Unit-6

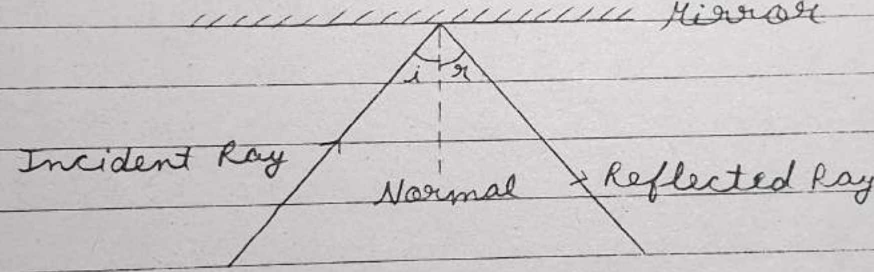
Optics

Reflection (b)

OPTICS is branch of physics which deals with study of phenomenon related to light.

Reflection is the phenomenon of bouncing back of light after striking through any surface

Laws →
- The incident ray, reflected ray and normal to the surface lies in same medium.
- The angle of incidence and angle of reflection are equal i.e., $\angle i = \angle r$.



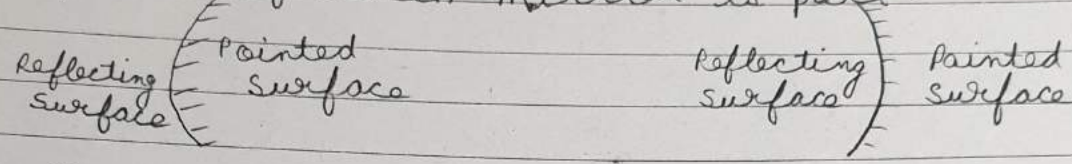
Limitation of law of reflection → when the surface is not plane surface, in that case angle of incidence will not equal to the angle of reflection.

Types of mirror →
- ★ Plane mirror
- ★ Spherical mirror

Spherical mirror is the part of hollow sphere whose one side is reflecting and other side is opaque.

It is of two types →

- Concave mirror is mirror whose reflecting surface is towards the center of sphere of which mirror is part.
- Convex mirror is mirror whose reflecting surface is away from centre of sphere of which mirror is part.



convex mirror   concave mirror

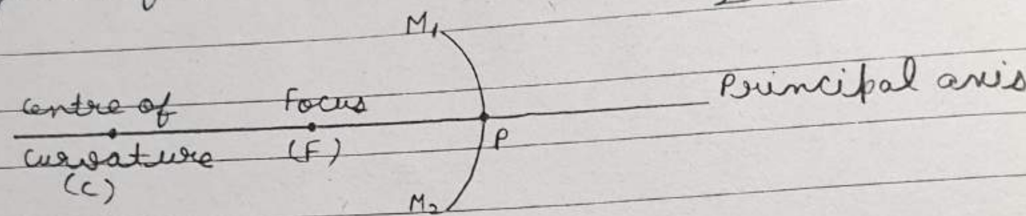
☆ Radius of curvature is radius of sphere of which mirror is a part (It also acts as normal)
☆ Centre of curvature (c) of mirror is centre of the sphere of which mirror forms a part.
☆ Pole / Vertex is middle point or centre of spherical mirror. It is denoted by P.
☆ Normal is line joining that point to centre of curvature C of the mirror.
☆ Aperature is diameter $M_1 M_2$ of spherical mirror
☆ Angular Aperture is the angle $M_1 C M_2$ subtended at C by the diameter of spherical mirror.
☆ Principal axis is straight line joining the pole and centre of curvature of spherical mirror extended on both side.
☆ Principal section is a section of spherical mirror cut by a plane passing through pole and centre of curvature of the mirror
☆ Principal focus is the point on the principal axis of mirror at which ray incident on mirror in a direction parallel to principal

axis actually meet or meet to diverge after reflection from the mirror.

Note 1. Image formed by a plane mirror placed at an angle θ to each other

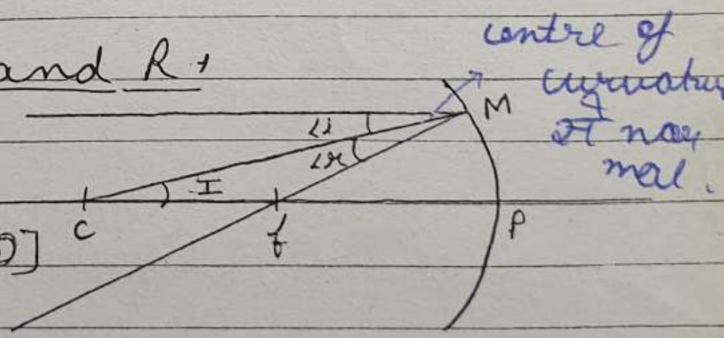
$n = \frac{360°}{\theta} - 1$ if $\frac{360°}{\theta}$ is even $\quad n = \frac{360°}{\theta}$ if $\frac{360°}{\theta}$ is odd

- height of mirror = $\frac{\text{height of object}}{2}$



Object Position	Image Position	Size	Nature of image
At infinity	Focus (F)	Point Size	Real
Beyond C	Between F and C	Small	Real and Inverted
At C	At C	Same	Real and Inverted
Between C and F	Behind C	Enlarged	Real and Inverted
At F	At infinity	Highly Enlarged	Real and Inverted
Between F and P	Behind mirror	Enlarged	Virtual and Erect

