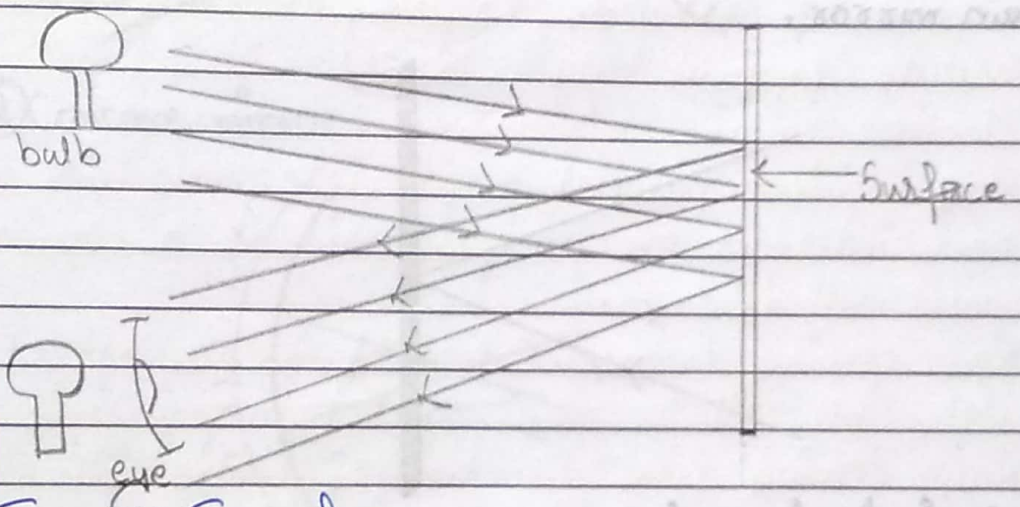
Chp-9 : Ray Optics

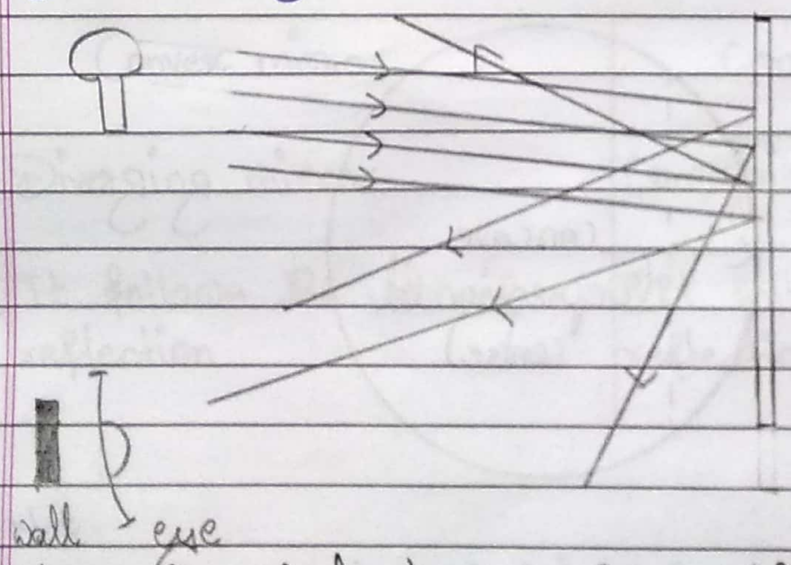
- Ray of light represents direction of propogation of light energy.

* Reflection :

- Type 1 : Regular



- Type 2 : Irregular

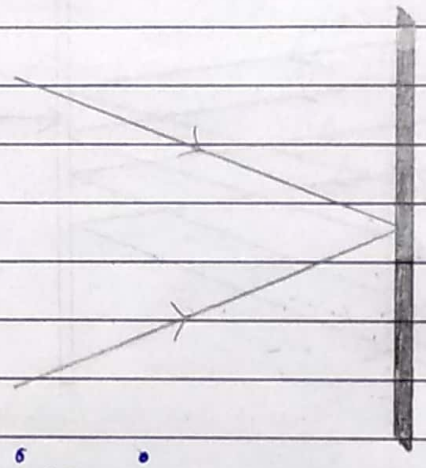


- Glass is optical plane surface which reflects light with same angle all around surface.

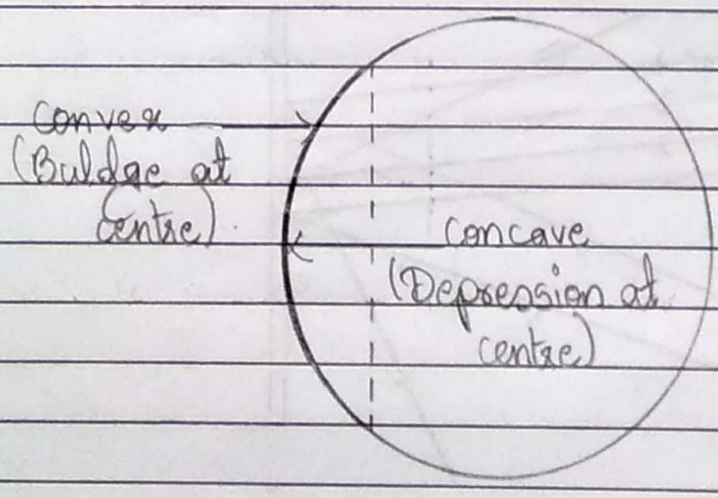
- In regular surface we see bulb which is source of light because of optically plane surface whereas in irregular surface we see that in irregular surface because light are reflected according to pattern of wall.

* Mirror type :

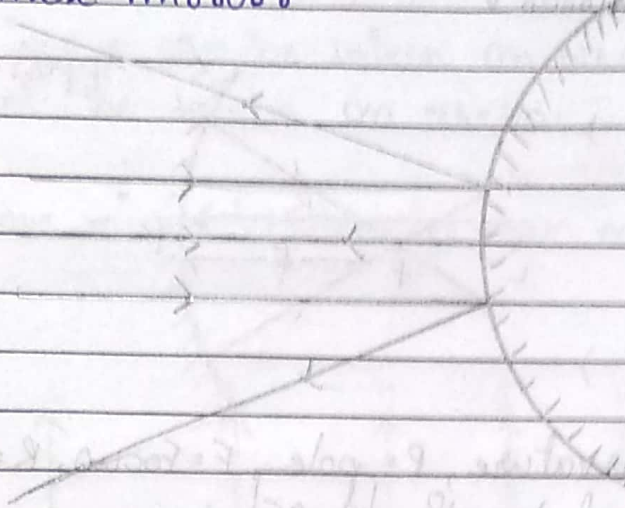
- Plain mirror :



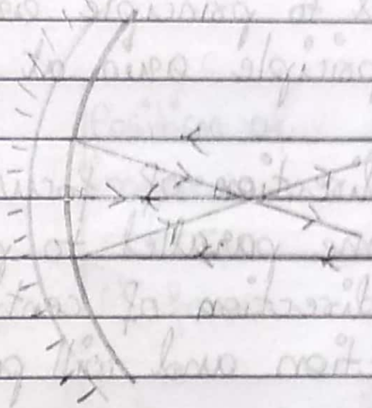
- Spherical mirror :



① Convex mirror :



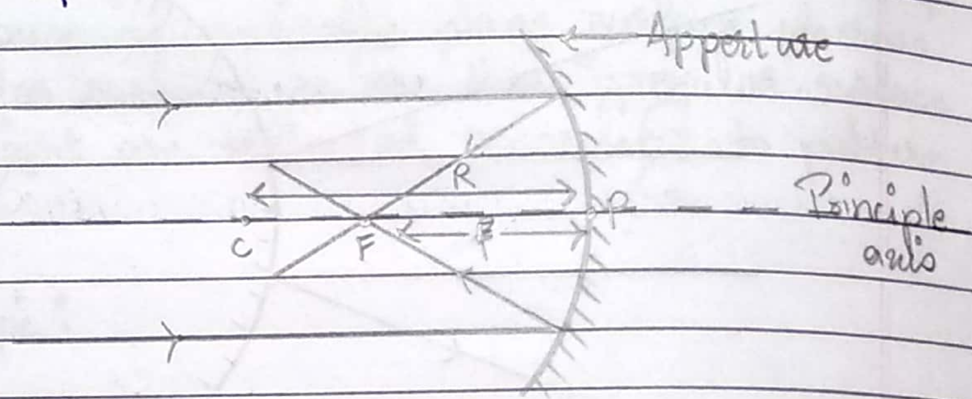
② Concave mirror :



	Convex mirror	Concave mirror
①	Diverging mirror	Converging mirror
②	It follows the rule of reflection	It follows the rule of reflection.

Note :
Object is a real material and perception of object is known as image.

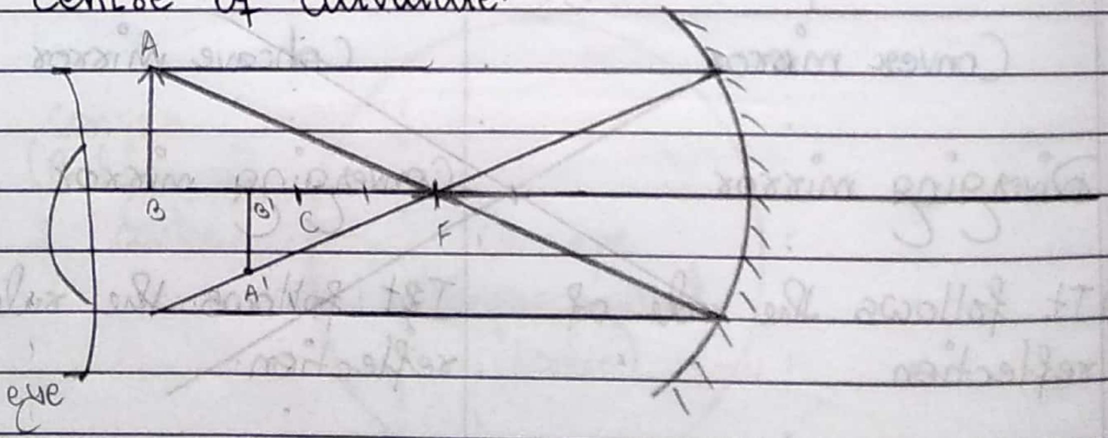
* Reflection of mirror:



C = Centre of curvature, P = pole, F = Focus, R = Radius of curvature, f = focal length, R = 2F

- Reflection rules:

