OPTICS (RAY OPTICS)

(I) REFLECTION OF LIGHT

Reflection → The phenomenon of return of light in the same medium when the light falls on a reflecting surface (eg. mirror) is known as reflection of light.

Laws of reflection → (i) Angle of incidence is equal to angle of reflection.

$$\Rightarrow \angle i = \angle r$$

(ii) The incident ray, reflected ray and normal to the reflecting surface lie in the same plane.

* There are two types of reflection

(i) Regular (specular) reflection

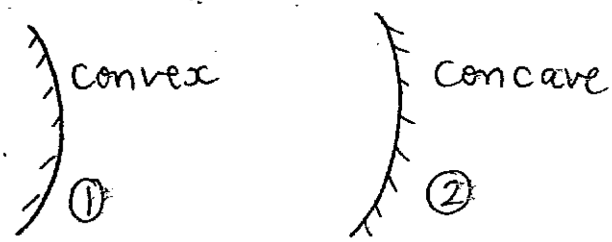
(ii) Irregular (diffuse) reflection

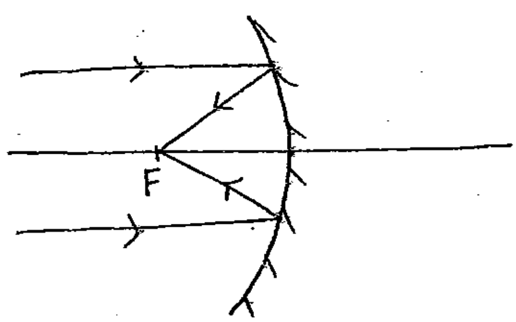
* Image formed by plane mirror is virtual, erect, same in size and at same distance from mirror as the object

Spherical mirrors

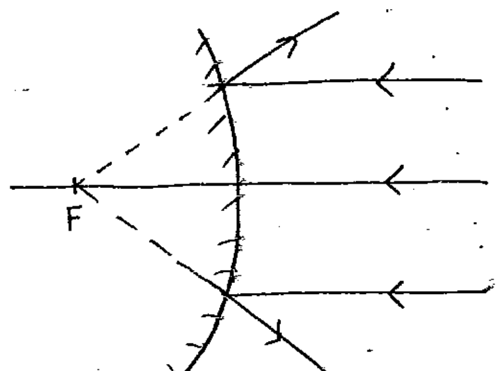
① Convex mirror

② Concave mirror





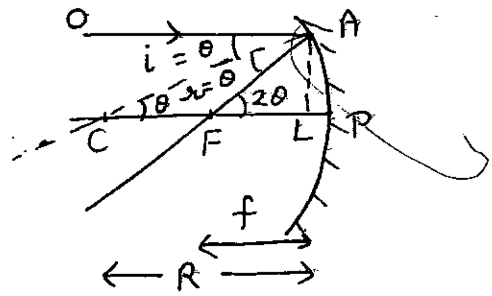
Real Focus in Concave mirror



Virtual Focus in Convex mirror

Relation between focal length and radius of curvature of spherical mirrors

i) Concave mirror



According to laws of reflection $\angle i = \angle r = \angle \theta$

$\angle ACF = \angle OAC = \theta$
(Alternate angles)

$\angle AFP = \angle ACF + \angle CAF = \theta + \theta = 2\theta$

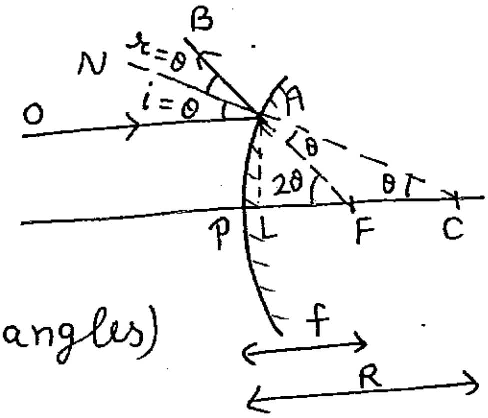
$\tan\theta \approx \theta = \frac{AL}{LC}$ $\quad\quad$ $\tan 2\theta \approx 2\theta = \frac{AL}{LF}$

$\Rightarrow LC = 2LF$ or $PC = 2PF$

(As aperture is small)

$\Rightarrow R = 2f$ or $f = R/2$

ii) Convex mirror



According to laws of reflection $\angle i = \angle r = \angle \theta$

$\angle CAF = \angle BAN = \theta$ (opposite angles)

$\angle PCA = \angle OAN = \theta$ (corresponding angles)

$\angle AFP = \theta + \theta = 2\theta$

$\tan\theta \approx \theta = \frac{AL}{LC}$ $\quad\quad$ $\tan 2\theta \approx 2\theta = \frac{AL}{LF}$

$LC = 2LF$ or $PC = 2PF$

(As aperture is small)

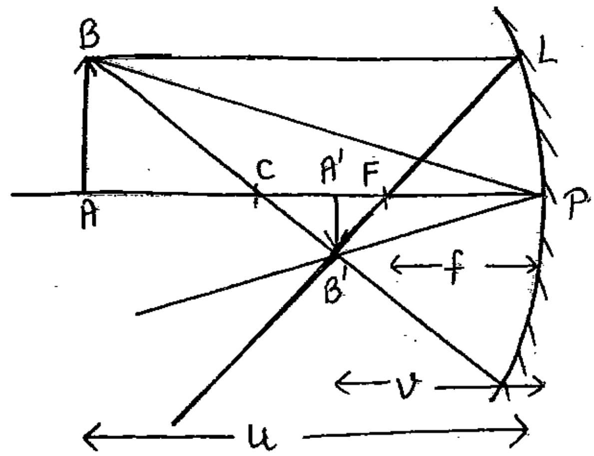
$\Rightarrow R = 2f$ or $f = R/2$

* Focal length of convex mirror is +ve and focal length of concave mirror is −ve according to sign convention.

Mirror Formula

(i) Concave mirror when real image is formed

From the diagram,



$\Delta s\ ABC$ & $A'B'C$ are similar

$$\Rightarrow \frac{A'B'}{AB} = \frac{CA'}{CA}$$

Now $\Delta s\ ABP$ & $A'B'P$ are similar

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

$$\Rightarrow \frac{CA'}{CA} = \frac{PA'}{PA} = \frac{PC - PA'}{PA - PC}$$

$PA' = -v$, $PC = -R$, $PA = -u$

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

$$\Rightarrow uv - vR = uR - uv$$

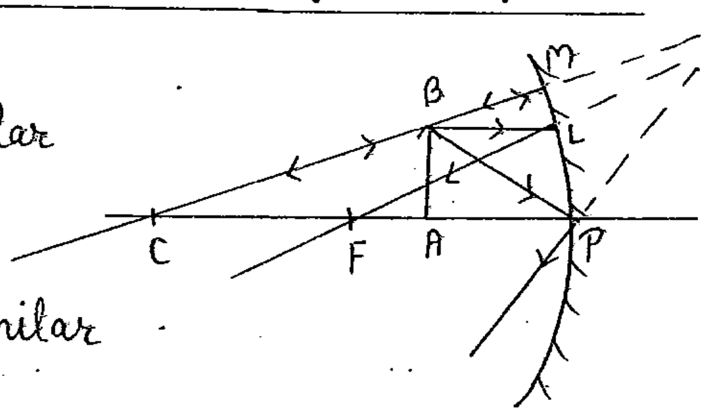
$$\Rightarrow 2uv = uR + vR \qquad \because R = 2f$$

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

This is required mirror formula

(ii) Concave mirror when virtual image is formed

From the diagram



$\Delta s\ ABC$ & $A'B'C$ are similar

$$\frac{A'B'}{AB} = \frac{CA'}{CA} = \frac{PC + PA'}{PC - PA}$$

& $\Delta s\ ABP$ & $A'B'P$ are similar

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

$$\Rightarrow \frac{PC + PA'}{PC - PA} = \frac{PA'}{PA}$$

$PA' = +v$, $PC = -R$, $PA = -u$

$$\Rightarrow \frac{-R+v}{-R+u} = \frac{v}{-u} \quad \text{or} \quad uR - uv = -vR + uv$$

