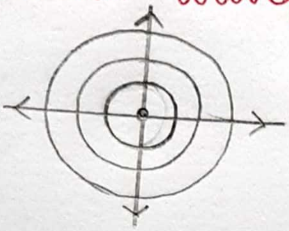
WAVE OPTICS

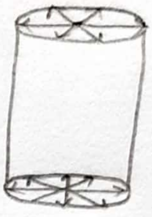
Wave Front - A wavefront is the locus of points having the same phase of oscillations. A wavelet is the point of disturbance due to propagation of light

TYPES OF WAVEFRONT

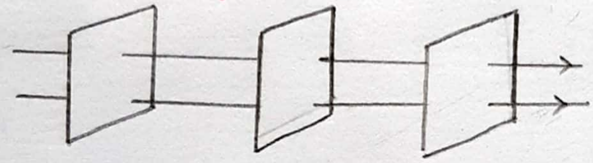
1. Spherical wavefront -



2. Cylindrical wavefront -



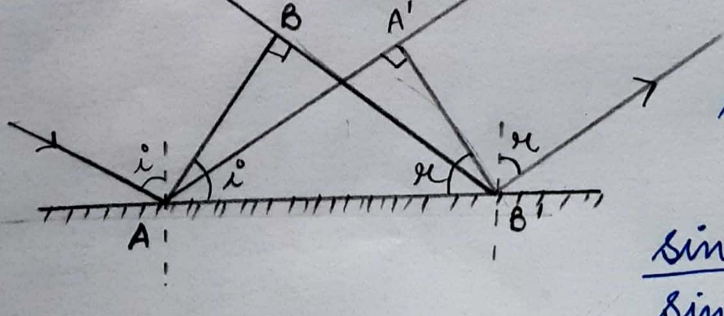
3. Plane wavefront -



HUYGEN'S PRINCIPLE-

According to Huygen, each point on the wavefront acts as a secondary disturbance and to generate secondary wavelet tangents are drawn from primary wavelet and a common line touching the tangent will form a secondary wavelet.

