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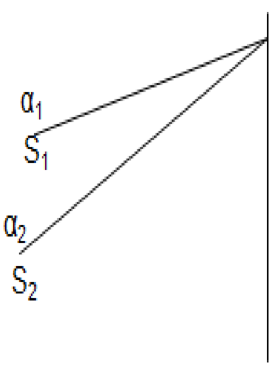
Q29. What are coherent sources? Why are coherent sources required to produce interference of light? Give an example of interference of light in everyday life.
In Young's double slit experiment, the two slits are 0.03 cm apart and the screen is placed at a distance of 1.5 m away from the slits. The distance between the central bright fringe and fourth bright fringe is 1 cm. Calculate the wavelength of light used.

Answer: Two sources of light which continuously emit light waves of same frequency with a zero or constant phase difference between them are called **coherent sources.** Two independent sources such as two bulbs or two candles or two lamps can never be coherent source. Coherent sources are always produced from a single source in two different ways.

1. By division of wave front
2. By division of amplitude



$$\beta_1 = \alpha_1 + \frac{2\pi}{\lambda}x_1$$

$$\beta_2 = \alpha_2 + \frac{2\pi}{\lambda}x_2$$

$$\phi = \beta_2 - \beta_1 = \alpha_2 + \frac{2\pi}{\lambda}x_2 - \left(\alpha_1 + \frac{2\pi}{\lambda}x_1\right)$$

$$\phi = (\alpha_2 - \alpha_1) + \frac{2\pi}{\lambda}(x_2 - x_1)$$

$$\phi = (\alpha_2 - \alpha_1) + \frac{2\pi}{\lambda}(x_2 - x_1)$$

$$I = \text{constant}\left[a^2 + b^2 + 2ab\cos\phi\right]$$

If the sources are not coherent the initial phase difference (α_2 - α_2) changes with time 10^8 times per second, i.e. intensity (I) at every point changes 10^8 times per second. Since human eye can not follow such quick change hence intensity at every point appears to be same i.e. no fringes can be seen. But if the sources are coherent initial phase are same α_2- α_2=0 . Hence Coherent sources are necessary to produce sustained interference pattern.

Example: Oil spread over water (thin film) shows beautiful colours due to interference of light.

Numerical Problem: Distance of nth bright fringe from the central bright fringe is $x_n = \frac{nD\lambda}{d}$
Hence distance of fourth bright fringe (n= 4) from the central bright fringe is

$x_4 = \frac{4D\lambda}{d}$

$\therefore \lambda = \frac{dx_4}{4D} = \frac{0.03\times10^{-2}\times1\times10^{-2}}{4\times1.5}$

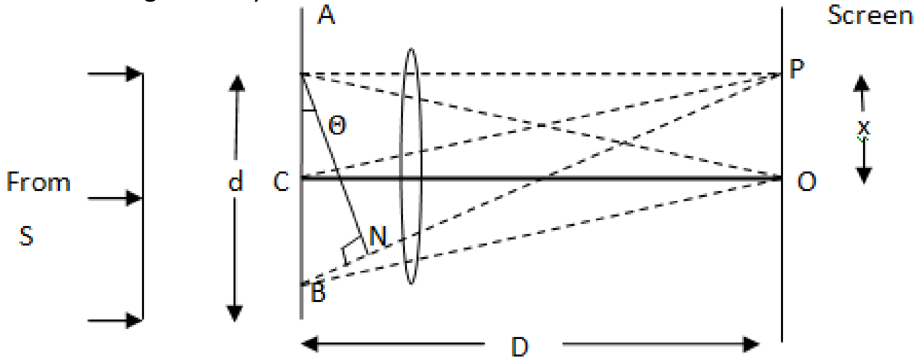
$= 5 \times 10^{-7}\ m$

Or, State the condition under which the phenomenon of diffraction of light takes place. Derive an expression for the width of the central maximum due to diffraction of light at a single slit.
A slit of width 'a' is illuminated by a monochromatic light of wavelength 700 nm at normal incidence. Calculate the value of 'a' for position of

(I) First minimum at an angle of diffraction of 30^0.
(II) First maximum at an angle of diffraction of 30^0.

Answer: Condition for Diffraction (bending of light) to take place , is light in its path should face small obstacle which are either (i) round a sharp edge (ii) a narrow opening Sharp narrow or small means sizes should be comparable to the wave length of light. Thus Diffraction of light takes place when the width of the slit is comparable to the wavelength of light used.

