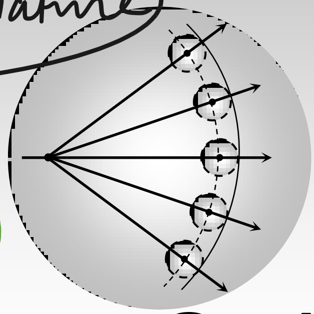
light has dual Nature

some times acts as particle + light act as wave

actully light is a packet of energy.



Wave Optics

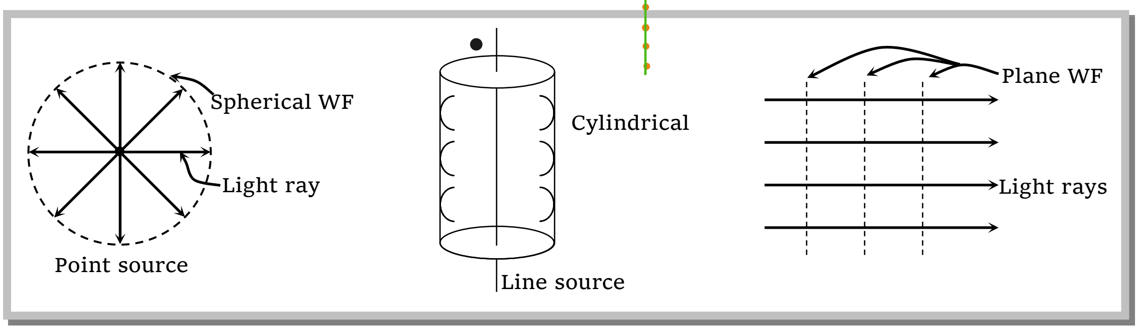
Wave front

(i) Suggested by Huygens

(ii) The locus of all particles in a medium, vibrating in the same phase is called Wave Front (WF)

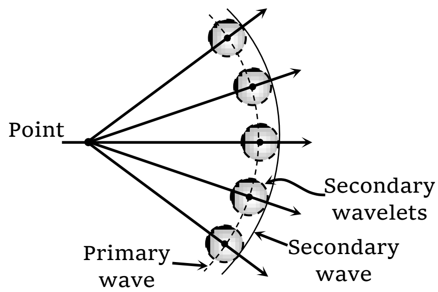
(iii) The direction of propagation of light (ray of light) is perpendicular to the WF.

(iv) **Types of wave front**



(v) Every point on the given wave front acts as a source of new disturbance called secondary wavelets. Which travel in all directions with the velocity of light in the medium.

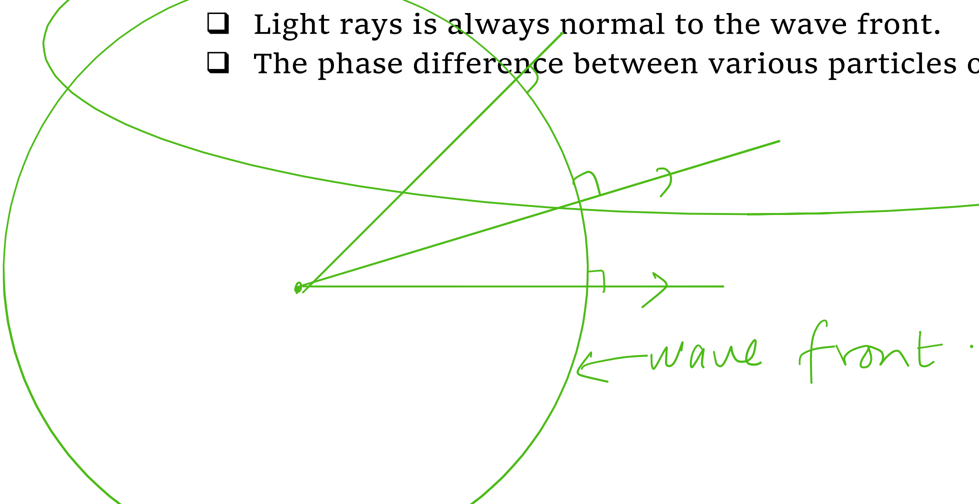
A surface touching these secondary wavelets tangentially in the forward direction at any instant gives the new wave front at that instant. This is called secondary wave front



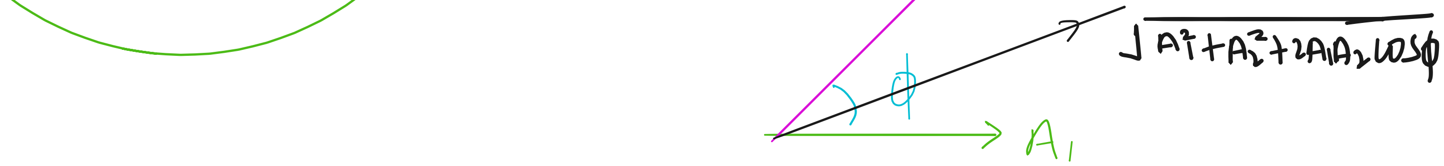
Note : ❑ Wave front always travels in the forward direction of the medium.

❑ Light rays is always normal to the wave front.

❑ The phase difference between various particles on the wave front is zero.



A_2

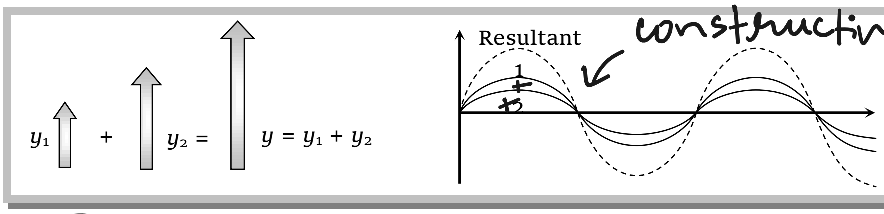


Principle of Super Position

$y_1 = A_1 \sin \omega t$, $y_2 = A_2 \sin(\omega t + \phi)$

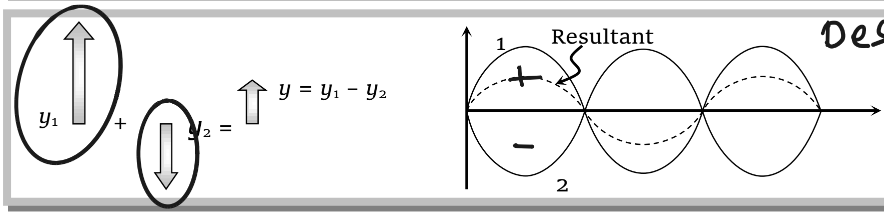
(1) **Graphical view :**

(i) constructive interfarance



Waves are meeting at a point in same phase

(ii) Destructive interfarance.