Relation between f and R:



$\angle i = \angle I$ — (1)

$\angle i = \angle r$ — (2)

$\angle I = \angle r$ [From (1) & (2)]

$\therefore\ Cf = fM$

When apparture is small

$fM = fP$ — (4)

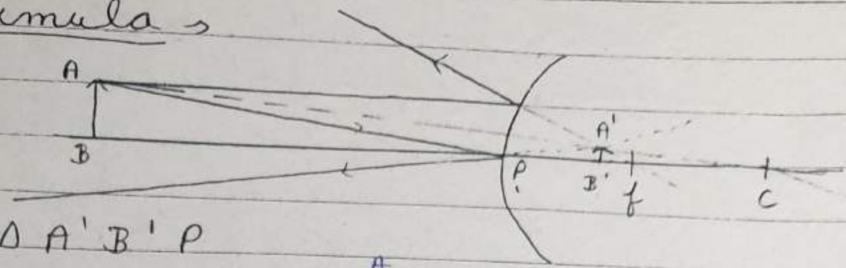
$Cf = fP$ [From (4)]

$Cf = fP$

$2f = R$

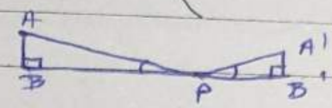
$f = \frac{R}{2}$

Mirror Formula :-



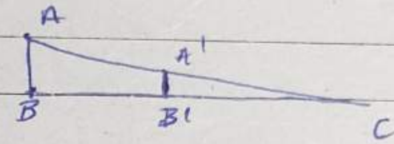
$\Delta ABP \sim \Delta A'B'P$

$$\frac{AB}{A'B'} = \frac{BP}{B'P} \quad \text{—(1)}$$



$\Delta ABC \sim \Delta A'B'C$

$$\frac{AB}{A'B'} = \frac{BC}{B'C} \quad \text{—(2)}$$



From (1) & (2)

$$\frac{BP}{B'P} = \frac{BC}{B'C}$$

$$\frac{-u}{v} = \frac{-u+R}{R-v}$$

$$-uR + uv = -uv + vR$$

$$2uv = uR + vR$$

Dividing by uvR

$$\frac{2}{R} = \frac{1}{v} + \frac{1}{u}$$

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$$

Magnification :- $m = \frac{h'}{h} = \frac{-v}{u} = \frac{A'B'}{AB}$

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$$

Multiplying by v

$$\frac{v}{f} = \frac{v}{v} + \frac{v}{u}$$

$$\frac{v}{f} = 1 + (-m) \qquad \left[\frac{v}{u} = -m\right]$$

$$1 - \frac{v}{f} = m$$

Variation in Image distance w.r.t of object distance :

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$$

differentiate

$$0 = -\frac{1}{v^2} dv - \frac{1}{u^2} du$$

$$\frac{1}{v^2} dv = -\frac{1}{u^2} du$$

$$\frac{dv}{du} = -\frac{v^2}{u^2}$$

$$\frac{dv}{du} = -\left(\frac{v}{u}\right)^2$$

Unit - 6 (b)

~~Diffraction and~~ Polarization

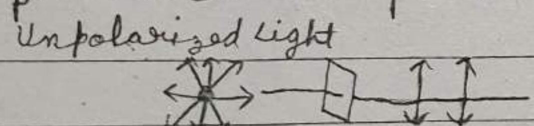
Transverse waves are those waves in which medium particles oscillate perpendicular to direction of propagation of light.

Longitudnal waves are the waves in which medium particles oscillates along the direction of propagation of waves

Unpolarized light → If the vibration of electric vector is uniformly distributed in all direction plane perpendicular to direction of propagation of light.

Plane polarized light is light wave in which vibration of electric vector are confined to single plane.

Polarization of light is phenomenon of restricting vibrations of electric vector of light in a particular plane.



If I = Intensity of unpolarized light
I_0 = Int. of polarized light
$I_0 = \frac{I}{2}$

Polariods are crystals which are used to polarize the light.

E.g. → Nicole prism or Tourmaline

Plane of vibrations is the plane in which all vibrations are present in plane polarized light.

Plane of Polarization is plane perpendicular to plane of vibration.

Polarization by Reflection - when an ordinary light incidents on a transparent medium, it is refracted as well as reflected. At a certain angle of incidence, the light is plane polarized.

Polarizing Angle (i_p) is the angle of incidence at which reflected light is completely polarized.

