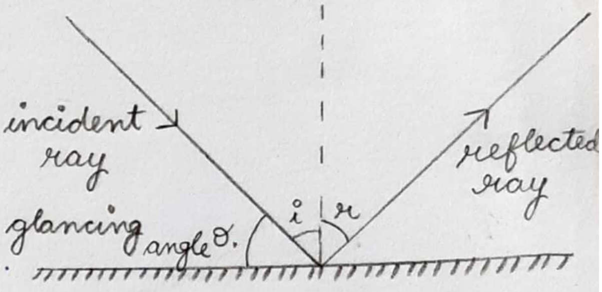
RAY OPTICS

Reflection – The bouncing back of light in the same medium.

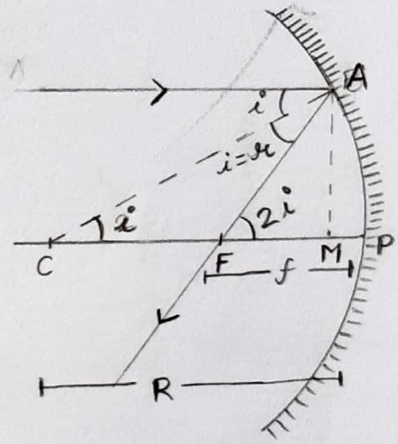
Laws of reflection –

1. The angle of incidence is equal to the angle of reflection.
2. The normal, incident ray and reflected ray lie in the same plane.



Relation between f and R

I] Using concave mirror



concave mirror

In ΔAFM

$$\tan 2i = \frac{AM}{FM} \approx \frac{AM}{PF}$$

$$2i = \frac{AM}{PF} \quad (\because 2i \text{ is small})$$

$$i = \frac{AM}{2PF} \quad \text{——} \quad (1)$$

In ΔACM

$$\tan i = \frac{AM}{MC} \approx \frac{AM}{PC}$$

$$i = \frac{AM}{PC} \quad \text{——} \quad (2)$$

From equations (1) and (2)

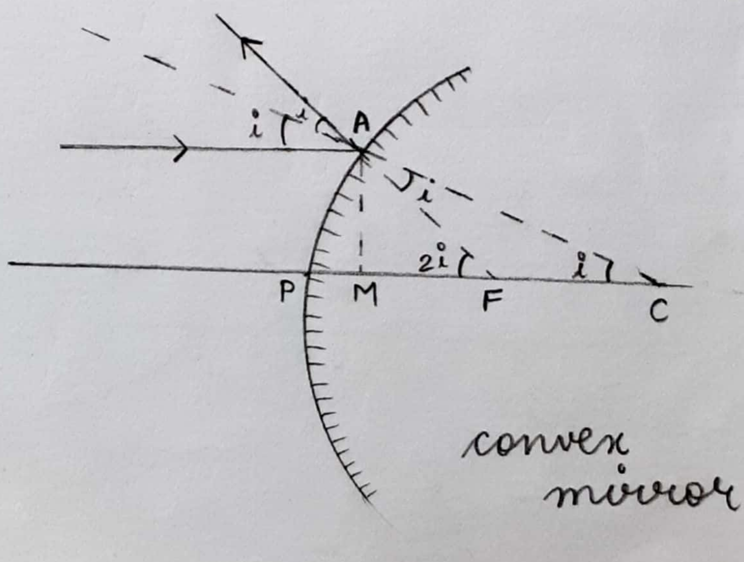
$$\frac{AM}{2PF} = \frac{AM}{PC}$$

$$2PF = PC$$

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

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

II] Using convex mirror



convex mirror

In ΔAFM

$$\tan 2i = \frac{AM}{MF} \approx \frac{AM}{PF}$$

$$2i = \frac{AM}{PF} \quad \text{——} \quad (1)$$

In ΔAMC

$$\tan i = \frac{AM}{MC} \approx \frac{AM}{PC}$$

$$i = \frac{AM}{PC} \quad \text{——} \quad (2)$$

From equations 1 and 2

$$\frac{AM}{PC} = \frac{AM}{2PF}$$

$$PC = 2\,PF$$

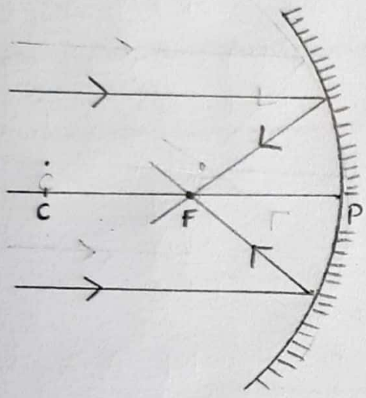
$$\boxed{R = 2f}$$

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

- The radius of curvature of a plane mirror is infinity.

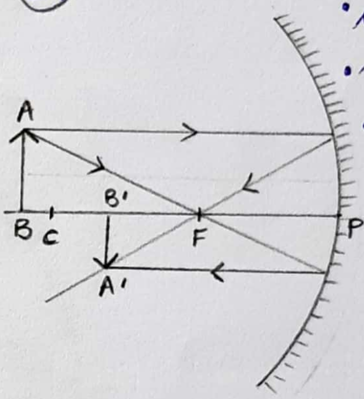
Ray Diagrams due to concave mirror

1.



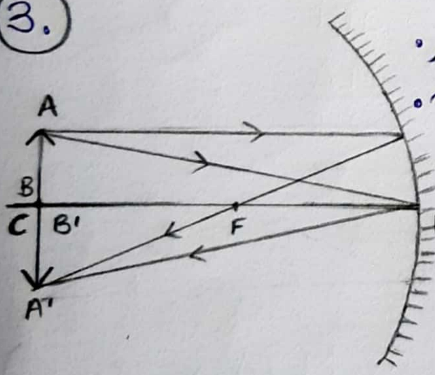
- $u \rightarrow$ infinity
- $v \rightarrow$ focus
- real & inverted
- point sized image

2.



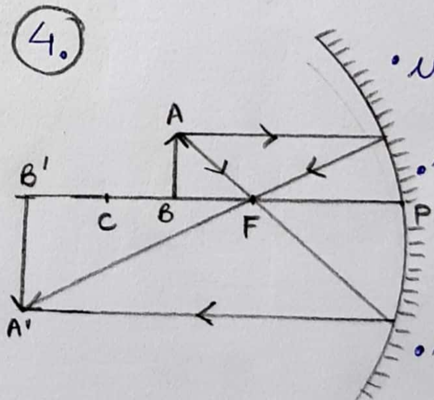
- $u \rightarrow$ beyond C
- $v \rightarrow$ between F & C
- real & inverted
- diminished image

3.