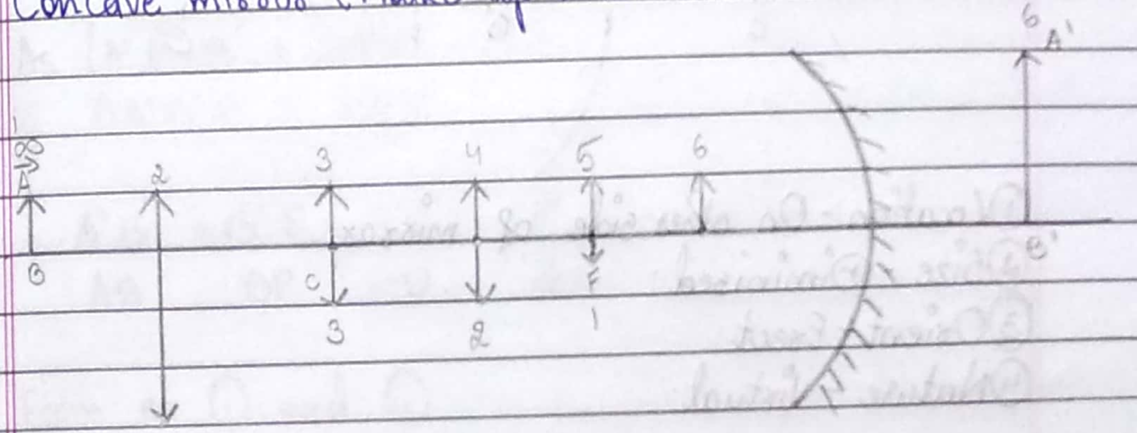
1. Ray incident parallel to principle axis will reflect and intersect on priciple axis at a common point called, focus.
2. Rays coming from direction of focus, after reflection will become parallel to principle axis.
3. Rays coming from direction of centre will retrace its path after reflection and will pass through centre of curvature.



1. Location (of object and image).
2. Size (of AB or A'B').
3. Orientation (inverted or erect).
4. Nature (Real or virtual).

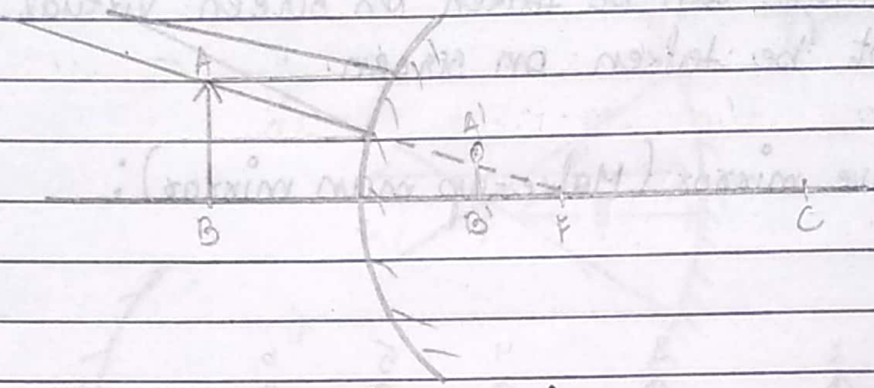
Note:
Real image can be taken on screen. Virtual image cannot be taken on screen.

- Concave mirror (Make-up man mirror):



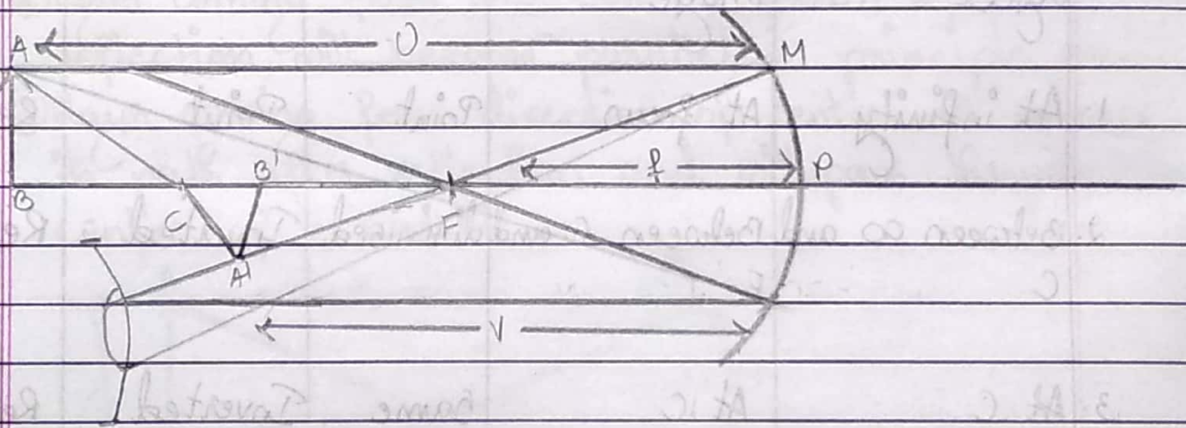
Position of object	Position of image	Size	Orientation	Nature
1. At infinity	At focus	Point	Point	Real
2. Between ∞ and C	Between C and F	diminised	Inverted	Real
3. At C	At C	Same	Inverted	Real
4. Between C and F	Between C and ∞	Magnified	Inverted	Real
5. At Focus	At infinity	Very large	N.D	N.D
6. Between F and P	On other side of mirror	Large	Erect	Virtual

- Convex mirror (Back view mirror):



① Location - On other side of mirror.
② Size - Diminised.
③ Orient - Erect.
④ Nature - Virtual.

* Mirror Formula (Concave mirror):



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

Object distance BP = -u
Image distance B'P = -v.
Focal length PF = -f
Radius of curvature CP = -R = -2F

Now, $\Delta A'B'C$ and ΔABC are similar.

$$\therefore \frac{A'B'}{AB} = \frac{A'C}{AC} = \frac{PC - PB'}{PB - PC} = \frac{-R + V}{-U + R} \quad \text{--- (i)}$$

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

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

$$\therefore \frac{A'B'}{AB} = \frac{B'P}{BP} = \frac{-V}{-U} = \frac{V}{U} \quad \text{--- (ii)}$$

From eq (i) and (ii)

$$\frac{V}{U} = \frac{-R + V}{R - U}$$

$$VR - VU = -RU + VU$$

$$RU - UV = UV + VR$$

Dividing both sides by UVR,

$$\frac{1}{V} - \frac{1}{R} = \frac{1}{R} - \frac{1}{U}$$

$$\frac{1}{U} + \frac{1}{V} = \frac{2}{R}$$

But $R = 2F$

$$\therefore \frac{1}{U} + \frac{1}{V} = \frac{1}{F}$$

* Sign convention:

- The direction of incident ray is taken as +ve origin to be taken. Pole and distance will be measured from pole and accordingly sign will be given.

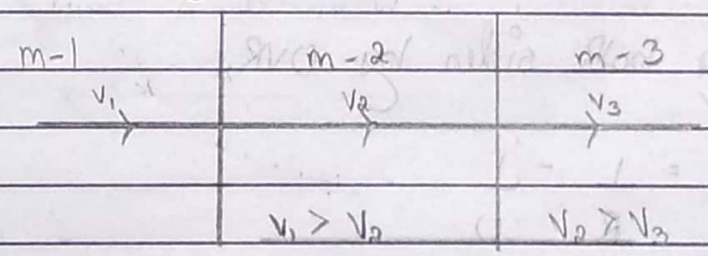
* Magnification:

Magnification $(m) = \frac{-A'B'}{AB} = \frac{-B'P}{BP} = \frac{-(-v)}{-u} = \frac{-v}{u}$

Note:
For real image m is -ve, $-m = \frac{-v}{u}$

For virtual image m is +ve, $m = \frac{-v}{u}$

* Refraction of light:

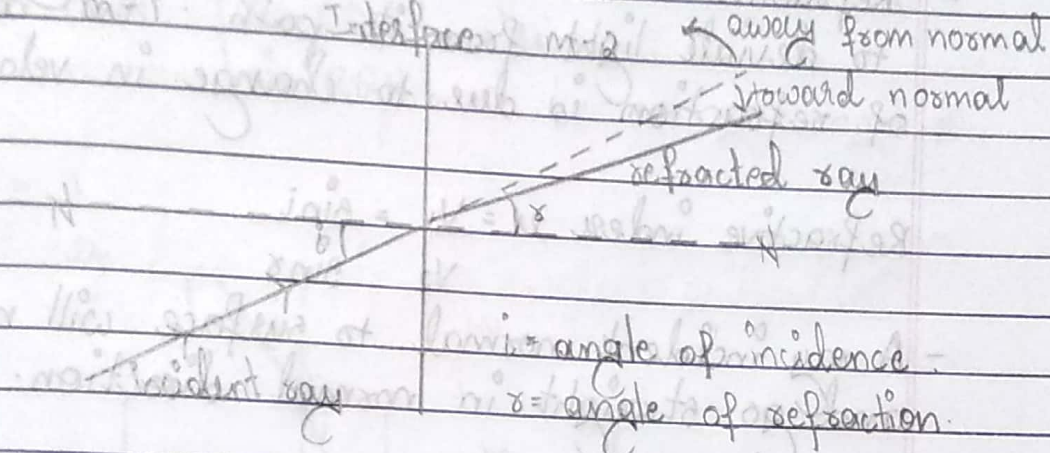


- Velocity of light is constant for one medium in other medium it is another constant.

$\frac{V_1}{V_2}$ = constant, or $\frac{\text{velocity in free space}}{\text{velocity in medium}}$ = Refractive index (μ).

- Refractive index of a medium is its property to decrease the velocity of light. It is expressed by,

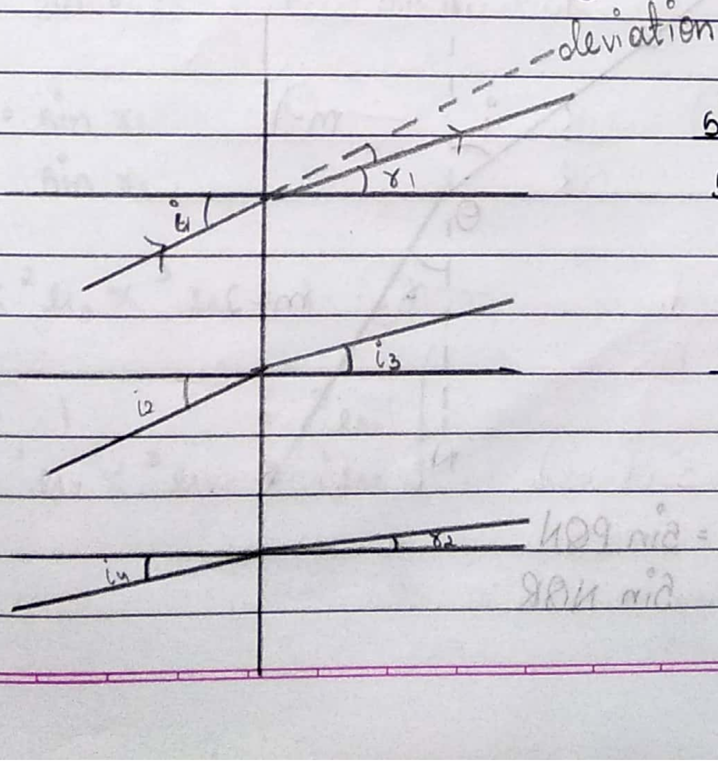
$\mu = \frac{\text{velocity in free space}}{\text{velocity in medium}}$ and its value is always more than one.



