# Unit IV Optics

The branch of ~~optics~~ (optics) science which deals with the nature of light, its production & propagation is called physical optics.

Newton proposed corpuscular theory of light.

According to this theory, a luminous body continuously emits tiny, light and elastic particles in all directions.

1.) This theory was capable to explain the phenomenon of reflection and refraction of light but not velocity of light. According to this theory the velocity of light in denser medium is higher than the vel. in rarer medium. which is contrary of Foucault & Michelson's expt.

2.) This theory was not capable to explain the phenomenon of Interference, diffraction & polarisation.

But in 1679 Huygens proposed the wave theory of light. According to this theory, each point in a source of light sends out waves in all directions in a hypothetical medium called ether.

It was capable to explain the phenomenon of interference, diffraction & polarisation.

~~The phenomenon of interference is due to superposition of two light waves in the region of crossover.~~

wave front → is the locus of points having same state of vibration.

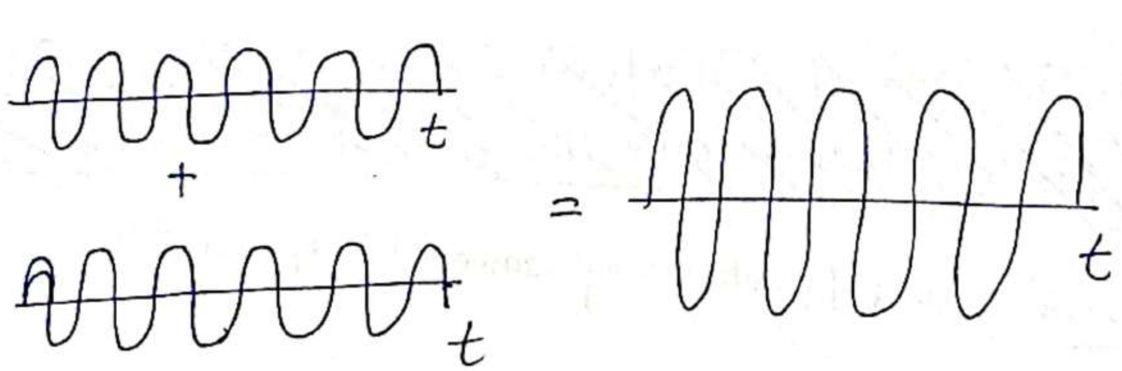
Superposition principle : It states when two or more waves overlap, the resultant displacement at any point and at any time is equal to the individual displacement.

Interference of Light : when two waves of the same freq. and having constt. phase difference travelling along the same direction in the same region of medium are allowed to superimpose over each other, then there is a modification in the intensity of light in the region of superposition. This phenomenon is called the interference of light.

OR

" The modification in the distribution of light energy obtained by the superposition of two or more waves of same freq. & constt phase difference in the region of superposition is called Interference."

When the resultant amplitude at certain points is the sum of the amplitude due to two waves then the interference is known as constructive interference. A stationary bright band of light is observed at the point of constructive interference.




[ fig. (A) ]

Interference is the direct evidence of the wave nature of light.

Thomas Young in 1802 demonstrated the concept of interference of light.

Interference is based on the principle of superposition of waves

e.g. of Interference

multiple colours on soap bubble as well as on thin layer of floating oil when viewed under sun light.

## Principle of Superposition

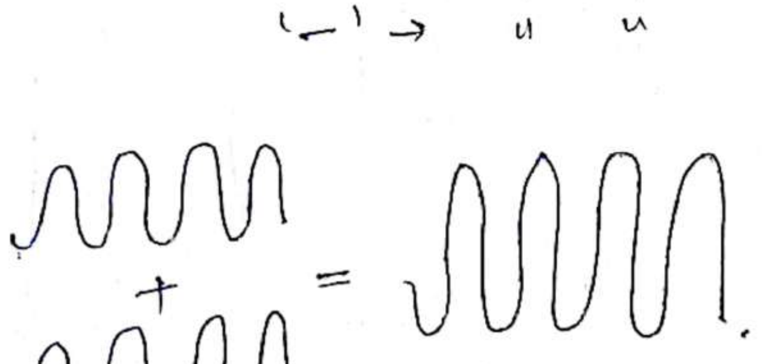
" It states when two or more waves travel simultaneously in a medium, the resultant displacement at any point at any time is equal to the algebraic sum of individual displacement of waves. "