Waves are meeting at a point with out of phase

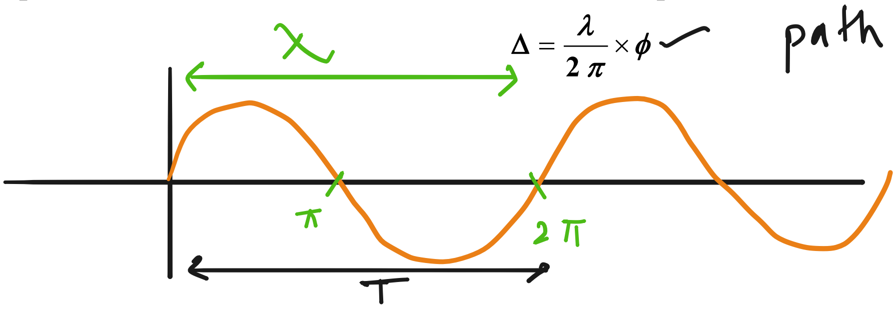
(2) **Phase / Phase difference / Path difference / Time difference**

Phase difference (ϕ) : The difference between the phases of two waves at a point is called phase difference *i.e.* if $y_1 = a_1 \sin \omega t$ and $y_2 = a_2 \sin(\omega t + \phi)$ so phase difference = ϕ

Path difference (Δx) : The difference in path length's of two waves meeting at a point is called path difference between the waves at that point. Also

$\Delta = \frac{\lambda}{2\pi} \times \phi$

path diffrence $= \frac{\lambda}{2\pi} \Delta\phi$



$\Delta x = \frac{\lambda}{2\pi} \Delta \phi$

Path diffrence

phase diffrene

Time difference ($T.D.$) : Time difference between the waves meeting at a point is $T.D. = \frac{T}{2\pi} \times \phi$

$\Delta t = \frac{T}{2\pi} \Delta \phi$

$\Delta t = \frac{T}{2\pi} \Delta x$

(3) **Resultant amplitude and intensity**

If suppose we have two waves $y_1 = a_1 \sin \omega t$ and $y_2 = a_2 \sin(\omega t + \phi)$; where a_1, a_2 = Individual amplitudes, ϕ = Phase difference between the waves at an instant when they are meeting a point. I_1, I_2 = Intensities of individual waves

Resultant amplitude

$$A = \sqrt{a_1^2 + a_2^2 + 2a_1 a_2 \cos \phi}$$

$\Delta \phi = 90^\circ$

For the interfering waves $y_1 = a_1 \sin \omega t$ and $y_2 = a_2 \cos \omega t$, Phase difference between them is 90°. So resultant amplitude $A = \sqrt{a_1^2 + a_2^2}$

Resultant intensity

$(\text{Amplitude})^2 \propto$ Intensity of light

$A_1^2 \propto I_1$, $A_2^2 \propto I_2$, $A_{Net}^2 \propto I_{Net}$

$A \propto \sqrt{I}$

$A_{Net} = \sqrt{A_1^2 + A_2^2 + 2A_1A_2\cos\phi}$

$A_{Net}^2 = A_1^2 + A_2^2 + 2A_1A_2\cos\phi$

$I_{Net} = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos\phi$

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos \phi$$

if phase diffrence is 0°

$I_{Net} = 4I_0 \cos^2 0$

$I_{Net_{max}} = 4I_0$ ← maximum intensity

$\boxed{I_{Net} = I_{max}\cos^2(\phi/2)}$ ← more imp.

$I_{max} = I_1 + I_2 + 2\sqrt{I_1 I_2}$

$I_{max} = (\sqrt{I_1} + \sqrt{I_2})^2$

$I = I_0 + I_0 + 2\sqrt{I_0 \times I_0}\cos\phi$

special case $\boxed{I_1 = I_2 = I_0}$

$I_{Net} = 2I_0 + 2I_0\cos\phi$

$I_{Net} = 2I_0(1 + \cos\phi)$

$\cos 2\theta = 2\cos^2\theta - 1$

$1 + \cos 2\theta = 2\cos^2\theta$

$1 + \cos\phi = 2\cos^2(\frac{\phi}{2})$

$I_{Net} = 2I_0(2\cos^2 \phi/2)$

ϕ is phase diffrence b/w I_1 & I_2

$\boxed{I_{Net} = 4I_0\cos^2(\phi/2)}$

$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$

$\cos 0 = 1$

$\phi = 0, 2\pi, 4\pi \ldots$

$I_{max} = I_1 + I_2 + 2\sqrt{I_1 I_2}$

$I_{max} = (\sqrt{I_1} + \sqrt{I_2})^2$

$\phi = \pi, 3\pi, 5\pi,$

$\cos\pi = -1$

$I_{Net} = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\pi$

$I_{Net} = I_1 + I_2 - 2\sqrt{I_1 I_2}$

$I_{Net} = (\sqrt{I_1} - \sqrt{I_2})^2$

$I_{min} = (\sqrt{I_1} - \sqrt{I_2})^2$

Note : ❑ The term $2\sqrt{I_1 I_2} \cos \phi$ is called interference term. For incoherent interference this term is zero so resultant intensity $I = I_1 + I_2$

$(\text{Amp})^2 \propto I$

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$$\frac{I_{max}}{I_{min}} = \left(\frac{\sqrt{I_1}+\sqrt{I_2}}{\sqrt{I_1}-\sqrt{I_2}}\right) = \left(\frac{A_1+A_2}{A_1-A_2}\right)$$