LAWS OF REFLECTION -



AB → incident wavefront
A'B' → reflected wavefront

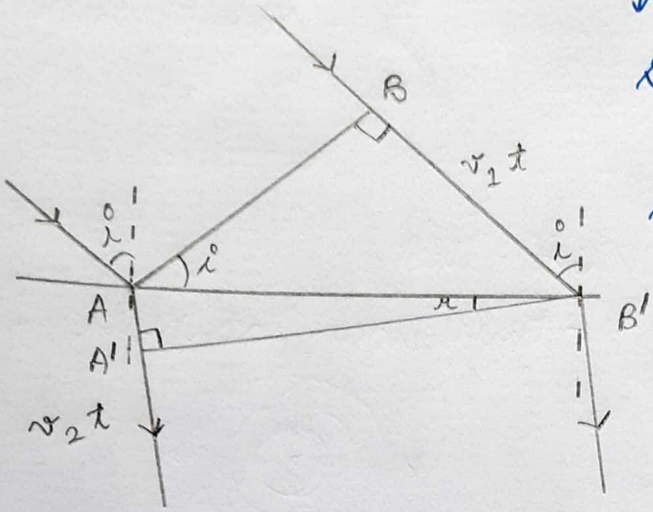
In $\Delta ABB'$ and $\Delta AB'A'$

$$\sin i = \frac{BB'}{AB'} \qquad \sin r = \frac{AA'}{AB'}$$

$$\frac{\sin i}{\sin r} = \frac{BB'}{AA'} = \frac{ct}{ct} \qquad \sin i = \sin$$

$$\boxed{i = r}$$

LAWS OF REFRACTION -



In $\Delta ABB'$ and $\Delta AA'B'$

$$\sin i = \frac{BB'}{AB'} \qquad \sin r = \frac{AA'}{AB'}$$

$$\sin i = \frac{v_1 t}{AB'} \qquad \sin r = \frac{v_2 t}{AB'}$$

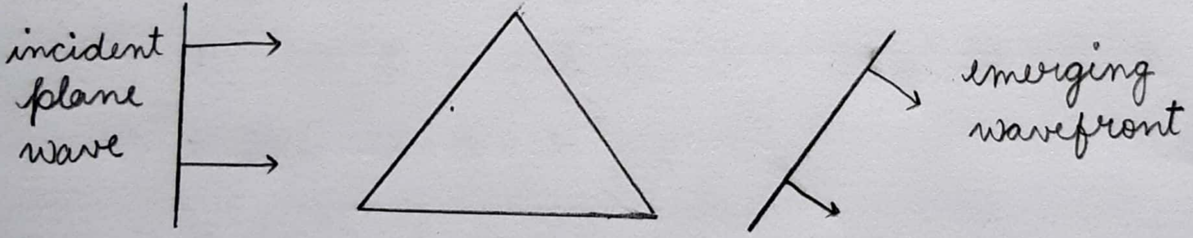
$$\frac{\sin i}{\sin r} = \frac{v_1}{v_2} \rightarrow \text{constant}$$

AB → incident wave
A'B' → refracted wave

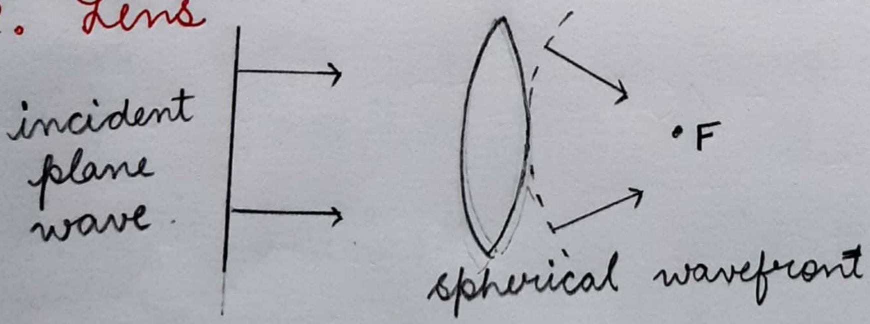
$$\therefore \frac{\sin i}{\sin r} = {}_1n_2$$

BEHAVIOUR OF PRISM, LENS AND SPHERICAL MIRROR TOWARDS WAVEFRONT

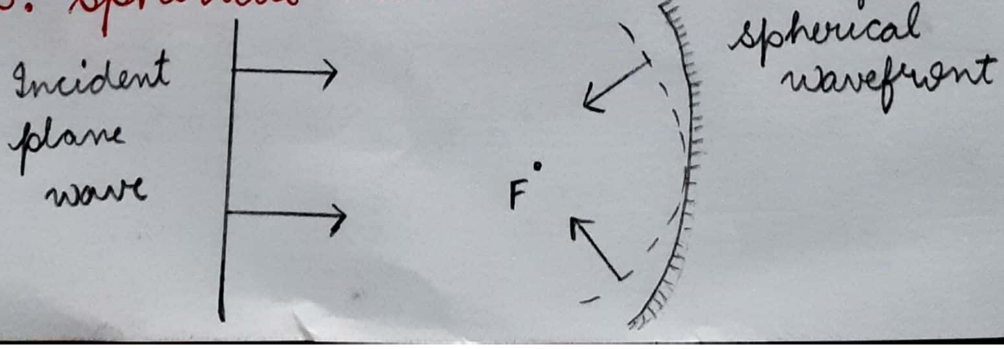
1. Prism



2. Lens



3. Spherical Mirror



PRINCIPLE OF SUPERPOSITION

$Y = \overline{y_1} + \overline{y_2}$

vector sum

$y_1 = a \sin \omega t$

$y_2 = b \sin(\omega t + \phi)$

$Y = \overline{y_1} + \overline{y_2}$

$= a \sin \omega t + b \sin(\omega t + \phi)$

$Y = a \sin \omega t + b [\sin \omega t \cos \phi + \cos \omega t \sin \phi]$

$Y = \sin \omega t [a + b \cos \phi] + \cos \omega t \sin \phi$

$a + b \cos \phi = R \cos \theta$ —— ① $\sin \phi = R \sin \theta$ —— ②

$Y = R \sin \omega t \cos \theta + R \cos \omega t \sin \theta$

$Y = R \sin(\omega t + \theta)$ $R \rightarrow$ amplitude $\theta \rightarrow$ phase diff.

