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V. Imp (6-marks)

# Chapter ⇒ 11
## ⇒ Ray optics

Part :- 1

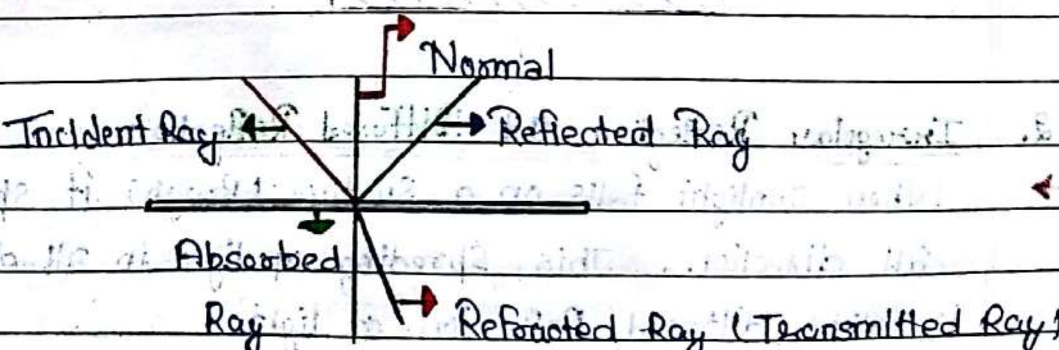
- **Light**

→ Light is a form of Energy. When it is falls an objects we see them.
→ Light is a part of Visible spectrum of Electromagnetic Waves.
→ It have wavelength range from 400nm to 700nm.
→ The Velocity of light is $3 \times 10^8$ m/s and its Value is maximum at Vaccum.
→ light Approximately propogates in Straight line.
→ The path of light is Called Rays and it Can represented by Arrow (→) which represent direction of Energy Transmission.

- **Propogation Of Light**

→ When light falls over a surface a part of it is Absorbed Some part is reflected back and remaining part is Transmitted OR refrated, On the Other side of Surface.

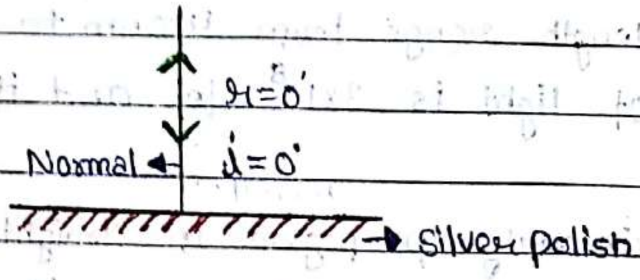
→ The parts absorbed, reflected and transmitted depends upon nature of surfuce.




⇒ "Phenomena of bouncing Back of light from a surface in the Same medium is known as Reflection of light." ⇐

NOTE — After Reflection of light, frequency, wavelength and velocity remain same and do not change.
But Energy will be loss in this process.

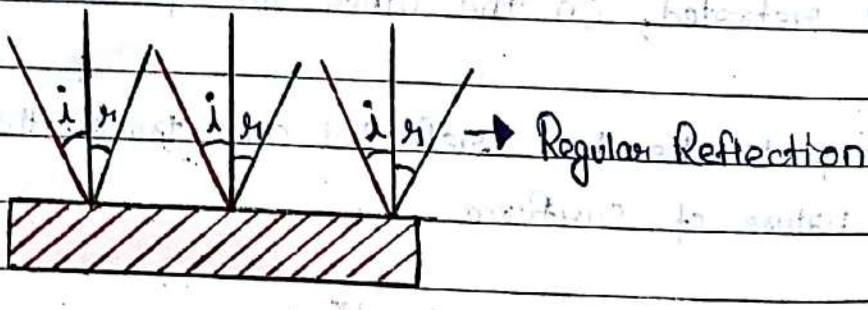
NOTE — If rays are incident Normally then rays are return Back on same path.




• Types of Reflection

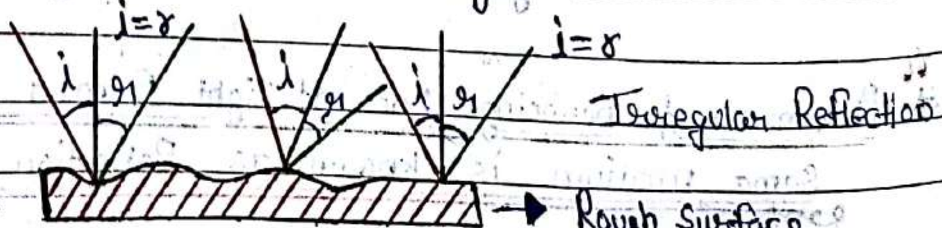
1. **Regular Reflection** (Mirror) → Absorption → Not (Slab → Glass prism → Absorption ✓ Transmit)

→ When light Rays falls from a Source on plane mirror all rays are reflected in a particular direction According to the laws of Reflection. These type of reflection is called regular reflection.




2. **Irregular Reflection OR Diffused Reflection**

→ When sunlight falls on a Surface (Rough) it spreds in all direction. This spreding of light in all direction is called diffused Reflection of light.

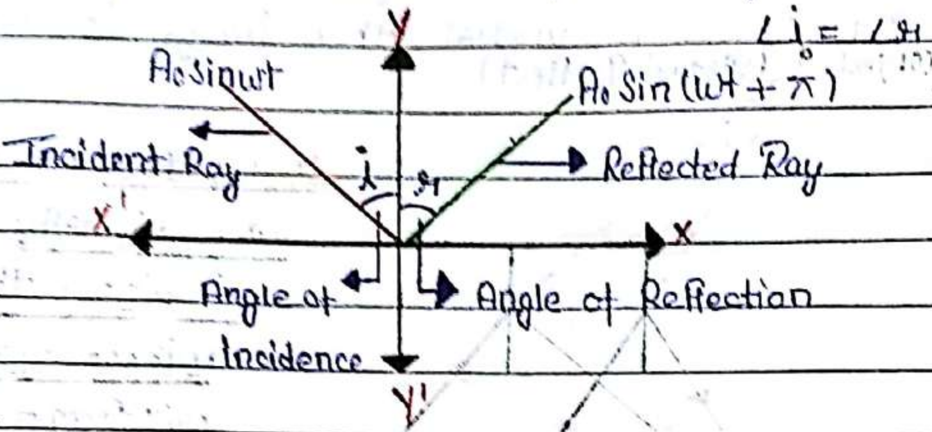


- Law of Reflection of Light

→ There are two laws of Reflection.

1. Incident Ray, Reflected Ray and Normal lies in same plane.
2. The angle of incidence is Equal to Angle of Reflection

$\angle i = \angle r$




- Important Point

1. Stokes' Law

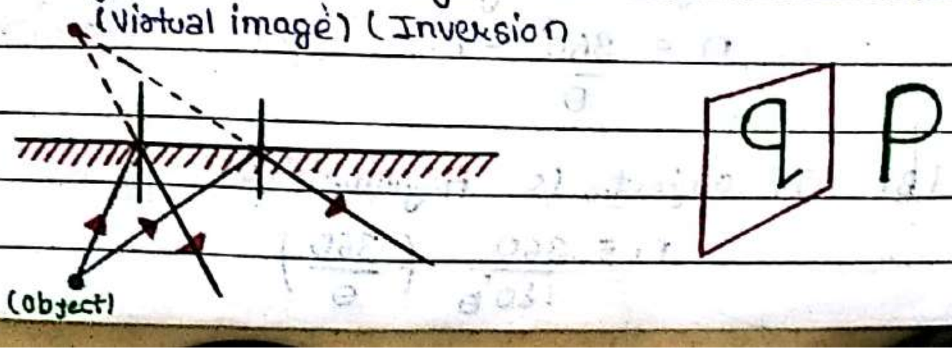
→ If reflection takes place By a Surface Backed by denser medium a change of 180° phase takes place. This is Stokes Law. This law is valied for plane as well as Rough Surface or Curved Surface

→ If reflection takes place By same medium no phase takes place.

- Formation Of Image By plane Mirror

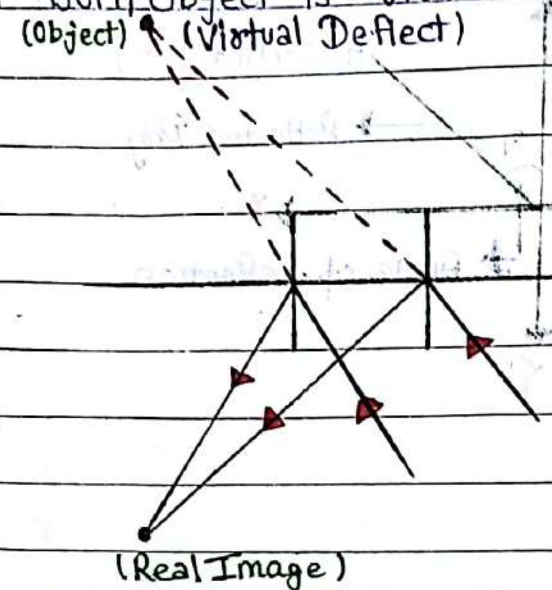
1. lateral Inversion OR Virtual Inversion

→ In plane mirror, Size of image is Equal to size of object But there is change in shape, the left Side of the object Apperes as Right side of image this is Called lateral inversion



→ The distance of image behind the plane mirror should be Equal to distance of object in front of mirror.

→ In plane mirror the nature of image is Virtual if object is real But if Object is virtual then image is real.




men → placed on mirror And Trigonally a mirror Is placed then on this mirror real image will formed.

men → □ (mirror) (inverted)

□ (Real Image) (upward)

**NOTE** ⇒ "Image formed By two plane mirror inclined at some angle. If Angle Between two mirror is $\theta$ then number of images formed is $n$" ⇐

→ If $\frac{360^\circ}{\theta}$ = even Angle —(1)

then $n = \frac{360^\circ}{\theta} - 1$

E.g $\theta = 60^\circ$ then $n = \frac{360^\circ}{60} - 1$

then $n = 5$ image

→ If $\frac{360^\circ}{\theta}$ = odd Angle —(2)

then their is two possibilities

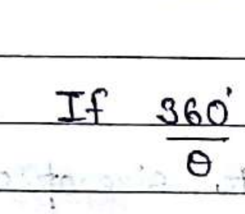
(A) If Object is Symmetrical

$n = \frac{360^\circ}{\theta} - 1$

E.g. $\theta = 120^\circ$ then

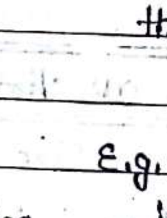
If Asymmetrical then

$n = \frac{360^\circ}{120} = 3$ image



(B) If object is Asymmetrical

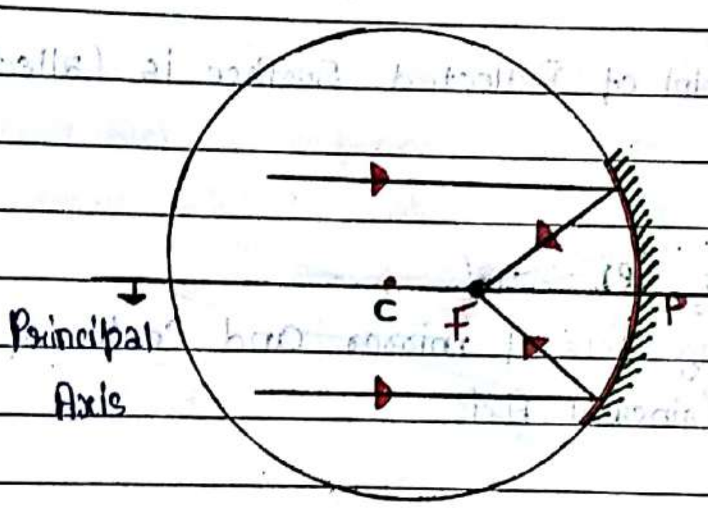
$n = \frac{360}{180^\circ \theta} \left(\frac{360}{\theta}\right)$



## Spherical Mirror

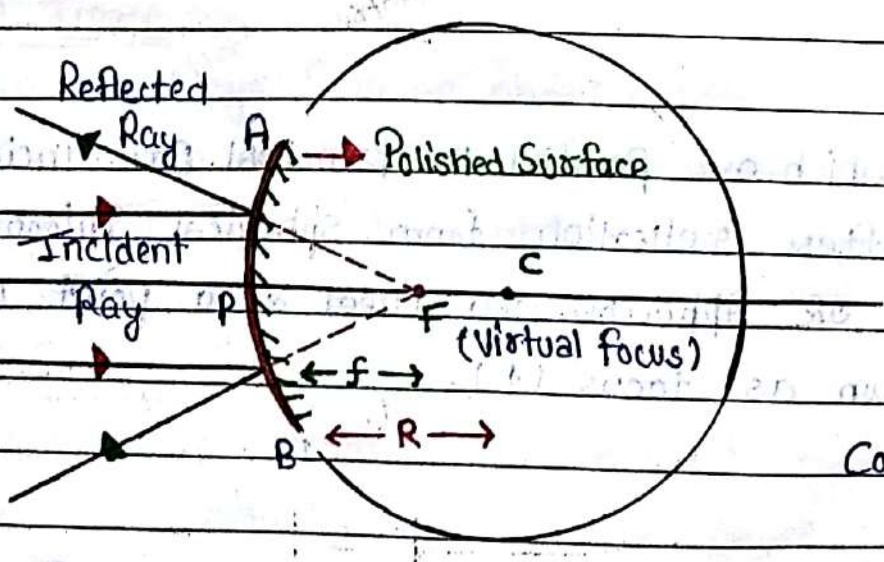
→ Some mirror have spherical surface in such mirror the image size, and nature depends upon position of object and nature of curvature of mirror. The mirror whose surfaces are curved called spherical mirror.

→ When outer curved surface of hollow transparent sphere is polised and reflection takes place from inner surface such mirror is called concave mirror.




Concave mirror
(Converging mirror)
(Polished outside)

→ If inner surface is polised and reflection take place from outer surface such mirror are called convex mirror.




~~Concave~~ Convex mirror
(Diverging mirror)
and (Inversion polish)

- Terms And defination related to Spherical Mirror

1. **Aperture (AB)**

→ The portion of mirror from which reflection takes place is Called Aperture.

2. **Centre of Curvature (C)**

→ The Centre of a Curved part Cut from a Hollow Sphere is Called Centre of Curvature.

3. **Pole of mirror**

→ The middle point of Reflected Surface is Called Pole of mirror (P).

4. **Principal Axis (P)**

→ The line joining Pole of mirror and Centre of Curvature is called Principal Axis.

5. **Radius of Curvature (R)**

→ The distance Between pole and centre of Curvature is Called Radius of Curvature (R).

6. **Focus (F)**

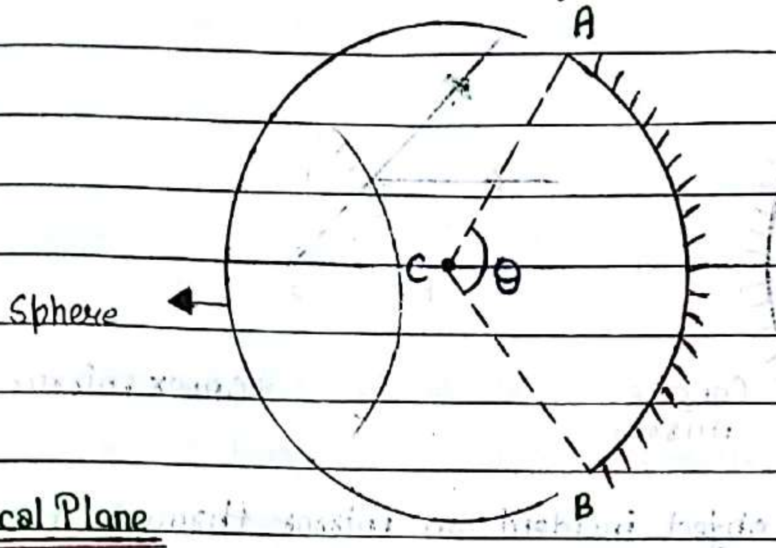
→ The rays which are parallel to Principal Axis incident on mirror After reflection from spherical mirror meets at a point OR Appears to meet at a point on principal axis known as Focus (F).

7. **Focal length**

→ The distance Between pole and focus is Called Focal Length

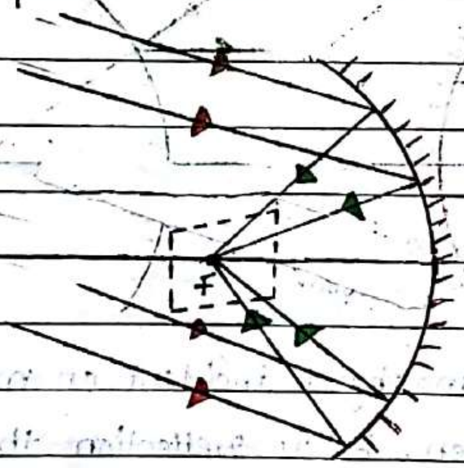
8. Angular Aparature

→ The Angle Substended by diameter of Spherical mirror on centre of Curvature is Called Angular Aparature.




9. Focal Plane

→ The plane which is perpendicular to principal Axis and passing from focus point is called focal plane.




- Virtual Image

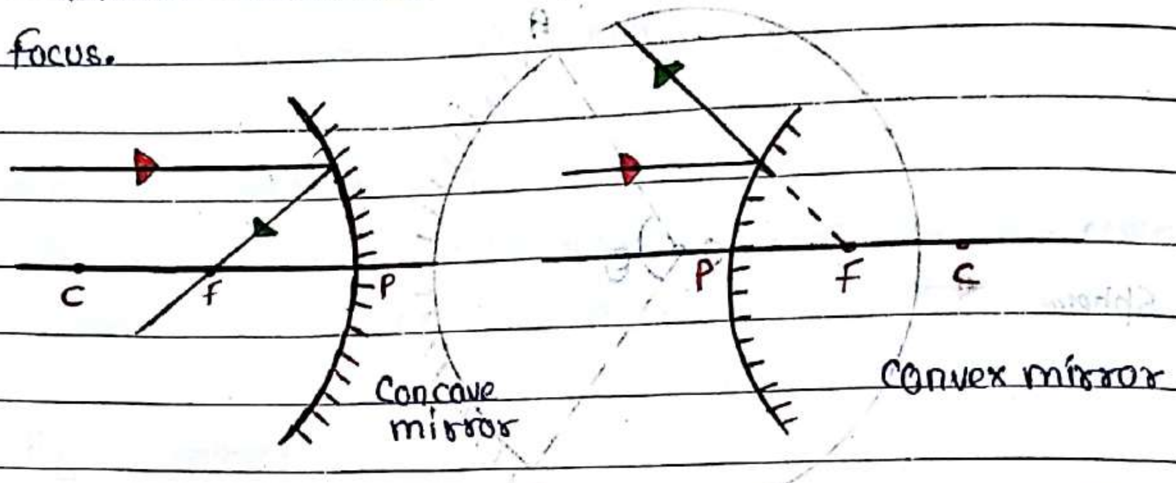
→ When two rays from an object, After reflection from mirror Appears to be meeting then Virtual image of Object is formed. It Can not be obtained on screen.

- Real Image

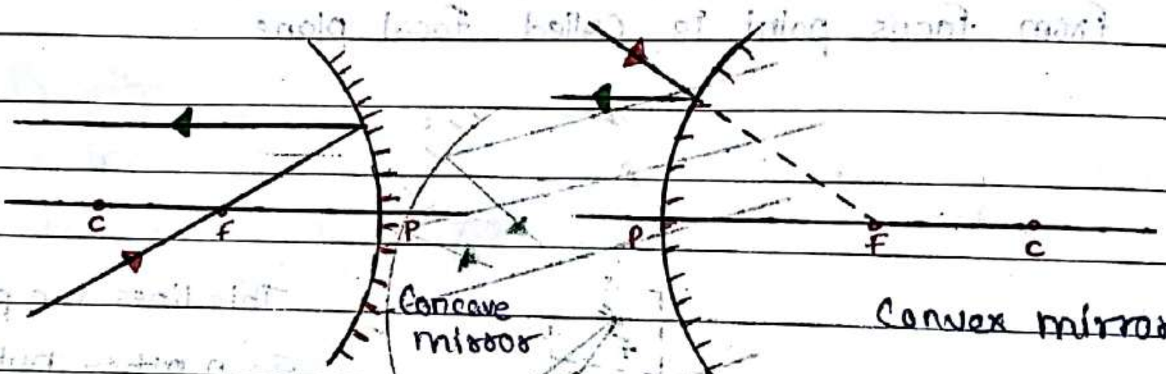
→ When two rays from object incident on a mirror and after reflection actually meet then the real Image of Object is formed. It Can be obtained on Screen.

- **Rules for Image formation**

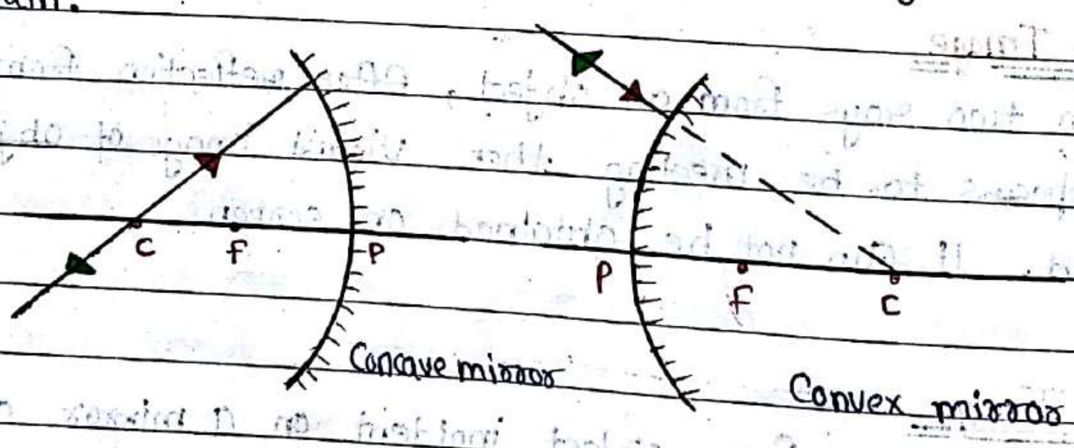
1. when rays are incident parallel to principal Axis on mirror then After reflection it passes through the focus.




2. When rays from object incident on mirror through Focus then After reflection it becomes parallel to the principal Axis




3. When rays from an object incident on mirror through Centre of Curvature then after reflection they retraces their path.




4.

- **Image formation By Concave mirror**

1. If Object is at infinity.


$u$ = object distance
$v$ = Image distance
$f$ = focal length

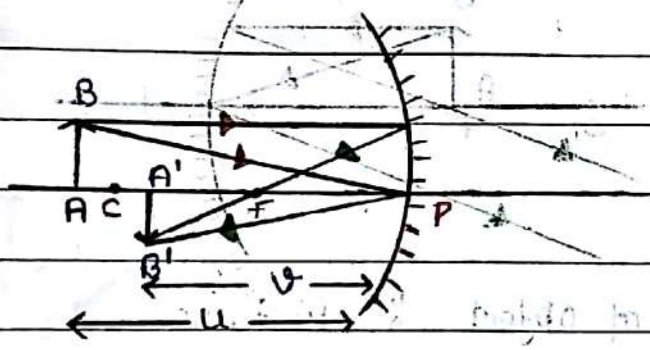
Position of object At infinity
:- $u = -\infty$

Position of Image
:- At focus (f)
then $v$ = $v$ distance and $v = -f$

Nature of image :- real and inverted

Size of image :- Point size, Highly diminished (small)

2. When Object is Between Centre of Curvature and infinity.



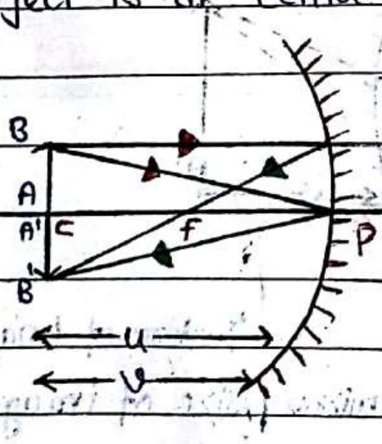

Position of Object :- Beyond C centre of curvature

Position of image :- Between f (focus) and C (COC)

Nature of image :- Real and Inverted

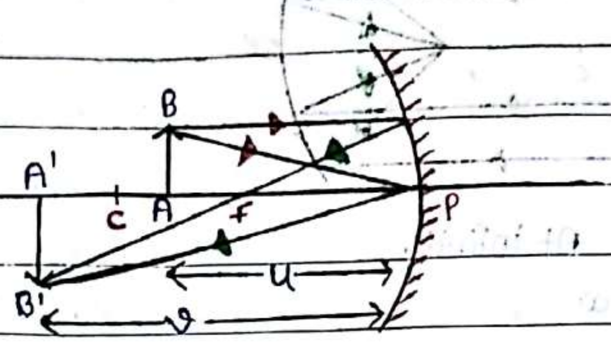
Size of image :- smaller the object, diminished

3. when object is at centre of Curvature (C).




Position of Object :- At C
Position of image :- At C
Nature of image :- real and inverted
Size of image :- Equal to object size.

4. When Object is Between focus (f) and Centre of Curvature (C)



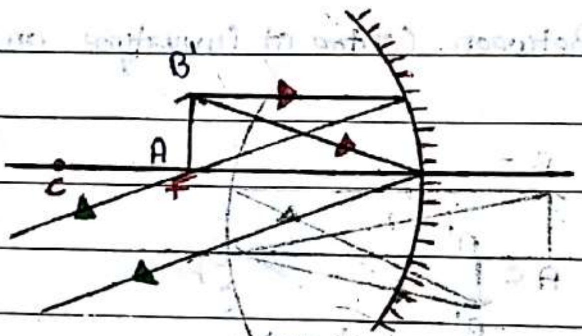

Position of Object :- Between f and C

Position of image :- Beyond C

Nature of image :- Real and inverted

Size of image :- larger then Object, Enlarged.

