Ray Optics

CBSE *CLASS NOTES*

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Ray Optics and Optical Instruments.

Optics

It is the branch of physics which deals with the study of Nature, production and propagation of light.

Branches

(1) Ray or geometrical optics

It concerns itself with the particle nature of light and is based on

(i) Rectilinear propagation of light

(ii) the laws of reflection and refraction of light.

(2) wave or Physical optics

It concerns itself with the wave nature of light and is based on the phenomena like

(i) Interference

(ii) diffraction

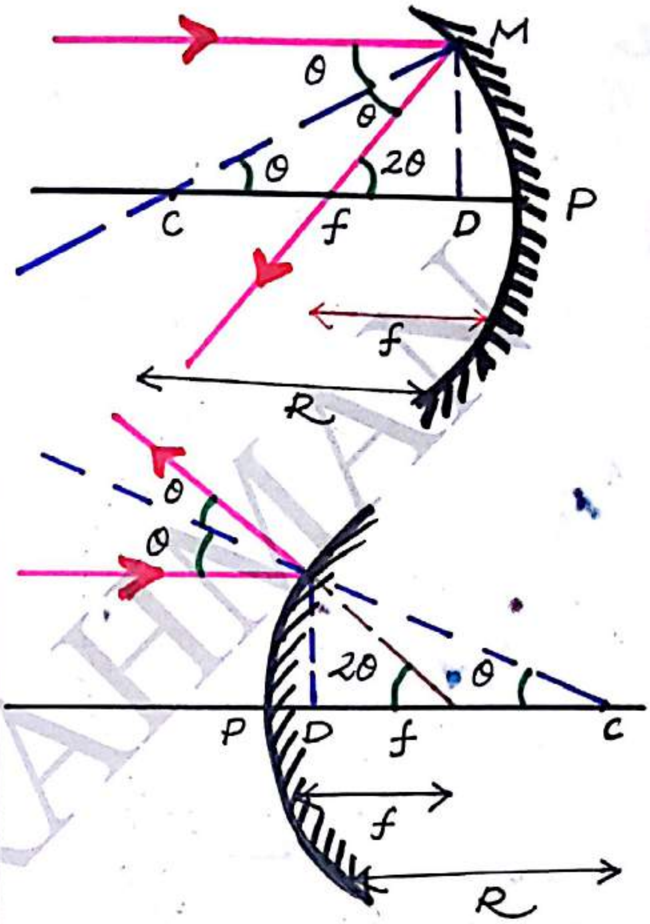
(iii) Polarisation

laws of reflection

(i) $\angle i = \angle r$

(ii) Incident ray, reflected ray and normal all lie in the same plane.

Relation b/w f and R



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

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

for small angles

$\tan\theta = \theta$

$\tan 2\theta = 2\theta$

$$\therefore \theta = \frac{MD}{CD} \quad \ldots (1)$$

$$2\theta = \frac{MD}{DF} \quad \ldots (2)$$

sub (1) in (2)

$$2\frac{MD}{CD} = \frac{MD}{DF}$$

$$\frac{2}{CD} = \frac{1}{DF}$$

$CD \approx CP$

$CP = R$

$\therefore CD = R$

$DF = f$

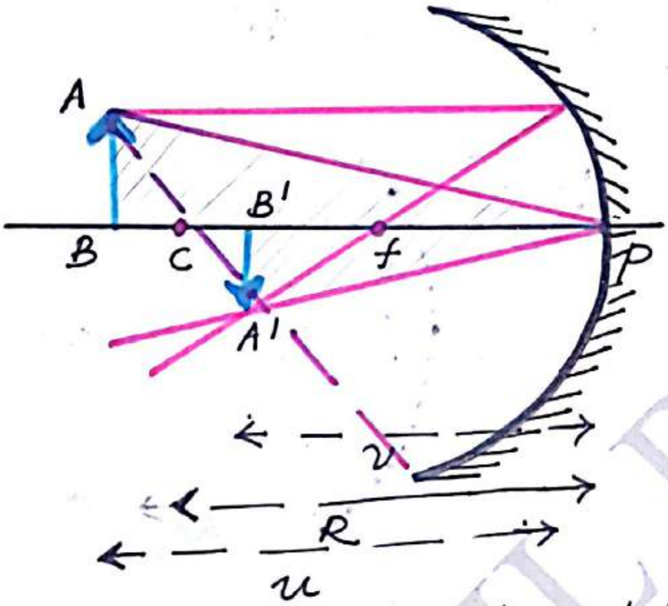
$$\therefore \frac{2}{R} = \frac{1}{f}$$

$R = 2f$

Spherical Mirrors

A spherical mirror is a reflecting surface which forms part of hollow sphere.
- convex
- concave

