Chapter-9 Ray optics & optical Instruments

Optics- is the branch of physics which deals with the Sources properties and effects of light.

"Light is the form of energy which makes the object visible".

Ray optics

Ray optics describe light propagation in term of rays. The ray in geometric optics is an abstraction useful for approximating the paths along which light propagates under certain circumstances.

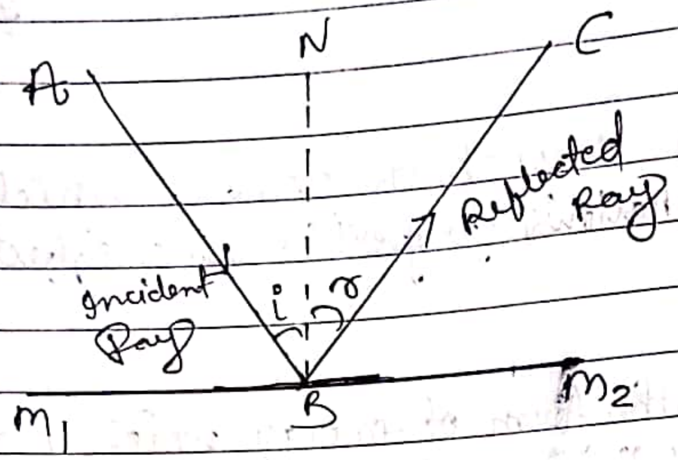
Light

Light is electromagnetic radiation within a certain portion of electromagnetic spectrum. The word usually refers to visible light, which is the responsible for the sense of light.

Speed $= 3 \times 10^8$ m/sec

Range of wave length of visible light is $4000\ \mathring{A}$ to $7800\ \mathring{A}$

Reflection of light



i = angle of incident
r = angle of reflection

Reflection of light is a process of sending back the the light rays which falls on the surface of an object.

"when a ray of light falls on a polished and shining surface of an object then it is send back in the same medium"

Laws of Reflection

i. The incident ray, the reflected ray and the normal to the surface at the point of incident all lie in the same surface.

ii. The angle of reflection (r) is every time equal to angle of incident (i)

Image

The rays emerging from a point of object actually meet at a point after reflection (or refraction) or appears diverse from the point then this point is called image of first point.

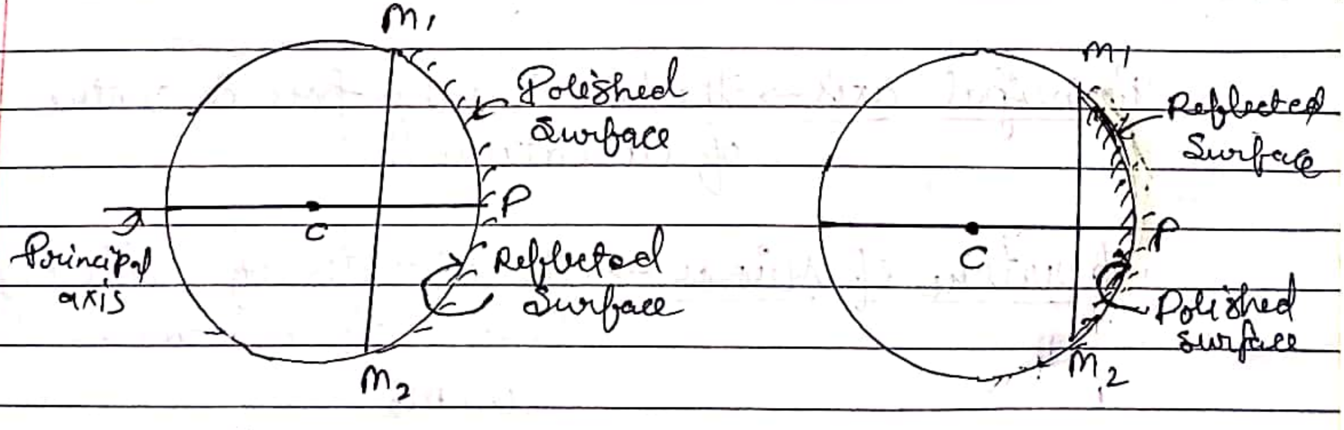
There are two types of image.

① Real Image – Image will be real if ray actually meet at point after reflection.

② Virtual Image – If the rays do not actually meet after reflection but appear to diverge from the point when produced backward the image is called Virtual.

★ "The real image can be taken on screen while Virtual image can not be taken on screen"

Spherical Mirror



(i) Concave mirror

(ii) Convex mirror

Concave mirror → Concave mirror is a spherical mirror whose reflecting surface is curved outwards.

Convex mirror → reflecting surface is curved outwards.

A reflecting surface which is a part of a sphere is called spherical mirror

Centre of Curvature → The centre of that sphere which mirror is a part is called centre of curvature.

Radius of curvature → The radius of that sphere which mirror is a part is called radius of curvature

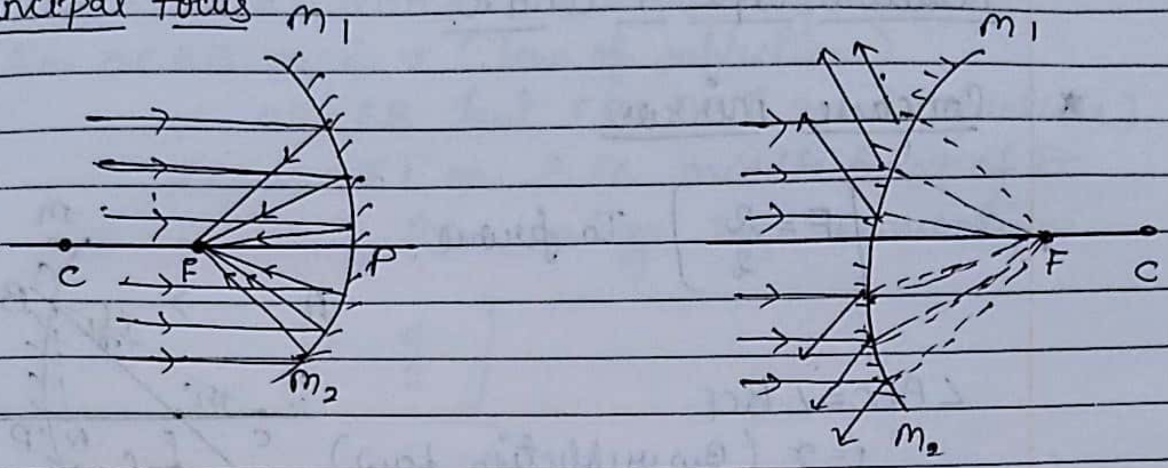
Pole → The middle point of reflecting surface of mirror is called pole.

Principal axis → The line joining pole & centre of curvature.

Aperature of Mirror → The diameter of reflecting surface of mirror.

$M_1 M_2$

Principal Focus

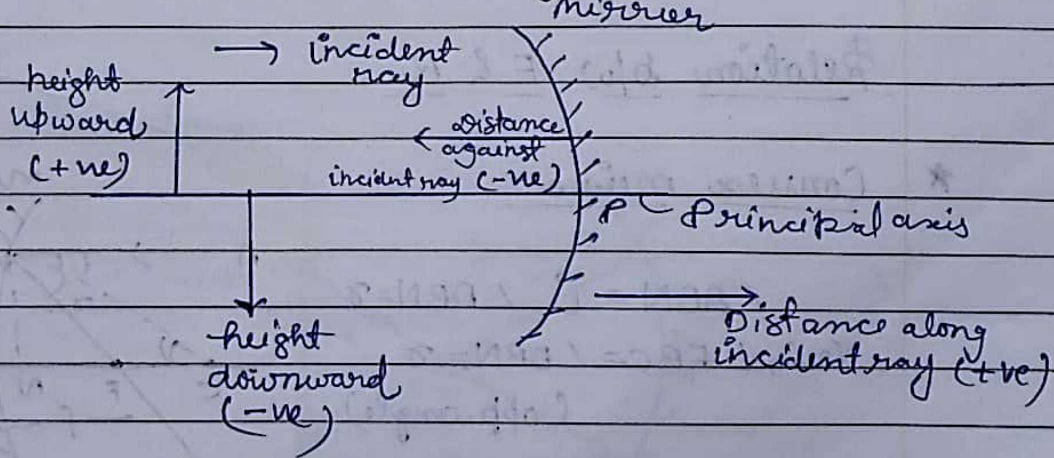


The light rays coming parallel to principal axis after reflection from mirror really meet or appear to meet at a point of principal axis is called principal focus of mirror. (F).

Focal length → the distance b/w Pole and principal focus.

Sign Convention of measuring Distances

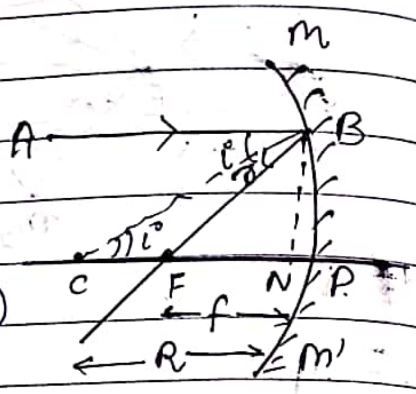
(co-ordinate system)



Relation b/w F and R

★ **Concave mirror**

$\left[F = \frac{R}{2}\right]$ To prove



$\angle ABC = \angle BCF$

$i = r$ (By reflection law)

$\angle ABC = \angle BCF$

(alternate angle)

So, $\angle BCF = \angle CBF$

$\Rightarrow CF = BF$

$\because$ Aperture of mirror MM' is very small to

$BF = PF$

So, $CF = FP$

$CF + PF = PF + PF$

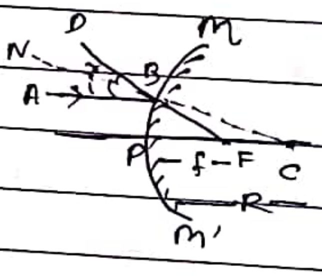
$CP = 2FP$

$R = 2f$

$\left[f = \frac{R}{2}\right]$

Relation b/w F & R

★ **Convex mirror**



$\angle ABN = i$ $\angle DBN = r$

Now, $\angle FBC = \angle DBN = r$

(opp. angle)

$\angle BCF$, ~~as~~ $= \angle NBA = i$ (corresponding angle)

In ΔCBF, as $i = r$ (law of reflection)

$\therefore CF = FB$ but $FB = FP$ (small aperture)

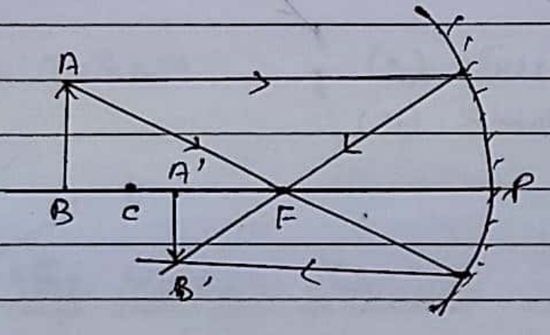
$\therefore CF = FP$ or F is middle point of PC

$\therefore F = \frac{1}{2} PC$, using sign convention

$$\boxed{F = \frac{R}{2}}$$

Formation of image by concave Mirror

(a) Object beyond C



The image is :-
1) B/w C & F
2) Real
3) Inverted
4) Smaller than object.

(b) Object at C.

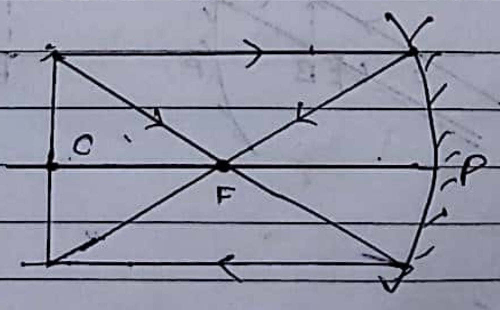


Image is :-

(1) At C
(2) Real
(3) Inverted
(4) Same size as object.

(c) Object between F and C

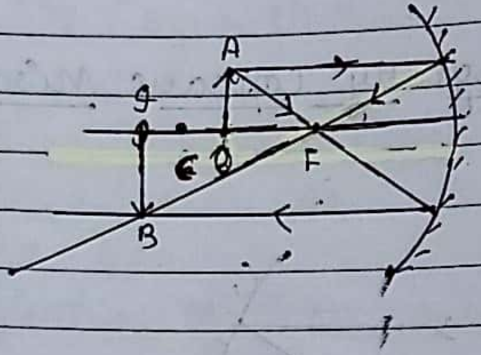


Image is
(1) Beyond C
(2) Real
(3) Inverted
(4) Layer Larger than object.