Squaring and adding

$(a + b \cos \phi)^2 + (\sin \phi)^2 = R^2$

$a^2 + b^2 \cos^2 \phi + 2ab \cos \phi + b^2 \sin^2 \phi = R^2$

$a^2 + 2ab \cos \phi + b^2 = R$

$R = \sqrt{a^2 + b^2 + 2ab \cos \phi}$

$R_{max.}$, $\cos \phi = 1$

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

$R_{max.} = \sqrt{(a+b)^2}$

$R_{max.} = (a+b)$

$R_{min.}$, $\cos \phi = -1$

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

$R_{min.} = \sqrt{(a-b)^2}$

$R_{min.} = (a-b)$

Intensity $\propto$ amplitude^2

$I_1 \propto a^2$ $I_2 \propto b^2$ $I_R \propto R^2$

$I_1 = K a^2$ $I_2 = K b^2$ $I_R = K R^2$

$$I_R = K(a^2 + b^2 + 2ab\cos\phi)$$

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

$I_{max.} = (\sqrt{I_1} + \sqrt{I_2})^2$ → constructive interference

$I_{min.} = (\sqrt{I_1} - \sqrt{I_2})^2$ → destructive interference

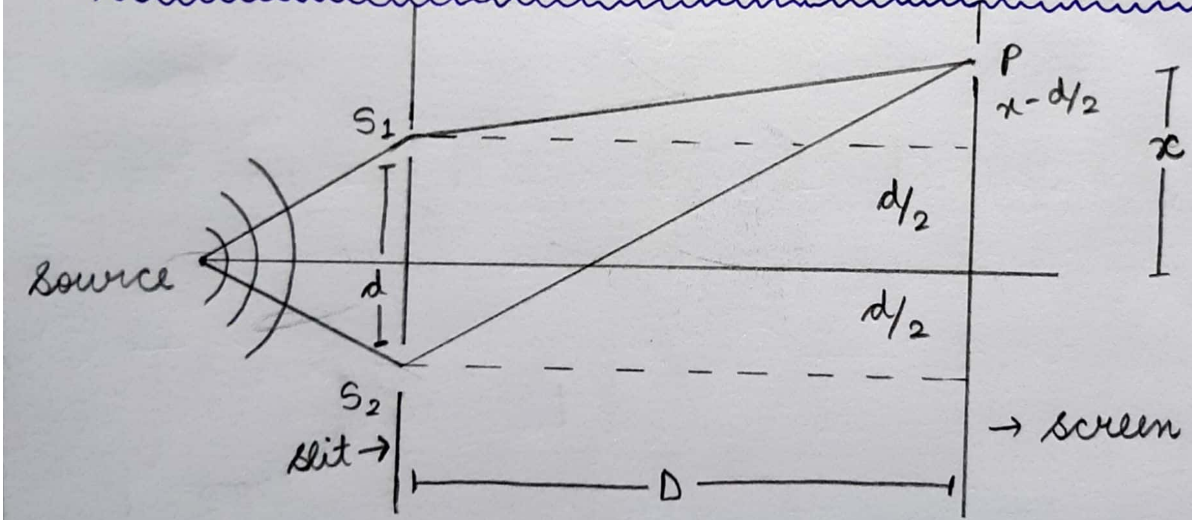
INTERFERENCE OF LIGHT

Redistribution of light energy from two coherent sources superimposing at a point.

Coherent Sources -

→ Same frequency → zero / constant phase differenc

YOUNG'S DOUBLE SLIT EXPERIMENT



In young's double slit experiment,

(i) Fringe width of bright and dark fringe

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

where, λ = wavelength of wave

D = distance between slit and screen

d = distance between two slits

$$\boxed{\text{Angular fringe, width } \theta = \frac{\beta}{D} = \frac{\lambda}{d}}$$

