10. WAVE OPTICS

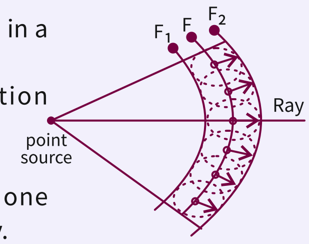
Huygen's Wave Theory

According to Huygen each point in the primary wavefront acts as secondary source and emits secondary wavelets in all directions.

Wavefront

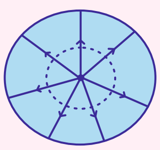
The locus of all points which are in same phase in a wave is called wavefront.

- The energy of wave travels in a direction perpendicular to wavefront.
- Rays are perpendicular to wavefront.
- The time taken by light to travel from one wavefront to another is the same along any ray.



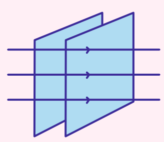
Types of wavefronts

Spherical wavefront



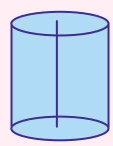
Due to point Source of light

Plane wavefront



Due to point source at large distance

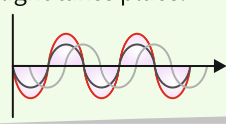
Cylindrical wavefront



Due to line Source of Light

INTERFERENCE

Interference is a phenomenon of superposition of two coherent waves through which redistribution of intensity of light takes place.



Mathematical Interpretation Of Interference Of Two Waves

Let a_1 and a_2 be amplitudes of the waves and ϕ the phase difference between them.

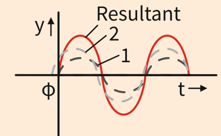
Then $y_1 = a_1 \sin \omega t$;

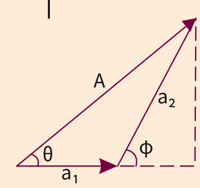
$y_2 = a_2 \sin(\omega t + \theta)$;

$Y = y_1 + y_2 = A \sin(\omega t + \theta)$;

$A = \sqrt{a_1^2 + a_2^2 + 2a_1a_2 \cos\theta}$

$\tan\theta = \dfrac{a_2 \sin\theta}{a_1 + a_2 \cos\theta}$

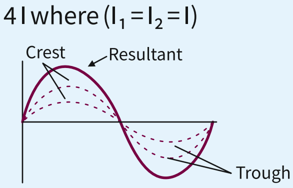




Types of Interfrence

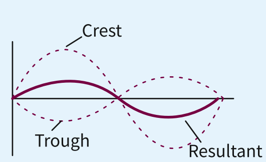
Constructive Interference

- Phase difference $\rightarrow (\Delta\varphi) = 2n\pi$; $n = 0,1,2,\ldots$
- Path difference $\rightarrow \Delta X = 2n\left|\dfrac{\lambda}{2}\right|$
- Resultant Amplitude $\rightarrow A = a_1 + a_2$; if $\varphi = 0, 2\pi, 4\pi \ldots\ldots\ldots 2n\pi$
- Resultant Intersity $\rightarrow$
  $I_{max} = I_1 + I_2 + 2\sqrt{I_1 I_2}$
  $= (\sqrt{I_1} + \sqrt{I_2})^2$
- $I_{max} = 4I$ where $(I_1 = I_2 = I)$



Destructive Interference

- Phase difference $\rightarrow \Delta(\varphi) = (2n-1)\pi$, Where $n = 1, 2, 3, \ldots$
- Path difference $\rightarrow \Delta x = (2n-1)\dfrac{\lambda}{2}$
- Resultant Amplitude $\rightarrow A = a_1 - a_2$;
  If $\varphi = \pi, 3\pi, 5\pi \ldots\ldots (2n-1)\pi$
- Resultant Intersity $\rightarrow I_{max} = I_1 + I_2 - 2\sqrt{I_1 I_2}$
  $= (\sqrt{I_1} - \sqrt{I_2})^2$
- $I_{min} = 0$ (When $I_1 = I_2 = I$)



Young's Double Slit Experiment

(i) For Bright Fringes

$S_2P - S_1P = n\lambda$; d = slit width

$X_n = \dfrac{n\lambda D}{d}$

X_n = Distance between Central Fringe and n^{th} Bright fringe;

λ = wavelength; Bright fringes are also called maxima's.