5. When object is at focus (f)



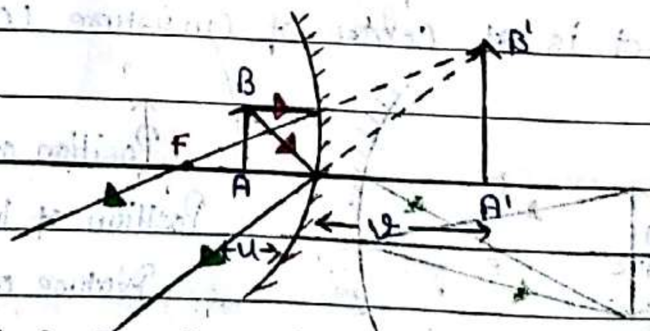

Position of object :- At focus

Position of image :- At Infinity

Nature of Image :- Real and inverted

Size of image :- Highly Enlarged

6. When Object is Between focus and Pole




Position of Obgect :- B/w f and P

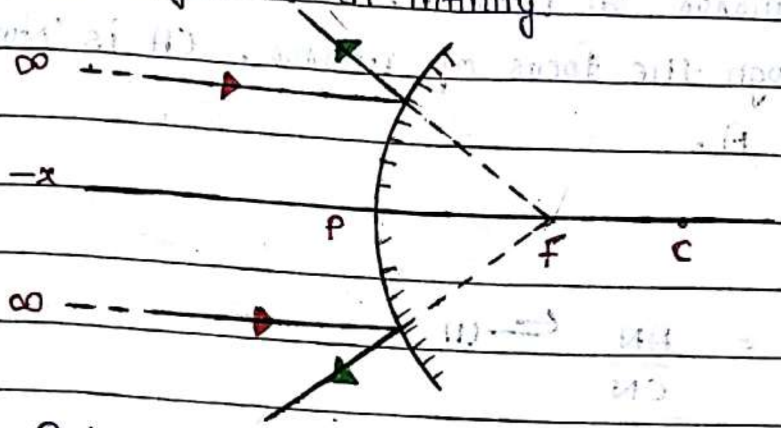
Position of Image :- Behind the mirror

Nature of Image :- Virtual or Erect

Size of image :- Highly magnified

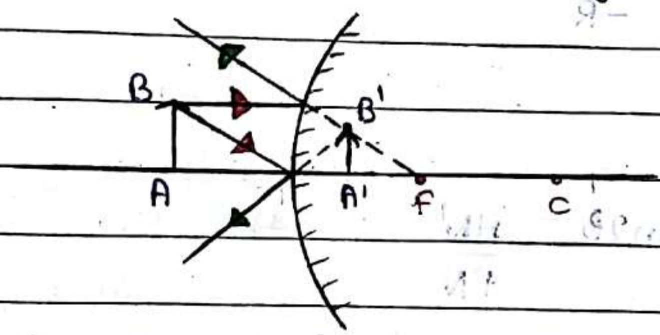
- ## Image formation By Convex mirror

1. When Object is at infinity



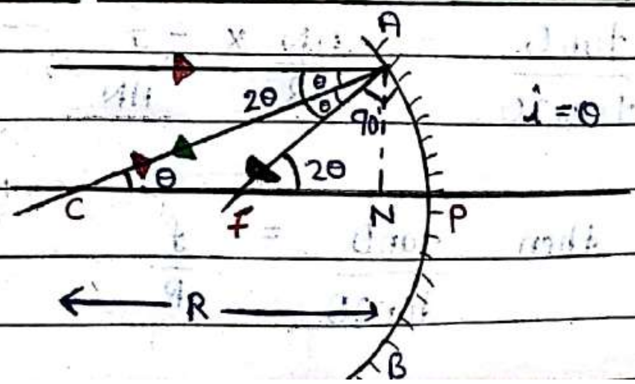

Position of Object :- At infinity
Position of image :- At focus
Nature of image :- Virtual and Erect
Size of image :- point size, diminished (Highly).

2. when object is between pole and infinity




Position of Object :- Between Pole OR infinity
Position of Image :- Between Pole (P) and Focus (F)
Nature of image :- Virtual OR Erect
Size of image :- diminished (lesser then object)

- ## Relationship Between focal length And Radius of Curvature of A Spherical mirror




$i = \theta$ and $r = \theta$

→ Let a ray OA travelling parallel to the principal Axis, incident on a Concave mirror at Point A. After reflection, the ray pass through the focus of mirror. CA is Normal to the mirror At A.

In $\Delta ACN$

$$\tan\theta = \frac{P}{B} = \frac{AN}{CN} \quad \text{---(1)}$$

and AN = ? CN = is nearly Equal to CP

$CN \simeq CP$ Because N and P are very near to Each other.

then $CN \simeq CP = -R$

$$\text{then} \quad \tan\theta = \frac{AN}{-R} \quad \text{---(2)}$$

In $\Delta AfN$

$$\text{then} \quad \tan 2\theta = \frac{AN}{fN} \quad \text{---(3)}$$

Here $fN \simeq fP = -f$ (focal length)

$$\text{then} \quad \tan 2\theta = \frac{AN}{-f}$$

By dividing Equation (ii) and (iii)

$$\frac{\tan\theta}{\tan 2\theta} = \frac{AN}{-R} \times \frac{-f}{AN} \quad \text{---(4)}$$

$$\text{then} \quad \frac{\tan\theta}{\tan 2\theta} = \frac{f}{R}$$

If Angle is small

$\tan\theta \simeq \theta$ and $\tan 2\theta \simeq 2\theta$

then $\dfrac{\theta}{2\theta} = \dfrac{f}{R}$ —(5)

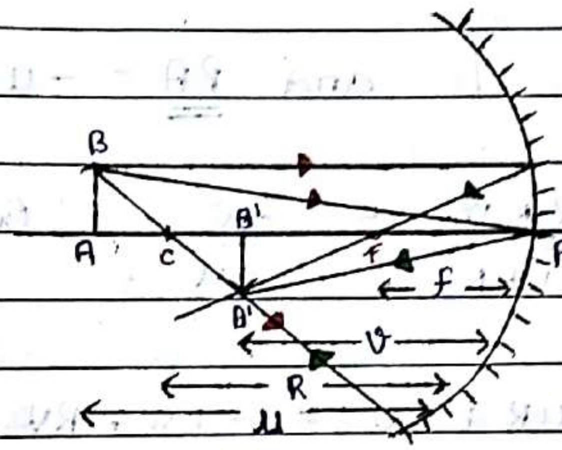
then $\Rightarrow$ "$R = 2f$" $\Leftarrow$

- Mirror formula

$\Rightarrow$ "$\dfrac{1}{f} = \dfrac{1}{u} + \dfrac{1}{v}$" $\Leftarrow$

$u \Rightarrow$ object distance

$v \Rightarrow$ Image distance




Proof

from $\Delta ABC$ and $\Delta A'B'C$

Both are similar. Hence their ratio of sides are Equal.

$$\frac{A'B'}{AB} = \frac{A'C}{AC} \quad —(1)$$

from $\Delta ABP$ and $\Delta A'B'P$ Both are similar Hence their ratio of sides are Equal.

$$\frac{A'B'}{AB} = \frac{PA'}{PA} \quad —(2)$$

from Equation (1) and (2)

$$\frac{CA'}{CA} = \frac{PA'}{PA} \quad \text{---} (3)$$

from figure values will be

$CA' = PC - PA' = -R + v$ $\qquad \because v = -v$

$CA = PA - PC = -u + R$ $\qquad \because R = (-R)$

$PA' = -v$ and $PA = -u$

then $\frac{-R + v}{-u + R} = \frac{-v}{-u}$ from (3) Equation

then $-uR + vu = -uv + Rv$

then $2vu = R(v + u)$

Both side divide by $vuR$

then $\frac{2vu}{uvR} = \frac{R(v+u)}{vuR}$

then $\frac{2}{R} = \frac{Rv}{vuR} + \frac{Ru}{vuR}$ and $R = 2f$

then $\Rightarrow$ "$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$" $\Leftarrow$

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- Statement of mirror formula

→ The relation among position of the object $u$, position of image $v$ and focal length $f$ of the mirror is known as mirror formula.

- Important points

1. mirror formula or mirror Equation is same for both concave or convex in all cases.

Imp

2. Every part of a mirror forms a complete image of an object therefore a mirror whose Half part is painted Black forms full size image of an object. (But their Intensity is decreses) Brightness of image depends upon the amount of light reflected by the mirror (the Appartuse of the mirror).

- Linear magnification (m)

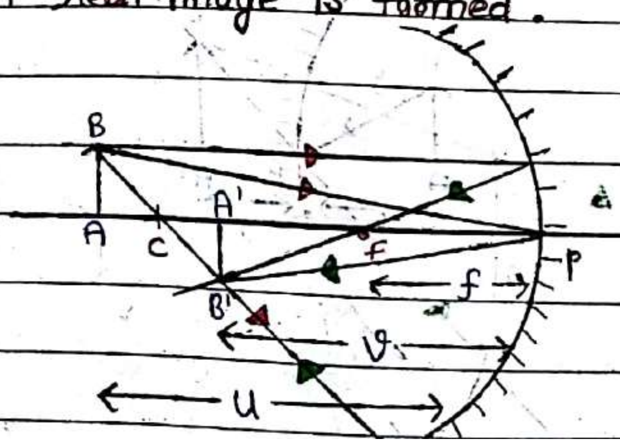
→ Linear magnification produced by mirror is defined as the ratio of the size of image to size of object.

It is denoted by "m".

$$\Rightarrow m = \frac{h_i}{h_o} \begin{matrix} \leftarrow \text{(Height of Image)} \\ \text{(Height of Object)} \end{matrix}$$

- magnification is produced by concave mirror

(A) when real image is formed.



from $\Delta ABC$ and $\Delta A'B'C$

Both are similar. Hence their ratio are Equal.

$$\frac{A'B'}{AB} = \frac{PA'}{PA}$$

and $A'B' = -h_i$ (−ve axis)

and $AB = h_o$ (+ve axis)

$PA' = -v$ and $PA = -u$.

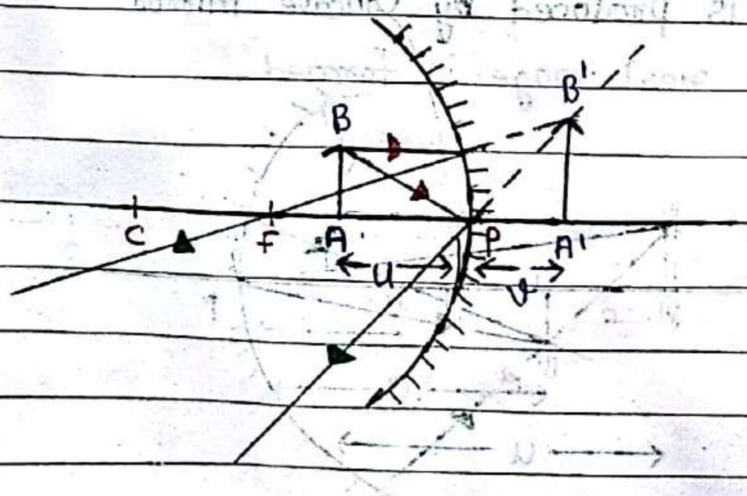
put in (1) Equation

$$\frac{-h_i}{h_o} = \frac{+v}{+u}$$

then $\frac{h_i}{h_o} = \frac{-v}{u}$ and $\frac{h_i}{h_o} = m$

then ⇒ "$m = \frac{-v}{u}$" ⇐

(B) when virtual Image is formed



In $\Delta ABP$ and $\Delta A'B'P$ are Similar then ratio are Equal.

$$\frac{A'B'}{AB} = \frac{PA'}{PA}$$

$A'B' \Rightarrow$ Height of image ($h_i$)
and $AB \Rightarrow$ Height of object ($h_o$)
and $PA' = +v$
and $PA = -u$.

then $$\frac{h_i}{h_o} = \frac{-v}{u}$$

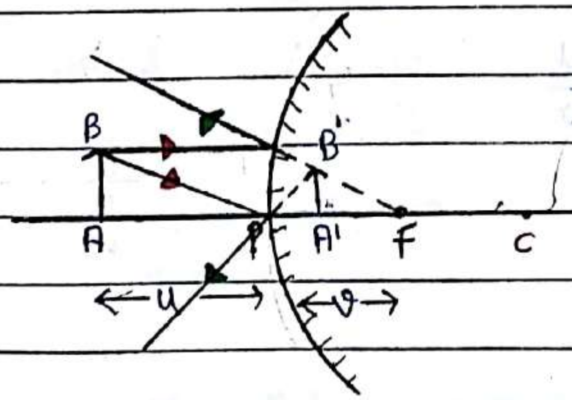
and $$\frac{h_i}{h_o} = m \text{ (linear magnification)}$$

then $\Rightarrow$ "$m = -\frac{v}{u}$" $\Leftarrow$

→ linear magnification is same for Both Cases which is Concave real image or Virtual image.

- Magnification produced by Convex mirror

→




→ In $\Delta ABP$ and $\Delta A'B'P$ are similar. Hence their ratio of Sides are Equal.

then $$\frac{A'B'}{AB} = \frac{A'P}{AP}$$

( mirror → magnification → minus )
( MMM )

( lens → magnification → positive )

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Here $A'B'$ = Height of image
and $AB$ = Height of object
and $PA' = v$ and $PA = -u$

then $\frac{h_i}{h_o} = \frac{-v}{u}$ and $\frac{h_i}{h_o} = m$

then ⇒ " $m = \frac{-v}{u}$ " ⇐

NOTE ⇒ " linear magnification is same for ~~both~~ all spherical mirror in all case. " ⇐

- Magnification in terms of u, v and f (linear magnification) from mirror formula

→ $$\frac{1}{f} = \frac{1}{u} + \frac{1}{v} \quad \text{---(1)}$$

multiply both side by $u$ then

$$\frac{u}{f} = 1 + \frac{u}{v} \quad \text{---(2)}$$

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

$$\frac{u-f}{f} = \frac{u}{v} \quad \text{---(3)}$$

reverse the term

then $\dfrac{f}{u-f} = \dfrac{v}{u}$

multiply both side by (−) minus

$\dfrac{-f}{\cancel{v}-\cancel{f}} = \dfrac{-v}{u}$ and $\dfrac{-v}{u} = m$

then $\Rightarrow$ "$m = \dfrac{f}{\cancel{u}-f-u}$" $\Leftarrow$

the from mirror formula.

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

Both side multiply by $v$

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

then $\dfrac{v}{f} - 1 = \dfrac{v}{u}$

then $\dfrac{v-f}{f} = \dfrac{v}{u}$

Both side minus multiply

$\dfrac{-v}{u} = \dfrac{f-v}{f}$

then $\Rightarrow$ "$m = \dfrac{f-v}{f}$" $\Leftarrow$

**NOTE** ⇒ "When mirror is imersed into liquid its focal length does not change." ⇐

**NOTE** ⇒ "focal length of plane mirror is infinite and radius of curvature is also infinite." ⇐

- Important Points for Numericals

1. When $m > 1$ (−ve)

$\uparrow h_o$

$\downarrow h_i$ (inward = −ve)

2. When $m < 1$ (−ve)

$\uparrow h_o$

$\downarrow h_i$

∵ $u$ is always Negative

∵ focal length of Concave mirror is negative

∴ focal length of Convex mirror is positive.

∴ for Convex mirror $v$ is always positive

3. $m > 1$ (+ve)

$\uparrow h_o$ $\uparrow h_i$

4. $m < 1$ (+ve)

$\uparrow h_o$ $\uparrow h_i$

5. $m = 1$ (+ve)

$\uparrow h_o$ $\uparrow h_i$ ∵ In Case of plane mirror.

## Numerical

Q. Find the position of object when placed in front of a convex mirror of focal length 20cm produces a virtual image which is half the size of the object.

Sol$^n$ $u = ?$ and $f = +20cm$

and $m = \frac{1}{2}$ —(1)

and $m = \frac{-v}{u} = \frac{1}{2}$ from (1) Equation

then $-2v = u$

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

then $\frac{1}{20} = \frac{1}{v} + \frac{1}{-2v}$

then $\frac{1}{20} = \frac{-2+1}{-2v} = \frac{+1}{2v}$

then $v = 10$ cm.

from (1) eq

then $-2v = u$ then $u = -2 \times 10 = -20cm.$

Q. An object 0.04m High is placed at a distance of 0.8 m from a concave mirror of Radius of Curvature 0.4 m find the position, nature and size of the image

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Reflection :- 1 medium

Refraction :- 2 medium

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Sol$^n$ $h_o = 4cm$ and $u = -80cm$ , $R = -40cm$ .

and $f = -20$ cm $R = 2f$

then $-\frac{40}{2} = f$

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

then $\frac{-1}{20} = \frac{-1}{80} + \frac{1}{v}$

then $v = -26.67$ cm

nature :- real and inverted.

and $m = \frac{h_i}{h_o} = \frac{-v}{u}$

then $h_i = \frac{-v.h_o}{u} = \frac{26.67 \times 4}{-80}$

then $h_i = -1.13$ cm (real and inverted)

Ques An object is kept in front of a concave mirror of focal length $-20$cm. The image forms the 3 times the size of object. Calculate the possible distance of object from the mirror.

Sol$^n$ CASE 1 If image is real

then $m = -3$ and $f = -20$cm

then $\cancel{+}\frac{v}{u} = \cancel{+}3$ then $v = 3u$

Speed of light is $3\times10^8$ (Vaccum) $= \frac{3}{2.2} = 1.33$ time ↓ decrease
in water is $2.2\times10^8$ — Refractive index

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Glass $= 2\times10^8$ $\left(\frac{3}{2} = 1.5 \downarrow\right)$

Vaccum > Air > water > Glass is Ratio order

then $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ and $v = 3u$ then

then $\frac{1}{f} = \frac{1}{u} + \frac{1}{3u}$ and $f = -20\text{cm}$

then $u = -26.6$ cm.

CASE 2 If image is Virtual
then $m = 3$ and $f = -20\text{cm}$

then $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ and $\frac{-v}{u} = 3$

then $v = -3u$

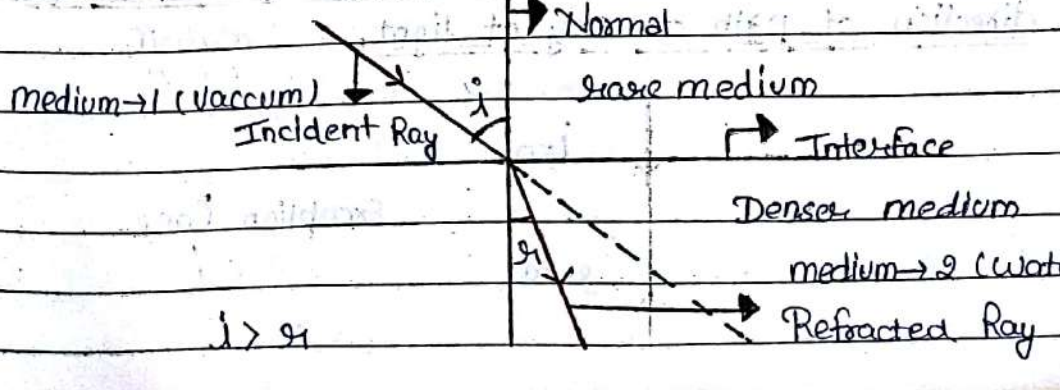
then $-\frac{1}{20} = \frac{1}{u} - \frac{1}{3u}$

then $u = -13.33$ cm.

**Part :- 2**

• **Refraction of Light**

➤ The phenomenon of change in the direction of path of light when it goes from one medium to another medium is called Refraction of light



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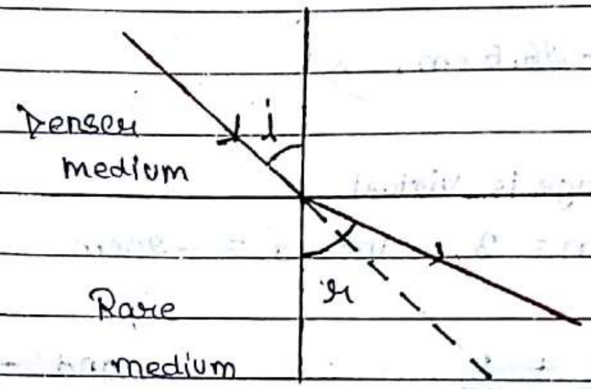
"⇒ when a ray of light Goes from rare medium to denser medium it bends towards the Normal." ⇐

"⇒ When a ray light Goes from denser medium to rare medium it bends away from the Normal." ⇐

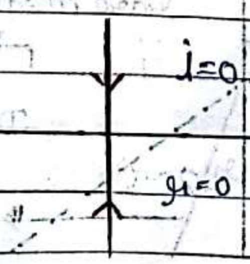



• **Cause of Refraction of light**

The refraction of light occurs Because of the fact that speed of light changes when it Goes from one medium to another medium. speed of light in rare medium is Greater then Speed of light in denser medium.

When light travels from a rare medium to denser medium its speed decreses and Hence light deviates more due to interaction with denser medium.

NOTE: For a ray of light incident normally there is no change in the direction of path of ray of light.




Exception Case.

## Refractive index of medium

### (1) Absolute Refractive index (One medium is surely fixed)

- Absolute Refractive index of a medium can be defined as the ratio of speed of light in vaccum to speed of light in another medium.

It is denoted by $n$ or $\mu$.

i.e., $\frac{c}{v} = \mu$ Example $\mu = \frac{3\times10^8}{2.2\times10^8}$ (water) $= 1.33$ times

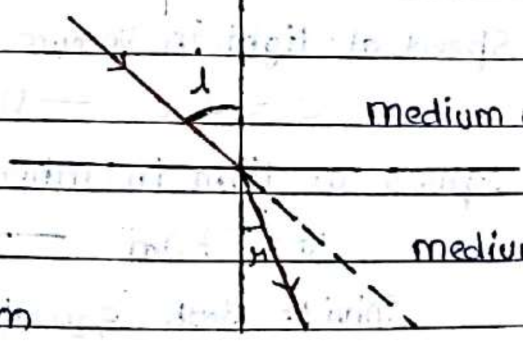
and Refractive index is dimensionless and unitless.
And it is just a number.

and $c$ is always greater then $v$ then
$\mu \geq 1$.

### (2) Relative Refractive index (medium not fixed)

- If light ray goes from one medium to another medium then refractive index of medium 2 with respect to medium 1 is given as the ratio of speed of light in medium 1 ($v_1$) to speed of light in medium (2) → ($v_2$).

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




- relative refractive index of one with respect to medium two which is $^2\mu_1$.

- **Relation Between Relative refractive index OR Absoulte Refraction Refractive index.**

→ If light ray come from medium one to medium two then relative refractive index

$${}^{1}\mu_2 = \frac{v_1}{v_2} \quad \text{---(1)}$$

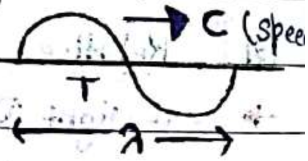
and $${}^{1}\mu_2 = \frac{v_1}{v_2} \times \frac{c}{c} \quad \text{---(2)}$$ multiply and divide of c

and $\mu_1 = \frac{c}{v_1}$ ---(A) and $\frac{v_1}{c} = \frac{1}{\mu_1}$ ---(B)

and $\mu_2 = \frac{c}{v_2}$ ---(B) put both value in (2) eq.

then ⇒ "$${}^{1}\mu_2 = \frac{\mu_2}{\mu_1}$$" ⇐

Rough work




- **Relation Between wavelength of light in Vaccum and medium**

$C = \frac{\lambda}{T} = \lambda f$

If c ↑ then λ

and f ⇒ (c

then $c = \lambda f$

and f = v

→ Speed of light in Vaccum

$$c = f\lambda \quad \text{---(1)}$$

speed of light in other medium

$$v = f\lambda_m \quad \text{---(2)}$$

Divide Both Equation then

$$\frac{c}{v} = \frac{\lambda}{\lambda_m} \quad \text{---(3)}$$ and ∵ $\frac{c}{v} = \mu$

then ⇒ "$$\mu = \frac{\lambda}{\lambda_m}$$" ⇐

→ And $\lambda = \mu \lambda_m$
means $\lambda > \lambda_m$

⇒ "It means that wavelength of light decreses when it goes from Vaccum to other medium." ⇐

• **Important Points**

1. In Refraction frequency and phase of light do not change while wavelength and velocity of light change.

Q What is the speed of light in medium whose refractive index is $\frac{3}{2}$. Given speed of light in Vaccum = $3 \times 10^8$ m/s.

Sol$^n$ Here $\mu = \frac{c}{v}$ and $c = 3 \times 10^8$ m/s
and $v = ?$ and $\mu = \frac{3}{2}$.

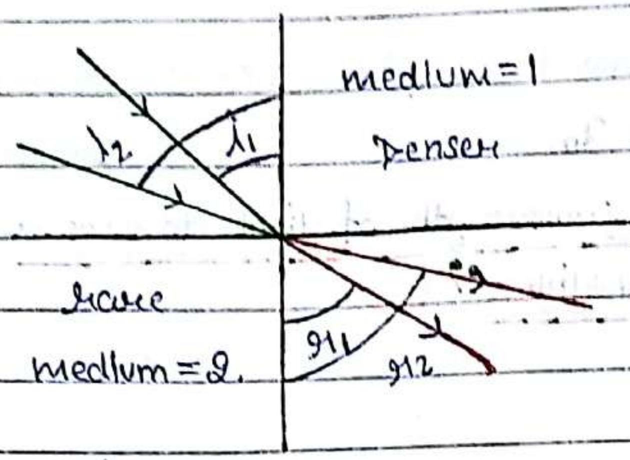
then $\frac{3}{2} = \frac{3 \times 10^8}{v}$ then $v = 2 \times 10^8$ m/s

• **Laws of Refraction of Light**

1. The incident ray, the Refracted Ray and the Normal to the interface at the point of incidence lie in the same plane. They all are coplaner.

2. The ratio of the sine of Angle of incidence to the sine of Angle of reflection is constant. And this constant is known as Relative refractive index (${}^1\mu_2$)

$\frac{\sin i_1}{\sin r_1} = k$ and $\frac{\sin i_2}{\sin r_2} = k = {}^1\mu_2$ and $\frac{\sin i_n}{\sin r_n} = {}^1\mu_2$




then $\frac{\sin i}{\sin r_1} = {}^1\mu_2$

then $\frac{\sin i}{\sin r} = {}^1\mu_2 = \frac{\mu_2}{\mu_1}$

then $\Rightarrow$ "$\mu_1 . \sin i = \mu_2 . \sin r$" $\Leftarrow$

This Equation is known as <u>Snell's Law</u>.