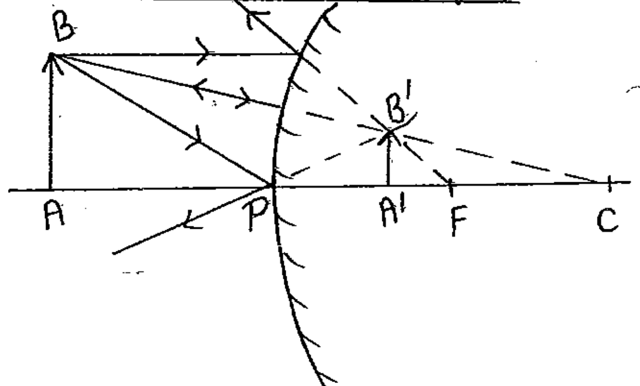
$$\Rightarrow 2uv = uR + vR$$

As $R = 2f$

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

This is required mirror formula.

ii) <u>Convex mirror (Always virtual image)</u>



From the diagram

Δs ABC & A'B'C are similar

$$\Rightarrow \frac{A'B'}{AB} = \frac{CA'}{CA}$$

& Δs ABP & A'B'P are similar

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

$$\Rightarrow \frac{PA'}{PA} = \frac{CA'}{CA} = \frac{PC - PA'}{PC + PA}$$

$PC = R$, $PA' = v$, $PA = -u$

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

$$\Rightarrow -uR + uv = vR - uv$$

or $2uv = uR + vR$

As $R = 2f$

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

This is required mirror formula.

Linear Magnification

Ratio of size of image to the size of object.

$$m = \frac{I}{O}$$

(i) In concave mirror

(a) when real image is formed

$$m = -\frac{I}{O} = \frac{-v}{-u} = \frac{v}{u}$$

Magnification is negative

(b) When virtual image is formed

$$m = \frac{I}{O} = \frac{v}{-u}$$

Magnification is positive

(ii) In convex mirror

$$m = \frac{I}{O} = -\frac{v}{u}$$

Magnification is positive

Magnification in terms of u, v & f

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

using $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ $\quad m = -\left(\frac{f}{u-f}\right)$

$$\text{or} \quad m = \frac{f}{f-u}$$

$$\& \quad m = -\left(\frac{v-f}{f}\right)$$

$$\text{or} \quad m = \frac{f-v}{f}$$

II REFRACTION OF LIGHT

Refraction of light → The phenomenon of change in direction of path of light when it goes from one medium to another is called refraction of light.

Laws of refraction → (i) The incident ray, refracted ray and the normal to the interface at the point of incidence lie in the same plane.

(ii) The ratio of sine of angle of incidence (i) to the sine of the angle of refraction (r) is constant for any two given media.

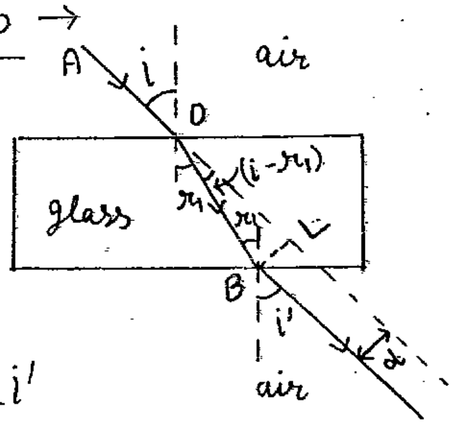
(Snell's law) $$\frac{\sin i}{\sin r} = \text{Constant } (\mu)$$

Principle of reversibility of light → If the path of ray of light is reversed after suffering a number of reflections & refractions, it retraces its path.

i.e. $$^1\mu_2 = \frac{\sin i}{\sin r} \qquad ^2\mu_1 = \frac{\sin r}{\sin i}$$

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

Refraction through a glass slab →



$$^a\mu_g = \frac{\sin i}{\sin r_1}, \quad ^g\mu_a = \frac{\sin r_1}{\sin i'}$$

Now $$^a\mu_g = 1/{^g\mu_a}$$

$$\Rightarrow \quad \sin i = \sin i' \Rightarrow \angle i = \angle i'$$

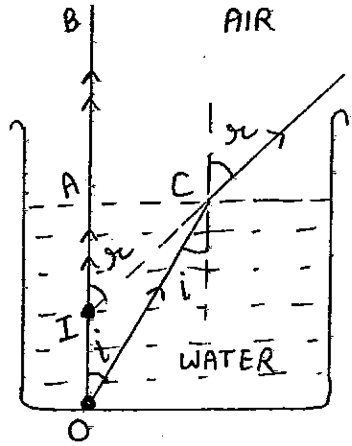
Lateral shift (d) $\rightarrow$ $\sin(i-r_1) = \dfrac{BL}{OB} = \dfrac{d}{OB}$

$\because OB = \dfrac{t}{\cos r_1}$ (From fig.)

$$\Rightarrow d = \frac{t\sin(i-r_1)}{\cos r_1}$$

Relation between Real depth & Apparent depth

According to Snell's law



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

$\sin i = \dfrac{AC}{OC}$, $\sin r = \dfrac{AC}{IC}$

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

Now ${}^{w}\mu_a = \dfrac{1}{{}^{a}\mu_w}$

$$\Rightarrow {}^{a}\mu_w = \frac{OC}{IC} = \frac{\text{Real depth}}{\text{Apparent depth}}$$

Few examples of refraction of light

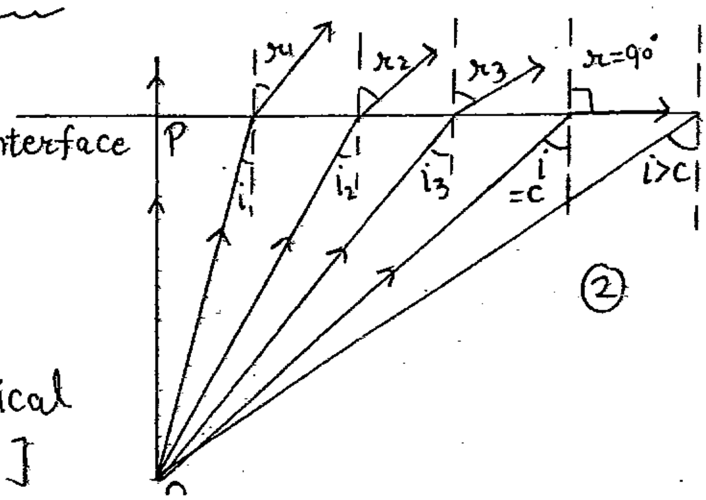
(i) Twinkling of stars

(ii) Bending of an immersed object

(iii) Flattening of Sun

(iv) Time difference during sun-rise & sun-set

Total Internal reflection



$${}^{2}\mu_1 = \frac{\sin i}{\sin r}$$

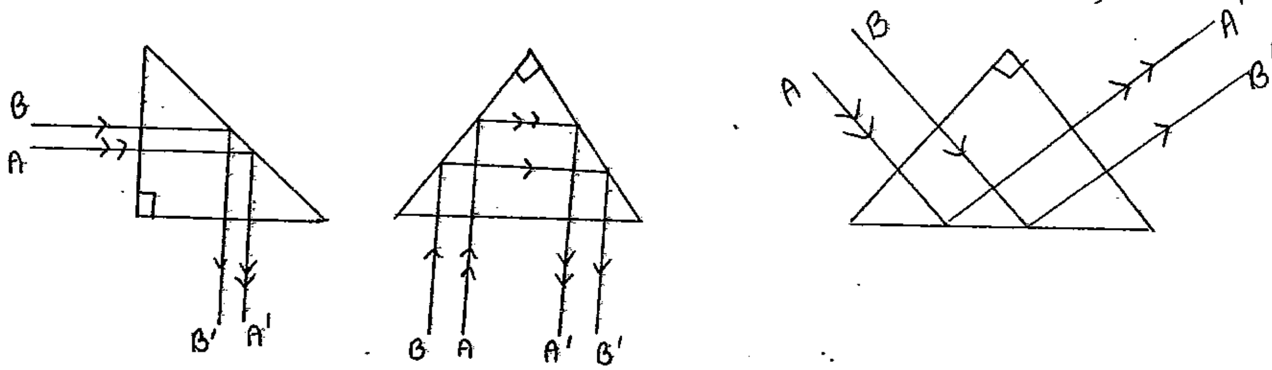
If $i = c$, $r = 90°$

$${}^{2}\mu_1 = \frac{\sin c}{\sin 90°} = \frac{\sin c}{1}$$

& ${}^{1}\mu_2 = \dfrac{1}{\sin c}$ [c is critical angle]