(ii) Separation of nth order bright fringe from central fringe

$$y_n = \frac{Dn\lambda}{d} \quad \text{where, } n = 1, 2, 3\ldots$$

(iii) Separation of nth order dark fringe from central fringe

$$y_n = (2n-1)\frac{D\lambda}{2d}, \quad \text{where } n = 1,2,3\ldots$$

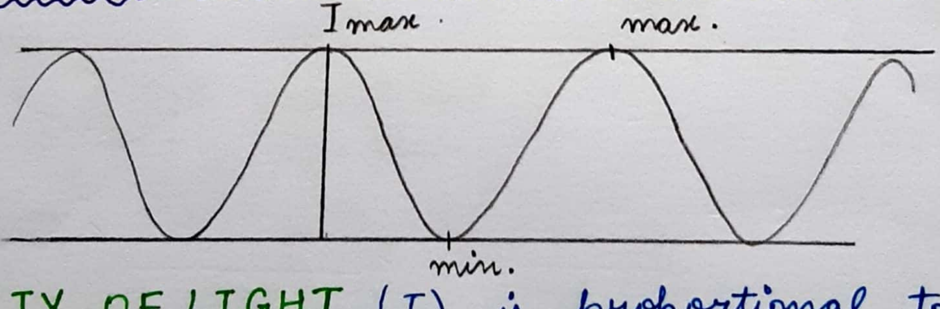
(iv) Angular position of nth order

(a.) Bright fringe $= \frac{y_n}{D} = \frac{n\lambda}{d}$

(b.) Dark fringe $= \frac{y_n}{D} = (2n-1)\frac{\lambda}{d}$ where, $n = 1,2,3\ldots$

(v) Fringe width decreases, when whole apparatus is taken from air to a denser medium, due to the decrease in wavelength of the light.

DISTRIBUTION OF INTENSITY



- **INTENSITY OF LIGHT** (I) is proportional to the width (d) of slit and ratio of slit-width (a)

$$\frac{d_1}{d_2} = \frac{I_1}{I_2} = \frac{a_1^2}{a_2^2}$$

- Ratio of max.^m and min.^m intensity of light

$$\frac{I_{max.}}{I_{min.}} = \frac{(a_1+a_2)^2}{(a_1-a_2)^2} = \left(\frac{r+1}{r-1}\right)^2$$

where, $r = \frac{a_1}{a_2} = \sqrt{\frac{I_1}{I_2}}$

FRINGE WIDTH

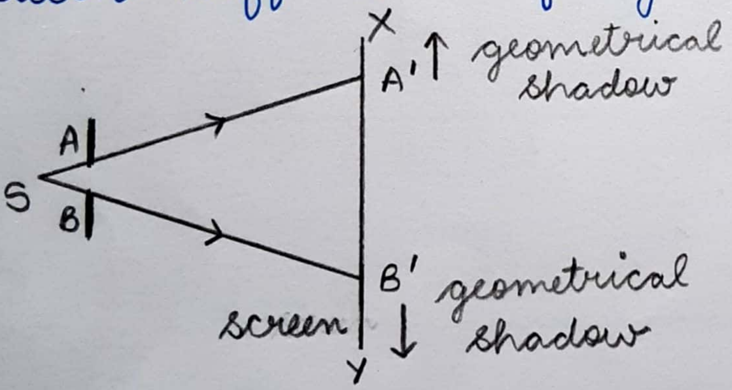
The difference between two consecutive dark and bright fringes.

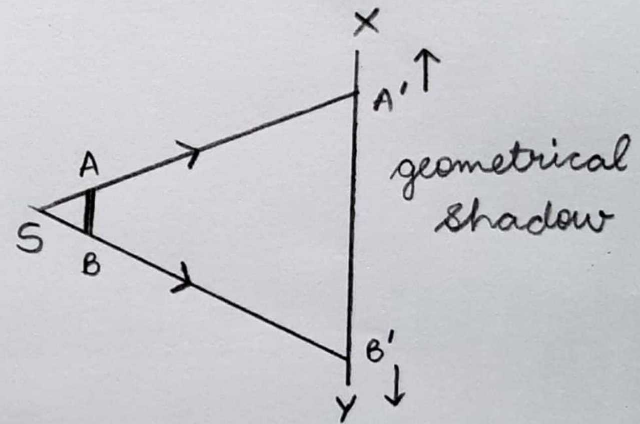
Conditions for interfernce -

1. Sources must be coherrent.
2. Distance between slit and screen should be large.
3. Distance between slits must be small.