- **Principal of Reversibility**

<u>Prove</u> :- ${}^1\mu_2 = \frac{1}{{}^2\mu_1}$

${}^1\mu_2 = \frac{\mu_2}{\mu_1}$ —(1) and ${}^2\mu_1 = \frac{\mu_1}{\mu_2}$ —(2)

and from (2) Eq.

$\because {}^1\mu_2 = \frac{\mu_2}{\mu_1}$

$\frac{1}{{}^2\mu_1} = \frac{\mu_2}{\mu_1}$ —(3)

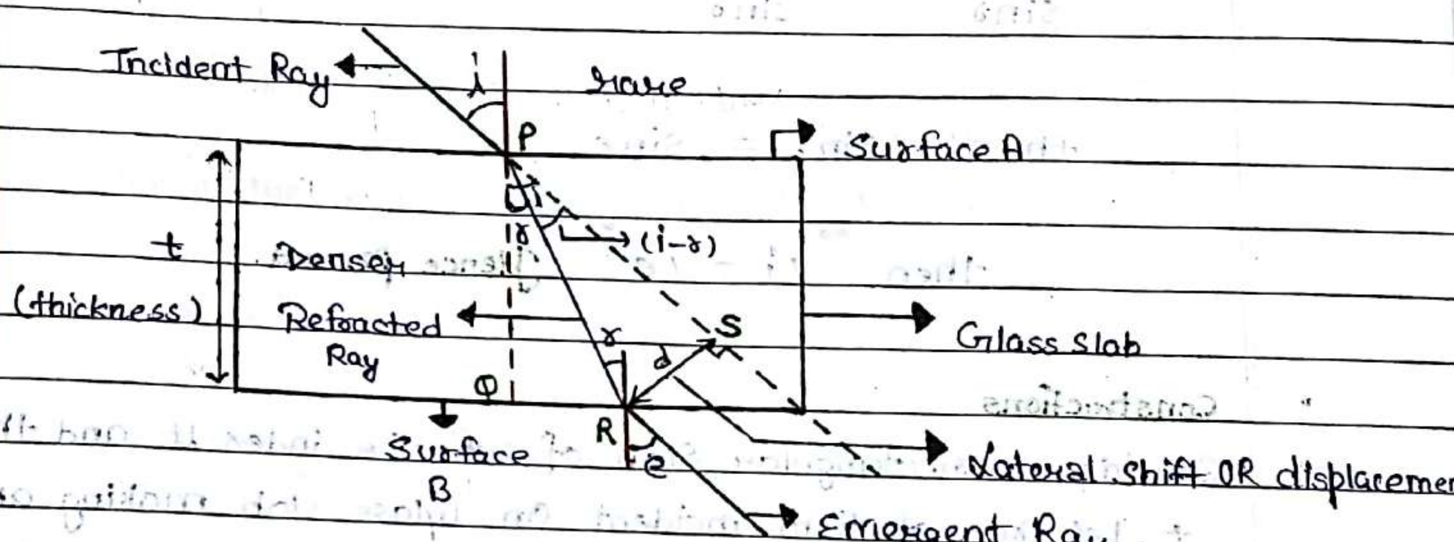
Compare (1) and (3)

$\Rightarrow$ "$\frac{1}{{}^2\mu_1} = {}^1\mu_2$" $\Leftarrow$

Q Find the relative refractive index of Glass with respect to water.

Sol$^n$ $^{w}\mu_g = \frac{\mu_g}{\mu_w} = \frac{1.5}{1.33} = 1.1$ $\therefore \mu_g = 1.5$
$\therefore \mu_w = 1.33$

- **Refraction of light through Glass slab (Lateral Refraction) (Shift)**




**Proove** "$\angle i = \angle e$"

from Snell's Rule At Surface A

$$^{1}\mu_2 = \frac{\sin i}{\sin r} \quad -(1)$$

then $\frac{\mu_2}{\mu_1} = \frac{\sin i}{\sin r}$ —(2) and $^{1}\mu_2 = \frac{\mu_2}{\mu_1}$

from Snell's Rule At Surface B

$$^{2}\mu_1 = \frac{\sin r}{\sin e} \quad -(3)$$

$$\frac{\mu_1}{\mu_2} = \frac{\sin r}{\sin e} \quad -(4)$$ By $\therefore$ Now reverse the term

then $\frac{\mu_2}{\mu_1} = \frac{\sin e}{\sin r}$ — (5)

By Equating (5) and (2)

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

then $\sin i = \sin e$

then "$\angle i = \angle e$" Hence proved.

- **Constructions**

→ Consider a rectangular slab of refractive index $\mu$ and thickness t. let ray of light incident on Glass Slab making an angle i with normal. After refraction through the Glass Slab it bends towards the normal and when it Emergent through the Glass slab it moves away from the Normal and parallel to the incident ray.

⇒ "A ray of light incident Obliquely on the parallel Side Glass Slab Emerges out parallel to the Incident ray."

- **lateral Shift**

→ Perpendicular distance Between incident and Emergent ray is known as lateral shift OR lateral displacement.

from figure :-

In $\Delta PRS$

then $\sin(i-r) = \frac{RS}{PR}$ —(1) and $RS = d$

then $\sin(i-r) = \frac{d}{PR}$ —(2)

then ~~sin~~ ~~PR~~ $d = \sin(i-r) \cdot PR$ —(3)

In $\Delta PQR$

$\cos r = \frac{PQ}{PR}$ —(4)

then $PR = \frac{PQ}{\cos r} = \frac{t}{\cos r}$ —(5) $\therefore PQ = t$

put Value of (5) Equation in (3) Equation

then $PR \sin(i-r) = d$ —(6)

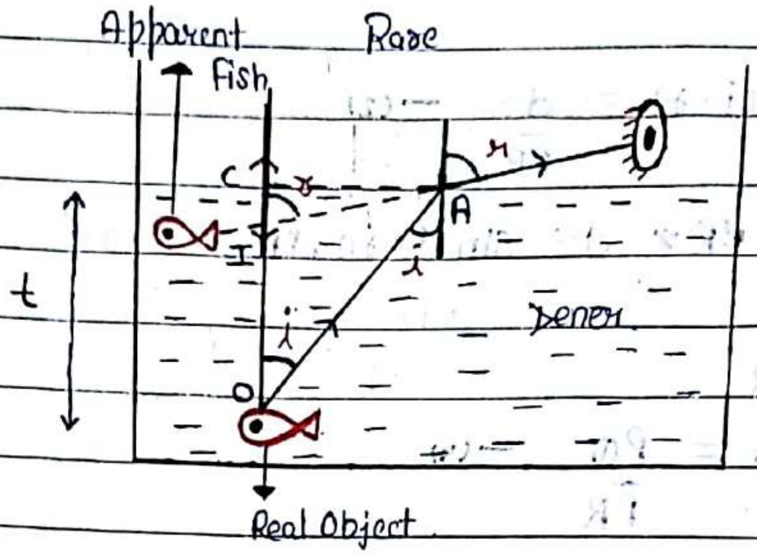
then $\frac{t \cdot \sin(i-r)}{\cos r} = d$

then ⇒ " $d = \frac{t \cdot \sin(i-r)}{\cos r}$ " ⇐

- **Show that the Bottom of Water tank Appears to be raised And find An Expression for the Normal shift In the position of Object Placed in a denser medium.**

→ Consider a tank filled with water upto the level. let an object O lies at the bottom of the water tank the depth CO = t of the object is known as the real depth.

→ And CI is known as Apparent depth OR Virtual depth.




(Ray of light is from Denser to Air)

According to Snell's law

$$^{w}\mu_a = \frac{\sin i}{\sin r}$$

then $\frac{\mu_a}{\mu_w} = \frac{\sin i}{\sin r}$ — (1)

from $\Delta OCA$

then $\sin i = \frac{CA}{AO}$ — (2)

and in $\Delta CIA$

then $\sin r = \frac{AC}{AI}$ — (3)

then put value of (2) and (3) in (1) Equation

then $\frac{\mu_a}{\mu_w} = \frac{CA}{AO} \times \frac{AI}{AC}$

then $\frac{\mu_a}{\mu_w} = \frac{AI}{AO}$ — (4)

If point A and C are near to Each Other

then $AI \simeq CI$

and $AO \simeq CO$

then from (4) Equation.

$$\frac{\mu_{air}}{\mu_{water}} = \frac{CI}{CO} \quad \text{and } \mu_{air} = 1$$

(Refractive Index)

then $\frac{1}{\mu_w} = \frac{CI}{CO}$ $\qquad \mu_w = \mu$

then "$\Rightarrow \mu = \frac{CO}{CI}$" $= \frac{\text{Real depth}}{\text{Apparent depth}}$ ⇐

**Normal Shift (x)**

$x$ = Real depth (CO) − Apparent depth (CI)

then $x = CO - CI$ —(1)

when $CO \Rightarrow$ common

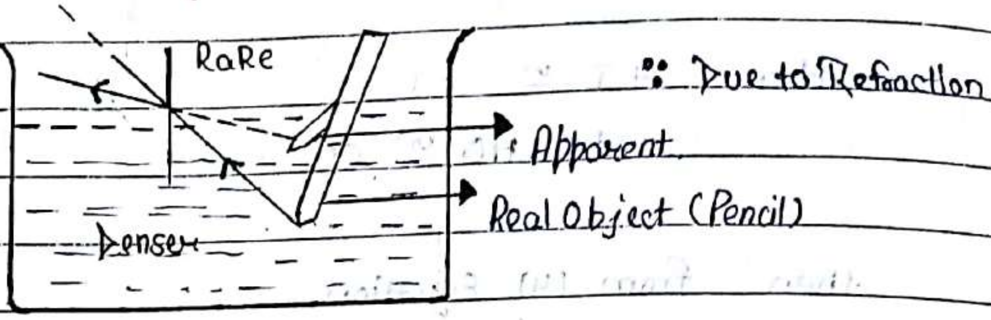
then $x = CO\left[1 - \frac{CI}{CO}\right]$ and $\frac{CI}{CO} = \frac{1}{\mu}$

then "$\Rightarrow x = t\left[1 - \frac{1}{\mu}\right]$" ⇐ $\qquad$ and $CO = t$

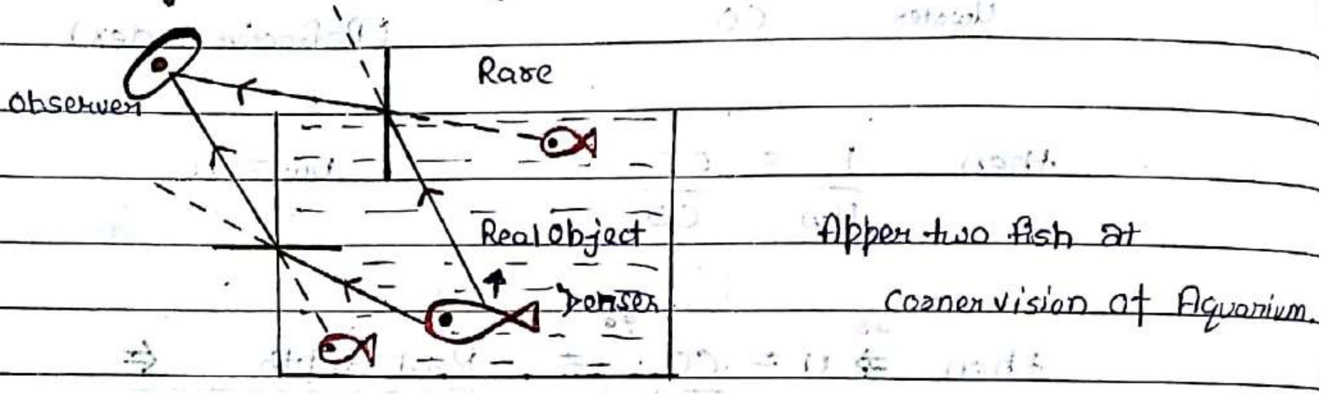
It is defined as the difference Between Real depth and Apparent depth.

(2-mark)

• Bending of an Emerge portion of an Object



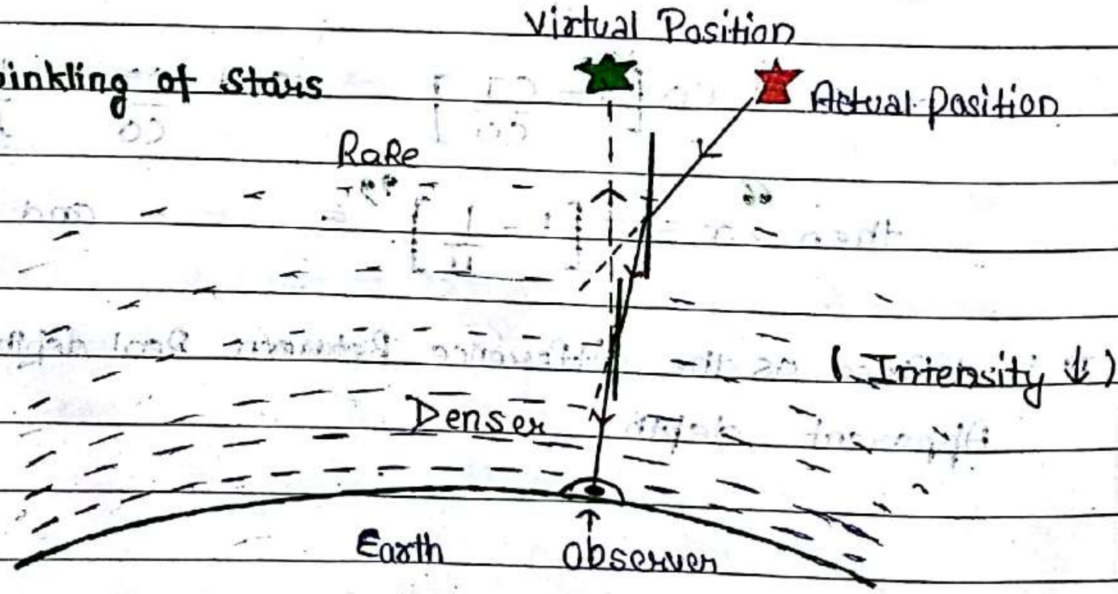

• Visibility Of two Images of An Object floating inside water




• Atmospheric Refraction

→ The Bending of light from its direction of Propagation through atmosphere is Called Refraction of light through atmosphere OR Atmospheric Refraction of light.

(1) Twinkling of Stars

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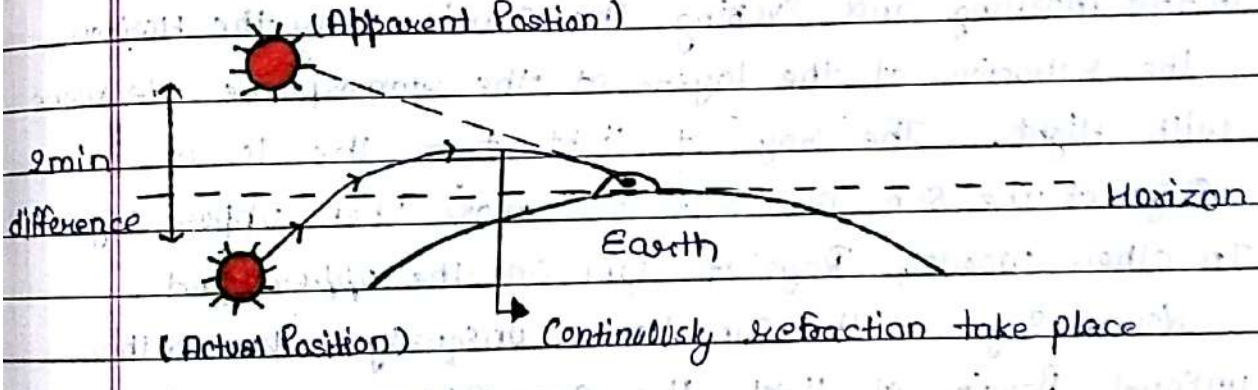
→ The light Emitted By Stars is refracted Continuosly by the different layer of the atmosphere Before it reaches the Earth.

→ Due to repeated Refraction of light through the atmosphere the Apparent position of Star is different from it Actual Position. Since the temperature and density of atmosphere are changing Continuosly and the atmosphere is mobile (motion). So the Apparent position of Star also changes Continuosly. This Continouse change in the Apparent position of Star leads to the twinkling of stars.

(2) Time difference during Sunrise and Sunset




→ Sun is visible to an observer after the actual Sunset Because of refraction of light due to denser atmospher near the Earth.

→ Due to refraction of light Sun is apparently shift Half degree. And due to these their is 2 min delay in actual and apparent Sunset.

$24\ hour = 360^\circ$ (Rotation of Sun with respect to Earth)

then $1^\circ = \frac{24\ h}{360} = \frac{1}{15}\ h$

→ and in minute.

$$1^\circ = \frac{60 \text{ min}}{15} = 4 \text{min}$$

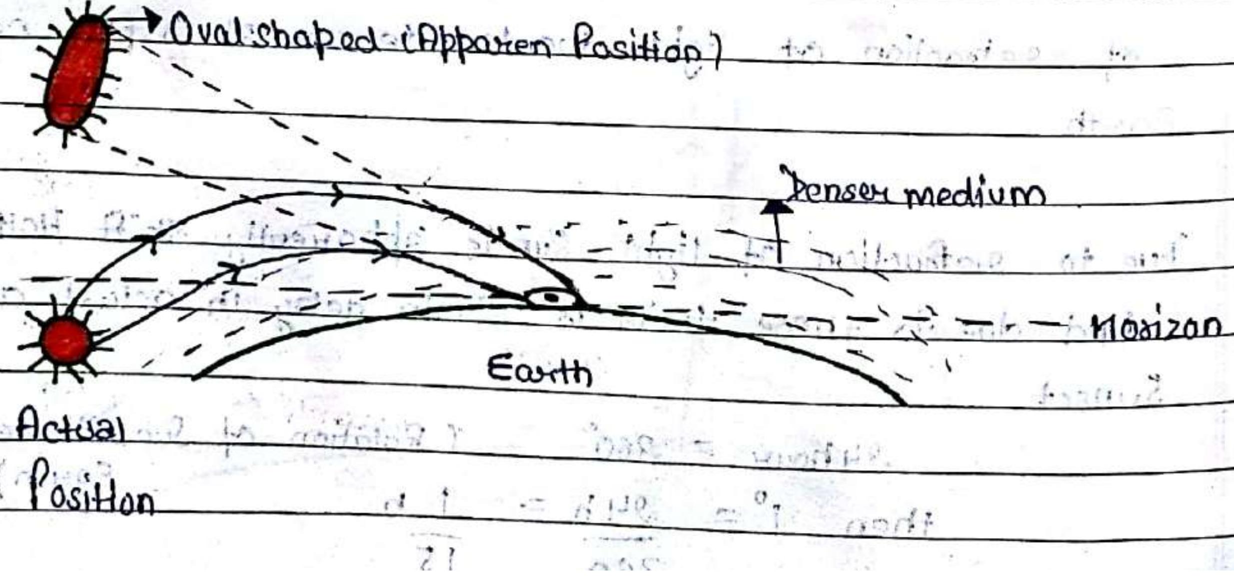
and for Half degree

$$1/2^\circ = 2 \text{min}.$$

→ for the Same reason Sun Appears to rises about 2 minute Before the actual Sunrise. Hence day is increses by 4 minutes.

(3) Sun Appears Oval Shaped At Morning And Evening
( flattening of the Sun )

→ In the morning and Evening the sun is near the Horizon the refractive of the layers of the atomosphere decreses with Hight. The rays of light from the lower Edge of the Sun are refracted more then upper edge. In other words, Rays of light on the upper and lower Edge of the sun bends unequally. Due to this unequal Bending of light the sun Appears oval in Shaped.



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Imp

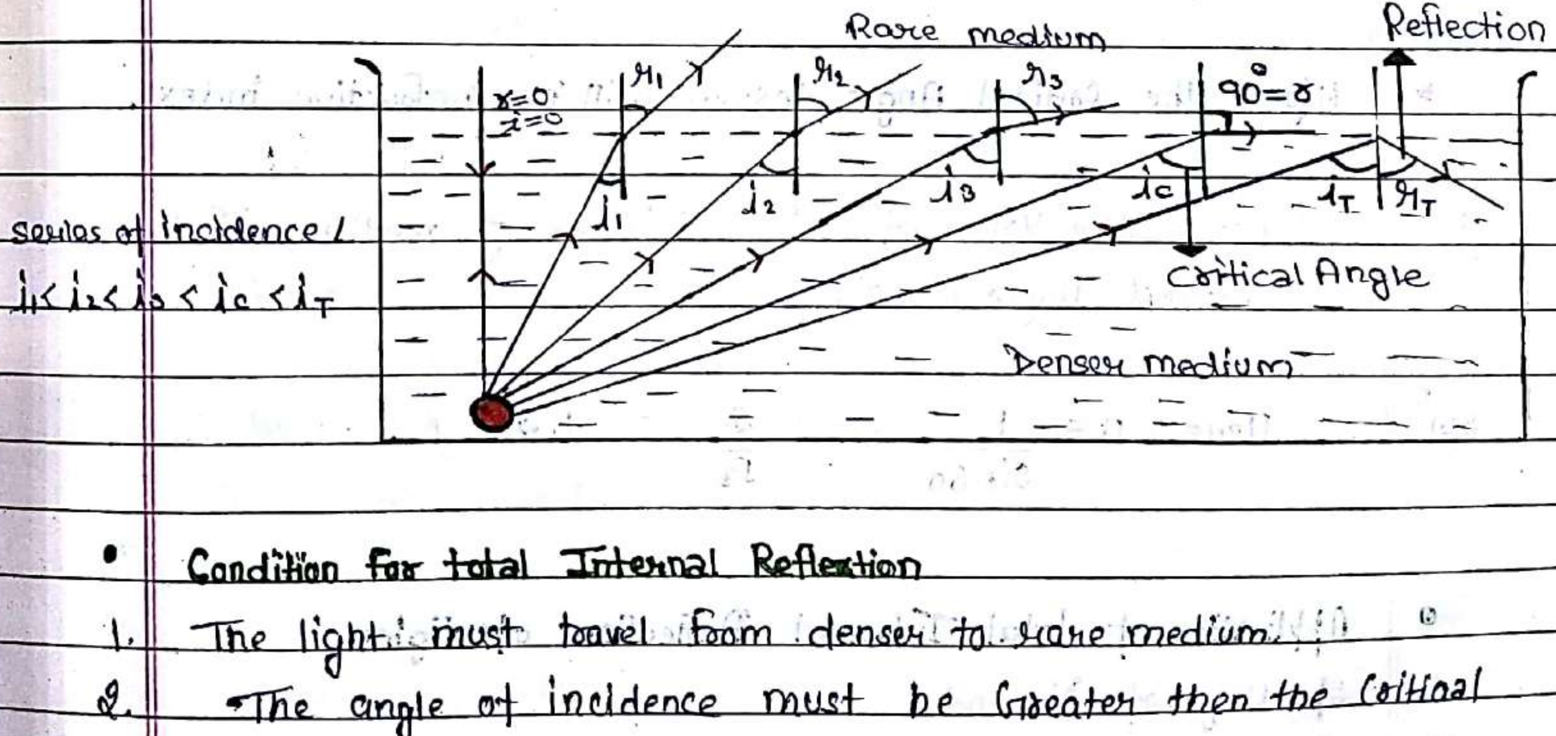
- **Total internal Reflextion (TIR)**

→ The phenomenon due to which a ray of light travelling from a denser medium to a rare medium is send back to the Same denser medium provided that the incident angle should be Greater then the Critical angle ($i_c$) is Called total Internal Reflextion of light.

→ The angle of incidence Corresponding to which angle of refrection is become 90° is Called Critical Angle. $i = i_c$ when $r = 90°$

- **Another defination of TIR**

→ When the Angle of Incidence becomes Greater then the Critical Angle there is no refraction of light and whole of the incident light is reflected back to the denser medium this phenomenon known as total Internal Refraction.




- **Condition for total Internal Reflextion**

1. The light must travel from denser to rare medium.
2. The angle of incidence must be Greater then the Critical Angle.
3. After $r = 90°$ then next $r$ angle will be reflection

Diamond (Refractive index) = 2.4 then $\frac{3\times10^8}{2.4}$ = 0.7 ...

$\mu = 2.4$
$i_c = 24.4^\circ$ (more than cutting) upper shining

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- Relation Between Refractive index of medium And Critical Angle

from Snell's Rule

$$\frac{\sin i}{\sin r} = {}^2\mu_1 = \frac{\mu_1}{\mu_2} \quad \text{(Denser to rare)}$$

and $\mu_1 = \text{Air} = 1$

and $\mu_2 = \text{water} = \mu$

and when $i = i_c$ then $r = 90$

then $\frac{\sin i_c}{\sin 90^\circ} = \frac{1}{\mu}$ $\quad \because \sin 90^\circ = 1$

$\therefore \mu = \frac{1}{\sin i_c}$

then $\Rightarrow$ " $i_c = \sin^{-1}\left(\frac{1}{\mu}\right)$ " $\Leftarrow$

→ Critical Angle is inversely propotional to the refractive index of medium.

→ Higher the Critical Angle lesser will be refractive index.

**Q** What is the value of Refractive index of medium if the Critical Angle is 60°.

**Sol$^n$** Here $\mu = \frac{1}{\sin 60} = \frac{2}{\sqrt{3}} = 1.2$

- **Application of total Internal Reflection of light**

1. **Sparkling of Diamond**

→ Sparking of diamond, the Brillience (Shine) of diamond is due to the total internal refloxtion of light.

The refractive index of Diamond is 2.4 and its Critical Angle is 24.4°c.

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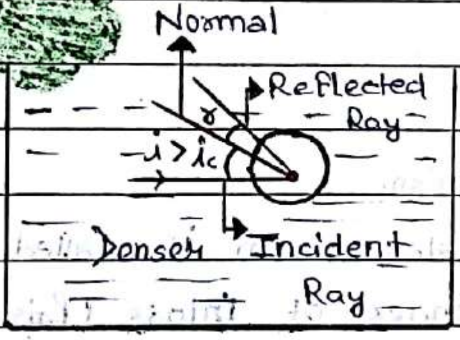
→ A natural diamond Hardly show any Brillience (Shining). It is the Special Cutting of diamond by a jewellar which makes it to Shine.