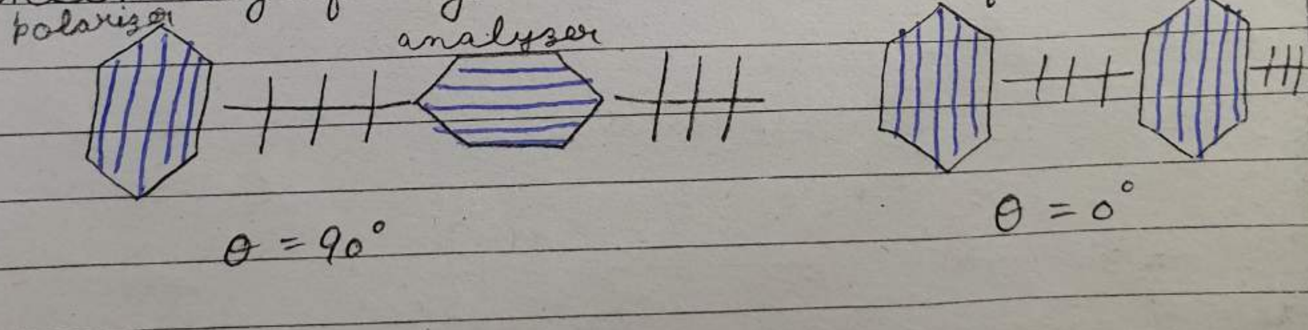
Brewster's Law states that tangent of polarizing angle (i_p) is always equal to refractive index of medium.

$$\mu = \tan i_p$$

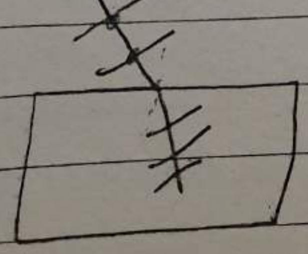
Law of Malus - As intensity of light is maximum if polarizer and analyzer are placed parallel to each other

$$I = \cos^2\theta$$

Intensity of light (minimum) if $\theta = 0°$



Polarization by Refraction -



Refracted ray is polarized light.

vibrations are present in plane polarized light.

Plane of Polarization is plane perpendicular to plane of vibration.

Polarization by Reflection → when an ordinary light incidents on a transparent medium, it is refracted as well as reflected. At a certain angle of incidence, the light is plane polarised.

Polarizing Angle (i_p) is the angle of incidence at which reflected light is completely polarized.

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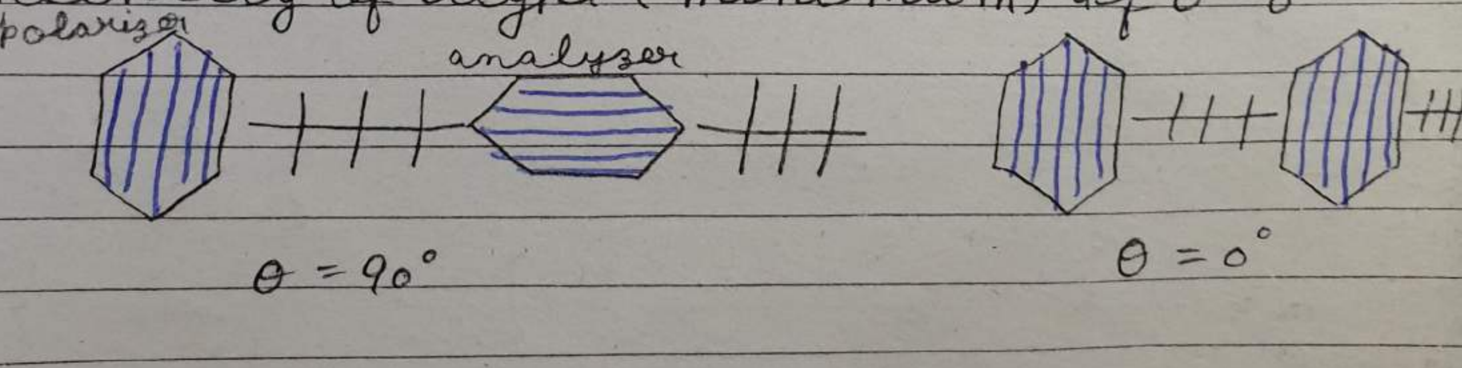
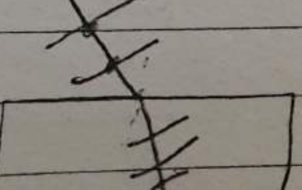
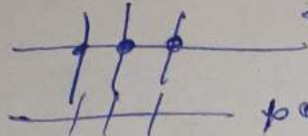


Polarization by Refraction →



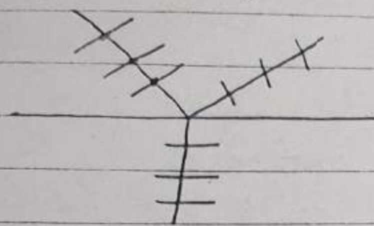
Refracted ray is polarized light.



unpolarised light.

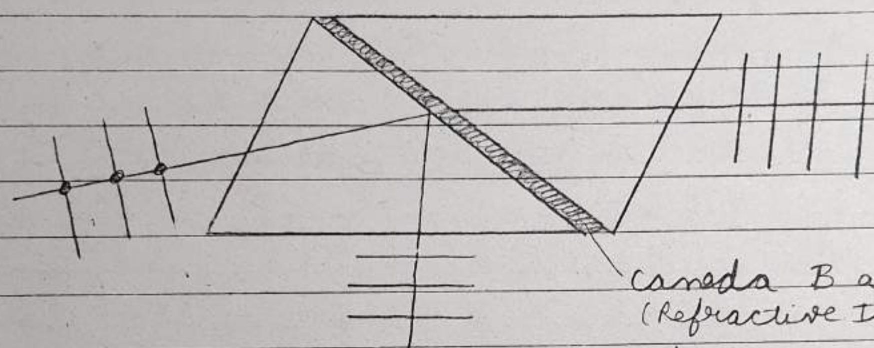
polarised light

Polarization by scattering:



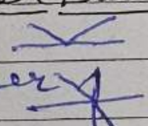
In scattering, either of ray is polarized or both.