- Refraction is phenomena of light in which light ~~energy~~ entering from one medium to another, changes its direction at the end of incidence on interference.
- Rules:

① In some medium its bents towards normal then in second medium it is optically denser.

② In some medium it bents away from normal, the second medium it is optically rarer.



$\frac{\sin i_1}{\sin r_1} = \mu$

$\frac{\sin i_2}{\sin r_2} = \mu$

$\frac{\sin i_3}{\sin i_3} = \mu$

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

- "Refractive index is a number indicating the power to deviate light from its path". The basic cause of refraction is due to change in velocity.

Refractive index $\mu = \frac{V_1}{V_2} = \frac{\sin i}{\sin r}$

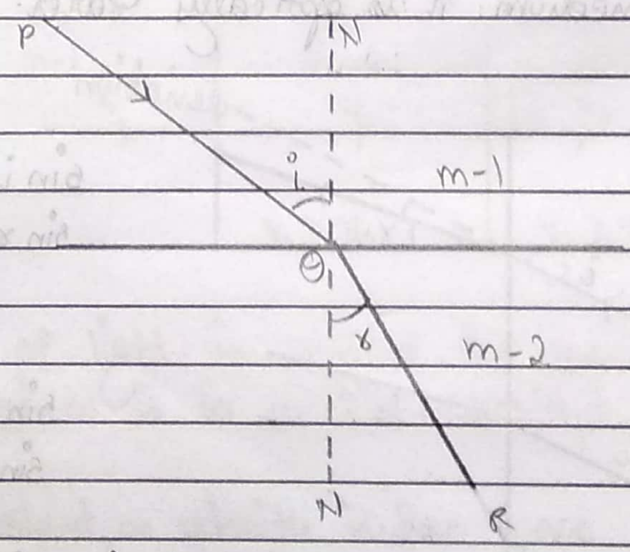
- A ray incident normal to surface will not deviate and go straight in normal direction.

*** Rule of reversibility:**

- When direction of a ray going through many directions is reversed at any point then it will reverse its path in same direction.

*** Refraction relation:**

-

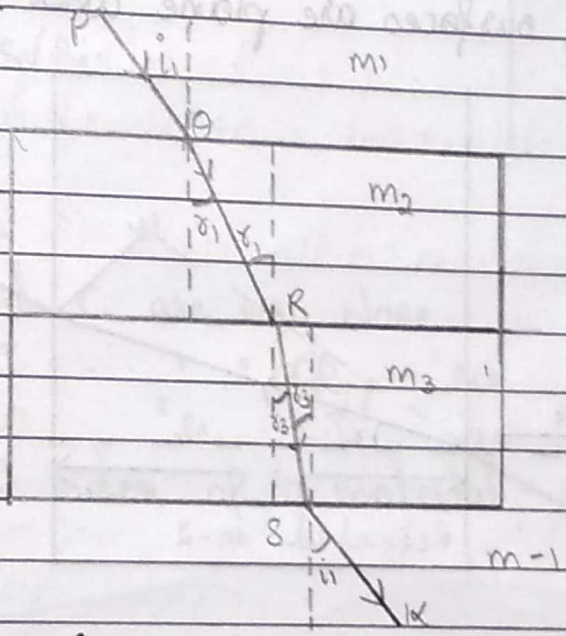


$^1\mu_2 = \frac{\sin i}{\sin r} = \frac{\sin PQN}{\sin NQR}$

Applying reversibility,

$$^{2}\mu_1 = \frac{\sin RQN}{\sin PQN} = \frac{1}{\left(\frac{\sin PQN}{\sin RQN}\right)} = \frac{1}{^{1}\mu_2}$$

$$\therefore\ ^{2}\mu_1 = \frac{1}{^{1}\mu_2}$$



$$^{1}\mu_2 = \frac{\sin i_1}{\sin r_1} \qquad ^{3}\mu_1 = \frac{\sin r_2}{\sin i_1}$$

$$^{2}\mu_3 = \frac{\sin r_1}{\sin r_2}$$

$$^{1}\mu_2 \times {}^{2}\mu_3 \times {}^{3}\mu_1 = 1$$

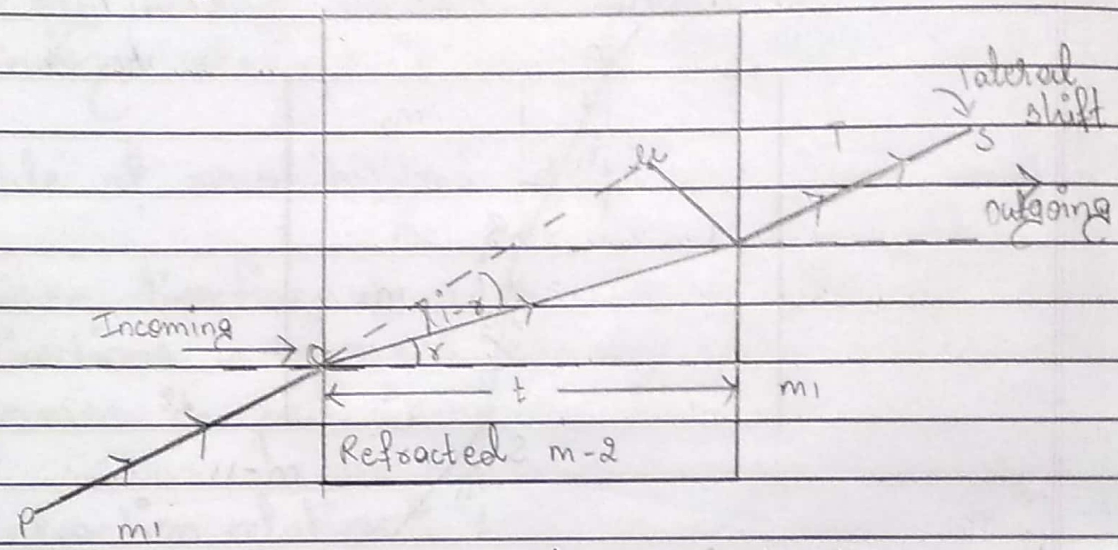
$$\boxed{^{2}\mu_3 = \frac{1}{^{1}\mu_2 \times {}^{3}\mu_1} = \frac{^{3}\mu_1}{^{1}\mu_2}}$$

Note:
Sunrise takes place early and sunset is delayed due to normal.

* Light ray through transparent medium:

- Slab:

① Refracting surfaces are plane and parallel.



In a slab, light ray undergoes lateral shift.

② Let 't' be the thickness and 'i' be the angle of incidence.

$$\sin(i-r) = \frac{UR}{QR} \quad \text{— (i)}$$

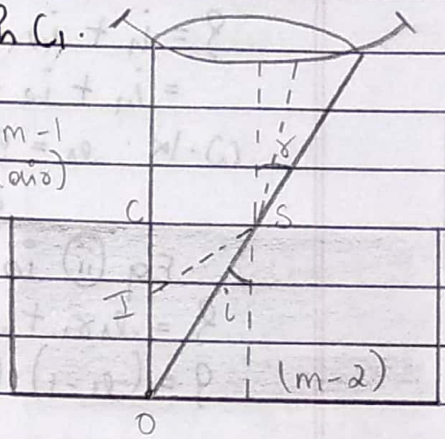
$$\cos r = \frac{t}{QR} \quad \text{— (ii)}$$

$$\therefore \frac{UR}{t} = \frac{\sin(i-r)}{\cos r}$$

$\therefore$ Lateral displacement = $\frac{t \sin(i-r)}{\cos r}$

③ Change in direction due to refraction.

Original depth CO. Apparent depth CI.



$^{2}\mu_{1} = \frac{\sin i}{\sin r}$

$= \frac{CS/OS}{CS/SI}$

$= \frac{SI}{OS}$

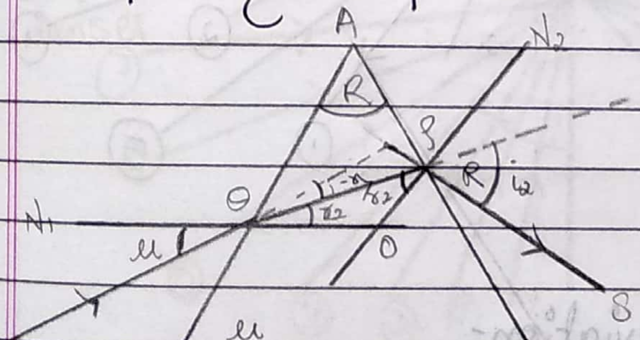
Sin S and C are very close.

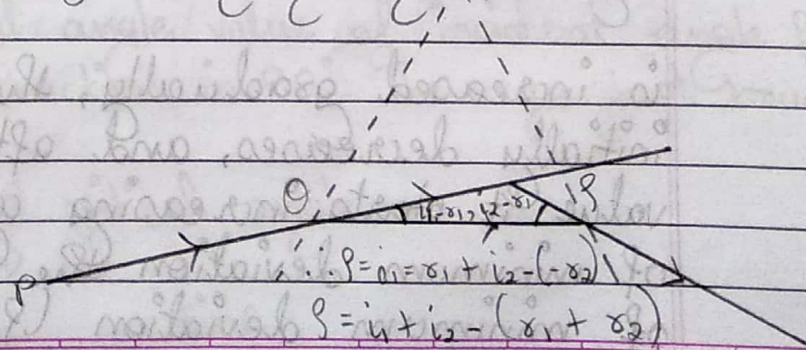
$^{2}\mu_{1} = \frac{CI}{CO}$ $\therefore \frac{1}{^{2}\mu_{1}} = \frac{CO}{CI} = {}^{1}\mu_{2}$

Refractive index of a material = $\frac{\text{Real depth}}{\text{Apparent depth}}$

- Prism:

① Refracting surfaces are plane but not parallel.





