I_C also increases.
- The plot of I_C versus V_{CE} for different fixed values of I_B gives one output characteristic.



SECTION-D

23) Meeta's father was driving her to the school. At the traffic signal she noticed that each traffic light was made of many tiny lights instead of a single bulb. When Meeta asked this question to her father, he explained the reason for this.

Answer, the following questions based on above information :

a) What were the values displayed by Meeta and her father ?

b) What answer did Meeta's father give ?

c) What are the tiny lights in traffic signals called and how do these operate ?

SOL: (a) Curiosity, Power of Observation , sharing of knowledge

(b) Meeta’s Father answered that these traffic light are made up of LED. An LED traffic light looks very similar to a regular traffic light. LED is actually very small and therefore the traffic light is made up of a bunch of smaller lights, this is apparent when you look closely. The colour of the light depends on the exact composition inside the bulb.

c) The tiny light in Traffic signal are called LED lights.

It is an important light source used in optical communication, and **is based on the principle of conversion of biasing electricity into light.** It is a specially designed ***forward-biased*** *p-n* junction diode which emits light spontaneously when energized.

1. Since, LEDs do not have a filament that can burn out, they last longer.
2. They do not get hot during use.
3. LED can operate at very low voltage and consumes less power in comparison to incandescent lamps.

SECTION – E

24) Define the term drift velocity.

On the basis of electron drift, derive an expression for resistivity of a conductor in terms of number density of free electrons and relaxation time. On what factors does resistivity of a conductor depend ?

Why alloys like constantan and manganin are used for making standard resistors

SOL: *The average velocity acquired by the free electrons along the length of a metallic conductor under a p.d. applied across the conductor is called 'drift velocity' of the electrons.*

Let l be the length and A the area of cross-section of a metallic wire. When a potential difference V is applied across its ends, an electric current i flows in it. If the free-electron density in the wire (number of free electrons per unit volume of the wire) be n and the drift velocity of the electrons be v_d , then

$i = neAv_d$, ...(i)

where e is electronic charge. Since the potential difference across the ends of the length l of the wire is V, the intensity of electric field at every point of the wire is given by

$E = V/l$.

The force exerted by this field on each free electron is given by

$F = eE = eV/l$.

If the mass of electron be m, then the acceleration of the electron due to this force is

$a = F/m = eE/m = eV/ml$. ...(ii)

The average velocity of all the n electrons is the drift velocity v_d of free electrons. Thus

$$v_d = \frac{v_1 + v_2 + v_3 + ...v_n}{n}$$

$$v_d = \frac{(u_1 + a\,\tau_1) + (u_2 + a\,\tau_2) + ...\,(u_n + a\,\tau_n)}{n}$$

$$= \frac{u_1 + u_2 + ...\,u_n}{n} + a\,\frac{\tau_1 + \tau_2 + ...\,\tau_n}{n}$$

$$= 0 + a\,\tau = a\,\tau, \qquad ...(iii)$$

where $\tau\,[=\tau_1 + \tau_2 + ………\tau_n\,/\,n]$ represents the average time-interval of electrons between two successive collisions (relaxation time).

Substituting the value of *a* from eq. (ii) in eq. (iii), we have

$$v_d = a.\tau = \frac{F}{m}\tau = \frac{eE}{m}\tau = \frac{eV}{ml}\tau \qquad [v_d \propto E \propto V]$$

$$v_d = \frac{eV}{ml}\tau$$

This is the relation between the drift velocity v_d of free electrons in the wire and the potential difference V across the ends of the wire. Substituting this value of v_d in eq. (i), we have

$$i = neA\left(\frac{eV}{ml}\right)\tau = \frac{ne^2\tau}{m}\,\frac{A}{l}\,V$$

$$\frac{V}{i} = \frac{m}{ne^2\tau}\,\frac{l}{A}.$$

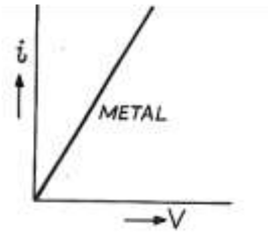
At a given temperature τ is also a constant .

$$\frac{V}{i} = \frac{ml}{ne^2 A\tau} = \text{constant}$$

$\frac{V}{i} = \text{constant} = R$ = electric resistance of the conductor

$$R = \frac{ml}{ne^2 A\ \tau}$$

$\therefore \frac{V}{i} = R = constant$ This is the ohm's law.