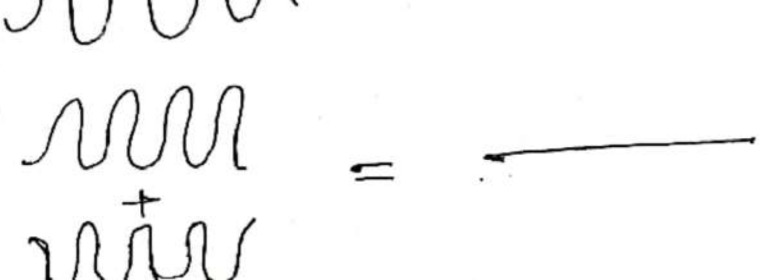
When two waves travel simultaneously in a medium with displacements $y_1$ & $y_2$ resp. then by the principle of superposition the resultant displacement will be

$$y = y_1 \pm y_2$$

'+' → when both displacements $y_1$ & $y_2$ are in same dir.

'−' → " " " " " " " opp. dir.

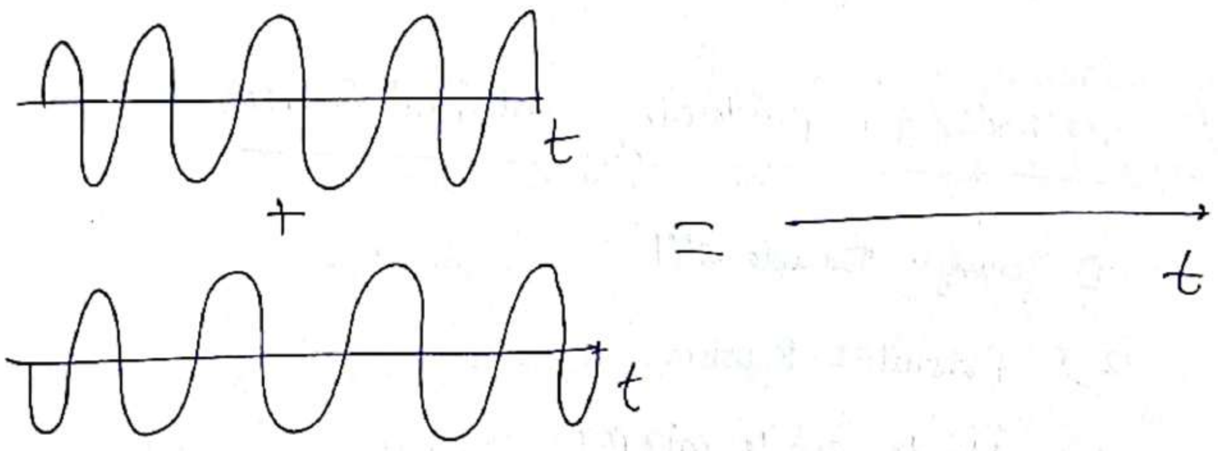




[Principle of Superposition]

When the resultant amplitude at certain points is equal to the difference of two amplitudes the interference is known as the destructive interference.

A dark stationary band of the light is observed at the point of destructive interference.




[fig: (b)]

**for fig A** : resultant amplitude $A_R = A + A = 2A$

resultant intensity $I_R \propto A_R^2 = 2^2 A^2 = 2^2 I$

$\therefore \quad I_R > I + I = 2I$

**for fig. B**

$A_R = A - A = 0$

$I_R \propto A_R^2 = 0^2 = 0$

$\therefore \quad I_R < 2I$.