<u>Applications of Total Internal Reflection</u>

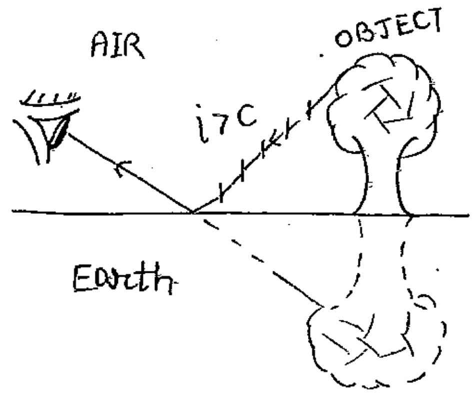
(i) Porro Prism (A right angled isosceles prism)



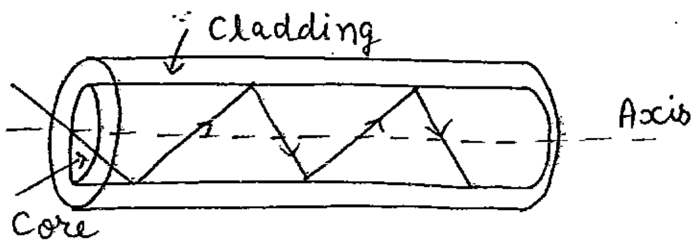
(ii) Sparkling diamond → critical angle for diamond is 24°. Cutting of the diamond is done in such a way that $i > 24°$

(iii) Mirage (optical illusion)

When $i > c$ then total internal reflection takes place



(iv) Optical Fibres



$\mu_{core} = 1.458$ $\mu_{cladding} = 1.440$

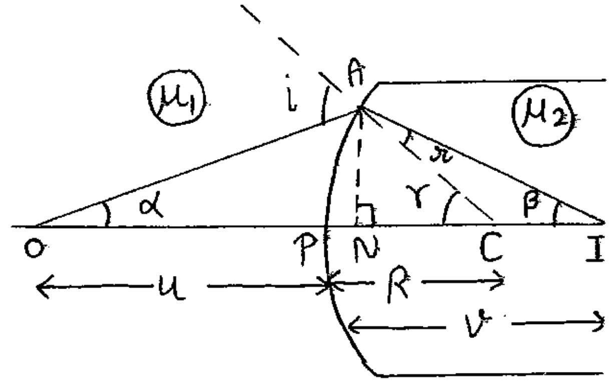
Light goes from denser to rarer at $i > c$ so total internal reflection takes place.

<u>Uses</u> → optical fibres are used in light transmission devices, endoscopes, telecommunication transducers etc

Refraction at a spherical surface

(i) Convex spherical surface when object is in
(a) rarer medium and image formed is real

From the figure:



$$i = \alpha + \gamma$$

$$\gamma = r + \beta \text{ or } r = \gamma - \beta$$

$\sin\theta \approx \tan\theta \approx \theta$ when θ is small so

$$\alpha = \frac{AN}{NO}, \quad \gamma = \frac{AN}{NC}, \quad \beta = \frac{AN}{NI}$$

$$\Rightarrow i = \frac{AN}{NO} + \frac{AN}{NC} \approx \frac{AN}{PO} + \frac{AN}{PC}$$

$$\& \ r = \frac{AN}{NC} - \frac{AN}{NI} \approx \frac{AN}{PC} - \frac{AN}{PI}$$

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

or $\mu_1 i = \mu_2 r$ $\quad$ [as $\sin\theta \approx \theta$]

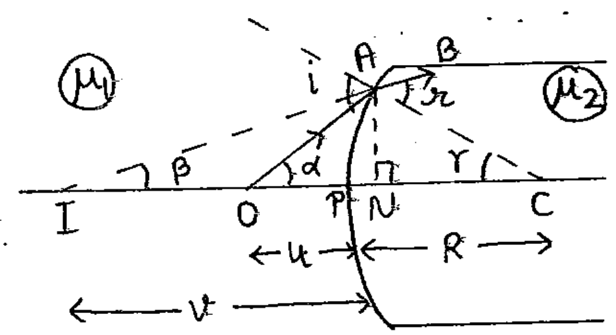
$$\Rightarrow \mu_1\left[\frac{AN}{PO} + \frac{AN}{PC}\right] = \mu_2\left[\frac{AN}{PC} - \frac{AN}{PI}\right]$$

$$\Rightarrow \frac{\mu_1}{PO} + \frac{\mu_2}{PI} = \frac{\mu_2 - \mu_1}{PC}$$

$$\Rightarrow \frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R} \quad [\because PO = -u, PI = v, PC =$$

(i) (b) When image formed is virtual

From the figure:



$$i = \alpha + \gamma$$

$$\& \ r = \beta + \gamma$$

$$\alpha = \frac{AN}{NO}, \quad \beta = \frac{AN}{NI} \ \& \ \gamma = \frac{AN}{NC}$$

$$\Rightarrow i = \frac{AN}{NO} + \frac{AN}{NC} = AN\left[\frac{1}{PO} + \frac{1}{PC}\right]$$

$$r = \frac{AN}{NI} + \frac{AN}{NC} = AN\left[\frac{1}{PI} + \frac{1}{PC}\right]$$

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

$\Rightarrow \mu_1 i = \mu_2 r$ [as $\sin\theta \approx \theta$]

$$\Rightarrow \mu_1\left[\frac{AN}{PO} + \frac{AN}{PC}\right] = \mu_2\left[\frac{AN}{PI} + \frac{AN}{PC}\right]$$

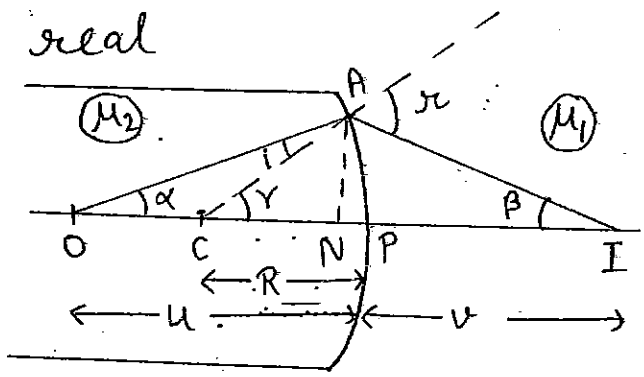
$$\Rightarrow \frac{\mu_1}{PO} - \frac{\mu_2}{PI} = \frac{\mu_2 - \mu_1}{PC}$$

$PO = -u$, $PI = -v$, $PC = R$

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

Refraction at convex spherical surface when object lies in denser medium

i) When image formed is real



From the figure :

$\gamma = i + \alpha$ or $i = \gamma - \alpha$

& $r = \beta + \gamma$, $\theta \approx \sin\theta \approx \tan\theta$

$\alpha = \frac{AN}{NO}$, $\beta = \frac{AN}{NI}$, $\gamma = \frac{AN}{NC}$

Then $i = \frac{AN}{NC} - \frac{AN}{NO}$, $r = \frac{AN}{NI} + \frac{AN}{NC}$

& $\frac{\sin i}{\sin r} \approx \frac{i}{r} = \frac{\mu_1}{\mu_2} \Rightarrow \mu_2 i = \mu_1 r$

$$\Rightarrow \mu_2\left[\frac{AN}{NC} - \frac{AN}{NO}\right] = \mu_1\left[\frac{AN}{NI} + \frac{AN}{NC}\right]$$

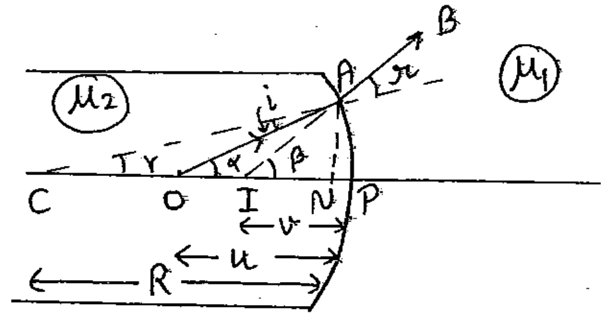
$$\Rightarrow \frac{-\mu_2}{PO} - \frac{\mu_1}{PI} = \frac{\mu_1 - \mu_2}{PC}$$