$$R = \frac{ml}{ne^2 A\ \tau}$$

$$\frac{\rho\ l}{A} = \frac{m\ l}{ne^2 A\ \tau}$$

$$\boxed{\rho = \frac{m}{ne^2\tau}}$$

It depends upon

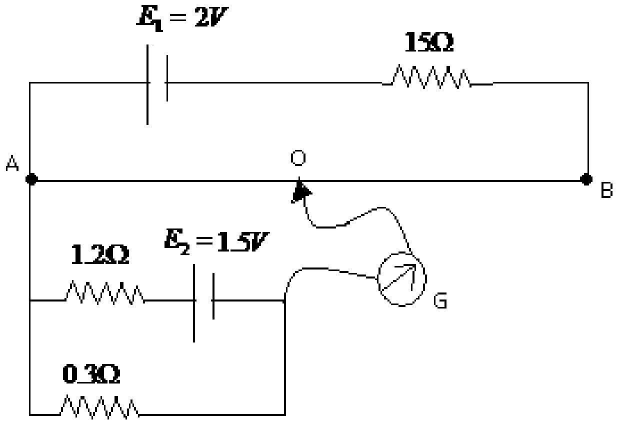
i) free electron density $\left(\rho \propto \frac{1}{n}\right)$ and

ii) Temperature (It increases with rise in temperature). $\left(\mathrm{v}_{rms} \propto \sqrt{T} \propto \frac{1}{\tau}\right)$

OR

State the principle of working of a potentiometer.

In the following potentiometer circuit AB is a uniform wire of length 1 m and resistance 10Ω. Calculate the potential gradient along the wire and balance length AO (= *l*).



SOL: **Principle of potentiometer:** The potential difference across any two points of current carrying wire, having uniform cross-sectional area and material, of the potentiometer is directly proportional to the length between the two points, i.e., $V \propto l$

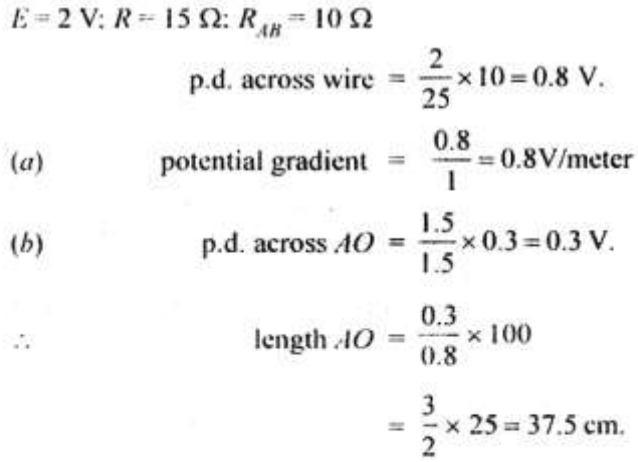
$$\because V = IR = I\left(\rho \frac{l}{A}\right)$$

$$V = \left(\frac{I\rho}{A}\right) l$$

for uniform current and cross-sectional area

$\frac{\rho I}{A} = K$ (constant)= Pot. Gradient (pot. drop per unit length)

$V \propto l$



$E = 2$ V; $R = 15\ \Omega$; $R_{AB} = 10\ \Omega$

$$\text{p.d. across wire} = \frac{2}{25} \times 10 = 0.8 \text{ V.}$$

$$(a) \quad \text{potential gradient} = \frac{0.8}{1} = 0.8\text{V/meter}$$

$$(b) \quad \text{p.d. across } AO = \frac{1.5}{1.5} \times 0.3 = 0.3 \text{ V.}$$

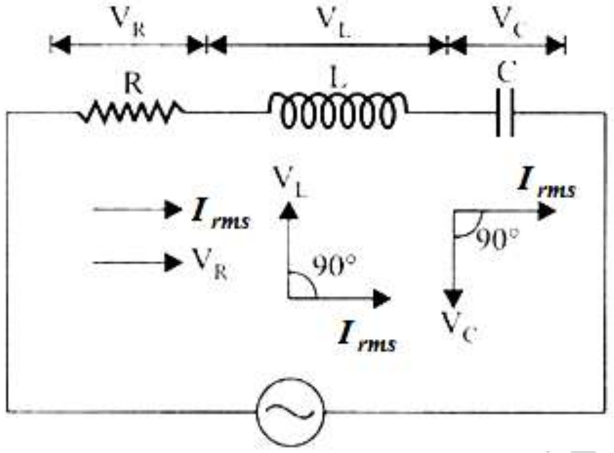
$$\therefore \quad \text{length } AO = \frac{0.3}{0.8} \times 100$$