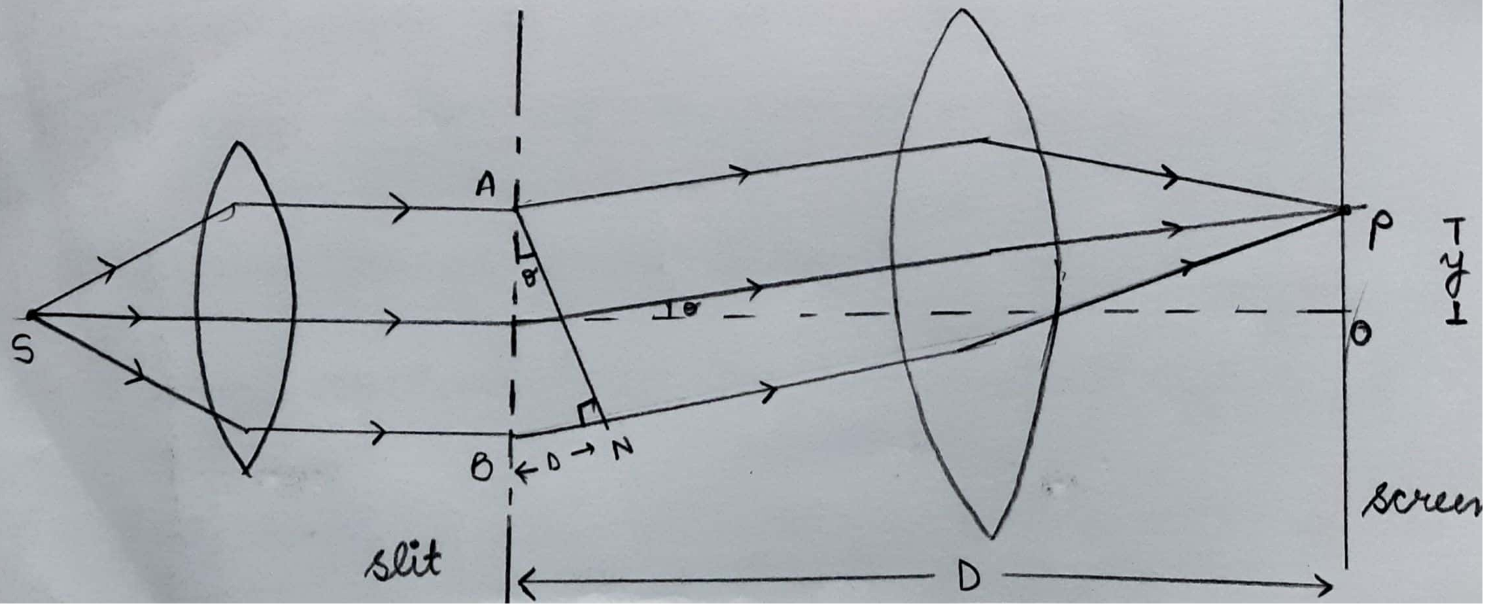
DIFFRACTION OF LIGHT

The phenomenon of bending of light around the sharp corners and the spreading of light within the geometrical shadow of the opaque obstacles is called diffraction of light.





YOUNG'S SINGLE SLIT



$$\cos(90-\theta) = \frac{B}{a}$$

$$B = a\sin\theta$$

For minima

$a\sin\theta = n\lambda \quad n = 1, 2, 3 \ldots$

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

$n = 1 \quad \theta_1 = \frac{\lambda}{a}$

$n = 2 \quad \theta_2 = \frac{2\lambda}{a}$

For maxima

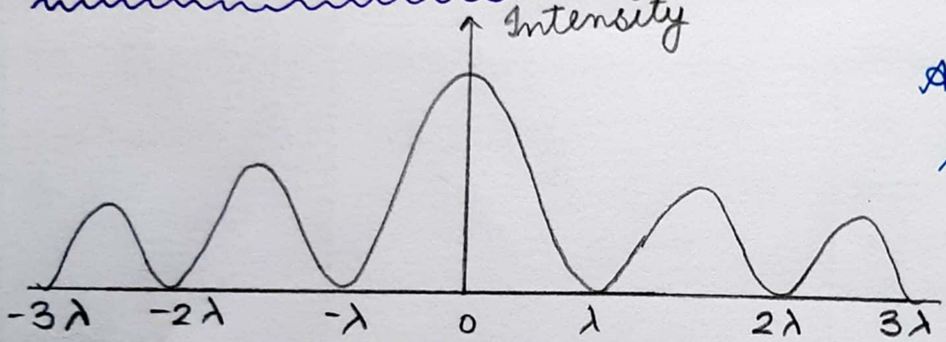
$$a\sin\theta = (2n+1)\frac{\lambda}{2}$$