Coherent Sources :

Two waves are said to be coherent if their waves have

(i) same wavelength
(ii) same amplitude 4
(iii) Constt. phase difference.

only such waves on superposition give rise to interference pattern ie bright & dark fringes.

Incoherent Sources : Two waves of different frequency can never maintain constt. phase difference. They are said to incoherent,

## Coherent Sources :

Two (or more) source of light are said to be coherent if they have a constt. phase difference and they must emit radiations of same wavelength & of same amplitude.

## Incoherent Source :

Two waves of different frequency can never maintain ~~a~~ constt. phase differen- They are said to be incoherent.

## methods for producing Coherent Sources

1) Young's Double slit
2) Fresnel's Biprism
3) Llyod's single mirror

## Types of Inteference

1) Divison of wavefront
2) Division of Amplitude.

**Division of wavefront** : The incident wavefront is divided into two parts by reflection, refraction or diffraction. These two parts of the same wavefront travel unequal distance and reunite* at small angle and produce interference.

Note — It is necessary either to use a point source or a narrow illuminated slit parallel to the intersection of the two wavefronts.

**Division of Amplitude** : The amplitude of the incoming beam is divided into two by a combination of reflection and refraction to be reunited later to produce interference.

Note — In this method it is not essential to employ a point source or a narrow line-source but an extended bright source is invariably used to obtain bright fringe.

e.g. interference in thin film
Newton's ring &
Michelson's Interferometer.

* reunite रीयूनाईट - unite again दोबारा मिलना, जोड़ना

## Essential Conditions for producing interference

1) The two interfering waves must be of same frequency or wavel. i.e they must be coherent; otherwise the phase difference b/ the interfering waves will vary and consequently the position of maximum and minimum intensity will change with time.

2) The interfering waves must have equal amplitude.

3) The seperation b/w two coherent sources must be small since fringe width is inversely proportion to the seperation hence if seperation is not small, then fringe width will be small. As a result of this maximum & min. intensity fringes will be very close to other & they will not be visible seperately.

4). The coherent sources must be narrow.

✓5) The two interfering waves must propage along the same line.

6) If the interfering waves are polarised, they must be in the same state of polarisation.

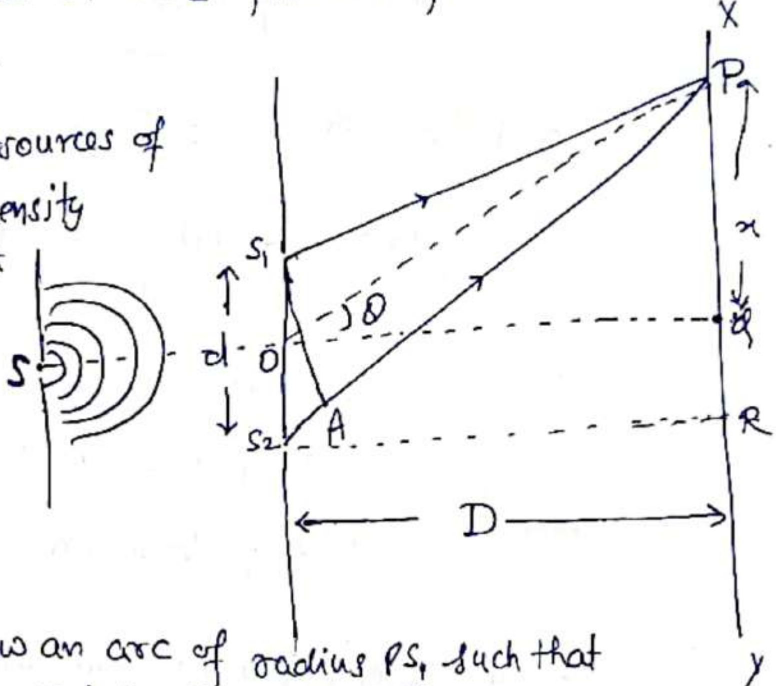
7) The background or screen should be black or dark; If the background is not dark, the min intensity will not appear to be zero; resulting into a poor contrast b/w maxima & minima.