Mirror formula - concave mirror real image



ΔABC and $\Delta A'B'C$ are similar

$$\frac{AB}{A'B'} = \frac{CB}{CB'} \quad \dots (1)$$

ΔABP and $\Delta A'B'P$ similar

$$\frac{AB}{A'B'} = \frac{PB}{PB'} \quad \dots (2)$$

$(1) = (2)$

$$\frac{CB}{CB'} = \frac{PB}{PB'}$$

$$\frac{PB - PC}{PC - PB'} = \frac{PB}{PB'}$$

$$\frac{-u-(-R)}{-R-(-V)} = \frac{-u}{-V}$$

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

$$-uV + VR = -uR + uV \quad \dots (3)$$

$(3) \div uVR$

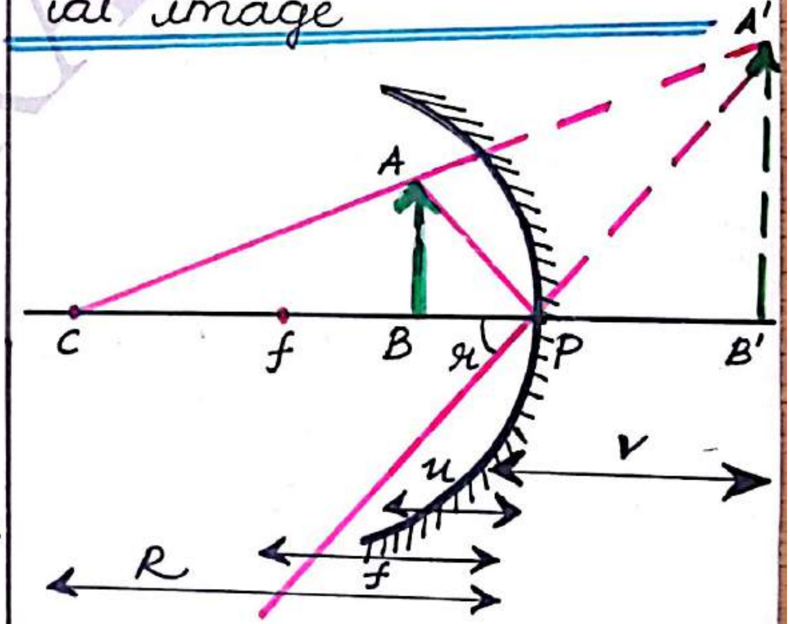
$$-\frac{1}{R} + \frac{1}{u} = -\frac{1}{V} + \frac{1}{R}$$

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

but $\frac{2}{R} = \frac{1}{f}$

$$\frac{1}{V} + \frac{1}{u} = \frac{1}{f} \quad \dots \text{mirror formula}$$

Mirror formula - concave mirror - virtual image



ΔABC and $\Delta A'B'C$ similar

$$\frac{AB}{A'B'} = \frac{CB}{CB'} \quad \dots (1)$$

ΔABP and $\Delta A'B'P$. similar

$$\frac{AB}{A'B'} = \frac{PB}{PB'} \quad \dots (2)$$

$(1) = (2)$

$$\frac{CB}{CB'} = \frac{PB}{PB'}$$

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

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

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

$$-RV+uV = uR-uV \cdots (3)$$

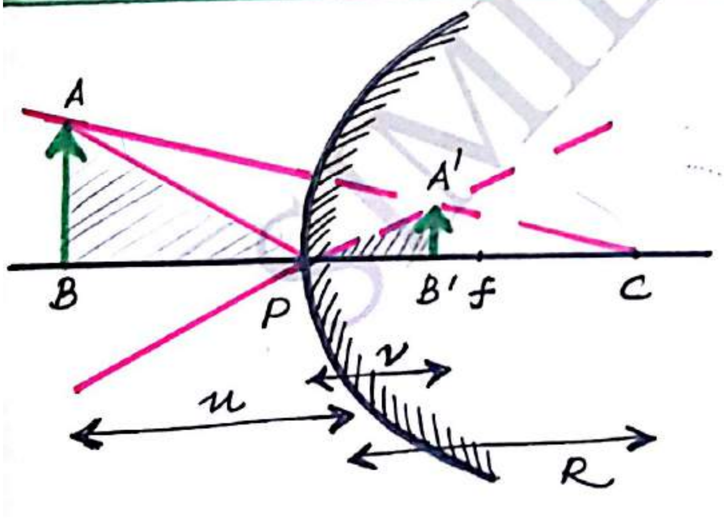
(3) $\div\ uVR$

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

$$\frac{1}{V}+\frac{1}{u} = \frac{2}{R} \qquad \frac{2}{R}=\frac{1}{f}$$

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

Mirror formula -
convex mirror - virtual image



ΔABC and $\Delta A'B'C$ - similar

$$\frac{AB}{A'B'} = \frac{CB}{CB'} \cdots\cdots (1)$$

ΔABP & $\Delta A'B'P$ - similar

$$\frac{AB}{A'B} = \frac{PB}{PB'} \cdots\cdots (2)$$

(1) = (2)

$$\frac{CB}{CB'} = \frac{PB}{PB'}$$

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

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

$$-uV+VR = -uR+uV \cdots (3)$$

(3) $\div\ uVR$

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

$$\frac{1}{V}+\frac{1}{u} = \frac{2}{R} \qquad \frac{2}{R}=\frac{1}{f}$$

$$\boxed{\frac{1}{V}+\frac{1}{u} = \frac{1}{f}}$$ → mirror formula

Magnification
- Mirror

$$\boxed{m = \frac{h_i}{h_o} = \frac{-V}{u} = \frac{f}{f-u} = \frac{f-V}{f}}$$

Applications of convex and concave mirrors

concave mirror:- Dentists, torch light, shaving mirror.

convex mirror:- Rear view mirror, reflection in streat lamps.

REFRACTION

The phenomenon of the change in

the path of light as it passes obliquely from one transparent medium to another is called refraction of light.