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

$n = 1 \quad \theta_1 = \frac{3\lambda}{2a}$

$n = 2 \quad \theta_2 = \frac{5\lambda}{2a}$

CENTRAL MAXIMA



Angular width of central maxima

RESOLVING POWER OF OPIICAL INSTRUMENTS

Resolving power of an optical instrument is the ability of the instrument to produce distinctly separate images of two close objects.

(i) Resolving power of microscope $= \frac{1}{\Delta d} = \frac{2\mu\sin\beta}{\lambda}$

(ii) Resolving power of a telescope $= \frac{1}{d\theta} = \frac{D}{1.22\lambda}$

$d\theta$ = angle subtended by the two distinct objects of objective

β = half angle of cone of light   D = diameter of the objective

DIFFERENCE BETWEEN INTERFERENCE PATTERN AND THE DIFFACTION PATTERN

CHARACTERISTICS	INTERFERENCE	DIFFRACTION
FRINGE WIDTH	All bright and dark fringes are of equal width.	The central bright fringe have got double width to that of width of secondary maxima or minima
INTENSITY OF BRIGHT FRINGES	All bright fringes are of same intensity.	Central fringe is the brightest and intensity of secondary maxima, decreases with the increase of order of secondary maxima on either side of central maxima.

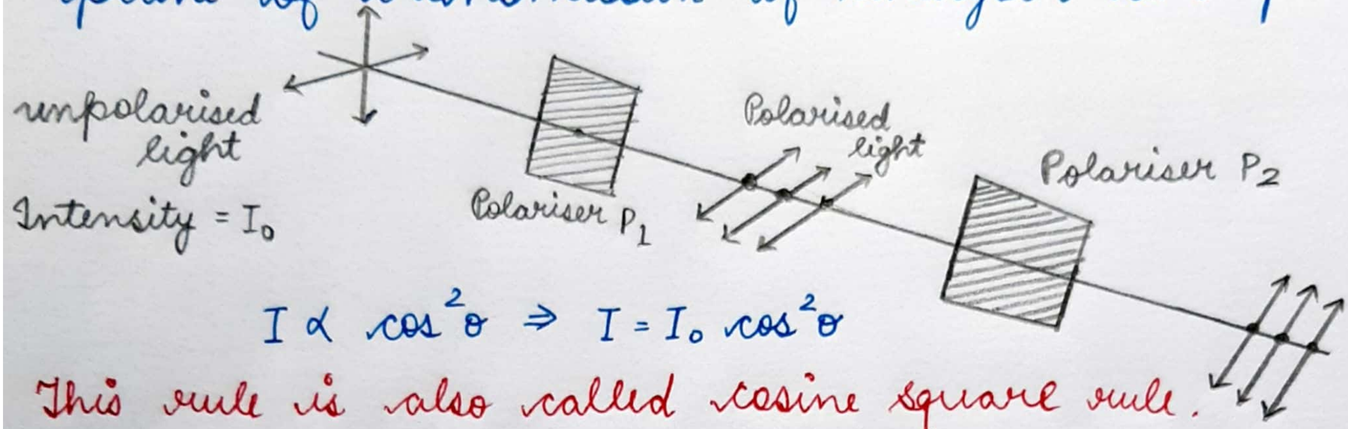
POLARISATION

The phenomenon of restricting the vibrations of light in a particular direction, perpendicular to the direction of wave motion is called polarisation of light. Polarisation ensures the transverse nature of light.

- **Polarisers** - A device that plane - polarises the unpolarised light passed through it is called a polariser. Example - Crystal, nicol prism, polaroid. Tourmaline.