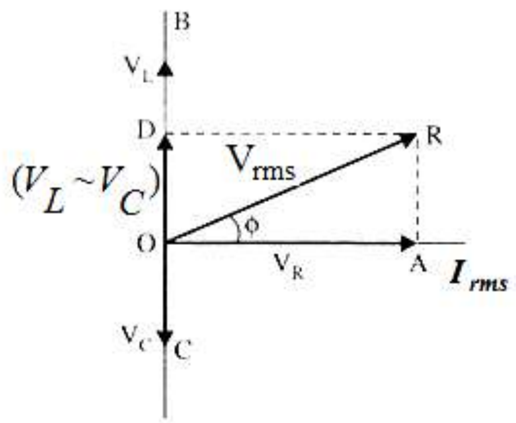
$$= \frac{3}{2} \times 25 = 37.5 \text{ cm.}$$

25) (i) An a.c. source of voltage $V = V, \sin \omega t$ is connected to a series combination of L, C and R. Use the phasor diagram to obtain expressions for impedance of the circuit and phase angle between voltage and current. Find the condition when current will be in phase with the voltage. What is the circuit in this condition called ?

(ii) In a series LR circuit $X_L = R$ and power factor of the circuit is P_1. When capacitor with capacitance C such that $X_L = X_C$ is put in series, the power factor becomes P_2. Calculate P_1/P_2.

SOL: **AC VOLTAGE APPLIED TO A SERIES LCR CIRCUIT**





$V = V_0 \sin \omega t$

The current through the three elements would have the same amplitude and phase. Whereas, the voltage across each element has a different phase relationship with current.

The potential differences V_L, V_C and V_R across L, C and R respectively at any instant are given by :

$V_L = I_{rms} X_L$, $V_C = I_{rms} X_C$ and $V_R = I_{rms}R$

where I_{rms} is the current at that instant. Here X_L and X_c are the inductive and capacitive reactances respectively.

V_R is in phase with I_{rms} But V_L leads I_{rms} by 90°. V_C lags behind I_{rms} by 90°.

In the phasor diagram, OA represents V_R (which is in phase with I_{rms}). OB represents V_L (which leads I_{rms} by 90^0). OC represents V_C (which lags behind I_{rms} by 90°).

V_L, and V_C are opposite to each other. If $V_L > V_C$, then their resultant will be $(V_L - V_C)$ which is represented by OD. OR represents the resultant of V_R and $(V_L - V_C)$. It is equal to the applied emf V_{rms}.

$V_{rms}^2 = V_R^2 + (V_L - V_C)^2$

Or $\quad I_{rms}^2 Z^2 = I_{rms}^2[R^2 + (X_L - X_C)^2]$

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$ = impedance of LCR series circuit.

$$I_{\text{rms}} = \frac{V_{\text{rms}}}{Z} = \frac{V_{\text{rms}}}{\sqrt{R^2 + (X_L - X_C)^2}}$$

$$\tan\phi = \frac{V_L - V_C}{R} = \frac{X_L - X_C}{R} = \frac{\omega L - \frac{1}{\omega C}}{R}$$

Where ϕ is phase angle between net emf (V_{rms}) and current I_{rms}.

Or between V and I or Between V_0 and I_0

When $X_L = X_C$ i.e. , when $\omega_0 L = \frac{1}{\omega_0 C}$,then

$$\tan\phi = 0 \qquad or \qquad \phi = 0^0$$

In this case, the current and the emf are in the same phase.

$Z = \sqrt{R^2 + (X_L - X_C)^2} = R$ (At electrical resonance)

So, the LCR circuit behaves like a purely resistive circuit. The impedance is now independent of the frequency of alternating current.

