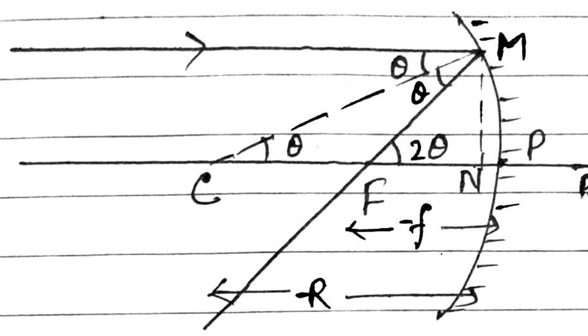
Derivations of Ray Optics

1. Reflection by Spherical Mirrors

• Relation b/w f and R

Case I - For concave mirror:



P → Pole
F → Focus
C → Centre of curvature

In ΔMNC

$$\tan\theta = \frac{MN}{NC} = \frac{MP}{PC}$$ [∵ P and N are very close]

for small angle θ,

$$\tan\theta \simeq \theta = \frac{MP}{PC} \Rightarrow \theta = \frac{MP}{PC} \quad -(1)$$

and in ΔMNF

$$\tan 2\theta = \frac{MN}{NF} = \frac{MP}{PF}$$ [∵ P and N are close]

for small angle θ

$$\tan 2\theta \simeq 2\theta = \frac{MP}{PF} \Rightarrow 2\theta = \frac{MP}{PF} \quad -(2)$$

From (1) and (2)

$$2 \times \frac{MP}{PC} = \frac{MP}{PF}$$

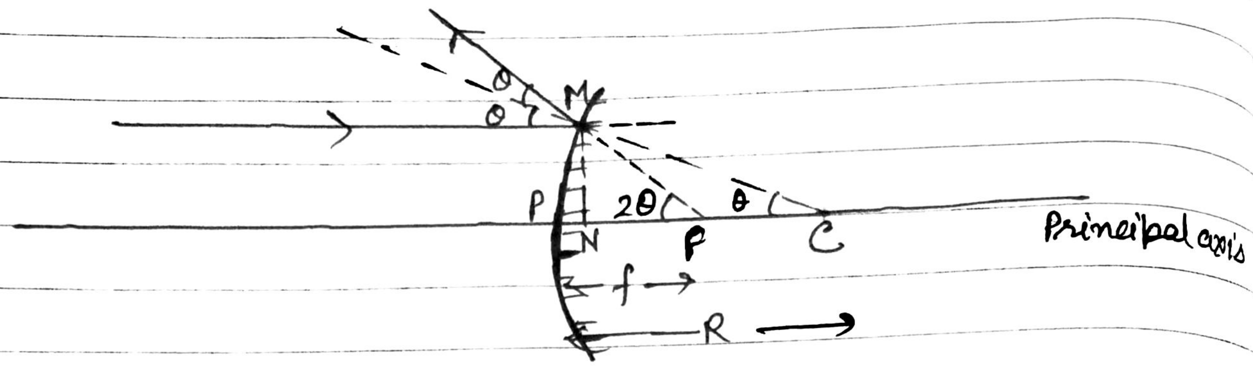
or $2 \times PF = PC$

or $2 \times (-f) = (-R)$

or $\boxed{R = 2f} \Rightarrow \boxed{f = \frac{R}{2}}$

i.e focal length of a spherical mirror is half of its radius of curvature.

Case II - for convex mirror



In ΔMNC

$$\tan\theta \simeq \theta = \frac{MN}{NC} = \frac{MP}{PC} \quad (1)$$

[P & N are close and θ is very small]

In ΔMNF

$$\tan 2\theta \simeq \theta = \frac{MN}{NF} = \frac{MP}{PF} \quad (2)$$

from (1) and (2)

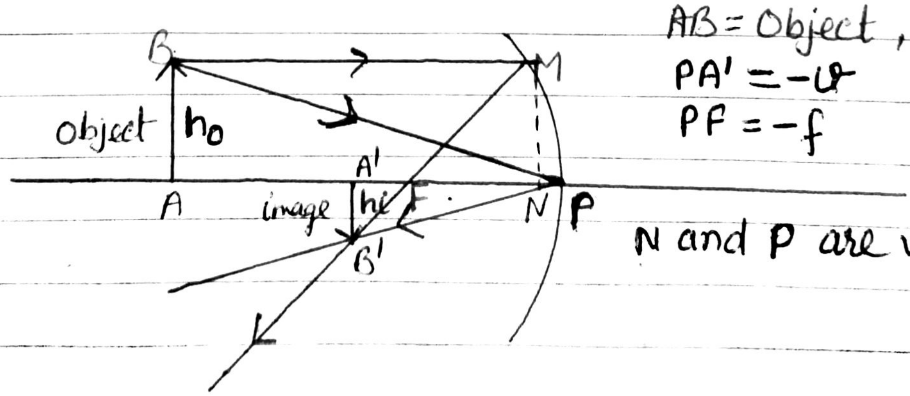
$$2 \times \frac{MP}{PF} = \frac{MP}{PC}$$

or $2f = R$ [$PF = +f$ and $PC = +R$]

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

2. Mirror Formula

Case I   For concave mirror (Real Image)



AB = Object, $A'B'$ = Image

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

$PF = -f$

N and P are very close

(*We can take any case of image formation)

ΔABP and $\Delta A'B'P$ are similar Δ's. So,

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

$\Delta A'B'F$ and ΔMNF are similar Δ's, So,

$$\frac{A'B'}{MN} = \frac{FA'}{NF}.$$

but P and N points are close so $N \rightarrow P$, then

$$\frac{A'B'}{MN} = \frac{FA'}{PF} = \frac{PA' - PF}{PF} \quad \left[\because FA' = PA' - PF\right]$$

As $MN = AB$

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

from (1) and (2)

$$\frac{PA'}{PA} = \frac{PA' - PF}{PF}$$

put the values

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

or $$-vf = -uv + uf$$

divide both sides by uvf

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

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

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

Magnification (m): Ratio of height of image to height of object.

ΔABP and $\Delta A'B'P$ are similar Δ's.

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

$$\frac{-h_I}{h_o} = \frac{-v}{-u} \qquad \left[\because A'B' = -h_I,\ AB = h_o \atop PA' = -v,\ PA = -u\right.$$