→ The Phases of a diamond are Cut In Such a way that whenever light falls on any of the phases the Angle of incidence is Greater than the Critical Angle of diamond Air interface.

**(2) Shining of Air Bubble In water**

→ When light propogating from water and incident on the Surface of Air Bubble at angle angle which is Greater then 48°45' the total Internal Reflextion takes place and Air Bubble Shine.




incident ray and reflecting ray not touch at Centre of Air Bubble.

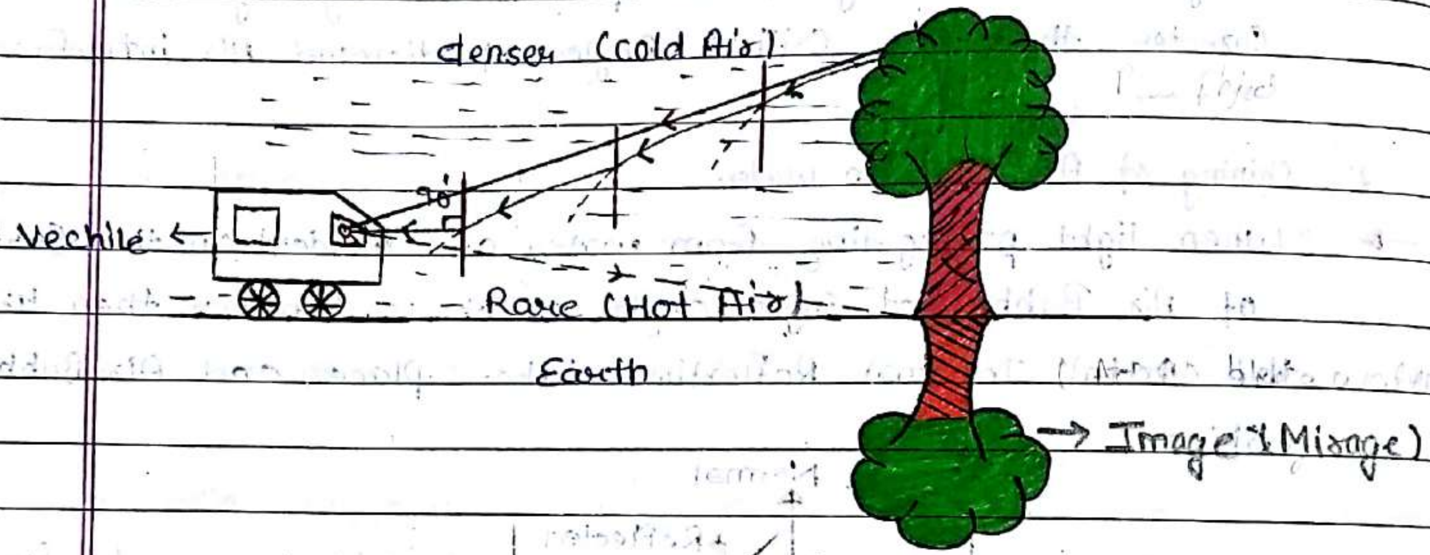
**(3) Mirage**

→ Mirage is an optical illusion of water observed Generally in Deserts. when an inverted image of an object is observed along with Object itself on a Hot day.

→ The Surface of Earth Becomes Very Hot On a Hot Summer day Therefore the density of layer of Air near Surface of Earth decreses. And it behaves as rare medium with respect to far layer of Air.

→ When the rays of light from the distinct Object (tree) travel

towards the Observer on the Surface of Earth they Bend more and more and away from normal.
And When the angle of Incidence is Greater then the Critical Angle then the ray of light Suffer total internal Reflextion.




(4) Totally Reflecting Prism

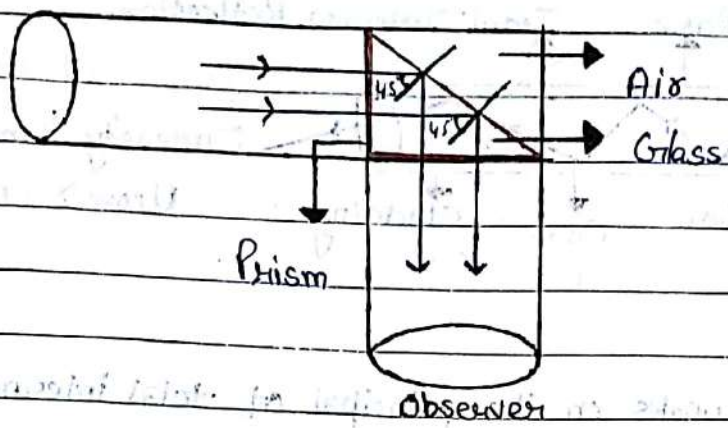
A right angle isoscales Prism is Called totally reflecting Prism. The refractive index of Glass (Prism) is 1.5 therefore the Critical Angle for Glass-Air interface is 41.8°.

then $i_c = \sin^{-1}\left(\frac{1}{u}\right)$ and $u = 1.5$

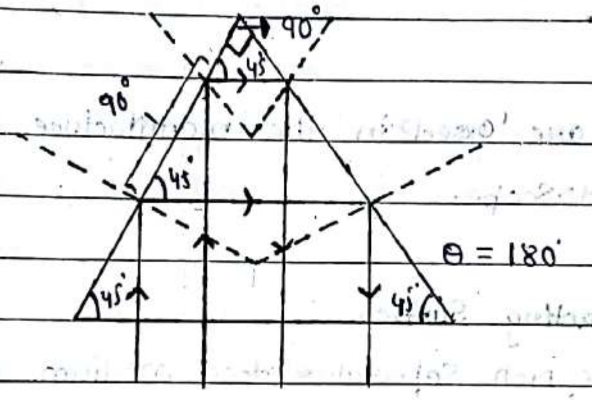
"then $i_c = 41.8°$" → Glass.

When the ray of light falls on the face of a right angle Prism at an angle Greater then 41.8° it will suffer total internal reflextion.

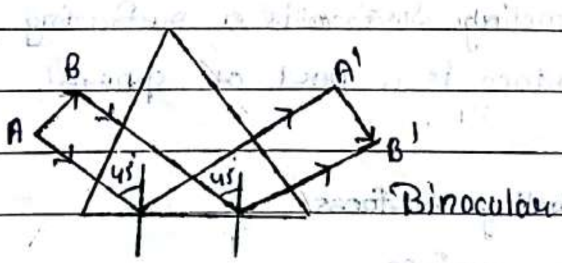
A) Right Angle prism used to deviate the ray of light through 90°. This type of prism is used in periscope.




(B) Right angle prism used to deviate the rays of light through 180°. This type of Prism is known as Porro prism.




(C) Right angle prism is used to invert the image of an object without changing its sides. This type of prism is used in Binoculars.




(5) **Optical fibre**

→ Optical fibre is an Extremely thin and long Strand (thread) of very fine Quality Glass. The thin fibre of Optical fibre is Called Core the Coating or Surrounding of optical fibre is known as cladding.

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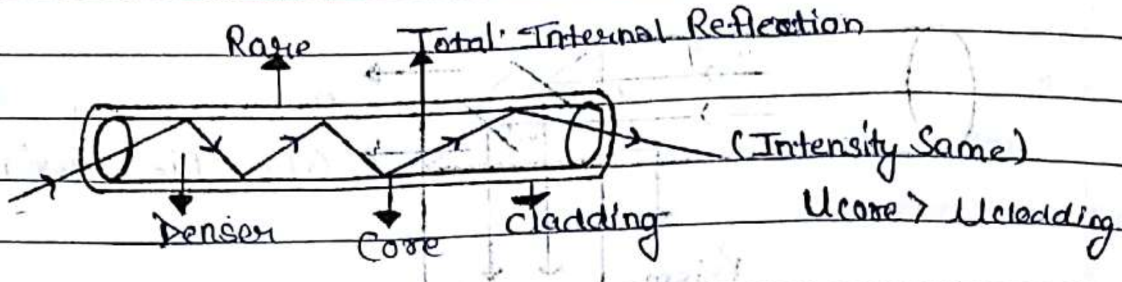



- Principal

→ Optical fibre works on the principal of total internal reflextion of light.

→ Optical fibres are used to transmitt light without any loss in its Intensity.

→ Optical fibres are used in the manufacture of medical instrument Called Endoscope.

- **Spherical Refracting Surface**

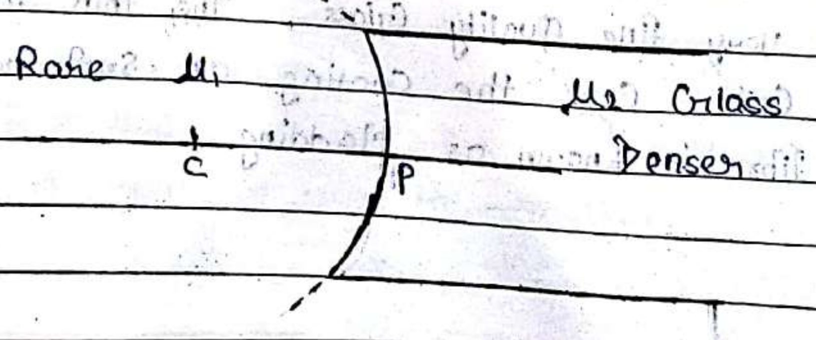
→ A Surface which separates two medium of different refractive index is Called Refracting Surface.

→ Spherical Refracting Surface is a refracting medium whose Curved Surface is a part of sphere.

- **Types of Refracting Surfaces**

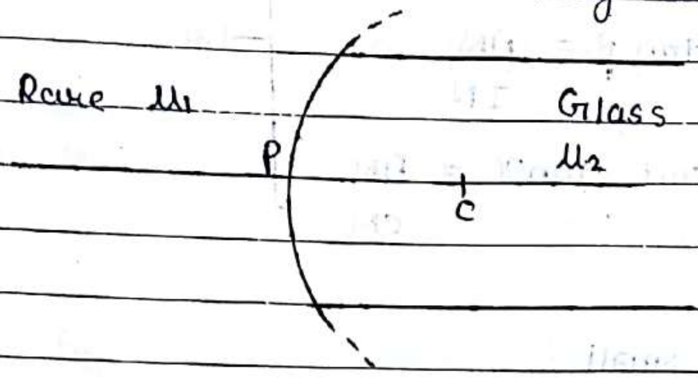
1. **Concave Refracting Surface**

→ A Spherical Refracting Surface which is Concave towards rare medium is Called Concave refraction spherical SurfacE.



(2) Convex Refracting Surface

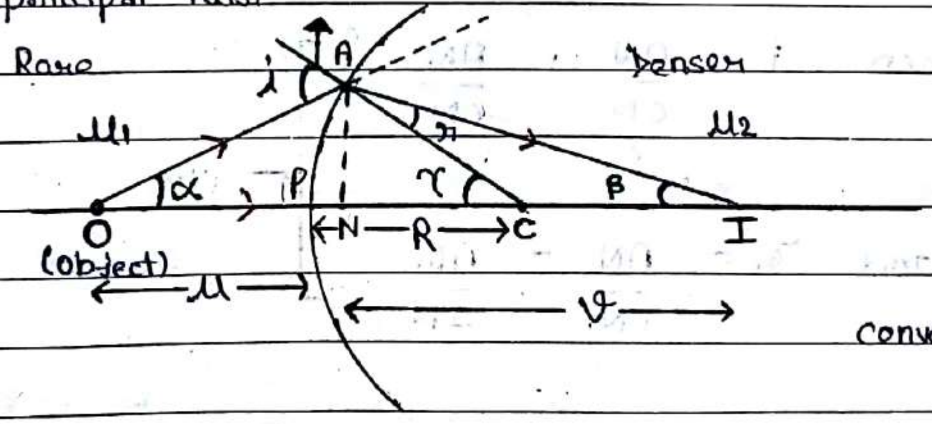
→ A spherical Refracting Surface which is Convex toward rare medium is Called Convex Refracting Surface.




Imp • **Refraction at a Convex Refracting Surface when observer or object lies in rarer medium.**

→ Consider a Convex spherical Refracting Surface of refractive index $\mu_2$. let it be placed in a rarer medium of refractive Index $\mu_1$.

→ A Object O lies on the principal axis at distance $u$ in rarer medium. let $\alpha, \beta,$ and $\gamma$ be the angles made by incident ray, refracted ray and the normal respectively with the principal Axis.




convex spherical Surface

→ from $\Delta AOC$

Exterior Angle = Sum of Interior Angle

$$i = \alpha + \gamma \quad \text{---(1)}$$

from $\Delta ACI$

then $\gamma = r + \beta$ then $r = \gamma - \beta$ ---(2)

from figure $\theta$ will be

$$\left.\begin{aligned} \tan\alpha &= \frac{AN}{ON} \\ \text{and } \tan\beta &= \frac{AN}{IN} \\ \text{and } \tan\gamma &= \frac{AN}{CN} \end{aligned}\right] \text{---(3)}$$

If angles is small

then $\tan\alpha \simeq \alpha$ and $\tan\beta \simeq \beta$

and $\tan\gamma \simeq \gamma$

from Equation (3)

then $\alpha = \frac{AN}{ON}$ and $\beta = \frac{AN}{IN}$ and $\gamma = \frac{AN}{CN}$

put value of $\alpha$, $\beta$ and $\gamma$ in Equation (1) and (2)

$$\left.\begin{aligned} \text{then } i &= \frac{AN}{ON} + \frac{AN}{CN} \\ \text{and } r &= \frac{AN}{CN} - \frac{AN}{IN} \end{aligned}\right] \text{---(4)}$$

By using Snell's law

$$\frac{\sin i}{\sin r} = {}^1\mu_2 = \frac{\mu_2}{\mu_1}$$

then $\mu_1 \sin i = \mu_2 \sin r$ —(A)

If angle is small then $\sin i \simeq i$ and $\sin r \simeq r$

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then put of Angle in (A) Equation

then $\mu_1 i = \mu_2 r$ —(5)

put Value of $i$ and $r$ in Equation (5)

then $\mu_1 \left[ \frac{AN}{ON} + \frac{AN}{CN} \right] = \mu_2 \left[ \frac{AN}{CN} - \frac{AN}{IN} \right]$

By taking AN Common from Both side

then $\mu_1 . AN \left[ \frac{1}{ON} + \frac{1}{CN} \right] = \mu_2 . AN \left[ \frac{1}{CN} - \frac{1}{IN} \right]$

If points P and N are near to Each other.

then $ON \simeq OP$ and $CN \simeq CP$

and $IN \simeq IP$

then $\mu_1 \left[ \frac{1}{OP} + \frac{1}{CP} \right] = \mu_2 \left[ \frac{1}{CP} - \frac{1}{IP} \right]$

from figure $OP = -u$ and $CP = R$

and $IP = v$

then $\mu_1 \left[ \frac{-1}{u} + \frac{1}{R} \right] = \mu_2 \left[ \frac{1}{R} - \frac{1}{v} \right]$

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

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

multiply by (-ve) Both side

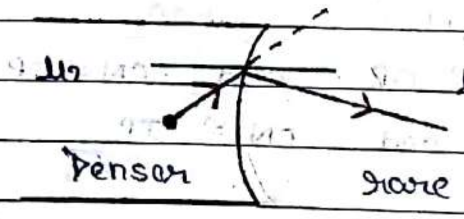
then $\frac{\mu_1}{u} - \frac{\mu_2}{v} = \frac{\mu_1}{R} - \frac{\mu_2}{R}$

then $\Rightarrow$ "$\frac{\mu_1}{u} - \frac{\mu_2}{v} = \frac{\mu_1 - \mu_2}{R}$" $\Leftarrow$

- **Refraction formula (Short trick)**

→ when ray of light Goes from rare to denser then "$\frac{\mu_1}{u} - \frac{\mu_2}{v} = \frac{\mu_1 - \mu_2}{R}$"

→ and when ray of light Goes from denser to rare




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

Q. light from a point Source in air falls on a Spherical Glass Surface ($\mu = 1.5$) of radius of Curvature 20cm. The distance of Source from Glass is 100cm at what position will the Image be formed. (Convex)

Sol. $u = -100\text{cm}$ (object distance)

$v = ?$ $\quad\therefore R = +20\text{cm}$

$\frac{\mu_1}{u} - \frac{\mu_2}{v} = \frac{\mu_1 - \mu_2}{R}$ $\quad\therefore \mu_1 = 1$

$\therefore \mu_2 = 1.5$

then $-\frac{1}{100} - \frac{1.5}{v} = \frac{1-1.5}{20}$

then $-\frac{1}{100} + \frac{0.5}{20} = \frac{1.5}{v}$

then $v = 100\,cm$. Ans

Q. If a point object is placed in Air at a distance of 40cm from a Concave Refracting Surface of material of refractive index 1.5, find the position of image if R = 10cm

Sol$^n$ $R = -10\,cm$ and $\mu_2 = 1.5$ and $\mu_1 = 1$
and $u = -40\,cm$

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

then $-\frac{1}{40} - \frac{1.5}{v} = \frac{1-1.5}{-10} = \frac{0.5}{10}$

then $-\frac{1}{40} - \frac{0.5}{10} = \frac{1.5}{v}$

then $v = -20\,cm$ Ans.

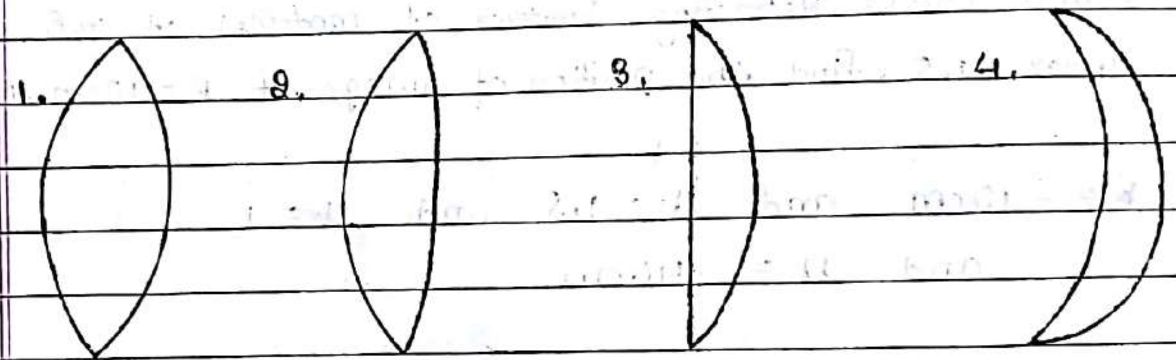
- Part :- 3
- Lens

→ A lens is a piece of transparent material bounded by two refracting surfaces out of which at least one is curved.

- Types of lens

1. Convex lens

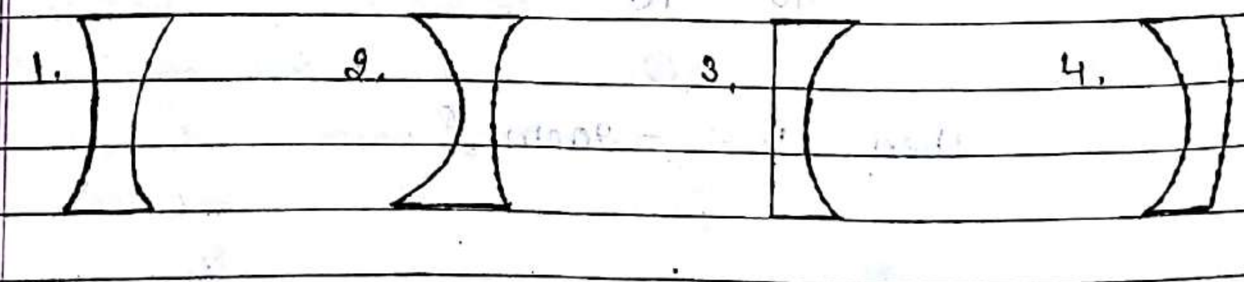
→ If the centre portion of a lens is thicker (Big) then its Edges then it behaves as a convergent lens, and known as Convex lens.




Equi Convex lens | Bi-convex lens | Plano-Convex lens | Concavo-Convex lens

2. Concave lens (Headlights of Car → Diverge)

→ If the centre portion of a lens is thiner (Small) then its Edges then it behaves as a divergent lens and known as Concave lens.




Equi Concave lens | Bi-Concave lens | Plano-Concave lens | Convexo-concave lens

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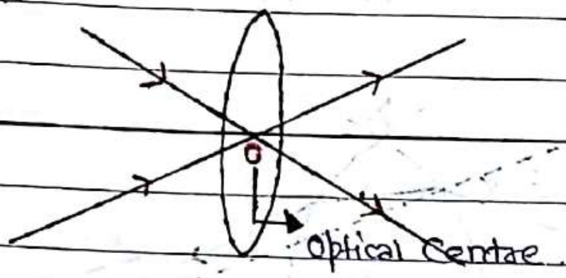
- Uses of lens

1. Used to Correct Vision defect of Human Eye.
2. Used in microscope, telescope, Camera and projector etc.

- Terms used in lens

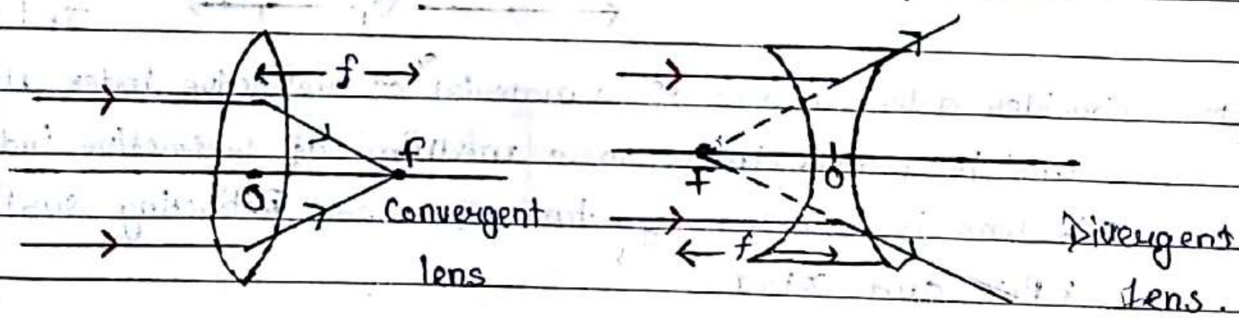
1. Optical Centre (O)

→ The point in the lens through which ray of light passes and undeviated.




2. Principal focus (F)

→ The point on the principal Axis where the incident ray of light travelling parallel to the principal Axis meet OR Appers to meet after refracting through a lens is Called Principal focus.




3. focal length (f)

→ The distance Between the optical Centre and the principal focus of a lens is known as focal length of lens.

→ focal length of Concave lens or Convex lens is denoted by f.

$P_1 \to$ Image $\to I_1$
$P_2 \to$ Image $\to I$
$P_1 \to$ Object $\to O$ Incident to Principal axis meet $\to$ object
$P_2 \to$ Object $\to I_1$

Myopia $\to$ (Far vision Not seen)
Hypermetropia $\to$ (near vision Not seen)

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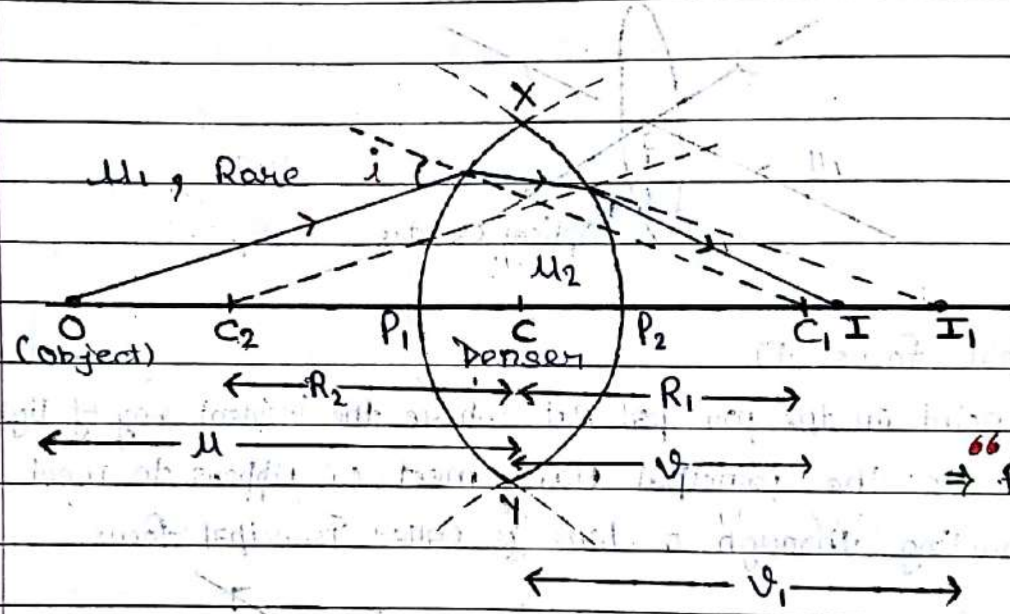
V.V. Imp

## Lens Maker's formula

→ The formula OR Equation Giving Relationship Between focal length 'f' of the lens, refractive index of the material of the lens '$\mu$' and the radius of curvature of its Surfaces ($R_1$ and $R_2$) is known as lens maker's formula.

$$\Rightarrow \text{"}\ \frac{1}{f} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]\ \text{"} \Leftarrow$$




⇒ "for $XP_2Y$ $I_1$ is object and $XP_1Y$ $I_1$ is Image"

→ Consider a lens made of a material of refractive index $\mu_2$. This lens is placed in a rare medium of refractive index $\mu_1$. This lens is Bounded by two spherical Refracting surfaces $XP_1Y$ and $XP_2Y$

**Step 1** Refraction through surface $XP_1Y$

At this Surface light rays goes from rare medium to denser medium.