Due to minimum value of impedance, the current in LCR series circuit is maximum. This condition is **called resonance.**

(ii) R = R , X_L = R , $Z = \sqrt{R^2 + (X_L)^2} = \sqrt{R^2 + R^2} = \sqrt{2}R$

$$\cos\phi = \frac{R}{Z} = \frac{R}{\sqrt{2}R} = \frac{1}{\sqrt{2}} = P_1$$

$$P_1 = \frac{1}{\sqrt{2}}$$

Second case R = R , $X_L = X_C$

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = R$$

$$\cos\phi = \frac{R}{Z} = \frac{R}{R} = 1 = P_2$$

$$P_2 = 1$$

$$\frac{P_1}{P_2} = \frac{\frac{1}{\sqrt{2}}}{1} = \frac{1}{\sqrt{2}}$$

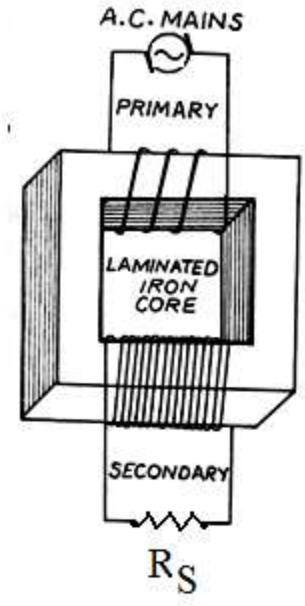
OR

(i) Write the function of a transformer. State its principle of working with the help of a diagram. Mention various energy losses in this device.

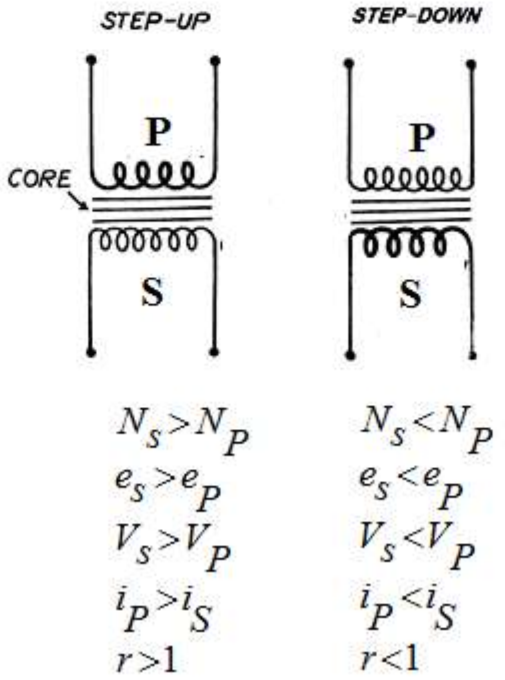
(ii) The primary coil of an ideal step- up transformer has 100 turns and the transformation ratio is also 100. The input voltage and power are 220 V and 1100 W respectively. Calculate

- a) **number of turns in the secondary**
- b) **the current in the primary**
- c) **voltage across the secondary**
- d) **the current in the secondary**
- e) **power in the secondary**

SOL: (i) **<u>Transformers</u>**



TRANSFORMER



The **ac device** used to **transform** an alternating voltage from one value(High voltage) to another value (Low voltage) and vice-versa is called **transformer**.

Step up transformer is used to change a low ac voltage (at high currents) into a high ac voltage (at low currents) and **Step down transformer** is used to change a high ac voltage (at low currents) into a low ac voltage (at high currents).

This does not violate the law of **conservation of energy.** The current is reduced/increased by the same proportion as the voltages is increased/reduced.

Principle: *It works on the principle of* ***mutual induction****, i.e., when an alternating voltage is applied to the primary, the resulting current produces an alternating magnetic flux which links the secondary and induces an emf in it .*

Working: When an ac voltage is applied to the primary , the resulting current produces an alternating magnetic flux in core which also passes through the secondary coil . This change in magnetic flux sets up an induced emf in the secondary and depends upon the number of turns in it.

In case of ideal transformer in which primary has negligible resistance and all the flux in the core links both primary and secondary windings.

Theory:

Let ϕ be the flux in each turn in the core at time t due to current in the primary when a voltage V_P is applied to it.