Nicole Prism:

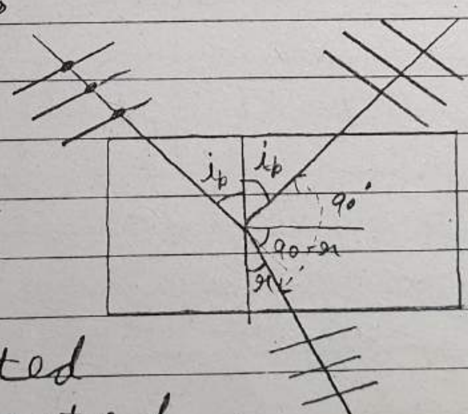


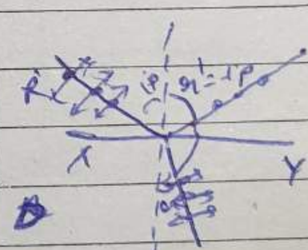
Brewster Law:

surface पर reflection
Rare medium से Denser
से refraction.



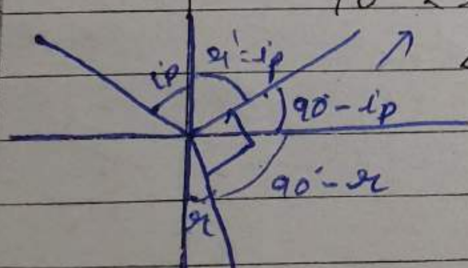
i_p = angle of polarization





If either reflected wave or refracted wave is plane polarized.

$$90 - \angle i_p + 90 - \angle r = 90°$$



$$\angle i_p + \angle r = 90°$$

$$\angle r = 90° - i_p$$

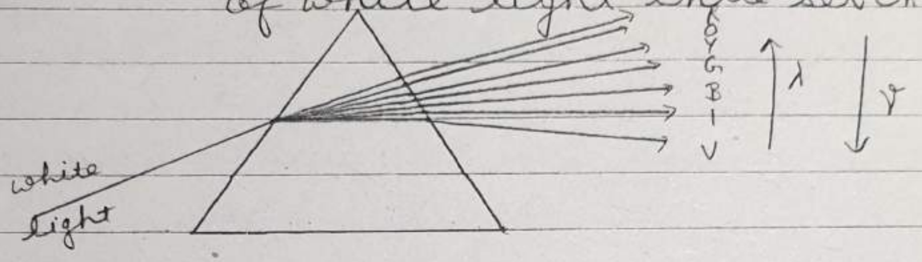
$$\frac{\sin i_p}{\sin(90 - i_p)} = \frac{\sin i_p}{\cos i_p} = \mu$$

$$\tan i_p = \mu$$

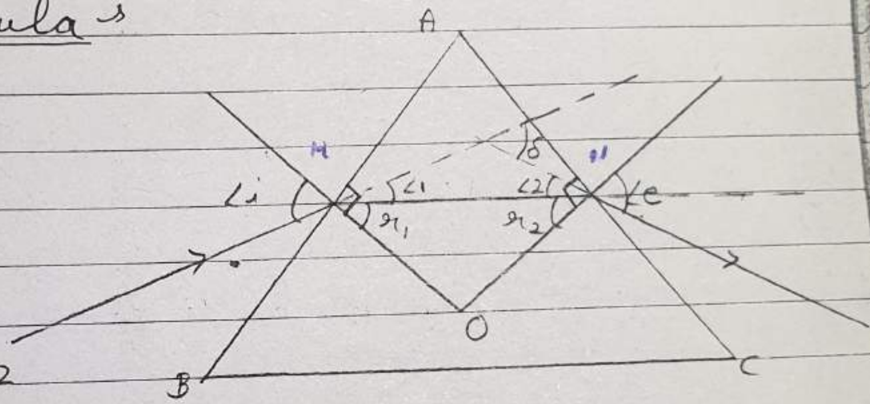
Unit - 6 (d)

Dispersion of Light

Dispersion is the phenomenon of splitting of white light into seven colors.



Prism formula:



$\angle 1 + \angle 2 = \angle \delta$

$\angle i = \angle 1 + \angle r_1$

$\angle i - \angle r_1 = \angle 1$

$\angle r_2 + \angle 2 = \angle e$

$\angle e - \angle r_2 = \angle 2$

$\angle i - \angle r_1 + \angle e - \angle r_2 = \angle \delta$

$\angle i + \angle e - (\angle r_1 + \angle r_2) = \angle \delta$ — (1)

$\angle r_1 + \angle r_2 + \angle O = 180^\circ$

In quad AMON $\quad [\angle M = \angle N = 90^\circ]$

$\angle A + \angle O = 180^\circ$

$\angle O = 180^\circ - \angle A$

$\angle r_1 + \angle r_2 + (180^\circ - \angle A) = 180^\circ$

$\angle r_1 + \angle r_2 = \angle A$ — (3)

By putting value in eqⁿ (1)

$\angle i + \angle e - \angle A = \angle \delta$

$\angle \delta + \angle A = \angle i + \angle e$ — (2)