$\therefore \delta = i_1 - r_1 + i_2 - (-r_2)$

$\delta = i_1 + i_2 - (r_1 + r_2)$

$\angle O + \angle A = 180°$

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

$\therefore A = r_1 + r_2$ — (i)

$\delta = i_1 + i_2 - (r_1 + r_2)$

$= i_1 + i_2 - A$ — (ii)

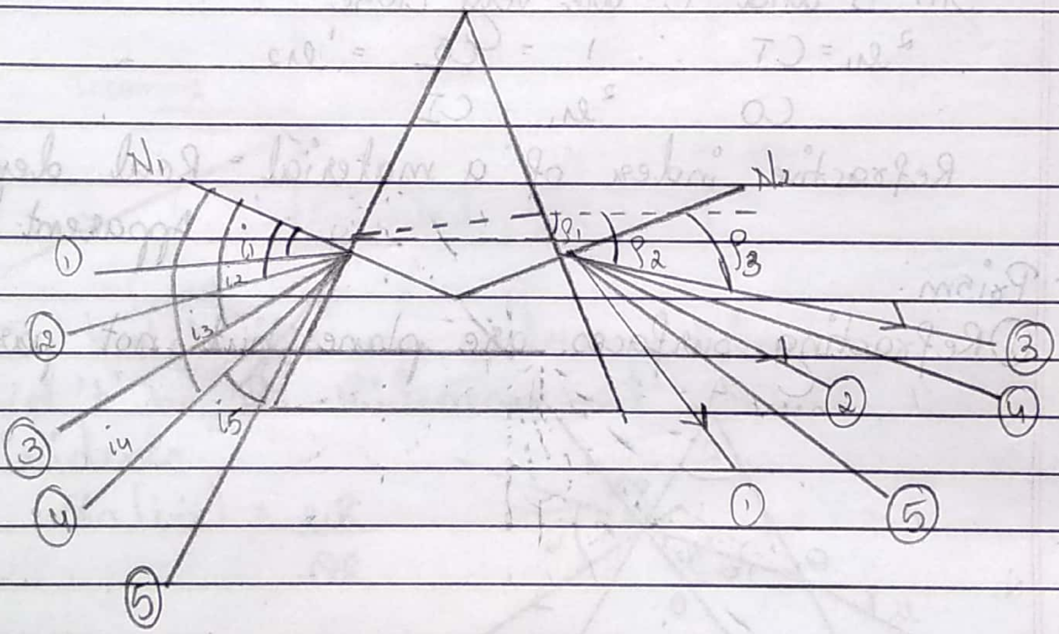
W.K. $\mu = \frac{\sin i}{\sin r} \simeq \frac{i}{2}$ $\therefore i = \mu . r$

$\therefore$ Eq (ii) is,

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

$\delta = (\mu - 1)(r_1 + r_2)$ $\therefore \delta = (\mu - 1) A$ — (iii)

* Relation between delta and 'i' :



Angle of minimum deviation-

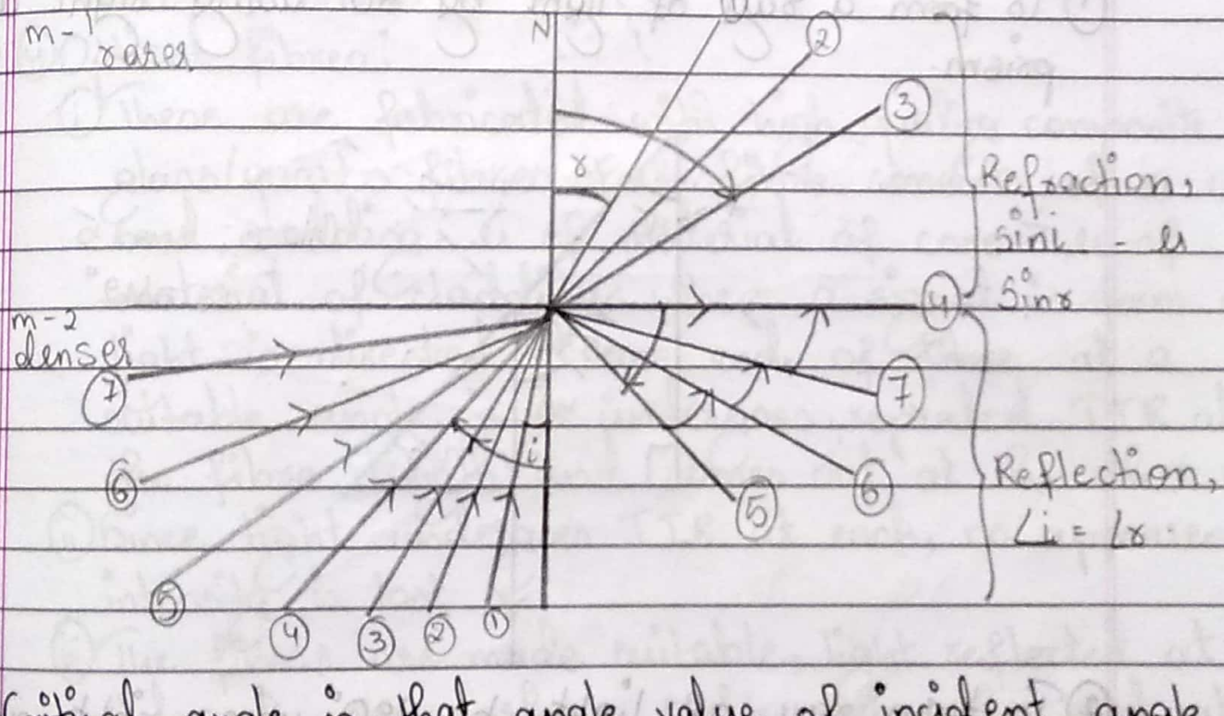
When incident angle is increased gradually, the angle of deviation initially decreases, and after obtaining a minimum value it starts increasing again. At that situation of minimum deviation the angle is called angle of minimum deviation (δ_m).

Note:
At this state it is observed that angle of $i_1 = i_2 = (i)$ and $r_1 = r_2 = (r)$.
Then by eq (i), $r = \frac{A}{2}$

Then, $\mu = \frac{\sin i}{\sin r} = \frac{\sin\left(\frac{\delta_m + A}{2}\right)}{\sin(A/2)}$

By eq (ii), $i = \frac{\delta_m + A}{2}$

* Total internal reflection:



- Critical angle is that angle value of incident angle for which angle of refraction is 90°. The ray just touches the surface.

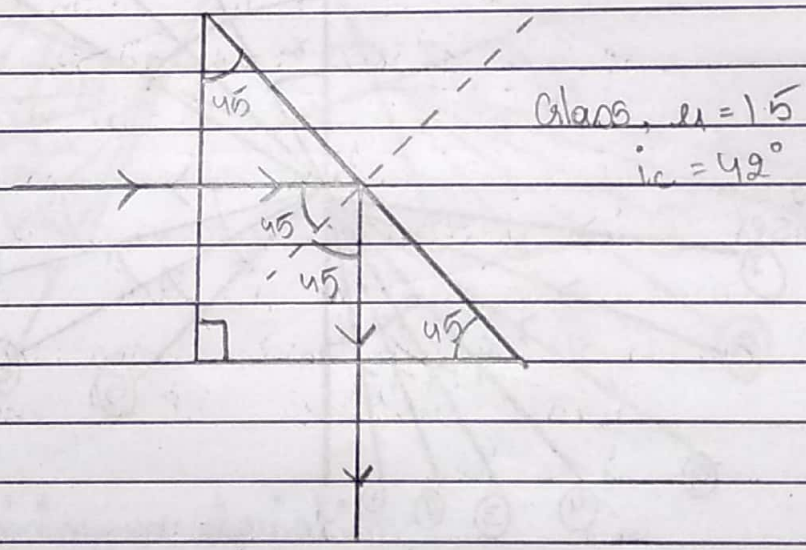
At that situation of critical angle -

$\frac{\sin i}{\sin r} = {}^2\mu_1 = \frac{\sin C}{1} \Rightarrow {}^1\mu_2 = \frac{1}{\sin C}$.

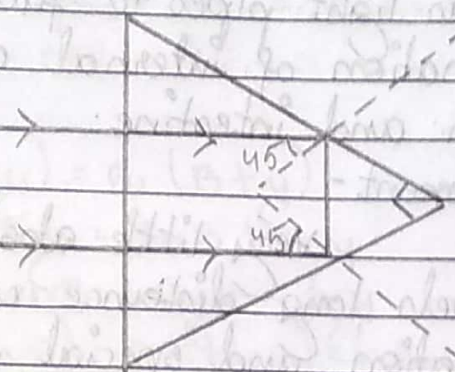
- Condition for total internal reflection:
  1. Incident ray is in denser medium.
  2. Angle of incidence should be larger than critical angle.

Medium	μ	Critical angle
1. Water	1.33	48.75°
2. Crown glass	1.52	41.14°
3. Flint glass	1.62	37.31°
4. Diamond	2.42	24.41°

- Application of total internal reflection:
  1. To form a ray of light by 90° using right angle prism.



  2. To turn ray of light by 180° using right angle prism.



③ Brilliance of diamond-

The brilliance of diamond is due to total internal reflection of light inside them. $i_c = 24°$ is very small. Therefore once light enters a diamond, it is very likely to go under TIR and by cutting the diamond suitably, multiple TIR can be made to occur.

④ Optical fibres:

(i) 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 form of light is directed at one end of fibre, at a suitable angle, it ~~is~~ undergoes repeated TIR along the fibre length and comes out at the other end.

(ii) Since light undergoes TIR at each, no appearence intensity is lost.

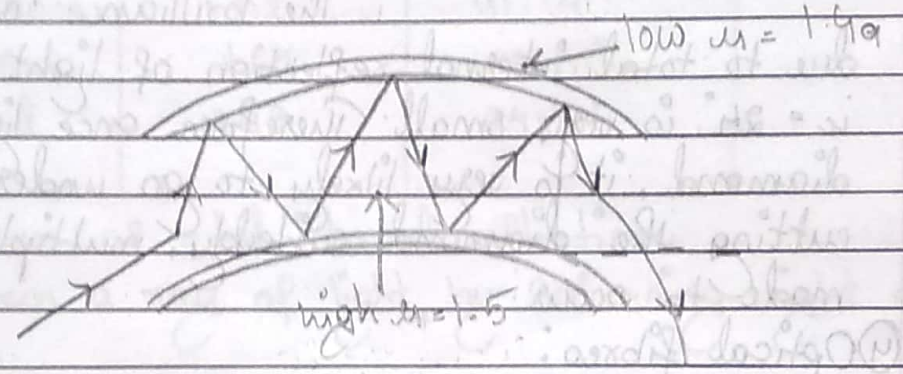
(iii) The fibres are made suitable, light reflected at one side of inner surface strike, the other end at an angle larger than this.