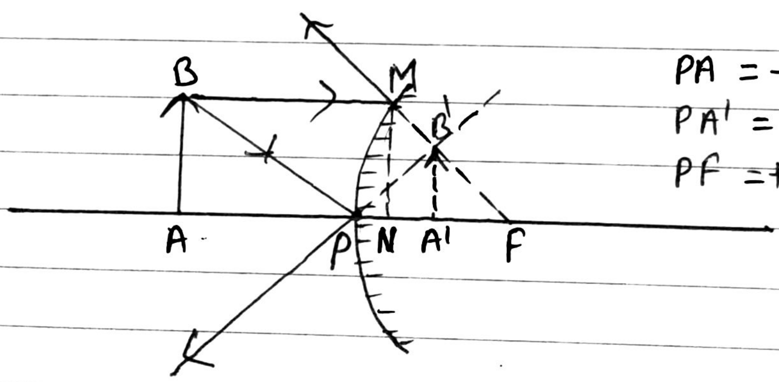
or

$$\frac{h_I}{h_o} = \frac{-v}{u}$$

or

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

Case II By convex mirror



$PA = -u$, $AB = h_o$

$PA' = v$, $A'B' = h_I$

$PF = +f$

ΔABP and $\Delta A'B'P$ are similar

$$\frac{A'B'}{AB} = \frac{PA'}{PA} \quad -①$$

ΔMNF and $\Delta A'B'F$ are similar and $MN = AB$

also $N \rightarrow P$ as N & P are close, then

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

or

$$\frac{A'B'}{AB} = \frac{PF - PA'}{PF} \quad -② \qquad [A'F = PF - PA']$$

From ① and ②

$$\frac{PA'}{PA} = \frac{PF - PA'}{PF}$$

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

or $vf = -uf + uv$

divide by uvf

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

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

also Magnification (m) by ΔABP and $\Delta A'B'P$

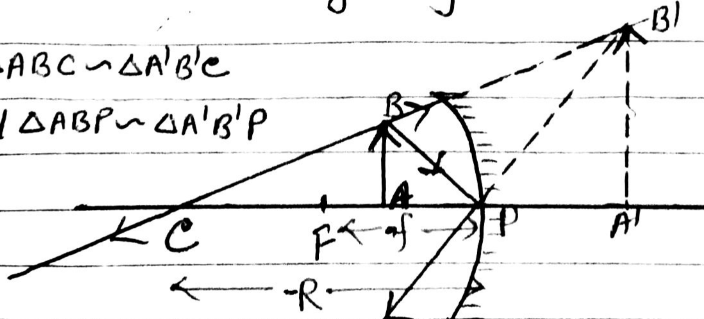
$$\boxed{m = \frac{h_I}{h_o} = -\frac{v}{u}}$$

* If $m = -ve$ ⇒ Real and inverted image
* If $m = +ve$ ⇒ Virtual and erect image.
* If $m > 1$ ⇒ Image is larger than object ($h_I > h_o$)
* If $m < 1$ ⇒ Image is smaller than object ($h_I < h_o$)
* If $m = 1$ ⇒ $h_I = h_o$

* Virtual Image by concave mirror

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

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



$PF = -f$ $AB = h_o$

$PC = -R$ $A'B' = h_I$

$PA = -u$

$PA' = +v$

$A'C = PA' + PC$

We can derive same mirror formula for this case also. by using similar Δ's.

3. Refraction

Relation b/w Real and Apparent depth

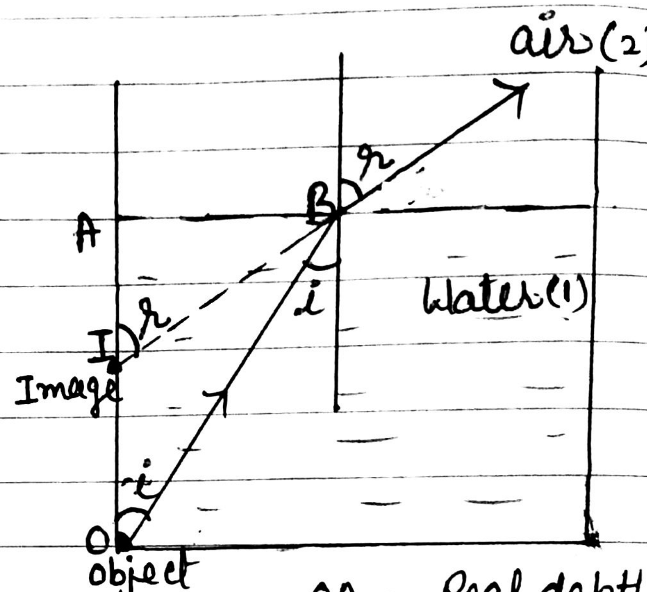
From fig

In Δ AOB

$$\sin i = \frac{AB}{OB}$$

and In ΔAIB

$$\sin r = \frac{AB}{IB}$$



OA = Real depth

IA = Apparent depth

Now by snell's law

$$\frac{\sin i}{\sin r} = {}_w n_a$$

or $${}_w n_a = \frac{\sin i}{\sin r} = \frac{AB/OB}{AB/IB}$$

or $${}_w n_a = \frac{IB}{OB}$$

for small angle 'i' and 'r' IB = IA and OB = OA

then $${}_w n_a = \frac{IA}{OA}$$

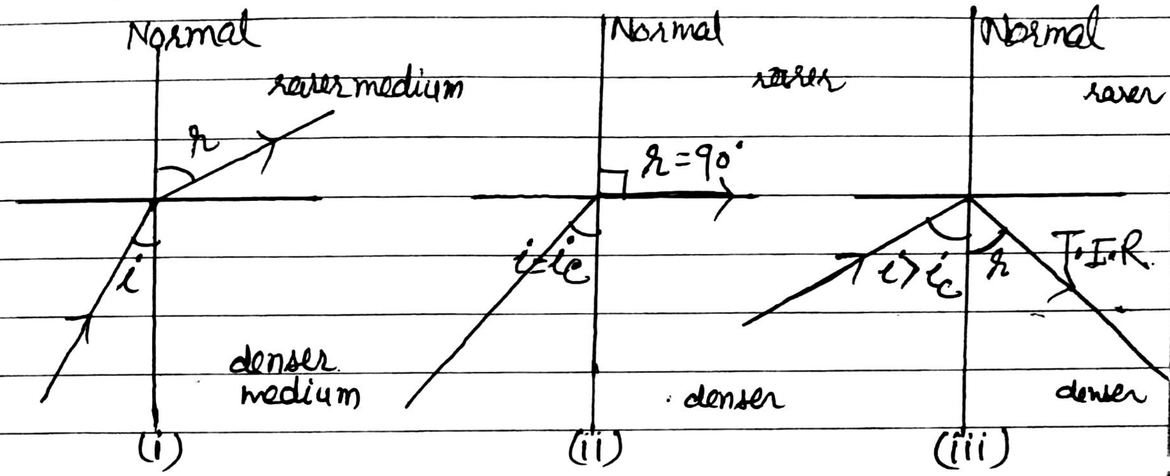
or $${}_a n_w = \frac{OA}{IA} = \frac{\text{Real depth}}{\text{App. depth}}$$

or $${}_2 n_1 = \frac{\text{Real depth}}{\text{App. depth}} = n_{\text{rarer}}^{\text{denser}}$$

here ${}_2 n_1$ is Refractive index of denser medium.

Total Internal Reflection

When a ray moves from rarer to denser medium, it moves away from normal. Also $\angle i \propto \angle r$ i.e on increasing $\angle i$, refraction angle $\angle r$ also increases.
At a perticular value of $\angle i$, $\angle r$ becomes $= 90°$.
This angle of $\angle i$ is called critical angle i_c or C.