(d) Object between F and P

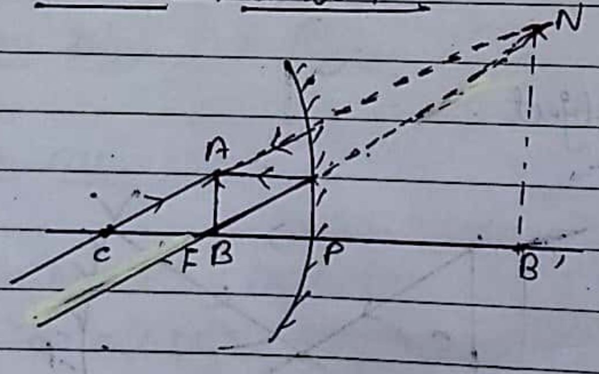
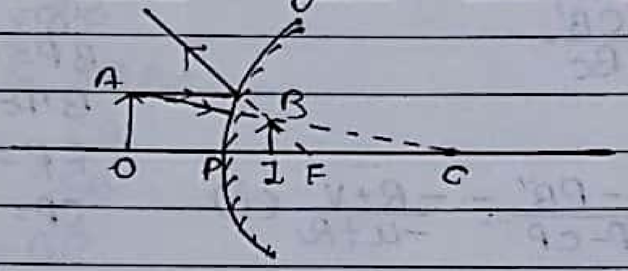


Image is
(1) Behind the mirror
(2) Virtual
(3) Larger than object
(4) Erect.

Image formation by Convex mirror



(1) Behind the mirror
(2) Erect
(3) Virtual
(4) Smaller than object.

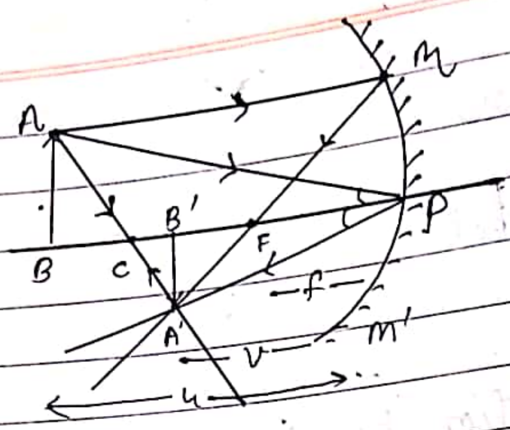
The Mirror formula

It is a mathematical relationship b/w object distance u, image distance v and the focal length f

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

Derivation for a Concave mirror

i real image



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

$\therefore \frac{A'B'}{AB} = \frac{CB'}{BC}$

Sign
$BP = -u$
$B'P = -v$
$FP = f$
$CP = -R = -2f$

$$\frac{A'B'}{AB} = \frac{CP-PB'}{BP-CP} = \frac{-R+v}{-u+R} \quad (i)$$

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

$$\therefore \frac{A'B'}{AB} = \frac{PB'}{BP} = \frac{-v}{-u} = \frac{v}{u} \quad (ii)$$

from eq i) & ii)

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

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

$$vR + uR = 2uv$$

Divide by uvR both side

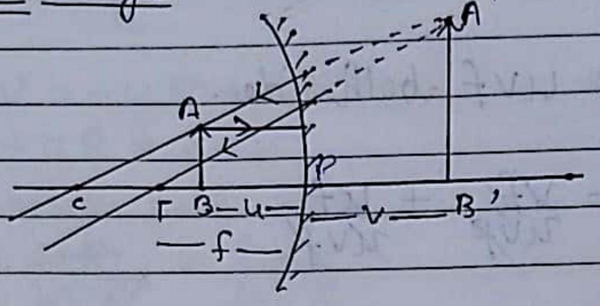
$$\frac{\cancel{vR}}{u\cancel{vR}} + \frac{\cancel{uR}}{\cancel{u}v\cancel{R}} = \frac{2\cancel{uv}}{\cancel{uv}R}$$

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

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

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

ii for virtual image



Now $\triangle A'B'C \sim \triangle ABC$

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

$$\frac{AB}{A'B'} = \frac{CP-BP}{CP+PB'}$$

$$\frac{AB}{A'B'} = \frac{-2f+u}{-2f+v} \quad -(i)$$

$B'P = v$

$BP = -u$

$FP = -f$

$CP = -R = -2f$

Also $\triangle MPF \sim \triangle A'B'F$

$$\frac{MP}{A'B'} = \frac{PF}{FB'} = \frac{PF}{FP+PB'}$$

$$\frac{AB}{A'B'} = \frac{-f}{-f+v} \quad -(ii)$$

from eq (i) & (ii)

$$\frac{-2f+u}{-2f+v} = \frac{-f}{-f+v}$$

$$(-2f+u)(-f+v) = -f(-2f+v)$$

$$\cancel{2f^2} - 2fv - uf + uv = \cancel{2f^2} - vf$$

$$-vf - uf + uv = 0$$

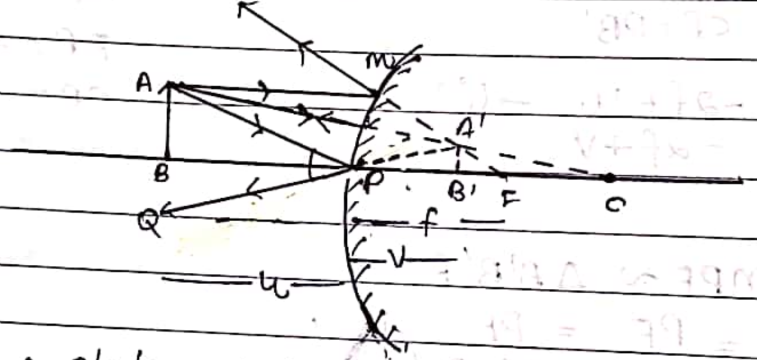
$uv = vf + uf$

divide by uvf both side.

$$\frac{\cancel{uv}}{\cancel{uv}f} = \frac{\cancel{vf}}{u\cancel{vf}} + \frac{\cancel{uf}}{\cancel{u}v\cancel{f}}$$

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

Derivation for a convex mirror



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

$$\frac{A'B'}{AB} = \frac{B'C}{BC}$$

$BP = -u$

$B'P = +v$

$PF = +f$

$PC = +2f = +R$

$$\frac{A'B'}{AB} = \frac{PC - PB'}{BP + PC} = \frac{R - v}{-u + R} \quad \text{---(i)}$$

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

$$\frac{A'B'}{AB} = \frac{PB'}{BP} = \frac{v}{-u} \quad \text{---(ii)}$$

from eq (i) & (ii)

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

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

$$vR + uR = 2uv$$

Divide by uvR both side

$$\frac{\cancel{vR}}{u\cancel{vR}} + \frac{\cancel{uR}}{\cancel{u}v\cancel{R}} = \frac{2\cancel{uv}}{\cancel{uv}R}$$

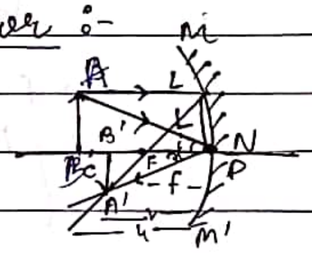
$$\frac{1}{u} + \frac{1}{v} = \frac{\cancel{2}}{\cancel{2}f}$$

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

Magnification :- Ratio of height of image to that of the object is called linear magnification.

$$m = \frac{\text{height of image}}{\text{height of object}} = \frac{h_i}{h_o}$$

Derivation for a concave mirror :-



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

$$\frac{A'B'}{AB} = \frac{B'P}{BP}$$

$$-\frac{h_2}{-h_1} = \frac{-v}{-u}$$

$$\left[m = \frac{h_2}{h_1} = \frac{-v}{u}\right]$$

$A'B' = -h_i\ (h_2)$

$AB = +h_o\ (h_1)$

$B'P = -v$

$BP = -u$

Magnification in term of u & f

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

multiply both side by u

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

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

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

In term of v & f

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

multiply both side by v.

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

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

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

Uses of Mirrors

i) Plane Mirror :- As daily use looking glasses ii Concave mirror → used as a head lights of vehicles, telescope, Shaving mirror, Solar cookers, Surgeon's mirror

iii Convex mirror → As reflector in Street lamps, driver's mirror.

Longitudinal Magnification

Let a small object of length d is placed along the principal axis then longitudinal magnification

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

$$m_L = \frac{-dv}{du}$$

where dv is the size of the image along Principle axis from mirror formula.

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

Partial differenciating it with respect u or v.

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

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

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

$$\therefore m_L = -\left(\frac{-v^2}{u^2}\right)$$

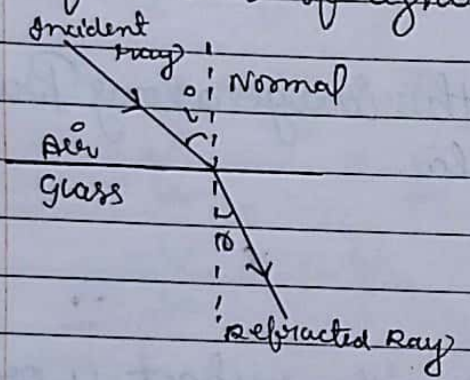
$$m_2 = \frac{-v^2}{u^2}$$

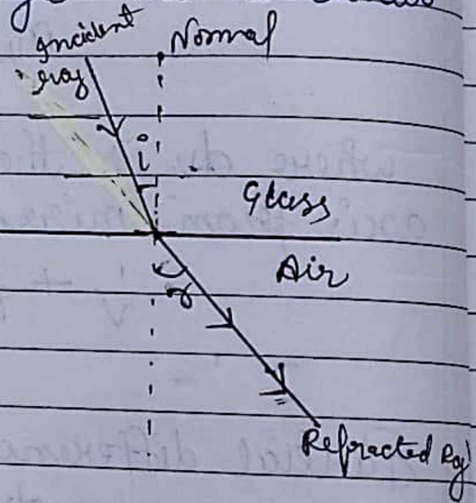
$$m_2 = -\left(\frac{v}{u}\right)^2$$

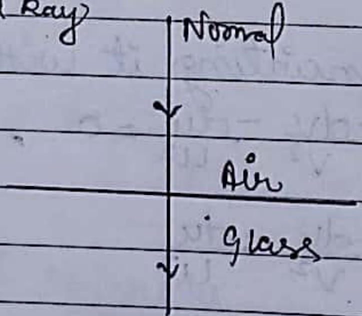
$$\left[m_2 = m^2\right]$$

Refraction of Light

When a light travels in the same homogenous medium, it travels along a straight path. However, when it passes obliquely from one transparent medium to another, the direction of its path changes. This is called Refraction of light







It is observed that

(1) When a ray of light passes from an optically rarer medium to a denser medium, it bends towards the normal ($\angle r < \angle i$)

(2) When a ray of light passes from an optically denser to a rarer medium, it bends away from the normal ($\angle r > \angle i$)

(3) A ray of light travelling along the normal passes undeflected. $\angle i = \angle r = 0°$

Laws of Refraction

1st Law:- Incident ray, refracted ray & the normal to the interface at the point of incidence all lie in the same plane.

2nd Law:- The ratio of the sine of the angle of incidence and the sine of the angle of refraction is constant.

$$\left[\frac{\sin i}{\sin r} = \text{Constant}\right] = {}^1\mu_2$$

It is also known as Snell's Law.

The ratio ${}^1\mu_2$ is called refractive index of second medium with respect to first medium.

Refractive Index

In terms of speed of light:- The refractive index of a medium for a light of given wavelength may be defined as the ratio of the speed of light in vacuum to its speed in that medium.

$$\text{Refractive Index} = \frac{\text{Speed of light in Vacuum}}{\text{Speed of light in medium}}$$

$$\left[\mu = \frac{c}{v}\right]$$

Refractive index of a medium with respect to vacuum is also called absolute refractive index

In term of wavelength — since the frequency (ν) remains unchanged when light passes from one medium to another.

$$n = \frac{c}{v} = \frac{\lambda_{vac} \times \nu}{\lambda_{med} \times \nu} = \frac{\lambda_{vac}}{\lambda_{med}}$$

It is defined as the ~~radio~~ ratio of wavelength of light in vacuum to its wavelength in that medium.