(4) **Coherent sources**

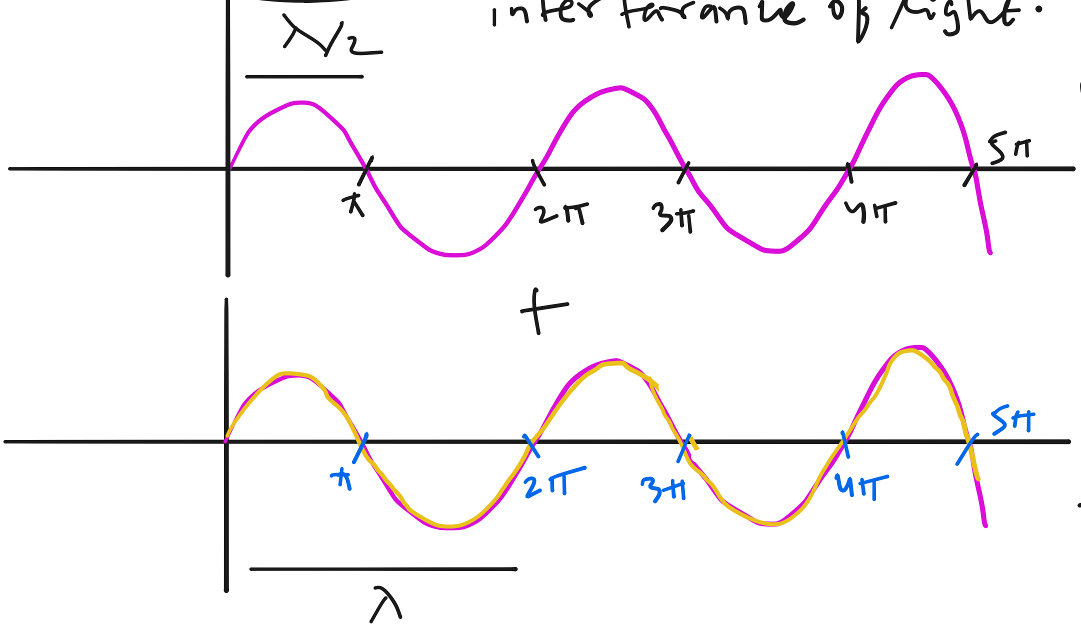
The sources of light which emits continuous light waves of the same wavelength, same frequency and in same phase or having a constant phase difference are called coherent sources. Two coherent sources are produced from a single source of light

Note : ❑ Laser light is highly coherent and monochromatic.

❑ Two sources of light, whose frequencies are not same and phase difference between the waves emitted by them does not remain constant *w.r.t.* time are called non-coherent.

❑ The light emitted by two independent sources (candles, bulbs *etc.*) is non-coherent and interference phenomenon cannot be produced by such two sources.

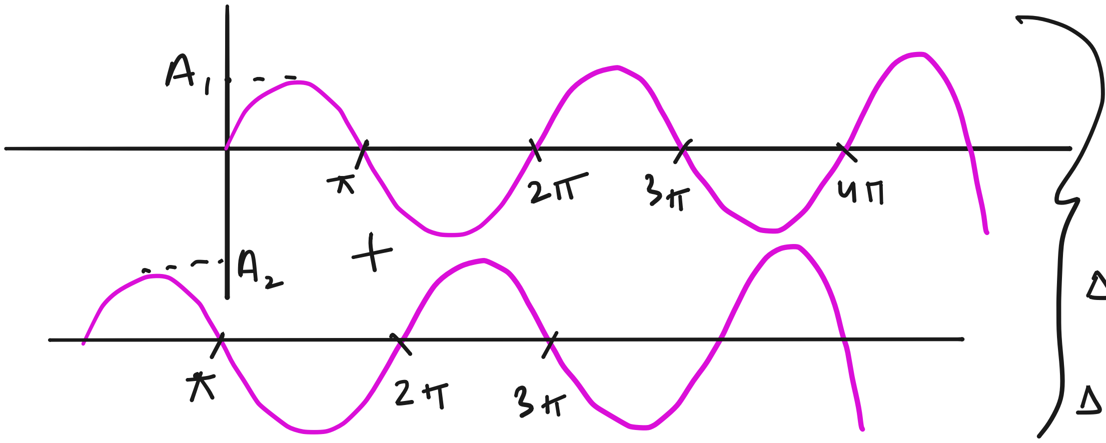
interfarance of light.



constructive interfarance.

$\Delta\phi = 0, 2\pi, 4\pi$ ....

$\Delta x = 0, \lambda, 2\lambda$ ....



distructive interfarce

$\Delta\phi = \pi, 3\pi, 5\pi$

$\Delta x = \frac{\lambda}{2}, \frac{3\lambda}{2}, \frac{5\lambda}{2}$

$\Delta x = (2n-1)\frac{\lambda}{2}$, $\Delta\phi = (2n-1)\pi$

Interference of Light

When two waves of exactly same frequency (coming from two coherent sources) travels in a medium, in the same direction simultaneously then due to their superposition, at some points intensity of light is maximum while at some other points intensity is minimum. This phenomenon is called Interference of light.

Condition For constructive interfarance

$$\Delta\phi = 0, 2\pi, 4\pi, 6\pi \ldots\ldots 2n\pi$$

$$\Delta x = 0, \lambda, 2\lambda, \ldots\ldots n\lambda$$

Conditions for distructive interfarance

$$\Delta\phi = \pi, 3\pi, 5\pi \ldots\ldots (2n-1)\pi$$

$$\Delta x = \frac{\lambda}{2}, \frac{3\lambda}{2}, 5\frac{\lambda}{2} \ldots\ldots (2n-1)\frac{\lambda}{2}$$

(1) **Types :** It is of following two types

Constructive interference	Destructive interference
(i) When the waves meets a point with same phase, constructive interference is obtained at that point (*i.e.* maximum light)	(i) When the wave meets a point with opposite phase, destructive interference is obtained at that point (*i.e.* minimum light)
(ii) Phase difference between the waves at the point of observation $\phi = 0^o$ or $2n\pi$	(ii) $\phi = 180^o$ or $(2n-1)\pi$; n = 1, 2, ... or $(2n+1)\pi$; $n = 0,1,2.....$
(iii) Path difference between the waves at the point of observation $\Delta = n\lambda$ (*i.e.* even multiple of $\lambda/2$)	(iii) $\Delta = (2n-1)\frac{\lambda}{2}$ (*i.e.* odd multiple of $\lambda/2$)
(iv) Resultant amplitude at the point of observation will be maximum $a_1 = a_2 \Rightarrow A_{\min} = 0$ If $a_1 = a_2 = a_0 \Rightarrow A_{\max} = 2a_0$	(iv) Resultant amplitude at the point of observation will be minimum $A_{\min} = a_1 - a_2$ If $a_1 = a_2 \Rightarrow A_{\min} = 0$
(v) Resultant intensity at the point of observation will be maximum $I_{\max} = I_1 + I_2 + 2\sqrt{I_1 I_2}$ $I_{\max} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2$ If $I_1 = I_2 = I_0 \Rightarrow I_{\max} = 2I_0$	(v) Resultant intensity at the point of observation will be minimum $I_{\min} = I_1 + I_2 - 2\sqrt{I_1 I_2}$ $I_{\min} = \left(\sqrt{I_1} - \sqrt{I_2}\right)^2$ If $I_1 = I_2 = I_0 \Rightarrow I_{\min} = 0$