Then the induced emf e_S or voltage V_S , in the secondary with N_S turns is

$$e_S = V_S = -N_S \frac{d\phi}{dt} \quad \text{…………(i)}$$

The alternating flux ϕ also induces an emf e_P or voltage V_P, in the primary with number of turns N_P

$$e_P = V_P = -N_P \frac{d\phi}{dt} \quad \text{………(ii)}$$

(i) / (ii)

$$\frac{e_S}{e_P} = \frac{V_S}{V_P} = \frac{N_S}{N_P} \quad \text{…………(iii)}$$

In actual practice small **energy losses do occur in the transformer** due to the following reason:

1) **Flux Leakage(Magnetic loss):** There is always some flux leakage. i.e., The coupling of primary and secondary windings is never perfect (Due to poor design of the core or air gaps in the core). So the whole of the magnetic flux produced by the primary does not pass through the secondary. It can be reduced by winding the primary and secondary coil one over the other.
2) **Resistance of the windings (Copper loss):** The wire used for the windings has some resistance and so, energy is lost in the form of heat ($H = I^2R\,t$). In high current, low voltage windings, these are minimised by using thick copper wire (low resistance).
3) **Eddy currents (Iron loss):** The alternating magnetic flux induces eddy currents in the iron core and causes heating.

   The eddy current can be reduced by using a core of thin laminated sheets in place of single thick lamina .

4) **Hysteresis:** The core is repeatedly magnetised and demagnetised due to alternating currents so some energy is lost as heat this is called hysteresis loss .

This can be minimised by using a magnetic material (soft iron) which has a low hysteresis loss.

5) Magnetostriction: humming noise of a transformer.

On account of these losses $P_S < P_P$

$$V_S \times i_S < V_P \times i_P$$

The efficiency of transformer $\eta = \frac{P_{out}}{P_{in}} = \frac{V_S \times i_S}{V_P \times i_P}$.

For an ideal transformer η is 1 but in actual practice η is less then 1 (efficiency is not 100%)

(ii) $N_p = 100$, Transformation ratio = 100,

$$V_P = 220\text{ V},\ P_P = 1100\text{ W}$$

(i) N_s = Transformation ratio × N_P

$= 100 \times 100 = \mathbf{10000}$

(ii) $I_P = \frac{P_P}{V_P} = \frac{1100}{220} = \mathbf{5\ A}$

(iii) V_s = Transformation ratio × V_P

$= 100 \times 220\text{ V} = \mathbf{22000\ V}$

(iv) $I_s = \frac{V_P I_P}{V_s} = \frac{220 \times 5}{22000} = \mathbf{0.05\ A}$

(v) For an ideal transformer,

$P_s = P_P = \mathbf{1100\ W}$

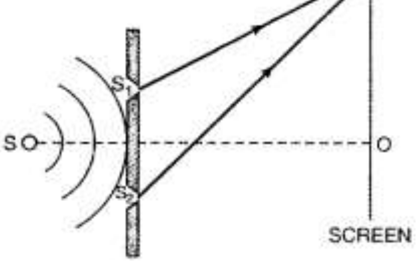
26) In Young's double slit experiment, deduce the condition for (a) constructive, and (b) destructive interference at a point on the screen. Draw a graph showing variation of intensity in the interference pattern against position 'x' on the screen.

Compare the interference pattern observed in Young's double slit experiment with single slit diffraction pattern, pointing out three distinguishing features.

SOL: **Condition for maximum and minimum:** Let the displacements of the waves from the sources S_1 and S_2 at point P on the screen at any time t be given by

$$y_1 = a_1 \sin \omega t$$
$$and \quad y_2 = a_2 \sin(\omega t + \phi)$$

where ϕ is the constant phase difference between the two waves.



By the superposition principle, the resultant displacement at point P is given by

$$y = y_1 + y_2 = a_1 \sin\omega\, t + a_2 \sin(\omega\, t + \phi) = a_1 \sin\omega\, t + a_2 \sin\omega\, t \cos\phi + a_2 \cos\omega\, t \sin\phi$$

$$y = (a_1 + a_2 \cos\phi)\sin\omega\, t + a_2 \sin\phi \cos\omega\, t ....(1)$$

$$Let \quad a_1 + a_2 \cos\phi = A\cos\theta ....(2)$$

$$and \quad a_2 \sin\phi = A\sin\theta ....(3)$$

Then the equation (1) becomes

$$y = A\cos\theta \sin\omega t + A\sin\theta \cos\omega t$$

$$y = A\sin(\omega t + \theta)$$

Hence, resultant displacement at point P is simple harmonic wave having amplitude A and phase difference θ with the harmonic wave from the source S_1. In order to know the amplitude of the resultant simple harmonic wave, we proceed as below :