Laws of refraction

1; Incident ray, refracted ray, normal all lie in the same plane

2; Snells law

$$\frac{\sin i}{\sin r} = n_{21} = \frac{n_2}{n_1}$$

* Absolute Refractive Index

$$\mu = \frac{c}{v} = \frac{\nu \lambda_{air}}{\nu \lambda_{med}} = \frac{\lambda_{air}}{\lambda_{med}}$$

μ = velocity of light in vaccum / velocity of light in medium

$$\therefore \mu = \frac{c}{v} = \frac{\lambda_{air}}{\lambda_{medium}}$$

* write expressions for the refractive index of second medium w.r.t refractive index of first medium interms of speed, λ and refractive index

$$n_{21} = \frac{n_2}{n_1} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} = \frac{1}{n_{12}}$$

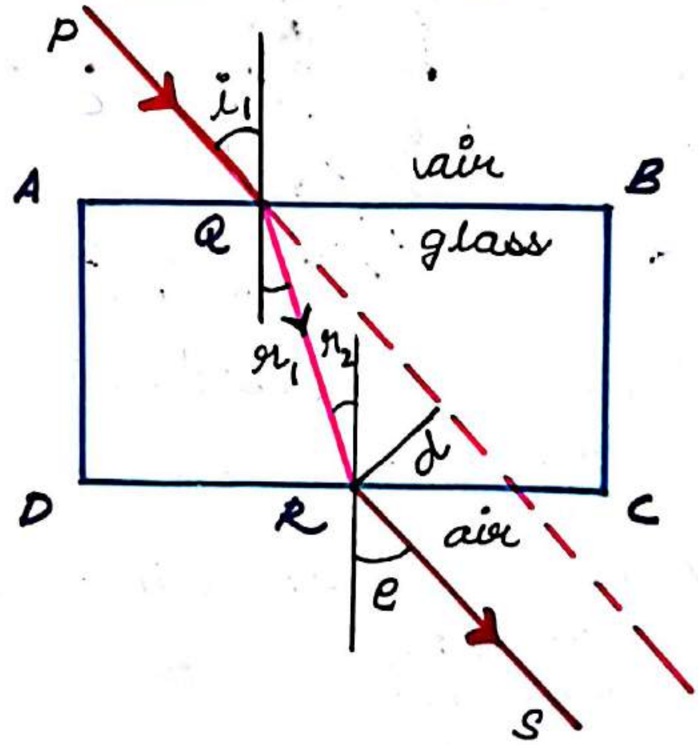
* constant quantities in refraction
(a) frequency
(b) energy $E = h\nu$

* write physical quantities which changes when a light ray passes from one medium to another medium.

λ and speed will change.

* factors on which refractive index depend upon
(a) nature of medium
(b) λ of light

* when a light ray passes through parallel sides of a glass slab
(i) show that $\angle i = \angle e$
(ii) Give expression for lateral shift.



Let ABCD be a glass prism, PQ - Incident ray
QR - refracted ray
RS - emergent ray.

Due to refraction at face AB

$$\mu = \frac{\sin i_1}{\sin r_1} \quad \ldots (1)$$

Due to refraction at face CD

$$\mu = \frac{\sin e}{\sin r_2} \quad \ldots (2)$$

from (1) and (2)

$i_1 = e$
$r_1 = r_2$

$\therefore \angle i = \angle e$
$\angle r_1 = \angle r_2$

* Emergent ray is parallel to incident ray, but it is laterally displaced
* Expression for lateral shift

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

Lateral Shift

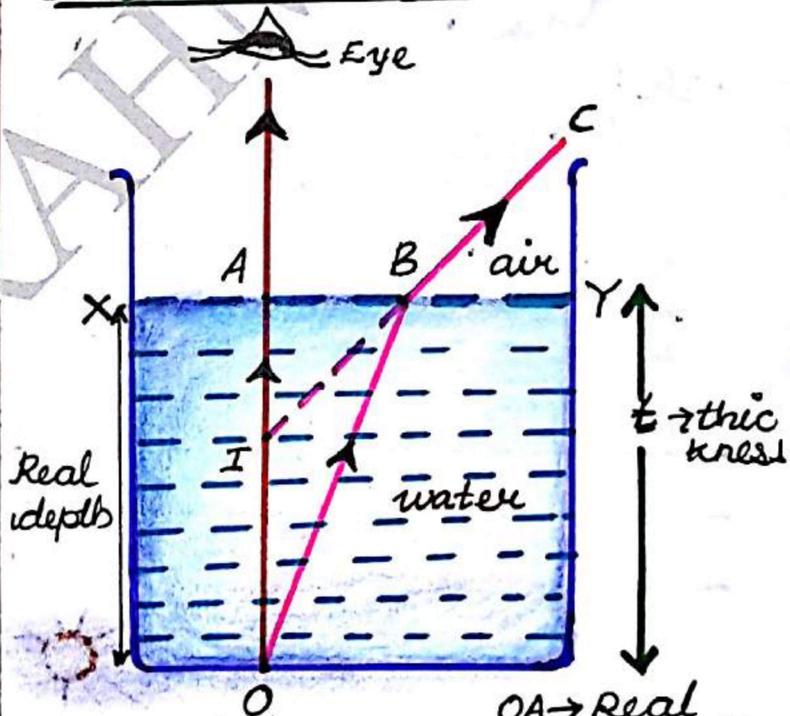
The perpendicular distance between the direction of incident ray and emergent ray, when light ray passes through parallel sides of a glass slab.

(3)

* lateral shift Increases with
  (1) increase in thickness of glass slab
  (2) Increase of angle of Incidence
  (3) Increase of refractive Index of glass slab.