(iv) Even if wire is bent, light can travel easily. Thus it acts as optical pipes.

(v) Used for transmitting and receiving electrical signals.

(vi) Used as light pipes to facilitate visual examination of internal organs like oesophagus, stomach and intestine.

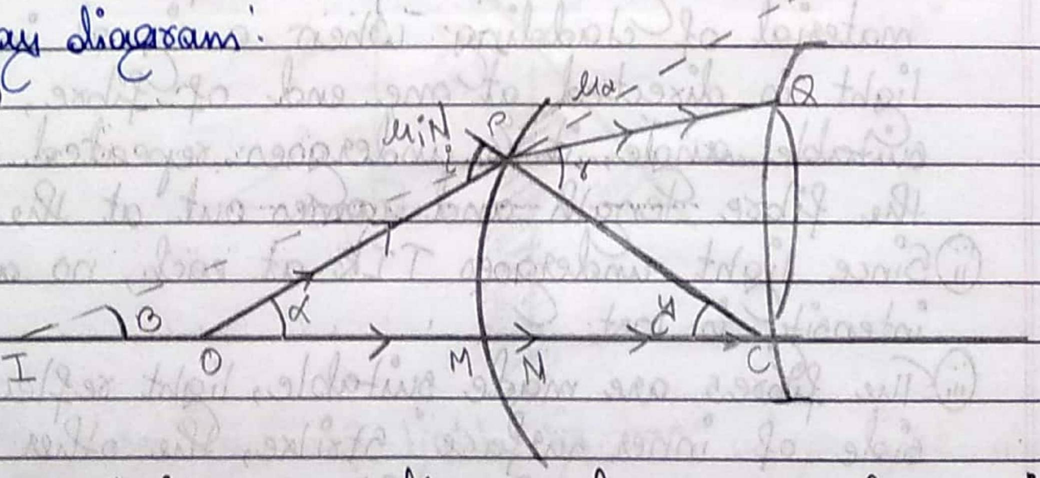
(vii) Requirement -
Very little absorption of light and it travels long distance can be done by purification and special preparation of material like quartz.



* Refraction at spherical surface:

- Ray diagram:

(1)



Object in rarer medium, surface convex, image virtual

For convenience - For small $\angle i = \sin i = i = \tan i$

Curvature is small.

∴ M and N are very close, μ_2 is always denser.

By Snells law: $\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1} \Rightarrow \mu_1 i = \mu_2 r$

$= \mu_1(\alpha + y) = \mu_2(\beta + y)$

$= \mu_1 \alpha + \mu_1 y = \mu_2 \beta + \mu_2 y$

$= \mu_1 \alpha - \mu_2 \beta = \mu_2 y - \mu_1 y$

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

$= \mu_1\left(\frac{PN}{ON}\right) - \mu_2\left(\frac{PN}{IN}\right) = (\mu_2 - \mu_1)\left(\frac{PN}{NC}\right)$

We know, $ON \simeq OM = -u$, $IN \simeq IM = -v$, $NC \simeq MC = R$.

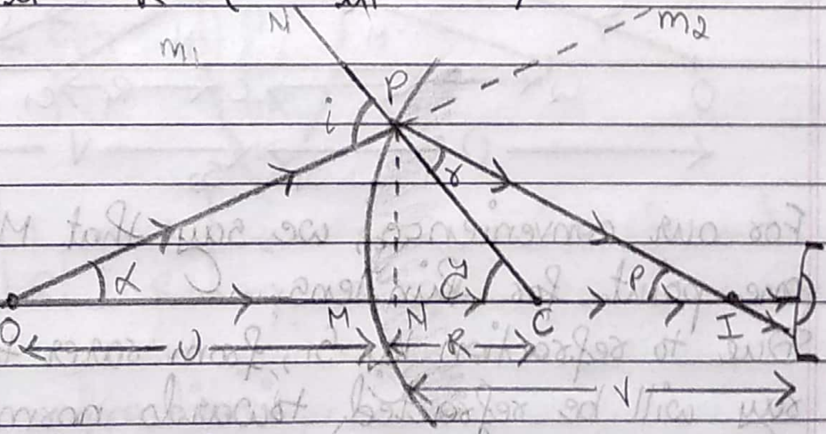
Putting value,

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

Dividing eq by μ_1

$\therefore \frac{\mu}{v} - \frac{1}{u} = \frac{\mu - 1}{R}$ $\left[\mu = \frac{\mu_2}{\mu_1} = \mu_{21}\right]$

(2)



Object in a rarer medium surface is convex, image is real

By Snells' law, $\mu_1 i = \mu_2 r$

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

$= \mu_1 \alpha + \mu_1 y = \mu_2 y - \mu_2 \beta$

$= \mu_1 \alpha + \mu_2 \beta = \mu_2 y - \mu_1 y$

$= \mu_1(\tan\alpha) + \mu_2(\tan\beta) = (\mu_2 - \mu_1)\tan y$

$= \mu_1\left(\frac{PN}{NO}\right) + \mu_2\left(\frac{PN}{NI}\right) = (\mu_2 - \mu_1)\left(\frac{PN}{NC}\right)$

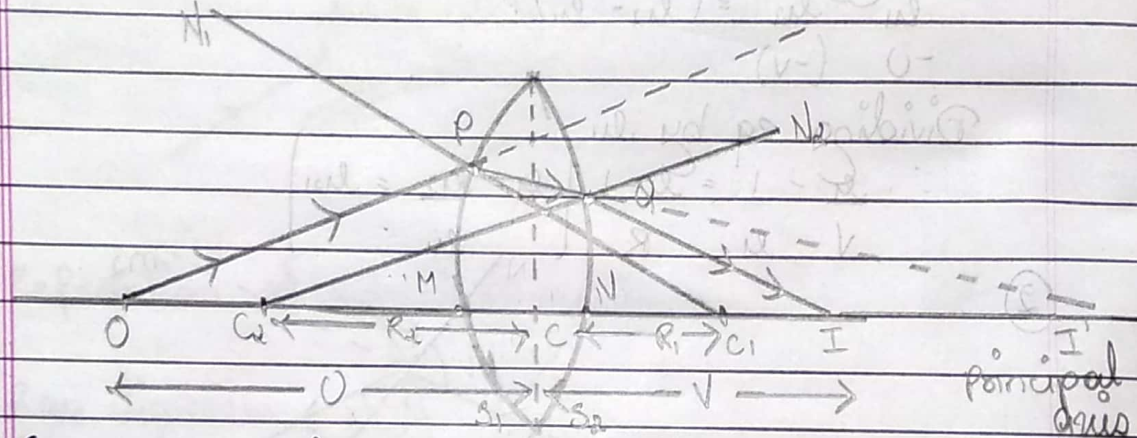
Putting values (NO = -u, NI = v, NC = R)

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

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

Note:
If object is in denser medium, exchange μ_1 & μ_2

* Lens maker formula:



For our convenience, we say that M & C & N are at one point for thin lens.
Due to refraction by S_1, from rarer to denser medium, ray will be refracted towards normal.

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

Putting values (geometrical)

$$\frac{\mu_2}{CI'} - \frac{\mu_1}{(-CO)} = \frac{\mu_2 - \mu_1}{+CC_1} \quad \text{— (i)}$$

Refraction due to S_2, from denser to rarer medium, ray will be refracted away from normal.

$$\frac{\mu_1}{V} - \frac{\mu_2}{U} = \frac{\mu_1 - \mu_2}{R}$$

Putting values,

$$\frac{\mu_1}{CI} - \frac{\mu_2}{CI'} = \frac{\mu_1 - \mu_2}{(-CC_2)} \quad \text{—— (ii)}$$

Adding eq (i) and (ii)

$$\frac{\mu_1}{CI} + \frac{\mu_1}{CO} = (\mu_2 - \mu_1)\left(\frac{1}{CC_1} + \frac{1}{CC_2}\right)$$

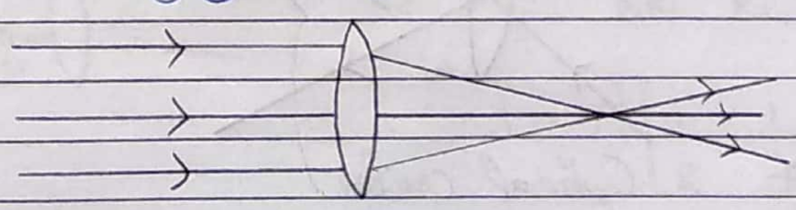
$$\frac{1}{CI} + \frac{1}{CO} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{CC_1} + \frac{1}{CC_2}\right)$$

$$\frac{1}{V} - \frac{1}{U} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{F} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$ ← Lens maker formula.

* Lens and its refraction:

- Convex (converging). Bulged at centre:



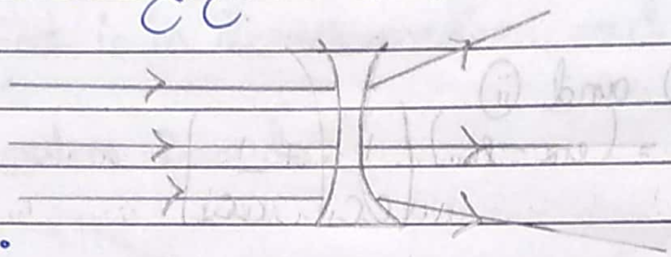
Types:

① Double convex - 

② Plance convex - 

③ Concave convex - 

- Concave (diverging). Pressed at centre:



Types:

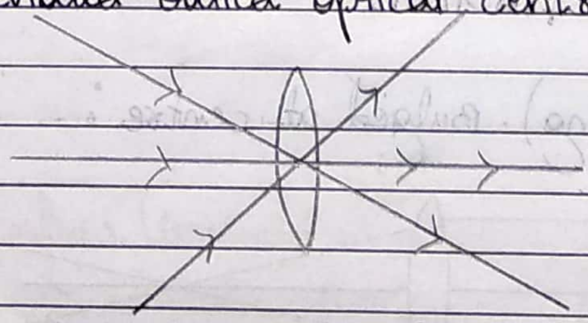
① Double concave - 

② Convex concave - 

③ Plane concave - 

- Focus of a lens:

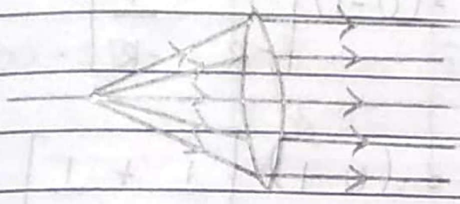
① There is a point on principal axis incide lens such that any rays passing through it comes out undeviated called optical centre.