MALUS LAW

According to law of Malus, when a beam of completely plane polarised light is incident on an analyser, the resultant intensity of light (I) transmitted from the analyser varies directly as the square of the cosine of the angle θ between the plane of transmission of analyser and polariser.



$$I \propto \cos^2\theta \Rightarrow I = I_0 \cos^2\theta$$

This rule is also called cosine square rule.

where, I_0 = intensity of plane polarised light after passing through P_1.

BREWSTER'S ANGLE

(i) The angle of incidence at which the reflected light is completely plane polarised is called polarising angle or Brewster's angle (i_B)

(ii) According to this law, when unpolarised light is incident at polarising angle, i_B on an interface separating air from a medium of refractive index μ, then the reflected light is plane polarised, provide

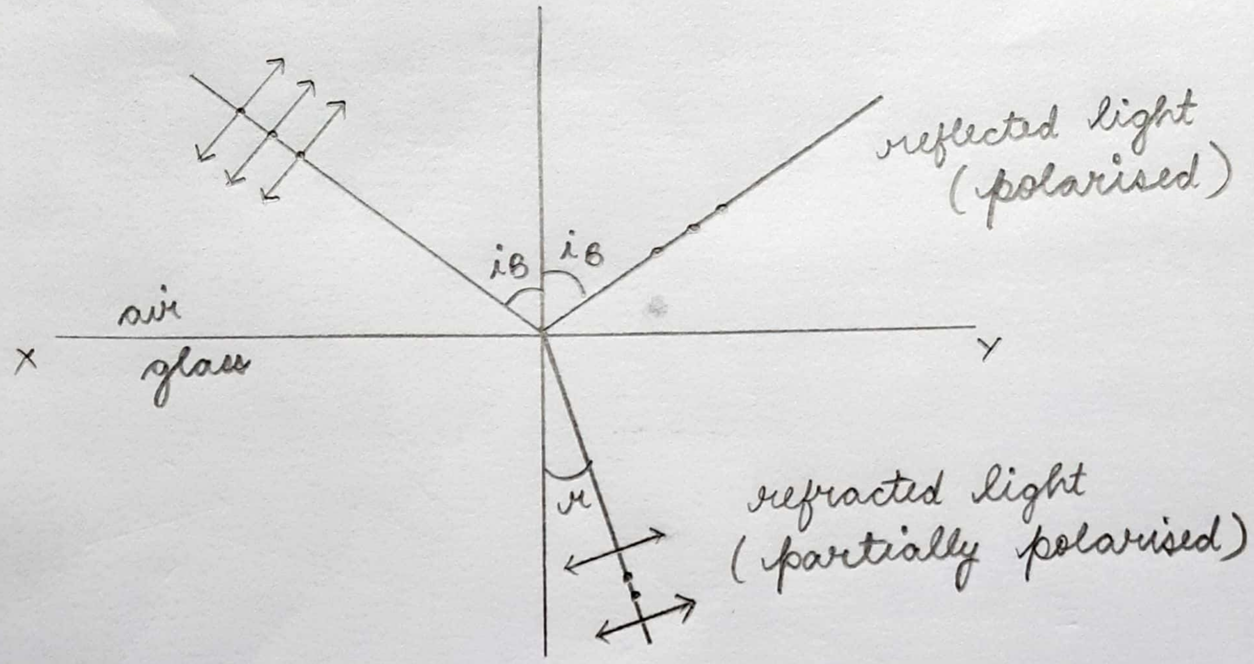
$\mu = \tan i_B$

where, i_B = Brewster's angle μ = refractive index

$i_B + r = 90^\circ$.

From Snell's law,

$$\boxed{\mu = \frac{\sin i_B}{\sin r_B} = \frac{\sin i_B}{\sin(90 - i_B)} = \frac{\sin i_B}{\cos i_B} = \tan i_B}$$



POLAROIDS

Polaroids are the commercial devices to produce plane polarised light making use of selective absorption. Polaroids are used in sunglasses, wind screen, window panes of aeroplane and to make images vivid and clear.

Modes of production of plane polarised light -

(i) Reflection (Brewster's law)
(ii) Scattering
(iii) Double refraction (calcite)
(iv) Selective absorption (dichroism)