Application of Refraction

Normal Shift



OA → Real depth
AI - apparent depth
OI - shift

Eg; coins appears to be raised.

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

$$\mu = \frac{OA}{AI}$$

$$\boxed{AI = \frac{OA}{\mu}} \quad \dots\dots (1)$$

* [if the observer is in rarer medium and object is in denser medium]

shift in position

$$\boxed{S = OI = OA - AI} \quad \dots\dots (2)$$

(1) in (2)

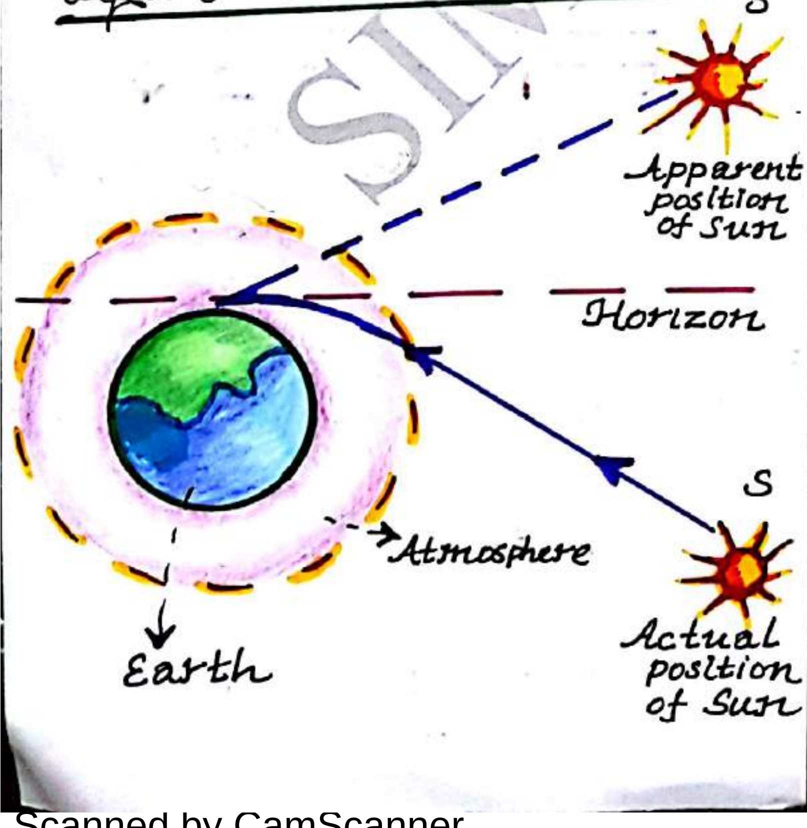
$$S = OA - \frac{OA}{\mu} = OA\left(1 - \frac{1}{\mu}\right)$$

$$\boxed{S = t\left(1 - \frac{1}{\mu}\right)}$$

Note:

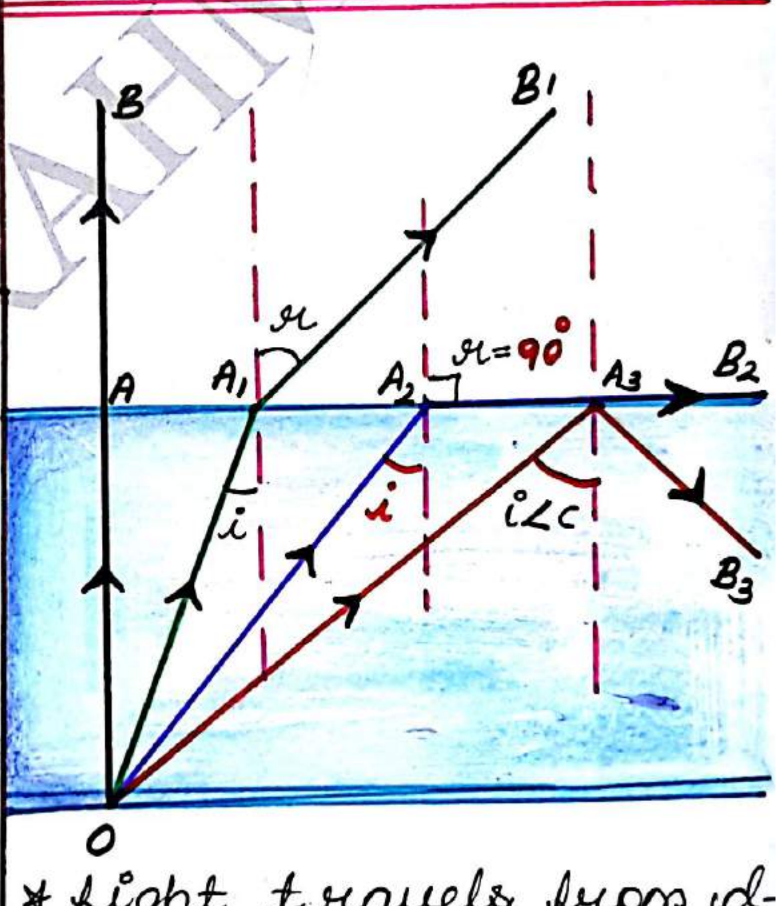
$$\mu = \frac{\text{App depth}}{\text{Real depth}}$$ if observer is in denser medium and object is rarer medium

* <u>Sun is visible before actual sunrise and after actual sunset.</u>



* Before sunrise and after sunset - sun 'S' is below the horizon.
* Sun light bends towards the normal as it travels from sun (rarer) to earth (denser) to reach observer
* Due to this atmospheric refraction sun appears above horizontal.