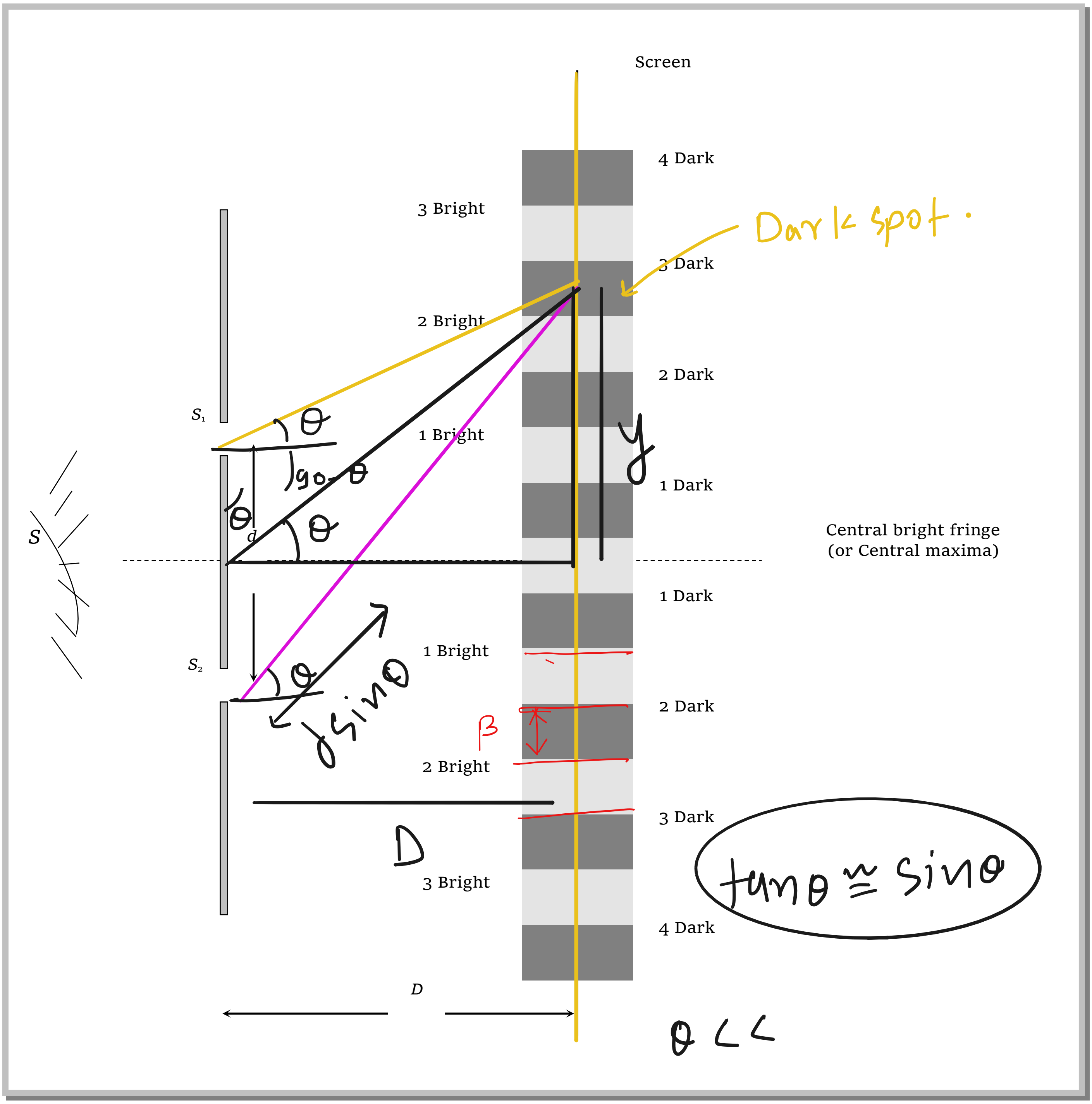
(2) **Resultant intensity due to two identical waves :**

For two coherent sources the resultant intensity is given by $I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$

For identical source $I_1 = I_2 = I_0 \Rightarrow I = I_0 + I_0 + 2\sqrt{I_0 I_0}\cos\phi = 4I_0\cos^2\frac{\phi}{2}$

[1 + $\cos\theta = 2\cos^2\frac{\theta}{2}$]

Young's Double Slit Experiment (YDSE)



Path diffrence

$$\Delta x = d\sin\theta = d\tan\theta = \frac{dy}{D}$$

$$\Delta x = \frac{dy}{D} \text{ — (A)}$$

For constructive interfarance

$$\Delta x = n\lambda, \quad \frac{dy}{D} = n\lambda, \quad y = \frac{n\lambda D}{d}$$

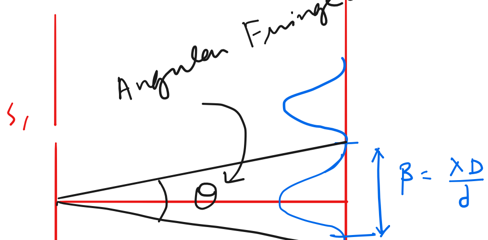
Where y is distance of n^{th} bright spot From centre.

$$\Delta x = \frac{(2n-1)\lambda}{2}$$

$$\frac{dy}{D} = (2n-1)\frac{\lambda}{2}$$

$$y = \frac{(2n-1)\lambda D}{2d}$$

Angular Fringe width



Distance b/w two consecutive bright spot or dark spot know as Fringe width (β)

$$\beta = \frac{2\lambda D}{d} - \frac{\lambda D}{d} = \frac{\lambda D}{d}$$

If we increase D

β (linear Fringe width) will also increase.

distance of n^{th} dark spot From central maxima

S_2

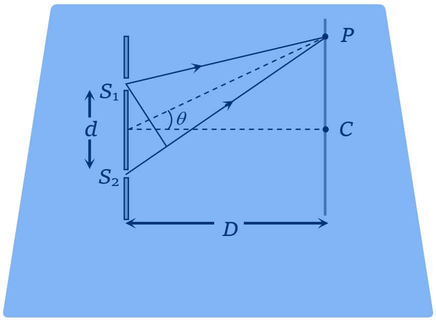
D

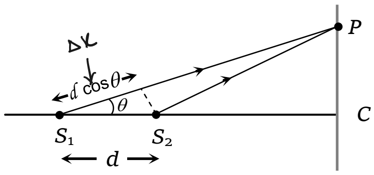
$$\theta = \frac{\text{arc}}{\text{radius}}$$

$$\theta = \frac{\frac{\lambda D}{d}}{D} = \frac{\lambda}{d}$$

Independent From D.