Relation b/w Refraction Index And critical Angle

$d \to$ denser, $r \to$ rarer

From (ii)

$$_d\mu_r = \frac{\sin i_c}{\sin 90°}$$

[By Snell's law $\frac{\sin i}{\sin r} = {}_1\mu_2$

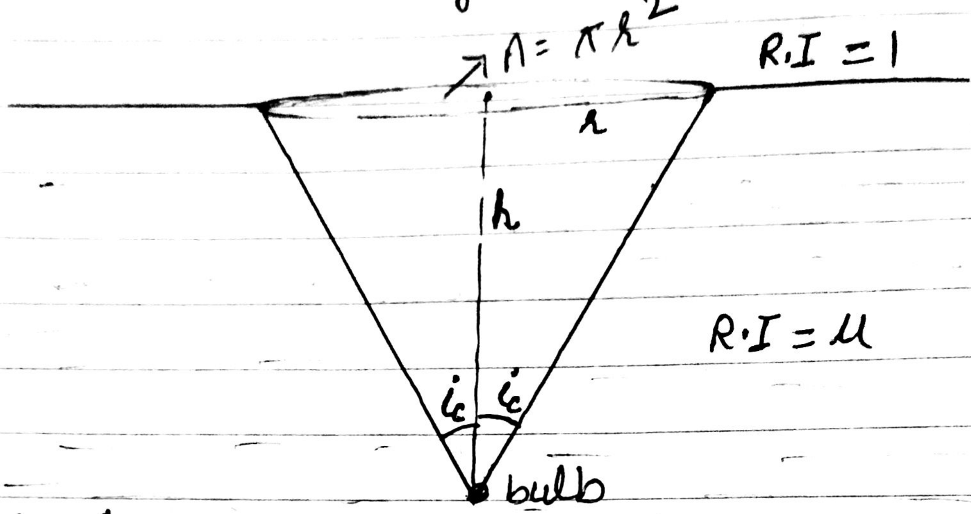
or $\quad _d\mu_r = \sin i_c$

or $\quad \frac{1}{_r\mu_d} = \sin i_c \qquad \left[\because \frac{1}{_1n_2} = {}_2n_1\right]$

or $\quad \boxed{_r\mu_d = \frac{1}{\sin i_c} = \frac{1}{\sin C}}$

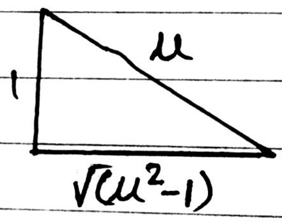
or $\quad \boxed{\sin C = \frac{\text{Velocity of light in denser medium}}{\text{Velocity of light in air}}}$

* Area Illuminated By Bulb In Pool (For numericals)



$\tan i_c = \frac{r}{h} \Rightarrow r = h \tan i_c$

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



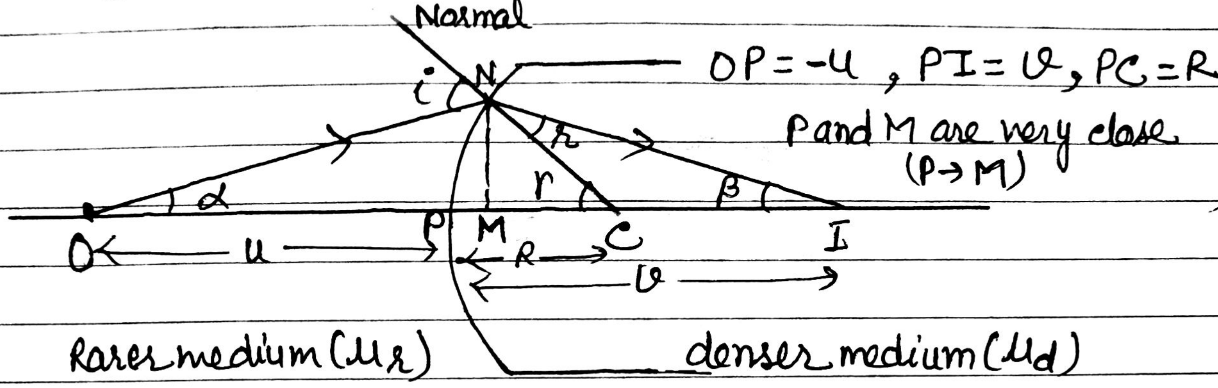
$\Rightarrow r = \frac{h}{\sqrt{\mu^2-1}}$

and Area $= \frac{\pi h^2}{(\mu^2-1)}$ [Area $= \pi r^2$]

Refraction at Spherical Surfaces

1 Refraction at a convex spherical surface

(1) Object lie in rarer medium (For Real Image)



In $\triangle NOC$

$$i = \alpha + \gamma \quad -① \qquad [\because \angle i \text{ is exterior angle}]$$

Similarly in $\triangle NIC$

$$\gamma = r + \beta \qquad [\gamma \text{ is exterior angle}]$$

or $r = \gamma - \beta$ –②

Now for small angles α, β and γ

$$\tan\alpha \simeq \alpha = \frac{NM}{OM} = \frac{NM}{OP} \qquad [M \& P \text{ are very close}]$$

$$\tan\beta \simeq \beta = \frac{NM}{PI}$$

$$\tan\gamma \simeq \gamma = \frac{NM}{PC}$$

Now by Snell's law

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

for small angle of i and r

$$\mu_1 i = \mu_2 r$$

from ① and ② put value of i and r.

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

Now put value of α, β and γ

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

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

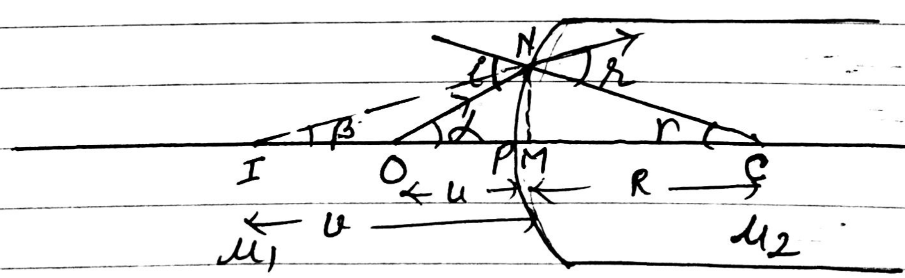
or $$\boxed{-\frac{\mu_1}{u}+\frac{\mu_2}{v}=\frac{\mu_2-\mu_1}{R}}$$