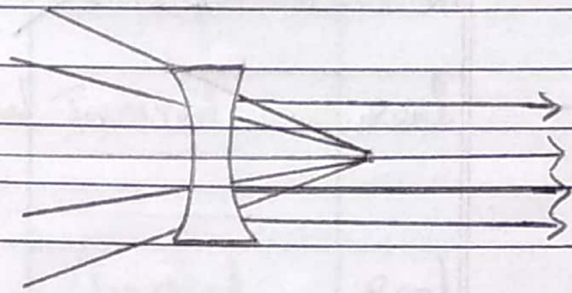


Optical centre

② Principal focus 1 -

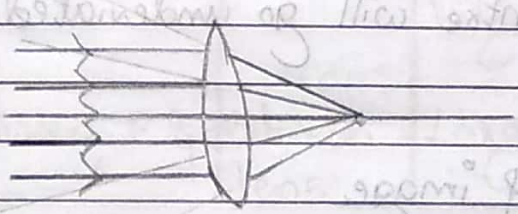
A point on principal axis such that rays coming from its direction will become parallel after reflection.

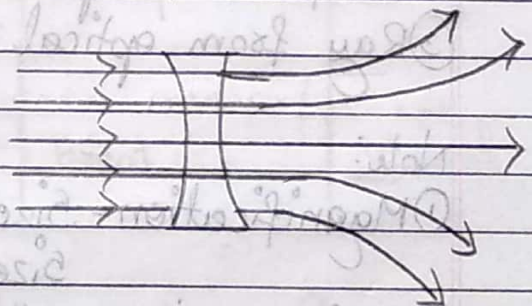




③ Principle focus 2 -

Principle focus 2 is a point on priciple axis such that parallel incident rays, after refraction, converge at this point or appear to come from this point.

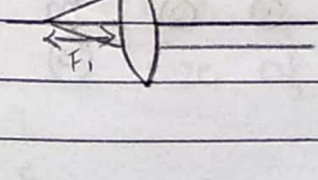




Note:
Focal length, $F_1 = F_c = F$.

- Positive (+ve) or negative (-ve) focal length:

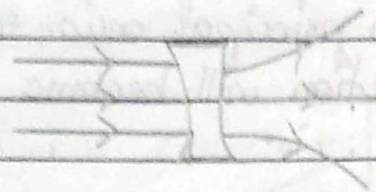
① Convex lens:



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

$$= (\mu - 1)\left[\frac{1}{R} - \frac{1}{-R}\right] = +ve.$$

② Concave lens:



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

$$= (\mu - 1)\left[\frac{1}{-R} - \frac{1}{-R}\right]$$

$$= -(\mu - 1)\left[\frac{1}{R} + \frac{1}{R}\right] = -ve.$$

- Rules for image formation in lens:

① Ray coming from direction of focus will become parallel to principle axis.

② Ray incident parallel to principle axis will insert at focus on principle axis.

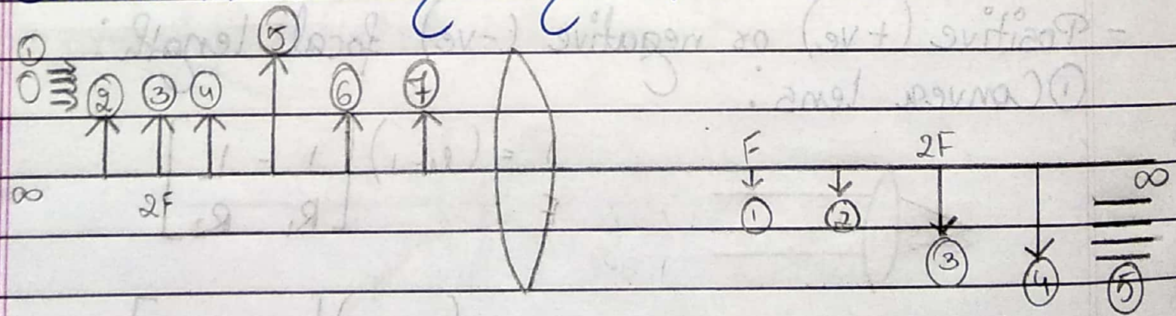
③ Ray from optical centre will go undeviated.

Note:

① Magnification = $\frac{\text{Size of image}}{\text{Size of object}}$

② Thick lens: Less focal → More power.

- Convex mirror (Ray diagram):



Object	Image			
	Location	Size	Orientation	Nature
① ∞	At focus	Point	Point inverted	Real
② ∞ - 2F	Between F & 2F	Diminished	Inverted	Real
③ At 2F	At 2F	Same	Inverted	Real
④ Between 2F & F	Between 2F & ∞	Enlarged	Inverted	Real
⑤ At F	At ∞	Very large	Undefined	Undefined
⑥ Between F & O	Between lens	Large	Erect	Virtual

* Lens formula and combination of lens:

- Lens formula:

$$\frac{1}{V} - \frac{1}{U} = \frac{1}{F}$$

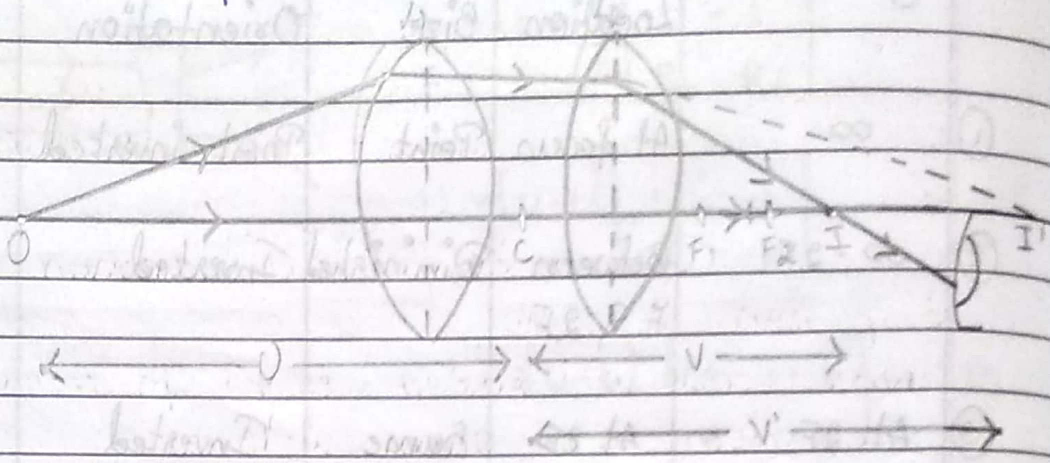
- Magnification (m):

$$m = \frac{\text{size of image}}{\text{size of object}} = \frac{V}{U}$$

- $P = \frac{1}{F}$

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

- Combination of lens:



By refraction through 1st lens;

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{F} \Rightarrow \frac{1}{CI'} - \frac{1}{(-CO)} = \frac{1}{CF_1}$$

$$= \frac{1}{CI'} + \frac{1}{OC} = \frac{1}{CF_1}$$

By refraction through 2nd lens:

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{F} \Rightarrow \frac{1}{CI} - \frac{1}{CI'} = \frac{1}{CF_2}$$

Adding 1st and 2nd eq.

$$\frac{1}{CI} + \frac{1}{CO} = \frac{1}{CF_1} + \frac{1}{CF_2}$$

Putting values in terms of u, v and F.

$$= \frac{1}{V_c} + \frac{1}{(-U)_c} = \frac{1}{F_1} + \frac{1}{F_2}$$

$$= \frac{1}{V_c} - \frac{1}{U_c} = \frac{1}{F_c} = \frac{1}{F_1} + \frac{1}{F_2}$$

Scanned by CamScanner

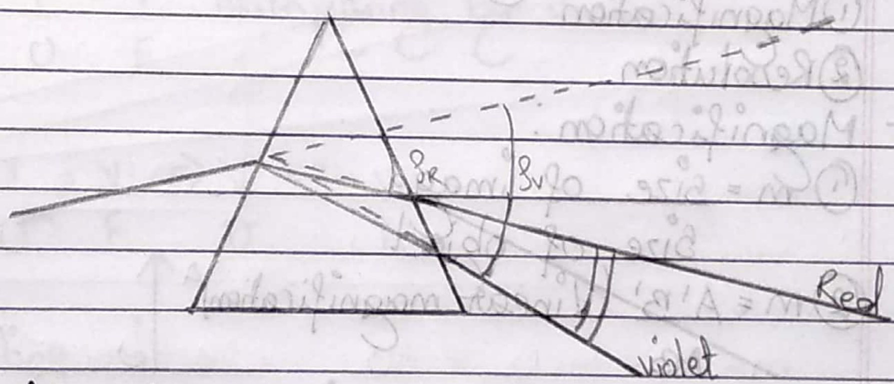
* Dispersion of light :

- A light which is combination of different colours travelling in parallel direction, pass through a prism then their direction become different and angle is developed between them. This phenomena is called dispersion of light.
- These colours are divided into 7 main types - Violet, Indigo, Blue, Green, Yellow, Orange and Red.
- Reason -

Refractive index of one medium is different for different colours. Therefore, deviation is different.

$\mu_v = \mu_{red}$, δ_v δ_{Red}

- Angle of dispersion:



Angle of dispersion $= \delta_v - \delta_R$
$= (\mu_v - 1)A - (\mu_R - 1)A$

$\therefore$ Angle of dipersion $= (\mu_v - \mu_R)A$

- Power of dispersion (ω):

$$\omega = \frac{\text{dispersion angle}}{\text{mean deviation}}$$

$$= \frac{\delta_v - \delta_R}{\delta_m} = \frac{(\mu_v - \mu_R)A}{(\mu_y - 1)A}$$

$= \frac{\mu_v - \mu_R}{\mu_y - 1}$ (Independent of 'A' (Prism): It is a property of material of prism).

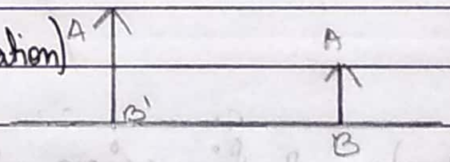
* Natural phenomena - 'Rainbow':

Q Why rainbow is semicircular arc?