Note : ❑ If the slits are vertical, the path difference (Δ) is $d\sin\theta$, so as θ increases, Δ also increases. But if slits are horizontal path difference is $d\cos\theta$, so as θ increases, Δ decreases.





$$\beta_{water} = \frac{\beta_{air}}{\mu} = \frac{\lambda D}{\mu d}$$

Mead

(7) **More about fringe**

(i) All fringes are of

equal width. Width of each fringe is $\boldsymbol{\beta = \frac{\lambda D}{d}}$ and angular fringe width $\boldsymbol{\theta = \frac{\lambda}{d} = \frac{\beta}{D}}$

(ii) If the whole YDSE set up is taken in another medium then λ changes so β changes

e.g. in water $\lambda_w = \frac{\lambda_a}{\mu_w} \Rightarrow \beta_w = \frac{\beta_a}{\mu_w} = \frac{3}{4}\beta_a$

(iii) Fringe width $\beta \propto \frac{1}{d}$ *i.e.* with increase in separation between the sources, β decreases.

(iv) Position of n^{th} bright fringe from central maxima $\boldsymbol{x_n = \frac{n\lambda D}{d} = n\beta}$**;** $n = 0, 1, 2 ....$

(v) Position of n^{th} dark fringe from central maxima $\boldsymbol{x_n = \frac{(2n-1)\lambda D}{2d} = \frac{(2n-1)\beta}{2}}$**;** $n = 1, 2, 3 ....$

(vi) In YDSE, if n_1 fringes are visible in a field of view with light of wavelength λ_1, while n_2 with light of wavelength λ_2 in the same field, then $\boldsymbol{n_1\lambda_1 = n_2\lambda_2}$.

(vii) Separation (Δx) between fringes

Between n^{th} bright and m^{th} bright fringes $(n > m)$	Between n^{th} bright and m^{th} dark fringe
$\Delta x = (n - m)\beta$	(a) If $n > m$ then $\Delta x = \left(n - m + \frac{1}{2}\right)\beta$ (b) If $n < m$ then $\Delta x = \left(m - n - \frac{1}{2}\right)\beta$

(8) **Identification of central bright fringe**

To identify central bright fringe, monochromatic light is replaced by white light. Due to overlapping central maxima will be white with red edges. On the other side of it we shall get a few coloured band and then uniform illumination.

(9) **Condition for observing sustained interference**

(i) The initial phase difference between the interfering waves must remain constant : Otherwise the interference will not be sustained.

(ii) The frequency and wavelengths of two waves should be equal : If not the phase difference will not remain constant and so the interference will not be sustained.

(iii) The light must be monochromatic : This eliminates overlapping of patterns as each wavelength corresponds to one interference pattern.

(iv) The amplitudes of the waves must be equal : This improves contrast with $I_{\max} = 4I_0$ and $I_{\min} = 0$.

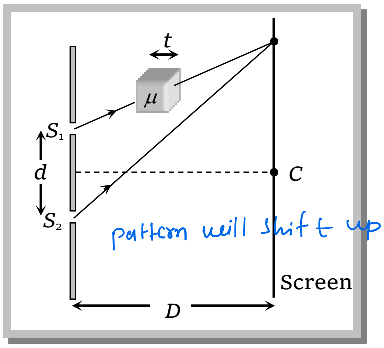
(v) The sources must be close to each other : Otherwise due to small fringe width $\left(\beta \propto \frac{1}{d}\right)$ the eye can not resolve fringes resulting in uniform illumination.

$$\frac{(\mu-1)tD}{d} = \Delta y \text{ shift in spot}$$

(10) **Shifting of fringe pattern in YDSE**

If a transparent thin film of mica or glass is put in the path of one of the waves, then the whole fringe pattern gets shifted.

If film is put in the path of upper wave, fringe pattern shifts upward and if film is placed in the path of lower wave, pattern shift downward.



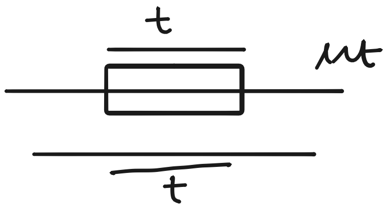
$$\text{Fringe shift} = \frac{D}{d}(\mu-1)t = \frac{\beta}{\lambda}(\mu-1)t$$

⇒ Additional path difference $=(\mu-1)t$

⇒ If shift is equivalent to n fringes then $n = \dfrac{(\mu-1)t}{\lambda}$ or $t = \dfrac{n\lambda}{(\mu-1)}$

⇒ Shift is independent of the order of fringe (*i.e.* shift of zero order maxima = shift of n^{th} order maxima.

⇒ Shift is independent of wavelength.



path difference

extra path

$\mu t - t$, $t(\mu-1) = \Delta x$ extra path diff.

(11) **Fringe visibility (*V*)**

With the help of visibility, knowledge about coherence, fringe contrast an interference pattern is obtained.

$V = \dfrac{I_{max} - I_{min}}{I_{max} + I_{min}} = 2\dfrac{\sqrt{I_1 I_2}}{(I_1 + I_2)}$ If $I_{min} = 0$, $V = 1$ (maximum) *i.e.*, fringe visibility will be best.

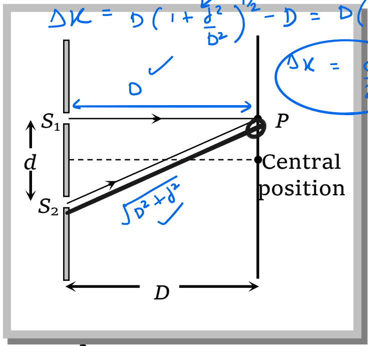
Also if $I_{max} = 0, V = -1$ and If $I_{max} = I_{min}, V = 0$

$\Delta x = (D^2+d^2)^{1/2} - D$

$\Delta x = D\left(1+\frac{d^2}{D^2}\right)^{1/2} - D = D\left(1+\frac{1}{2}\frac{d^2}{D^2}\right) - D$

$\Delta x = \frac{d^2}{2D}$

(12) **Missing wavelength in front of one of the slits in YDSE**



From figure $S_2P = \sqrt{D^2+d^2}$ and $S_1P = D$

So the path difference between the waves reaching at P

$$\Delta = S_2P - S_1P = \sqrt{D^2+d^2} - D = D\left(1+\frac{d^2}{D^2}\right)^{1/2} - D$$

From binomial expansion $\Delta = D\left(1+\frac{1}{2}\frac{d^2}{D^2}\right) - D = \frac{d^2}{2D}$

For Dark at P $\Delta = \frac{d^2}{2D} = \frac{(2n-1)\lambda}{2}$ $\Rightarrow$ Missing wavelength at P $\lambda = \frac{d^2}{(2n-1)D}$

By putting $n = 1, 2, 3 \ldots.$ Missing wavelengths are $\lambda = \frac{d^2}{D}, \frac{d^2}{3D}, \frac{d^2}{5D} \ldots.$