* If medium 1 is air, $\mu_1=1$ and $\mu_2=\mu$, then

$$-\frac{1}{u}+\frac{\mu}{v}=\frac{\mu-1}{R}$$

or $$\boxed{\frac{\mu}{v}-\frac{1}{u}=\frac{\mu-1}{R}}$$

(ii) For virtual Image



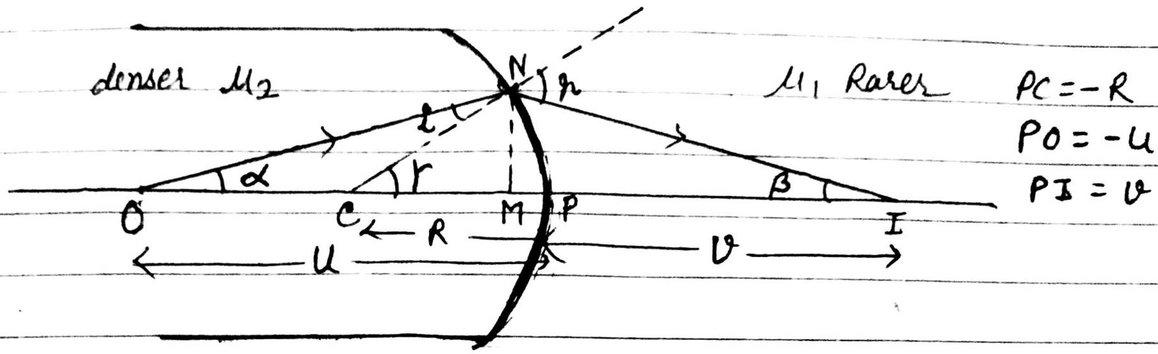
$OP=-u$
$IP=-v$
$PC=R$

from fig $i=\alpha+\gamma$ in ΔNOC
and $r=\beta+\gamma$ in ΔNIC

-- same method --
same formula we get i.e

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

(iii) Object lie in the denser medium

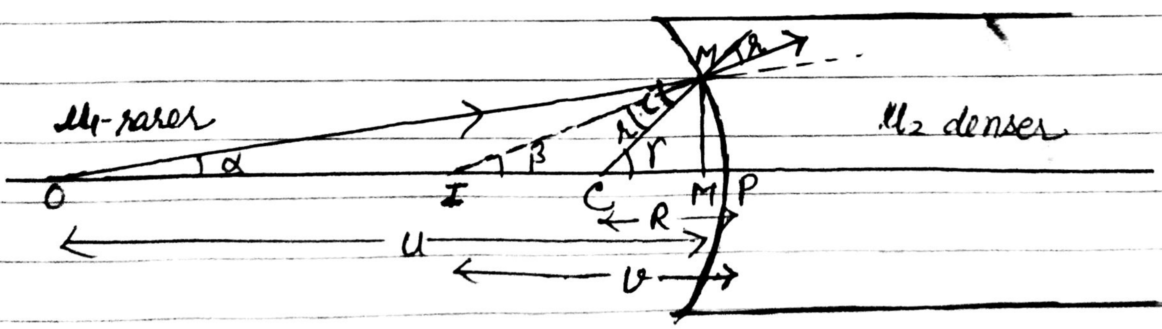


From fig.

$r = \alpha + i \Rightarrow i = r - \alpha$ [In ΔONC]

$\theta = \beta + r$ [In ΔCNI]

2. Refraction at concave surface



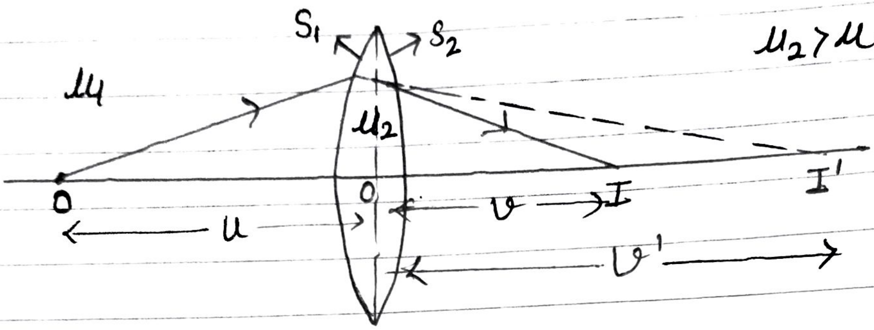
From fig

$i = r - \alpha$ [In ΔMOP]

$\theta = r - \beta$ [In ΔMIC]

Lens Maker's Formula

For convex lens



$\mu_2 > \mu_1$, $\mu_2 \rightarrow$ of lens
$\mu_1 \rightarrow$ of medium

For refraction at surface S_1

$$-\frac{\mu_1}{u} + \frac{\mu_2}{v'} = \frac{\mu_2-\mu_1}{R_1} \quad -①$$

For surface S_2

$$-\frac{\mu_2}{v'} + \frac{\mu_1}{v} = \frac{\mu_1-\mu_2}{R_2} \quad -②$$

on adding ① and ②

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

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

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

or $$\frac{1}{v} - \frac{1}{u} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad -③$$

If object is placed at ∞ $(u=\infty)$, $v=f$

$$\Rightarrow \frac{1}{f}-\frac{1}{\infty}=\left(\frac{\mu_2}{\mu_1}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

or $$\boxed{\frac{1}{f}=\left({}_m\mu_l-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)} \quad (4)$$

$\left[\frac{\mu_2}{\mu_1}=\frac{\mu_{lens}}{\mu_{medium}}\right.$

This is the lens maker's formula.

* When lens is placed in air, $\mu_1=1$, $\mu_2=\mu$, then

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

* From eq^n (3) and (4)

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

This is the lens formula.

* Focal length in diff. medium

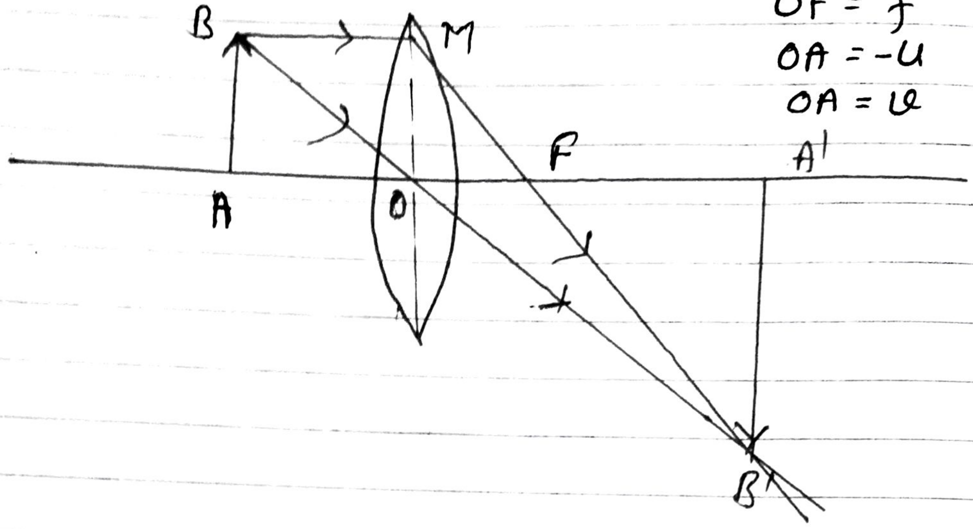
$$\frac{f_{air}}{f_{med.}}=\frac{\mu_l-\mu_m}{(\mu_l-1)\mu_m}$$

here,

$\mu_l \rightarrow$ R.I of lens

$\mu_m \rightarrow$ R.I of med.

Derivation of Lens Formula



OF = f

OA = −u

OA = v

In ΔABO and A'B'O

$$\frac{AB}{A'B'} = \frac{OA}{OA} \quad — (1) \quad [\Delta ABO \sim \Delta A'B'O]$$

In ΔMOF and A'B'F

$$\frac{MO}{A'B'} = \frac{OF}{FA'} \quad [\text{similar } \Delta\text{'s}]$$

but MO = AB, then

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

from (1) and (2)

$$\frac{OA}{OA'} = \frac{OF}{FA'} = \frac{OF}{OA' - OF}$$

or

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

or,

$$-uv + uf = vf$$

dividing by uvf

$$\frac{-uv}{uvf} + \frac{uf}{uvf} = \frac{vf}{uvf}$$

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

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

This is the lens formula and true for every case of convex and concave lens.