(ii) For Dark Fringes

$S_2P - S_1P = \dfrac{(2n-1)\lambda D}{2d}$

$\Rightarrow Xn = \dfrac{(2n-1)\lambda D}{2d}$

X_n = Distance between central bright and nth dark fringe

= Dark fringes are also called minima's

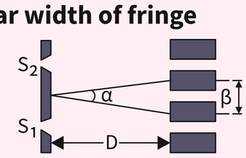
Fringe Width

Fringe width of dark & bright fringes are same and given by

$\beta = X_n - X_{n-r} = \dfrac{\lambda D}{d}$

Angular width of fringe

$\alpha = \dfrac{\beta}{d} = \dfrac{\lambda}{d}$

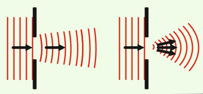


DIFFRACTION

Bending of light waves around the sharp edges of opaque obstacles or aperture and their encroachment in the geometrical shadow of obstacles or aperture.

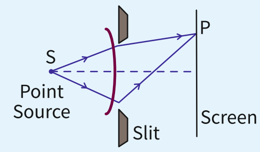
Necessary Condition:- Size of obstacle (a) must be the order of wavelength

(λ).i.e $\frac{a}{\lambda} > 1$

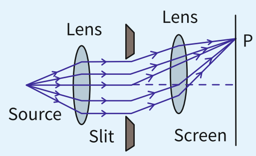


Types of Diffraction

Fresenel Diffraction:- Fresnel Diffraction involves spherical wavefronts, So that Source 's' and Point 'P' are at finite distance.



Fraunhofer Diffraction:- It deals with plane wavefronts and an effective viewing distance of infinity.



Fraunhofer Diffraction for Single Slit

In this diffraction Pattern Central maxima is bright on the both side of it, maxima & minima occurs symmetrically.

(i) Position of Secondary Maxima in diffraction

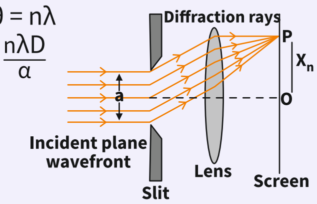
$\alpha \text{ Sin } \theta = (2n + 1)\ \frac{\lambda}{2}$

$X_n = \frac{(2n+1)}{2a}\lambda$

(ii) Position of Secondary Minima in diffraction:-

$\alpha \text{ Sin } \theta = n\lambda$

$\Rightarrow X_n = \frac{n\lambda D}{\alpha}$



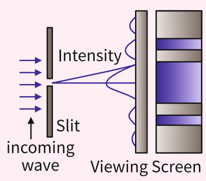
Width of Central Maximum

The distance between two secondary minima formed on two sides of Central maximum is known as width of Central maximum.

$W = \frac{2f\lambda}{\alpha}$

f = Focal length of Convex lenses

α = Slit width



Resolving Power (R.P)

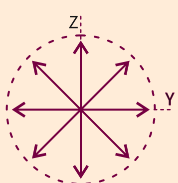
Resolving Power an optical instrument is its ability to distinguish two closely placed objects.

POLARISATION

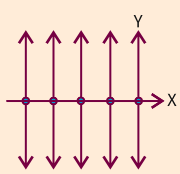
The Process of Confining the vibrations of unpolarised light in one single plane using polariser is called polarisation.

Unpolarised light

An ordinary beam of light whose electric field vectors vibrates in all possible plane.



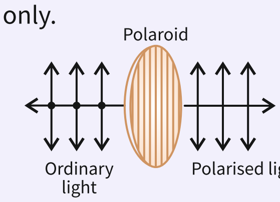
unpolarised light moving along x axis



unpolarised light

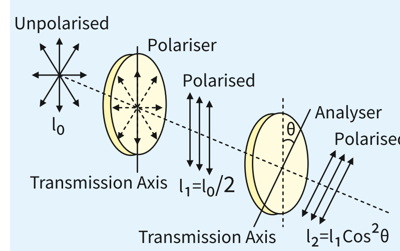
Plane Polarised light

Beam of light in which Vibration of Electric field Vector are perpendicular to wave motion and Confined to Single plane only.



MALUS' LAW

$I_2 = I_1 \text{Cos}^2\theta$



BREWSTER'S LAW

This Law state that when light is incident on a transparent sustenance at polarising angle QP, the reflected light is completely plane polarised.

$\mu = \tan\theta_P$; θ_P = Polarising angle.

μ = Refractive Index of medium