If δ is very-very small

$\angle i \simeq \angle e \;,\; \angle r_1 \simeq \angle r_2 = \angle r$

From eq^n (3) $2\angle r = \angle A$

$\angle r = \frac{\angle A}{2}$

From eq^n (2)

$2\angle i = \angle \delta + \angle A$

$\angle i = \frac{\angle \delta + \angle A}{2}$

By use of Snell Law

$\frac{\sin i}{\sin r} = \mu$

Prism Formula: $\frac{\sin \frac{\delta + A}{2}}{\sin \frac{A}{2}} = \mu$

Relation b/w μ, δ and A:
[upto eq^n (2)]

$\angle \delta + \angle A = \angle i + \angle e$

Refraction on AB

$\frac{\sin i}{\sin r_1} = \mu$

when $\angle i$ & $\angle r_1$ are very-very small

$\frac{i}{r_1} = \mu$

$i = \mu r_1$

Refraction on AC

$\frac{\sin e}{\sin r_2} \simeq \frac{e}{r_2} = \mu$

$e = \mu r_2$

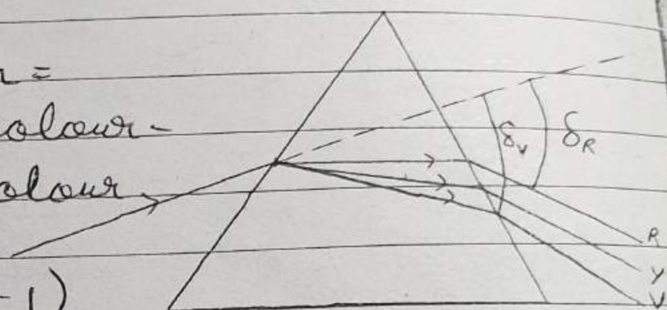
Put value of $\angle i$ & $\angle e$ in eq^n (2)

$\angle \delta + \angle A = \mu r_1 + \mu r_2$

$$\delta + A = \mu(r_1 + r_2)$$
$$\delta + A = \mu A$$
$$\delta = \mu A - A$$
$$\delta = A(\mu - 1)$$

Angular Dispersion is difference between deviation angle of two extreme colours i.e., voilet and red

Angular dispersion = Deviation of violet colour - Deviation of red colour



$$\theta = \delta_V - \delta_R$$

$\delta_V = A(\mu_V - 1)$, $\delta_R = A(\mu_R - 1)$

$$\delta_V - \delta_R = A(\mu_V - 1 - \mu_R + 1)$$
$$\theta = \delta_V - \delta_R = A(\mu_V - \mu_R)$$

Dispersive Power is ratio of angular dispersion of extreme colours to the deviation suffered by mean light.

☆ Deviation for yellow colour is called the mean deviation.

$$\omega = \frac{\theta}{\delta} = \frac{A(\mu_V - \mu_R)}{A(\mu - 1)} = \frac{\mu_V - \mu_R}{\mu - 1}$$

Lord RayLeigh Law of Scattering → It states that intensity of scattered light varies inversely as the fourth power of the wavelength of incident light.

$$I_s \propto \frac{1}{\lambda^4}$$

$a = \frac{AV}{r\lambda^2}$ where A = amplitude of incident light
λ = wavelength of ———
V = volume of scattering light
a = amplitude of scattered light at a distance r from scattering particle

$\left[I_s \propto a^2 \quad \therefore I_s \propto \frac{1}{\lambda^4} \right]$

Applications of scattering of light:

1. Blue Colour of Sky - Light gets scattered by large number of molecules in the earth's atmosphere. As, blue colour has a short wavelength, it is scattered more strongly. Hence, the sky looks blue.
2. White colour of clouds: The clouds are at much lower height. Lower part of atmosphere contain large dust particles, water droplets, etc. All colour are scattered nearly equally.
3. The sun looks reddish at the time of sun rise and sun sets: At this time, sun is near the horizon. The sun rays have to travel large part of atmosphere, most of blue colour scatter away. Only red colour is visible to our eyes.
4. Danger signals are red: Because wavelength of red colour is large and red colour is least scattered. It can be seen from maximum distance.

Rainbow: It is a spectrum of sun's ligth.

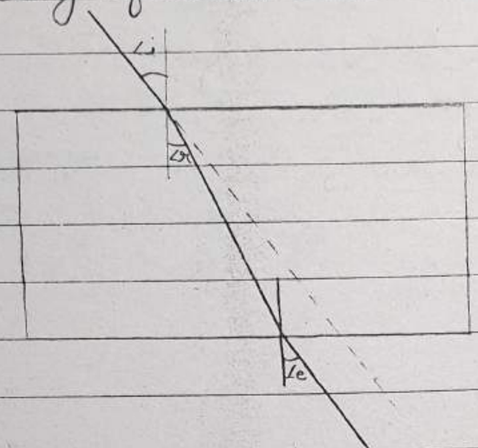
Types: (i) Primary rainbow is inner of two bows and is brighter. It subtends an angle of 42° at the eye of the observer (red colour → 43°, voilet → 41°)

(ii) Secondary rainbow is outer of two bows & not bright. Angle → 52.5° (red → 51°, voilet → 54°)

Unit-6(c)

Refraction of Light

Refraction is the phenomenon of deviation in path of light while travelling from one medium to another.