$PO = -u$, $PI = v$, $PC = -R$

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

(ii) (b) When virtual image is formed

From the figure:



$\alpha = i + \gamma$ or $i = \alpha - \gamma$

& $\beta = r + \gamma$ or $r = \beta - \gamma$

Now $\alpha = \frac{AN}{NO}$, $\beta = \frac{AN}{NI}$, $\gamma = \frac{AN}{NC}$

$\Rightarrow i = \frac{AN}{NO} - \frac{AN}{NC} = \frac{AN}{PO} - \frac{AN}{PC}$

& $r = \frac{AN}{NI} - \frac{AN}{NC} = \frac{AN}{PI} - \frac{AN}{PC}$

Now $\frac{\sin i}{\sin r} \approx \frac{i}{r} = \frac{\mu_1}{\mu_2} \Rightarrow \mu_2 i = \mu_1 r$

$\Rightarrow \mu_2 \left[\frac{AN}{PO} - \frac{AN}{PC}\right] = \mu_1 \left[\frac{AN}{PI} - \frac{AN}{PC}\right]$

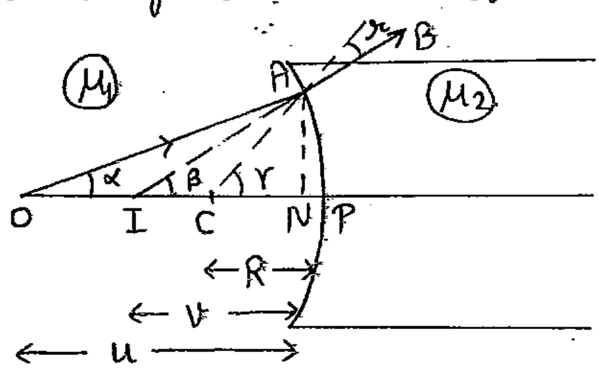
$PO = -u$, $PI = -v$, $PC = -R$

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

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

iii) Refraction at concave spherical surface when object lies in Rarer medium

From the figure:



$\gamma = i + \alpha$

or $i = \gamma - \alpha$

& $\gamma = r + \beta$ or $r = \gamma - \beta$

Now $\alpha = \frac{AN}{NO}$, $\beta = \frac{AN}{NI}$, $\gamma = \frac{AN}{NC}$

Then $i = \frac{AN}{NC} - \frac{AN}{NO} = \frac{AN}{PC} - \frac{AN}{PO}$

& $r = \frac{AN}{NC} - \frac{AN}{NI} = \frac{AN}{PC} - \frac{AN}{PI}$

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

$$\Rightarrow \mu_1\left[\frac{AN}{NC}-\frac{AN}{NO}\right] = \mu_2\left[\frac{AN}{NC}-\frac{AN}{NI}\right]$$

or $$\frac{\mu_2-\mu_1}{NC} = \frac{\mu_2}{NI} - \frac{\mu_1}{NO}$$

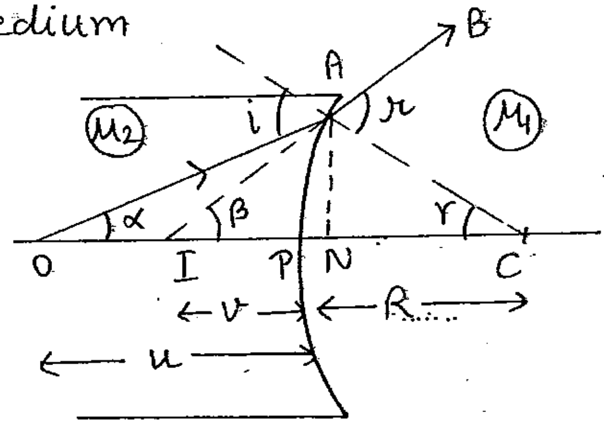
or $$\frac{\mu_2-\mu_1}{PC} = \frac{\mu_2}{PI} - \frac{\mu_1}{PO}$$

$PC = -R$, $PO = -u$, $PI = -v$

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

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

iv) Refraction at concave spherical surface when object lies in denser medium



From the figure :

$i = \alpha + \gamma$ & $r = \beta + \gamma$

$\alpha = \frac{AN}{NO}$, $\beta = \frac{AN}{NI}$, $\gamma = \frac{AN}{NC}$

$$\Rightarrow i = \frac{AN}{NO} + \frac{AN}{NC} = \frac{AN}{PO} + \frac{AN}{PC}$$

$$\& \quad r = \frac{AN}{NI} + \frac{AN}{NC} = \frac{AN}{PI} + \frac{AN}{PC}$$

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

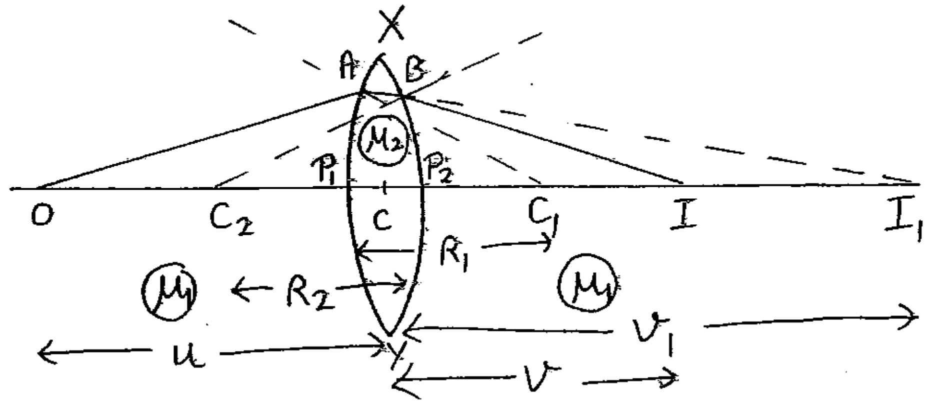
$$\Rightarrow \mu_2\left(\frac{AN}{PO} + \frac{AN}{PC}\right) = \mu_1\left(\frac{AN}{PI} + \frac{AN}{PC}\right)$$

$PO = -u$, $PI = -v$, $PC = R$

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

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

Lens Maker's Formula (For convex lens)



For refraction at surface XP_1Y

Since object lies in the rarer medium

so $$\frac{\mu_2}{v_1} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R_1} \quad \text{—— I}$$

For refraction at surface XP_2Y

I_1 acts as virtual object placed in the denser medium so $$\frac{\mu_1}{v} - \frac{\mu_2}{v_1} = \frac{\mu_1 - \mu_2}{R_2}$$

or $$\frac{\mu_1}{v} - \frac{\mu_2}{v_1} = -\frac{(\mu_2 - \mu_1)}{R_2} \quad \text{—— II}$$

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

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

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

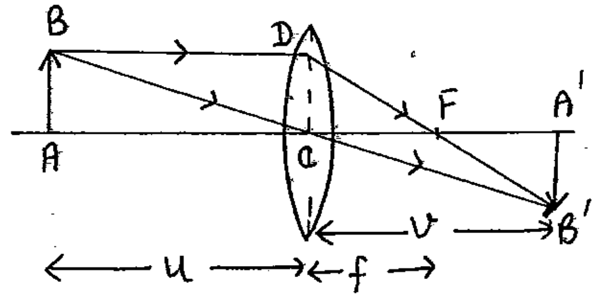
$$\Rightarrow \frac{1}{f} = ({}^1\mu_2 - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