TIR
Total Internal Reflection



* Light travels from denser to rarer medium along OA and gets refracted along AB
* Increase in angle of incidence the ray 'OA1' gets refracted along A_1B_1.
* Still Increase in angle of Incidence OA_2 gets

refracted along A_2B_2 so that $\angle r = 90°$. The Angle of Incidence is called critical Angle.

* still increase in angle of incidence ie, $\angle i > c$ (greater than critical angle), now the ray OA_3 gets refracted along A_3B_3. This is called Total internal Reflection.

* Define critical Angle?

It is the angle of incidence in the denser medium for which angle of refraction in rarer medium is 90°.

* Define Total Internal reflection?

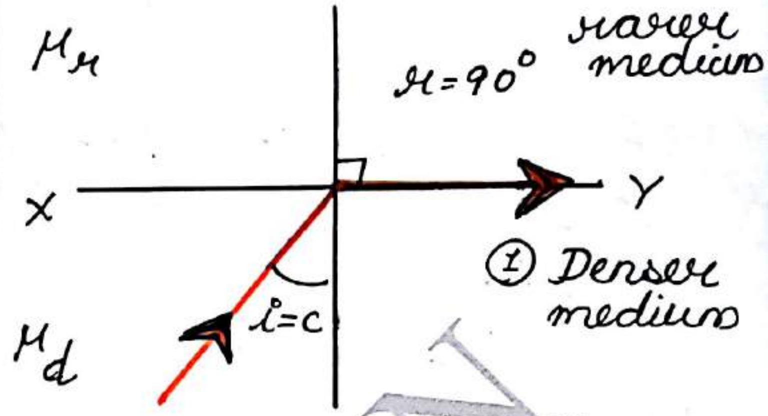
when light travels from denser medium to rarer medium and if $\angle i$ (angle of Incidence) is greater than critical angle, the light ray is reflected back internally without any loss of light.

* Conditions for Total Internal reflection

1. Light ray should travel from denser to rarer medium.
2. angle of Incidence should be greater than critical angle.

(4)

Derive $\mu = \frac{1}{\sin c}$



according to snells law

$$\frac{\sin i}{\sin r} = \mu_{rd}$$

$$\frac{\sin c}{\sin 90°} = \mu_{rd}$$

$$\frac{\sin c}{1} = \mu_{rd}$$

$$\mu_{dr} = \frac{1}{\sin c}$$

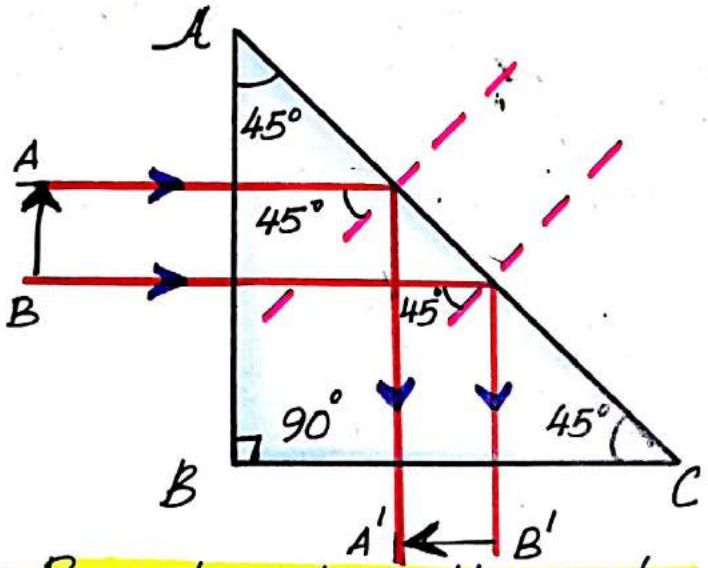
write the practical applications of total Internal reflection?

1. Total internal reflecting prisms
2. Mirage
3. Optical fibre
4. Brilliance of Diamonds.

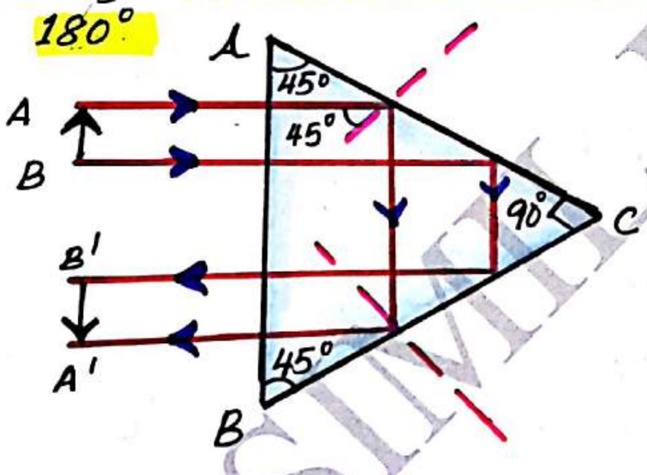
1. Total Internal reflecting prisms.

critical angle for glass is 42°. If a ray incident at a glass surface at an angle greater than 42°, the ray is reflected internally.