# Young's Double Slit Experiment

The phenomenon of interference was first observed by Thomas Young & he demonstrated it in 1802. He allowed a beam of sunlight to pass through a pin hole S in the dark room and then at some distance away, through two pin-holes $S_1$ & $S_2$ placed very closed to each other & symmetric w.r.t S.

$S_1$ & $S_2$ are two coherent sources of the light of the same intensity

Q be the point on the screen equidistant from $S_1$ & $S_2$. The path difference b/w waves from $S_1$ & $S_2$ reaching Q is zero. Hence Q will be bright.




Let $S_1S_2 = d$

$OQ = D$ and

$PQ = x$

with P as centre draw an arc of radius $PS_1$ such that $S_2A = S_2P - S_1P$ which is the path difference b/w two wave trains starting from $S_1$ & $S_2$ and reaching at P.

from $\Delta S_2RP$; $\quad (S_2P)^2 = (S_2R)^2 + (PR)^2$

$$(S_2P)^2 = D^2 + \left(x + \frac{d}{2}\right)^2$$

$$\& \quad (S_1P)^2 = D^2 + \left(x - \frac{d}{2}\right)^2$$

$$\therefore (S_2P)^2 - (S_1P)^2 = 2xd$$

$$\text{ie } (S_2P + S_1P)(S_2P - S_1P) = 2xd$$

$$\& \quad S_2P - S_1P = \frac{2xd}{2D} = \frac{xd}{D} \qquad \text{where } S_2P + S_1P \approx 2D$$

and phase difference $(\phi) = \frac{2\pi}{d} \times$ path difference

$$\phi = \frac{2\pi}{d} \times \frac{xd}{D}$$

**Bright fringe :** If the path difference is an even multiple of $\lambda/2$ then the point P will be bright

$$\therefore \frac{xd}{D} = 2n\frac{\lambda}{2}$$

$$\boxed{x = \frac{D}{d}\cdot n\lambda}$$

and for $n^{th}$ bright fringe.

$$\boxed{x_n = \frac{D}{d}\cdot n\lambda}$$ when $n = 0, 1, 2, 3 \ldots$

$x_0 = 0$ ; $n = 0$ ( ~~first~~ Central order fringe )

$x_1 = \frac{D}{d}\lambda$ ; $n = 1$ ( ~~Second~~ Ist " " )

$x_2 = \frac{D}{d}\cdot 2\lambda$ ; $n = 2$ ( ~~third~~ IInd " " )

⋮

So the distance b/w two consecutive ~~maxima~~ bright fringe $= \frac{D}{d}\lambda$

**Dark fringe :** If the path difference is an odd multiple of $\lambda/2$ then P will be dark

$$\therefore \frac{xd}{D} = (2n+1)\frac{\lambda}{2}$$

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

for $n^{th}$, $$\boxed{x_n = \frac{D}{d}(2n+1)\frac{\lambda}{2}}$$ when $n = 0, 1, 2, 3 \ldots$

$x_0 = \frac{D}{d}\cdot\frac{\lambda}{2}$ ; $n = 0$ ( Central order fringe )

$x_1 = \frac{3D\lambda}{2d}$ ; $n = 1$ ( ~~second~~ first " " )

$x_2 = \frac{5D}{2d}\cdot\lambda$ , $n = 2$ ( IInd " " )

⋮

So the distance b/w two consecutive fringe $= \frac{D}{d}\lambda$.

thus the distance b/w two successive dark & bright fringe is same, this distance is called fringe width which is indep. of the order of the fringe.

$\therefore$ fringe width $\boxed{\beta = \frac{D}{d}\lambda}$

ie $\beta \propto D$

$\propto \frac{1}{d}$