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

Thin Lens Formula

(i) Convex lens ; when real image is formed

Δs ABC & A'B'C are similar



$$\Rightarrow \frac{AB}{A'B'} = \frac{CA}{CA'}$$

Illy Δs CDF & A'B'F are similar

$$\Rightarrow \frac{CD}{A'B'} = \frac{CF}{FA'} = \frac{AB}{A'B'}$$

[$\because$ CD = AB]

$$\Rightarrow \frac{CA}{CA'} = \frac{CF}{FA'} = \frac{CF}{CA'-CF}$$

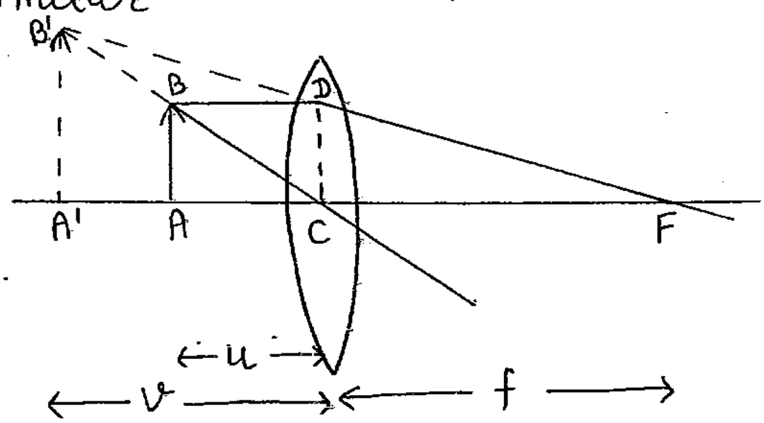
$CA = -u$, $CA' = v$, $CF = f$

$$\Rightarrow -\frac{u}{v} = \frac{f}{v-f} \quad \text{or} \quad -uv + uf = vf$$

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

ii) Convex lens ; when virtual image is formed

Δs ABC & A'B'C are similar



$$\Rightarrow \frac{AB}{A'B'} = \frac{CA}{CA'}$$

Illy Δs CDF & A'B'F are similar

$$\Rightarrow \frac{CD}{A'B'} = \frac{CF}{A'F} = \frac{AB}{A'B'}$$

[$\because$ CD = AB]

$$\Rightarrow \frac{CA}{CA'} = \frac{CF}{CA'+CF}$$

$CA = -u$, $CA' = -v$, $CF = f$

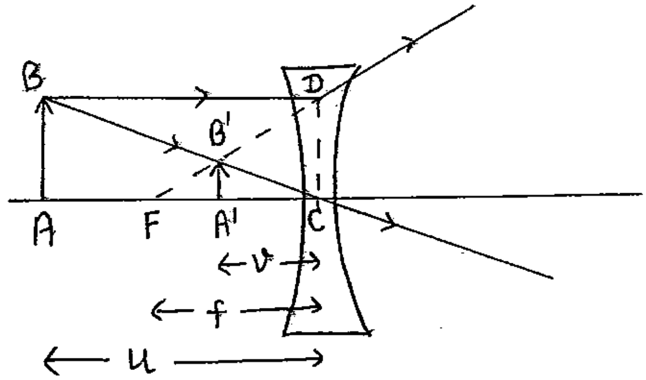
$$\Rightarrow \frac{-u}{-v} = \frac{f}{-v+f} \quad \text{or} \quad uv - uf = -vf$$

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

(iii) Concave lens (Virtual image always)

Δs ABC & A'B'C are similar

$$\Rightarrow \frac{AB}{A'B'} = \frac{CA}{CA'}$$



Illy Δs CDF & A'B'F are similar

$$\Rightarrow \frac{CD}{A'B'} = \frac{AB}{A'B'} = \frac{CF}{A'F}$$

$$\Rightarrow \frac{CA}{CA'} = \frac{CF}{CF - CA'} \quad [\because A'F = CF - CA']$$

$\because CA = -u$, $CA' = -v$, $CF = -f$

$$\Rightarrow \frac{-u}{-v} = \frac{-f}{-f+v} \quad \text{or} \quad uf - uv = vf$$

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

Linear magnification (i) Convex lens ; real image

$$m = -\frac{I}{O} = \frac{v}{-u} = \frac{v-f}{f} = \frac{-f}{u+f}$$

Magnification is negative.

(ii) Convex lens ; Virtual image

$$m = \frac{I}{O} = \frac{-v}{-u} = \frac{f-v}{f} = \frac{f}{u+f}$$

Magnification is positive.

(iii) Concave lens

$$m = \frac{I}{O} = \frac{-v}{-u} = \frac{f-v}{f} = \frac{f}{u+f}$$

Magnification is always positive.

Power of a lens → It is reciprocal of focal length

$$P = \frac{1}{f\,(\text{in m})} = \frac{100}{f\,(\text{in cm})}$$ [S.I. unit is

Thin lenses in contact

Focal length of the combination of lenses

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} + \text{---}$$

Power, $P = P_1 + P_2 + P_3 + \text{---}$

* If 'd' is the distance between them, then

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2} \quad \& \quad P = P_1 + P_2 - dP_1P_2$$

Magnification of an equivalent lens :

$$m = m_1 \times m_2 \times m_3 \times \text{---}$$

Spherical Aberration of a lens is the inability of the lens to focus all the rays of light falling on it at a single point.

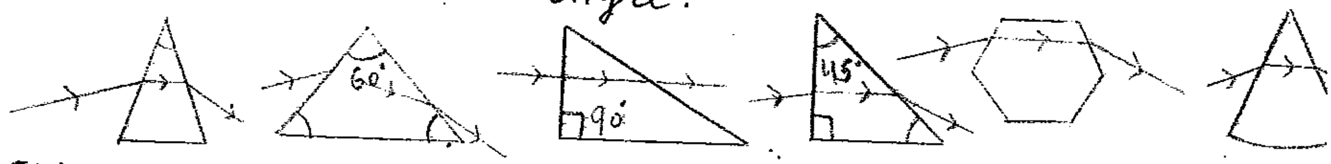
· Table for position of object & image in convex lens

	Position of object	Position of image	Nature & size of image
1	At Infinity	At focus	Real, inverted, small
2	Beyond 2F	Between F & 2F	Real, inverted, small
3	At 2F	At 2F	Real, inverted, same
4	Between F & 2F	Beyond 2F	Real, inverted, large
5	At Focus.	At infinity	Real inverted large
6	Between F & optical centre	on the side of the object	virtual, erect & very large

* In case of concave lens image is always Virtual, erect & small.

DISPERSION

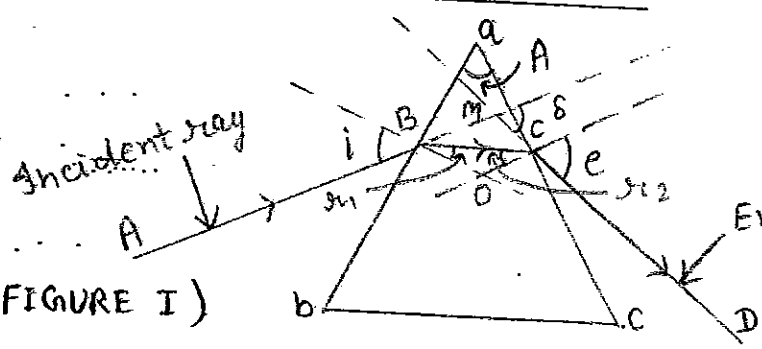
Prism → A simple prism is a homogeneous transparent refracting medium bounded by at least two non parallel plane surfaces inclined at some angle.



[FIGURES OF DIFFERENT SECTION WHICH BEHAVE AS PRISM]

out of all these, common used prisms are equilateral & right angled prism.