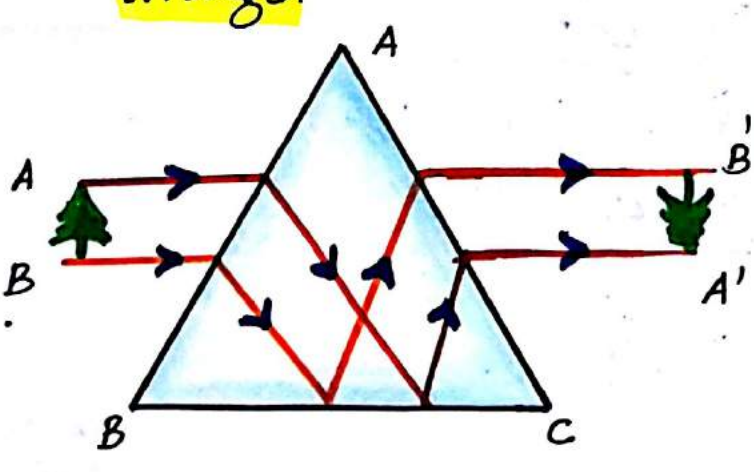
(a) Ray deviation through 90°



(b) Ray deviation through 180°

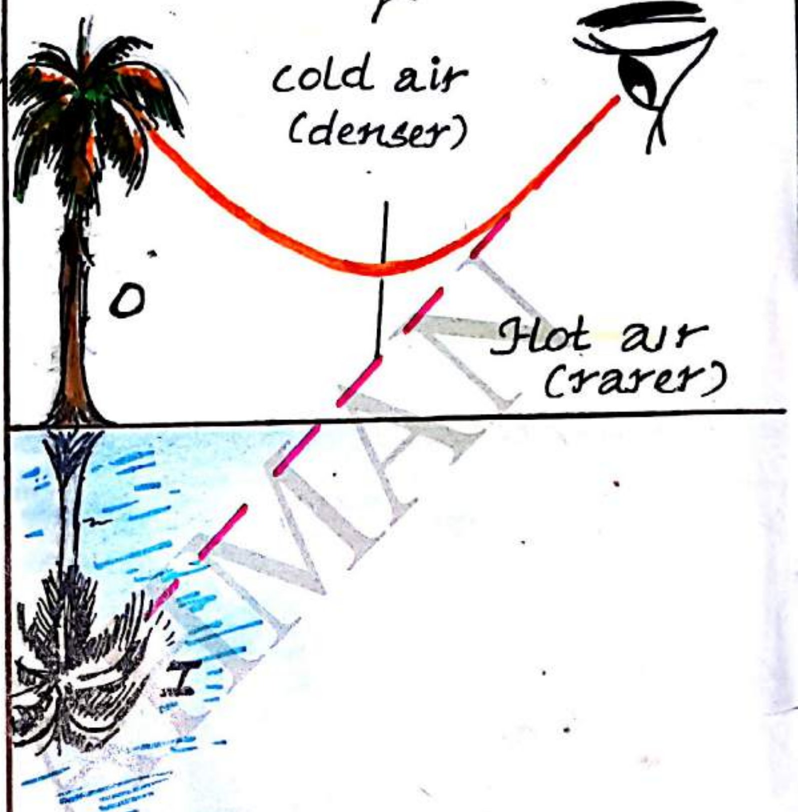


(c) Formation of Inverted image.



Mirage

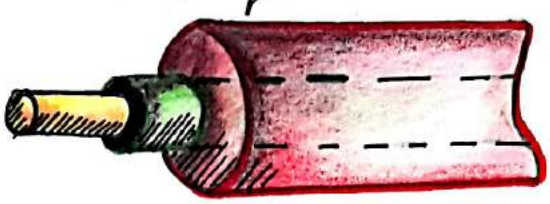
principle :- Total Internal reflection.

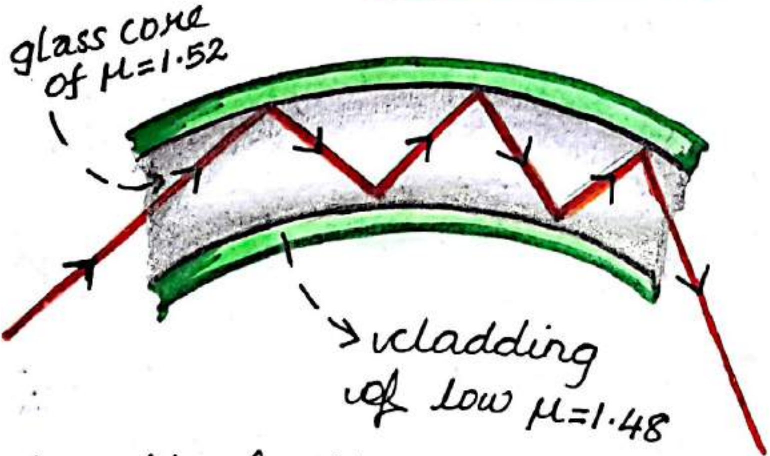


* It is an optical Illusion
* In hot deserts the object 'O' appears inverted and the observer gets an impression formed by a pond of water.
* when light from object 'O' travels from denser medium (cool air well above the ground) to the rarer medium (hot air near ground) it bends away from normal.
* when $\angle i > \angle c$, it undergoes total Internal reflection, and forms an inverted image.