Laws →

(i) Whenever light goes from one medium to another medium, the frequency of light and phase of light don't change. However, the velocity and wavelength of light changes

(ii) The incident ray, reflected ray and normal to surface at the point of incident all lies in same plane.

(iii) Product of refractive index and sine of angle of incident at a point is constant.

$$\mu_1 \times \sin i_1 = \mu_2 \times \sin i_2$$

$$\frac{\mu_2}{\mu_1} = \frac{\sin i}{\sin r} = \frac{1}{{}^2\mu_1} = {}^1\mu_2 \; (\mu \text{ of } 2 \text{ w.r.t. } 1)$$

$${}^1\mu_2 = \frac{\frac{c}{v_2}}{\frac{c}{v_1}} = \frac{v_1}{v_2}$$

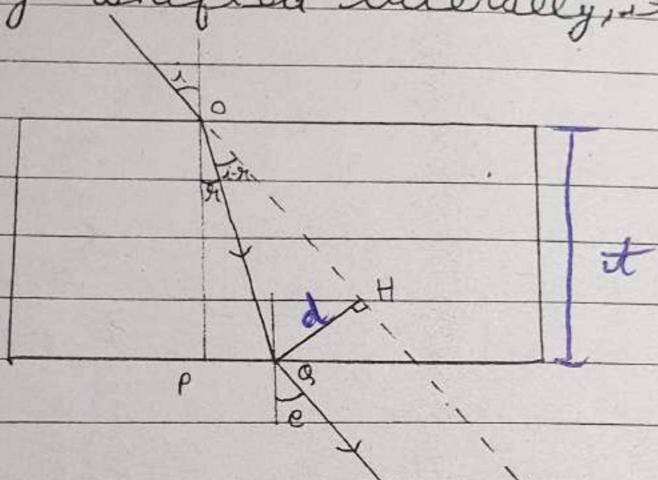
Snell's Law states that ratio of sine of angle of incidence to sine of angle of refraction is always equal to refractive index of medium in which refraction takes place.

Refractive Index (μ) is ratio of velocity of light in free space to that of medium

$$\mu = \frac{c}{v} \Rightarrow c = 3 \times 10^8 \, ms^{-1}$$

- Higher the refractive index, denser is medium

__Lateral Shift__ → The emergent ray is parallel to incident ray but it is slightly shifted laterally, it is called lateral shift.



Let d is lateral shift and t is thickness of slab.

$$\sin(i-r) = \frac{d}{OQ}$$

$$d = OQ \sin(i-r)$$

In ΔOPQ

$$\cos r = \frac{OP}{OQ} = \frac{t}{OQ}$$

$$OQ = \frac{t}{\cos r}$$

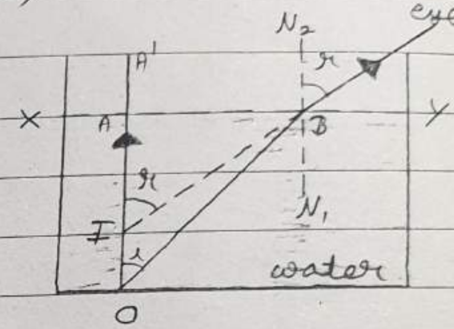
$$\therefore, \quad d = \frac{t}{\cos r} \sin(i-r)$$

Real and apparent depth → The coin place at bottom of water filled container appear slightly above the bottom surface, this is due to refraction of light and upward shift in coin is called normal shift.

$${}^{w}\mu_a = \frac{\sin i}{\sin r} \quad \text{(snell's law)}$$

$${}^{a}\mu_w = \frac{1}{{}^{w}\mu_a}$$

$${}^{a}\mu_w = \frac{\sin r}{\sin i}$$



In ΔABO, $\sin i = \frac{AB}{OB}$

In ΔABI, $\sin r = \frac{AB}{BI}$

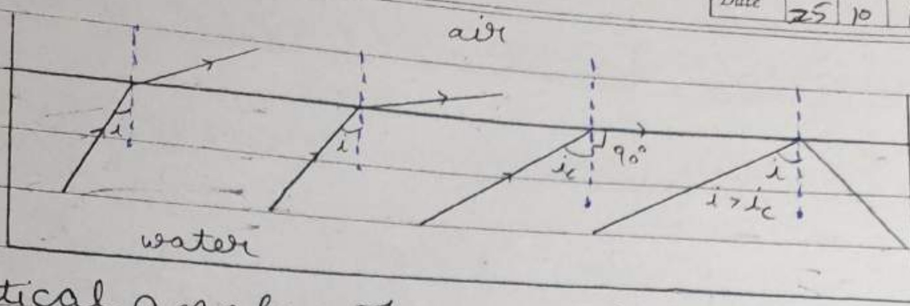
$${}^{a}\mu_w = \frac{AB}{BI} \times \frac{OB}{AB} = \frac{OB}{BI}$$

$${}^{a}\mu_w = \frac{AO}{AI} = \frac{OB}{BI}$$

Thus, $\frac{\text{Real depth}}{\text{apparent depth}} = {}^{a}\mu_w$

Total Internal Reflection is phenomenon of bouncing back of light in same medium but by use of refraction phenomenon.

OR It is the phenomenon of reflection of light into a denser medium from an interface of this denser medium and a rarer medium.