Relative Refractive Index

The relative refractive index of medium 2 with respect to medium 1 is defined as the ratio speed of light (v_1) in medium 1 to the speed of light (v_2) in medium 2 and is denoted by ${}^1\mu_2$

$$\left[{}^1\mu_2 = \frac{v_1}{v_2}\right]$$

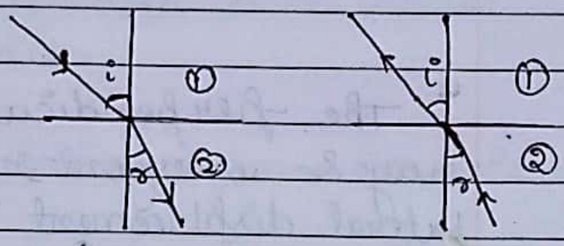
It has no units & dimensions.

Factors on which refractive index of a medium depends :

i Nature of the medium
ii Wavelength of the light used
iii Temperature
iv Nature of the surrounding

Reversibility Theory

The principle that a beam of light is refracted back on itself it will travels the same path as it did before reverse.



The principle of reversibility states that light will follow exactly the same path if its direction of travel is reversed.

$$ {}_1n_2 = \frac{\sin i}{\sin r}, \quad {}_2n_1 = \frac{\sin r}{\sin i} $$

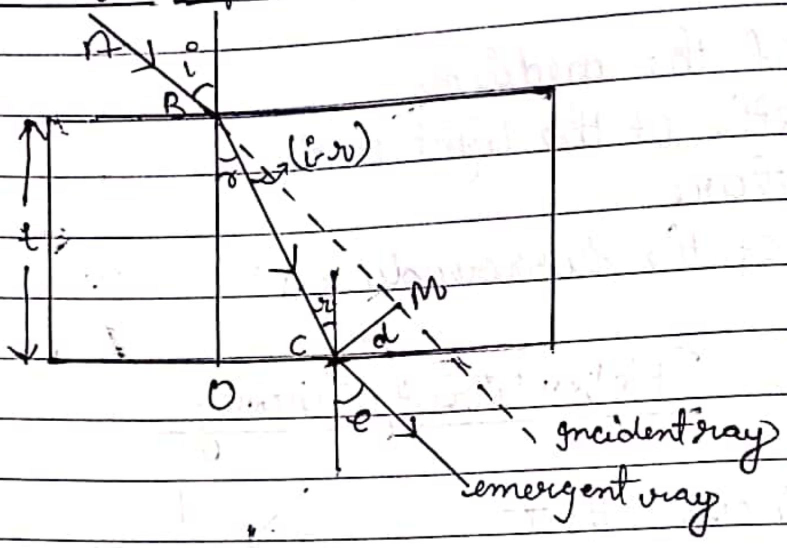
$$ \text{so, } {}_1n_2 \times {}_2n_1 = \frac{\cancel{\sin i}}{\cancel{\sin r}} \times \frac{\cancel{\sin r}}{\cancel{\sin i}} $$

$$ {}_1n_2 = \frac{1}{{}_2n_1} $$

Ex:- If ${}_an_g = 1.5$ then ${}_gn_a = \frac{1}{1.5}$

DATE

Refraction of light through a glass slab & lateral displacement.



"The perpendicular distance b/w incident ray & emergent ray parallel rays is called lateral displacement"

[CM = lateral displacement]

In ΔBOC

$$\cos r = \frac{BO}{BC} = \frac{t}{BC} \quad \text{—(i)}$$

In ΔBMC

$$\sin(i-r) = \frac{MC}{BC} = \frac{d}{BC} \quad \text{—(ii)}$$

eq (i) ÷ eq (ii)

$$\frac{\cos r}{\sin(i-R)} = \frac{t/\cancel{BC}}{d/\cancel{BC}} = \frac{t}{d}$$

$$\boxed{d \Rightarrow \frac{\sin(i-r)}{\cos r} \times t}$$

The lateral displacement depend upon following factor–

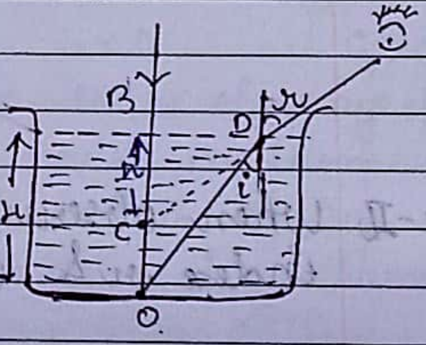
i If angle of incidence i is increase the lateral displacement will increase.

ii The absolute refractive index of glass increase then lateral displacement will increase.

iii If thickness of slab is greater then lateral displacement will be greater.

iv Lateral displacement is also depend on Colour of light.

Real & Apparent depth



In Δ OBD

$\tan i = \frac{BD}{OB} = \frac{BD}{x}$

$\because$ i is very small

$\therefore \tan i = i$

$i = \frac{BD}{x}$ —(i)

Similarly, In Δ CBD

$\tan r = \frac{BD}{BC} = \frac{BD}{h}$

or $r = \frac{BD}{h}$ —(ii)

$${}_{l}n_{a} = \frac{\sin i}{\sin r} = \frac{i}{r}$$

$${}_{l}n_{a} = \frac{BO/x}{BO/h} = \frac{h}{x}$$

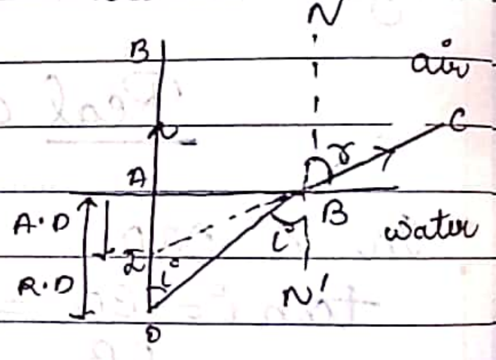
$$\text{so, } {}_{a}n_{l} = \frac{1}{{}_{l}n_{a}} = \frac{1}{\frac{h}{x}}$$

$$\left[{}_{a}n_{l} = \frac{x}{h}\right]$$

<u>Case-I</u> when observer is in a air & the object is in a medium of refractive Index μ.

$$\frac{\mu}{R} = \frac{1}{A}$$

$$\left[\text{or } A = \frac{R}{\mu}\right]$$

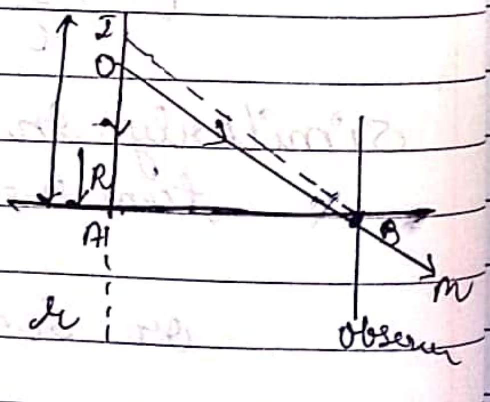


Case-II when observer is in a medium of refractive index μ & object is in air

$$\frac{\mu_2}{R} = \frac{\mu_2}{A}$$

$$\frac{1}{R} = \frac{\mu}{A}$$

$$\Rightarrow [A = \mu R]$$

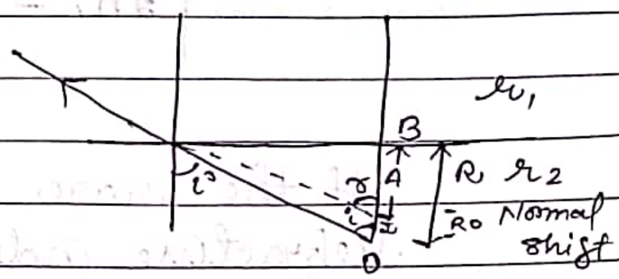


Normal Shift

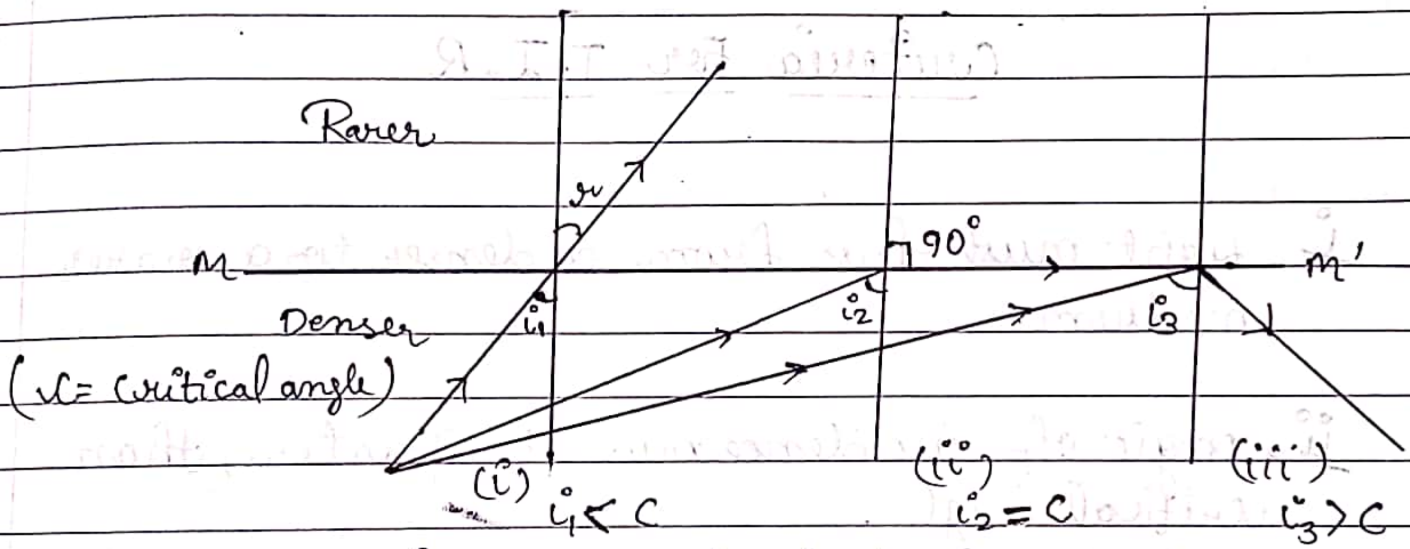
$OI = OB - IB$

$OI = R - A$

$R - \frac{R}{{}_1\mu_2} = R\left(1 - \frac{1}{{}_1\mu_2}\right)$



Total internal reflection & Critical angle



Critical angle is an angle of incidence of ray of light moving from denser to rarer medium such that provides an angle of refraction of 90°.

Total internal reflection is a phenomenon which occurs at the boundary of two medium such that if the angle of incidence greater than critical angle than light is reflected back into that media.

If $i = C$ then $r = 90°$

$${}_1n_2 = \frac{\sin i}{\sin r} = \frac{\sin C}{90°} = \sin C$$

Therefore

$$\left[{}_an_1 = \frac{1}{\sin c}\right]$$

If the rarer medium is air than absolute refractive index of medium

$$\left[n = \frac{1}{\sin c}\right]$$

Criteria For T.I.R

i. Light must pass from a denser to a rarer medium.

ii. Angle of incidence must be greater than critical angle.

i.e. $i > i_c$

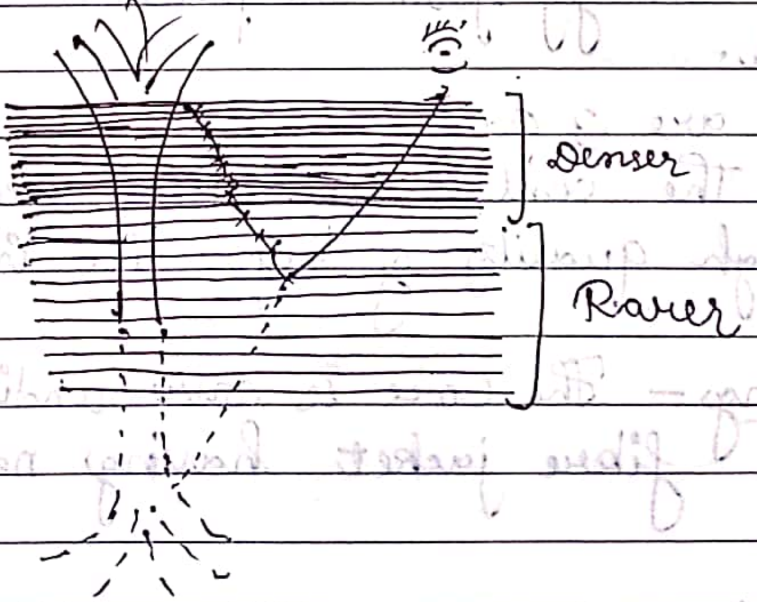
Some examples of total internal reflection

1) Sparking of diamond :- Sparking of diamond is due to internal reflection —

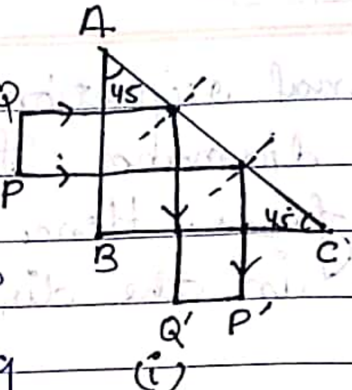
The refractive index of diamond is very high it is about 2.42 therefore its critical angle is very small that is about 24° The faces of diamond are so cut that light entering inside the crystal suffers total internal reflection and hence, gets collected inside the diamond. It comes out throughly only a few faces. Hence, the diamond sparkles. when seen in the direction of emergent of light.