Squaring and adding both sides of the equations (2) and (3), we obtain

$$A^2 \sin^2\theta + A^2 \cos^2\theta = \left(a_1 + a_2 \cos\phi\right)^2 + \left(a_2 \sin\phi\right)^2$$

$$or \quad A^2 = a_1^2 + a_2^2(\cos^2\phi + \sin^2\phi) + 2a_1a_2\cos\phi$$

$$or \quad A^2 = a_1^2 + a_2^2 + 2a_1a_2\cos\phi$$

The intensity of light is directly proportional to the square of amplitude of the wave. For the sake of simplicity, we assume that intensity of light is equal to the square of the amplitude. Therefore, intensity of light at point P on the screen is given by

$$I = A^2 = a_1^2 + a_2^2 + 2a_1a_2\cos\phi \text{ ....(4)}$$

Constructive interference. From the equation (4), it follows that the intensity of light at point P will be maximum, if

$$\cos\phi = +1 \quad or \quad \phi = 0, 2\pi, 4\pi, ...$$

$$\boxed{\phi = 2\pi n} \quad , \quad where \quad n = 0, 1, 2, ... \qquad \textbf{.......(5)}$$

$$\phi = 0\pi, 2\pi, 4\pi, 6\pi ......2\text{n}\,\pi$$

$$\phi = \frac{2\pi}{\lambda}x \text{ ....(6)}$$

Using the equation (6), the condition for constructive interference i.e.

$$\frac{2\pi}{\lambda}x = 2\pi n$$

$$\boxed{or \quad x = n\lambda} \qquad where \quad n = 0, 1, 2, 3.......... \qquad \textbf{.........(7)}$$

$$x = 0\lambda, 1\lambda, 2\lambda, 3\lambda, 4\lambda................n\,\lambda$$

It is the condition for constructive interference .

Destructive interference. :-From equation (4), it follows that the intensity of light at point P will be minimum, if

$$\cos\phi = -1 \qquad or \qquad \phi = 1\pi, 3\pi, 5\pi....$$

$$\phi = (2n+1)\pi, \quad where \quad n = 0,1,2,.... \qquad \textbf{.......(8)}$$

Also from the equation (6)and (8), we have-

$$\frac{2\pi}{\lambda}x = (2n+1)\pi$$

$$\boxed{or \qquad x = (2n+1)\frac{\lambda}{2}} \qquad where \quad n = 0,1,2,......... \qquad \textbf{.........(9)}$$

$$x = 1\frac{\lambda}{2}, 3\frac{\lambda}{2}, 5\frac{\lambda}{2}, 7\frac{\lambda}{2}................(2\,n+1)\frac{\lambda}{2}$$

OR x= 0.5 λ , 1.5 λ , 2.5 λ ,……………(n + 0.5) where n ≥ 0

This is the conditions for destructive interference.

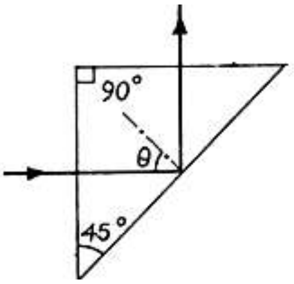
Interference	Diffraction
1. Width of central maxima is same as that of the other fringes. 2. All bright fringes are of equal intensity. 3. Large number of fringes.	1. Width of central maxima is more than of the other fringes. 2. Intensity of secondary maxima keeps on decreasing. 3. Only a small number of fringes.

OR

(i) Plot a graph to show variation of the angle of deviation as a function of angle of incidence for light passing through a prism.' Derive an expression for refractive index of the prism in terms of angle of minimum deviation and angle of prism.

(ii) What is dispersion of light ? What is its cause ?

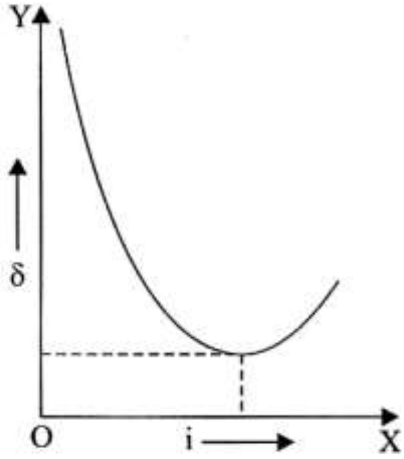
(iii) A ray of light incident normally on one face of a right isosceles prism is totally reflected as shown in fig. What must be the minimum value of refractive index of glass ? Give relevant calculations.