Optical fibre

* The principle used in optical fibre is total internal reflection





* optical fibre consists of a core of high refractive index and a cladding of low refractive Index.
* when light enters optical fibre at suitable angle, it undergoes multiple total internal reflection without any loss of light and energies.

uses of optical fibre

1. communication - Transmission of audio and video signals.
2. Medical purpose - For visual examination of internal organs like stomach, intestine etc
3. In decorative lamps.

Brilliance of Diamond

* critical angle for diamond is 24.4°
* A ray entering Diamond undergoes multiple total internal reflection as a result it shines brilliantly

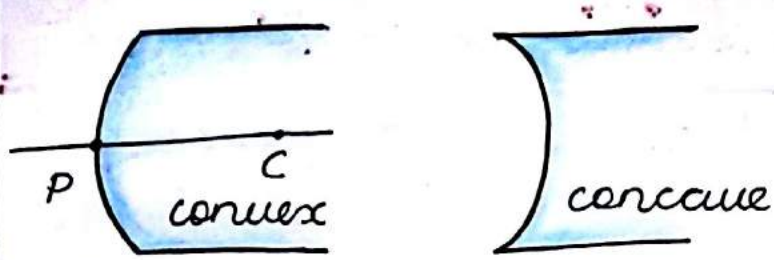
smul...

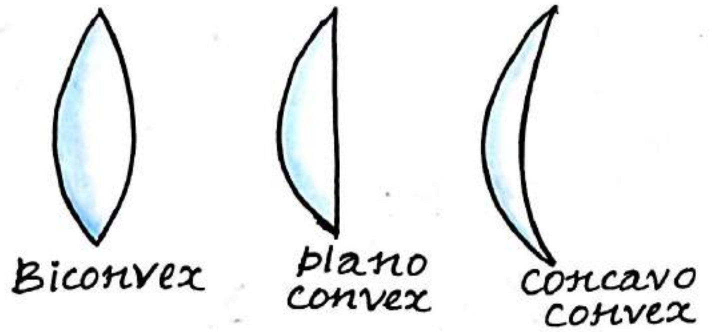
Advantages of total internal reflecting prism over the silvered plane mirror.

* silvering is not required
* 100% reflection can be achieved
* Image will be brighter
* Long lasting.

SPHERICAL REFRACTING SURFACES..

A refracting surface which forms a part of sphere of transparent refracting material.



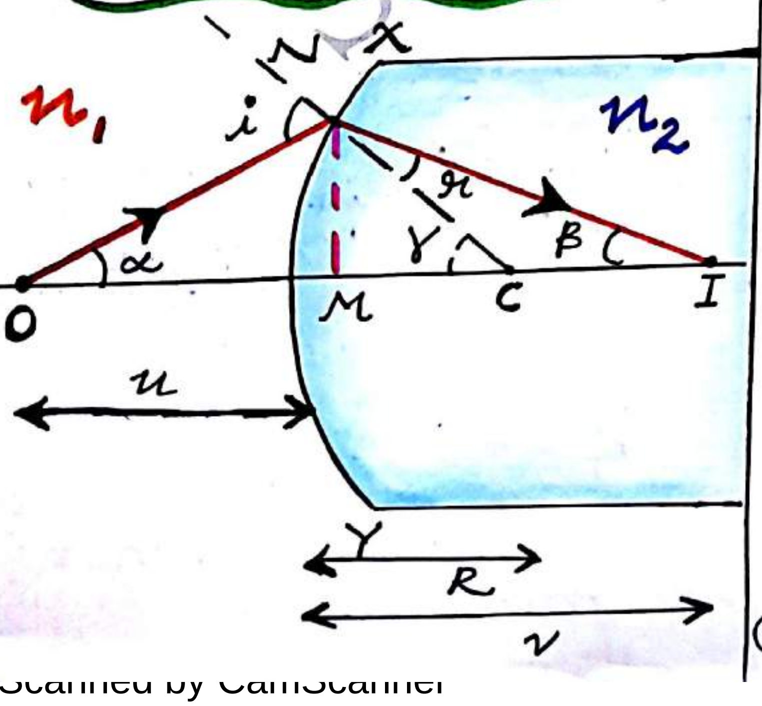


Assumptions to be made in dealing spherical surface.

1. Aperture should be small
2. The object should be a point object
3. Incident ray and refracted ray make small angles with principal axis.

Derive the relation

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



Relation b/w u, v, n & R

The figure shows the formation of image I of an object O on the principal axis of a spherical surface XY with the centre of curvature C and radius of curvature R.

A ray ON incident from a medium of refractive index n_1 to a medium of refractive index n_2 and it gets refracted along NI

From the diagram

$$\left.\begin{array}{l} i = \alpha + \gamma \\ \gamma = r + \beta \\ r = \gamma - \beta \end{array}\right\} \cdots (1)$$

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

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

$\tan\gamma = \frac{MN}{NC}$

For small angles

$$\left.\begin{array}{l} \tan\alpha = \alpha = MN/MO \\ \tan\beta = \beta = MN/MI \\ \tan\gamma = \gamma = MN/MC \end{array}\right\} \cdots (2)$$

According to snells law

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

for small angles $\sin i = i$

$\sin r = r$

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

$$n_1 i = n_2 r \quad \cdots (3)$$

(1) in (3) $\Rightarrow$ $n_1(\alpha + \gamma) = n_2(\gamma - \beta)$

②in③

$$n_1\left(\frac{MN}{MO}+\frac{MN}{MC}\right)=n_2\left(\frac{MN}{MC}-\frac{MN}{MI}\right)$$

$$n_1\left(\frac{1}{MO}+\frac{1}{MC}\right)=n_2\left(\frac{1}{MC}-\frac{1}{MI}\right)$$

$\{MO=-u,\ MC=R,\ MI=v\}$

$$\frac{n_1}{MO}+\frac{n_1}{MC}=\frac{n_2}{MC}-\frac{n_2}{MI}$$

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

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

what is meant by a lens?