Suppose we get distructive interfarance at P.

$$\Delta x = \frac{d^2}{\cancel{2}D} = (2n-1)\frac{\lambda}{\cancel{2}}$$

$$\lambda = \frac{d^2}{(2n-1)D}$$

$n = 1, 2, 3, \ldots\ldots$

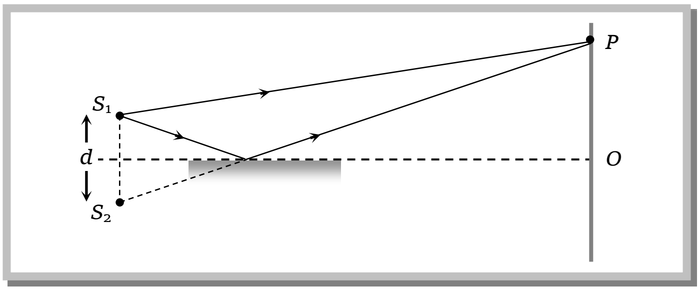
problem solving ir will take 2 Qustions

Interference in reflected light	**Interference in refracted light**
Condition of constructive interference (maximum intensity) $\Delta = 2\mu\, t\cos r = (2n \pm 1)\frac{\lambda}{2}$ For normal incidence $r = 0$ so $2\mu t = (2n \pm 1)\frac{\lambda}{2}$	Condition of constructive interference (maximum intensity) $\Delta = 2\mu t\cos r = (2n)\frac{\lambda}{2}$ For normal incidence $2\mu t = n\lambda$
Condition of destructive interference (minimum intensity) $\Delta = 2\mu t\cos r = (2n)\frac{\lambda}{2}$ For normal incidence $2\mu t = n\lambda$	Condition of destructive interference (minimum intensity) $\Delta = 2\mu t\cos r = (2n \pm 1)\frac{\lambda}{2}$ For normal incidence $2\mu t = (2n \pm 1)\frac{\lambda}{2}$

Note : ❑ The Thickness of the film for interference in visible light is of the order of $10,000\,\mathring{A}$.

IIT students

(2) **Lloyd's Mirror**



exchange conditions of constructive & distructive interfarce

$y = \frac{n\lambda D}{d}$ n^{th} dark spot from centre.

$y = \frac{(2n-1)\lambda D}{2d}$ n^{th} bright spot.

Real NEET

Concepts

- *The angular thickness of fringe width is defined as* $\delta = \frac{\beta}{D} = \frac{\lambda}{d}$, *which is independent of the screen distance D.*
- *Central maxima means the maxima formed with zero optical path difference. It may be formed anywhere on the screen.*
- *All the wavelengths produce their central maxima at the same position.*
- *The wave with smaller wavelength from its maxima before the wave with longer wavelength.*
- *The first maxima of violet colour is closest and that for the red colour is farthest.*
- *Fringes with blue light are thicker than those for red light.*
- *In an interference pattern, whatever energy disappears at the minimum, appears at the maximum.*
- *In YDSE, the nth maxima always comes before the nth minima.*
- *In YDSE, the ratio* $\frac{I_{\max}}{I_{\min}}$ *is maximum when both the sources have same intensity.*
- *For two interfering waves if initial phase difference between them is* ϕ_0 *and phase difference due to path difference between them is* ϕ'. *Then total phase difference will be* $\boldsymbol{\phi = \phi_0 + \phi' = \phi_0 + \frac{2\pi}{\lambda}\Delta}$.
- *Sometimes maximm number of maximas or minimas are asked in the question which can be obtained on the screen. For this we use the fact that value of sin* θ *(or* cos θ*) can't be greater than 1. For example in the first case when the slits are vertical*

  $\sin\theta = \frac{n\lambda}{d}$ *(for maximum intensity)*

  $\because \quad \sin\theta \not> 1 \quad \therefore \quad \frac{n\lambda}{d} \not> 1 \quad$ *or* $\quad n \not> \frac{d}{\lambda}$

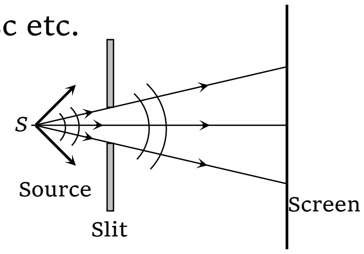
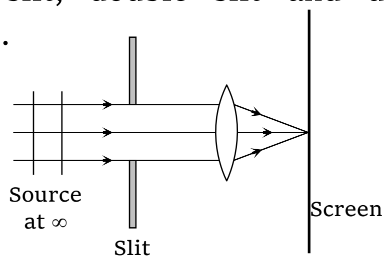
  Suppose in some question d/λ *comes out say 4.6, then total number of maximuas on the screen will be 9. Corresponding to* $n = 0, \pm 1, \pm 2, \pm 3$ *and* ± 4.

Diffraction of Light

Note :

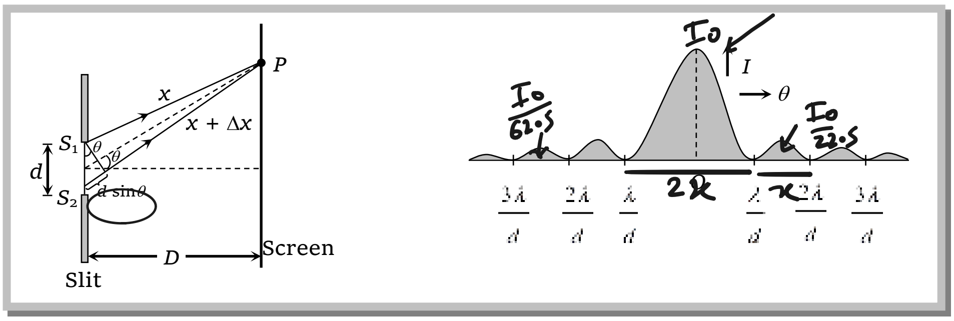
- Diffraction is the characteristic of all types of waves.
- Greater the wavelength of wave, higher will be it's degree of diffraction.
- Experimental study of diffraction was extended by Newton as well as Young. Most systematic study carried out by Huygens on the basis of wave theory.
- The minimum distance at which the observer should be from the obstacle to observe the diffraction of light of wavelength λ around the obstacle of size d is given by $x = \frac{d^2}{4\lambda}$.