From the Refraction formula

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

and $u = u$
and $v = v_1$
and $R = R_1$

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then $\frac{\mu_1}{u} - \frac{\mu_2}{v_1} = \frac{\mu_1 - \mu_2}{R_1}$ —(1)

**Step 2.** Refraction through Surface $XP_2Y$.

At this Surface light rays cross from denser medium to rare medium.

from the refraction formula

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

and $u = v_1$ and $v = v$ and $R = R_2$

then $\frac{\mu_2}{v_1} - \frac{\mu_1}{v} = \frac{\mu_2 - \mu_1}{R_2}$ —(2)

**Step 3.** By Adding (1) and (2) Equation

$$\frac{\mu_1}{u} - \cancel{\frac{\mu_2}{v_1}} + \cancel{\frac{\mu_2}{v_1}} - \frac{\mu_1}{v} = \frac{\mu_1 - \mu_2}{R_1} + \frac{\mu_2 - \mu_1}{R_2}$$

then $\mu_1 \left[\frac{1}{u} - \frac{1}{v}\right] = \frac{\mu_1 - \mu_2}{R_1} - \frac{[\mu_1 - \mu_2]}{R_2}$

then $\mu_1 \left[\frac{1}{u} - \frac{1}{v}\right] = (\mu_1 - \mu_2)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$

∵ Both side divide by $\mu_1$

then $\left[\frac{1}{u} - \frac{1}{v}\right] = \left[1 - \frac{\mu_2}{\mu_1}\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$

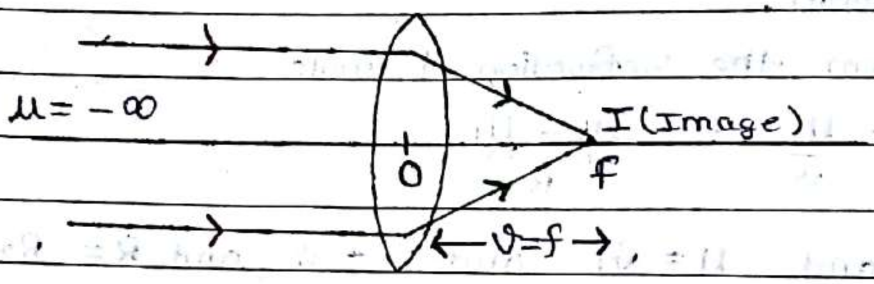
Both side multiply by minus

then $\left[\frac{1}{v} - \frac{1}{u}\right] = \left[\frac{\mu_2}{\mu_1} - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$ —(3)

and $\frac{\mu_2}{\mu_1} = {}^1\mu_2$ then from (3) Equation

then $\left[\frac{1}{v} - \frac{1}{u}\right] = \left[{}^1\mu_2 - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$ —(4)

→ If object is at infinity, Image is at Focus




then from Equation-(4) $u = -\infty$ and $v = f$

then $\left[\frac{1}{f} - \frac{1}{\infty}\right] = \left[{}^1\mu_2 - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$

then ⇒ "$\frac{1}{f} = \left[{}^1\mu_2 - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$" ⇐ —(5).

This is known as lens maker's formula.

On Comparing Equation-(4) and (5)

then ⇒ "$\frac{1}{f} = -\frac{1}{u} + \frac{1}{v} = \frac{1}{v} - \frac{1}{u}$" ⇐

This is lens formula.

→ Lens maker's formula is same for both convex and concave lens.

R will be Equal to f in lens case
Not mirror case

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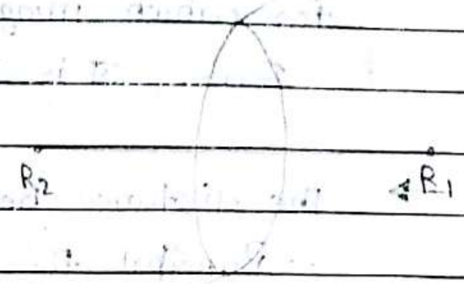
**Ques** The focal length of an Equiconvex lens is Equal to the radius of Curvature of Either phase. What is the refractive index of the material of lens.

**Sol$^n$** Here $R_1 = R$ and $R_2 = -R$

and $f = R$

then $\frac{1}{f} = ({}^1\mu_2 - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$




then $\frac{1}{f} = \left[\frac{\mu_2}{\mu_1} - 1\right]\left[\frac{1}{R} - \frac{1}{(-R)}\right]$ and $\mu_2 = \mu$ and $\mu_1 = 1$

then $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R} + \frac{1}{R}\right)$ and $f = R$

then $\frac{1}{R} = (\mu - 1)\left(\frac{2}{R}\right)$

then $\mu = \frac{3}{2} = 1.5$ Ans.

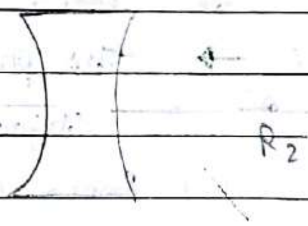
---

Concave focal length = -ve surely

**Q** A double concave lens of Glass of refractive index 1.6 has radius of Curvature of 40 cm ($R_1$) and 60 cm ($R_2$). Calculate the focal length of the lens in air.

**Sol$^n$** Here $\mu = 1.6$ and $R_1 = -40\,cm$

$R_2 = 60\,cm$ and $f = ?$




then $\frac{1}{f} = (\mu - 1)\cdot\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

then $\frac{1}{f} = (1.6 - 1)\left(\frac{1}{-40} - \frac{1}{60}\right) \Rightarrow$ then $f = -40\,cm$ Ans.

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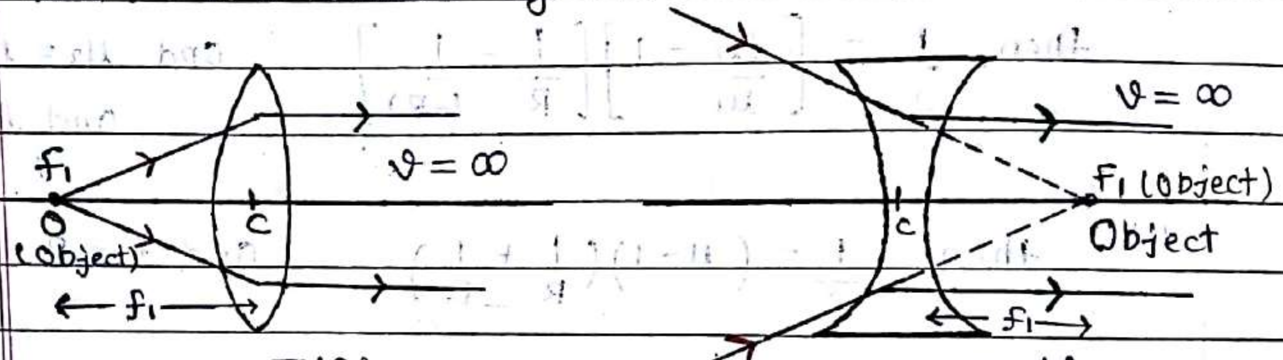
- first And Second Principal focus

1. first Principal focus and focal length ($f_1$)

→ The position of an Object on the principal axis of lens for which image is formed at infinity is called first principal focus. It is denoted by $F_1$.

→ The distance Between Optical Centre of the lens and first Principal focus is called first principal focal length of lens. It is denoted by $f_1$.




I(a) I(b)

From diagram I(a) then

$$-\frac{1}{u} + \frac{1}{v} = \left[{}^1\mu_2 - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

Here $u = -f_1$ and $v = \infty$

$$\text{then } \frac{1}{f} = \left[\mu - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \quad \text{—(1)}$$

2. Second Principal focus And focal length ($f_2$)

→ The position of an image on the principal axis of lens whose Object is lying at infinity is called second principal focus of the lens. It is denoted by $F_2$.

→ Second Principal focal length of the lens is the distance Between optical centre of the lens and second principal focus. ($f_2$).

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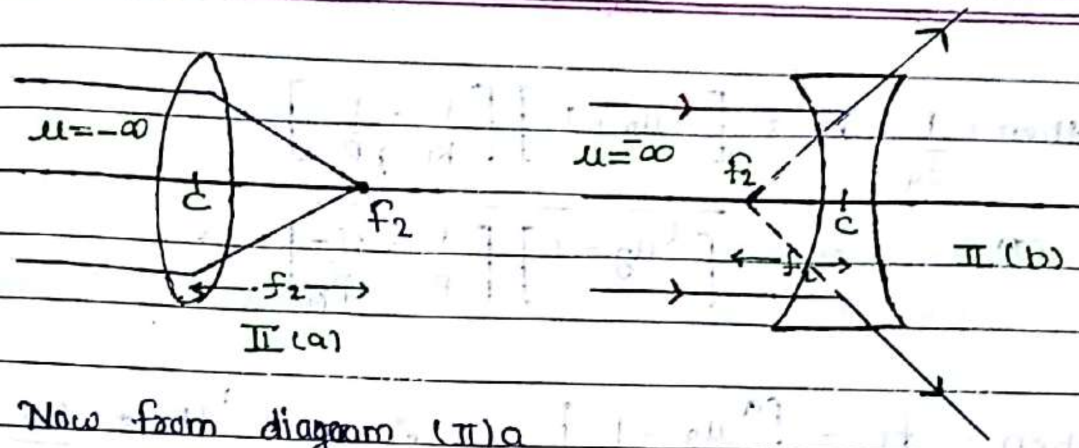


Now from diagram (II)a

from lens maker formula

$$-\frac{1}{u}+\frac{1}{v}=\left[{}^{1}u_2-1\right]\left[\frac{1}{R_1}-\frac{1}{R_2}\right]$$

and $u=-\infty$ and $v=f_2$

then $$\frac{1}{f_2}=\left[u-1\right]\left[\frac{1}{R_1}-\frac{1}{R_2}\right] \quad \text{---(2)}$$

from (1) and (2) Equation

$$\frac{1}{f_1}=\frac{1}{f_2}$$ then $\Rightarrow$ "$f_1=f_2$" $\Leftarrow$ ...

- **focal length of lens Immersed in liquid**

→ At first lens is kept in air then rays of light Goes from air (rare) to Glass (denser).

Hence from lens maker formula

then $$\frac{1}{f_a}=\left[{}^{a}u_g-1\right]\left[\frac{1}{R_1}-\frac{1}{R_2}\right] \quad \text{---(1)}$$

→ Now lens is kept in liquid. then rays of light Goes from liquid to Glass.

Hence from lens maker formula.

$$\frac{1}{f_L}=\left[{}^{l}u_g-1\right]\left[\frac{1}{R_1}-\frac{1}{R_2}\right] \quad \text{---(2)}$$

By dividing Equation (1) and (2) then

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then $\frac{1}{f_a} \times f_l = \frac{\left[{}^a\mu_g - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]}{\left[{}^l\mu_g - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]}$

then $\frac{f_l}{f_a} = \left[\frac{{}^a\mu_g - 1}{{}^l\mu_g - 1}\right]$ ∴ and ${}^1\mu_2 = \frac{\mu_2}{\mu_1}$

then $\frac{f_l}{f_a} = \left[\frac{\frac{\mu_g}{\mu_a} - 1}{\frac{\mu_g}{\mu_l} - 1}\right] = \left[\frac{\mu_g - \mu_a}{\mu_a}\right] \times \left[\frac{\mu_l}{\mu_g - \mu_l}\right]$ —(3)

and $\mu_a$ (air) $= 1$ then

$\frac{f_l}{f_a} = \left[\frac{\mu_g - 1}{\mu_g - \mu_l}\right] \cdot \mu_l$

then ⇒ "$f_l = f_a \left[\frac{\mu_g - 1}{\mu_g - \mu_l}\right] \cdot \mu_l$" ⇐

- **Special Case**

1. If $\mu_l > \mu_g$
   then $f_l = -ve$ (Concave lens) (diverging lens)

2. If $\mu_l < \mu_g$
   then $f_l = +ve$ (Convex lens) (Converging lens)

Q. A lens made of Glass of refractive index $\frac{3}{2}$ has $f = 20$cm in Air. Calculate the focal length of the lens. when it is Immersed in water.

Sol$^n$ $f_l = f_a\left(\frac{\mu_g - 1}{\mu_g - \mu_l}\right) \cdot \mu_l$ and $\mu_g = \frac{3}{2}$ and $\mu_l = 1.33\left(\frac{4}{3}\right)$

and $f_a = 20cm$

then $f_l = 20\left(\frac{3}{2} - 1\right) \times \frac{4}{3} \times \frac{1}{\left(\frac{3}{2} - \frac{4}{3}\right)} = 80cm$ Ans.

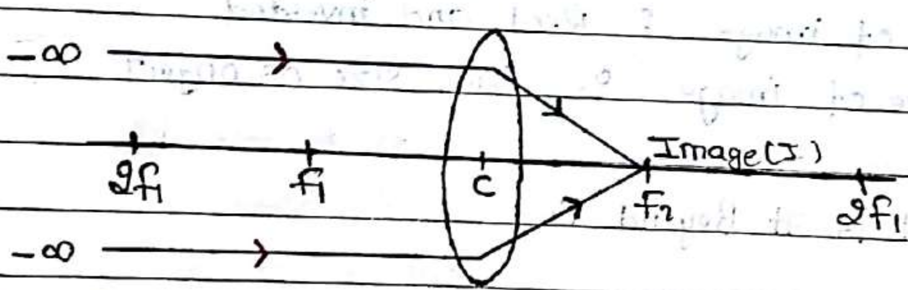
**Short trick**

$f_w = 4 \times f_a$ then $f_w = 4 \times 20 = 80cm$ Ans.

when lens is immersed into water its focal length increses by 4 times.

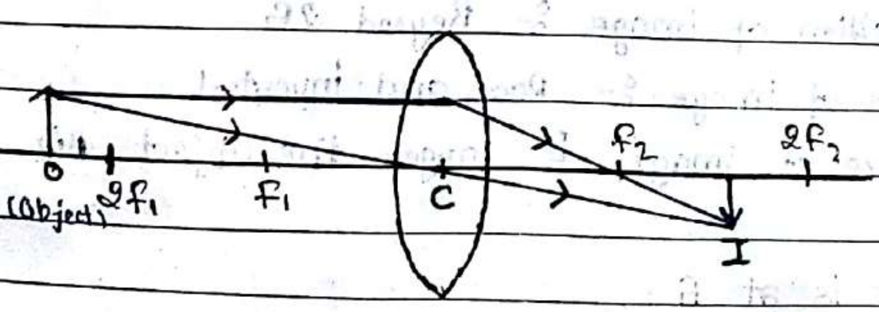
- **Image formed by Convex lens**

1. When Object Is At infinity




Position of Object :- At infinity
Position of image :- At focus ($f_2$)
Nature of Image :- Real and inverted
Size of Image :- Point size, Highly diminished.

2. When object is Between infinity and $2f_1$



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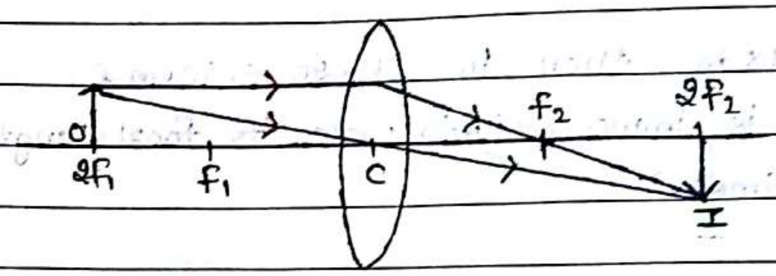
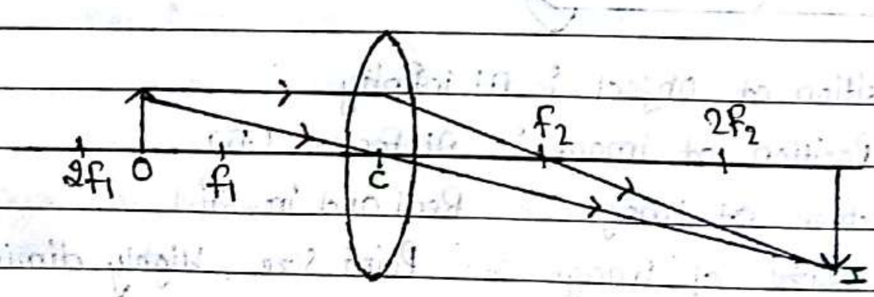
Position of Object :- Between infinity and $2f_1$ and Beyond $2f_1$
Position of image :- Between $f_2$ and $2f_2$
Size of image :- Smaller then Object OR diminished
Nature of image :- Real and inverted.

3. When Object is at $2f_1$



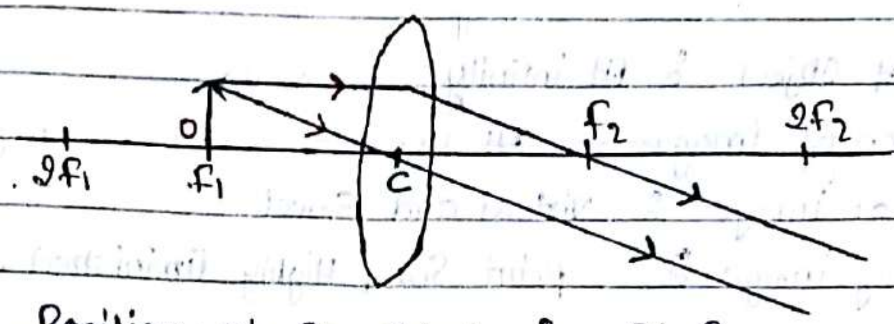

Position of Object :- At $2f_1$
Position of Image :- At $2f_2$
Nature of image :- Real and inverted
Size of image :- Same size as object.

4. When Object is at Beyond $f_1$




Position of object :- Between $2f_1$ and $f_1$
Position of image :- Beyond $2f_2$
Nature of image :- Real and inverted
Size of image :- larger the Object, Big.

5. When object is at $f_1$



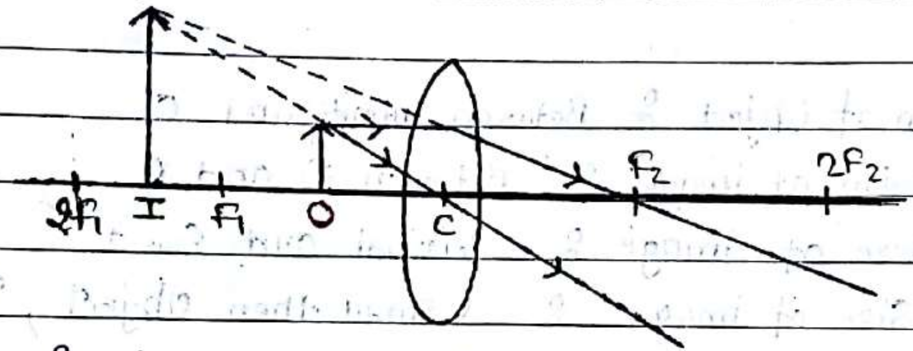

Position of An object :- At $f_1$

Position of Image :- At infinity

Nature of image :- Real and inverted

Size of image :- Enlarged (Highly)

6. When Object is Between $f_1$ and C




Position of object :- Between $f_1$ and C

Position of Image :- same side of Object.

Nature of image :- Virtual And Erect

Size of image :- larger then object.

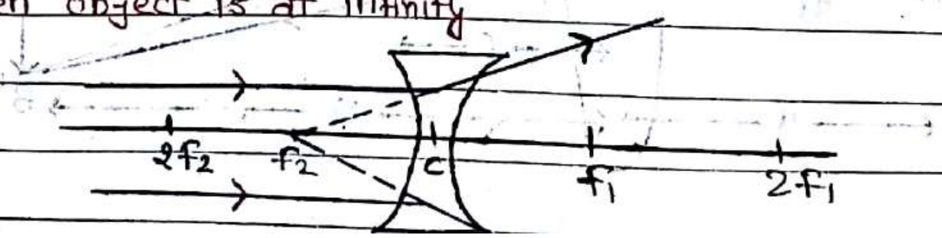
Imp.

Q. At what position Convex lens behaves as magnifine Glass.

Sol. when Object is placed Between optical Centre and focus Image is Virtual and Erect and as the Same side of the object. And at this position lens behaves as magnifine Glass.

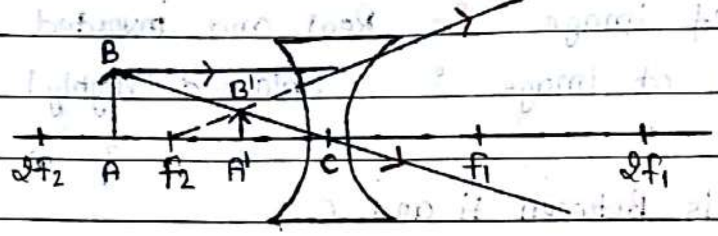
- Image Formed by a Concave lens

1. When object is at infinity



Position of Object :- At infinity
Position of image :- At $f_2$
Nature of image :- Virtual and Erect
Size of image :- point Size, Highly diminished.

2. When Object is Between infinity And Optical Centre

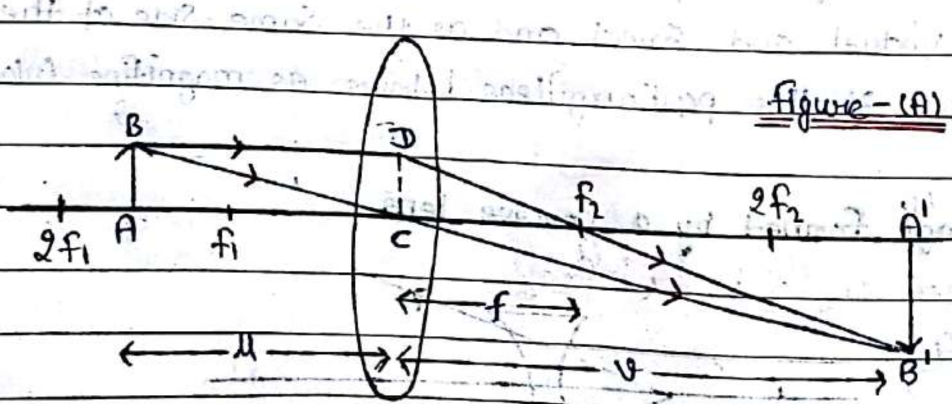



Position of Object :- Between infinity and C
Position of image :- Between $f_2$ and C
Nature of image :- Virtual and Erect
Size of image :- Small then object, Diminshed

- **Thin lens formula (lens formula)**

→ The relation among the object distance u, image distance v, and focal length of the lens f, is known as lens formula. Consider a convex lens of focal length f and object is Between $f_1$ and $2f_1$ its image is real and inverted and formed Beyond $2f_2$.

figure-(A)



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Proof

In $\Delta CDF_2$ and $\Delta A'B'F_2$ are Similar.
Hence their ratio of sides are Equal.

then $\frac{A'B'}{CD} = \frac{A'F_2}{CF_2}$

from figure $CD = AB$ (object)

then $\frac{A'B'}{AB} = \frac{A'F_2}{CF_2}$ —(1)

In $\Delta ABC$ and $\Delta A'B'C$ are Similar.
Hence their ratio of sides are Equal.

then $\frac{A'B'}{AB} = \frac{CA'}{CA}$ —(2)

On Compairing (1) and (2) Equation

$\frac{A'F_2}{CF_2} = \frac{CA'}{CA}$ —(3)

∴ from figure
$CA' = v$ and $CA = -u$
$A'F_2 = v - f_2$
and $CF_2 = f$

put all Value in (3) Equation

$\frac{v-f}{f} = \frac{-v}{u}$ —(A)

then $-uv + uf = fv$ —(4)

Divide Both Side by $uvf$

then $\frac{-uv}{uvf} + \frac{uf}{uvf} = \frac{fv}{uvf}$

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

then $\Rightarrow$ "$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$" $\Leftarrow$

This is lens formula.

- Linear magnification of lens

→ It is defined as the ratio of height of image to hight of Object

$\Rightarrow$ "$m = \frac{h_i}{h_o}$" $\Leftarrow$

- Linear magnification in terms of u and v

→ from figure (A) in previous derivation:

In $\Delta ABC$ and $\Delta A'B'C$ are similar. Hence their ratio of sides are Equal.

$$\frac{A'B'}{AB} = \frac{A'C}{AC} \quad -(1)$$

from figure $A'B' = -h_i$ and $AB = h_o$
and $A'C = v$ and $AC = -u$

then $\frac{-h_i}{h_o} = \frac{v}{-u}$

then $\Rightarrow$ "$\frac{h_i}{h_o} = \frac{v}{u}$" $\Leftarrow$

$\Rightarrow$ "$m = \frac{v}{u}$" $\Leftarrow$

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- Linear magnification in terms of u and f

$$-\frac{1}{u}+\frac{1}{v}=\frac{1}{f} \quad -(1)$$

Both side multiply by u

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

then $\frac{u}{v}=\frac{u+f}{f} \quad -(2)$

Now reverse Both term

$$\Rightarrow \text{“} \frac{v}{u}=m=\frac{f}{f+u} \text{”} \Leftarrow$$

- Linear magnification in term of v and f

Here $\frac{1}{v}-\frac{1}{u}=\frac{1}{f} \quad -(1)$

Both side multiple by v

then $\Rightarrow$ “ $1-\frac{v}{u}=\frac{v}{f}$ ” $\Leftarrow$

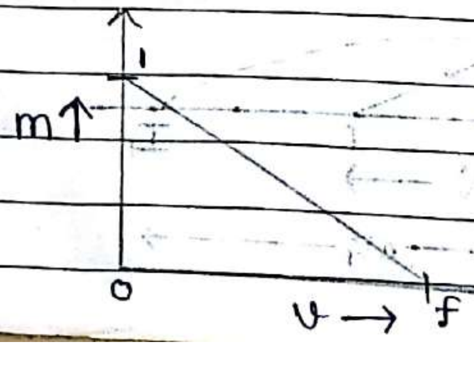
then $1-m=\frac{v}{f}$

$\Rightarrow$ “ then $1-\frac{v}{f}=m$ ” $\Leftarrow$

$\frac{v}{u}=m$

Q. Draw variation of magnification with image distance.

Sol$^n$




and $y=mx+c$ $m \Rightarrow$ -slope (-ve)

when $v=0$ then $m=1$

$v=f$ then $m=0$ &

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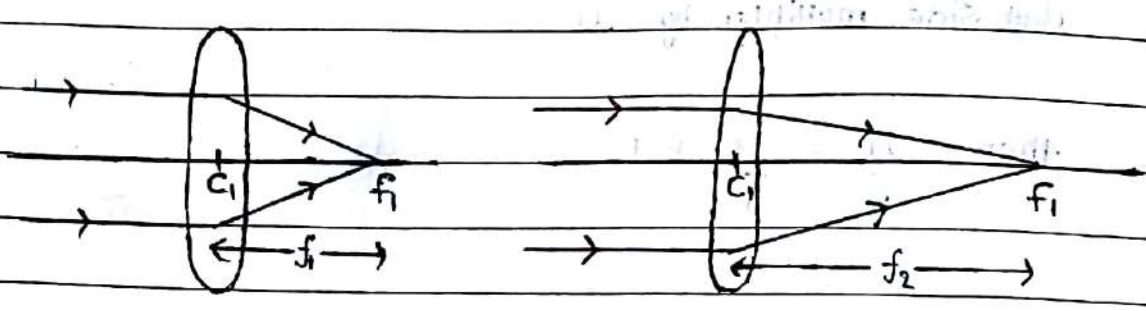
- **Power of A lens**

→ The ability of the lens to converge OR diverge the rays of light falling on it known as Power of A lens.




then $f_2 > f_1$

then ⇒ "Power (P) $\alpha$ $\frac{1}{\text{focus } (f) \text{ (in meter)}}$" ⇐ Power of a lens is 4 times decrease when immersed in liquid.