Linear Magnification (m) The ratio of size of image to the size of object is called linear magnification.

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

$\Delta AOB \sim \Delta A'OB'$

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

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

or $$m = \frac{h_I}{h_o} = \frac{v}{u}$$

$$* \quad m = \frac{v}{u} = \frac{f}{f+u} = \frac{f-v}{f} \qquad \left[\because \frac{1}{v} = \frac{1}{f} + \frac{1}{u},\ \frac{1}{u} = \frac{1}{v} - \frac{1}{f}\right.$$

$|m| > 1 \Rightarrow$ larger image

$|m| < 1 \Rightarrow$ smaller image

$|m| = 1 \Rightarrow$ same size image

m is +ve $\Rightarrow$ virtual and erect image

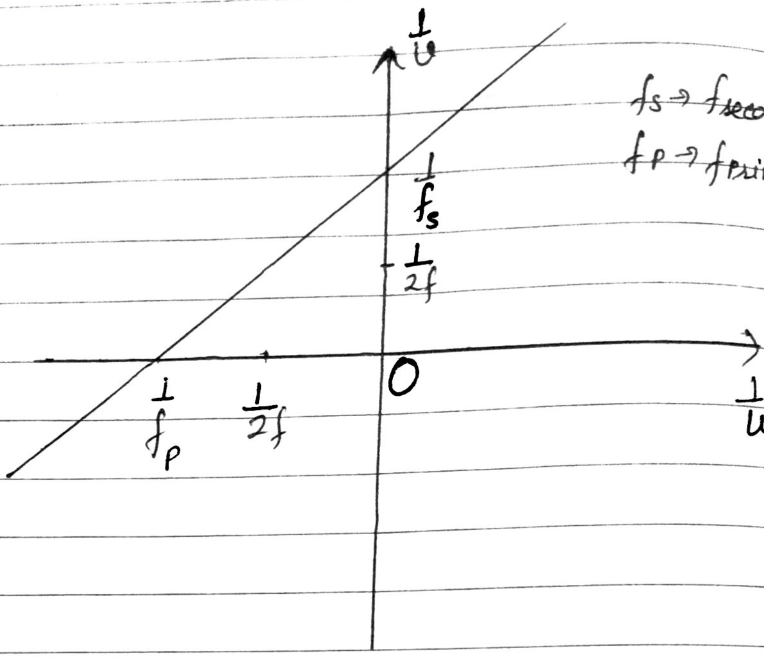
m is −ve $\Rightarrow$ real and inverted image

Graph b/w $\frac{1}{v}$ and $\frac{1}{u}$ for convex lens

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

$$\Rightarrow y - x = c$$

$$\Rightarrow y = x + c$$



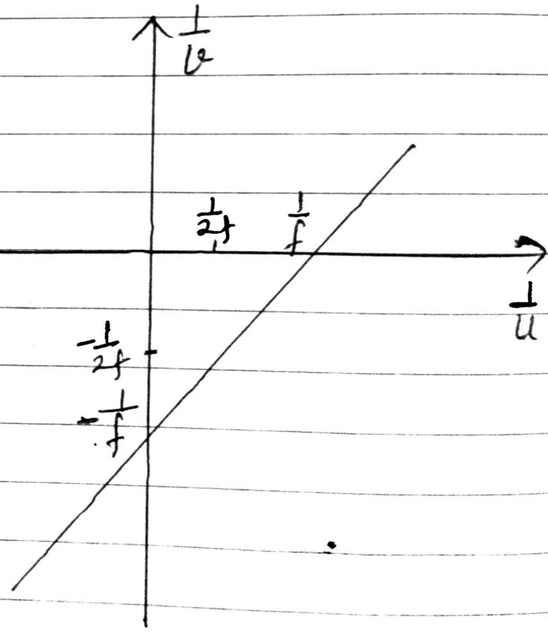
$f_s \rightarrow f$ secondary
$f_p \rightarrow f$ primary

For concave lens

$$y - x = -c$$

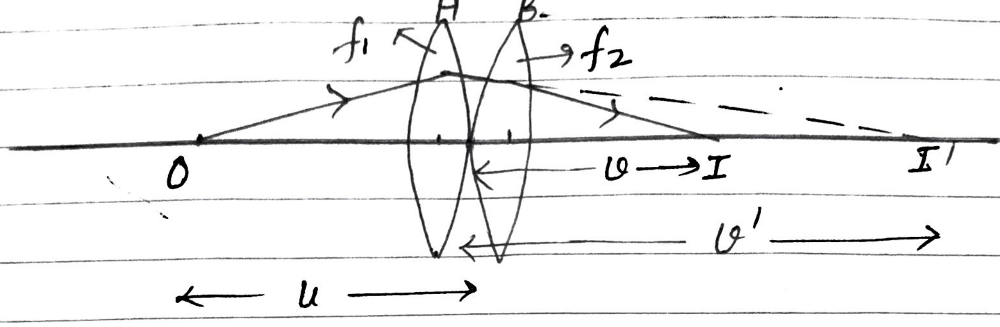
$$\Rightarrow y = x - c$$

It forms always virtual and erect image. Which is diminished of real image.



combination of thin lenses in contact

Consider two lenses A and B of focal length f_1 and f_2.



For image formed by lens 'A'

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

For lens 'B'

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

Adding ① and ②

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

or $$\frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{f} \qquad \left[\because \frac{1}{v} - \frac{1}{u} = \frac{1}{f}\right]$$