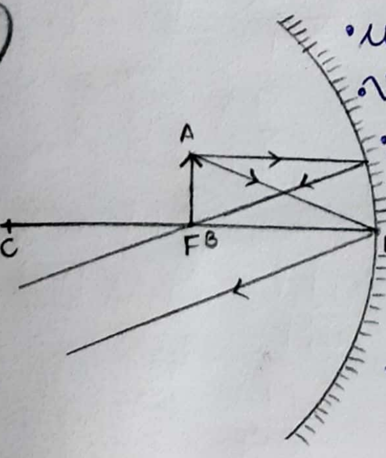
- $u \rightarrow$ curvature
- $v \rightarrow$ curvature
- real & inverted
- same sized image

4.



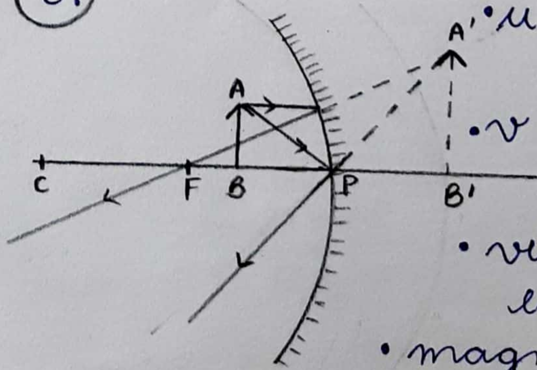
- $u \rightarrow$ between F and C
- $v \rightarrow$ beyond C
- real & inverted
- magnified image

5.



- $u \rightarrow$ F
- $v \rightarrow \infty$
- real and inverted
- highly enlarged image

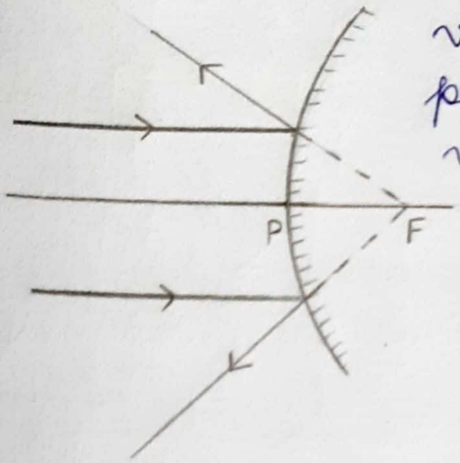
6.



- $u \rightarrow$ between F and P
- $v \rightarrow$ behind the mirror
- virtual and erect
- magnified image

Ray Diagrams due to convex mirror

1.

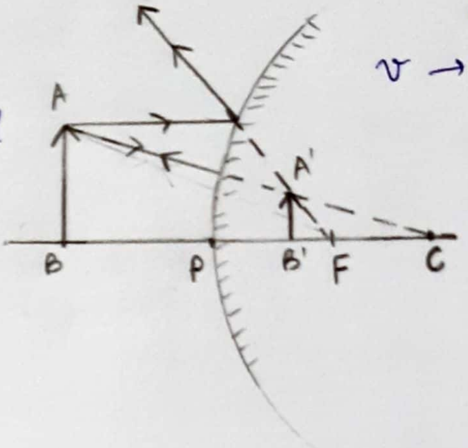


$u \rightarrow \infty$

$v \rightarrow F$

point sized virtual and erect image

2.



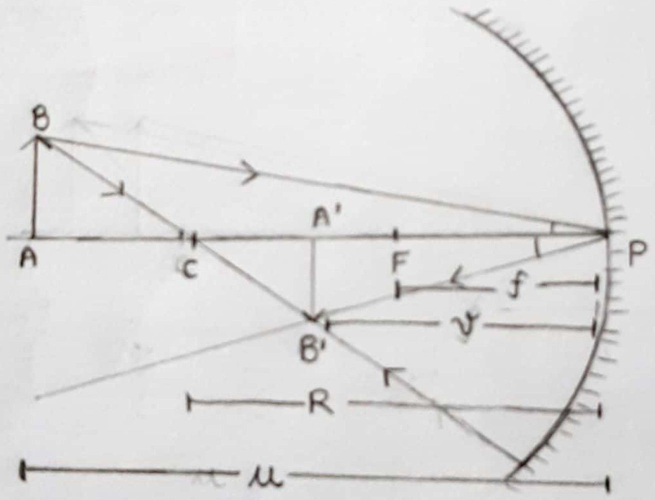
$u \rightarrow$ ~~beyond~~ b/w P and F

$v \rightarrow$ b/w P and F

diminished virtual and erect image

MIRROR FORMULA

I] Due to concave mirror



In ΔAPB and $\Delta A'PB'$

$\angle BAP = \angle PA'B'$ (90°)

$\angle APB = \angle A'PB'$

$\because \Delta APB \approx \Delta A'PB'$

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

In ΔACB and $\Delta A'CB'$

$\angle BAC = \angle B'A'C$

$\angle ACB = \angle A'CB'$

$\Delta ACB \approx \Delta A'CB'$

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

from (1) and (2)

$$\frac{PA}{PA'} = \frac{AC}{A'C} \Rightarrow \frac{-u}{-v} = \frac{-u+R}{-R+v}$$

$[PA = -u,\ PA' = -v,\ AC = -u+R,\ A'C = -R+v]$

$$uR - uv = uv - vR \qquad [\because R = 2f]$$

$$2uf - uv = uv - 2vf$$

$$2uf = 2uv - 2vf$$

$$uf = uv - vf$$

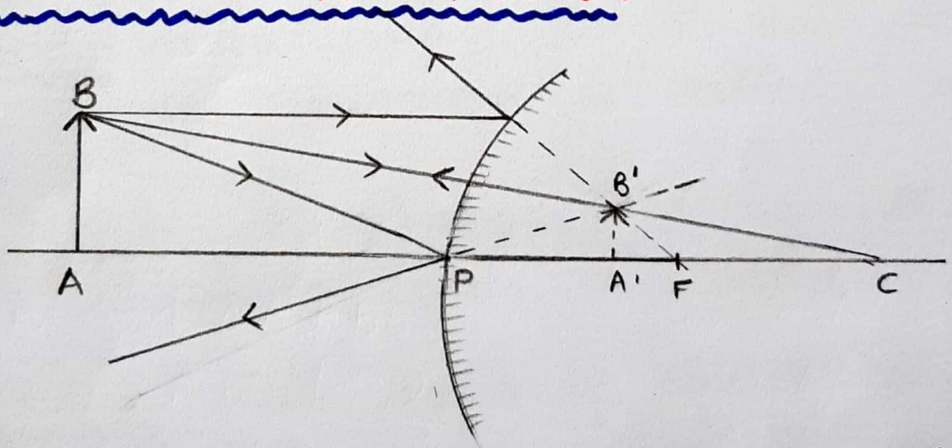
dividing both sides with uvf

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

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

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

II Due to convex mirror



The triangles $\Delta A'B'P$ and ABP are similar

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

Also the $\Delta A'B'C$ and ABC are similar

$$\therefore \frac{A'B'}{AB} = \frac{A'C}{AC} = \frac{PC - PA'}{PC + PA} \quad \text{———} \quad (2)$$