→ Power of a lens is Equal to the reciprocal of the focal length of the lens. Expressed in meter.

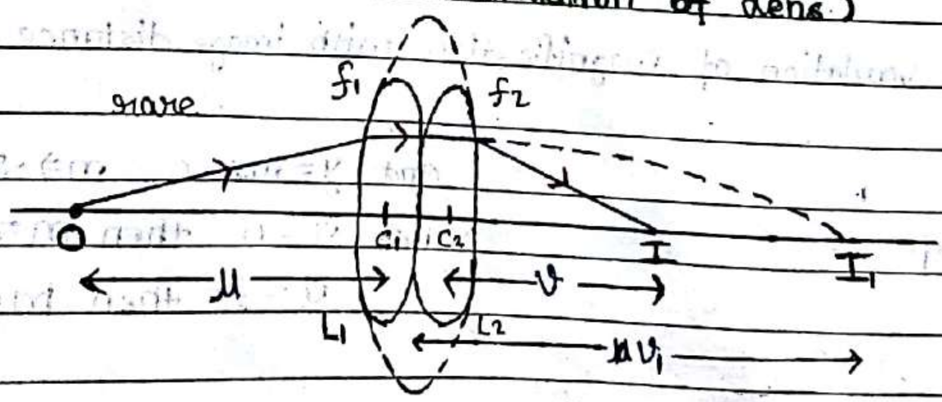
S.I unit of Power :- Dioptre (D) = $m^{-1}$.

and 1 Dioptre :- If focal length of lens is 1m then Power of a lens is 1 dioptre.

→ Power of Convex lens (converging lens) is positive.

Power of Concave lens ⇒ (diverging lens) is negative.

- **Thin lens in Contact ( Combination of lens )**



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from lens formula ($L_1$)

then $\frac{1}{v_1} - \frac{1}{u} = \frac{1}{f_1}$ —(1) Here $u = u$ and $v = v_1$

from lens formula ($L_2$)

$\frac{1}{v} - \frac{1}{v_1} = \frac{1}{f_2}$ —(2) Here $u = v_1$ and $v = v$

By adding Equation (1) and (2)

then $\frac{1}{v} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2}$ —(3)

And from Equivalent lens

$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ —(4) Here $u = u$ and $v = v$

By Compairing Equation (3) and (4)

$\Rightarrow$ "$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$" $\Leftarrow$

If more then two lenses are placed in Contact Coaxially then

$\Rightarrow$ "$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} + \ldots\ldots + \frac{1}{f_n}$" $\Leftarrow$

then $P = P_1 + P_2 + \ldots + P_n$

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- Power of an Equivalent lens

→ We known that
Power of A lens is Given by :-

$$\text{Power (P)} \propto \frac{1}{\text{focal length (f)}}$$

If two lenses are in contact then power

$$\text{then } \frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$\text{then} \Rightarrow \text{"} P = P_1 + P_2 \text{"} \Leftarrow$$

then for n lens

$$P = P_1 + P_2 + \ldots + P_n.$$

**magnification of Equivalent lens** :- when two co-Axial lens are contact then magnification of Equivalent lens is Given by :- $m = m_1 . m_2$

for more then two lens
then $m = m_1 . m_2 m_3 . \ldots m_n$

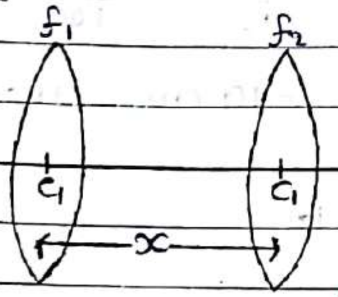
- Uses of Equivalent lens

1. Equivalent lens used in optical instrument like telescope, microscope, Camera and Binoculars etc.

Q. If magnifaction of lens $L_1$ is $-2$ and $L_2$ is $-2$ then find the nature of image and magnifaction of lens.

Sol. $m = m_1 . m_2 = 4$ Virtual and Erect

**NOTE:-** When two lens of focal length $f_1$ and $f_2$ are placed co-axially at distance $x$ from each other then the Equivalent focal length is Given by :-




$$\Rightarrow \text{“} \frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{x}{f_1 f_2} \text{”} \Leftarrow$$

then $\Rightarrow$ “ $P = P_1 + P_2 - P_1 . P_2 . x$ ” $\Leftarrow$

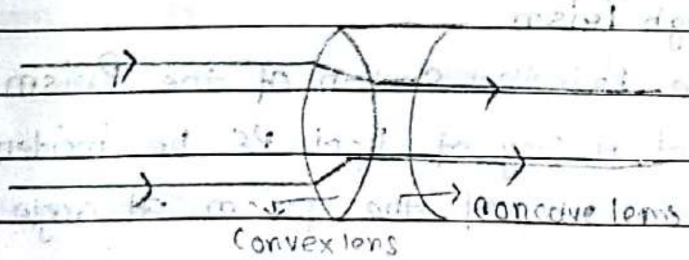
This is power of Equivalent lens.

**Q** Two thin lens Convex and Concave placed in Contact with each other having Same focal length then what is the behaviour of Combination of lens.

**Soln** $\underset{\text{convex}}{f_1 = +f}$ and $\underset{\text{concave}}{f_2 = -f}$ then $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$

then $\frac{1}{F} = \frac{1}{f} - \frac{1}{f} = 0$ then $f = \infty$ $\left[ \frac{1}{f} = 0 \right]$
and $P = 0$

then Combination of lens behaving as plane Glass.




**Q** Two thin lens of focal length 10cm and −5cm are kept in Contact what is the focal length and Power.

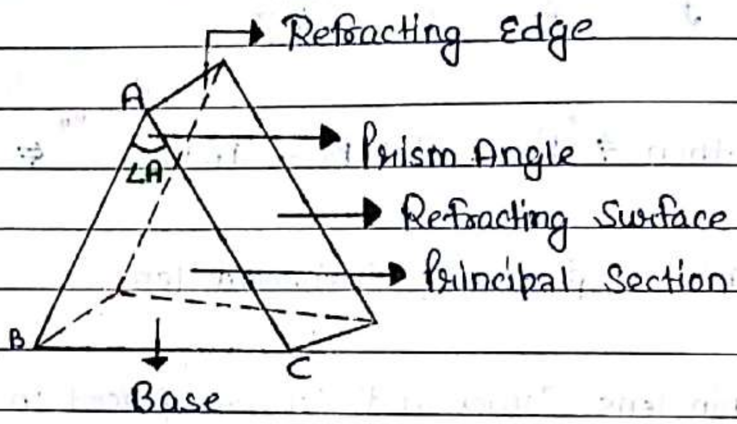
Sol$^n$ $f_1 = 10\,cm$ (convex) $f_2 = -5\,cm$ (concave)

then $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{10} - \frac{1}{5} = -\frac{1}{10}\,cm$

then $f = -10\,cm$ then $P = \frac{100}{f\,(in\,cm)} = -10D$

Behaves as Concave lens.

- **Part :- 4**
- **Prism**




→ A Simple Prism is a Homogenous transparent refracting medium, Bounded by atleast two non-parallel plane Surface inclined at Some angle.

→ The Angle Between two refracting Surfaces is Called Angle of Prism OR Refracting Angle. It is denoted by A.

- **Refraction through Prism**

→ Let ABC be the Principal Section of the Prism of refracting Angle ∠A. Let A ray of light PE be incident on a refracting Surface AB of the prism at angle of incidence i.

→ Rays EF And FQ are refracted And Emergent Ray respectively. The Angle Between Emergent ray And incident Ray is Called

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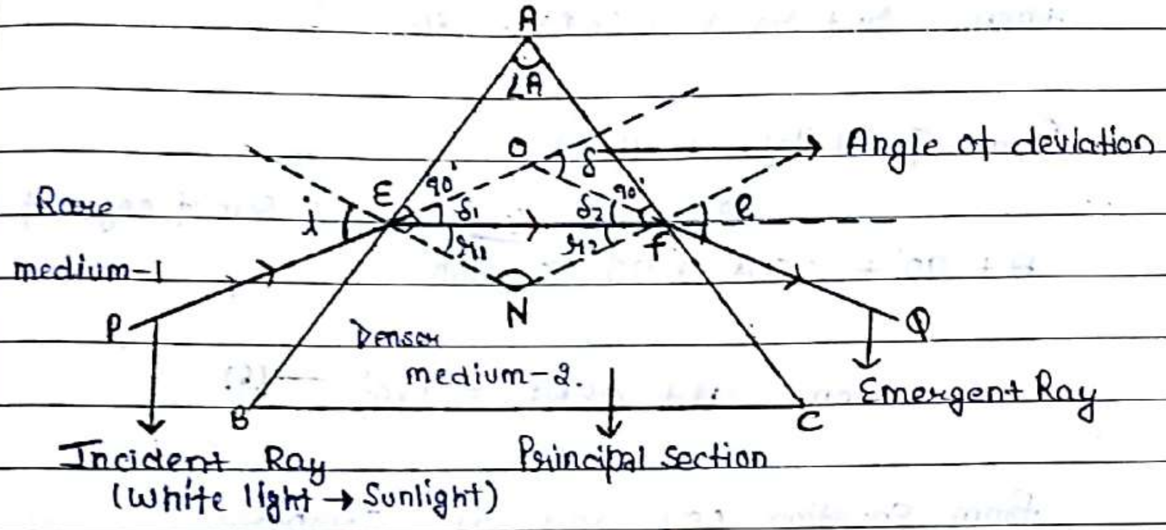
Angle of deviation ($\delta$).

"Angle of deviation is the Angle through which incident ray is turned while passing through the prism."




**Prove :-** ⇒ "$\delta + A = i + e$" ⇐

At refracting Surface AB

$i = \delta_1 + r_1$ — Exterior Angle = Sum of interior Angle

then $\delta_1 = i - r_1$ —(1)

At refracting Surface AC

$\delta_2 + r_2 = e$

then $\delta_2 = e - r_2$ —(2)

from $\Delta OEF$

Exterior Angle = Sum of Interior Angle

$\delta = \delta_1 + \delta_2$ —(3)

put Value of (1) and (2) in (3) Equation

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

then →

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Rough

| $i$ | $\delta$ |
|---|---|
| 30° | 48° - 52° → Reading Practical |
| 35° | 44° - 47 |
| 40° | 40° - 43° |
| 45° | 38° → $i = e$, $r_1 = r_2$ |
| 50° | 41° |
| 55 | 44 |
| 60° | 48° |

$$\delta = i + e - (r_1 + r_2) \quad \text{—(4)}$$

from $\Delta ENF$ : " Sum of Angle of $\Delta$ is 180°"

then $r_1 + r_2 + \angle ENF = 180°$ —(5)

from Quadrilateral AENF " Sum of angle of $\square$ is 360°"

$A + 90° + \angle ENF + 90 = 360°$

then $A + \angle ENF = 180°$ —(6)

from Equation (5) and (6) Compare

then $A = r_1 + r_2$ —(7)

put Value of (7) equation in Equation (4)

then $\delta = i + e - A$

then $\Rightarrow$ "$A + \delta = i + e$" $\Leftarrow$ Hence proved.

- **Prism formula**

**(Angle of minimum deviation OR Refractive index of Prism)**

→ As the Angle of incidence of the light increses the Angle of deviation ($\delta$) is decreses till it becomes minimum at a particular Angle of incidence. The minimum of Value of Angle of deviation is Called Angle of minimum deviation ($\delta m$). which is 38° ($\delta$)

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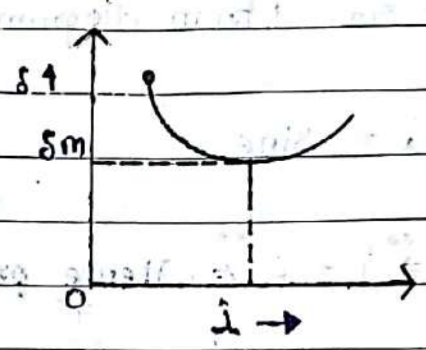
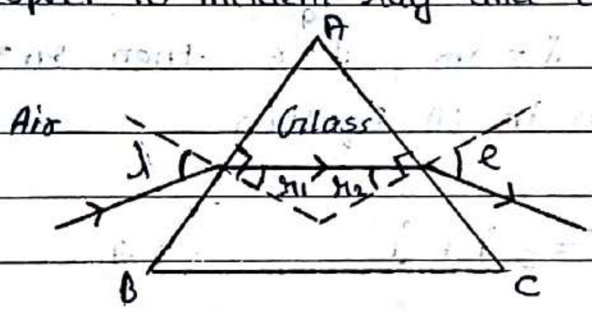
→ The position of a prism at minimum angle of deviation is called minimum deviation position. After minimum deviation position the deviation Angle is Increases with incident Angle.




- **Condition for minimum deviation ($\delta m$)**

→ In the position of minimum deviation the prism lies symmetrically with respect to incident ray and Emergent ray. ($i = e$)




In this $i = e$ and ($r_1 = r_2$)

**Prove :-** ⇒ "$i = e$ and $r_1 = r_2$" when $\delta = \delta m$

Refraction at Surface AB

By snell's law

$$^{a}\mu_g = \frac{\sin i}{\sin r_1} \quad \text{—(1)}$$

Now Refraction at Surface AC

then $$^{g}\mu_a = \frac{\sin r_2}{\sin e}$$

Now reciprocal Above term

$$^{a}\mu_g = \frac{\sin r_2}{\sin e} \quad \text{—(2)}$$

then from (1) and (2) Equation compare

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then $\frac{\sin i}{\sin r_1} = \frac{\sin e}{\sin r_2}$ —(3)

let $r_1 = r_2 = 45°$

then $r_1 = r_2$ (from diagram) when $\delta = \delta_m$ (minimum deviation)

then $\sin i = \sin e$

then ⇒ "$i = e$" ⇐ Hence proved.

- **Derivation of Prism - Formula**

From refraction formula of Prism

$\delta + A = i + e$ —(1)

At minimum deviation condition

then $\delta = \delta_m$, $i = e$ then $r_1 = r_2 = r$

put Above Values in (1) equation

then $\delta_m + A = i + i$

then $\frac{\delta_m + A}{2} = i$ —(2)

from Prism Refraction

$A = r_1 + r_2$ then $r_1 = r_2 = r_1$

then $A = 2r_1$

then $r = \frac{A}{2}$ —(3)

from Snell's law

${}^a\mu_g = \frac{\sin i}{\sin r_1} = \frac{\sin i}{\sin r}$ when $r_1 = r$

and $\mu_a = 1$

then $\frac{\mu_g}{\mu_a} = \frac{\sin i}{\sin r}$ and $\mu_g = \mu$

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then "$\mu = \dfrac{\sin\left[\dfrac{\delta m + A}{2}\right]}{\sin\left[\dfrac{A}{2}\right]}$" —(A) and $i = \dfrac{\delta m + A}{2}$

This is Prism formula.

Now for Small Angle Prism

$\sin\theta \simeq \theta$ ∴ and $\cos\theta \simeq 1$

then $\sin\left[\dfrac{\delta m+A}{2}\right] \simeq \left[\dfrac{\delta m+A}{2}\right]$

and $\sin\left[\dfrac{A}{2}\right] \simeq \dfrac{A}{2}$ then from (A) Equation

then $\mu = \dfrac{\delta m+A}{2} \times \dfrac{2}{A}$

then $\mu = \dfrac{\delta m+A}{A} = \dfrac{\delta m}{A} + 1$

then ⇒ "$\delta m = (\mu - 1).A$" ⇐

This is Angle of minimum deviation for small angle prism.

Q. A Ray of light Passes through a Glass prism Such that the angle of incidence is Equal to angle of Emergent. If Angle of Emergent is $\frac{3}{4}$ times the Angle of Prism. Calculate the Angle of deviation when Angle of prism is 30°.

Sol. Here $\delta + A = i + e$

and $i = e$ and $A = 30°$ and $e = \frac{3}{2} \times A$

then $\delta = i + e - A$

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then $\delta = 2e - A$ $\quad e = \frac{3}{4}A$

then $\delta = \frac{2\,3A}{4} - A$

then $\delta = \frac{3 \times 30^\circ}{2} - \frac{\cancel{3}}{4} 30'$

then $\delta = 30^\circ\left(\frac{3}{2} - 1\right) = 15^\circ$ Ans.

**Q** A thin prism of $2^\circ$ Angle Gives a deviation of $1^\circ$. what is the Value of Refractive index of the material of the prism.

**Sol$^n$**

$$\mu = \frac{\sin\left(\frac{\delta m + A}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

Here $\delta m = 1^\circ$
$A = 2^\circ$

for Small Angle.
Another method.

$$\mu = \frac{\sin\left(\frac{3}{2}\right)}{\sin\left(\frac{2}{2}\right)}$$

OR $\delta m = (\mu - 1)A$

then $\frac{\delta m + A}{A} = \mu$

then $\frac{1+2}{2} = \mu = 1.5$ Ans.

**Q** Calculate the Refractive index of the material of an Equilateral prism for which its angle of minimum deviation is $60^\circ$.

$\delta m = 60^\circ$, $A = 60^\circ$

**Sol$^n$**

$$\mu = \frac{\sin\left(\frac{\delta m + A}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

$\mu = \sqrt{3}$ Ans.

$\sin 60^\circ = \frac{\sqrt{3}}{2}$

$\sin 30^\circ = \frac{1}{2}$ Ans.

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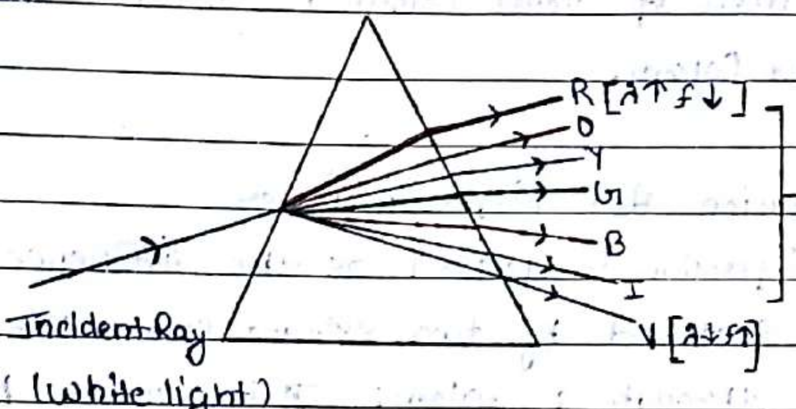
- **Dispersion of light through a Prism**

→ The phenomenon of spliting of white light into its constituent colour is called dispersion of light.

→ When light (white) beam falls on a prism the emergent light consist of different colours :- VIBGYOR which are constituents colours of white light this phenomena is called dispersion of light.




- **Cause of dispersion of light** (λ-change then Angle change → dispersion reason)

→ The separation of different colours present in white light is because of different deviation suffered by different colour. When they pass through a prism.

- **Cauchy's formula**

→ Cauchy's gives the relationship between refractive index and wavelength which is given as below:-

$$\Rightarrow \text{"} \mu \propto \frac{1}{\lambda^2} \text{"} \Leftarrow$$

→ Since, wavelength of red colour is highest its refractive index is lowest, and wavelength of voilet colour is lowest and its refractive index is highest.

$$\text{then} \Rightarrow \text{"} \mu_V > \mu_R \text{"} \Leftarrow$$

Now from deviation formula (small angle)

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$\delta = (\mu - 1)A$ —(1) ∴ μ is same as wavelength but inverse

for Red Colour $\delta = \delta_R$ and $\mu = \mu_R$

$\delta_R = (\mu_R - 1)A$ —(2).

for Voilet Colour $\delta = \delta_V$ and $\mu = \mu_V$.

$\delta_V = (\mu_V - 1)A$ —(3)

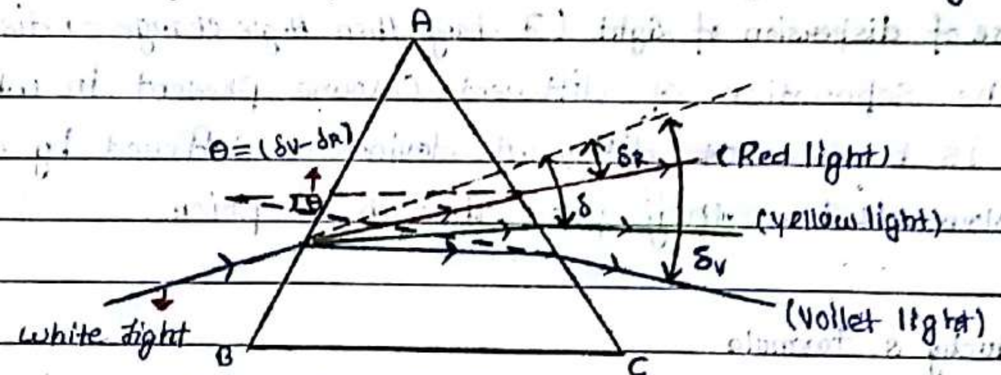
from (2) and (3) Equation

"$\mu_V > \mu_R$ then ⇒ $\delta_V > \delta_R$" ⇐

→ Hence deviation of Voilet Colour is Greater then deviation of Red Colour.

- **Angular Dispersion And Dispersion Power**

→ Angular Dispersion is defined as the difference in the deviation suffered by two extreme Colour (Red & Voilet) in passing through a prism. It is denoted by θ.




Here $\theta = \delta_V - \delta_R$ —(1)

from formula of deviation Small Angle prism

$\delta = (\mu - 1).A$

for Red Colour

$\delta_R = (\mu_R - 1)A$ —(2)

for Voilet Colour

$\delta_V = (\mu_V - 1)A$ —(3)

put value of (2) and (3) in (1) Equation

then $\theta = \mu_V A - A - \mu_R A + A$

then ⇒ "$\theta = A(\mu_V - \mu_R)$" ⇐

- **Dispersive Power**

→ Dispersive Power of a material is its ability to disperse the Constituents Colour of incident light.

→ Dispersive power is Equal to the ratio of Angular dispersion to mean deviation produced by the Prism. It is denoted by $\omega$.

Here Dispersion power $(\omega) = \frac{\text{Angular dispersion } (\theta)}{\text{Mean deviation } (\delta)}$

then $\omega = \frac{\theta}{\delta} = \frac{\delta_V - \delta_R}{\delta}$ $\quad \left[ \text{and } \delta_V - \delta_R = (\mu_V - \mu_R).A \right]$

then $\omega = \frac{(\mu_V - \mu_R).A}{(\mu - 1).A} = \frac{(\mu_V - \mu_R)}{(\mu - 1)}$

$$\Rightarrow \text{“} \omega = \left[ \frac{\mu_V - \mu_R}{\mu - 1} \right] \text{”} \Leftarrow$$

- **Natural phenomena Related to Sunlight**

1. Rainbow:

→ Rainbow is the beautiful illustration (Diagram) of dispersion of light. And it is observed during the Rainfall OR After Rainfall. OR When We looked at the water fountain provided the Sun is shining at the back of the Observer.

- Rainbow is a three steps Process

→ Rainbow is formed dispersion of light, refraction and total internal Reflextion of light in the droplets present in atmosphere. Thus Rainbow is the Combine Effect of refraction, Dispersion and total internal Reflection.

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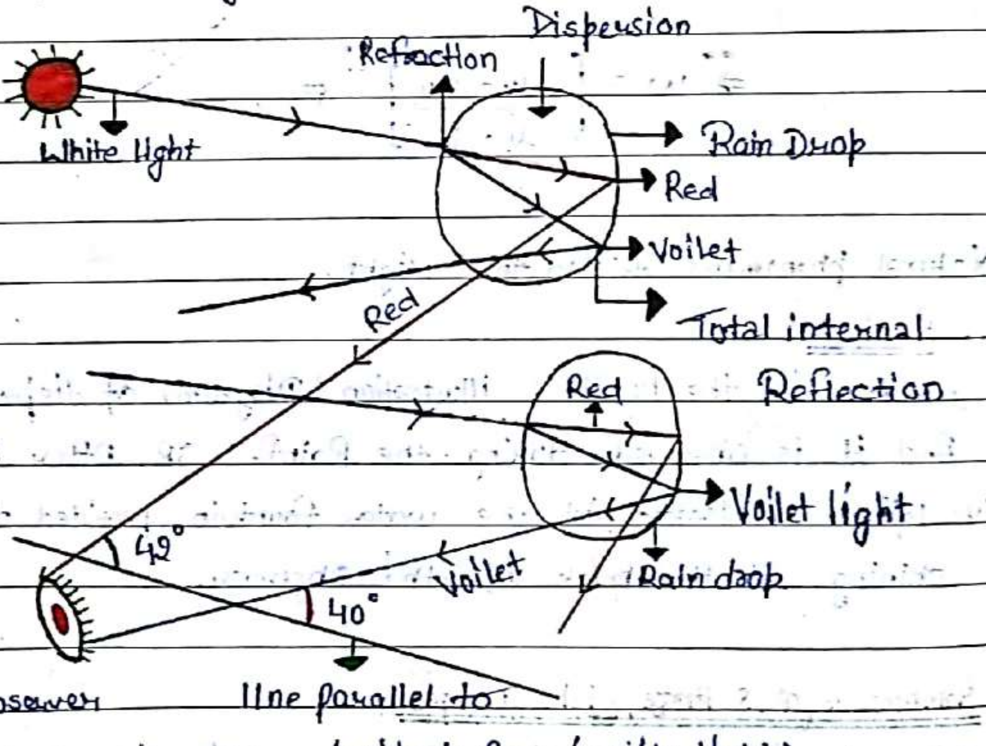
- Primary Rainbow

→ Primary Rainbow is formed due to two refraction, one Total internal Reflection and dispersion of light by the droplets suspended in Air. The outer Edge of the Primary Rainbow is red And the inner Egde is Voilet.