Critical angle: The angle of incidence in denser medium at which the angle of refraction is 90°.

Conditions: (i) The light must travel from denser to rarer medium.

(ii) The angle of incidence should be greater than critical angle.

<u>Relation b/w critical angle and refractive index</u>

From snell law $^{w}\mu_a = \frac{\sin i_c}{\sin 90^\circ}$

$$^{w}\mu_a = \sin i_c$$

$$^{a}\mu_w = \frac{1}{^{w}\mu_a}$$

R.I. of water w.r.t. air, $^{a}\mu_w = \frac{1}{\sin i_c}$

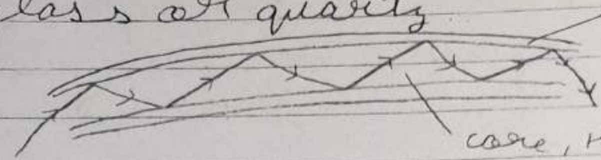
critical angle for water = 48° 42'

critical angle for glass = 41.8°

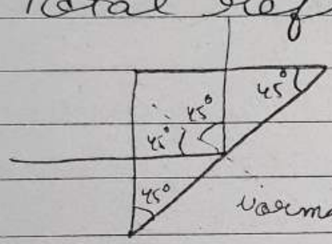
<u>Applications:</u>

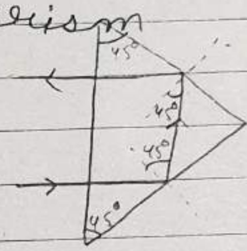
1. Mirage: It is an optical illusion which occurs usually in deserts on hot summer days. The object such as a tree appears to be inverted, as if tree is on the bank of a pond of water.
2. optical fibre: These consist of several thousands of very long fine quality fibres

of glass or quartz



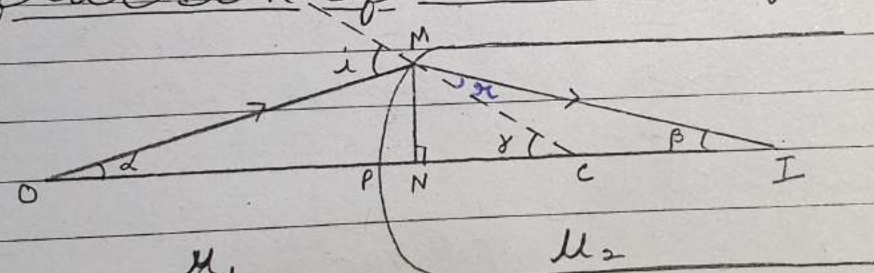
3. Diamonds Diamond is cut suitably so that light entering diamond from any face falls at an angle greater than 24.4°. It suffers multiple total reflection and sparkles
4. Total reflecting prism





From rare to denser medium →

Refraction of convex surface



$\mu_2 > \mu_1$

$$\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1}$$

* We are taking tangent ratio as we need slope of the line.

$$\frac{i}{r} = \frac{\mu_2}{\mu_1} \qquad \mu_1 i = \mu_2 r$$

$$\mu_1 (\alpha + \gamma) = \mu_2 (\gamma - \beta)$$

$$\mu_1 \left(\frac{MN}{NO} + \frac{MN}{NC}\right) = \mu_2 \left(\frac{MN}{NC} - \frac{MN}{NI}\right)$$

$$\mu_1 \left(\frac{1}{NO} + \frac{1}{NC}\right) = \mu_2 \left(\frac{1}{NC} - \frac{1}{NI}\right)$$

Let P lie close to N

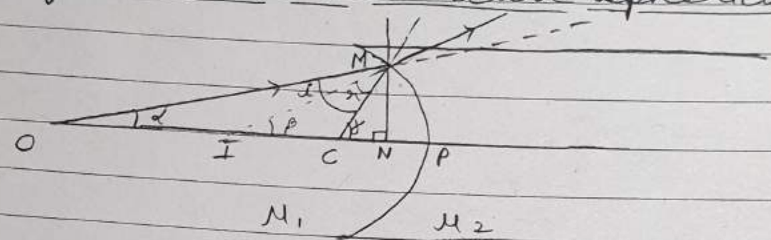
$$\mu_1\left(\frac{1}{PO}+\frac{1}{PC}\right)=\mu_2\left(\frac{1}{PC}-\frac{1}{PI}\right)$$

$$\mu_1\left(-\frac{1}{u}+\frac{1}{R}\right)=\mu_2\left(\frac{1}{R}-\frac{1}{v}\right)$$

$$-\frac{\mu_1}{u}+\frac{\mu_1}{R}=\frac{\mu_2}{R}-\frac{\mu_2}{v}$$

$$\boxed{\frac{1}{R}(\mu_2-\mu_1)=\frac{\mu_2}{v}-\frac{\mu_1}{u}}$$

Refraction at concave spherical surface:



$$\frac{\sin i}{\sin r}=\frac{\mu_2}{\mu_1} \qquad \frac{i}{r}=\frac{\mu_2}{\mu_1}$$

$$\mu_1 i=\mu_2 r$$

$$\mu_1(\gamma-\alpha)=\mu_2(\gamma-\beta)$$

$$\mu_1\left(\frac{MN}{NC}-\frac{MN}{NO}\right)=\mu_2\left(\frac{MN}{NC}-\frac{MN}{NI}\right)$$

$$\mu_1\left(\frac{1}{NC}-\frac{1}{NO}\right)=\mu_2\left(\frac{1}{NC}-\frac{1}{NI}\right)$$