From equations (1) and (2)

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

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

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

$$-vR + uv = Ru - uv$$

Dividing by uvR

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

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

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

$R = 2f$

$$\because \frac{2}{R} = \frac{\cancel{2}}{\cancel{2}f}$$

Real Image – An image which can be obtained on the screen is called a real image.

Virtual Image – An image that cannot be obtained on a screen is called a virtual image.

Magnification – The ratio of size of image to the size of object is called magnification.

$$\boxed{M = \frac{h_i}{h_o} = -\frac{v}{u}}$$

- Magnification of real image is positive.
- Magnification of virtual image is negative.

Refraction – When light goes from one transparent medium to another, it deviates from its path, this phenomenon is refraction.

Cause – Difference in speed of light in different mediums.

Laws of refraction –

1. Incident ray, refracted ray and the normal to the interface at the point of incidence, all lie in the same plane.

2. The ratio of sine of angle of incidence to the sine of angle of refraction is constant [Snell's Law]

$$\mu_1 \sin i = \mu_2 \sin r$$

$$\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1} = \mu_{21}.$$

- μ depends on –

1. Temperature (inversely)
2. Material (directly)
3. Wavelength (inversly)

Refraction through a glass slab

For direct light

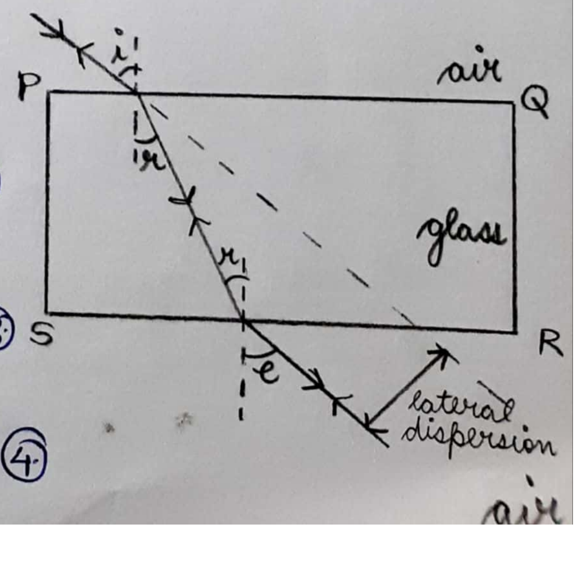
at surface PQ, $\mu_{ga} = \frac{\sin i}{\sin r}$ —— (1)

at surface RS, $\mu_{ag} = \frac{\sin r}{\sin e}$ —— (2)

For reflected light

at surface RS, $\mu_{ga} = \frac{\sin e}{\sin r}$ —— (3)

at surface PQ, $\mu_{ag} = \frac{\sin r}{\sin i}$ —— (4)



For equations 1 and 4

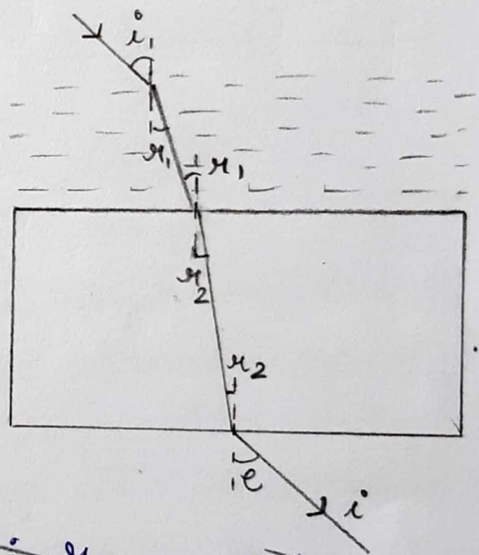
$$\boxed{\mu_{ga} = \frac{1}{\mu_{ag}}}$$

For equations 2 and 3

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

Provided : 1. Refracting surfaces are parallel to each other.
2. Incident and emergent ray are in same medium.

Refraction through multiple media



$$\mu_{wa} = \frac{\sin i}{\sin r_1} \quad \text{--- (1)}$$

$$\mu_{gw} = \frac{\sin r_1}{\sin r_2} \quad \text{--- (2)}$$

$$\mu_{ag} = \frac{\sin r_2}{\sin e} = \frac{\sin r_2}{\sin i} \quad \text{--- (3)}$$

$$(\because \angle i = \angle e)$$

1 × 2 × 3

$$\mu_{wa} \times \mu_{gw} \times \mu_{ag} = \frac{\cancel{\sin i}}{\cancel{\sin r_1}} \times \frac{\cancel{\sin r_1}}{\cancel{\sin r_2}} \times \frac{\cancel{\sin r_2}}{\cancel{\sin i}} = 1$$

$$\mu_{wa} \times \mu_{gw} = \frac{1}{\mu_{ag}}$$

$$\mu_{wa} \times \mu_{gw} = \mu_{ga}$$

$$\mu_{ba} \times \mu_{cb} \times \mu_{dc} \times \mu_{ed} = \mu_{ea} \qquad [\angle i = \angle e]$$

Optical Density – Ratio of speed of light in two media. Eg – terpentine and water.