→ An Observer Can See the red Colour of the rainbow, if the Angle Between the Beam of Sunlight And the light Coming out from the drop is 42°.

→ The Observer See the Voilet Colour of the rainbow, when the Angle Between the Beam of Sunlight And the light Coming out from the drop is 40°.

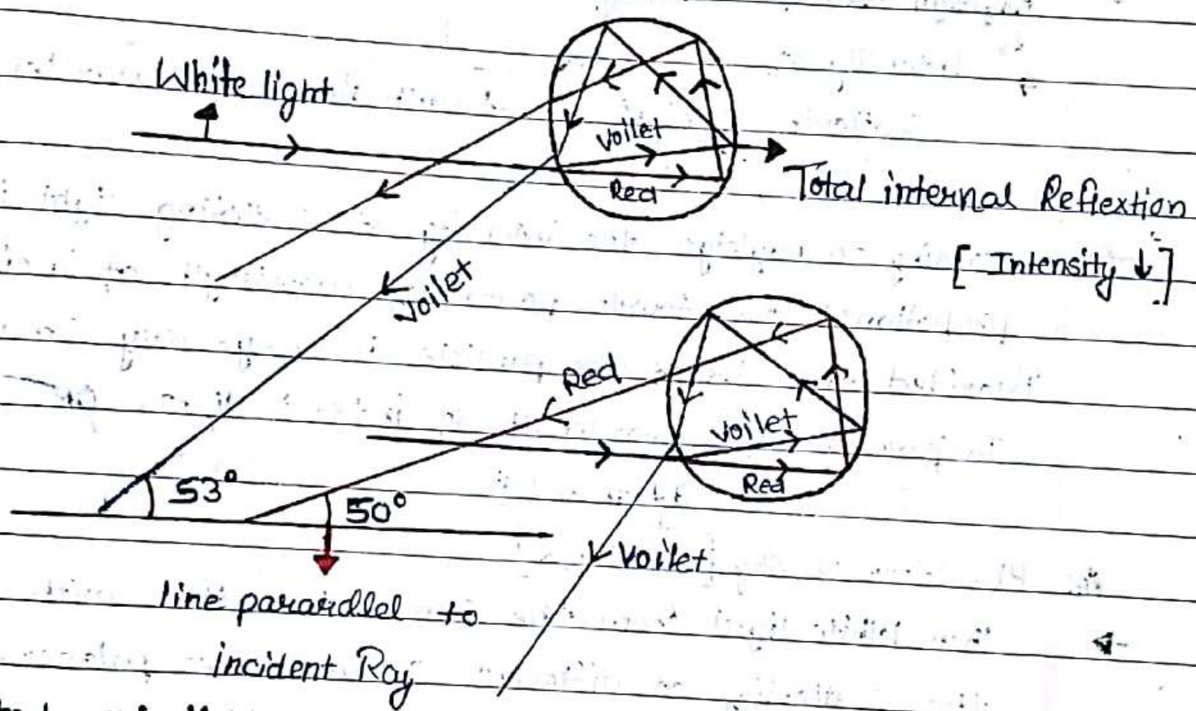



- Secondary Rainbow

→ It is formed due to two refraction, two internal Reflection and dispersion of light by the droplets suspended in Air

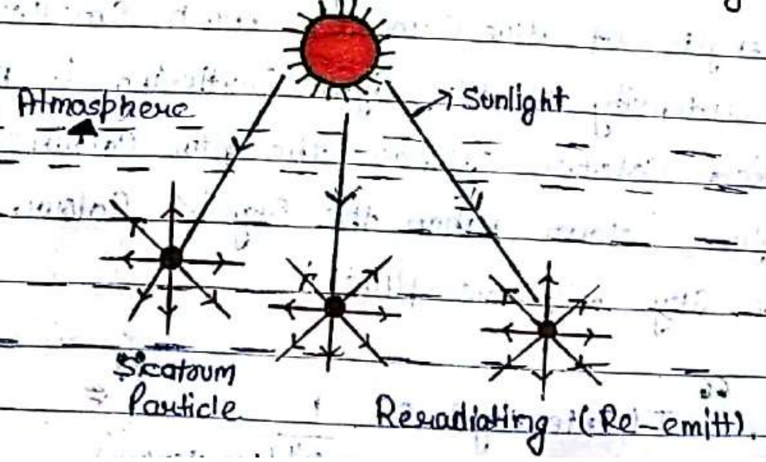
→ The Outer Edge of Secondary rainbow is voilet and Inner Edge is red. An Observer Can see the red Colour of the raibow if Angle Between the Beam of Sunlight And the light Coming Out from the drop is 50°.

→ The Observer See the Voilet ~~an~~ Colour of the rainbow, if the Angle Between the Beam of Sunlight And the light Coming out from the drop is 53°.




• **Scattering of light**

→ The process of reradiating the light by atom and molecules of Gas in all direction is known as Scattering of light.




∴ firstly atmospheric Scatrum particles absorbed light and then Emitts into Colours.

→ When Sunlight Entrs the atmosphere of Earth then this light is adsorbed by the atom or molecules of gas present in the Earth atm. This atoms and molecules reemitt light in all direction.

→ The atom OR molecule OR any other particle which Scatters the light is known as Scatterer.

- **Rayleigh law of Scattering**

"⇒ Intensity of Scattering of light $\propto$ $\frac{1}{\text{fourth Power of wavelength}}$" ⇐

→ According to Rayleigh the intensity of scattering light is inversly propotional to fourth power of wavelength of incident light. Provided the size of the particle is very-very small As Compare to the wavelength of incident light.

$\lambda\downarrow$ then $I\uparrow$

**(A) Blue Colour of sky** [VIBGYOR]

→ When White light from the Sun Entres the Earth atmosphere the scattering of different Colour takes palaces. Due to Interaction with large number of Very Small particles in the Earth atmospherie.

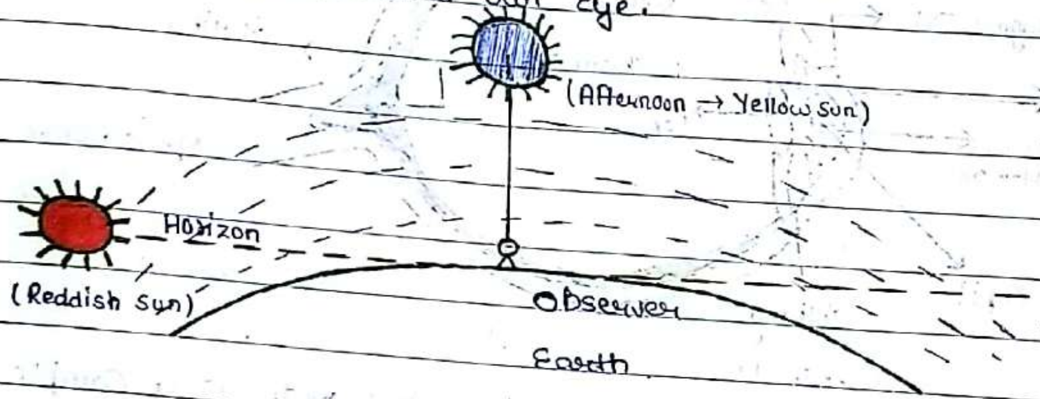
→ The wavelength of Blue Colour is much Smaller then red Colour. Intensity of Blue light Scattering is much more then Red Colour. Hence the Blue Colour is becomes the major Colour when the Sky is Colour. Due to this fact the sky Appears Blue.

Blue colour : mix of Voilet, indigo and Blue.

"⇒ I (Intensity) $\propto$ $\frac{1}{\lambda^4 \text{(wavelength)}}$" ⇐

**(B) Reddish Sun At Sunset OR Sunrise**

→ At Sunset OR Sunrise the Sun and its Surrounding appears red. Because of Scattering of light. The light from the Sun At Sunset OR Sunrise travells a longer distance through the Earth atmosphere to reaches over Eyes. Due to this only Red Colour remains Unscatted and reached our Eye.




**(C) Clouds Are Generally white.**

→ Clouds Consist of dust particle and water droplets. There size is Very large as Compare to the wavelength of incident light from the Sun. And Reyleigh's law Cannot be applicable on this Case. So All Colours are Scattered Equally. Hence the light be recived through the cloud be white.

**(D) Denger Signal Are Red**

→ When light falls on the Signal All Colours are Scattered much more then that of red Colour, So the red Colour Suffering least Scattering and it is visible from very far of distances.

**Part :- 4 (Prism) Is Complete. Now Part :- 5 (Optical instruments) is our last part of chapter Ray optics.**

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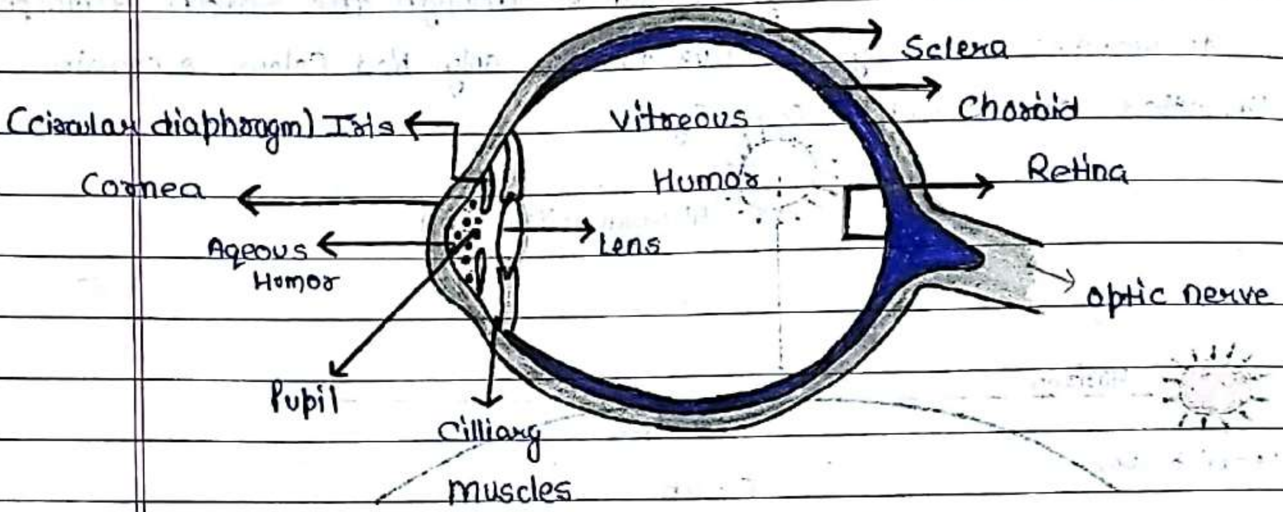
- Part – 5
- Optical Instrument

1. HUMAN EYE




→ Human Eye is an optical device And Acts as a Complex Natural Camera.

1. Sclera

The Outer White layer of Skin Eye is Called Sclera. It is a tough layer inside this layer their is a Black Colour layer Called Cooid (Choroid). Sclera provided protective Cover to the Eye. Choroid decrese of Reflection of light inside the Eye.

2. Cornea

It is the Outer frontal part of the Eye. It is transparent and allow light to Entre the Eye.

3. Iris

It is a Coloured Circular diaphragm having a Centre hole this hole is Called pupil. The function of Iris is to Control the amount of light Entring the Eye through the pupil.

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The pupil becomes small in Bright light and it becomes wide in dim light.

4. **Lens**

The Eye lens is a double Convex lens and made of transparent and flexible tissue. It is behind the pupil and held by the muscles, Called Cillary muscles. The lens focuses the image of Object On the retina of Eye.

5. **Ciliary muscles**

These muscles Hold the Eye lens in position. Cilliary muscles Control the focal length of Eye lens. When these muscles Contracts the focal length of Eye lens decreses. On the other Hand when Cilliary muscles are relexed then the focal length of the Eye lens Incereses. (P↑) → (near vision) (P↓) → (far fision)

6. **Retina**

It Act as a Screen to Obtained the image of the object. It Contains special cells which are sensitive to light. The retina of the Eye Contains two type of light sensitive cell in the shapes of rodes and cones.

7. **Optic Nerve**

Optic Nerve is formed by nerve fibre Coming from retina. It Carries Signal through the Brain the Brain finally interprete the Signal.

8. **Pupil**

The dotted part Shown in figure is known as pupil of Eye.

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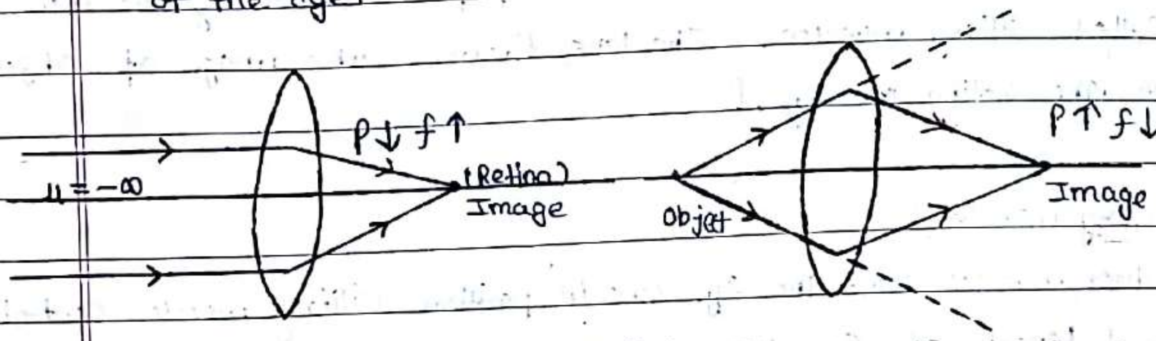
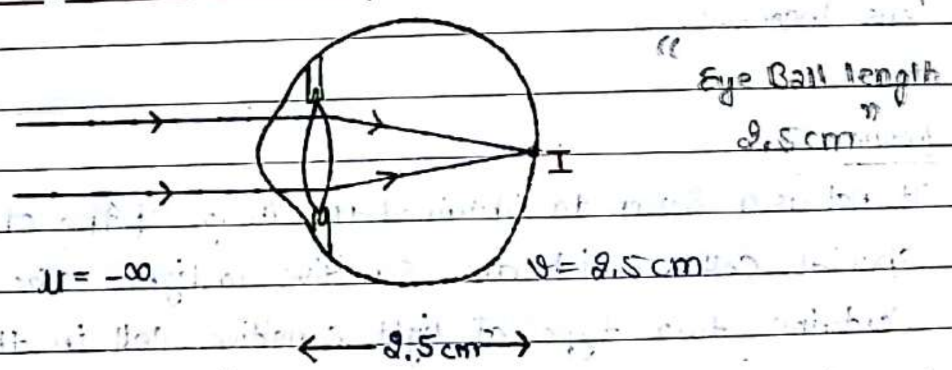
- **Accomodation**:

→ The process by which Cilliary muscles changes the focal length of Eye lens in such a way that the sharp image of an Object at any position from the Eye is formed on the retina is known as Accomodation of the Eye.




- **Accodation Power of Eye**

1. **When Object is at infinity**




then from lens formula

$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ Here $u = -\infty$ and $v = 2.5$ cm

then ⇒ "$f = 2.5$ cm." ⇐

and ⇒ "Power (P) $= \frac{100}{f(cm)} = 40D$." ⇐

2. **When Object is at near point (25cm)**

from lens formula

$u = -25$cm and $v = 2.5$cm then $f = \frac{25}{11}$ cm

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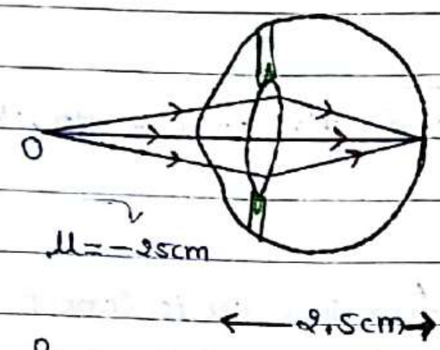



And Power = $\frac{100}{f(cm)}$

⇒ "then $P = 44D$" ⇐

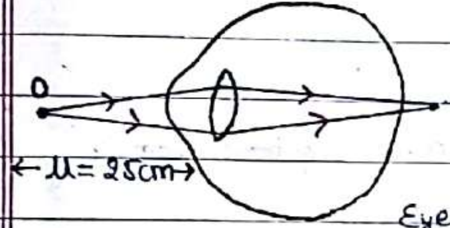
Hence, Power of Accomodation is

$44D - 40D = 4D$

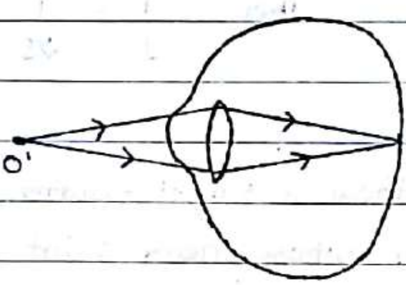
[Hypermetropia → Old Age → Convex.
myopia → Young Age → Concave.]

## • Defect of Vision

### 1. Hypermetropia (long Sightedness) (long vision see)




Eye suffered (Defected Eye) from long Sightdness




Near point of Hypermetropia Eye.

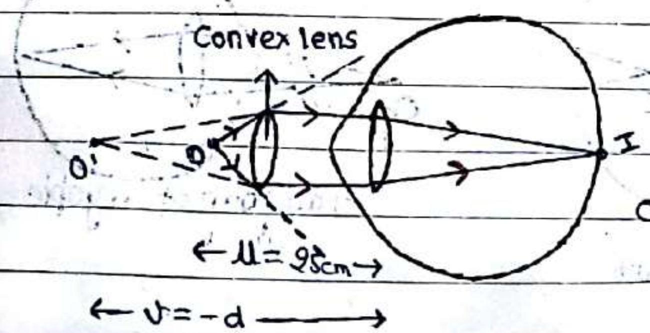
→ A Human Eye which Can see far off object or distant Object Clearly But Can not See the near Object clearly is Said to be Sufferering from a defect known as Hypermetropia.

### Cause of Hypermetropia

This defect Aries due to :-

1). focal length increse of Eye lens.

2). Decresece in the size of Eye ball.




Corrected Eye

## * Correction of Hypermetropia

→ By using a Convex lens of Suitable focal length this defect Can be Corrected.

- focal length And Power of Convex lens use to Correct Hypermetropia

Here from lens formula

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$ Here $u = -25cm$ and $v = -d$

then $$\frac{1}{f} = \frac{1}{-d} + \frac{1}{25}$$

then $$\frac{1}{f} = \frac{1}{25} - \frac{1}{d}$$

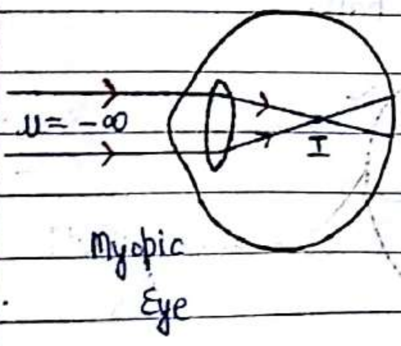
Q. What focal length of reading spectales are required for a person whose near point is 50cm.

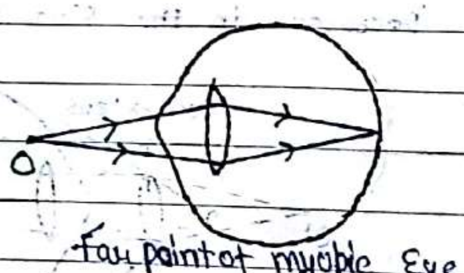
Sol$^n$ Here $$\frac{1}{f} = \frac{1}{25} - \frac{1}{d}$$ Here $d = 50cm$

then $f = 50cm$

then $$P = \frac{100}{f(cm)} = \frac{100}{50} = 2D.$$

2. Myopia (Shortdness) (far fission not see)



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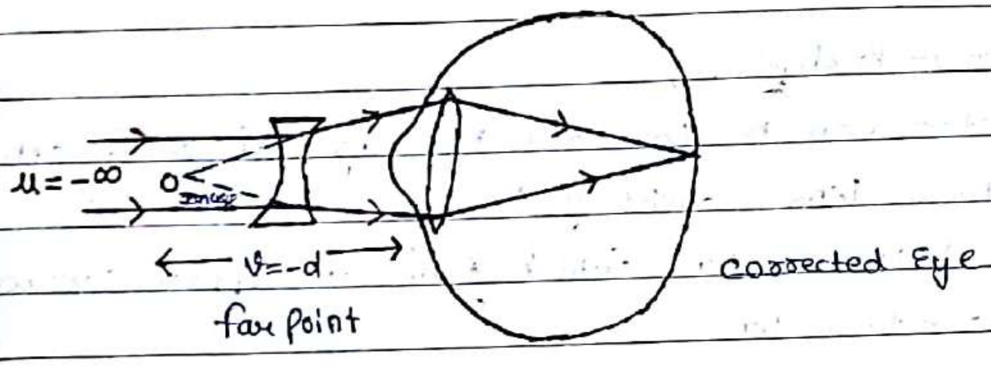
* A Human is mypic OR Shortdness if it Can see the near Object Clearly. But it is unable to Can see far off Object Clearly (distant Object)

* Cause of myopia

1. Decreses in focal length. 2. increse in the size of Eye ball.

* Correction of myopia

This defect Can be Corrected by using Concave lens of Suitable focal length.




Now from lens formula (for myopia correction)

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \quad \text{Here } u = -\infty \text{ and } v = -d$$

then ⇒ "$f = -d$," ⇐ and ⇒ "$P = \frac{100}{f(cm)} = \frac{-100}{d}$" ⇐

The far point of myopic person is 150cm in front of the Eye. Calculate the focal length and power of the lens required to Enable in to see distant Object Clearly.

Here $d = 150$ cm then $f = -d$ then $f = -150$cm

and $P = \frac{-100}{f(cm)} = \frac{-100}{150} = -\frac{2}{3} = -0.6$ D.

Presbyopia

A Human Eye which Can not see the near object clearly As Well as far object clearly is said to suffer from a defect known as presbyopia.

* Cause of Presbyopia

This defect is Aries in Older person Because effective-ness of cililary muscles is decrese and flexibility of lens of the Human Eye decrese with Age of the person. Due to this Eye Cannot able to See near as Well as far Object.

* Correction of Presbyopia

This defect Can be Corrected by using Bifocal Lens:

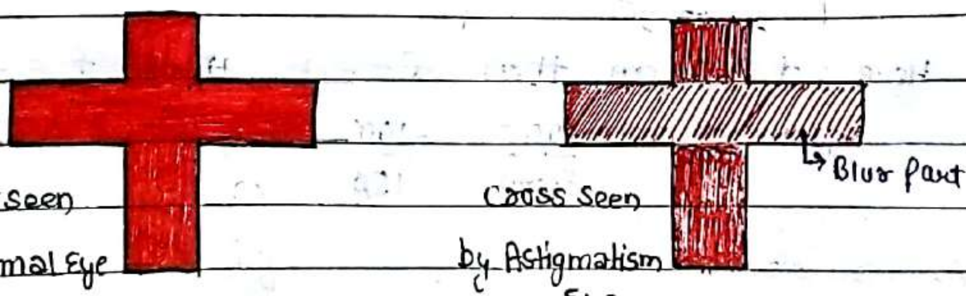
A Bifocal lens Consist of :-

1. A Concave lens which forms the upper Surface of the bifocal lens.

2. A Convex lens which forms the lower Surface of the Bifocal lens.

4. Astigmatism

A Human Eye which Can not See both Horizontal OR Verticle portion of an object Simentanously with same clearity is suffering from a defect known as Astigmatism




Cross Seen By Normal Eye

Cross Seen by Astigmatism Eye

* Cause of Astigmatism

This defect is Aries When the Cornea of the Eye have

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different Curvatures in different direction in the Horizontal OR Vertical Plane. (The Cornea is not spherical)

* **Correction of Astigmatism**

It Can be Corrected by used spectacles having Cylinderical lens

- **Simple Microscope**

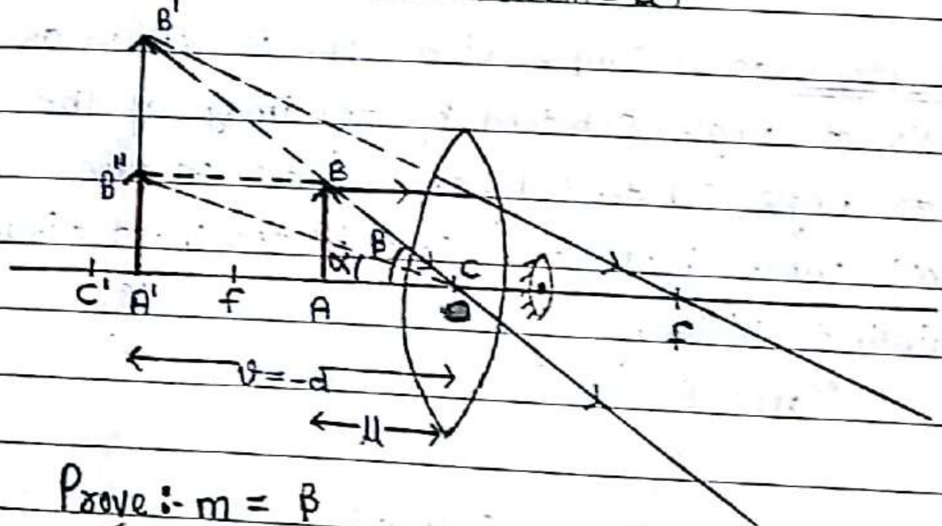
A simple microscope is an optical instrument to see very small object As magnified one. It consist of a Convex lens of small focal length. A magnifying Glass is an example of simple microscope.

- **Principal**

A simple microscope is based on the fact that an object placed Between the optical Centre and focus of a Convex lens forms a Virtual, erect and magnifying image on the same side of the lens.