Ans Rainbow is locus of all the point which fulfills condition of angle ($40° - 42°$) between sunrays and observer (a point). According to geometry only point in an arc fulfills this condition.

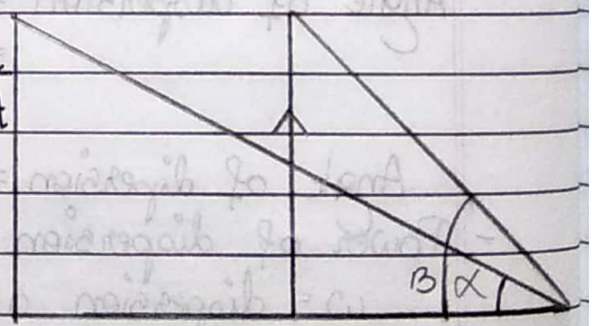
* Optical instrument (Microscope):

- Function of a good optical instrument:
  ① Magnification
  ② Resolution
- Magnification:
  ① $m = \frac{\text{Size of image}}{\text{Size of object}}$
  ② $m = \frac{A'B'}{AB}$ (Linear magnification)



③ Angular magnification:
$m = \frac{\text{angle subtended by image}}{\text{angle subtended by object placed at same place}}$

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

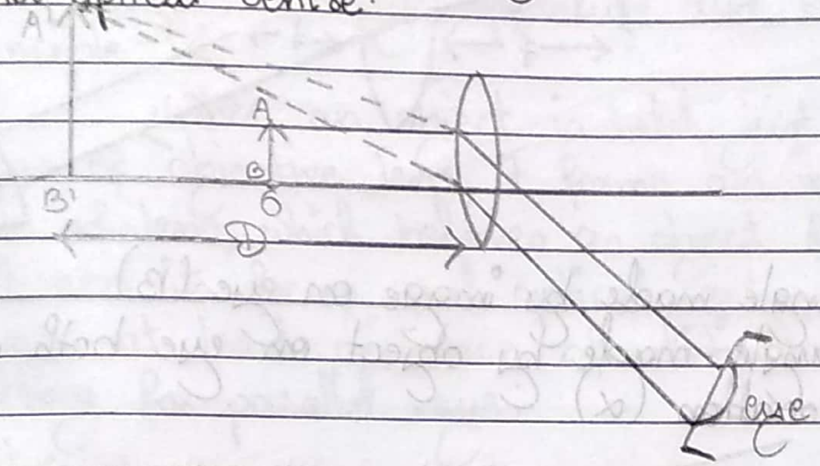


* Microscope :

- Simple microscope :

① Magnifying glass.

② Convex lens such that object is placed between focus and optical centre.



$\frac{1}{v} - \frac{1}{u} = \frac{1}{F}$. multiplying by v.

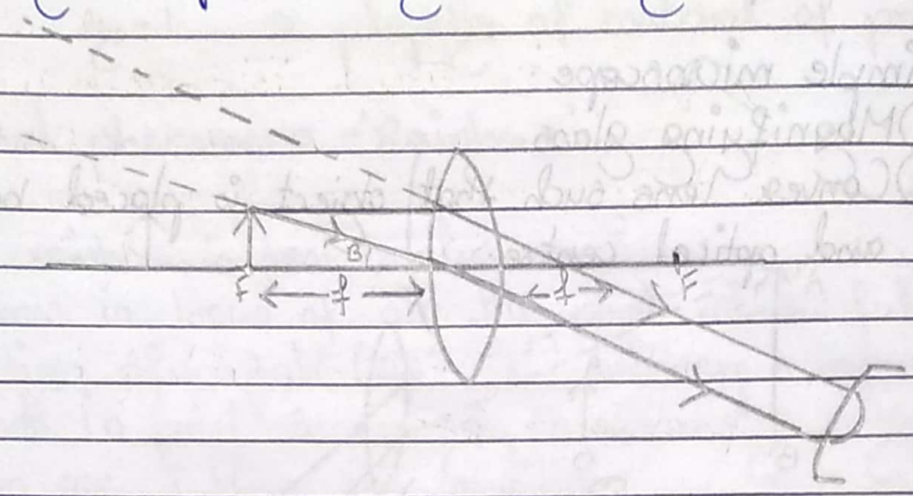
$1 - \frac{v}{u} = \frac{v}{F} \Rightarrow \frac{v}{u} = 1 - \frac{v}{F}$

Putting values

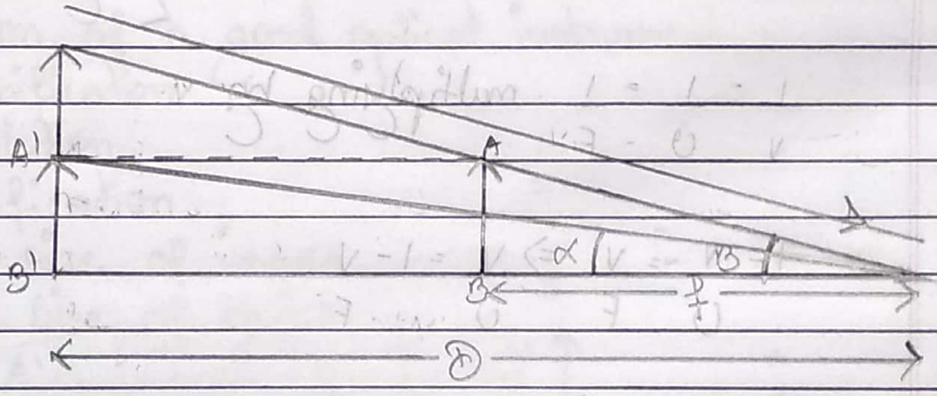
$m = 1 - \frac{(-D)}{F}$

$\therefore m = 1 + \frac{D}{F}$

③ Setting for parallel rays, relaxed eye:



$$m = \frac{\text{angle made by image on eye } (\beta)}{\text{angle made by object on eye both at same location } (\alpha)}$$



$$m = \frac{\beta}{\alpha} \simeq \frac{\tan\beta}{\tan\alpha} = \frac{\frac{AB}{OB}}{\frac{A'B'}{OB'}} = \frac{AB}{OB} \times \frac{OB'}{A'B'}$$

$$= \frac{OB'}{OB} = \frac{-D}{-F} = \frac{D}{F}$$

∴ For distint $m = 1 + \frac{D}{F}$, for parallel rays $m = \frac{D}{F}$

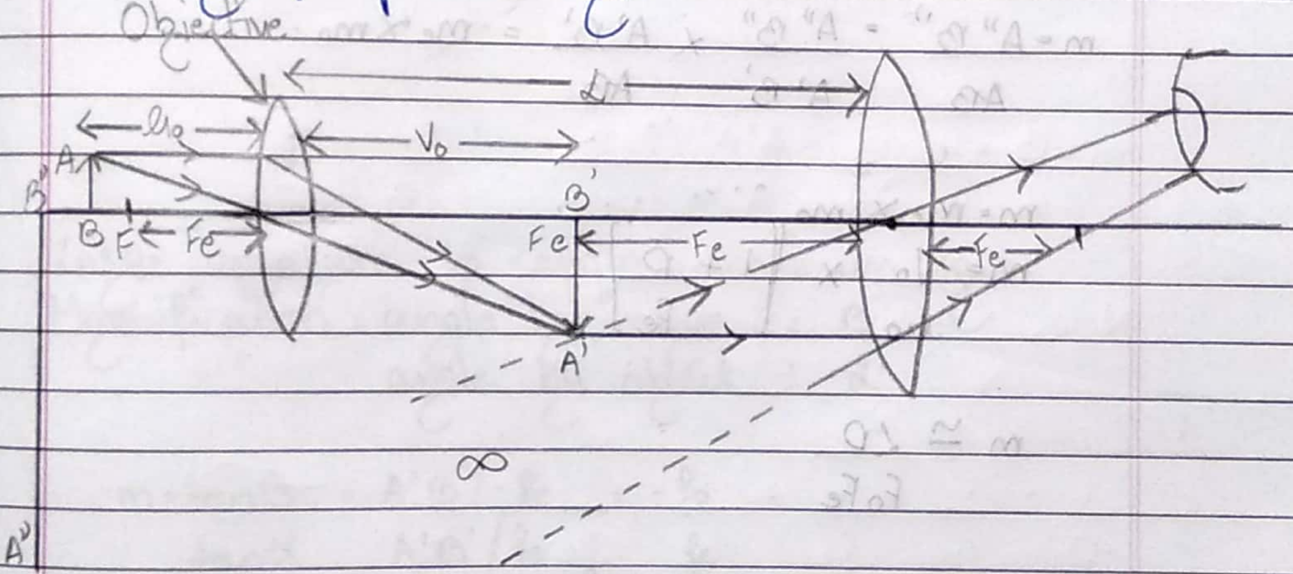
- Compound microscope:

① It consists of 2 lenses called objective and eye lens is ~~chosen as convex lens~~ respectively, objective lens is chosen as convex lens by short aperture and short focal length whereas eye lens is chosen as convex lens of large appeerature and short focal length.

② Principle -

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

③ Setting for parallel rays:



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

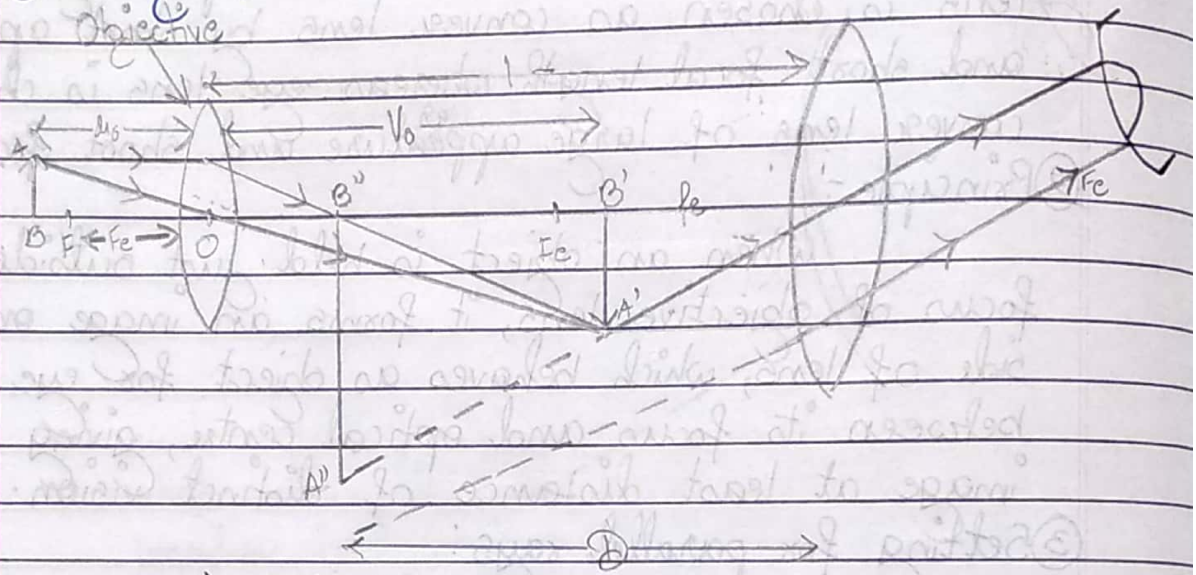
$$= m_e \times m_o$$

$$\therefore m = m_e \times m_o$$

$$m = \frac{v_o}{u_o} \times \frac{D}{F_e} \simeq \frac{LD}{F_oF_e}$$

In compound microscope Fo, Fe both should be small.