Real and apparent depth -

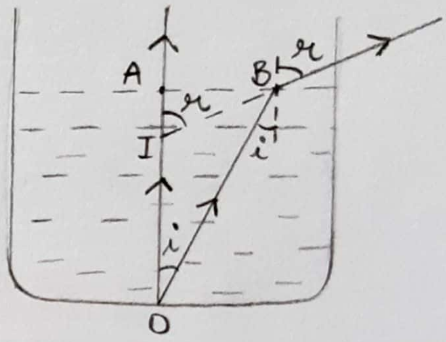
In ΔOAB,

$$\sin i = \frac{AB}{OB} = \frac{AB}{OA} \quad (\because i \text{ is small})$$

In ΔIAB

$$\sin r = \frac{AB}{BI} = \frac{AB}{AI} \quad (\because s \text{ is small})$$

$$\mu_{aw} = \frac{\sin i}{\sin r} = \frac{AB/OA}{AB/AI}$$



$$_w\mu_a = \frac{AI}{OA} = \frac{\text{Apparent}}{\text{Real}}$$

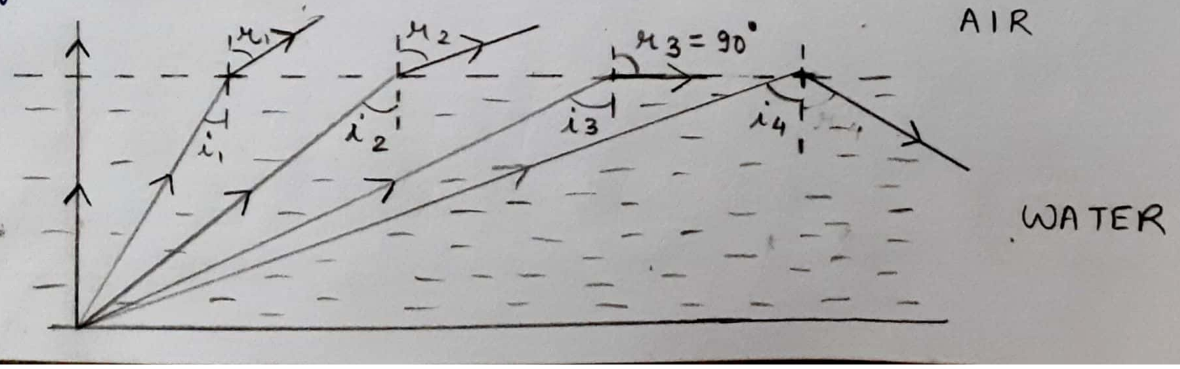
$$_a\mu_w = \frac{OA}{AI} = \frac{\text{Real}}{\text{Apparent}}$$

$$\boxed{\mu = \frac{\text{real depth}}{\text{apparent depth}}}$$

Critical Angle - It is the angle of incidence subtended by a ray of light travelling from denser to rarer for which refracted ray travels along the surface separating the 2 media i.e. for which angle of refraction equals 90°.

Total Internal Reflection -

When light travels from denser to rarer medium above a certain angle of incidence it will reflect back into the same medium.



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

when $i = i_c$ then $r = 90°$

$$ {}_w\mu_a = \frac{\sin i_c}{\sin 90°} $$

$$ {}_w\mu_a = \frac{\sin i_c}{1} $$

$$ {}_a\mu_w = \frac{1}{{}_w\mu_a} = \frac{1}{\sin i_c} \Rightarrow \boxed{\mu = \frac{1}{\sin i_c}} $$

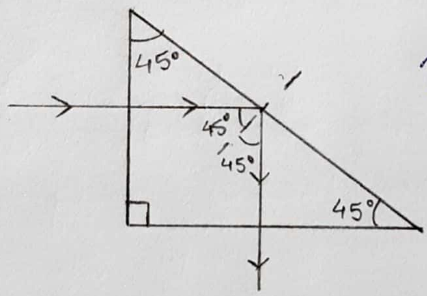
Conditions -

1. $\angle i > \angle i_c$
2. Light should travel from denser to rarer.

Applications of Total Internal Reflection -

1. Prism

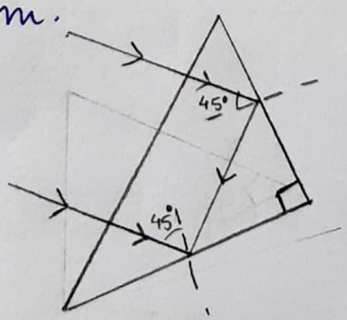
(i) To turn a ray of light by 90° using right angled prism.



glass $\mu = 1.5$

$i_c = 42°$

(ii) To turn a ray of light by 180° using right angled prism.

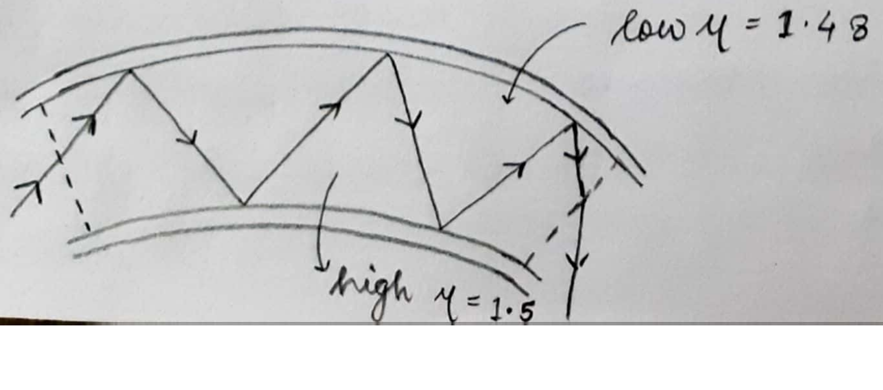


2. Brilliance of Diamond -

This brilliance is due to the total internal reflection of light inside them, $i_c = 2.4°$ is very small therefore once light enters a diamond, it is very likely to undergo TIR inside it. By cutting at the diamond suitably, multiple TIR's can be made to occur.

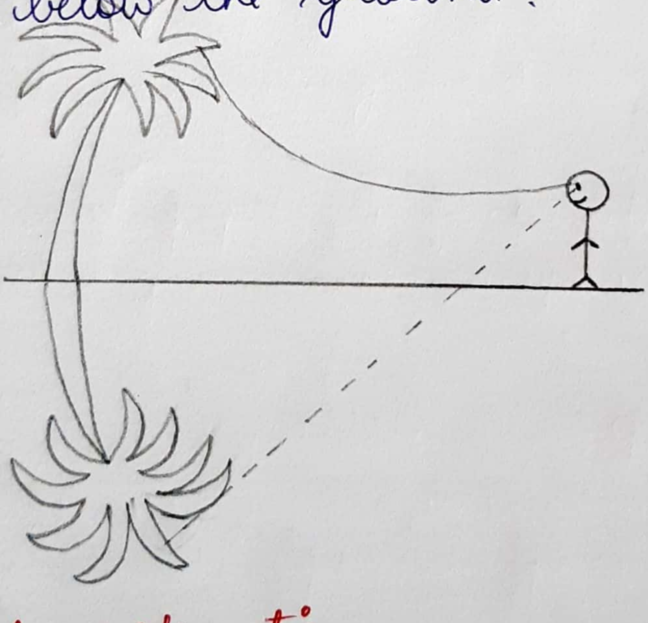
3. Optical Fibre -

- These are fabricated with high quality composite glass/quartz fibres Each fibre consists of a core and cladding. μ of material of core > μ of material of cladding. When a signal in the form of light is directed at one end of fibre at a suitable angle, it undergoes repeated TIRs along the fibre's length and comes out at the other end.
- Since light undergoes TIR at each, no appreciable intensity is lost.
- Used for transmitting and receiving electrical signal.
- Used as 'light pipes' to facilitate visual examination of internal organs like oesophagus, stomach and intenstines.
- Requirements : very little absorption of light as it travels long distance can be done by purification and special preparation of materials like quartz.
- Example - Silica glass fibres : 95% light - 1 km



4. Mirage -

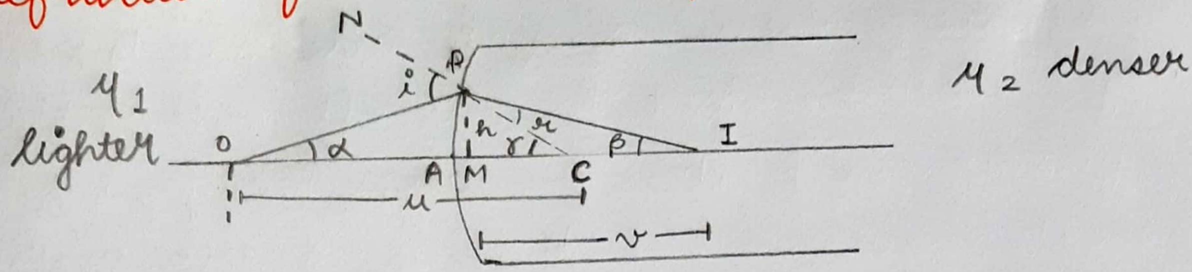
- On hot summer days, air near ground becomes hotter than the air at higher levels. Refractive index of air increases with ↑ in density. Hotter air is less dense and has smaller than cooler air is still, the optical density at different layers of air increases with height.
- As a result, light from tall object passes through a medium whose μ decreases towards the ground.
- Thus, a ray of light from such an object successively bends away from the normal and undergoes TIR if the $\angle i$ for air near ground exceeds i_c.
- To a distant observer, light appears to come from somewhere below the ground.



Examples of refraction-

1. Twinkling of stars.
2. Early sunrise and sunset.
3. Stars appear higher than they are.
4. Straight rod appears bent in water.
5. Fountain of fire.

Refraction from convex spherical surface -



$$\tan\alpha = \frac{PM}{MO}$$

$$\tan\beta = \frac{PM}{MI}$$

$$\tan\gamma = \frac{PM}{MC}$$

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

Snell's Law

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

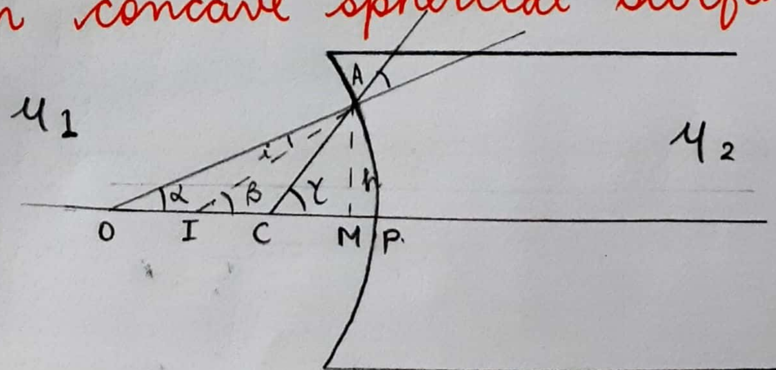
$$\frac{\alpha+\gamma}{\gamma+\beta} = \frac{\mu_2}{\mu_1}$$

$$\left(\frac{PM}{MO} + \frac{PM}{MC}\right)\mu_1 = \left(\frac{PM}{MC} + \frac{PM}{MI}\right)\mu_2$$

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

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

- From concave spherical surface -



$\alpha + i = \gamma$

$\tan\gamma + (-\tan\alpha) = \gamma$ —— (1) $[\because \alpha$ & γ are small$]$

$r + \beta = \gamma$

$\tan\gamma - \tan\beta = r$ —— (2)

$\mu_1 \sin i = \mu_2 \sin r$

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

$$\mu_1\left(\frac{AM}{MC} - \frac{AM}{MO}\right) = \mu_2\left(\frac{AM}{MC} - \frac{AM}{MI}\right)$$

$$\mu_1\left(\frac{1}{MC} - \frac{1}{MO}\right) = \mu_2\left(\frac{1}{MC} - \frac{1}{MI}\right)$$

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

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

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

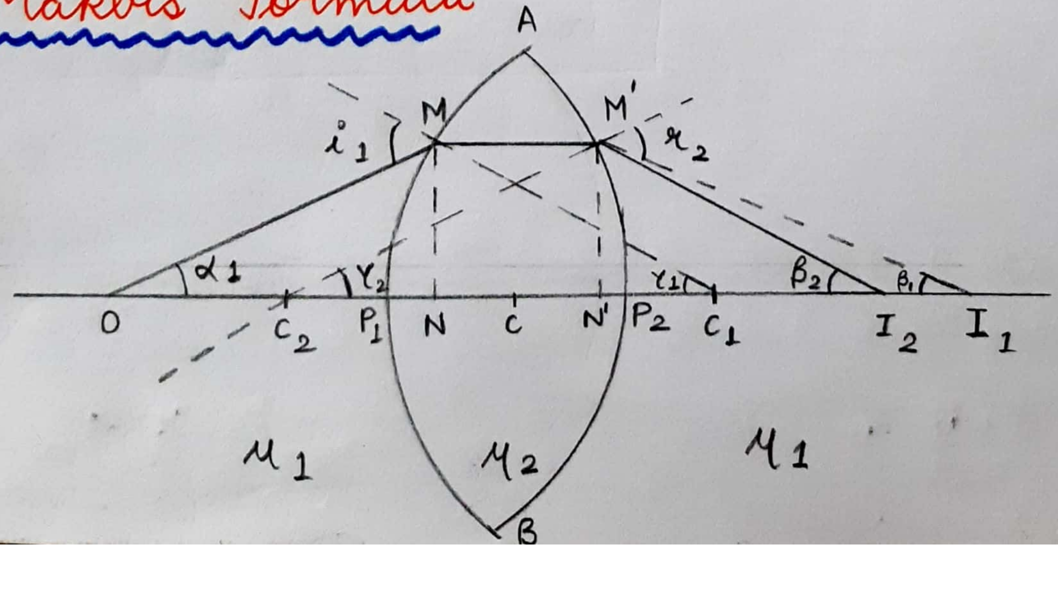
replace μ_1 by μ_2 and μ_2 by μ_1 and we'll get

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

Dividing by μ_1

$$\frac{1-\mu}{R} = \frac{1}{v} - \frac{\mu}{u} \quad \left[\because \frac{\mu_2}{\mu_1} = \mu\right]$$

Lens Makers Formula



Case I

First we consider beyond AP_1B surface onto the right of it. μ_2 only is extended i.e. there is no presence of AP_2B surface.

In $\triangle OMC$, $i_1 = \alpha_1 + \gamma_1$

$$i_1 = \tan\alpha_1 + \tan\gamma_1$$

$$= \frac{MN}{ON} + \frac{MN}{NC_1}$$

$$= \frac{MN}{OC} + \frac{MN}{CC_1}$$

In $\triangle I_1MC_1$

$$\gamma_1 = \beta_1 + r_1$$

$$r_1 = -\beta_1 + \cancel{\gamma_1} = -\tan\beta_1 + \tan\gamma_1$$

As light travelling from rarer to denser medium

$$\mu_1 \sin i_1 = \mu_2 \sin r_1$$

$$\mu_1 i_1 = \mu_2 r_1$$

$$\mu_1\left(\frac{MN}{CO} + \frac{MN}{CC_1}\right) = \mu_2\left(\frac{MN}{CC_1} - \frac{MN}{CI_1}\right)$$

$$\mu_1\left(\frac{1}{CO} + \frac{1}{CC_1}\right) = \mu_2\left(\frac{1}{CC_1} - \frac{1}{CI_1}\right)$$

$$\mu_1\left(-\frac{1}{u} + \frac{1}{R_1}\right) = \mu_2\left(\frac{1}{R_1} - \frac{1}{v_1}\right)$$

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

$$\left(\frac{\mu_2 - \mu_1}{R_1}\right) = \frac{\mu_2}{V_1} - \frac{\mu_1}{u} \quad \text{—— (1)}$$

Case II

Now we consider the presence of AP_2B surface for which I_1 behaves as virtual object and ray of light travels from denser to rarer medium forming the final image at I_2

In $\Delta I_1 M'C_2$

$$i_2 = \beta_1 + \gamma_2$$
$$= \tan\beta_1 + \tan\gamma_2$$
$$= \frac{M'N'}{N'I_1} + \frac{M'N'}{N'C_2}$$
$$= \frac{M'N'}{CI_1} + \frac{M'N'}{C_1C_2}$$

In $\Delta I_2 M'C_2$

$$r_2 = \beta_2 + \gamma_2$$
$$= \tan\beta_2 + \tan\gamma_2$$
$$= \frac{M'N'}{N'I_2} + \frac{M'N'}{N'C_2}$$
$$= \frac{M'N'}{CI_2} + \frac{M'N'}{CC_2}$$

As light is travelling from denser to rarer medium.

$$\mu_2 \sin i_2 = \mu_1 \sin r_2$$
$$\mu_2(\tan\gamma_2 + \tan\beta_1) = \mu_1(\tan\beta_2 + \tan\gamma_2)$$
$$\mu_2\left(\frac{M'N'}{CC_2} + \frac{M'N'}{CI_1}\right) = \mu_1\left(\frac{M'N'}{CC_2} + \frac{M'N'}{CI_2}\right)$$
$$\mu_2\left(\frac{1}{CC_2} + \frac{1}{CI_2}\right) = \mu_1\left(\frac{1}{CC_2} + \frac{1}{CI_2}\right)$$
$$\mu_2\left(-\frac{1}{R_2} + \frac{1}{V_1}\right) = \mu_1\left(\frac{-1}{R_2} + \frac{1}{V_1}\right)$$
$$-\frac{\mu_2}{R_2} + \frac{\mu_2}{V_1} = -\frac{\mu_1}{R_2} + \frac{\mu_1}{V}$$
$$\boxed{-\left(\frac{\mu_2 - \mu_1}{R_2}\right) = -\frac{\mu_2}{V_1} + \frac{\mu_1}{V}} \quad \text{——— (2)}$$

Adding (1) and (2) we get

$$\left(\frac{\mu_2 - \mu_1}{R_1}\right) - \left(\frac{\mu_2 - \mu_1}{R_2}\right) = \cancel{\frac{\mu_2}{V_1}} - \frac{\mu_1}{u} - \cancel{\frac{\mu_2}{V_1}} + \frac{\mu_1}{V}$$
$$\boxed{(\mu_2 - \mu_1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \mu_1\left(\frac{1}{V} - \frac{1}{u}\right)} \quad \text{—— (3)}$$

Dividing by μ, we get

$$\boxed{\left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{v} - \frac{1}{u}} \quad \text{——— (4)}$$

when $u = \infty$; $v = f$

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

$$(\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{f} \quad \text{——— (5)}$$

when $u = -f$ then $v = \infty$

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

$$(\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{f} \quad \text{——— (6)}$$

From equations (4) (5) and (6)

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

Power of a lens –

It gives the degree or extent of ~~conv~~ convergence or divergence of parallel rays of light incident on the lens.

Mathematically, it is equal to reciprocal of focal length.

$$\boxed{P = \frac{1}{f}}$$

unit : D (dioptre when f in m)

concave lens : negative

convex lens : positive

Combination of Lenses –

- When two lenses of focal length f_1 and f_2 are in contact with each other then,

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

$P = P_1 + P_2$

$m = m_1 \times m_2$

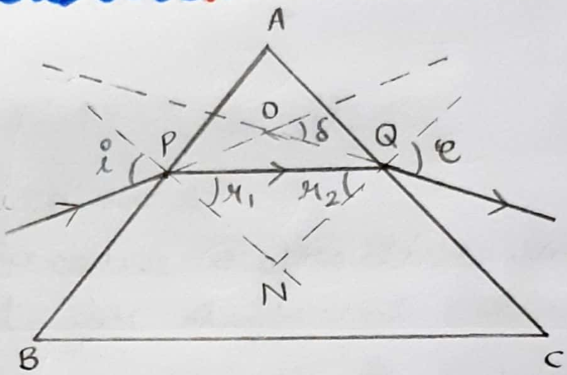
- When two lenses are d distance apart,

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$$

$$P = P_1 + P_2 - d P_1 P_2$$

$$\boxed{m = m_1 \times m_2}$$

Refraction due to glass prism



Using exterior angle property

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

$\delta = i + e - (r_1 + r_2)$ —— 1

In ΔNPQ

$\angle N + r_1 + r_2 = 180°$

In □ APNQ

$\angle N + \angle A = 180°$

$\angle A = r_1 + r_2$ —— 2

$\delta = i + e - \angle A$ —— 3

$\mu \rightarrow$ r.i using Snell's Law

$$\mu = \frac{\sin i}{\sin r} = \frac{i}{r_1}$$

$i = \mu r_1 \qquad e = \mu r_2$

$\delta = \mu(r_1 + r_2) - A$

$\delta = \mu A - A$

$$\boxed{\delta = A(\mu - 1)}$$

$\delta \rightarrow$ minimum then,

$i = e$, $r_1 = r_2$

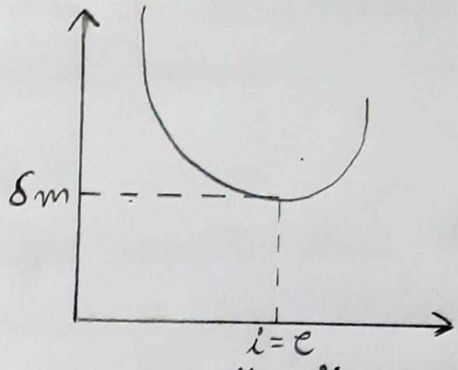
$A = 2r$

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

$\delta_m = 2i - A$

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

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



Dispersion - Splitting of light into its constituent colours.

- It occurs because refractive index of medium is different for different colours.
- Inversly proportional to wavelength.

Angular dispersion - Difference of angle of deviation of two extreme colours.

$$\delta_v - \delta_r = (\mu_v - 1)A - (\mu_r - 1)A$$
$$= (\mu_v - \mu_r)A$$

- depends on A and material of prism.

Dispersive power - The ratio of angular deviation and mean deviation.

$$\omega = \frac{(\mu_v - \mu_r)\cancel{A}}{(\mu - 1)\cancel{A}}$$

- depends on material of prism

Scattering - spreading of light

Examples -
- blue colour of sky
- reddish sun during sunrise & sunse
- white colour of clouds

Optical Instruments -

① **Simple Microscope** - Uses convex lens to magnify

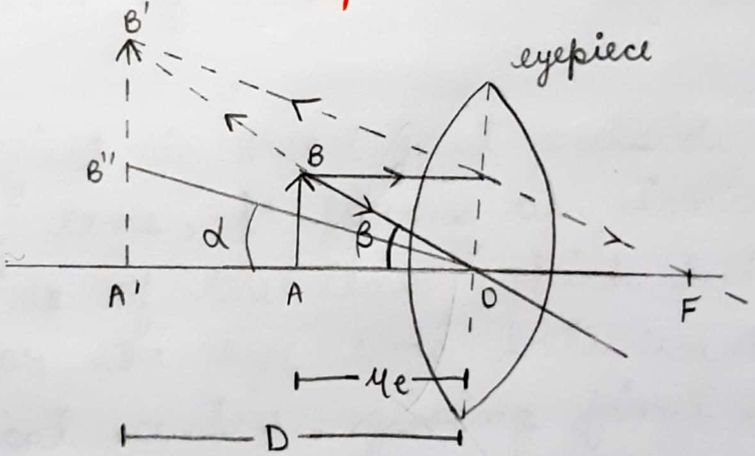
Principle - When an object is placed between the pole and the focus of a convex lens, it forms virtual, magnified and erect image at the least distance of distinct vision.

★ Magnifying Power -

Defined as the ratio of angle subtended by image at eye to angle subtended by object at eye when both of them are considered at the least distance of distinct vision.

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

I] Image at near point



In $\triangle AOB$

$$\tan\beta = \frac{AB}{-u_e} \quad \text{——— (1)}$$

In $\triangle A'OB''$

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

$$m = \frac{\beta}{\alpha} = \frac{AB}{-u_e} \times \frac{-D}{AB} = \frac{D}{u_e}$$

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

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

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

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

$$\boxed{\frac{D}{f_e} + 1 = m}$$

II] Image at infinity

$$f_e = u_e$$

$$m = \frac{D}{f_e}$$

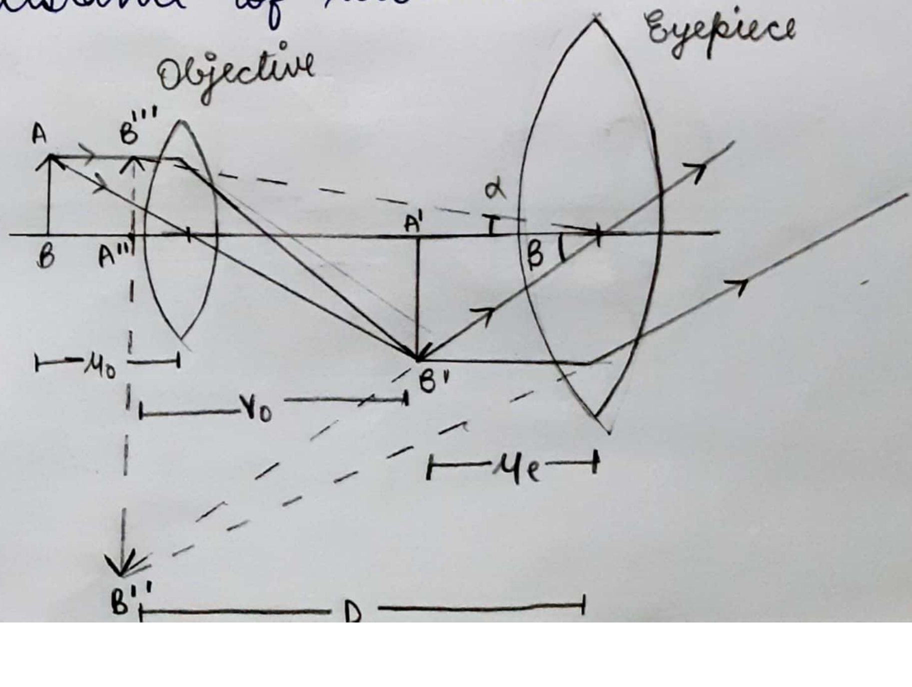
- Simple microscope has limited magnification.