(1) **Types of diffraction :** The diffraction phenomenon is divided into two types

Fresnel diffraction	**Fraunhofer diffraction**
(i) If either source or screen or both are at finite distance from the diffracting device (obstacle or aperture), the diffraction is called Fresnel type.	(i) In this case both source and screen are effectively at infinite distance from the diffracting device.
(ii) Common examples : Diffraction at a straight edge, narrow wire or small opaque disc etc. 	(ii) Common examples : Diffraction at single slit, double slit and diffraction grating. 

here also inter change
maxima & minima.

(2) **Diffraction of light at a single slit**



(i) Width of central maxima $\beta_0 = \frac{2\lambda D}{d}$; and angular width $= \frac{2\lambda}{d}$

(ii) Minima occurs at a point on either side of the central maxima, such that the path difference between the waves from the two ends of the aperture is given by $\Delta = n\lambda$; where $n = 1, 2, 3 ....$

i.e. $d \sin\theta = n\lambda \Rightarrow \sin\theta = \frac{n\lambda}{d}$

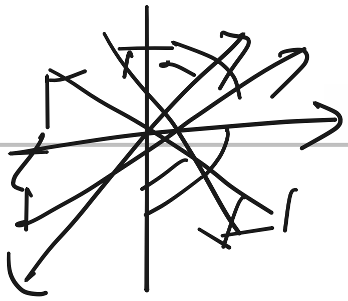
(iii) The secondary maxima occurs, where the path difference between the waves from the two ends of the aperture is given by $\Delta = (2n+1)\frac{\lambda}{2}$; where $n = 1, 2, 3 ....$

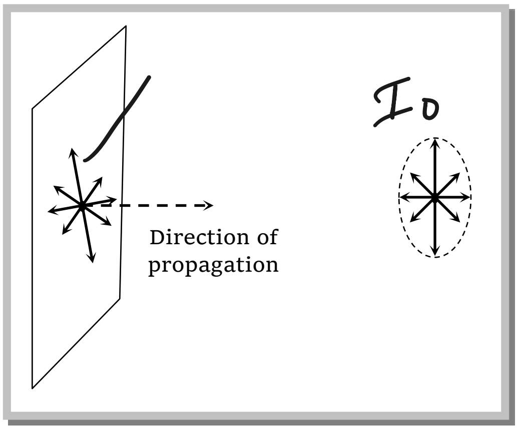
i.e. $d \sin\theta = (2n+1)\frac{\lambda}{2} \Rightarrow \sin\theta = \frac{(2n+1)\lambda}{2d}$

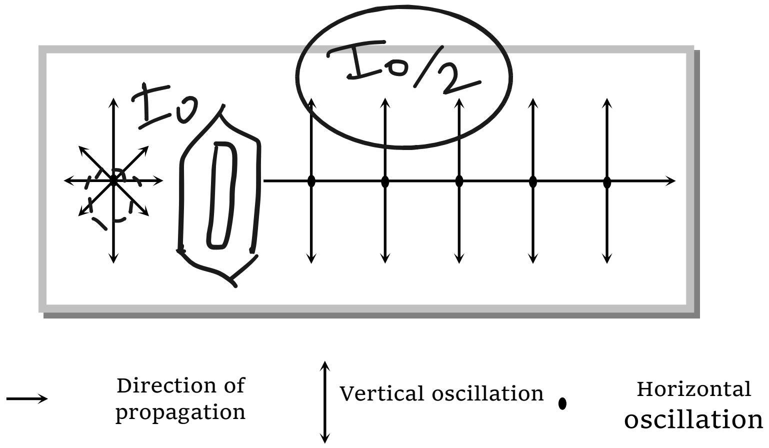
(3) **Comparison between interference and diffraction**

Interference	Diffraction
Results due to the superposition of waves from two coherrent sources.	Results due to the superposition of wavelets from different parts of same wave front. (single coherent source)
All fringes are of same width $\beta = \frac{\lambda D}{d}$	All secondary fringes are of same width but the central maximum is of double the width $\beta_0 = 2\beta = 2\frac{\lambda D}{d}$
All fringes are of same intensity	Intensity decreases as the order of maximum increases.
Intensity of all minimum may be zero	Intensity of minima is not zero.
Positions of *n*th maxima and minima $x_{n(\text{Bright})} = \frac{n\lambda D}{d}$, $x_{n(\text{Dark})} = (2n-1)\frac{\lambda D}{d}$	Positions of *n*th secondary maxima and minima $x_{n(\text{Bright})} = (2n+1)\frac{\lambda D}{d}$, $x_{n(\text{Dark})} = \frac{n\lambda D}{d}$
Path difference for *n*th maxima $\Delta = n\lambda$	for *n*th secondary maxima $\Delta = (2n+1)\frac{\lambda}{2}$
Path difference for *n*th minima $\Delta = (2n-1)\lambda$	Path difference for *n*th minima $\Delta = n\lambda$

Polarisation of Light





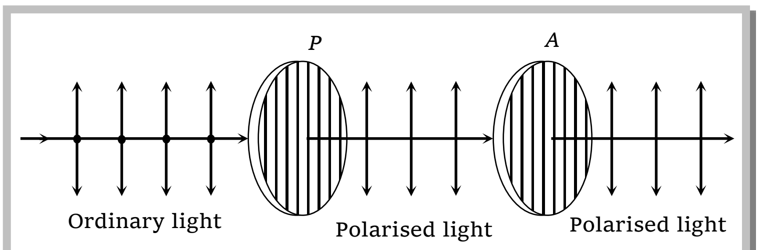


Malus law

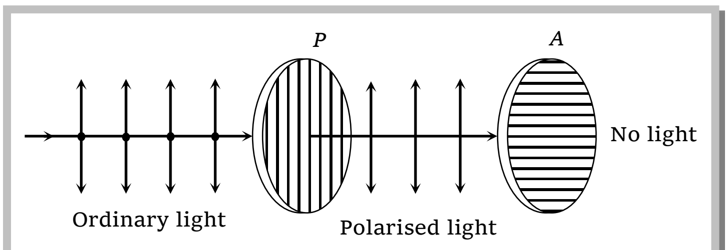
$$(\cos^2\phi)_{av} = \frac{1}{2}$$

$$I_{out} = I_0\langle\cos^2\phi\rangle$$

$$I_{out} = \frac{I_0}{2}$$



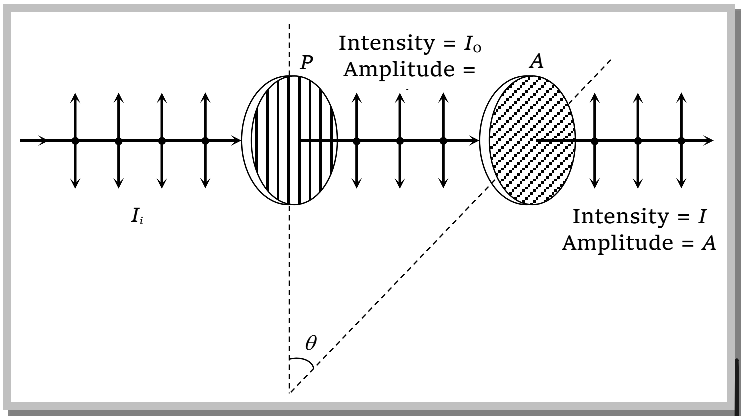
Transmission axes of the polariser and analyser are parallel to each other, so whole of the polarised light passes through analyser