For several thin lenses

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

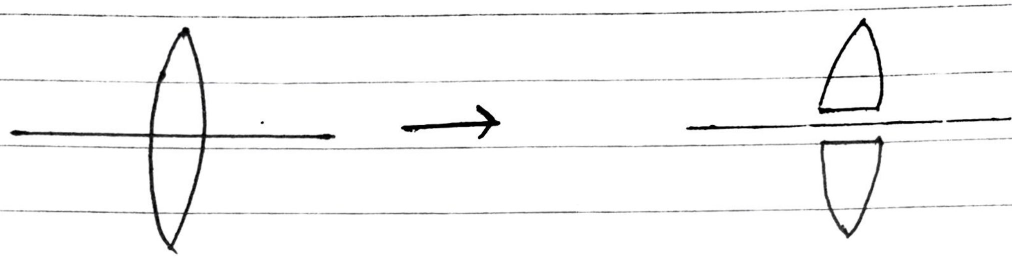
and power

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

* combination of lenses improve magnification

$$m = m_1 m_2 m_3 \cdots$$

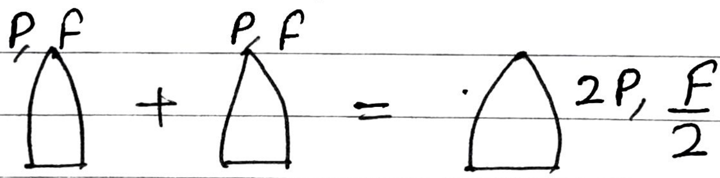
* Cutting of lens



- Power and focal length are unchanged
- Intensity become half as

Intensity $\propto$ Aperture area

*



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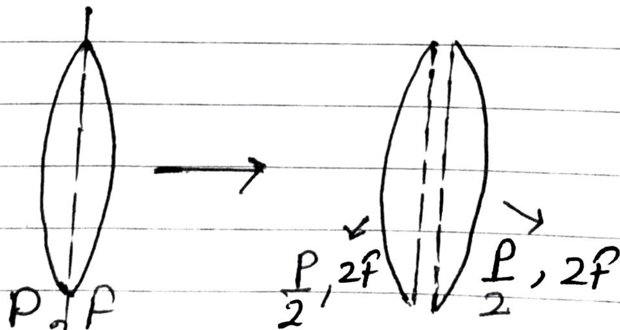
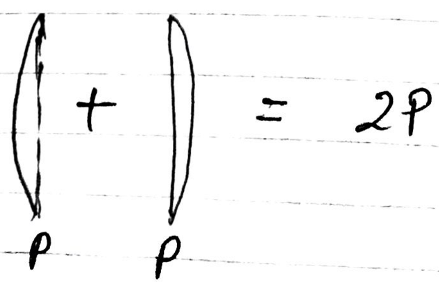
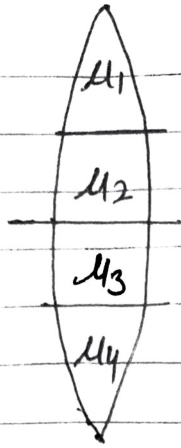


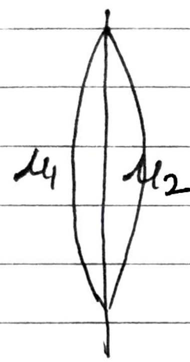
Intensity is unchanged as aperture is unaffected

*



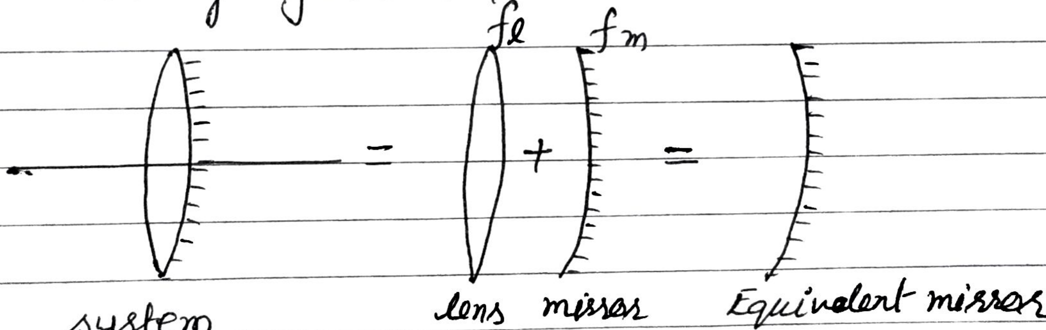
* 

→ • Four focal lengths
• Four Images

* 

→ • 1 object
• 1 focal length
• 1 Image

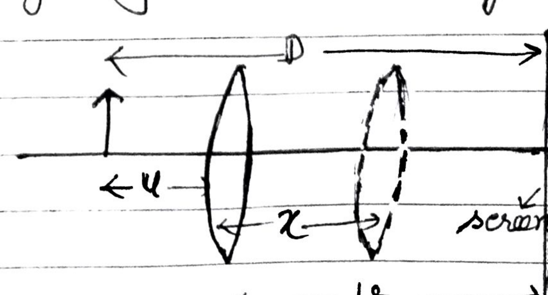
* Silvering of a lens / lens mirror combination



$$\frac{1}{f_{eq}} = \frac{-2}{f_l} + \frac{1}{f_m}$$

* Determination of focal length of convex lens by <u>displacement method</u>-

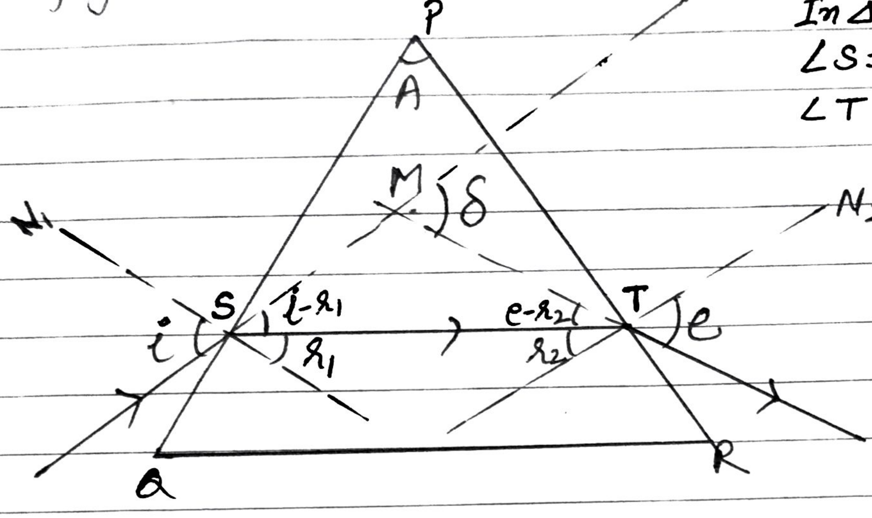
$$f = \frac{D^2 - x^2}{4D}$$



Refraction by Prism

Deviation Produced by a prism

In fig - $A \rightarrow$ Prism angle , $\delta \rightarrow$ Angle of deviation



In ΔPST
$\angle S = 90 - r_1$
$\angle T = 90 - r_2$

From fig.

In ΔPST

$$A + \angle S + \angle T = 180$$

$$A + (90 - r_1) + (90 - r_2) = 180$$

or $\quad A = r_1 + r_2 \quad$ — ①

In ΔMST

$$\delta = (i - r_1) + (e - r_2) \qquad [\delta \text{ is exterior angle}]$$

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

or $\quad \boxed{\delta = i + e - A}$ — ② $\quad [\because r_1 + r_2 = A$, from eqⁿ ①$]$

* δ depends upon i

Minimum Deviation - At minimum deviation

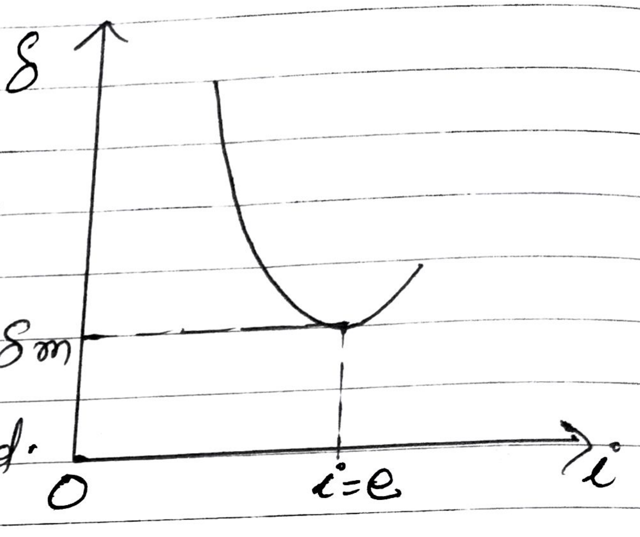
$$\delta = \delta m \ , \quad i = e$$

i.e $r_1 = r_2 \Rightarrow r = \dfrac{A}{2} \qquad$ [from eqⁿ (1)]

and $\quad \delta m = i + i - A = 2i - A$

$$\boxed{\delta m = 2i - A} \quad - ③$$

Graph b/w δ and i



Initially

$i \uparrow$, $\delta \downarrow$

at $i = e$, δ becomes δ_m

then, $i \uparrow$, $\delta \uparrow$

* δ remain same if i and e are interchanged.