- **Magnifying power (Angular Magnification)**

1. For distinct vision When the image is formed At the least distance of the distinct Vision (25cm = d)




Prove :- $m = \frac{\beta}{\alpha}$

from $\Delta A'B'C$ then

then $\tan\beta = \frac{A'B'}{CA'}$ —(1)

Now from $\Delta A'B''C$

then $\tan\alpha = \frac{A'B''}{CA'}$ —(2)

If Angle is Small

then $\tan\beta \simeq \beta$

and $\tan\alpha \simeq \alpha$

then $\beta = \frac{A'B'}{CA'}$ and $\alpha = \frac{A'B''}{CA'}$ ] —(3)

By dividing Equation ($\beta$) and ($\alpha$)

then $\frac{\beta}{\alpha} = \frac{A'B'}{A'B''} = \frac{h_i}{h_o} = m$

then ⇒ "$m = \frac{\beta}{\alpha} = \frac{h_i}{h_o}$" ⇐

* magnifying power of a simple microscope is defined as the ratio of Angle substend by the image of the Eye ($\beta$) to Angle substend by the Object at the Eye ($\alpha$) when both are place at the least distance of the distinct vision.

"$m = \frac{\beta}{\alpha}$"

* Magnification of lens in terms of $u$ and $v$

Here $m = \frac{v}{u}$ and $v = -d$

and $u = -u$

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d ⇒ distinct Vision of distance Vision

then $m = \frac{d}{u}$ Now from lens formula

$$\left[\frac{1}{f} = \frac{1}{v} - \frac{1}{u}\right]$$

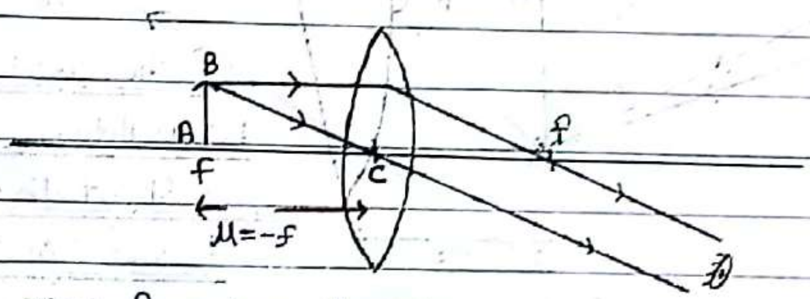
then $\frac{1}{f} = \frac{1}{-d} - \frac{1}{(-u)} = \frac{1}{u} - \frac{1}{d}$ —(1) ∵ $u = -u$ and $v = -d$

multiply both side by d

then $\frac{d}{f} = \frac{d}{u} - 1$ and $\frac{d}{u} = m$

then ⇒ $m = 1 + \frac{d}{f}$ ⇐ e.g. 5 times

For Normal Vision When the Image is formed At Infinity




Here $u = -f = -u$

and $v = \infty$

Now from lens formula

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

then $\frac{1}{f} = \frac{1}{\infty} - \frac{1}{(-u)}$

then $\frac{1}{f} = \frac{1}{u}$ —(1)

Both side divide by d then $\frac{d}{u} = m$ (Angular magnification)

then $\frac{d}{f} = m$

Here ⇒ $m = \frac{d}{f}$ ⇐ e.g. 4 times (Normal Vision)

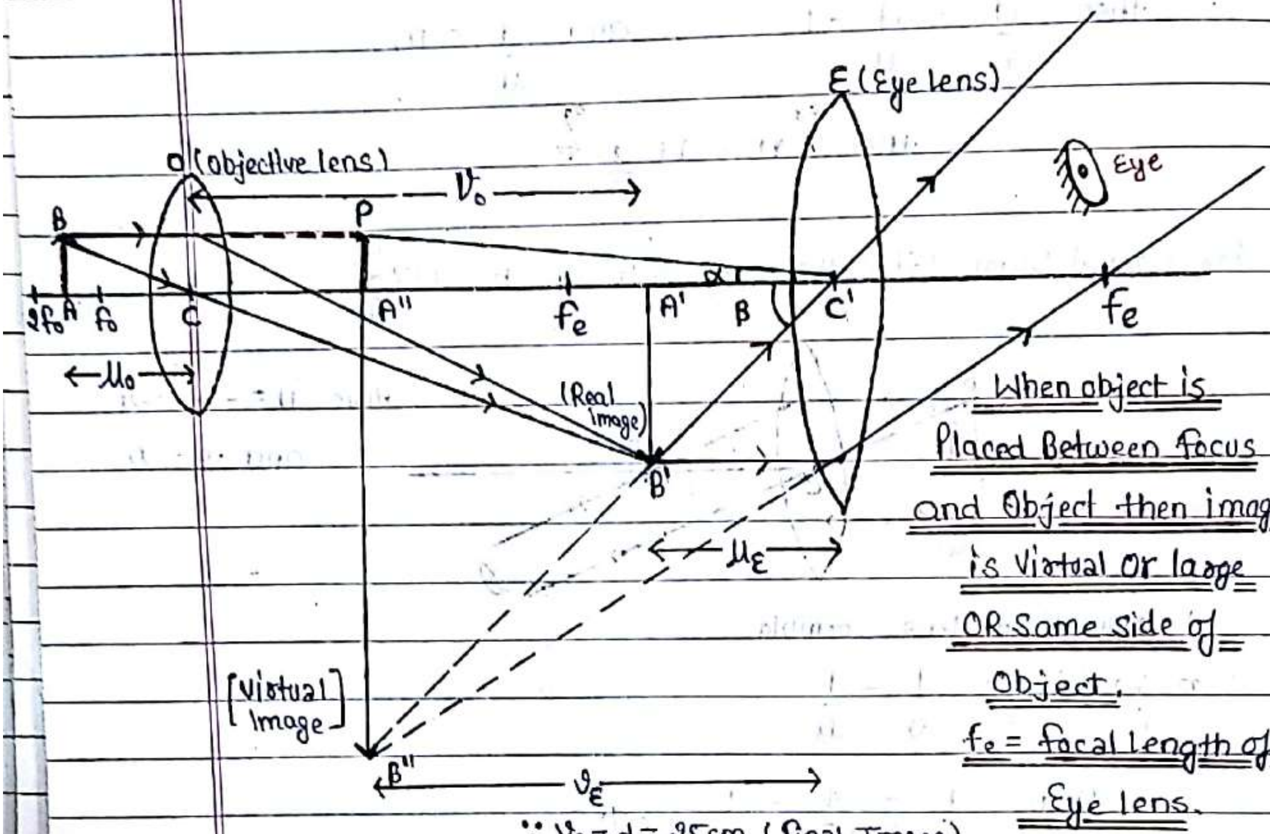
Scanned by CamScanner

To see the image with relexed Eye the image must be formed at infinity the microscope is in normal Arrangement when the image is formed at infinity.

V.V. Imp

• **Compound Microscope**

→ Compound microscope is used to See Very Small particle which Can not be Seen with the Simple microscope.




∵ $V_e = d = 25cm$ (final Image)

When object is Placed Between Focus and Object then image is Virtual or large OR Same side of Object.
$f_e$ = focal length of Eye lens.

• **Principal**

→ When object is placed in front of a Objective lens O B/w $f_o$ and $2f_o$ then its image is formed real, inverted and other side of lens (A'B'). If this image is formed Between optical Centre and focus ($f_E$) of a large apperture lens (Eye lens) then this Image acts as object for Eye lens. Image formed by the Eye lens is Virtual, Inverted High magnified.

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- Expression for Angular Magnification (m)

(A) Here Angular magnification is Given by :-

$$m = \frac{\beta}{\alpha} \quad -(1)$$

Now from $\Delta A''PC'$

then $\tan\alpha = \frac{PA''}{C'A''}$ and $PA'' = AB$ (Height of Object)

then $\tan\alpha = \frac{AB}{C'A''} \quad -(2)$

Now from $\Delta A''B''C'$

then $\tan\beta = \frac{A''B''}{A''C'} \quad -(3)$

By dividing Equation (2) and (3)

then $\frac{\tan\beta}{\tan\alpha} = \frac{A''B''}{AB} \quad -(4)$

If Angle is Small $\tan\beta \simeq \beta$ and $\tan\alpha \simeq \alpha$

then $\frac{\beta}{\alpha} = \frac{A''B''}{AB} \quad -(5)$

multiply and divide of $A'B'$

then $\frac{\beta}{\alpha} = \frac{A''B''}{AB} \times \frac{A'B'}{A'B'} = \frac{A''B''}{A'B'} \times \frac{A'B'}{AB}$ $\left[\frac{h_i}{h_o} = m\right]$

then $\frac{\beta}{\alpha} = m_e \times m_o$ and $\frac{\beta}{\alpha} = m$

then $\Rightarrow$ "$m = m_e \times m_o$" $-(6)$

Scanned by CamScanner

→ Magnification of Objective lens ($m_o$)

Here $m = \frac{v}{u}$ and $v = v_o$

and $u = -u_o$

then $m_o = \frac{-v_o}{u_o}$ —(A)

→ Magnification of Eye lens ($m_E$)

then $m = \frac{v}{u}$ Here $v = -d$

and $u = -u_E$

then $m_E = \frac{d}{u_E}$ —(B)

→ Now from lens formula

$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ for Eye lens

$f = f_e$, $u = -u_E$

and $v = -d$

then $\frac{1}{f_e} = \frac{-1}{d} + \frac{1}{u_E}$ —(C)

Both side ~~divide~~ multiply of d

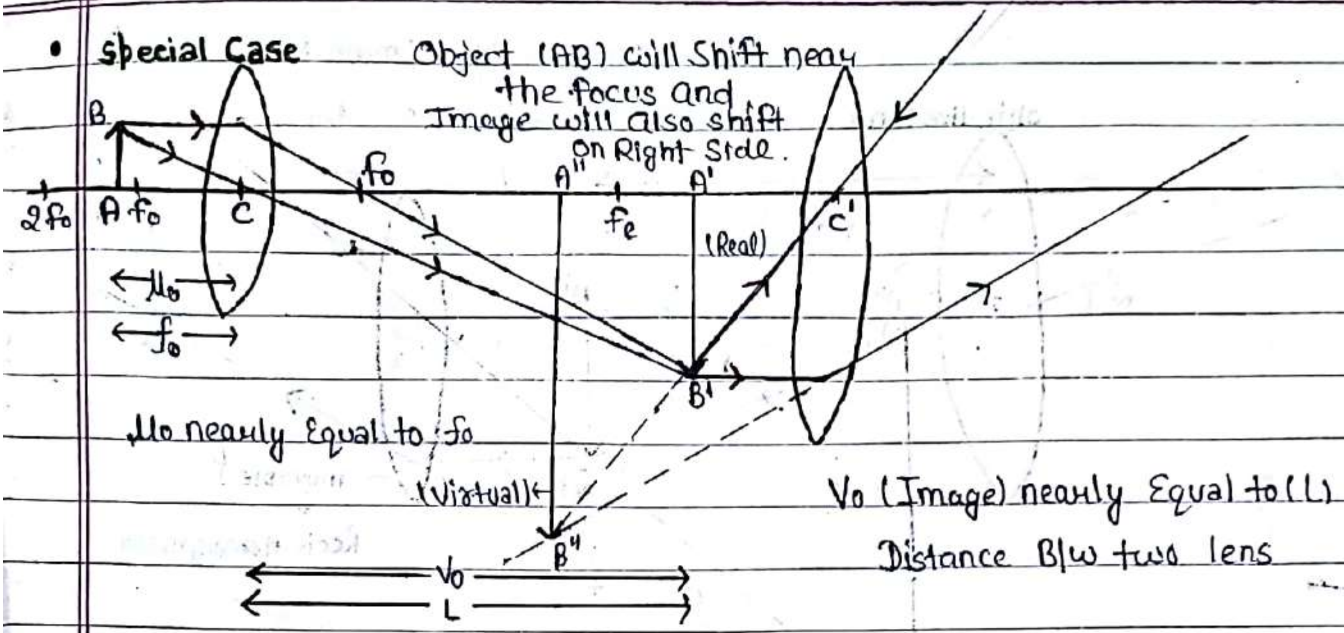
then $\frac{d}{f_e} = -1 + \frac{d}{u_E}$ and $\left[m = \frac{d}{u_E}\right]$

then $m_E = 1 + \frac{d}{f_e}$ —(D)

put Value of $m_e$ and $m_o$ in Equation (6)

then ⇒ $m =$ "$\left[\frac{-v_o}{u_o}\right]\left[1 + \frac{d}{f_e}\right]$" ⇐ from (D) and (A) Equation.

- Special Case




→ Some Compound microscope are used to see Very Small Objects.
In this type of microscope object AB is place very near to the focal point of Objective lens.

Hence $u_o = f_o$ —(1)

and $v_o = L$ —(2)

then $m = \left[\frac{-v}{u}\right]\left[1 + \frac{d}{f_e}\right]$ —(A)

then ⇒ "$m = \left[\frac{-L}{f_o}\right]\left[1 + \frac{d}{f_e}\right]$" ⇐

- Telescope (Far Object Can Seen)

→ Telescope is an optical instrument to see far of Object (distant Object) Clearly.

- Types of Telescope

1. Refracting Telescope (lens)

Refracting Telescope are of two types :-

(A) Astronomical Telescope

→ Astronomical Telescope is used to see Astronomial object like moon, Stars and Plants. These type of Telescope form Virtual and inverted image.

Parallel light (moon rays) refracted at focus.

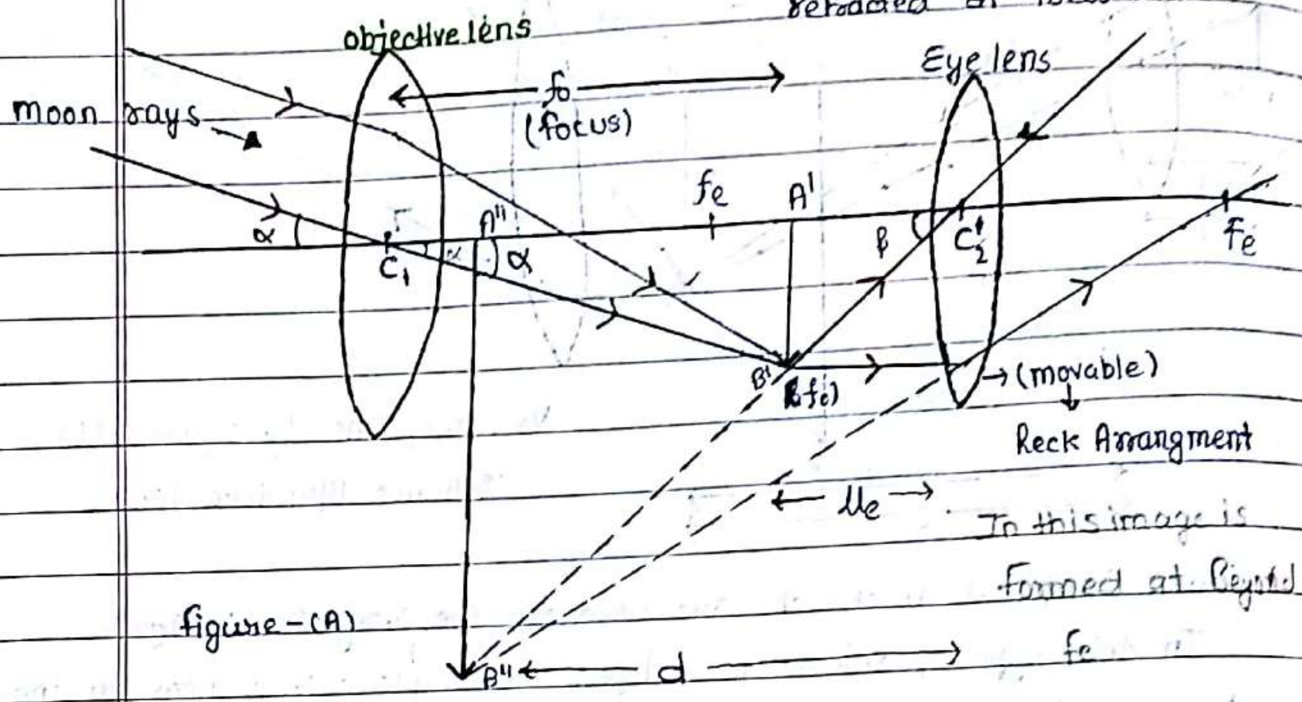



figure-(A)

- Since, Generally Astronomical objects are spherical. Hence its inverted Image does not effect the Observation.

- **Construction**

- In this there is two Convex lens which is Connected Co-axially by metal tubes. Lens which is Connected to object side k/a Objective lens. Its apprature is large and focal length is also large. Another lens from which image Can be Seen k/a Eye lens. Its Apparature and focal length is small.

- **Principal**

- When Objective lens of telescope is placed towards the Object at infinity then real and inverted image of object is formed at focal plane (A'B') of Objective lens.

- Eye lens is adjusted in such a way that final image $A''B''$ formed at minimum distance at distinct Vision.

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- **Magnifying Power OR Angular magnification of Astronomical telescope**

(A) Angular magnification of an Astronomical telescope is defined as the ratio of Angle Substend by the ~~eye~~ Image at the Eye to angle Substand by the Object at the Eye When image is at minimum distinct of minimum vision (distinct).

Here $m = \frac{\beta}{\alpha}$ — (1)

In $\Delta C_1A'B'$

$$\tan\alpha = \frac{A'B'}{A'C_1} \quad \text{— (2)}$$

[By taking Common Side to Cancel out one Side]

Now In $\Delta C_2A'B'$

$$\tan\beta = \frac{A'B'}{C_2A'} \quad \text{— (3)}$$

By Dividing (3) and (2)

$$\frac{\tan\beta}{\tan\alpha} = \frac{C_1A'}{C_2A'} \quad \text{— (4)}$$

If Angle is Small then $\tan\beta \simeq \beta$ and $\tan\alpha \simeq \alpha$

then $\frac{\beta}{\alpha} = \frac{C_1A'}{C_2A'} = \frac{f_o}{-u_e}$ ∴ from figure

then $m = -\frac{f_o}{u_e}$ — (5)

from lens formula

then $\frac{1}{f} = \frac{-1}{u} + \frac{1}{v}$ — (A)

for Eye lens $f = f_e$, $u = -u_e$, $v = -d$

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then from (A) Equation

$$\frac{1}{f_e} = +\frac{1}{u_e} - \frac{1}{d}$$

then $\frac{1}{u_e} = \frac{1}{f_e} + \frac{1}{d}$ — (6)

from Equation (5) $m = -\frac{f_o}{u_e}$

then $\frac{1}{u_e} = -\frac{m}{f_o}$ put this Value in (6) Equation

then $-\frac{m}{f_o} = \frac{1}{f_e} + \frac{1}{d}$

then $m = -f_o\left[\frac{1}{f_e} + \frac{1}{d}\right]$

By taking $f_e$ common

then ⇒ "$m = -\frac{f_o}{f_e}\left[1 + \frac{f_e}{f_d}\right]$" ⇐

**length of telescope**

Here $l = C_1 f_o + f_o C_2$ from figure (A)

then $L = f_o + u_e$ —(7)

from (6) Equation

$$\frac{1}{u_e} = \frac{1}{f_e} + \frac{1}{d}$$

then $\frac{1}{u_e} = \frac{f_e + d}{f_e d}$

then $u_e = \frac{f_e d}{f_e + d}$ —(8)

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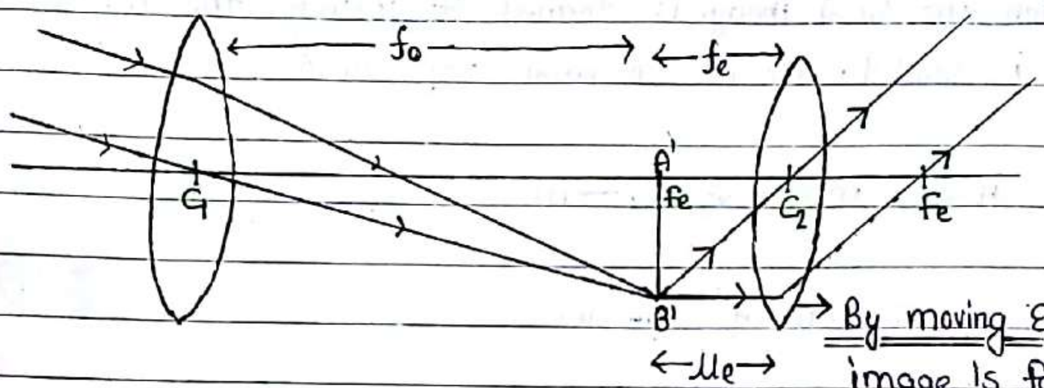
put Value (8) in (7) Equation

then $\Rightarrow$ "$L = f_o + \dfrac{f_e . d}{f_e + d}$" $\Leftarrow$

**(B) for Normal Adjusment**




By moving Eye lens the image Is formed at fe.

from Equation – (5)

$m = -\dfrac{f_o}{u_e}$ and $u_e = f_e$

then $\Rightarrow$ "$m = -\dfrac{f_o}{f_e}$" $\Leftarrow$

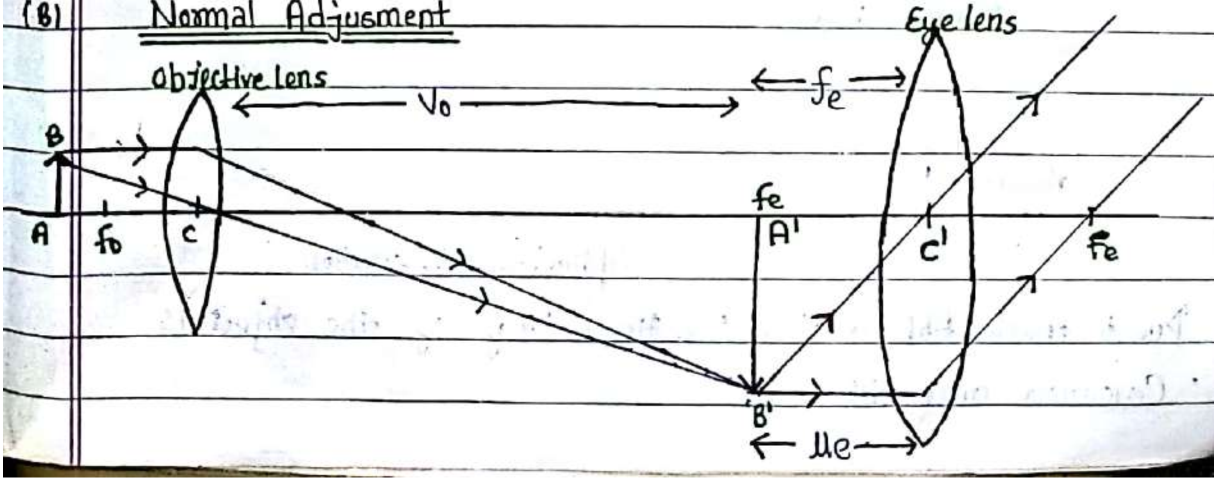
Length Of Telescope

$\Rightarrow$ "$L = f_o + f_e$" $\Leftarrow$

→ When the final image is formed at infinity the telescope is Said to be in Normal adjusment.

* Compound Microscope

(B) Normal Adjusment



Magnification of Compound Microscope

$$m = m_o . m_e \quad —(A)$$

magnification of Objective lens

→ When the final image is formed at infinity the microscope is said to be in Normal adjusment.

Here $m_o = -\frac{V_o}{u_o}$ —(1)

magnefication of Eye lens

$m_e = \frac{v}{u}$ , $v = -d$ and $u = -u_e = -f_e$

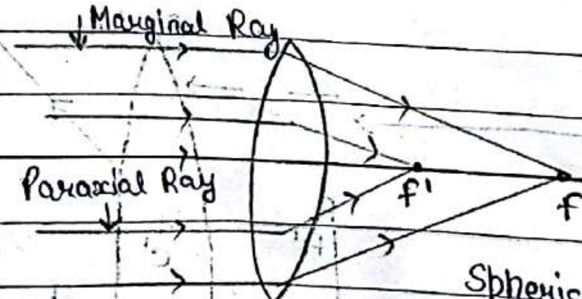
then $m_e = \frac{d}{f_e}$ —(2)

from $m_o, m_e$ put value in (A) equation

$$\Rightarrow m = -\frac{V_o}{u_o} \cdot \frac{d}{f_e}$$

- limitation of Refracting Type Telescope

1. The Refracting type telescope Suffers from spherical and Cromatic Abbration. (दोष, Defect)




Spherical Abberration

Due to these Abberration the final image of the object is Coloured and Blured.

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2. Objective lens of Very large Appartuse are very difficult to manufacture

2. Reflecting type telescope (Mirror)

Reflecting type telescope is used Over Refracting type telescope Because there is no spherical OR Chromatic abbreation in Reflecting type telescope.

Reflecting type telescope are mainly divided into two types

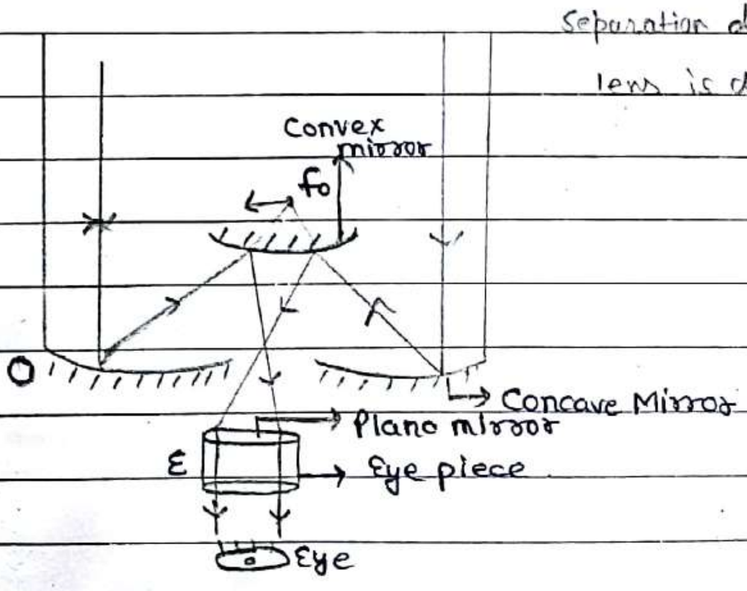
1). Cassegrain type telescope
2). Newtonian type telescope

(Banglore → 2.34 Diameter)

1. Cassegrain type telescope (large Appratusc → Concave mirror → used to see far obj. clearly)

It consist of a Concave mirror O have a large appratuse with a Circular hole at its centre. Small convex mirror is placed in front of the objective O of the telescope the final image is observed through an Eye piece (E) placed in front of the whole of the objective

Separation due B/w two Concave lens is due to no cromatic Abbera




• Magnifying Power

$$M = \frac{f_o}{f_e}$$