Let P close to N

$$\mu_1\left(\frac{1}{PC}-\frac{1}{PO}\right)=\mu_2\left(\frac{1}{PC}-\frac{1}{PI}\right)$$

$$\mu_1\left(\frac{-1}{R}+\frac{1}{u}\right)=\mu_2\left(\frac{-1}{R}+\frac{1}{v}\right)$$

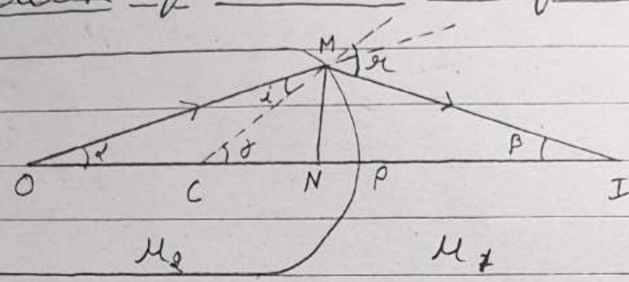
$$-\frac{\mu_1}{R}+\frac{\mu_1}{u}=\frac{-\mu_2}{R}+\frac{\mu_2}{v}$$

$$\boxed{(\mu_2-\mu_1)\frac{1}{R}=\frac{\mu_2}{v}-\frac{\mu_1}{u}}$$

26-10-17

From denser to rarer medium →

Refraction of convex surface –



$$\frac{\sin i}{\sin r} = \frac{\mu_1}{\mu_2} \qquad \frac{i}{r} = \frac{\mu_1}{\mu_2}$$

$$\mu_2 i = \mu_1 r$$

$$\mu_2(\gamma - \alpha) = \mu_1(\gamma + \beta)$$

$$\mu_2\left(\frac{MN}{NC} - \frac{MN}{NO}\right) = \mu_1\left(\frac{MN}{NC} + \frac{MN}{NI}\right)$$

$$\mu_2\left(\frac{1}{NC} - \frac{1}{NO}\right) = \mu_1\left(\frac{1}{NC} + \frac{1}{NI}\right)$$

let P lie close to N

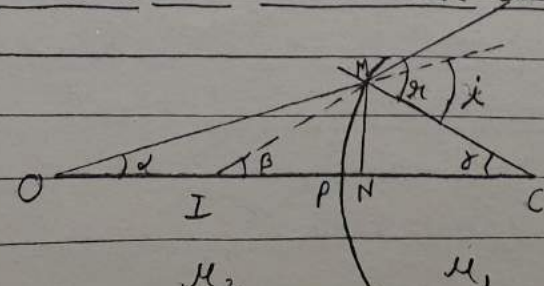
$$\mu_2\left(\frac{1}{PC} - \frac{1}{PO}\right) = \mu_1\left(\frac{1}{PC} + \frac{1}{PI}\right)$$

$$\mu_2\left(\frac{-1}{R} + \frac{1}{u}\right) = \mu_1\left(\frac{-1}{R} + \frac{1}{V}\right)$$

$$-\frac{\mu_2}{R} + \frac{\mu_2}{u} = \frac{-\mu_1}{R} + \frac{\mu_1}{V}$$

$$\boxed{(\mu_1 - \mu_2)\frac{1}{R} = \frac{\mu_1}{V} - \frac{\mu_2}{u}}$$

Refraction at convex surface →



$$\frac{\sin i}{\sin r} = \frac{\mu_1}{\mu_2} \qquad \frac{i}{r} = \frac{\mu_1}{\mu_2}$$

$$i \mu_2 = r \mu_1$$

$$\mu_2 (\alpha + \gamma) = \mu_1 (\beta + \gamma)$$

$$\mu_2 \left(\frac{MN}{NO} + \frac{MN}{NC} \right) = \mu_1 \left(\frac{MN}{NI} + \frac{MN}{NC} \right)$$

$$\mu_2 \left(\frac{1}{NO} + \frac{1}{NC} \right) = \mu_1 \left(\frac{1}{NI} + \frac{1}{NC} \right)$$

Let P lie close to N

$$\mu_2 \left(\frac{1}{PO} + \frac{1}{PC} \right) = \mu_1 \left(\frac{1}{PI} + \frac{1}{PC} \right)$$

$$\mu_2 \left(\frac{1}{-u} + \frac{1}{R} \right) = \mu_1 \left(\frac{1}{-v} + \frac{1}{R} \right)$$

$$-\frac{\mu_2}{u} + \frac{\mu_2}{R} = -\frac{\mu_1}{v} + \frac{\mu_1}{R}$$

$$\frac{\mu_2}{R} - \frac{\mu_1}{R} = \frac{\mu_2}{u} - \frac{\mu_1}{v}$$

$$\boxed{\frac{1}{R}(\mu_2 - \mu_1) = \frac{\mu_2}{u} - \frac{\mu_1}{v}}$$ or

$$\boxed{(\mu_1 - \mu_2)\frac{1}{R} = \frac{\mu_1}{v} - \frac{\mu_2}{u}}$$

Lens Maker formula: