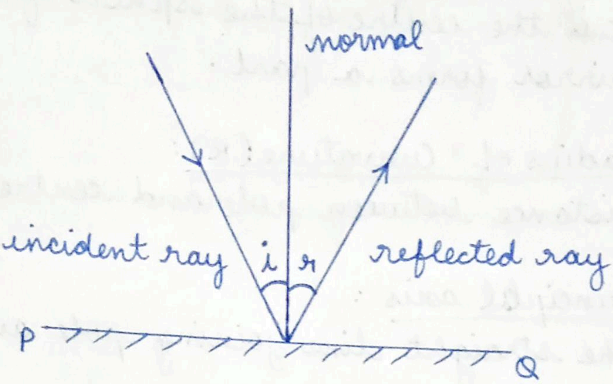
9. Ray Optics

Reflection :

Laws of Reflection :

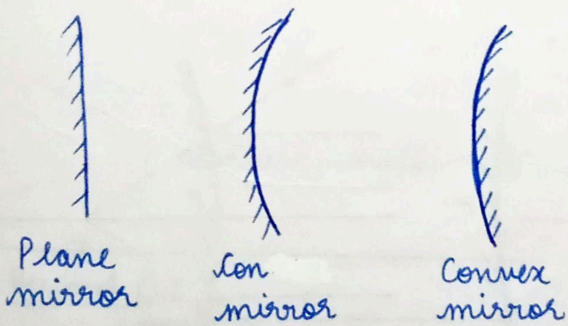
$\angle i = \angle r$.

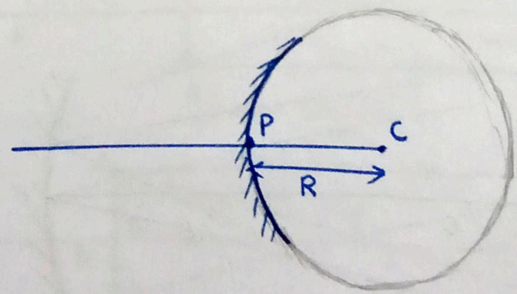


(i) The incident ray, the normal, and the reflected ray, all lie in the same plane

(ii) The angle of incidence is equal to the angle of reflection.

Mirrors : Ideal reflecting surfaces.





P – Pole

C – Centre of curvature

R – Radius of curvature

Pole (P) of the mirror:
It is the centre of the reflecting surface of the mirror.

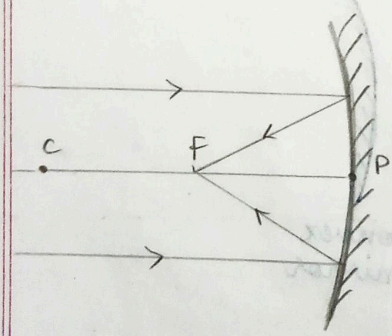
Centre (C) of curvature:
It is the centre of the sphere of which the mirror forms a part.

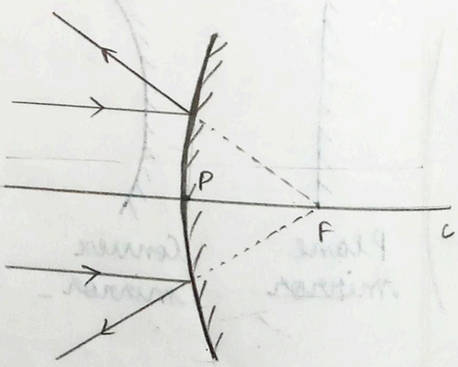
Radius of curvature (R):
Distance between pole and centre of curvature

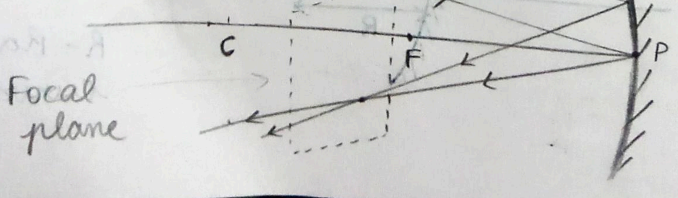
Principal axis:
The straight line joining pole and centre of curvature.

Principal Focus:
Paraxial rays after reflection converge at a point on the principal axis. This point is called principal focus

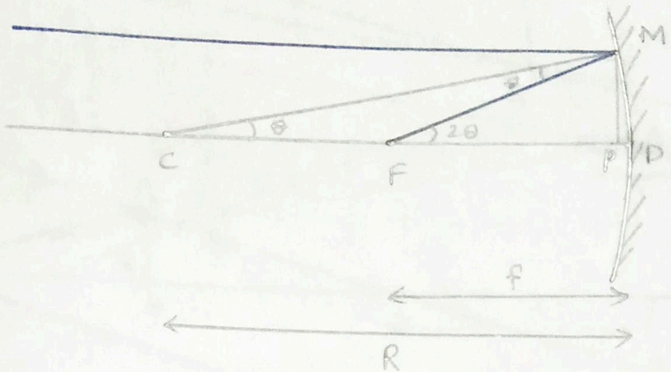
Focal length (f):
Distance between principal focus and pole of the mirror.







Relation between focal length and radius of curvature



ΔMFD:

$$\tan 2\theta = \frac{MD}{FD}$$

ΔMCD:

$$\tan \theta = \frac{MD}{CD}$$

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

$\tan \theta \simeq \theta$

$$\therefore \quad 2\theta = \frac{MD}{FD} \; ; \quad \theta = \frac{MD}{CD}$$

$$\Rightarrow \quad 2\left(\frac{MD}{FD}\right) = \frac{MD}{CD}$$

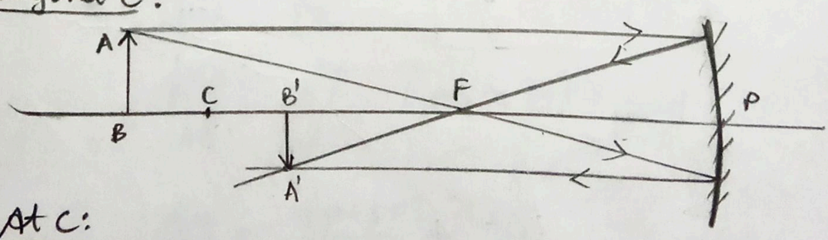
$$CD = 2FD$$

$$CP = 2FP$$

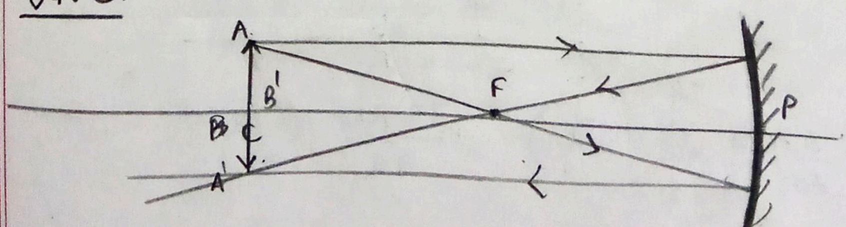
(Aperture small $\therefore$ $CP = CD$, $FD = FP$)

$$\therefore \quad R = 2f.$$

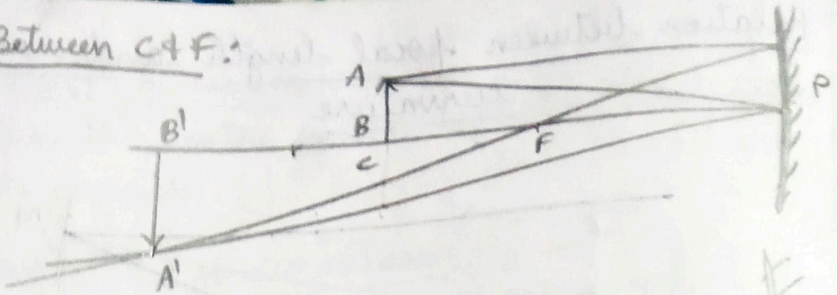
Beyond C:



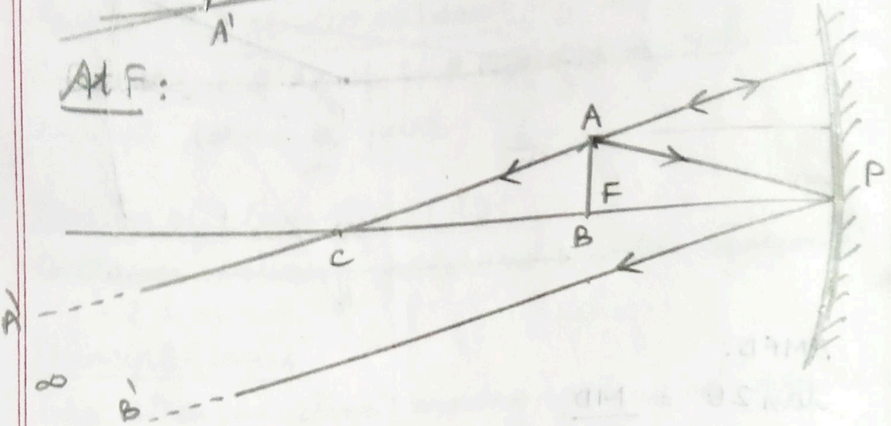
At C:



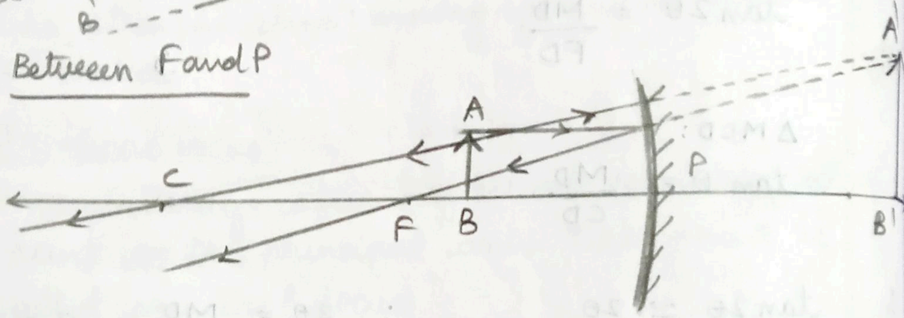
Between C & F:



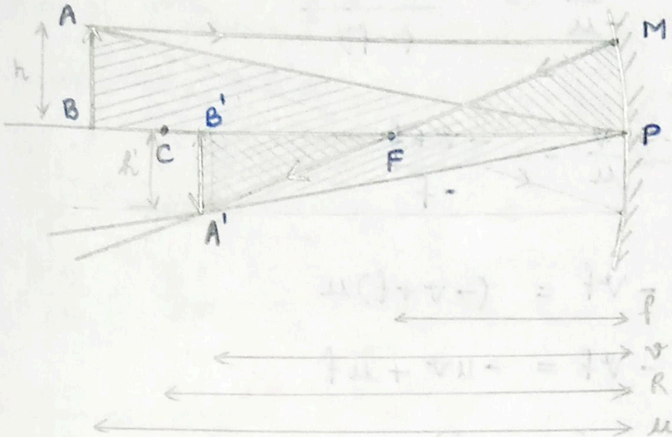
At F:



Between F and P



Mirror Formula



AB- object
A'B'- image
u- object distance
v- image distance
R- Radius of curvature
f- focal length

$\Delta ABP \sim \Delta A'B'P$ (By AAA)

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

$\Delta MPF \sim \Delta A'B'F$ (By AAA)

$$\frac{A'B'}{MP} = \frac{B'F}{PF}$$

$$\frac{A'B'}{AB} = \frac{B'F}{PF} \quad (AB \approx MP)$$

$$\frac{A'B'}{AB} = \frac{B'P - PF}{PF} \quad \text{— (2)}$$

$$\frac{B'P}{BP} = \frac{B'P - PF}{PF} \quad \left((1) = (2) = \frac{A'B'}{AB} \right)$$

$BP = -u$; $B'P = -v$; $PF = -f$.

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

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

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

$$-vf = -uv + uf$$

$(\div\, uvf)$

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

Magnification:

Defined as the ratio of size of image to size of object.

from ①, $\frac{A'B'}{AB} = \frac{B'P}{BP}$, $\left(\begin{array}{l} A'B' = h' \\ AB = h \end{array}\right)$

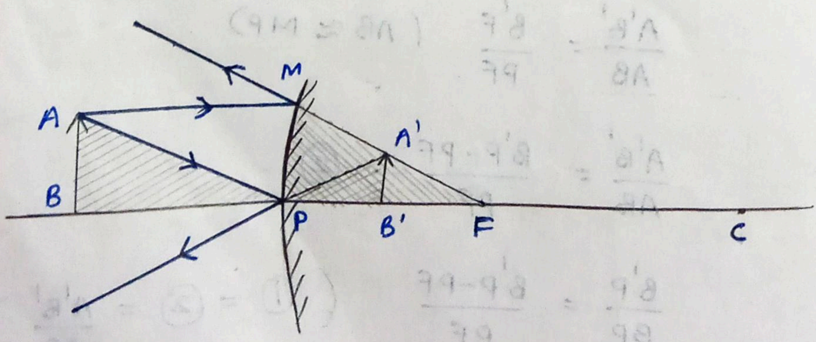
$$\frac{-h'}{h} = \frac{-v}{-u}$$

m -ve = Real image

m +ve = Virtual image

$$\frac{h'}{h} = \frac{-v}{u}$$

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



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

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

$\Delta MPF \sim \Delta A'B'F$

$$\frac{AB'}{MP} = \frac{B'F}{PF}$$

$$\frac{A'B'}{AB} = \frac{B'F}{PF}$$

$$\frac{A'B'}{AB} = \frac{PF - B'P}{PF}$$

$$\frac{B'P}{BP} = \frac{PF - B'P}{PF}$$

$PP = -u$; $B'P = v$, $PF = f$.

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

$$fv = -uf + uv$$

$(\div\, uvf)$

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

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

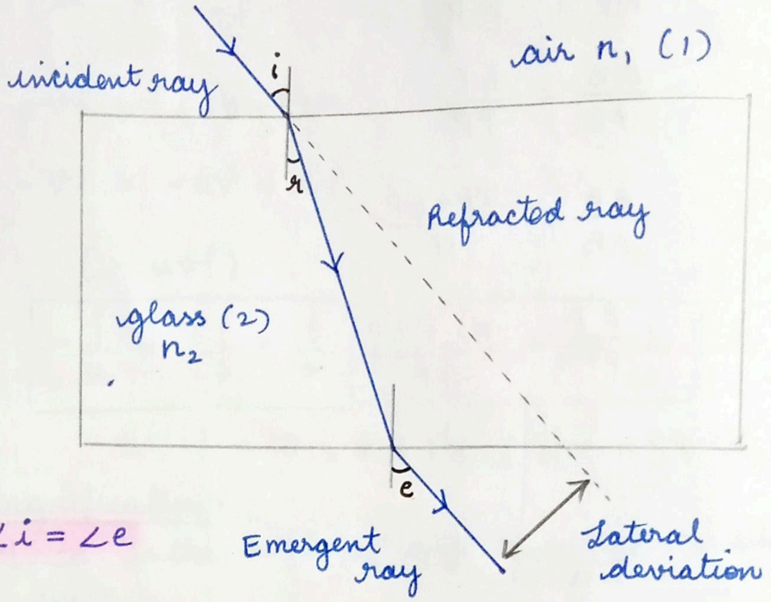
$$\frac{A'B'}{AB} = \frac{B'P}{BP}$$

$$\frac{h'}{h} = \frac{v}{-u}$$

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

Refraction of Light

When light moves from one medium to another medium, there is a change in direction of path of light due to change in speed of light. This phenomena is called refraction of light.



$\angle i = \angle e$

Laws of Refraction

(i) The incident ray, the refracted ray, and the normal at the point of incidence, at the interface separating the 2 media, all lie in the same plane.

(ii) Snell's law:

$$\frac{\sin i}{\sin r} = n_{21}$$ → refractive index of 2nd medium w.r.t. 1st medium.

If $n_{21} > 1$, $\angle i > \angle r$ (ray bends towards normal)

Rarer → denser (2nd medium is optically denser)

If $n_{21} < 1$, $\angle i < \angle r$ (ray bends away from normal)

(2nd medium is optically rarer)

Denser → Rarer

$n_{21} = \frac{v_1}{v_2}$; v_1 = speed of light in medium 1
v_2 = speed of light in medium 2

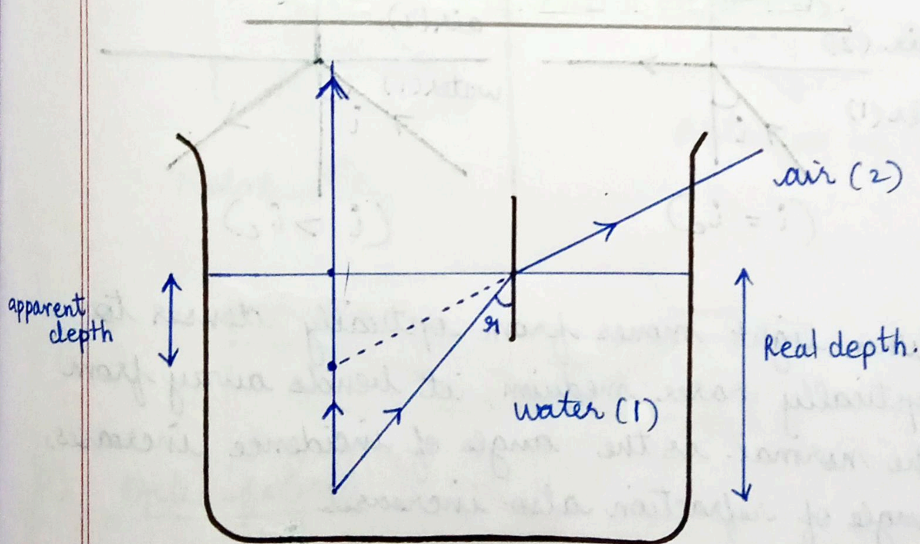
$n_{21} = \frac{n_2}{n_1} = \frac{1}{n_{12}}$

n_2 = refractive index of medium 2 w.r.t. vacuum
n_1 = refractive index of medium 1 w.r.t. vacuum.
n_{12} = refractive index of medium 1 w.r.t. medium 2

$$n_{32} = \frac{n_3}{n_2} = \frac{n_3 \times n_1}{n_2 \times n_1} = \frac{n_3}{n_1} \times \frac{n_1}{n_2}$$

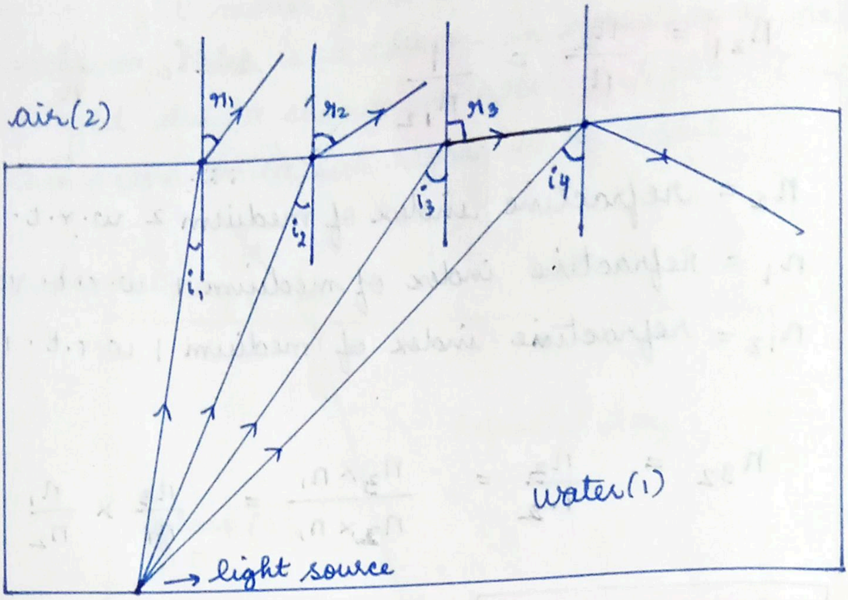
$\boxed{n_{32} = n_{31} \times n_{12}}$ (when there are 3 media)

- Depth of a pond appears to be raised up due to refraction.



$$n_{12} = \frac{\text{Real depth}}{\text{Apparent depth}}$$

TOTAL INTERNAL REFLECTION (TIR)

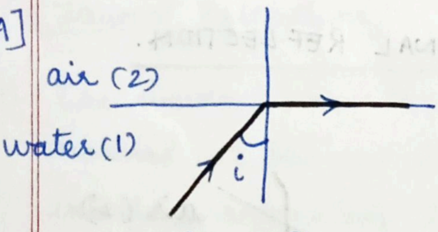


$i_1 < i_2 < i_3 < i_4$ $\qquad$ $i_4 > i_c$

$i_3 = i_c$

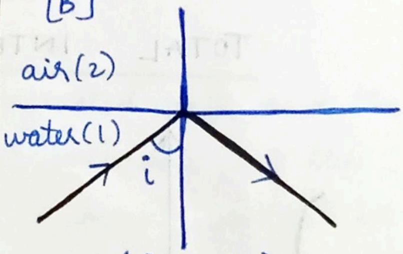
$r_1 < r_2 < r_3$

[A]



$(i = i_c)$

[B]



$(i > i_c)$

When light moves from optically denser to optically rarer meduim, it bends away from the normal. As the angle of incidence increases, angle of refraction also increases

When the angle of incidence = critical angle, it is found that the refracted ray moves along the surface separating the 2 media, angle of refraction is 90°

If the angle of incidence becomes greater than critical angle, the ray of light is totally internally reflected within the same medium. Such a phenomenon is called TIR.

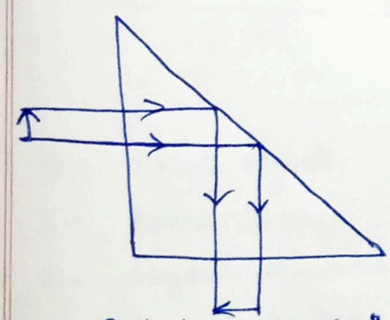
Conditions for TIR to occur:

(i) The ray of light should move from optically denser to optically rarer medium.

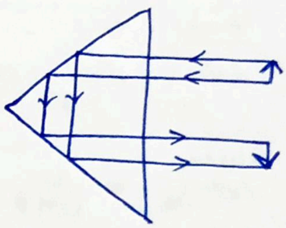
(ii) The angle of incidence should be greater than critical angle.

APPLICATIONS OF TIR

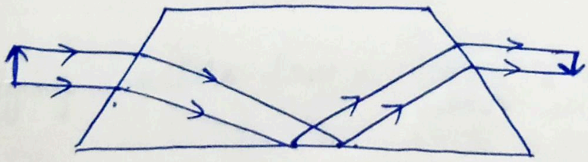
1) TIR prism



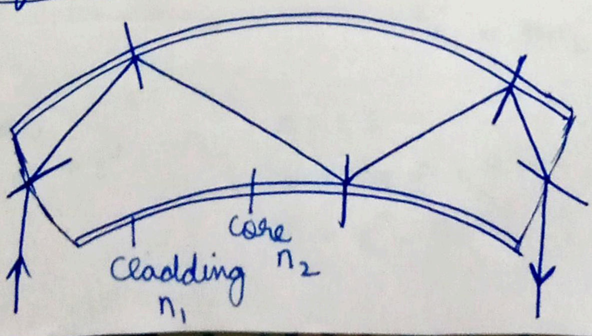
Rotation by 90°



Rotation by 180°.



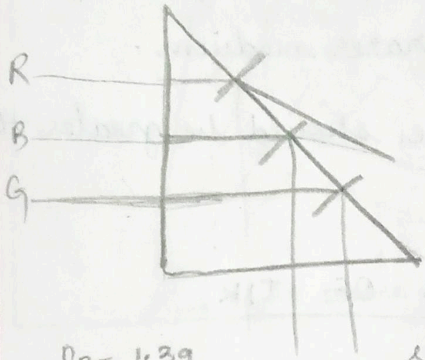
2) Optic fibres



Uses of TIR

1) Communication
2) Endoscope tubes in Medicine (light pipe)
3) Decorative lamps

Refer Pg - 322



$n_R = 1.39$
$n_B = 1.46$
$n_G = 1.43$

$\sin 45 = \frac{1}{\sqrt{2}} = \frac{1}{1.41}$

Red:
$\sin i_c = \frac{1}{1.39} > \frac{1}{1.41}$

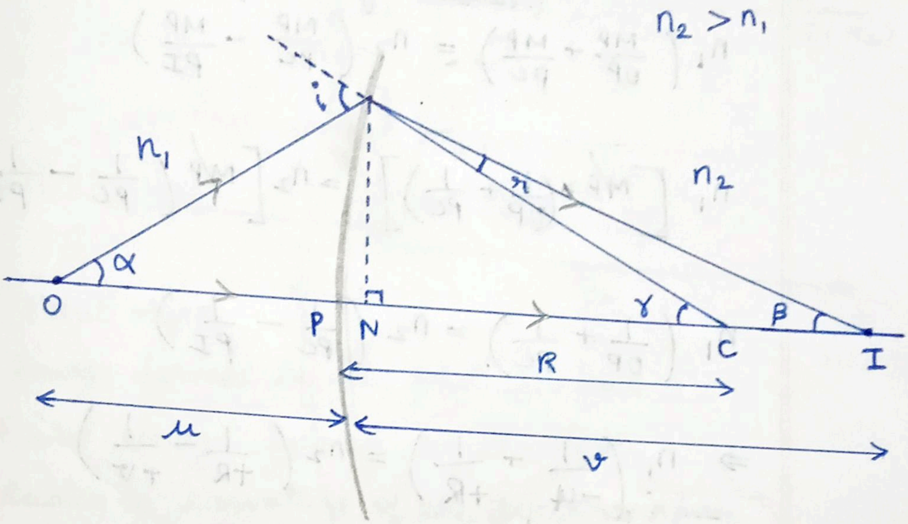
Blue
$\sin i_c = \frac{1}{1.46} < \frac{1}{1.41}$

Green
$\sin i_c = \frac{1}{1.43} < \frac{1}{1.41}$

Refraction through Spherical surface

Assumptions:

1) Aperture is small
2) Object is a point object, image is also a point image
3) Angle of incidence, angle of refraction, α, β, γ, all are small.



O - Point object
I - Point Image
u = Object distance
v = Image distance
R = Radius of curvature

Applying snell's law = $\frac{\sin i}{\sin r} = n_{21} = \frac{n_2}{n_1}$

(assumption 3) ← $\frac{i}{r} = \frac{n_2}{n_1}$

$i n_1 = r n_2$ — ①

ΔMCO

$i = \alpha + \gamma$

ΔMCI

$\gamma = r + \beta$

$r = \gamma - \beta$

$$n_1(\alpha+\gamma) = n_2(\gamma-\beta) \rightarrow (2)$$

$MP = MN$ (aperture is small)

ΔMPO $\qquad$ ΔMPI $\qquad$ ΔMPC

$$\tan\alpha = \frac{MP}{OP} \qquad \tan\beta = \frac{MP}{PI} \qquad \tan\gamma = \frac{MP}{PC}$$

$$\alpha = \frac{MP}{OP} \qquad \beta = \frac{MP}{PI} \qquad \gamma = \frac{MP}{PC}$$

(substituting in 2)

$$n_1\left(\frac{MP}{OP}+\frac{MP}{PC}\right) = n_2\left(\frac{MP}{PC}-\frac{MP}{PI}\right)$$

$$n_1\left[\cancel{MP}\times\left(\frac{1}{OP}+\frac{1}{PC}\right)\right] = n_2\left[\cancel{MP}\left(\frac{1}{PC}-\frac{1}{PI}\right)\right]$$

$$n_1\left(\frac{1}{OP}+\frac{1}{PC}\right) = n_2\left(\frac{1}{PC}-\frac{1}{PI}\right)$$

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

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

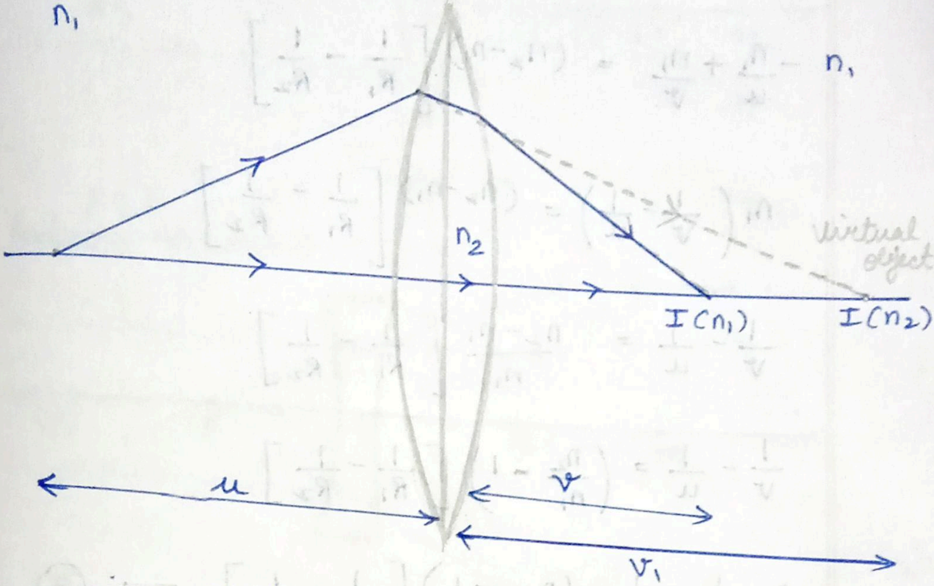
$$= \left(\frac{n_1}{R}-\frac{n_1}{u}\right) = \left(\frac{n_2}{R}-\frac{n_2}{v}\right)$$

$$\frac{n_2}{v}-\frac{n_1}{u} = \frac{n_2}{R}-\frac{n_1}{R} = \frac{n_2-n_1}{R}$$

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

Refraction through 2 spherical surfaces

– Lens maker's formula



O – Point object

I_1 – Image formed by the first surface

I – Final image formed by the lens

R_1 – Radius of curvature of the first surface

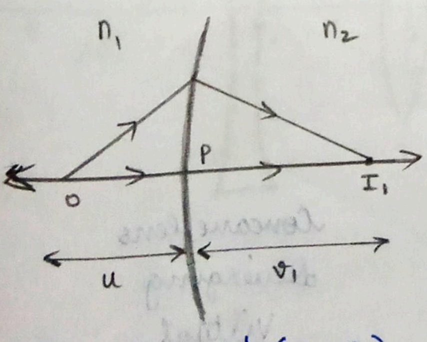
R_2 – Radius of curvature of the second surface

v – distance of final image formed by the lens

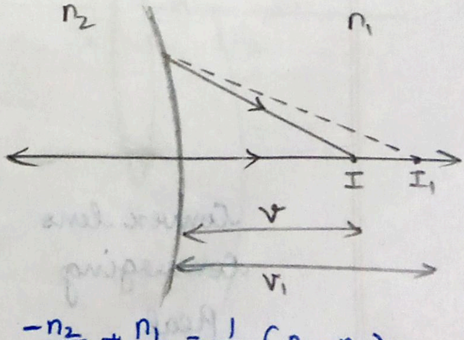
v_1 – distance of the image formed by the first surface

n_1 – refractive index of surrounding medium.

n_2 – refractive index of the lens.



$$-\frac{n_1}{u}+\frac{n_2}{v_1}=\frac{1}{R_1}(n_2-n_1) \quad (1)$$



$$-\frac{n_2}{v_1}+\frac{n_1}{v}=\frac{1}{R_2}(n_1-n_2) \quad (2)$$

① + ②

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

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

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

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

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

$$\Rightarrow \frac{1}{v} - \frac{1}{u} = (n_{21} - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \quad — ③$$

(substituting $u = \infty$, $v = f$ in ③)

$$\frac{1}{f} = (n_{21} - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \quad — ④$$

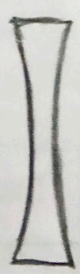
↳ lens makers' formula

From equations ③ and ④,

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$ ⇒ Thin lens formula.

LENSES

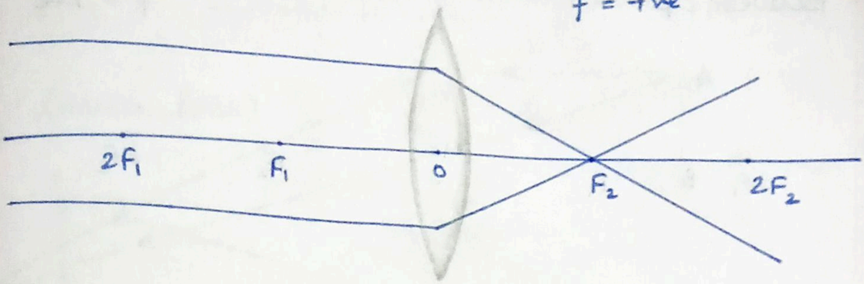
Convex lens
Converging
Real



Concave lens
Diverging
Virtual

At ∞

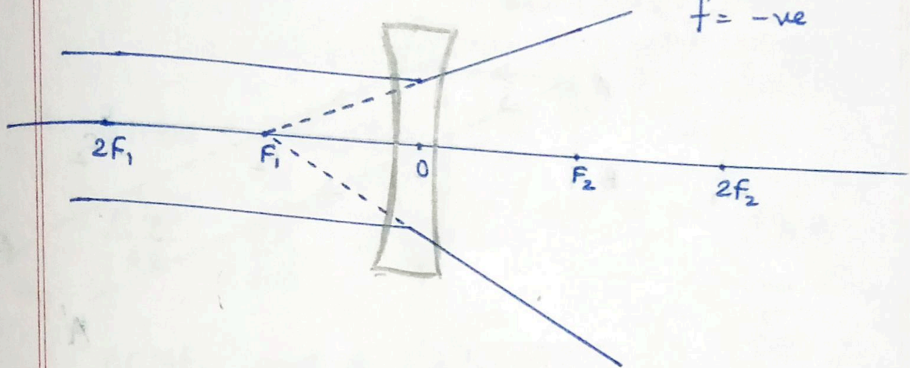
f = +ve



At F

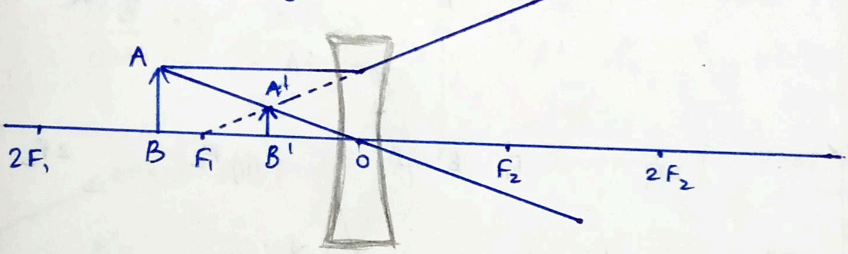
~~Between ∞ and O~~

f = -ve



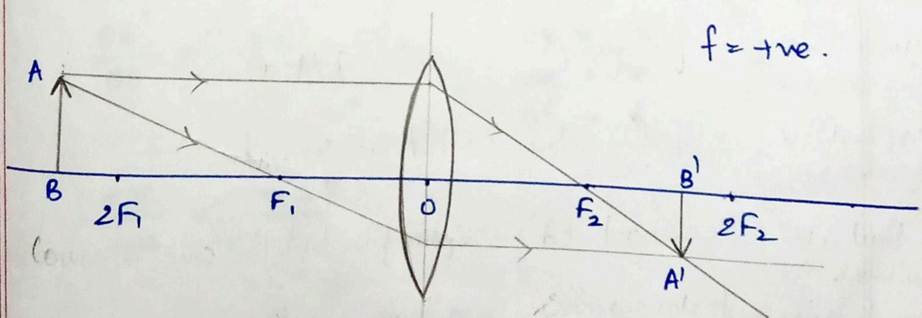
Between ∞ & O.

f -ve

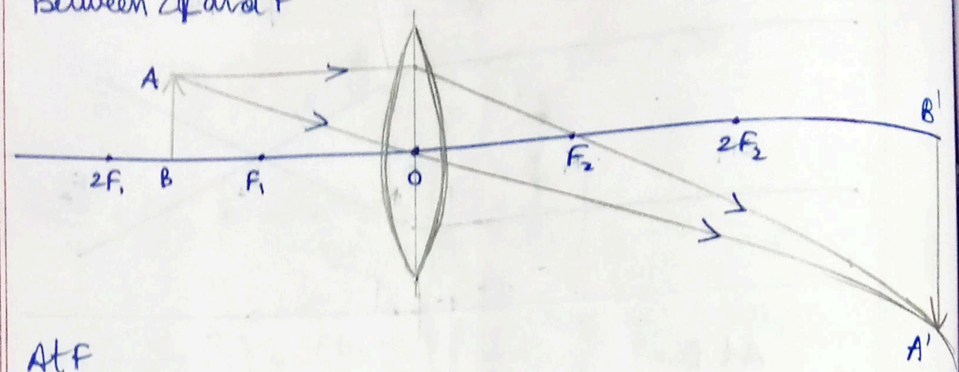


Beyond 2F

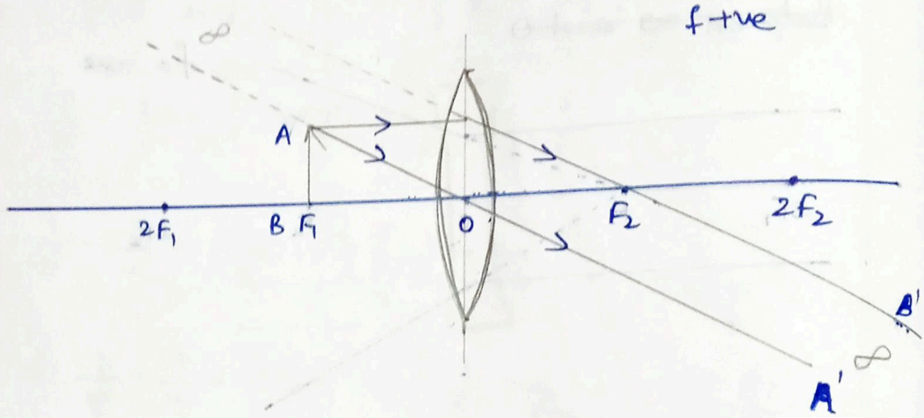
f = +ve.



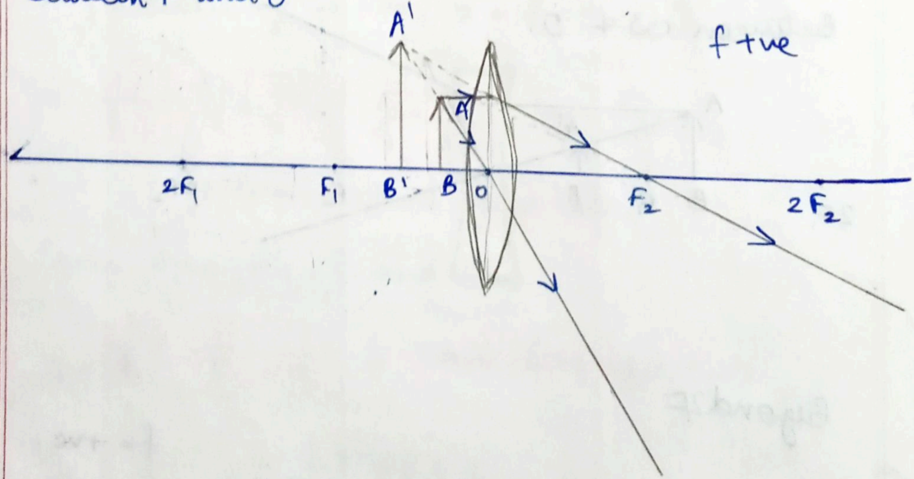
Between 2F and F



At F

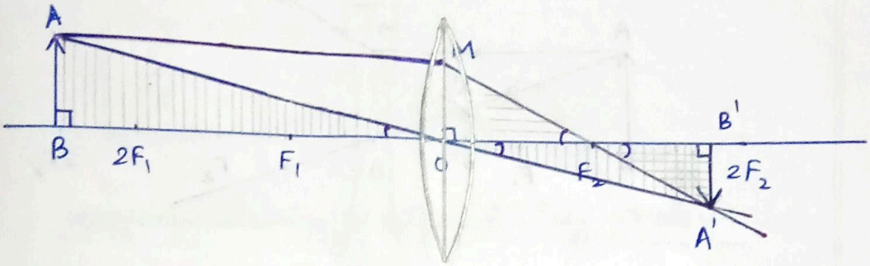


Between F and O



Thin lens formula

(Convex lens)



ΔABO & $A'B'O$

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

ΔOMF_2 and $\Delta A'B'F_2$

$$\frac{A'B'}{OM} = \frac{B'F_2}{OF_2}$$

$$OM = AB$$

$$\frac{A'B'}{AB} = \frac{OB' - OF_2}{OF_2} \quad — (2)$$

$$\frac{OB'}{OB} = \frac{OB' - OF_2}{OF_2}$$

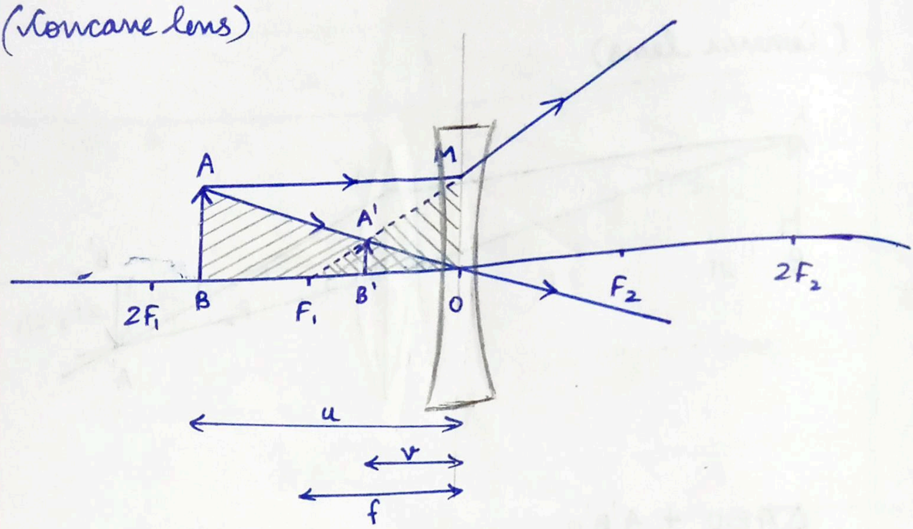
$OB = -u$
$OB' = v$
$OF_2 = f.$

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

$$+vf = -uv + uf. \quad (\div uvf)$$

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

(Concave lens)



ΔABO and $\Delta A'B'O$.

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

ΔOMF_1 and $\Delta A'B'F_1$

$$\frac{A'B'}{OM} = \frac{B'F_1}{OF_1}$$

$(OM = AB)$

$$\therefore \frac{A'B'}{AB} = \frac{B'F_1}{OF_1} \quad — \quad (2).$$

$$(1) = (2) = \frac{A'B'}{AB}.$$

$$\therefore \frac{OB'}{OB} = \frac{B'F_1}{OF_1} = \frac{OF_1 - OB'}{OF_1}$$

$OB = -u$; $OB' = -v$, $OF_1 = -f$.

$$\Rightarrow \frac{-v}{-u} = \frac{-f-(-v)}{-f}$$

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

$$-vf = uv - uf. \quad (\div uvf)$$

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

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

Magnification produced by a lens

It is defined as ratio of size of image to size of object.

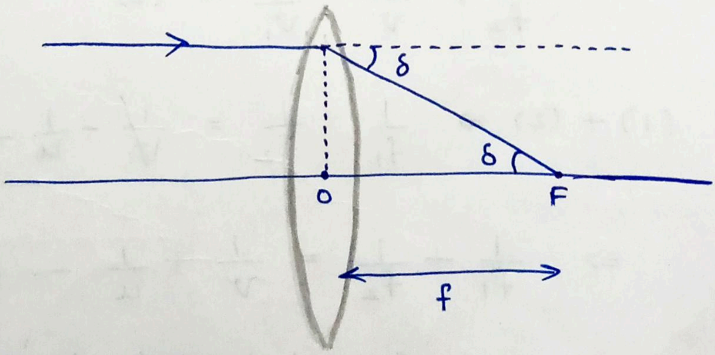
$$m = \frac{A'B'}{AB}$$

$$\frac{A'B'}{AB} = \frac{OB'}{OB} = \frac{-h'}{+h} = \frac{+v}{-u}$$

$$\frac{h'}{h} = \frac{v}{u} \Rightarrow \boxed{m = \frac{v}{u}}$$

Power of a lens:

It measures the degree of convergence or divergence produced by a lens



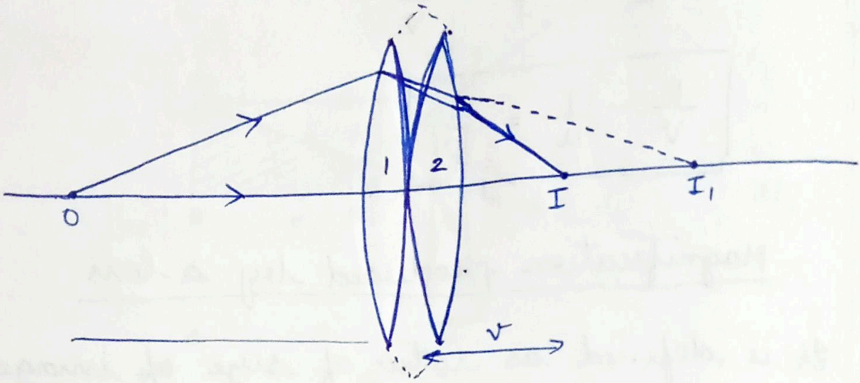
$$P = \tan \delta$$

$$P = \frac{h}{f} \quad (h = 1 \text{ unit})$$

$$\therefore P = \frac{1}{f}$$, S.I. unit = Dioptre (D)

$$1D = \frac{1}{1m}.$$

Power of combination of lenses



O - point object

I_1 - Image formed by the first lens

I - Final image formed by the combination

f_1 - focal length of lens 1

f_2 - focal length of lens 2

For refraction through first lens

$$\frac{1}{f_1} = \frac{1}{v_1} - \frac{1}{u} \quad \text{— (1)}$$

For refraction through second lens

$$\frac{1}{f_2} = \frac{1}{v} - \frac{1}{v_1} \quad \text{— (2)}$$

$$(1) + (2) \Rightarrow \frac{1}{f_1} + \frac{1}{f_2} = \cancel{\frac{1}{v_1}} - \frac{1}{u} + \frac{1}{v} - \cancel{\frac{1}{v_1}}$$

$$\Rightarrow \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{v} + \frac{1}{u} \quad \text{— (3)}$$

for a single lens of focal length 'F' that can generate the image at the same distance, then (Combination replaced by this lens)

$$\cancel{P} = \frac{1}{F} = \frac{1}{v} + \frac{1}{u} \quad \text{— (4)}$$

$(3) = (4) \Rightarrow \boxed{\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}} \quad \text{—} (5)$

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

$$P = P_1 + P_2 + P_3 + \cdots$$

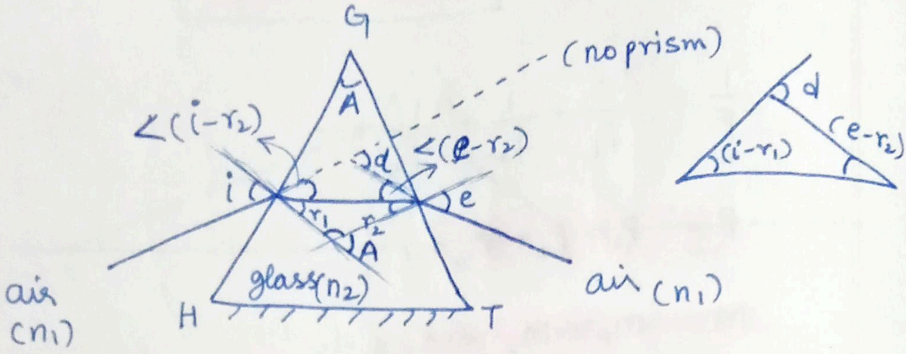
$$M = m_1 \times m_2 \times m_3 \times \cdots$$

Q) A converging and a diverging lens having the same focal length are in contact. What is the focal length and power of the combination?

A: Focal length = infinity
Power = 0

6, 7, 9, 10, 16, 22, 1, 2, 3, 4

REFRACTION THROUGH A PRISM



Consider a triangular glass prism GHI.

let PQ = Incident ray.

QR = Refracted ray.

RS = Emergent ray.

i = Angle of incidence @ face GH.

r_1 = Angle of refraction @ face GH

r_2 = Angle of incidence @ face GI.

e = Angle of emergence @ face GI.

d = Angle of deviation

A = angle of prism.

From the diagram:

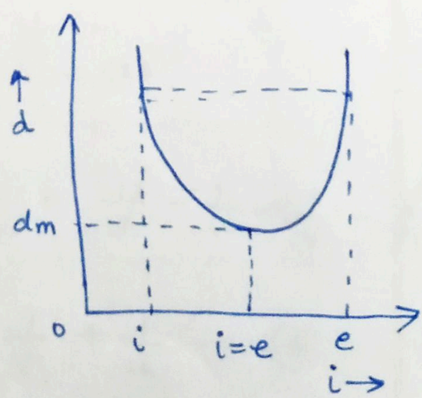
$d = i - r_1 + (e - r_2)$

$= (i+e) - (r_1 + r_2)$

$A = r_1 + r_2$ — ①

$d = (i+e) - A$

$d = i + e - A$ — ②



as the angle of incidence (↓) decreases, angle of deviation (↓) decreases and reaches a minimum value and then increases (↑).

- From the graph it is seen that for every angle of deviation there are 2 angles of incidences (due to principle of reversibility of light).
- For the angle of deviation corresponding to the lowest pt. on the graph, it is seen that $i = e$.
- This angle of deviation is called angle of min. deviation.

At $d = d_m$, $i = e$. $\quad (d = i + e - A)$

$\therefore d_m = 2i - A$

$$i = \frac{d_m + A}{2}$$

$r_1 = r_2$. $\quad (A = r_1 + r_2)$

$\therefore A = 2r$, $\quad r = A/2$.

for $A < 10^\circ$, $\sin\theta \approx \theta$.

$$\therefore n_{21} = \frac{A + d_m}{\cancel{2}} \times \frac{\cancel{2}}{A}$$

$$= A n_{21} = A + d_m.$$

$$d_m = (n_{21} - 1)A$$

(Narrow angled prism)

$$n_{21} = \frac{\sin i}{\sin r} = \frac{\sin\left(\frac{d_m + A}{2}\right)}{\sin(A/2)}$$

Optical instruments:

Telescope:

- It is an optical instrument which is used to view faraway objects.

2 types:

i) Astronomical telescope: Used to view celestial objects

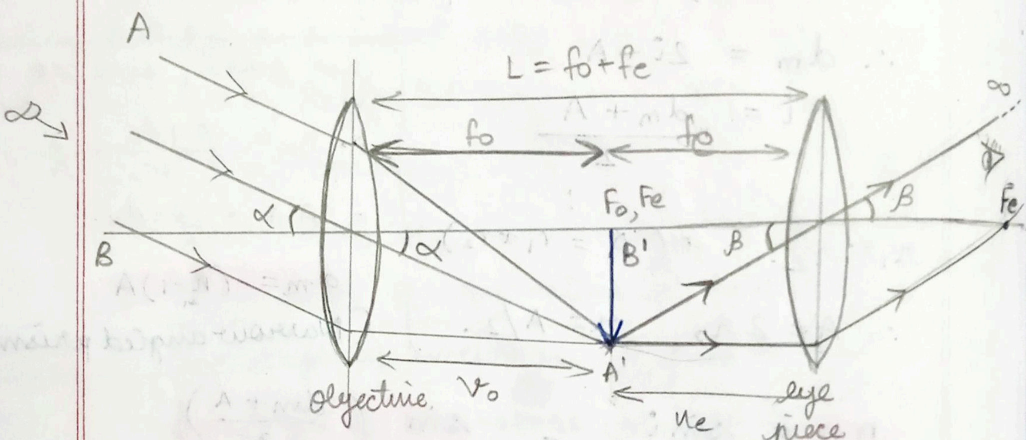
ii) Terrestrial telescope: Used to view faraway objects on land.

Refracting Astronomical Telescope

- It consists of 2 system of lenses namely objective and eye-piece. High f_o, low L. low f_e.
- The focal length of objective is very much greater than that of eye piece.

a) Normal adjustment position - final image at ∞

large objective



$V_e = -\infty$, $u_e = -ve$.

$\therefore \frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{f_e} = \frac{1}{-\infty} - \frac{1}{-u_e}$

$\frac{1}{f_e} = \frac{1}{u_e} \Rightarrow (f_e = u_e)$

$\therefore M = \frac{-f_o}{f_e}$ $\left[M = \underset{(\tan\beta)}{\frac{h'}{-u_e}} \times \underset{(\tan\alpha)}{\frac{f_o}{h'}} = \frac{f_o}{-u_e} \right]$ $M = \frac{\tan\beta}{\tan\alpha}$

Angular magnification:

It is defined as ratio of angle subtended by the image at the eye to the angle subtended by the object at the eye.

$M = \frac{\beta}{\alpha} = \frac{\tan\beta}{\tan\alpha}$ (β, α are small)

$\beta \approx \tan\beta$, $\alpha \approx \tan\alpha$

objective lens:
large focal length
large aperture

eye piece:
small focal length

Eyepiece of compound microscope and Eyepiece of telescope are similar to a simple microscope:

They all magnify (the image / object) things and all are virtual.

Whereas the objective lenses form real image and just brings the object closer (in telescope) and produces a magnified image (in microscope)

objective & eyepiece have common function, but obj forms real & eyepiece forms virtual.

Objective of microscope also produces an intermediate image to ~~be~~ magnified by the eyepiece.

Any converging rays meeting before the retina cannot be focussed. Eyes can't focus converging rays

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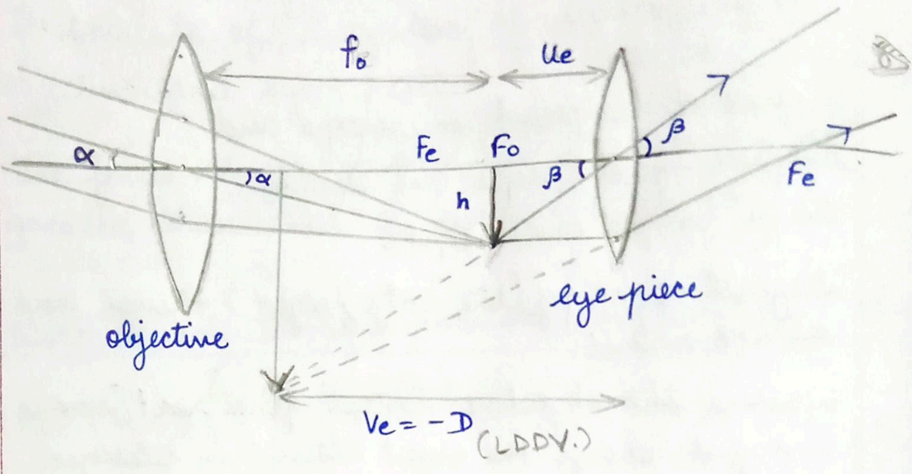
Focal length can decrease when ciliary muscles are stressed, but cannot increase.

b) Final image at least distance of distant vision (LDDV):-



$$M = \frac{\beta}{\alpha} = \frac{\tan\beta}{\tan\alpha}$$

$$M = \frac{h/u_e}{h/f_o} = \frac{f_o}{u_e}$$

For the eye piece

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

$$f = +f_e \,;\; v = -D \,;\; u = -u_e.$$

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

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

$$M = +f_o\left(\frac{1}{f_e} + \frac{1}{D}\right) = \frac{+f_o}{f_e}\left[1 + \frac{f_e}{D}\right]$$

While designing a telescope, following points to be

- Large magnification
- Large resolving power
- Large light gathering power.

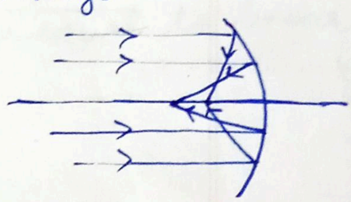
To satisfy all these, the objective lens should have as larger diameter as possible.

Disadvantages of refracting telescopes

- Objective lens of larger diameters are difficult to install, heavy and costly.
- Chromatic aberrations: Different colours do not converge at the same point on the principal axis

Advantage of refracting Telescopes:

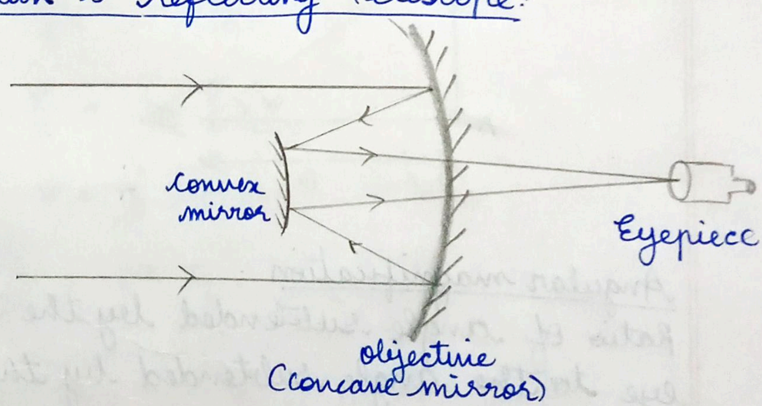
- No spherical aberrations: Usually seen in mirrors — paraxial & marginal rays do not converge at the same point



Solution: use parabolic shaped mirrors

Cassegrain's "reflecting" Telescope:

$$M = \frac{f_0}{f_e}$$



Advantages of reflecting telescope:

- Objective mirrors of larger diameter can be used as they are lighter, easy to install, and less costly.
- No chromatic aberration.
- No spherical aberration as parabolic shaped mirrors are used.

Microscope :

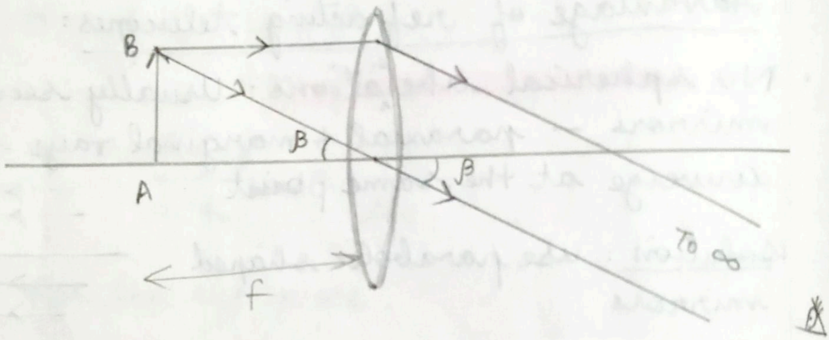
It is a device which is used to view micro - organisms (or) minute things.