Refraction due to a prism →



(FIGURE I)

A → Angle of prism
δ → Angle of deviati

$\angle MBC = \delta_1$
$\angle MCB = \delta_2$

Derivation of angle of deviation (δ)

In the diagram, AB is incident ray and CD is emergent ray.

$$\delta = \angle MBC + \angle MCB = \delta_1 + \delta_2$$

$$\delta_1 = i - r_1 \quad , \quad \delta_2 = e - r_2$$

$$\Rightarrow \quad \delta = i - r_1 + e - r_2 = (i + e) - (r_1 + r_2)$$

In quadrilateral aBOC, $\angle A + \angle BOC = 180°$

Also $\angle r_1 + \angle r_2 + \angle BOC = 180°$

$$\Rightarrow \angle A = \angle r_1 + \angle r_2$$

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

or $\boxed{A + \delta = i + e}$

Deviation produced by a prism of small angle (i.e. very thin prism) → In the same diagram, we can also write

$$\mu = \frac{\sin i}{\sin r_1} \quad \& \quad \mu = \frac{\sin e}{\sin r_2}$$

$$\Rightarrow \quad \mu = \frac{i}{r_1} \quad \& \quad \mu = \frac{e}{r_2} \quad \text{(If } i \text{ \& } e \text{ are small)}$$

$$\Rightarrow \quad i = \mu r_1 \quad \& \quad e = \mu r_2$$

Now $\delta = (i+e) - A \Rightarrow \delta = (\mu r_1 + \mu r_2) - A$

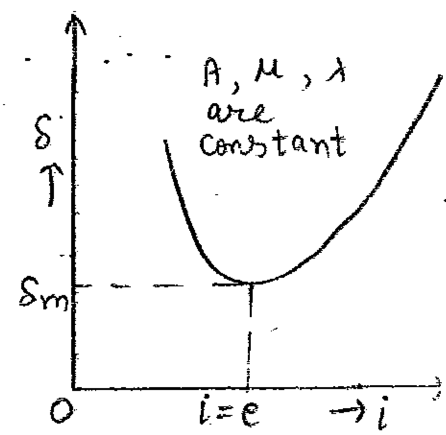
or $\delta = \mu(r_1 + r_2) - A$ $\{As\ r_1 + r_2 = A\}$

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

$$\boxed{\delta = (\mu - 1)A}$$ * when A is small

* Here δ does not depend on i (i.e. angle of incidence) if A is small.

Prism formula →



(FIGURE II)

From the figure I

$${}^{a}\mu_g = \frac{\sin i}{\sin r_1}, \quad {}^{g}\mu_a = \frac{\sin r_2}{\sin e}$$

$$\because \quad {}^{a}\mu_g = 1/{}^{g}\mu_a$$

$$\Rightarrow \quad \frac{\sin i}{\sin r_1} = \frac{\sin e}{\sin r_2}$$

$$\Rightarrow \quad i = e \quad \& \quad r_1 = r_2 \quad \text{(For minimum deviation)}$$

Now $A + \delta = i + e \Rightarrow \delta_m = 2i - A$ or $A = 2i - \delta_m$

or $i = (A + \delta_m)/2$

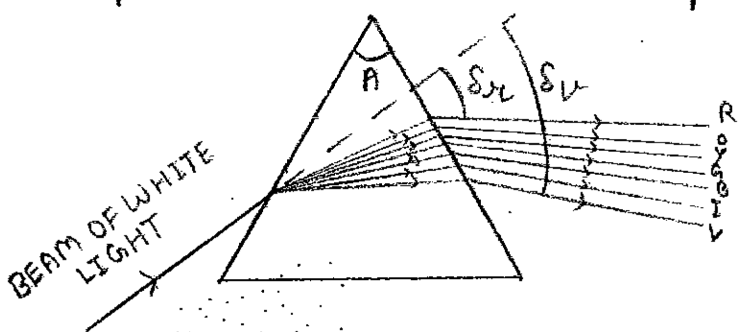
& $r_1 + r_2 = A \Rightarrow 2r = A$ & $r = A/2$

$$\Rightarrow \mu = \frac{\sin i}{\sin r} = \frac{\sin (A+\delta_m)/2}{\sin A/2}$$

which is prism formula.

Dispersion of light through a prism →

The phenomenon of splitting of white light into its constituent colours when it passes through a prism is called dispersion of light.



Cause of dispersion of light → It can be explained with the help of Cauchy's formula..

According to Cauchy's formula

$\mu = A + \frac{B}{\lambda^2} + \_\_\_$ where A & B are constants. This means $\mu \propto \frac{1}{\lambda^2}$

The wavelength of different colours is different. $\lambda_R > \lambda_V$ so $\mu_r < \mu_v$

Now $\delta = (\mu - 1) A \Rightarrow \delta_r = (\mu_r - 1) A$

& $\delta_v = (\mu_v - 1) A$ (If A is small)

$\Rightarrow \delta_r < \delta_v$

This shows that deviation for red colour is minimum and that of violet is maximum. The other colours suffer deviation in between the red & the violet colours.

Angular dispersion & Dispersive power

Angular dispersion, $\theta = \delta_v - \delta_r = (\mu_v - 1) A - (\mu_r - 1) A$

$\Rightarrow \theta = (\mu_v - \mu_r) A$

Dispersive power, $\omega = \frac{\theta}{\delta} = \frac{\delta_v - \delta_r}{\delta} = \frac{(\mu_v - \mu_r)}{(\mu - 1)}$

* δ is deviation for yellow colour

Scattering of light → The process of radiating the light by atoms and molecules in all directions is known as scattering of light.

Rayleigh criterion for scattering → The intensity of scattered light is inversely proportional to the fourth power of the incident light, provided the size of the particles scattering light is very-2 small as compared to the wavelength of incident light. $I \propto 1/\lambda^4$

Some phenomenon due to scattering of light

(i) Blue colour of the sky → According to Rayleigh $I \propto 1/\lambda^4$. $\lambda_B < \lambda_R$ so intensity of scattered light is more for blue. Hence sky appears blue.

(ii) Sun appears reddish at sun-set & sun-rise

At the time of sun-set & sun-rise, the light travels longer distance in atmosphere. Due to scattering, light is deprived of blue colour and rich in red colour. Hence sun appears reddish.

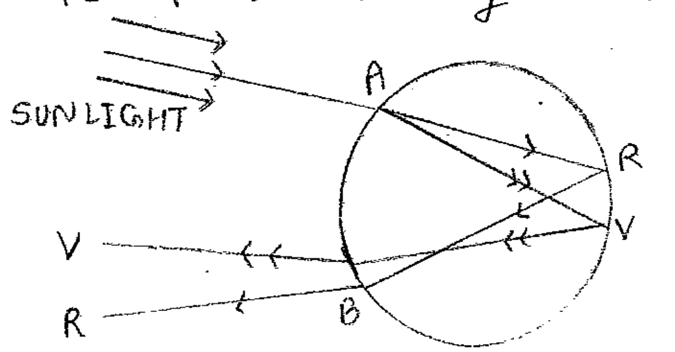
(iii) The clouds are generally white

Clouds consist of dust particles & water droplets which have size very large as compared to wavelength of light. So very little scattering of light occurs. Hence we receive almost white light. So they appear white.

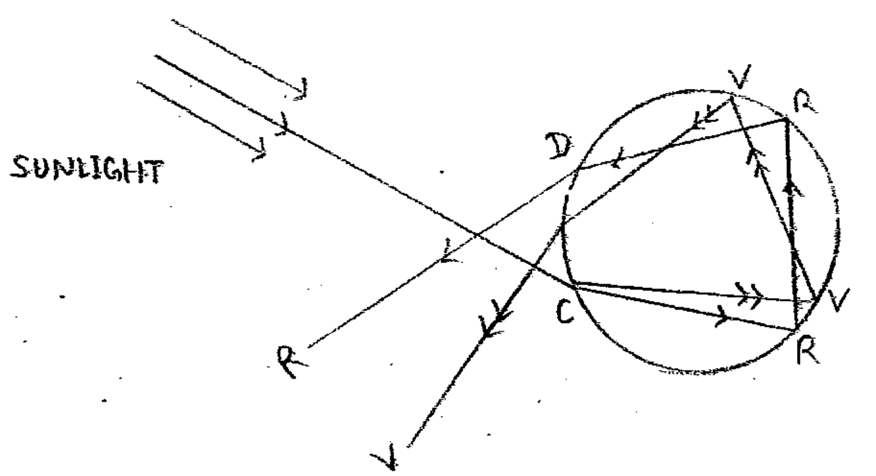
* <u>Formation of Rainbows</u> → The rainbow is produced by refraction, dispersion and internal reflection of sunlight by spherical rain drops.

We have two types of rainbows

① <u>Primary rainbow</u> → It is formed by rays which undergo one internal reflection and two refractions and finally emerge from raindrops at minimum deviation. Red rays emerge at 43° & violet rays emerge at 41°.



② <u>Secondary rainbow</u> → It is formed by the rays which undergo two internal reflections and two refractions before emerging from water droplets at minimum deviation. Red ray emerge at 51° & violet rays emerge at 53°.



<u>Simple microscope</u> → It is simply a convex lens of short focal length.

we I <u>Magnifying power</u> → It is defined as the ratio of the angles subtended by the image and the object at the eye, when both are at the least distance of distinct vision from the eye.