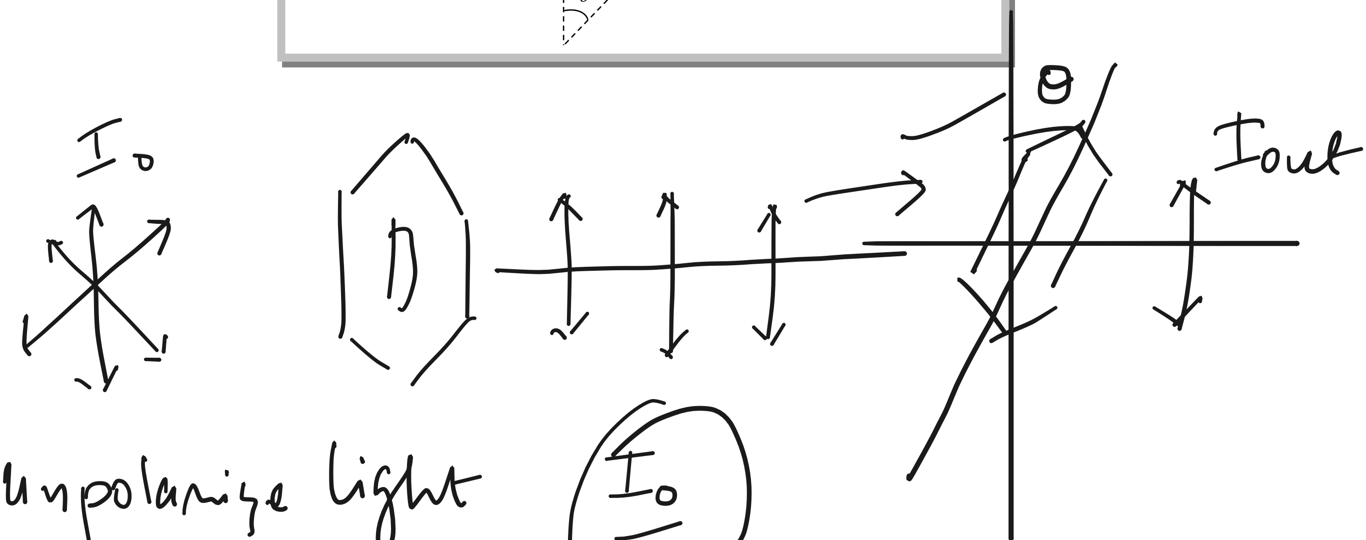


Transmission axis of the analyser is perpendicular to the polariser, hence no light passes through the analyser

(4) **Malus law**

This law states that the intensity of the polarised light transmitted through the analyser varies as the square of the cosine of the angle between the plane of transmission of the analyser and the plane of the polariser.





Unpolarize light

$\frac{I_0}{2}$

IIT mains V.IMP.

$$I_{out} = I_{in} \cos^2\theta$$

$$I_{out} = \frac{I_0}{2} \cos^2\theta$$

Note : ❑ Percentage of polarisation $= \dfrac{(I_{max} - I_{min})}{(I_{max} + I_{min})} \times 100$

(5) **Brewster's law :** Brewster discovered that when a beam of unpolarised light is reflected from a transparent medium (refractive index $=\mu$), the reflected light is completely plane polarised at a certain angle of incidence (called the angle of polarisation θ_p).

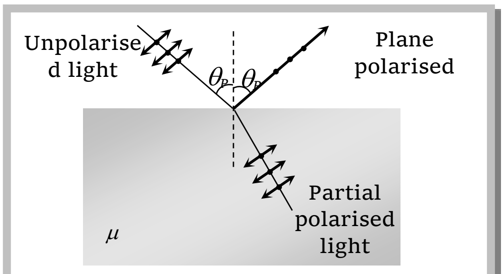
Also $\mu = \tan\theta_p$ Brewster's law

$\mu = \tan i_p$

(i) For $i < \theta_P$ or $i > \theta_P$

Both reflected and refracted rays becomes partially polarised

(ii) For glass $\theta_P \approx 57^o$, for water $\theta_P \approx 53^o$



Polarisation by

$i = \tan^{-1}(\mu)$

(6) **Optical activity and specific rotation**

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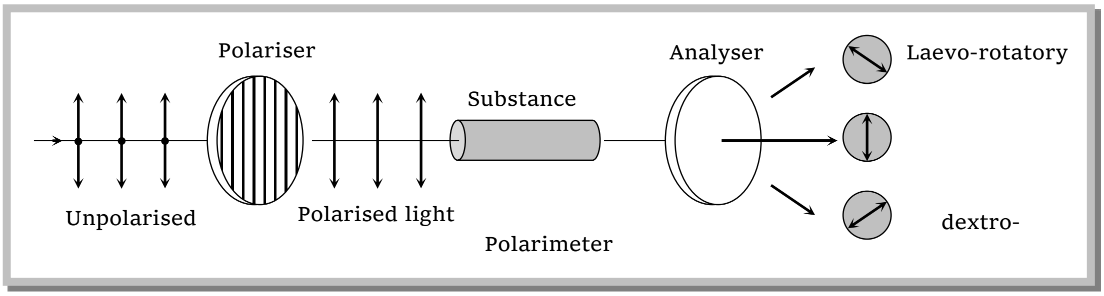

Polarimeter

(7) **Applications and uses of polarisation**

(i) By determining the polarising angle and using Brewster's law, *i.e.* $\mu = \tan\theta_P$, refractive index of dark transparent substance can be determined.

(ii) It is used to reduce glare.

(iii) In calculators and watches, numbers and letters are formed by liquid crystals through polarisation of light called liquid crystal display **(LCD)**.

(iv) In CD player polarised laser beam acts as needle for producing sound from compact disc which is an encoded digital format.

(v) It has also been used in recording and reproducing three-dimensional pictures.

(vi) Polarisation of scattered sunlight is used for navigation in solar-compass in polar regions.

(vii) Polarised light is used in optical stress analysis known as 'photoelasticity'.

(viii) Polarisation is also used to study asymmetries in molecules and crystals through the phenomenon of 'optical activity'.