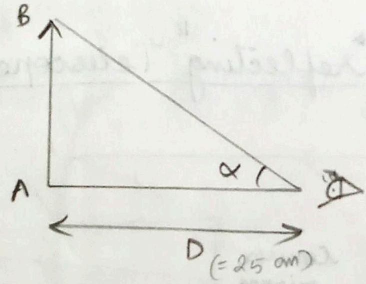
2 types :

(i) Simple microscope :

It is a single convex lens of fixed focal length.

a) Final image at infinity :



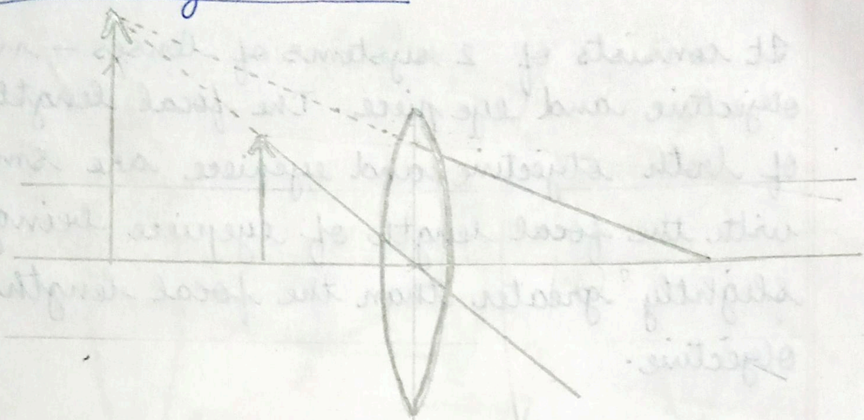


Angular magnification :

Ratio of angle subtended by the image at eye to the angle subtended by the object at eye. Object is assumed to be at LDDV.

$$M = \frac{\beta}{\alpha} \cong \frac{\tan\beta}{\tan\alpha} = \frac{AB/f}{AB/D} = \frac{D}{f}$$

b) Final image at LDDV



$$M = \beta/\alpha \cong \frac{\tan\beta}{\tan\alpha} = \frac{A'B'/D}{AB/D} = \frac{A'B'}{AB}.$$

$$M = \frac{A'B'}{AB} = \frac{v}{u}.$$

Hence angular magnification is equal to linear magnification.

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

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

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

$$v = -D.$$

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

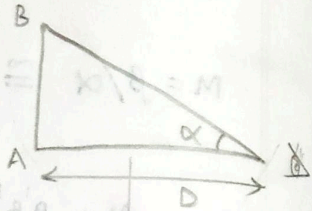
$$\boxed{M = 1 + \frac{D}{f}} \; ; \left(M = \frac{D}{u}\right)$$

Only when $v =$ LDDV, linear m = angular m.

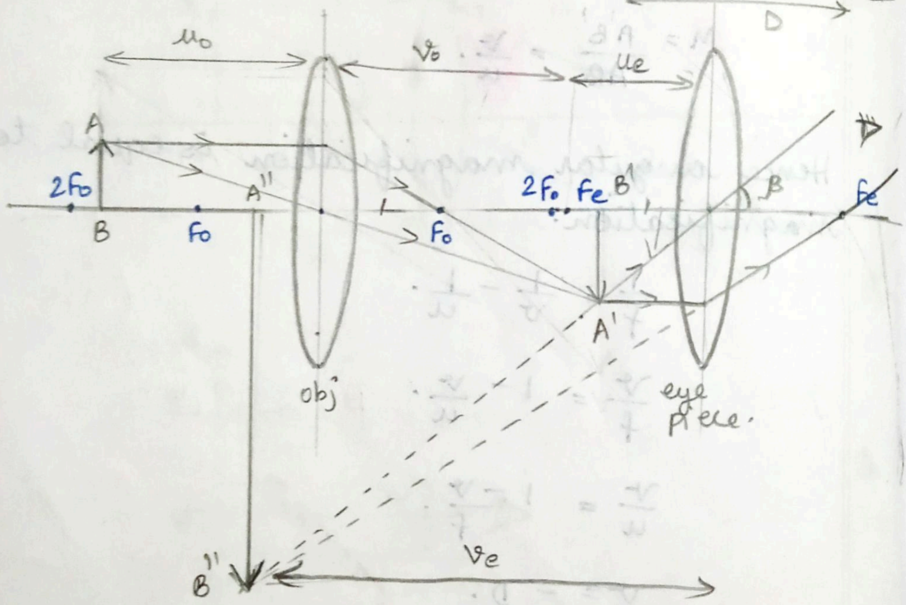
i.e; $\frac{v}{u} = 1 + \frac{D}{f}$.

COMPOUND MICROSCOPE

It consists of 2 systems of lenses – namely objective and eye piece. The focal length of both objective and eyepiece are small with the focal length of eyepiece being slightly greater than the focal length of objective.



Final image at LDDV:



$$M = \frac{\beta}{\alpha} \cong \frac{\tan\beta}{\tan\alpha} = \frac{A''B''/D}{AB/D} = \frac{A''B''}{AB}$$

$$= \frac{A''B''}{A'B'} \times \frac{A'B'}{AB} = M_e \times M_o.$$

$$M = M_o \times M_e = \frac{V_o}{u_o}\left(1 + \frac{D}{f_e}\right)$$

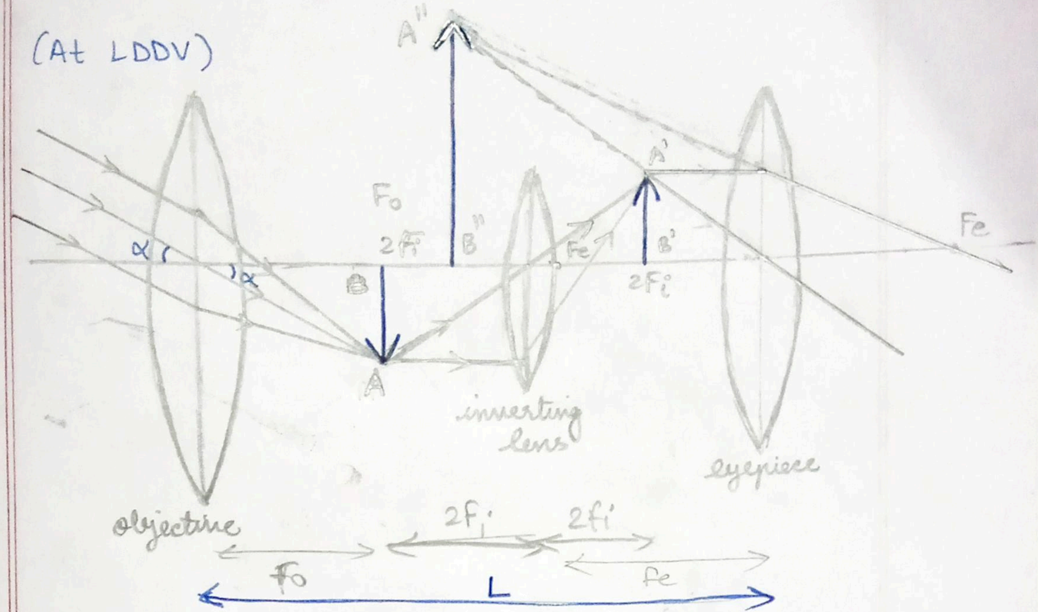
$[V_o \cong L,\ u_o \simeq f_o]$ $\therefore$ $M = \frac{L}{f_o}\left(1 + \frac{D}{f_e}\right)$

Final image at ∞

$$M = \frac{V_o}{u_o} \times \frac{D}{f_e} \quad \text{or} \quad M = \frac{L}{f_o} \cdot \frac{D}{f_e}$$

TERRESTRIAL MICROSCOPE

(At LDDV)



(i) Image at ∞ (Normal adjustment)

$$M = \frac{f_o}{f_e} \quad , \quad L = f_o + 4f_i + f_e.$$

(ii) Image at LDDV.

$$M = \frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right) \quad , \quad L = f_o + 4f_i + \frac{f_e D}{f_e + D}$$