Expression for Refractive Index of prism -

By snell's law

$$\frac{\sin i}{\sin r} = {}_1\mu_2$$

from eq^n ③ $\delta_m = 2i - A$

$$\boxed{i = \frac{\delta_m + A}{2}}$$

and from eq^n ① $r_1 + r_2 = A$, for $r_1 = r_2$

$$2r = A \Rightarrow \boxed{r = \frac{A}{2}}$$

So

$${}_1\mu_2 = \frac{\sin i}{\sin r} = \frac{\sin\left(\frac{\delta_m + A}{2}\right)}{\sin\frac{A}{2}}$$

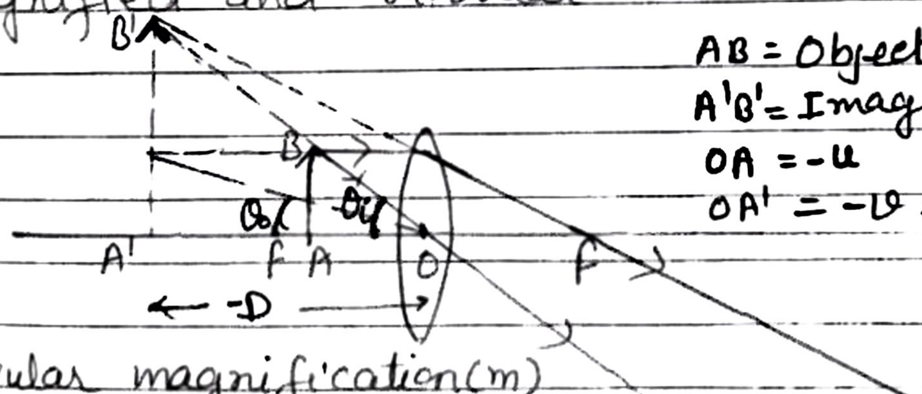
$$\boxed{\mu_{prism} = \frac{\sin\left(\frac{\delta_m + A}{2}\right)}{\sin\frac{A}{2}}}$$

Optical Instruments

The instruments which uses reflecting and refracting properties of mirror, lenses and prism are called optical intruments.
e.g. Periscope, kaleidoscope, binoculars, telescopes microscopes etc.

1 Simple Microscopes (Magnifying glass):

* It is a converging lens of small focal length.
* When object is place b/w focus 'F' and optical centre 'O', the image formed by convex lens is erect. magnified and virtual.



AB = Object height
A'B' = Image height
OA = -u
OA' = -v = -D

Angular magnification (m)

$$m = \frac{\tan\theta_i}{\tan\theta_0} = \frac{AB/OA}{AB/OA'} \Rightarrow m = \frac{\theta_i}{\theta_0} = \frac{OA'}{OA}$$ { ∵ $\tan\theta \approx \theta$ for small angles

or

$$m = \frac{OA'}{OA} = \frac{-D}{-u} = \frac{D}{u}$$

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

then

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

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

Case I - If image is formed at near point (D)
i.e $v = D$

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

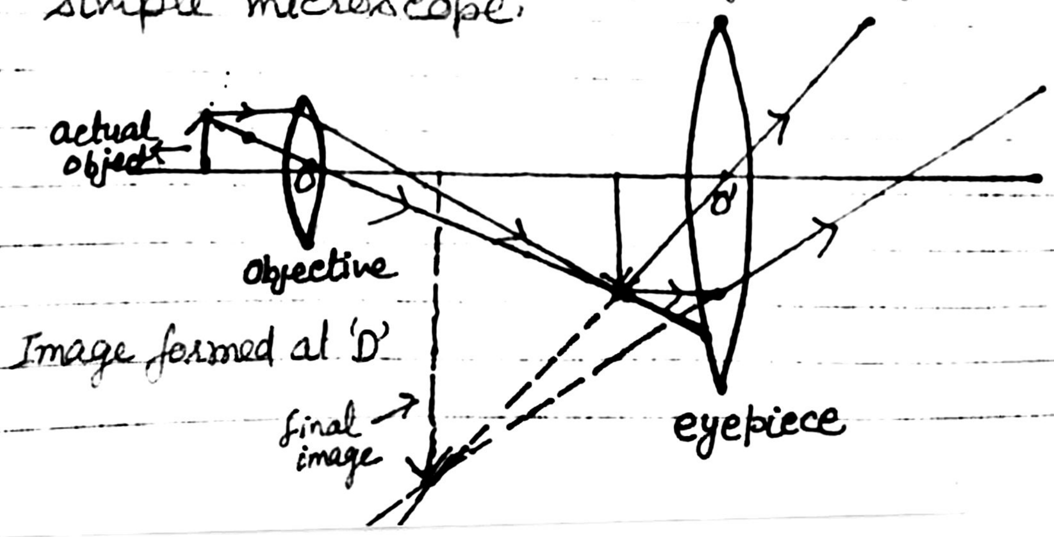
Case II - If image is formed at infinity (far point) i.e, $v = \infty$, then

In normal adjustment $m = \frac{D}{f}$ $\left[\because \frac{1}{\infty} = 0\right]$

* Generally m provided by simple microscope is not more than 9. $\boxed{m \leq 9}$

Compound Microscope

In compound microscope two convex lenses are used to increase the magnifying power. One lens is objective lens, which forms real and inverted magnified image.
Image formed by objective lens acts as an object for second lens (Eyepiece) and formed virtual and erect magnifying image like simple microscope.



magnification $m = m_o m_e$

where,

$m_o \rightarrow$ magnification by objective lens

and $m_e \rightarrow$ magnification by eyepiece lens

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

and $m_e = \frac{\theta_i}{\theta_o} = D\left[\frac{1}{v_e} + \frac{1}{f_e}\right]$ [for simple microscope]

then

$m = m_o m_e$

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

* Length of microscope = Distance b/w objective and eyepiece

$= v_o + u_e$

* Case I - If image is formed at near point (at D)

then, $v = D$

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

* Case II

If image is formed at ∞ (far point)

then, $v_e = \infty$ (Normal Adjustment)