Expression for width of central maximum: Considering a parallel beam of monochromatic light of wavelength λ falls normally on a slit AB of width d (of the order of the wave length of light). While passing through the slip diffraction occurs. The diffraction pattern is focused on to the screen by a convex lens. The diffraction pattern consists of a central bright fringe (or band), having alternate dark and bright fringes of decreasing intensity on both sides.



Position of central maximum: Let C be the center of the slit AB. According to Huygen's principle, when light falls on the slit, it becomes a source of secondary wavelets. All the wavelets originating from slit AB are in same phase. These secondary waves reinforce each other resulting the central maximum intensity at O.

1. **Position of secondary Maxima and Minima:** Considering a point P on the screen. All the secondary waves travelling in a direction making angle θ with CO, reach at a point P. The intensity at P depends on the path difference between secondary waves. Therefore, path difference between the secondary waves reaching P from points A and B is

$$\mathrm{BN} = \mathrm{d}\ \sin\theta$$

(I) The point P will be the position of **nth secondary maxima** if path difference

$$\mathrm{BN} = (2\mathrm{n}+1)\frac{\lambda}{2}, \text{where n is an integer.}$$

$\therefore\ d\ \sin\theta = (2n+1)\frac{\lambda}{2}$

$\sin\theta = (2n+1)\frac{\lambda}{2d}$

Where θ is very small then $\sin\theta = \theta$

$\therefore\ \theta = (2n+1)\frac{\lambda}{2d}$, when n is an integer.

for $n = 1, \theta_1 = \frac{3\lambda}{2d}$, first secondary maximum.

(II) The point P will be the position of **nth secondary minima** if path difference

$$BN = n\lambda$$

$d\ \sin\theta = n\lambda$, where n is an integer.

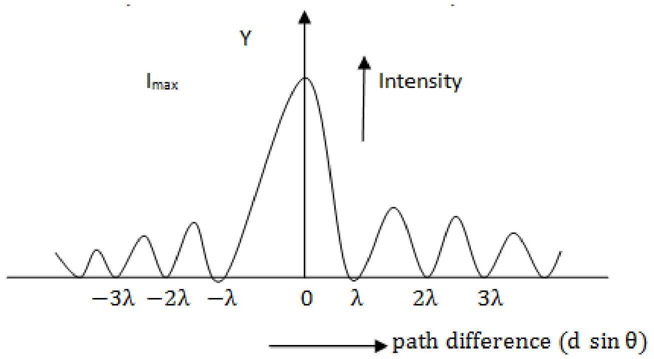
$\sin\theta = \frac{n\lambda}{d}$

Where θ is very small then $\sin\theta = \theta$

$\therefore\ \theta = \frac{n\lambda}{d}$, when n is an integer.

Hence the diffraction pattern due to single slit consists of a center bright maximum at P along with secondary maxima and minima on either side.

Intensity Distribution: The intensity distribution on the screen is represented as



Width of central maximum: If d is the distance between slit and screen and y_n is the distance of nth minimum from point O then

$\theta_n = \frac{y_n}{D}$ ……………………………………………..(i)

But the position of nth secondary minimum is

$\theta_n = \frac{n\lambda}{D}$ ……………………………………………..(ii)

$\therefore \frac{y_n}{D} = \frac{n\lambda}{D}$ [From (i)& (*ii*)]

$\beta = y_n - y_{n-1} = \frac{n\lambda D}{d} - (n-1)\frac{\lambda D}{d} = \frac{n\lambda D - n\lambda D + \lambda D}{d}$

$\therefore \beta = \frac{\lambda D}{d}$

Problem: (I) Condition for first minimum is

$$a \sin\theta = \lambda$$

$$a = \frac{\lambda}{\sin\theta} = \frac{700\text{ nm}}{\sin 30^o} = \frac{700\text{ nm}}{0.5} = 1400\text{ nm}$$

(II) Condition for first maximum is

$$a \sin\theta = \frac{3\lambda}{2}$$

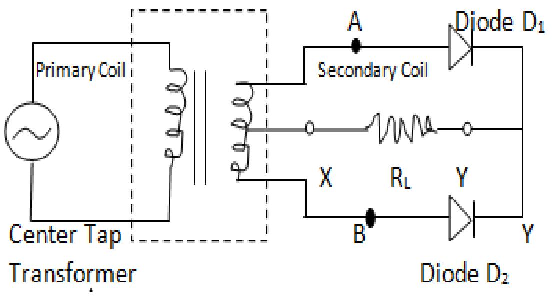
$$\therefore a = \frac{3\lambda}{2\sin\theta} = \frac{3\times700\text{ nm}}{2\times\sin 30^o} = 2100\text{ nm}$$