2- Mirage

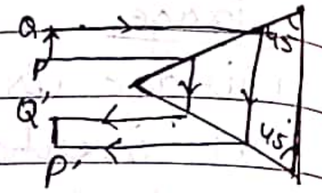
Mirage is an optical illusion (false idea) in desert or overheat extended surface like a coal tar road due to which a traveller sees shimmering pond of water. Due to which the image of object like tree appeared inverted. On a hot summer the surface of the earth becomes very hot therefore, the layer of air become denser when a light of beam comes from a tree it bends away from the normal after sometime when $\angle i$ become more than critical angle the rays are totally internal reflected. These rays reaches on the observers eye and he see an internal image of tree.



③ <u>Totally Reflecting Prisms</u>

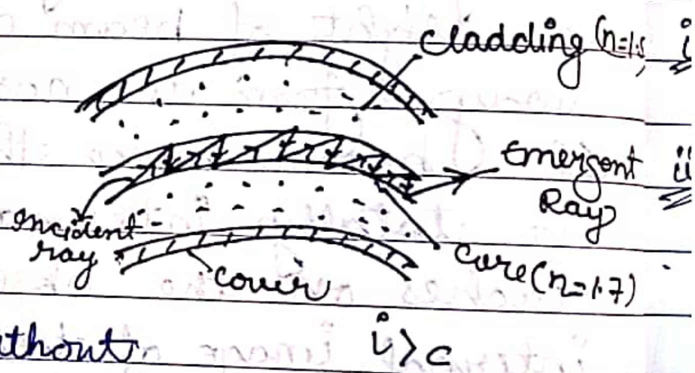


A right angle isoscales prism that is 45°-90°-45° is called totally reflecting prisms.



Whenever a ray falls normally on any faces of such prism it is incident inside the face at 45° which is greater than critical angle of glass therefore, the rays of totally internally reflected.

④ <u>Optical Fibre</u>



It is a thin fibre with a glass core through which light signal can be send without loss of energy from one place to another.

There are 3 part—

1- <u>Core</u>— The central cylindrical core is made of high quality of refractive index 1.7.

2- <u>Cladding</u>— The core is surrounding by a fibre jacket having n=1.5.

3- Cover :- For proving safety and strength of core the optical fibre is enclosed in plastic jacket.

Working :- When a beam of light incidence on one end of core at a small angle of incidence. It goes inside and suffered total internal reflection as there is no loss of energy & outcoming light beam has more intensity then incident ray.

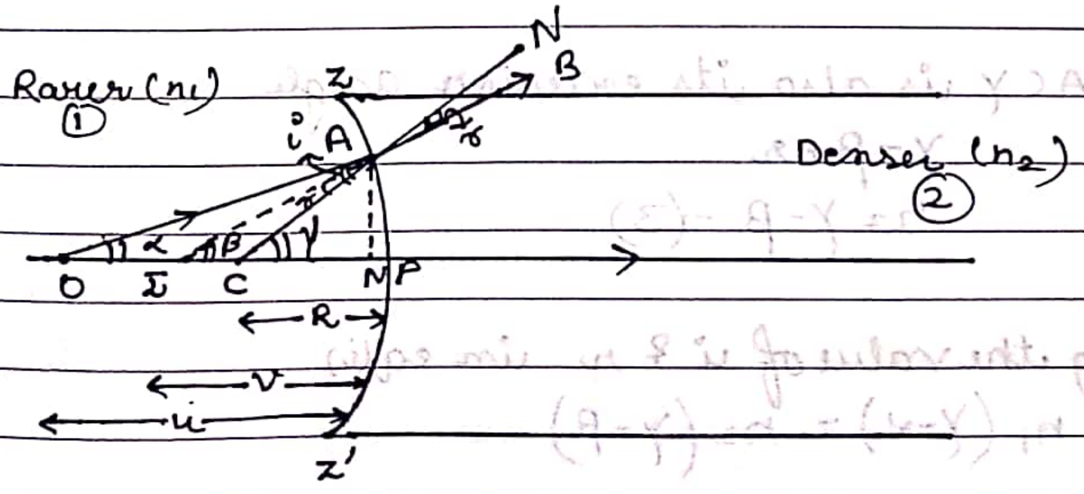
Use :-

i. It is used in medical & optical examination as endoscopy.

ii. It is used in transmissing & recieving optical signals in telecommunication.

Refraction at Spherical Surface

(i) Concave Surface :- (Rarer to Denser)



Let ZPZ' is a concave spherical surface of radius of curvature R. This is spherical seperating two medium of refractive index n_1 & n_2.

Let there is a point object O at principle axis an imaginary image I from by the spherical surface.

incident angle $OAC = i$

$\angle r\ NAB = r = \angle IAC$

Let OA, IA & CA makes angle α, β & γ with principal axis.

According to snell's law –

$$\frac{\sin i}{\sin r} = {}_1n_2 = \frac{n_2}{n_1}$$

∴ if r are very small

∴ $\sin i = i$

$\sin r = r$

or $\frac{i}{r} = \frac{n_2}{n_1}$

$n_1 i = n_2 r$ —(i)

In ΔOAC γ is an exterior angle

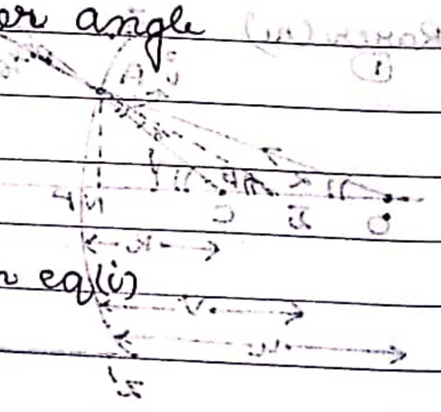
$\gamma = \alpha + i$

$i = \gamma - \alpha$ —(2)

In ΔIAC γ is also its exterior angle

$\gamma = \beta + r$

$r = \gamma - \beta$ —(3)



Putting the value of i & r in eq(i)

$n_1(\gamma - \alpha) = n_2(\gamma - \beta)$

$n_1\gamma - n_1\alpha = n_2\gamma - n_2\beta$

$$n_2\beta - n_1\alpha = n_2\gamma - n_1\gamma$$
$$n_2\beta - n_1\alpha = (n_2-n_1)\gamma \quad \text{-(iv)}$$

In ΔOAN $\alpha = \tan\alpha = \frac{AN}{ON} = \frac{AN}{-u}$

In ΔIAN
$$\beta = \tan\beta = \frac{AN}{IN} = \frac{AN}{-v}$$

In ΔCAN
$$\gamma = \tan\gamma = \frac{AN}{CN} = \frac{AN}{-R}$$

from eq-iv

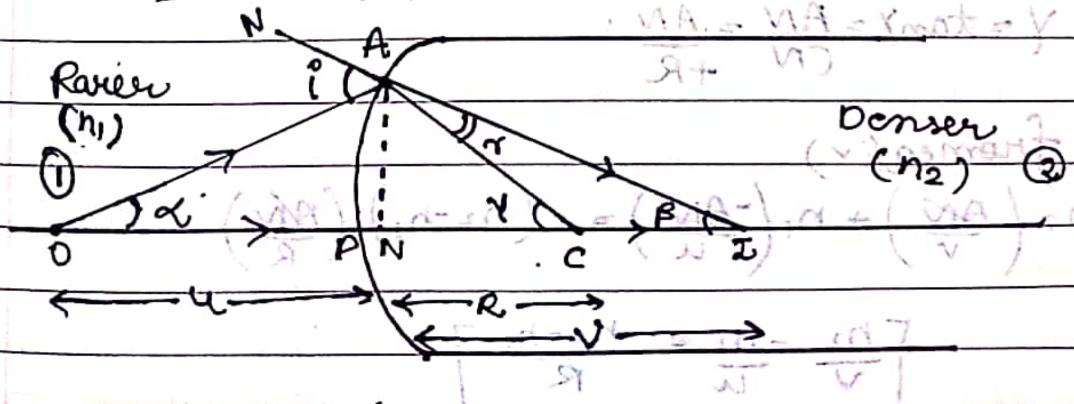
$$n_2\left(\frac{-\cancel{AN}}{v}\right) - n_1\left(\frac{-\cancel{AN}}{u}\right) = (n_2-n_1)\left(\frac{-\cancel{AN}}{R}\right)$$

$$\left[\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2-n_1}{R}\right]$$

$$\frac{\left(\frac{n_2}{n_1}\right)}{v} - \frac{1}{u} = \frac{\left(\frac{n_2}{n_1}-1\right)}{R}$$

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

(ii) Convex Surface :-



In ΔOAC, i is exterior angle

$$i = \alpha + \beta \quad -(i)$$

In ΔACI, γ is an exterior angle

$$\gamma = r + \beta$$
$$r = \gamma - \beta \quad -(ii)$$

From snell's law :-

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$$

Or $\frac{i}{r} = \frac{n_2}{n_1}$

$$\Rightarrow n_1 i = n_2 r \quad -(iii)$$

Putting the value of i & r in eq(iii)

$$n_1(\alpha + \gamma) = n_2(\gamma - \beta)$$
$$n_1 \alpha + n_1 \gamma = n_2 \gamma - n_2 \beta$$
$$n_2 \beta + n_1 \alpha = (n_2 - 1)\gamma \quad -(iv)$$

In ΔOAN

$$\alpha = \tan\alpha = \frac{AN}{ON} = \frac{AN}{-u}$$

In ΔIAN

$$\beta = \tan\beta = \frac{AN}{IN} = \frac{AN}{v}$$

In ΔCAN

$$\gamma = \tan\gamma = \frac{AN}{CN} = \frac{AN}{+R}$$

from eq(iv)

$$n_2\left(\frac{AN}{v}\right) + n_1\left(\frac{AN}{-u}\right) = (n_2 - n_1)\left(\frac{AN}{R}\right)$$

$$\left[\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}\right]$$

Notes:- n_1 is the refractive index of that medium from which ray of light is going. n_2 is the refractive index of that medium in which the ray of light is going.

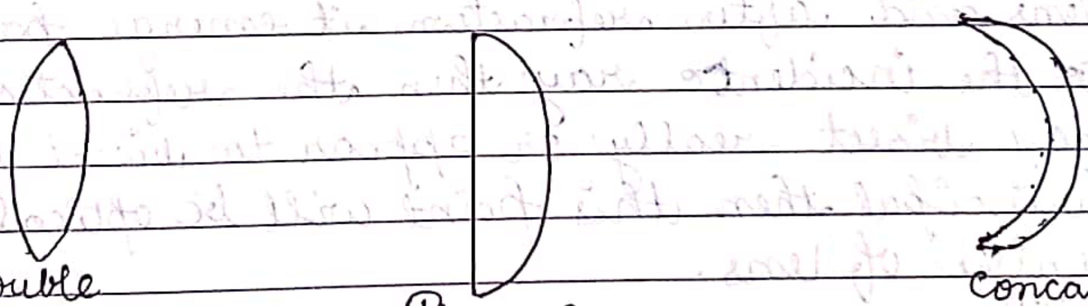
Lens

The covered homogenous transparent medium by two curved surface or one curve and another plane surface is called lens.

A lens is transmassive optical device that focus or disperse a light beam by means of refraction.