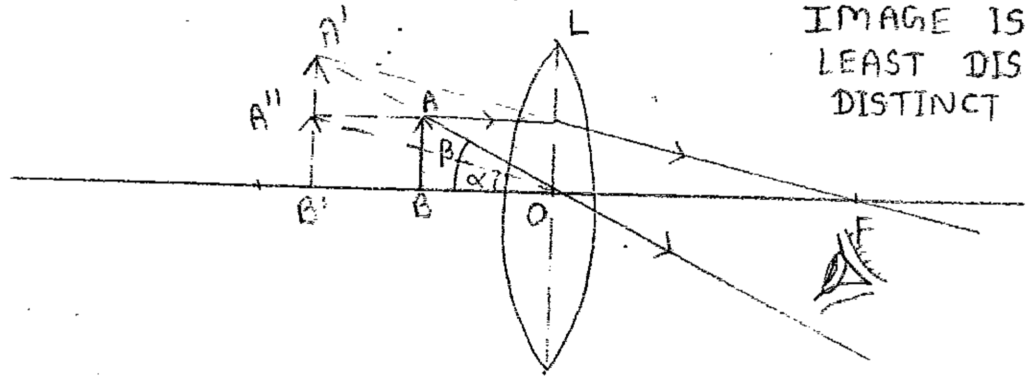


IMAGE IS AT THE LEAST DISTANCE OF DISTINCT VISION

According to the diagram,

magnifying power, $m = \frac{\beta}{\alpha} = \frac{\tan\beta}{\tan\alpha}$

$= \frac{AB/OB}{A''B'/OB'} = \frac{AB/OB}{AB/OB'} = \frac{OB'}{OB} = \frac{-D}{-x}$

or $m = \frac{D}{x}$

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

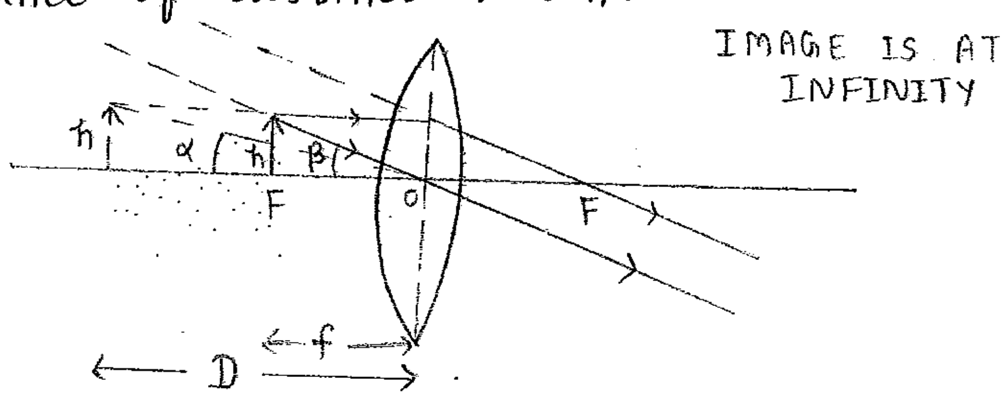
$\Rightarrow \frac{1}{-D} - \frac{1}{(-x)} = \frac{1}{f}$ or $\frac{1}{x} = \frac{1}{f} + \frac{1}{D}$

$\Rightarrow \frac{D}{x} = 1 + \frac{D}{f} = m$

$\Rightarrow m = 1 + \frac{D}{f}$

*When final image is formed at the least distance of distinct vision.

Case II <u>Magnifying power</u> → It is defined as the ratio of the angle formed by the image (when situated at infinity) at the eye to the angle formed by the object at the eye, when situated at the leas distance of distinct vision.



magnifying power, $m = \frac{\beta}{\alpha} = \frac{\tan\beta}{\tan\alpha}$

$\tan\beta = \frac{h}{f}$, $\tan\alpha = \frac{h}{D}$

$\Rightarrow m = \frac{D}{f}$

<u>Compound microscope</u> → It consists of an object and eye-piece. It is used to see magnified images of tiny objects.

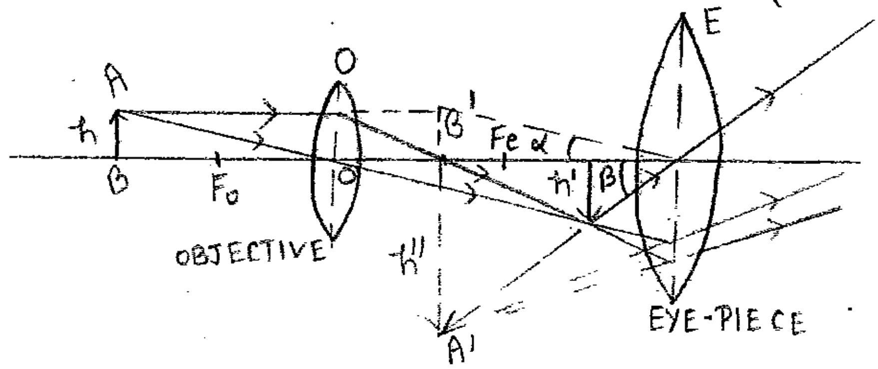
① <u>objective</u> → It is a convex lens of very small focal length & small apertur

② <u>Eye-piece</u> → It is a convex lens of comparatively larger focal length and larger aperture.

* objective is placed neare the object and eye-piece is positioned near the eye.

Case I | Magnifying power → It is defined as the ratio of the angle subtended at the eye by the final virtual image to the angle subtended at the eye by the object when both are at the least distance of distinct vision from the eye.

magnifying power $m = \frac{\beta}{\alpha} = \frac{\tan\beta}{\tan\alpha}$



According to the diagram $m = \frac{h'/u_e}{h/D} = \frac{h'}{h} \cdot \frac{D}{u_e}$

$\Rightarrow m = m_o \cdot m_e \qquad m_o = \frac{h'}{h} = \frac{V_o}{u_o}$

$m_e = \frac{D}{u_e} = 1 + \frac{D}{f_e} \qquad \Rightarrow m = \frac{V_o}{u_o}\left(1+\frac{D}{f_e}\right)$

Now $u_o = -f_o$

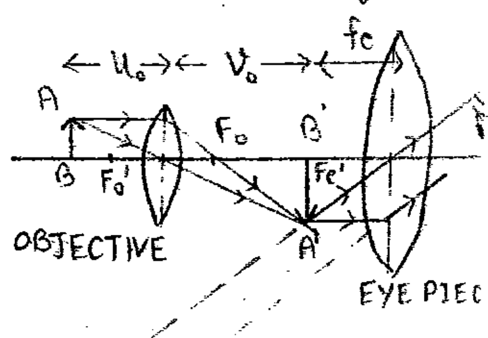
$m_o = \frac{V_o}{u_o} \approx \frac{L}{-f_o}$

$\Rightarrow m = -\frac{L}{f_o}\left(1+\frac{D}{f_e}\right)$

Case II | When final image is formed at infinity

then $m_e = \frac{D}{f_e}$

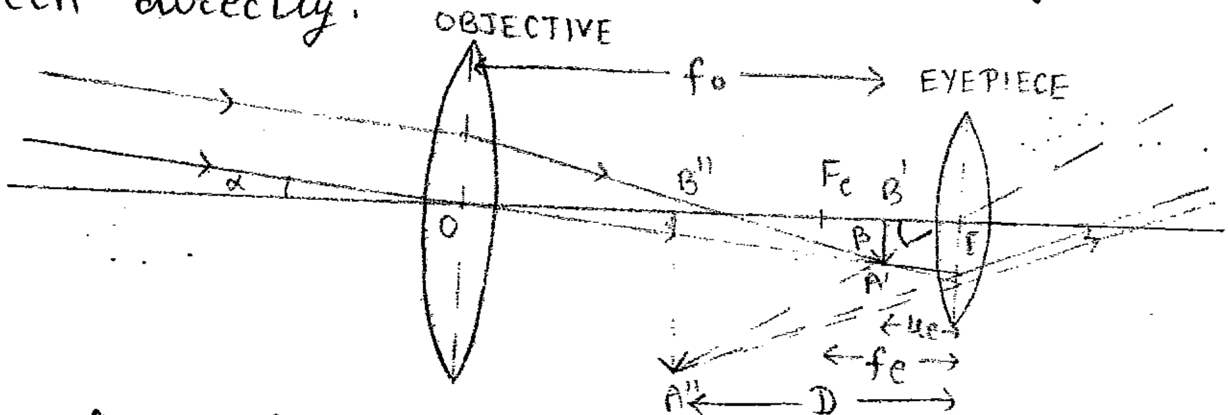
$\therefore m = -\frac{L}{f_o} \times \frac{D}{f_e}$



Astronomical Telescope → It is a refracting type telescope used to see heavenly bodies like stars, planets etc.
It consists of two converging lenses mounted co-axially at the outer ends of two sliding tube.
Objective → It is a convex lens of large focal length and a much larger aperture.
It faces the distant object.
Eye-piece → It is a convex lens of small focal length and small aperture.

se I When final image is formed at the least distance of distinct vision.