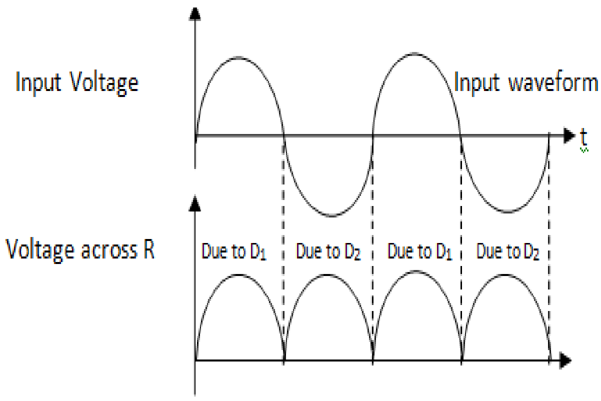
Q30. State the principle of working of p-n diode as a rectifier. Explain, with the help of a circuit diagram, the use of p-n diode as a full wave rectifier. Draw a sketch of the input and output waveforms.

Answer: **p-n junction diode as full wave rectifier:** For full wave rectifier two diodes are used so that during one half cycle of A.C one diode (say D_1) operational during the other half cycle second diode (D_2) is operational. A center tap transformer is used as shown in the circuit. The secondary transformer gives the desired A.C. voltage across A and B.

During the positive half cycle of A.C. input, the diode D_1 is in forward bias and conduct current while D_2 is in reverse biased and does not conduct current. So we get an output voltage across the load resistor R_L.

During negative half cycle of A.C. input, the diode D_1 is in reverse biased and does not conduct current while diode D_2 is in forward biased and conducts current. So we get an output voltage across the load resistor R_L.





$I = I_0 \sin\omega t$ be the input current to be rectified.

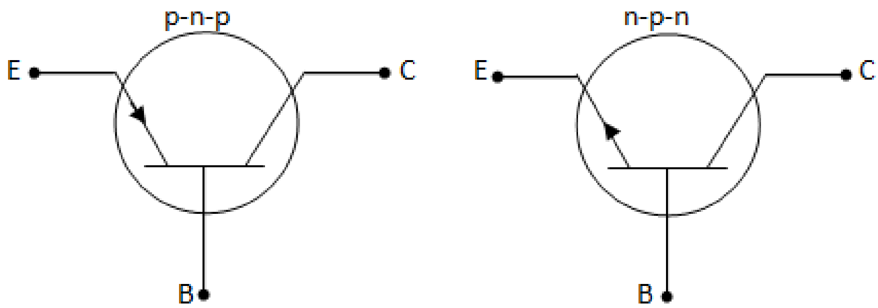
$\therefore$ The average current $= \frac{2I_0}{\pi}$

and the output voltage $= \frac{2I_0}{\pi} R_L$

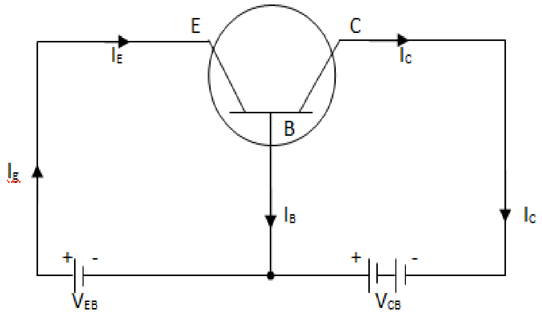
Or,

Draw the symbolic representation of a (I) p-n-p, (II) n-p-n transistor. Why is the base region of transistor thin and lightly doped? With proper circuit diagram, show the biasing of a p-n-p transistor in common base configuration. Explain the movement of charge carriers through different parts of the transistor in such a configuration and show that $I_E = I_C + I_B$.

Answer: The symbols of p-n-p and n-p-n transistors



Thin and lightly doped base region contains very few majority charge carriers. This reduces the recombination rate of electrons and holes across the emitter-base junction. Also increases collector current and hence increases current gain of the transistor.



Action of p-n-p transistor: The emitter base junction is forward biased by battery V_{EB} and collector-base junction is reversed biased by battery V_{CB}. The positive terminal of the battery V_{EB} repels the holes of the emitter towards the base about 5% of the holes recombine with the electrons of the base. The remaining 95%(approx) of the holes enter the collector region under the reverse bias. As the holes reach the end of the collector region, they attract the electrons from the negative terminal of the battery V_{CB} and combine with them. At the same time covalent bonds are broken in the emitter region, and an equal number of electrons get attracted towards the positive terminal of V_{EB} and holes flow towards the base. Hence Emitter current is sum of base and collector current i.e. $I_E = I_B + I_C$.