SOL: (i) VARIATION OF ANGLE OF DEVIATION WITH ANGLE OF INCIDENCE

From equation *(iv)*, $\delta = i + e - A$

It follows from the above equation that the angle of deviation, for a given prism, depends upon the angle of incidence. Fig. shows graphically the variation of angle of deviation with angle of incidence. It is clear from the graph that for the light of a given colour, as the angle of incidence is increased, the deviation produced goes on decreasing till it is minimum and thereafter it goes on increasing again. There is one particular angle of incidence corresponding to which angle of deviation is minimum. *The minimum value of the angle of deviation of a ray of light passing through a prism is called* ***angle of minimum deviation.*** It is denoted by δ_m.



When the prism is placed in the minimum deviation position, the refracted light is parallel to the base of the prism. At this position, the incident and the emergent rays are symmetrically inclined. To sum up, when the prism is placed in the minimum deviation position, the ray of light passes symmetrically through the prism.

EXPRESSION FOR REFRACTIVE INDEX OF MATERIAL OF PRISM When the prism is placed in the minimum deviation position,

$r_1 = r_2 = r$ (say) and $i = e$

Now, $A = r_1 + r_2 = r + r = 2r$

or $r = A/2$

Also, $i + i = A + \delta_m$ [From $i + e = A + \delta$]

$$2i = A + \delta_m \quad or \quad i = \frac{A+\delta_m}{2}$$

$$but \quad \mu = \frac{\sin i}{\sin r_1} = \frac{\sin i}{\sin r}$$

$$\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\frac{A}{2}}$$

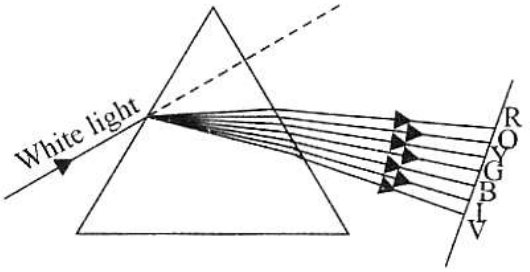
(ii) DISPERSION

White light is a mixture of all wavelengths. While the speed of a light wave in vacuum is the same for all wavelengths, the speed in a material substance is different for different wavelengths. So, the refractive index of a substance is a function of wavelength. A *substance in which the speed of a wave varies with wavelength is said to* ***exhibit dispersion.***

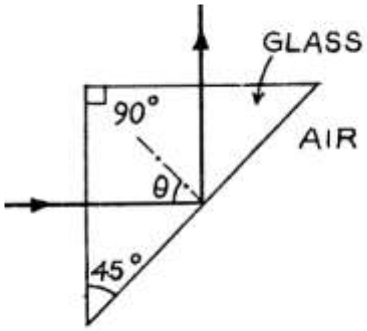
Consider white light incident on a prism. On emerging from the prism, the light is spread out into a fan-shaped beam of seven colours-violet, indigo, blue, green, yellow, orange and red.

The phenomenon of splitting a ray of white light into its constituent colours (wavelengths) is called ***dispersion.***

The band of colours, from red to violet, that emerges from the prism is called ***spectrum.***



(iii)



SOL: From the geometry of the figure, if follow that i = θ = 45° .

The light incident on the hypotenuse face of the glass prism at 45^0 undergoes total internal reflection.

45° > c Hence T.I.R.

It means that the critical angle for the glass-air interface should be less than 45°, that is,

$c < 45°$.

But, from the relation $\mu = \dfrac{1}{\sin c}$, we have

$$\sin c = \frac{1}{\mu}$$

$$c = \sin^{-1}\frac{1}{\mu}$$

$$\sin^{-1}\frac{1}{\mu} < 45^0$$

$$\frac{1}{\mu} < \sin 45^0$$

$$\mu > \frac{1}{\sin 45^0}$$

$$\mu > \sqrt{2}$$

$$\mu > 1.414$$

The refractive index of glass must be **greater than 1.414 ,** otherwise total internal reflection would not occur for the incident ray shown.