Magnifying Power → It is defined as the ratio of the angle subtended at the eye by the final image formed at the least distance of distinct vision to the angle subtended at the eye by the object at infinity, when seen directly.



Magnifying power, $m = \frac{\beta}{\alpha} = \frac{\tan\beta}{\tan\alpha} = \frac{A'B'/B'E}{A'B'/OB'} = \frac{OB'}{B'E}$

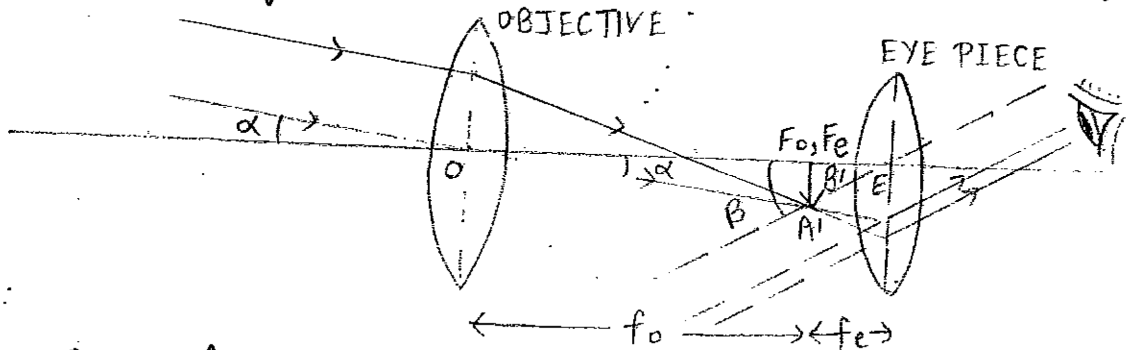
$\Rightarrow m = \frac{+f_o}{-u_e}$ Now $u = -u_e$, $v = -D$

$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{-D} + \frac{1}{u_e} = \frac{1}{f_e} \Rightarrow \frac{1}{u_e} = \frac{1}{f_e} + \frac{1}{D}$

$\Rightarrow m = -f_o\left(\frac{1}{f_e} + \frac{1}{D}\right) = -\frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right)$

Case II When final image is formed at infinity (Normal adjustment)

Magnifying Power → It is defined as the ratio of the angle subtended at the eye by the final image as seen through the telescope to the angle subtended at the eye by the object seen directly, when both the image and the object lie at infinity.



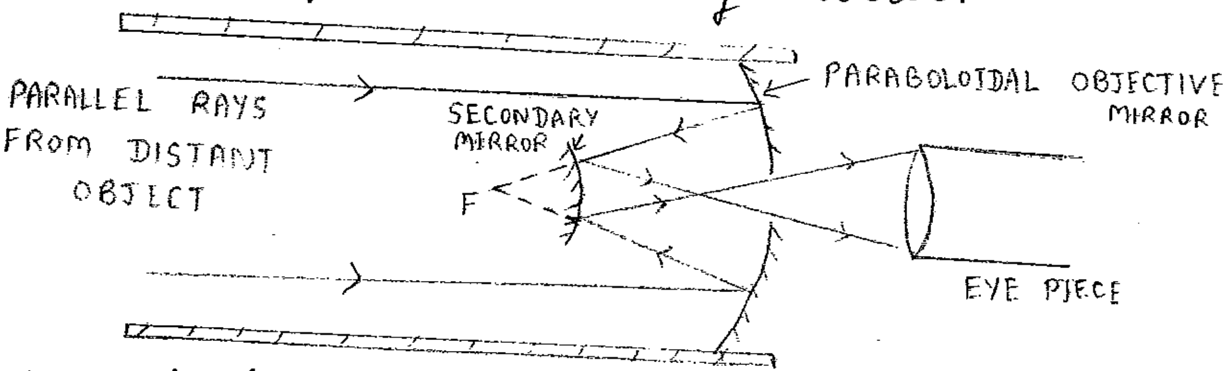
Magnifying Power $m = \dfrac{\beta}{\alpha} = \dfrac{\tan\beta}{\tan\alpha}$

$$= \frac{A'B'/B'E}{A'B'/OB'} = \frac{OB'}{B'E} = \frac{+f_o}{-f_e}$$

$$\Rightarrow \quad m = -\frac{f_o}{f_e}$$ (For normal adjustmen

Reflecting Telescopes → In case of reflecting type telescope, we see mirrors in place of lenses as they are based on reflection.

① Cassegrain reflecting telescope → It consists of a large concave paraboloidal (primary) mirror having a hole at its centre. There is a small convex (secondary) mirror near the focus of the primary mirror. Eyepiece is placed on the axis of the telescope near the hole of the primary mirror.

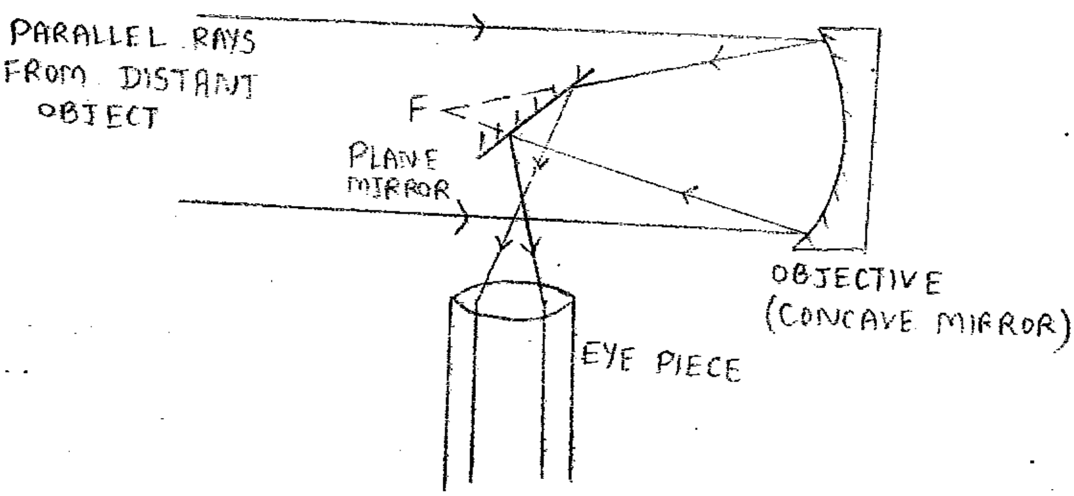


For final image at the least distance of distinct Vision , $m = \frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right)$

For final image formed at infinity

$$m = \frac{f_o}{f_e} = \frac{R/2}{f_e}$$

<u>Newtonian reflecting telescope</u> → It consists of a large concave mirror of large focal length as the objective, made of an alloy of copper and tin. The plane mirror is inclined at an angle of 45°. The eye-piece forms a highly magnified, virtual and erect image of the distant object.



Advantages of reflecting type telescope →

① A concave mirror of large aperture has high gathering power and absorbs very less amount of light than the lenses of large apertures.

② Due to large aperture of the mirror used, the reflecting telescopes have high resolving power

③ As objective is mirror and not a lens, it is free from chromatic aberration.

④ The use of paraboloidal mirror reduces spherical aberration.

⑤ A mirror requires grinding and polishing of one surface only. So cost of device reduces.

⑥ A lens of large aperture tends to be very heavy and therefore difficult to make.

Disadvantages of reflecting type telescope →

① These telescopes need frequent adjustments & hence not convenient.

② They can not be used for general purposes, as they are not handy.