② Compound Microscope -

It consists of two lens → objective and eyepiece

Principle -

When object is held just outside the focus of objective lens, it forms an image on the other side of the lens which behaves as an object for the eye lens between its focus and the optical centre, giving final image at the least distance of distinct vision.



In $\Delta A''OB''$

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

In $\Delta A''OB'''$

$$\tan\alpha = \frac{-AB}{-D}$$

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

$$m = -\frac{A''B''}{AB} \times \frac{A'B'}{A'B'} = m_e \cdot m_o$$

$$m = \frac{v_e}{u_e} \times \frac{v_o}{u_o}$$

$$m = \frac{-v_o}{u_o} \times \frac{D}{u_e} \quad \text{——— (1)}$$

- when at LDDV

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

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

$$\frac{D}{f_e} + 1 = \frac{D}{u_e} \quad \text{[multiple by D]}$$

put in (1)

$$\boxed{m = -\frac{v_o}{u_o}\left(1 + \frac{D}{f_e}\right)}$$

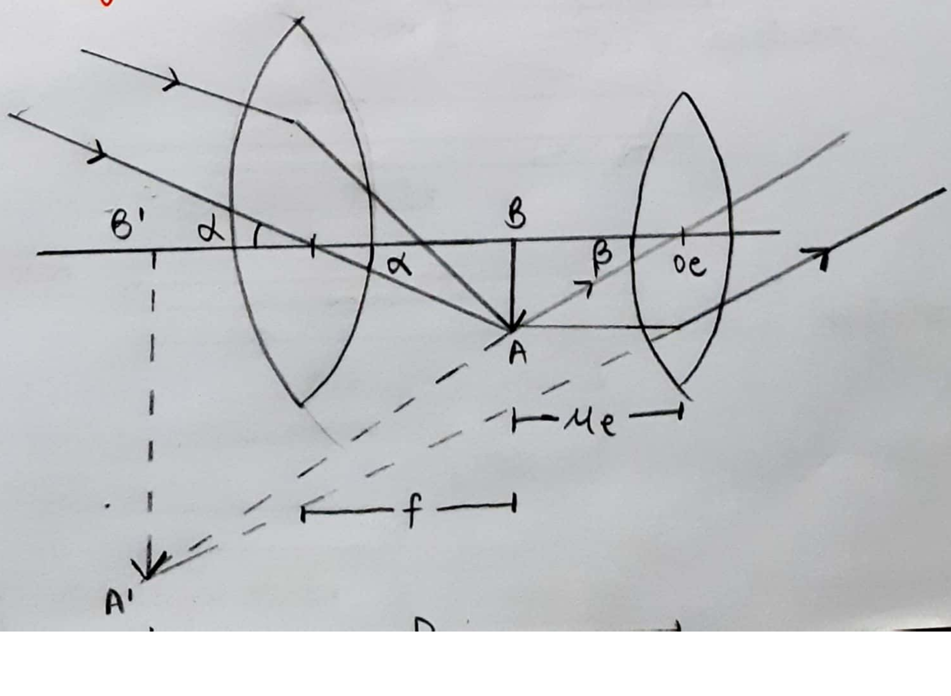
- when at ∞

$u_e = f_e$

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

(3) Astronomical Telescope -

(i) Refracting telescope



In ΔAOB

$$\tan\alpha = \frac{AB}{f}$$

In ΔAO_eB

$$\tan\beta = \frac{AB}{-u_e}$$

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

$$m = \frac{-f_o}{u_o}$$

- when at LDDV

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

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

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

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

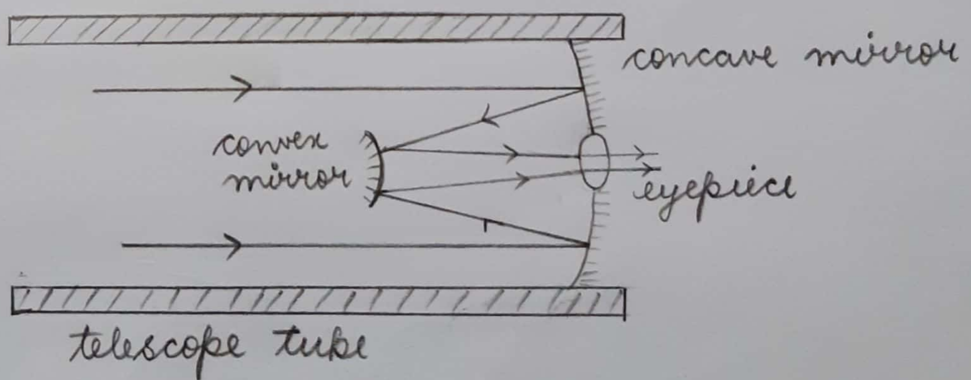
$$\boxed{m = -\frac{f_o}{f_e}\left[1 + \frac{f_e}{D}\right]}$$

- when image is at ∞

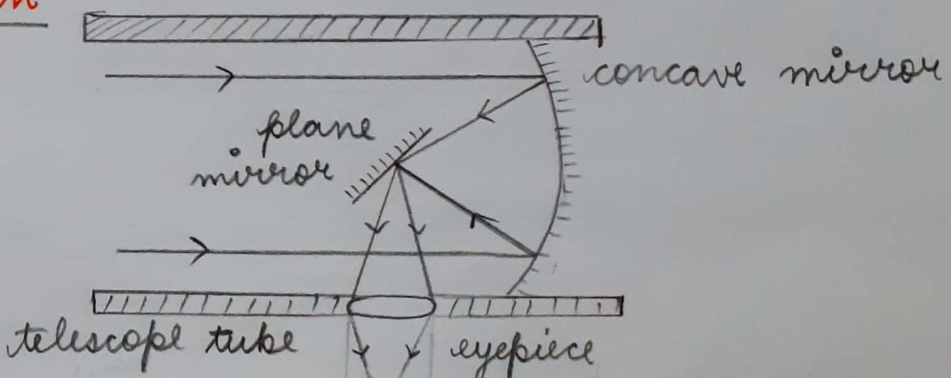
$$\boxed{m = \frac{-f_o}{f_e}}$$

(ii) Reflecting telescope

- Cassegrain



- Newtonian



Resolving power -

- The ability of an optical instrument to produce distinctly separate image of two close objects.
- The minimum distance between two objects which can be seen as separate is limit of resolution.

$$\text{Resolving power} \propto \frac{1}{\text{Limit of resolution}}$$