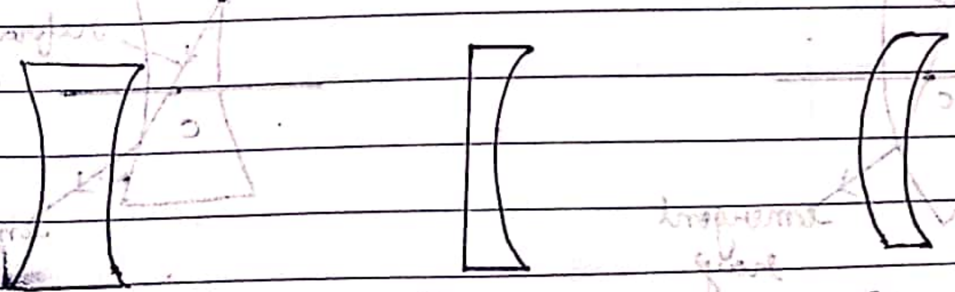
There are 2 types of lens:-

(1) Convex lens:- It is also divided in 3 parts.



Double Convex   Plano-Convex   Concavo Convex

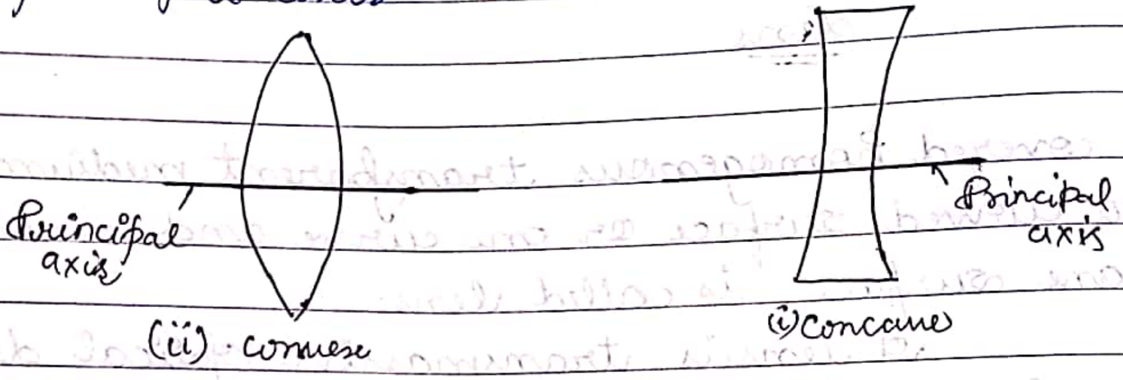
(2) Concave Lens:- It is also divided in 3 parts.



Double Concave   Plano Concave   Convexo-Concave

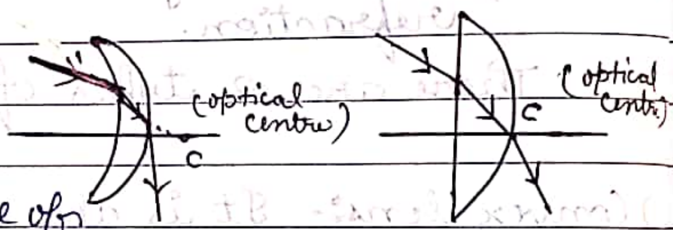
Some definitions about Lens:-

(1) Principal axis:- The line joining the centre of curvature of both spherical surface is called principal axis

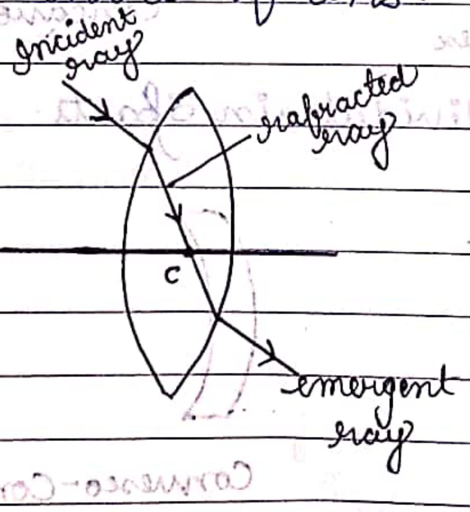


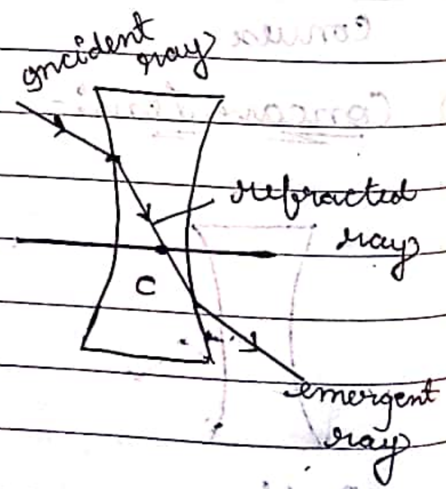
(2) Optical Centre

For a thick lens



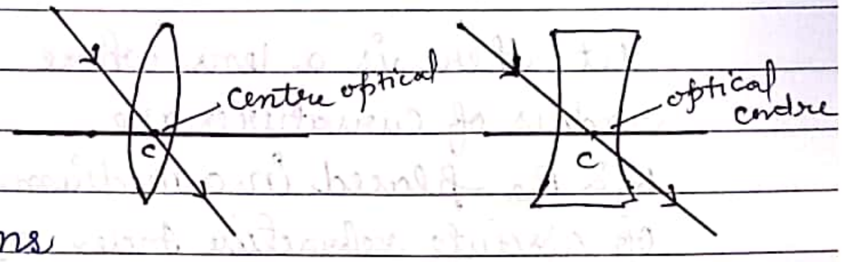
If a ray of light incident on a surface of lens and after refraction it emerge parallel to the incidence ray then the refracted ray bisect really or appear to bisect the principal then this point will be optical centre of lens.



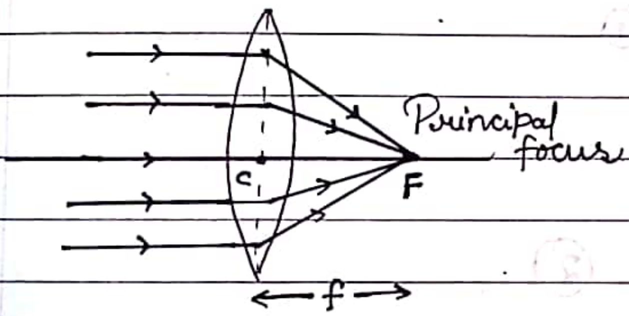


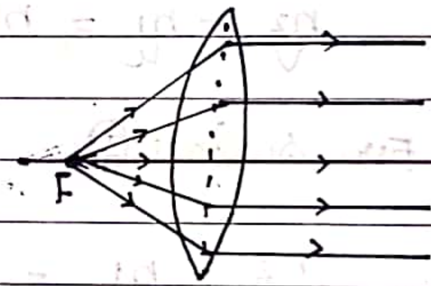
For thin lens

For a thin lens the optical centre of a lens is a point inside the lens on which a incident rays passing straight without bending i.e- it is corresponds to the physical centre of lens.

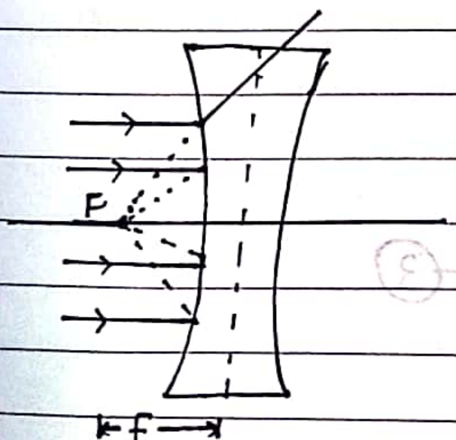


Focus of Lens

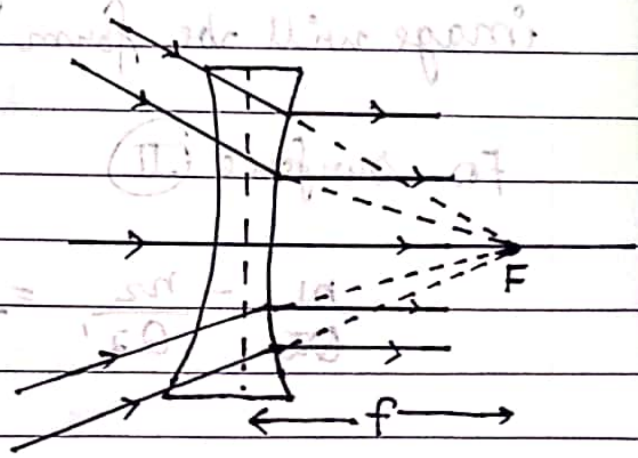




Secondary focus



Principal focus

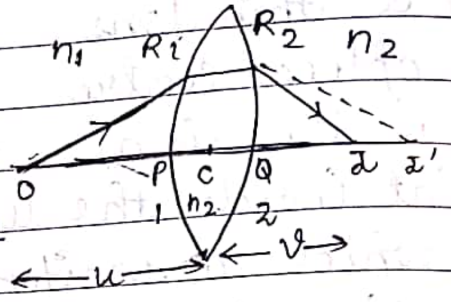


Secondary focus

★ Imp

Lens Maker formula

Let there is a lens whose radius of curvatures are R_1 & R_2 placed in a medium of absolute refractive Index n_1. Let the refractive index of lens material is n_2.



Let there is a point object O placed on principal axis and its image form I' by curved surface 1st

★ By refraction formula —

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R} \quad (1)$$

For surface (I)

$$\frac{n_2}{PI'} - \frac{n_1}{PO} = \frac{n_2 - n_1}{R_1} \quad (2)$$

I' will be virtual object for surface (II) its real image will be form at I.

For surface (II)

$$\frac{n_1}{QI} - \frac{n_2}{QI'} = \frac{n_1 - n_2}{R_2} \quad — (3)$$

For lens —

Adding eqn ② and ③

$$\frac{n_2}{PI'} - \frac{n_1}{PO} + \frac{n_1}{QI} - \frac{n_2}{QI'} = \frac{(n_2-n_1)}{R_1} + \frac{(n_1-n_2)}{R_2}$$

for thin lens

$PI' \simeq QI'$

$PO \simeq CO = u$

$QI \simeq CI = v$

so, $$\cancel{\frac{n_2}{QI'}} - \frac{n_1}{u} + \frac{n_1}{v} - \cancel{\frac{n_2}{QI'}} = \frac{n_2-n_1}{R_1} + \frac{n_1-n_2}{R_2}$$

$$\frac{n_1}{v} - \frac{n_1}{u} = (n_2-n_1)\left[\frac{1}{R_1} + \frac{1}{R_2}\right]$$

$$n_1\left[\frac{1}{v} - \frac{1}{u}\right] = (n_2-n_1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

$$\frac{1}{v} - \frac{1}{u} = \left(\frac{n_2}{n_1} - 1\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

$$\boxed{\frac{1}{v} - \frac{1}{u} = ({}_1n_2 - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]} \quad \text{— ④}$$

This is lens Maker formula.

If ${}_1n_2 = n$

$$\frac{1}{v} - \frac{1}{u} = (n-1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \quad \text{— ⑤}$$

If $u \to \infty$

$v \to f$

$$\frac{1}{f} - \frac{1}{\infty} = (n-1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

$$\boxed{\frac{1}{f} = (n-1)\left[\frac{1}{R_1} - \frac{1}{R_1}\right]} \quad \text{— ⑥}$$

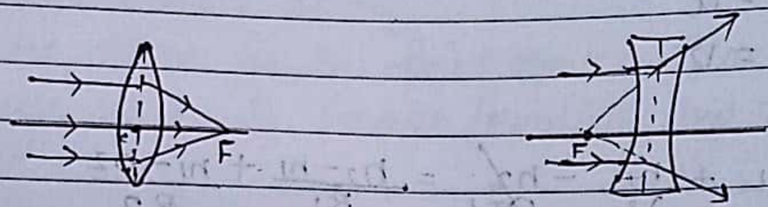
from eqn (5) and (6)

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

This is lens formula.

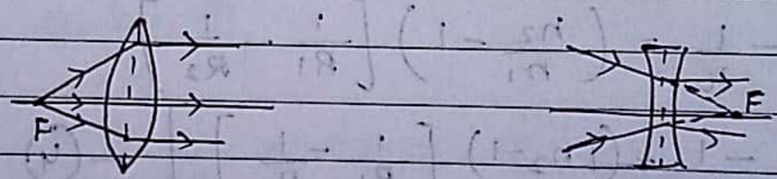
★ <u>Laws of image formation by lens</u>

(1)



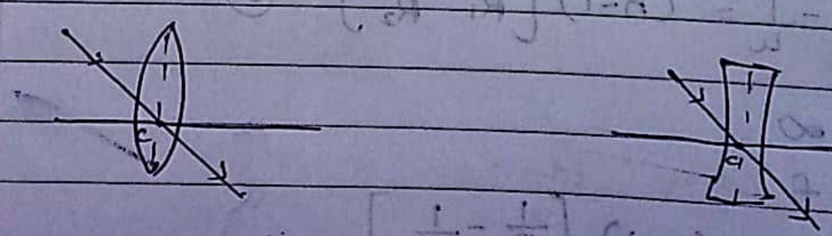
when the light incident parallel to optical axis of lens then after refraction it passes through 2nd focus or appear to passes from second focus.