④ Setting for distinct vision:



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

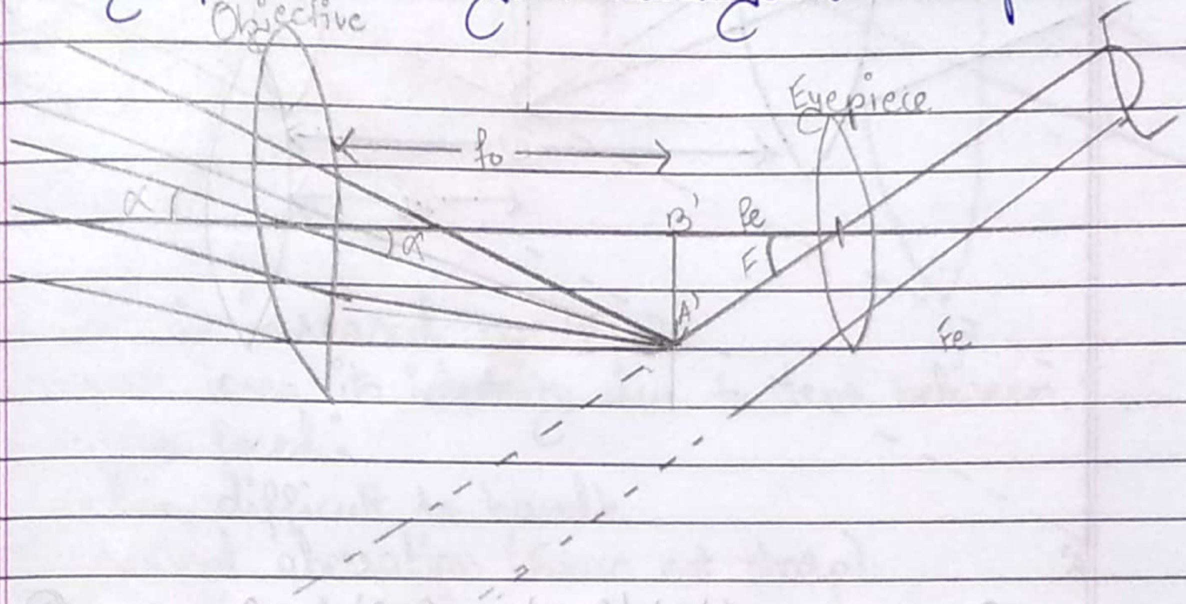
$$m = m_e \times m_o$$

$$m = \frac{V_o}{u_o} \times \left[1 + \frac{D}{F_e}\right]$$

$$m \simeq \frac{LD}{F_o F_e}$$

* Telescope:

- Telescope is a device used to observe far off objects.
- Used to magnify and resolved.
- Setting for relaxed eye and rays will be parallel:

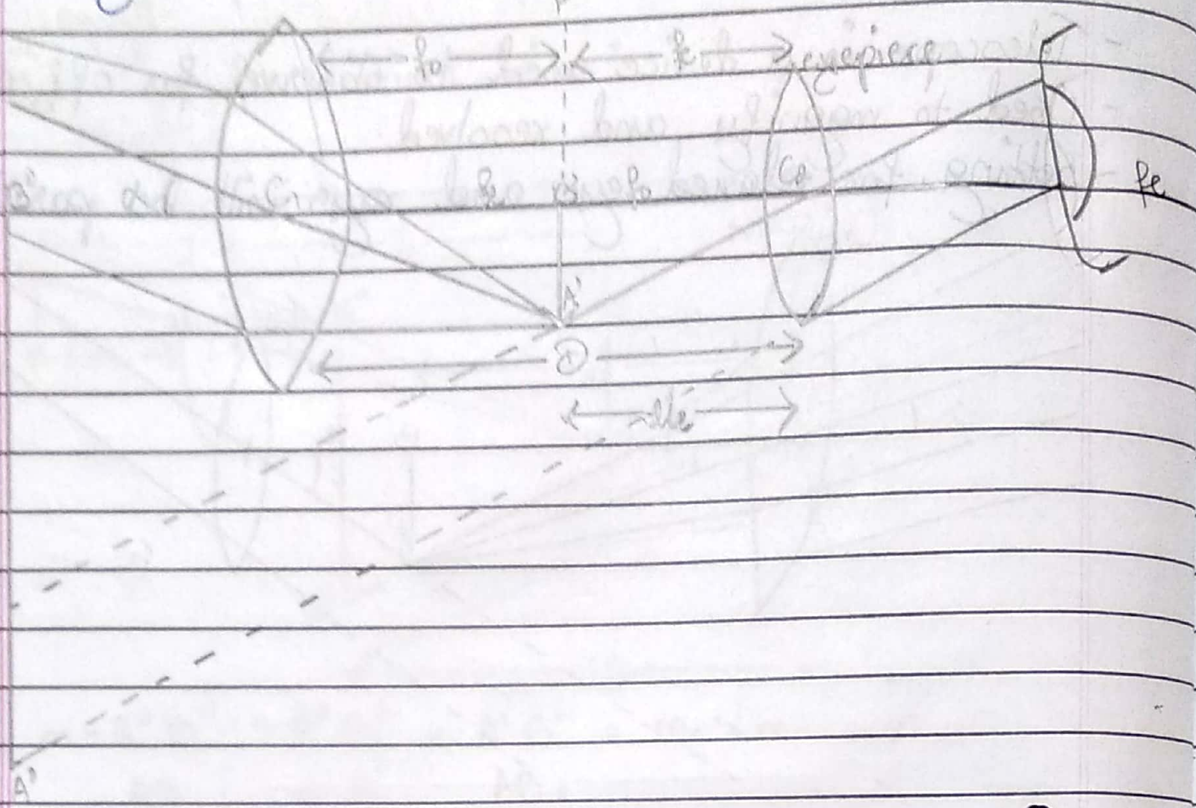


Large aperture to capture maximum rays.

Magnification = $\dfrac{\text{angle by image}}{\text{angle by object}} = \dfrac{\beta}{\alpha}$

$$\therefore\ m = \frac{\tan\beta}{\tan\alpha} = \frac{A'B'/-f_e}{A'B'/f_o} = \frac{-f_o}{f_e}$$

- Setting for distinct vision:



$$m = \frac{\beta}{\alpha} = \frac{\tan\beta}{\tan\alpha} = \frac{A'B'/C_2B'}{A'B'/C_1B'} = \frac{C_1B'}{C_2B'} = \frac{f_o}{-u_e} \quad \text{— (i)}$$

Now, $\frac{1}{v} - \frac{1}{u} = \frac{1}{F}$ (For eyepiece)

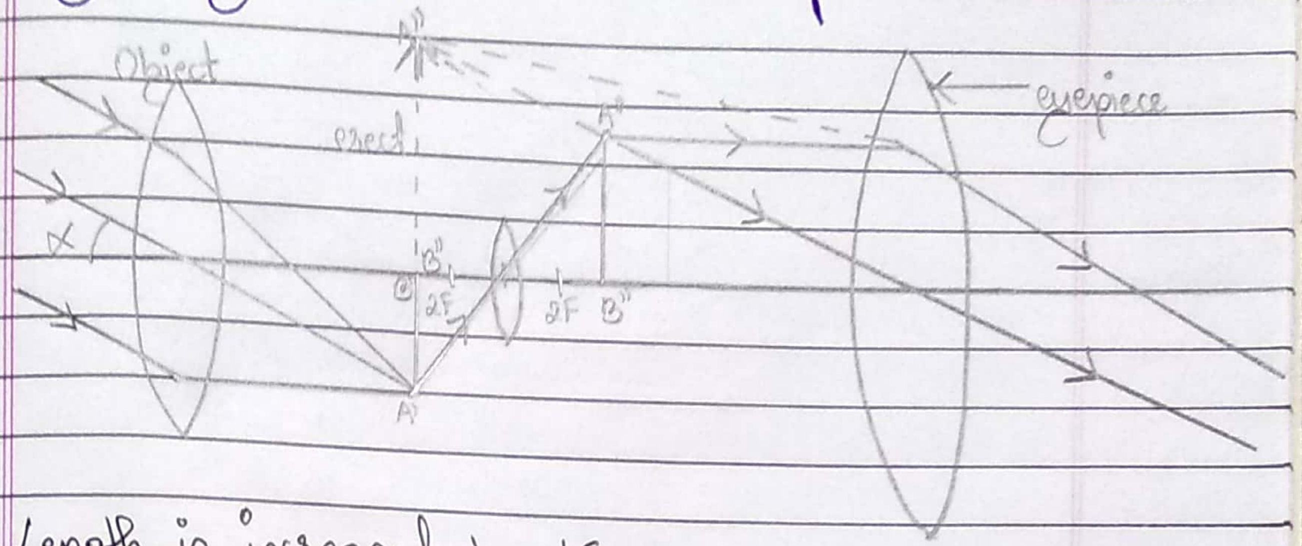
$$\frac{1}{-D} - \frac{1}{-u_e} = \frac{1}{f_e} = \frac{1}{u_e} = \frac{1}{f_e} + \frac{1}{D} \quad \text{— (ii)}$$

Now eq (i) becomes,

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

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

* Ray diagram for telestial telescope:



- Length is increased by 4F.
- Image loses its intensity due to lens between
- Problems faced:
  1. Bulky, difficult to handle.
  2. Spherical aberration (Focus not sharp).
  3. Chromatic aberration
- To overcome these problems we use reflective type telescope:
  1. Spherical aberration corrected.
  2. Chromatic aberration corrected.
  3. Light weight and easy to use.
  4. Aperture can be made very large. Therefore, light gathering capacity is large.