$m = \frac{v_o}{u_o} \cdot \frac{D}{f_e}$

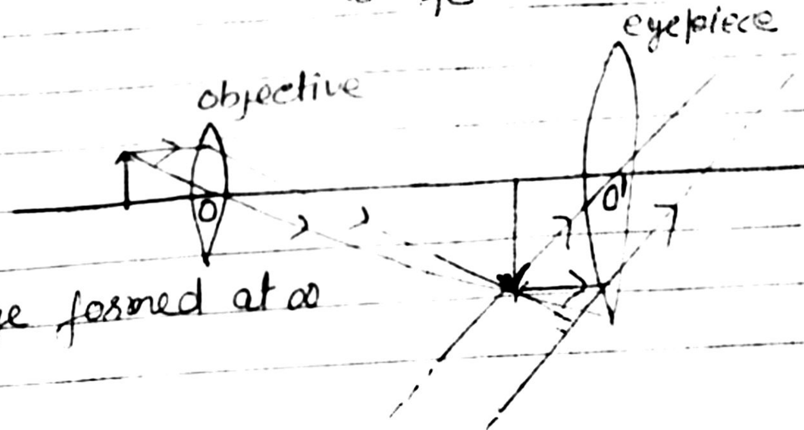


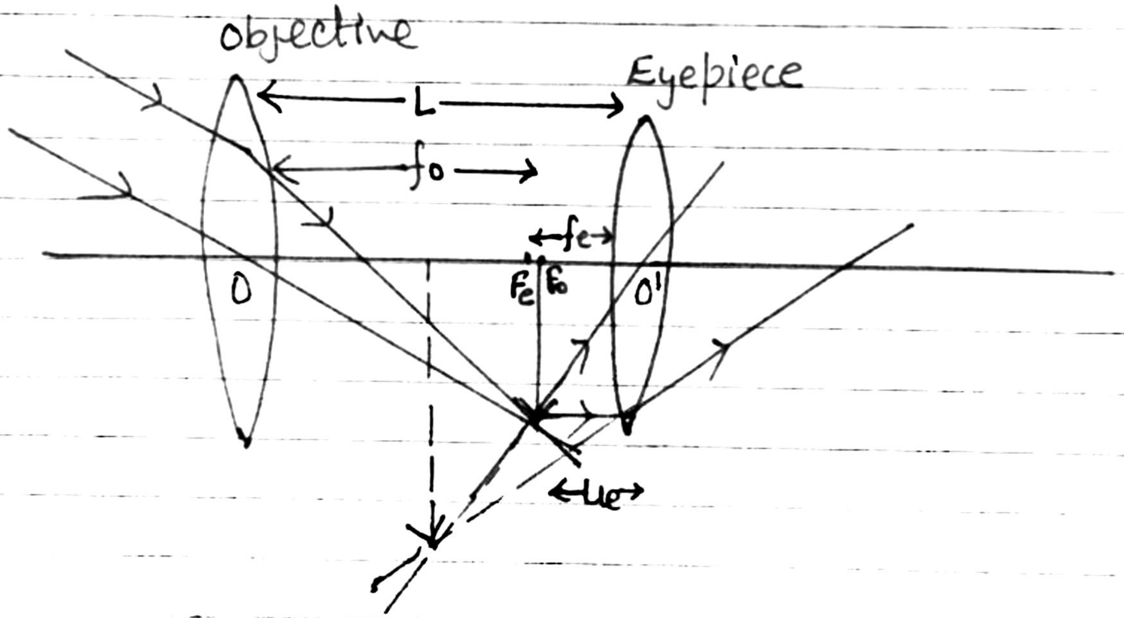
Image formed at ∞

Astronomical Telescope

It is used to provide angular magnification to distant objects.

It consists two convex lenses - Objective and eyepiece.

* Objective has larger ~~and~~ focal length and aperture.
* Light from distant object enters objective and a real image is formed at focus of objective. Eyepiece than magnifies its image producing a final inverted image.



Case I - Final image is formed at near point (at D)

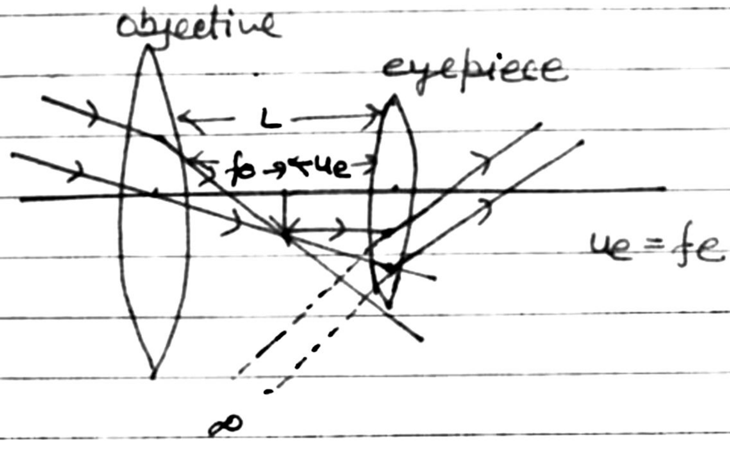
$$m = \frac{-f_o}{f_e}\left[1 + \frac{f_e}{D}\right]$$

* Length of telescope $= f_o + u_e = L$

Case II - If final image is formed at far point (at ∞)
for image to be at ∞, $u_e = f_e$

$$m = -\frac{f_o}{f_e} \quad \text{[Normal adjustment]}$$

$$L = f_o + f_e \quad \text{[}L \rightarrow \text{length of telescope]}$$

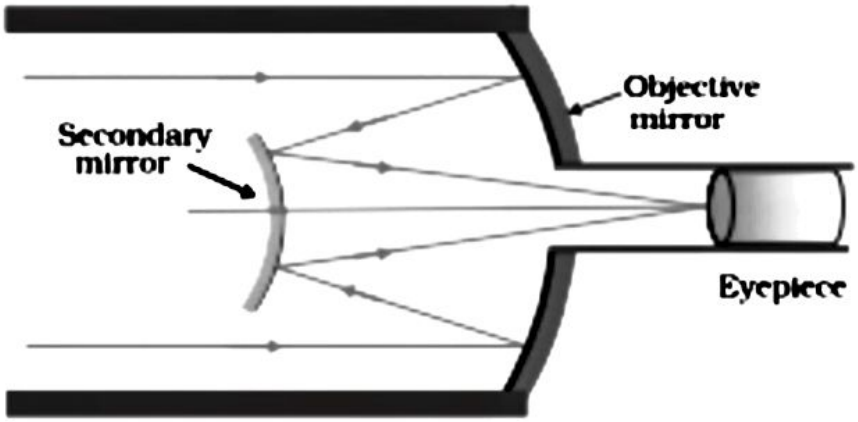


* Compound microscope is used to observe minute nearby objects whereas the telescope is used to observe distant objects.
* In compound microscope focal length of objective is lesser than that of eyepiece but in telescope objective has larger focal length than eyepiece.

* The objective of a telescope have large focal length and large aperture to increase the M.P and to collect large amount of light respectively.

Reflecting type Telescope (Cassegrian telescope)

In such telescope, one objective lens is replaced by a concave parabolic mirror of large aperture, which is free from chromatic and spherical aberrations.



Schematic diagram of a reflecting telescope (Cassegrain).

In normal adjustment, magnifying power

$$m = \frac{f_0}{f_e} = \frac{\frac{R}{2}}{f_e}$$

Advantages of Reflecting type telescope

1. There is no chromatic aberration as the objective is a mirror.
2. Spherical aberration is reduced using mirror objective in the form of a parabolic.
3. The image is brighter compared to that in a refracting type telescope.
4. Mirror requires grinding and polishing of only one side.
5. High resolution is achieved by using a mirror of large aperture.
6. A mirror weights much less than a lens of equivalent optical quality.