(2)



The rays coming from the 1st focus or appear to going the 1st focus of lens then after refraction it will be parallel to the optical axis.

(3)



If any rays incident on optical centre then it goes without any deviation.

★ Image formation by lens

(1) when object is placed at ∞

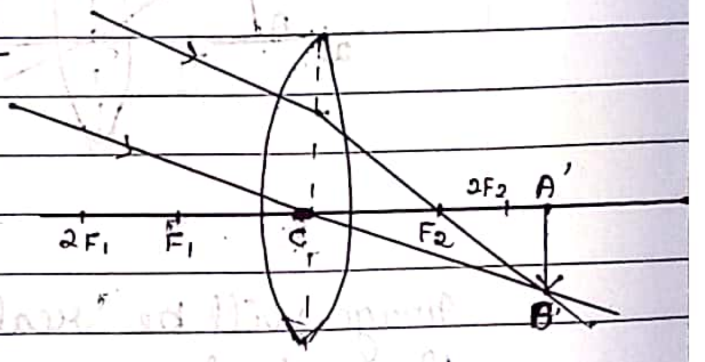


Image will be real, invert and smaller than object.

(2) when object is placed b/w ∞ and $2F_1$

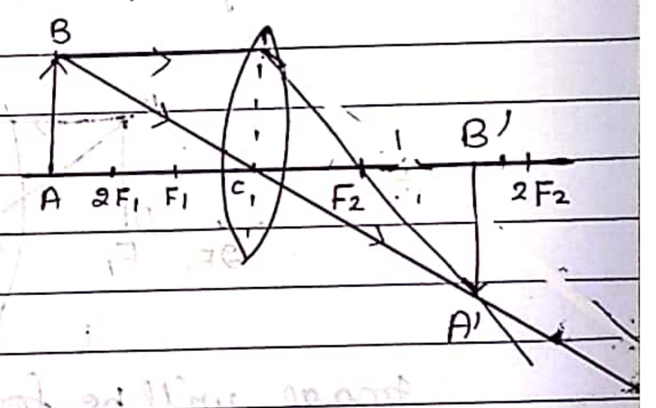


Image will be real & invert.

(3) when object is placed at $2F_1$

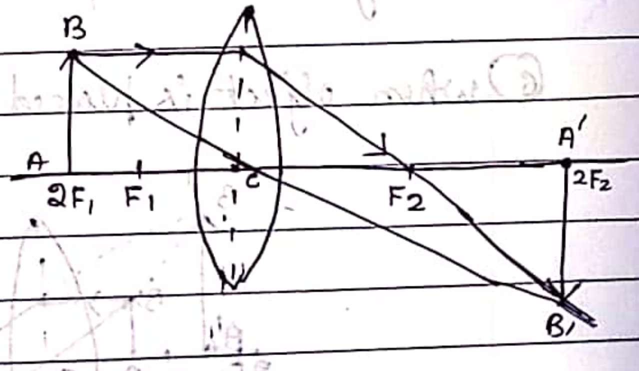


Image will be real & invert and same ~~siz~~ size of the object.

(4) when object is placed b/w $2F_1$ and F_1

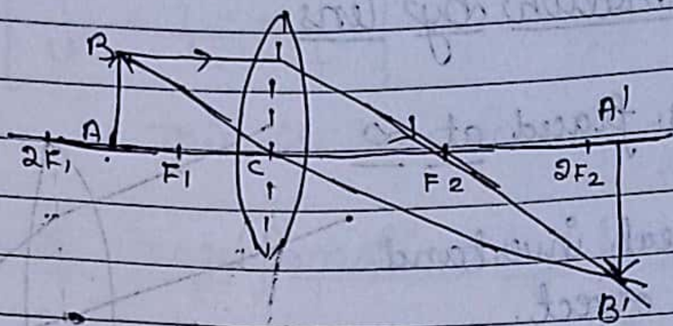


Image will be real, invert and greater than object.

(5) when object is at F_1

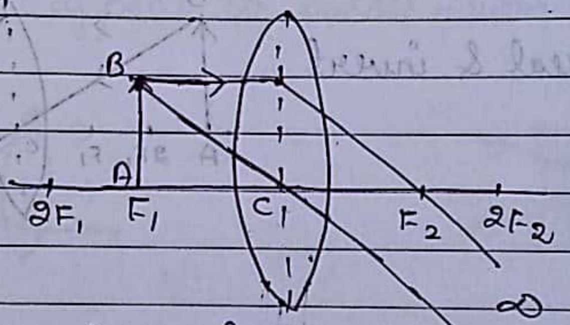


Image will be formed at ∞

(6) when object is placed b/w F & C

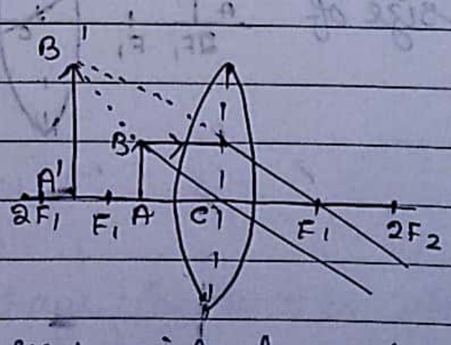


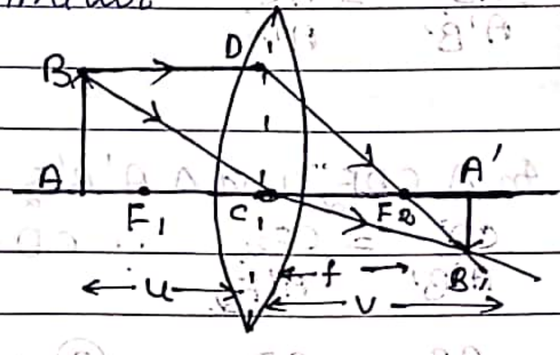
Image will be virtual, greater than object and in front of lens.

Thin Lens formula

i) For Convex lens

In ΔABC and $\Delta A'B'C$ are similar

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



ΔCDF_2 and $\Delta A'B'F_2$ are similar.

$$\frac{CD}{A'B'} = \frac{CF_2}{F_2A'} \quad \because CD = AB$$

$$\frac{AB}{A'B'} = \frac{CF_2}{F_2A'} \quad \text{—} (2)$$

from eqn (1) and (2)

$$\frac{AC}{A'C} = \frac{CF_2}{F_2A'}$$

$$\frac{AC}{A'C} = \frac{CF_2}{A'C - CF_2}$$

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

$$-uv + uf = vf$$

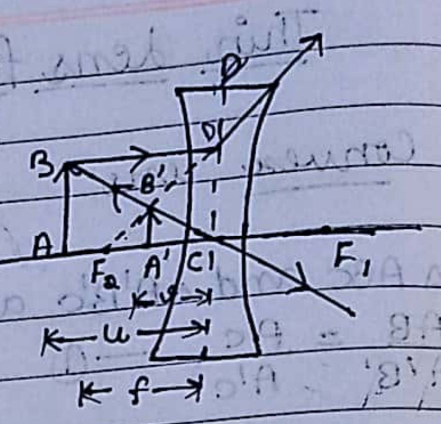
$$uf - vf = uv$$

dividing by uvf

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

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

ii) For Concave lens



In Δ ABC and A'B'C are similar

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

In Δ CDF_2 and Δ $A'B'F_2$ are similar

$$\frac{CD}{A'B'} = \frac{CF_2}{A'F_2} \quad \because CD = AB$$

$$\frac{AB}{A'B'} = \frac{CF_2}{A'F_2} \quad \text{--(2)}$$

from eqn (1) & (2)

$$\frac{AC}{A'C} = \frac{CF_2}{A'F_2}$$

$$\frac{AC}{A'C} = \frac{CF_2}{F_2C - A'C}$$

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

$$+uf - uv = vf$$

$$uf - vf = uv$$

dividing by uvf

$$\frac{\cancel{uf}}{\cancel{u}v\cancel{f}} - \frac{\cancel{vf}}{u\cancel{vf}} = \frac{\cancel{uv}}{\cancel{uv}f}$$

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

Linear Magnification

The linear magnification produced by a lens is the ratio of the size of image and size of object.

$$\left[\text{Linear magnification, } m = \frac{\text{Size of image}}{\text{Size of object}} = \frac{h_2}{h_1} \right]$$

i For Convex lens

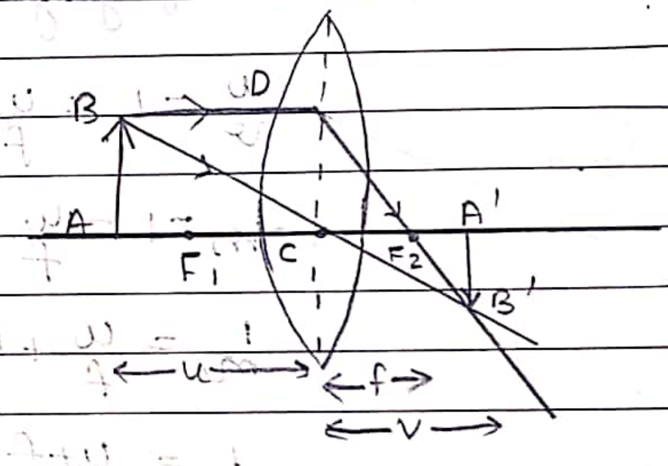
ΔABC and $A'B'C$ are similar

$$\frac{AB}{A'B'} = \frac{AC}{A'C}$$

or, $$\frac{A'B'}{AB} = \frac{A'C}{AC}$$

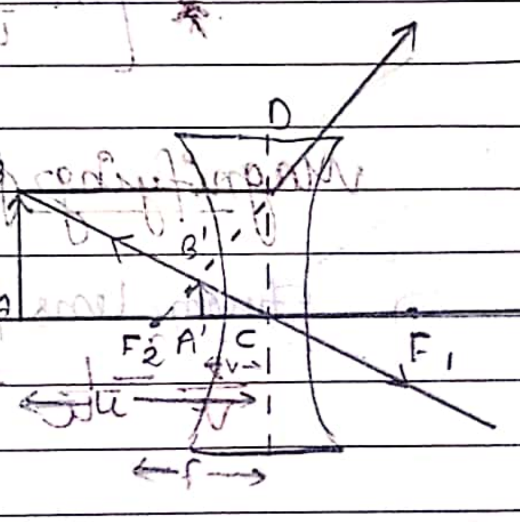
$$\frac{-h_2}{+h_1} = \frac{+v}{-u}$$

$$\left[m = \frac{v}{u} \right]$$



ii For Concave lens

ΔABC and $A'B'C$ are similar



$$\frac{AB}{A'B'} = \frac{AC}{A'C}$$

or, $$\frac{A'B'}{AB} = \frac{A'C}{AC}$$

or $\frac{+h_2}{+h_1} = \frac{-v}{-u} = \frac{v}{u}$

$\Rightarrow \left[m = \frac{v}{u}\right]$

Magnifying Power in form of u & f

From lens formula

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

multiplying by u

$$\frac{u}{v} - 1 = \frac{u}{f} \qquad \because m = \frac{v}{u}$$

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

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

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

$$* \left[m = \frac{f}{u+f}\right]$$

Magnifying Power in form of v & f

From lens formula

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

multiplying by v

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

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

★ $\left[m=\frac{f-v}{f}\right]$

Power of Lens

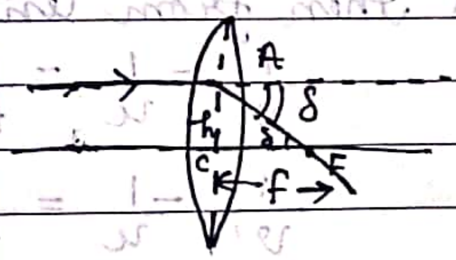
The power of lens is a measure of degree of convergence or divergence of light rays falling on it

'The power of lens is the reciprocal of its focal length'

$$\left[P=\frac{1}{f}\right]$$

If f is measured in metre
Then unit of power of lens is called Diopter (D)

★ ✓ $\tan\delta=\frac{h}{f}$



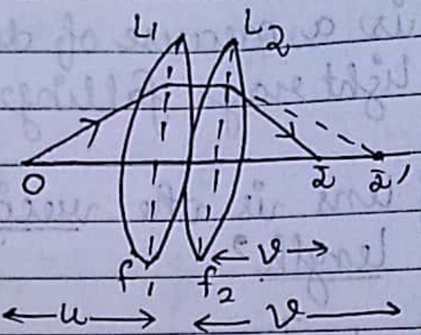
If $h=1$

$\tan\delta=\frac{1}{f}\Rightarrow\left[P=\frac{1}{f}\right]$

Therefore the power of lens is define as the tangent of the angle by which it Converges or diverges a light of beam falling on unit distance from the optical centre.

Smaller the focal length of a lens more is ability to bend light rays and greater is its power

Combination of lens



Let L_1 & L_2 are two lenses of focal lenth F_1 & F_2 placed co-axially in contact with one another. Let O be a point object on the principal axis of the lens system.

In absence of lens L_2 the first lens L_1 will form an image I' of O at a distance v'

★ then from lens formula —

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

$$\frac{1}{v'} - \frac{1}{u} = \frac{1}{f_1} \quad -①$$

I' will act as a virtual object for lens L_2 and its image will formed at distance v.

The For lens L_2

$$\frac{1}{v} - \frac{1}{v'} = \frac{1}{f_2} \quad -② \qquad \because u = v'$$

from ① + ②

$$\cancel{\frac{1}{v'}} - \frac{1}{u} + \frac{1}{v} - \cancel{\frac{1}{v'}} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2} \quad -③$$

If F is the equivalent focal length of lenses in contact and an object placed at distance u and its form image at distance v then—

$$\frac{1}{F} = \frac{1}{v} - \frac{1}{u} \quad -④$$

From eqn ③ & ④

$$\boxed{\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}}$$

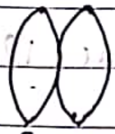
$$\boxed{P = P_1 + P_2}$$

If there are n lenses having focal length $f_1, f_2, f_3 \ldots f_n$ are in contact if their equivalent focal length is F then—

$$\boxed{\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} + \cdots + \frac{1}{f_n}}$$

$$\left[P = P_1 + P_2 + P_3 - - - - + P_n\right]$$

(1) When both lenses are Convex



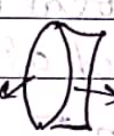
f_1 f_2

$f_1 = +ve$

$f_2 = +ve$

$[F = +ve]$ Contact lens behave like convex

(2) When one lens is convex & another is concave

F_1  F_2

$$F = \frac{+f_1 \times (-f_2)}{f_1 - f_2} \Rightarrow F = \frac{-f_1 f_2}{f_1 - f_2}$$

i) If $f_1 > f_2$

$f = -ve$

contact lens → Concave lens behave

ii) If $f_1 > f_2$

$F = +ve$

Contact lens → Convex lens behave

iii) If $f_1 = f_2$

$f = \infty$

glass plate behave

Dependency of focal length of lens :-

from lens maker formula

$$\frac{1}{f} = (n-1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

The focal length of lens depend upon following two parts.

i) Dependency on radius of curvature

for double convex lens

$R_1 = +ve$, $R = -ve$

Therefore,

$$\frac{1}{f} = (n-1)\left[\frac{1}{R_1} + \frac{1}{R_2}\right]$$

$f = +ve$

for Concave lens

$R_1 = -ve$ & $R_2 = +ve$

Therefore,

$$\frac{1}{f} = (n-1)\left[\frac{-1}{R_1} - \frac{1}{R_2}\right]$$

$$\frac{1}{f} = -(n-1)\left[\frac{1}{R_1} + \frac{1}{R_2}\right]$$

$f = -ve.$

Dependency upon refractive index of lens material.

According to lens maker formula the focal length is inversly proportional to refractive index. It means if refractive index decrease focal length increases & vice versa

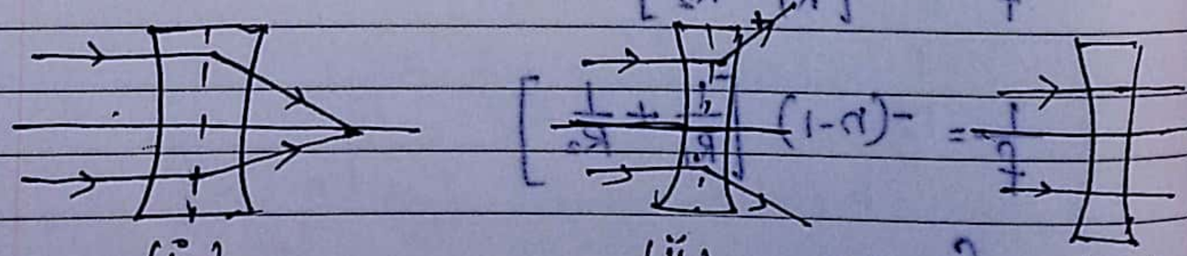
for ex -

(1) If we emerge a lens into such a liquid whose refractive index is less than n of lens material $n_g > n_g$ $n_l > n_g$

In this case focal length of lens will increase but nature will be unchanged.

(2) If $n_l > n_g$ In this case nature of lens will change i.e. Convex behave like convex.

(3) If $n_l = n_g$. In this case lens will behave like a transparent glass plate.



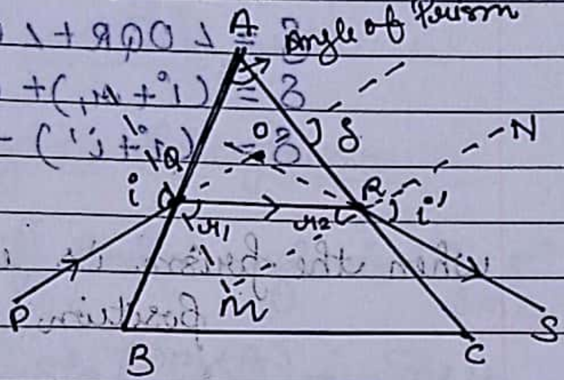
(i) $n_l > n_g$

(ii) $n_g > n_l$

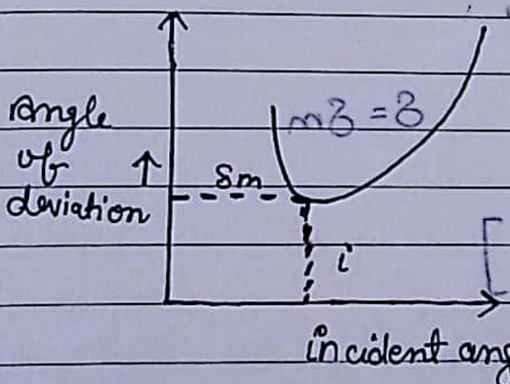
(iii) $n_g = n_l$

Prism- A prism is transparent refractive medium bounced by two faces inclined to each other at a certain angle.

Refraction through prism



PQ = incident Ray
QR = Refracted Ray
RS = emergent Ray
i = incident angle
r_1 = refracted angle
i' = emergent angle
δ = angle of deviation



$$\left[\begin{array}{c} i = i' \\ r_1 = r_2 = r \\ \delta = \delta m \end{array}\right]$$

Refractive index through prism material

In quad. AQMR
$A + \angle QMR = 180°$ —(i)

In Δ QMR
$r_1 + r_2 + \angle QMR = 180°$ —(ii)

from (i) & (ii)

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

$r_1 + r_2 = A$ ---(3)

In ΔOQR, δ is exterior angle

$\delta = \angle OQR + \angle ORQ$

$\delta = (i + r_1) + (i' - r_2)$

$\delta = (i + i') - (r_1 + r_2)$ ---(4)

when the prism is in minimum deviation position then–

$i = i'$

$r_1 = r_2 = r$

$\delta = \delta_m$

from eq (3)

$2r = A$

$\left[r = A/2 \right]$

from eq -(4)

$\delta_m = 2i - 2r$

$2i = \delta_m + A \quad \because 2r = A$

$\left[i = \frac{\delta_m + A}{2} \right]$

from Snell's Law

$n = \dfrac{\sin i}{\sin r}$

$$\boxed{n = \frac{\sin\left(\frac{\delta_m + A}{2}\right)}{\sin(A/2)}}$$

Deviation produced by a thin prism

A prism will be thin if prism angle is $A < 5^\circ$
$\delta_m <$

For thin Prism $\sin\left(\frac{\delta_m + A}{2}\right) = \frac{\delta_m + A}{2}$

$\sin\frac{A}{2} = A/2$

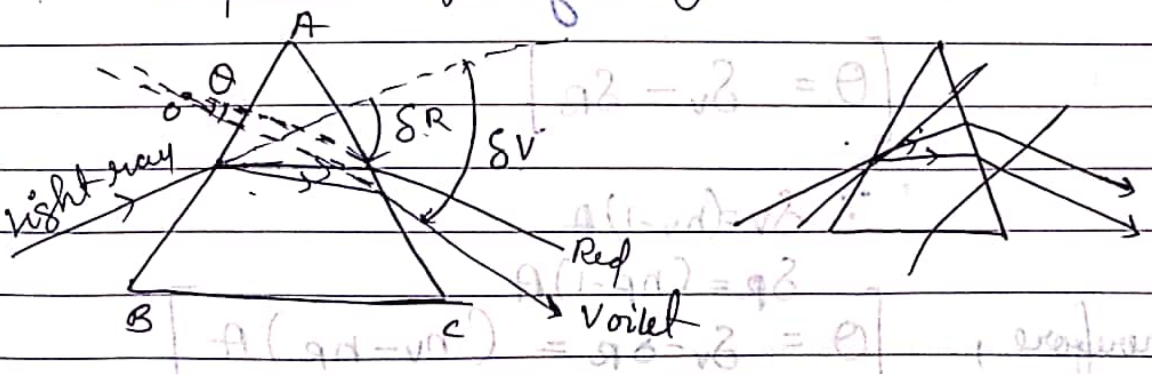
$$n = \frac{\delta_m + A/\cancel{2}}{A/\cancel{2}}$$

$$nA = \delta_m + A$$

$$\delta_m = nA - A$$

$$\boxed{\delta_m = (n-1)A}$$

Dispersion of white light



The phenomenon of splitting of white light into its Component colours on passing through a refracting medium is called dispersion of light.

The pattern of colour band obtained on screen is called spectrum

Cause of dispersion

From deviation formula

$$\delta_m = (n-1)A$$

it is clear that for which colour the refractive index will be greater the deviation for that colour will be greater

$\because \quad n_V > n_R$

$\Rightarrow \quad \delta_V > \delta_R$

Angular dispersion

The angular separation b/w two extreme colour light (violet & Red) in spectrum is called angular dispersion

It is denoted by θ

$$\boxed{\theta = \delta_V - \delta_R}$$

$\because \delta_V = (n_V - 1)A$

$\delta_R = (n_R - 1)A$

Therefore,

$$\boxed{\theta = \delta_V - \delta_R = (n_V - n_R)A}$$

Dispersion Power

It is the ability of Prism material to cause dispersion. It is defined as the ratio of angular dispersion to the mean deviation.

It is denoted by

$$\boxed{\omega = \frac{\theta}{\delta_y}}$$

$$\theta = (n_v - n_R)A$$

$$\delta_y = (n_y - 1)A$$

$$\omega = \frac{(n_v - n_R)\cancel{A}}{(n_y - 1)\cancel{A}}$$

$$\omega = \frac{(n_v - n_R)}{(n_y - 1)} \qquad \boxed{\omega = \frac{n_v - n_R}{n_y - 1}} \text{ Ans}$$

Scattering of light

This is the phenomenon in which light is deflected from its path due its intraction with the particle of medium through which it passes.

Basically the scattering process involves the absorption of light by the molecules followed by its reradiation in different direction.

There are two type of Scattering

(1) Rayleh or elastic Scattering

When the size of Scattering particle is much smaller than wavelength (λ) of incident ray there is no exchange of energy between the incidence light and scattering light. Cosequently there is no change in frequency or in wavelenth or Scattered light. This type of Scattering is called elastic or Rayleh Scattering.

its obey Rayleh's Law

Rayleh's Law

According to this law the intensity of scattered light is inversely proportional to fourth power of wavelength.

$$\left[I \propto \frac{1}{\lambda^4} \right]$$

(2) inelastic Scattering

When the size of scattering particle is much greater than the wavelength of incidence light then there is interchange of energy b/w incident rays & scattering particles. Consequently the scattered light has frequency or wavelength different from the incident light. this type of scattering is called inelastic scattering.

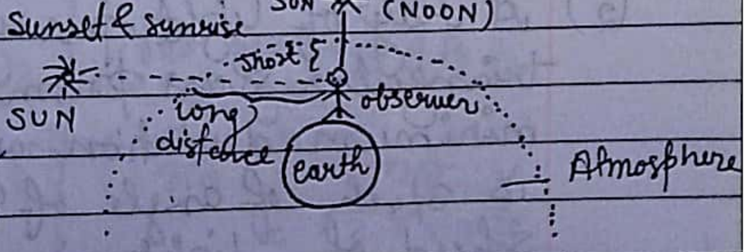
For. ex. Raman effect, Compton effect are the example of inelastic effect.

Daily Life Phenomenon based on Scattering of Light

1 Blue colour of sky

As sun light passes through atmosphere the light is absorb by air molecules & reemit it. The free gas molecules scattered light in all direction because $I \propto \frac{1}{\lambda^4}$ the light of short wavelength i.e. blue is scatter more than the light of long wavelength. Therefore, the sky looks blue.

2 Reddisness of Sunset and Sunrise



When the sun is near horizon at sunset or

unrise the light rays have to traverse a
hickness of atmosphere in accordance with
ayleigh's Law the lower wavelength lights
lmost completely scattered away by the ai
olecules. Higher wavelength in the red re
least scattered and reach our eyes
herefore the sun appears almost redd

Optical Instrument

1- Least distance of distinct vision

The minimum distance from the eye at which the eye can be see the object clearly and distinctly without any strain is called least distance of distinct vision.

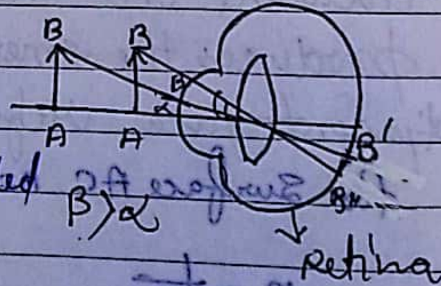
For a normal eye its values is 25 cm

2. Power of Accomadation

Power of Accomadation of optical instrument is the maximum variation of its power for ~~focin~~ focusing a near or far object.

3. Angle of vision

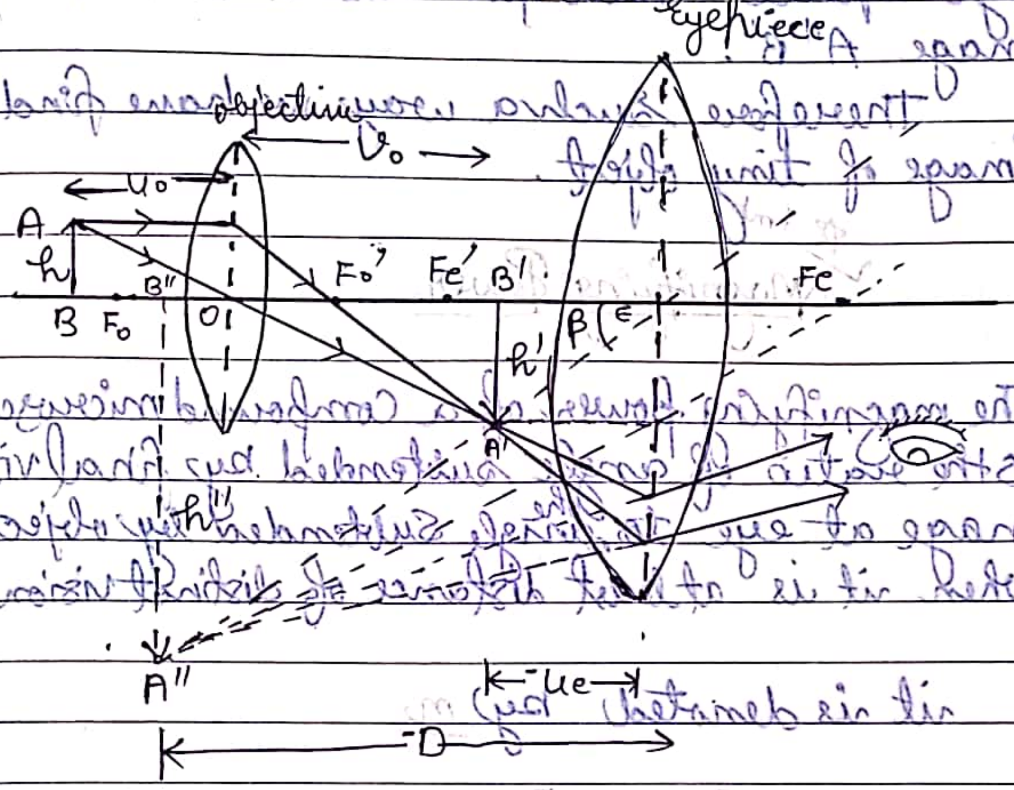
The angle form by any object on our eye is called angle of vision.



Compound Microscope

A Compound microscope is an optical device used ~~to~~ see magnifying image of a tiny object.

Construction



Objective

It is a Convex lens of very short focal length and small aperture.

eyepiece

It is a Convex lens of larger focal length & larger aperture.

Working

An object AB is place at distance u_o in front of objective. the objective forms a real & invert image A'B'. The separation b/w objective & eyepiece is so adjusted that the image $A'B'$ lies within the focal length of eyepiece. $A'B'$ acts as an object for eye piece which forms its virtual & magnify image $A''B''$.

Therefore such a way we have find a large image of tiny object.

☆ imp

Magnifying Power

The magnifying power of a compound microscope is the ratio of angle subtended by final virtual image at eye to the angle subtended by object when it is at least distance of distinct vision

it is denoted by m

$$\left[m = \frac{\beta}{\alpha} \right]$$

$$m = \frac{\tan\beta}{\tan\alpha} = \frac{A'B'/B'E}{AB/D}$$

$$m = \frac{A'B'}{AB} \times \frac{D}{B'E}$$

$$m = \frac{h'}{h} \times \frac{D}{u_e}$$

$$m = m_o \times m_e$$

$$m_o = \frac{v_o}{u_o}$$

$$m_e = \frac{-D}{u_e}$$

therefore

$$m = \frac{v_o}{u_o} \times \frac{-D}{-u_e}$$

$$\boxed{m = \frac{v_o}{u_o}\left(\frac{D}{u_e}\right)} \quad \text{①}$$

2) The magnifying power when final image is form at least distance of distinct vision

from lens formula

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \quad \text{for eyepiece}$$

$$\frac{1}{-D} - \frac{1}{-u_e} = \frac{1}{f_e}$$

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

Divide by D

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

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

from eqn ①

$$m = \frac{v_o}{u_o}\left[1 + \frac{D}{f_e}\right]$$

In this condition the length of microscop will be $v_o + u_e$

2 When the last image is form at infinite.

When the last image formed at infinite then—

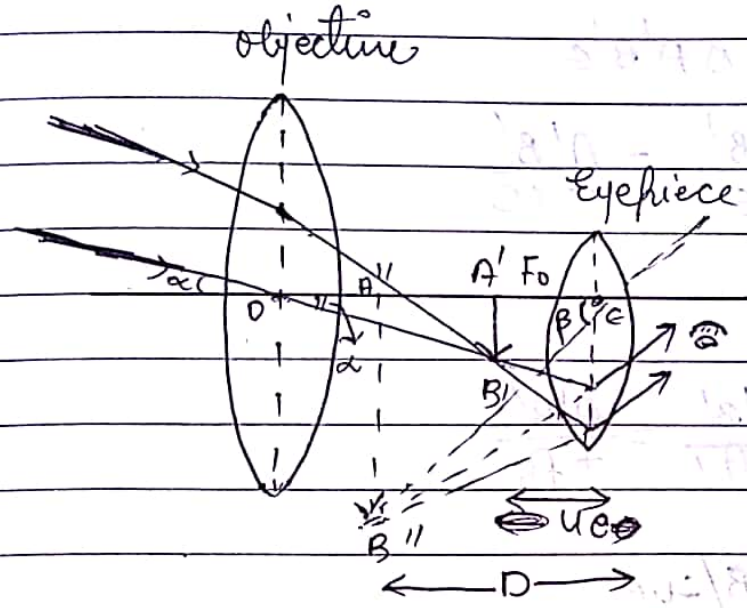
$$u_e = f_e$$

Then from eq (1)

$$\left[m = \frac{v_0}{u_0} \left(\frac{D}{f_e} \right) \right]$$

In this condition the length of microscope will be $v_0 + f_e$

Astronomical Telescope



It is a refracting type telescope use to see heavenly bodies like planet, star & Satellite etc.

Construction

1. objective → There is a convex lens of big aperture which placed in front of object is called objective lens.

2. Eyepiece → It is a Convex lens of small aperture in which we see magnifying image of object placed at far distance.

magnifying Power

It is the ratio of angle subtended at the eye by final image at the least distance of distinct vision to the angle of subtended at the eye by the object at infinity when seen directly.

$$\left[m = \frac{\beta}{\alpha}\right]$$

$\Delta A'B'C$

$$B = \tan\beta = \frac{A'B'}{A'C} = \frac{A'B'}{-u_e}$$

$\Delta OA'B'$

$$\tan\alpha = \frac{A'B'}{OA'} = \frac{A'B'}{+f_o}$$

$$m = \frac{\cancel{A'B'}/-u_e}{\cancel{A'B'}/f_o}$$

$$\left[m = -\frac{f_o}{u_e}\right] \quad -(1)$$

(1) when the last image form at least distance of distinct vision.

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \quad \text{(by lens formula)}$$

$$\frac{1}{-D} - \frac{1}{-u_e} = \frac{1}{f_e}$$

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

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

$$\frac{1}{u_e} = \frac{1}{f_e}\left[1 + \frac{f_e}{D}\right]$$

from eqn (1)

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

Length of telescope

$= f_o + u_e$

(2) when the last image formed at ∞

$u_e = f_e$

from eqn (1)

$$\left[m = \frac{-f_o}{f_e}\right]$$

Length of telescope $= f_o + f_e$

This position is called Normal position of telescope.

IMITATION OF REFRACTING TELESCOPE

acting telescope suffers from chromatic aberr
uses large sized lenses.

Scanned with CamScanner

ii) It is difficult and expensive to make such large sized lenses.

* REFLECTING TYPE ASTRONOMICAL TELESCOPE

Cassegrain Type Telescope:

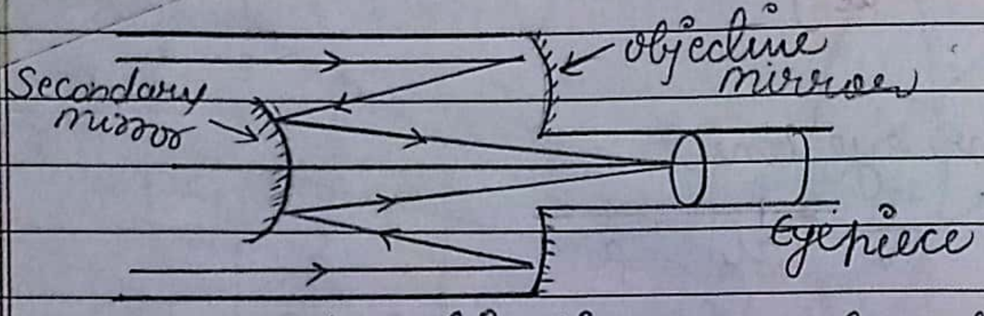


Fig - Schematic diagram of a reflecting teles

In normal adjustment, magnifying power at a reflecting type telescope is given by.

$$\left[m = \frac{f_o}{f_e} = \frac{R}{2f_e} \right]$$

Advantages :

- Reflecting telescope have high resolving power due to a large aperture of mirrors.

- Due to availability of paraboloidal mirror, the image is free from chromatic and spherical aberration.

- A mirror reflects the light, so the material that is made from does not have to be transparent and infrared and ultraviolet light reflects equally well.

- Mirror requires grinding and polishing of only one side.

* **RESOLVING POWER OF TELESCOPE**

$$R_P = \frac{A}{1.22\lambda}$$

where,
A = aperture or diameter of the objective telescope.
λ = wavelength of the objective

$$\Rightarrow R \propto A$$

$\therefore$ Ratio of resolving power of two telescopes

$$\frac{R_1}{R_2} = \frac{A_1}{A_2}$$

$\because A_2 > A_1$
$\therefore R_2 > R_1$

The larger the aperture of objective, higher the resolving power of telescope. As well more gathering of light to form the image and hence, brighter image would be obtained.