It is a portion of transparent medium bound by two spherical surfaces.

Biconcave   Plano concave   Convexo concave

Assumptions

1. Aperture of lens should be small.
2. lens should be thin.
3. Incident ray and refracted ray should make small angles with principal axis.

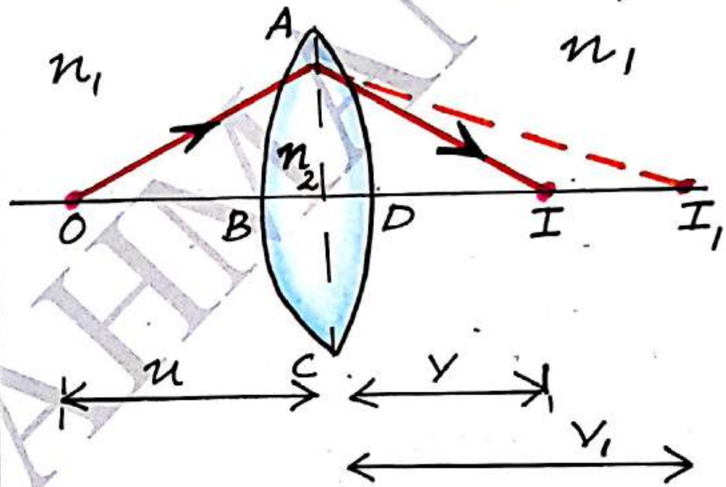
* **How is Intensity related with aperture?**

Intensity $\propto$ (Aperture)^2

Derive lens-makers formula

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

→ Relationship b/w f, n, R_1 and R_2.



The figure shows the image formation by a double convex lens.

when a light ray incident on the refracting surface ABC, it forms an image I_1 at a distance v_1.

The image I_1 acts as a virtual object for the formation of image I by the second surface ADC.

At face ABC

$$\frac{n_2}{v_1}-\frac{n_1}{u}=\frac{n_2-n_1}{R_1}\quad \text{...①}$$

At face ADC

$$\frac{n_1}{v} - \frac{n_2}{v_1} = \frac{n_1 - n_2}{R_2}$$

$$= \frac{-(n_2 - n_1)}{R_2} \quad \ldots (2)$$

(1)+(2)

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

$\div n_1$

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

$$\boxed{\frac{1}{v} - \frac{1}{u} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)} \quad \ldots (3)$$

If $u = -\alpha$, $v = f$

$$\boxed{\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)} \quad \ldots (4)$$

This is lens makers formula.

From (3) and (4) we can say that

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

* Derive the relation $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ for a biconvex lens.
* Derive laws of distances
* Derive the relation between object distance (u), Image distance (v) and focal length (f) of a lens.

Derive this lens formula?

(3) = (4)

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

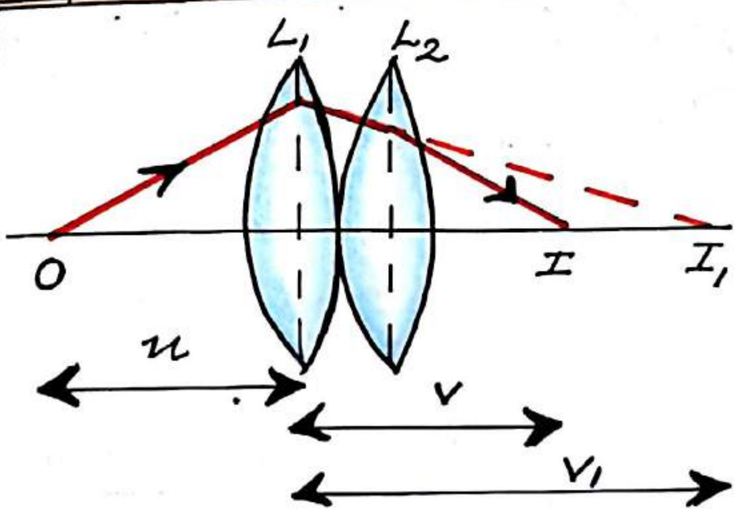
* How to estimate rough focal length of a converging lens in lab?

→ place lens infront of screen

→ adjust position of lens untill you get a clear image of a distant object.

→ Distance between lens and screen gives rough focal length of lens.

* Derive expression for the effective focal length of combination of thin lenses.?



f_1 – focal length of L_1

f_2 – focal length of L_2

L_1, L_2 are convex lens

A light ray incident on L_1 forms an image I_1 at a distance V_1 from C_1.

The image I_1 acts as a virtual object for the formation of image I by L_2. Distance of I from C_2 is V.

For image formed by L_1

$$\frac{1}{V_1} - \frac{1}{u} = \frac{1}{f_1} \quad \ldots\ldots (1)$$

For image formed by L_2

$$\frac{1}{V} - \frac{1}{V_1} = \frac{1}{f_2} \quad \ldots (2)$$

(1)+(2) $\frac{1}{V} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2}$

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

* Focal length of combined lenses.

* magnification produced by lens

$$m = \frac{h_i}{h_o} = \frac{V}{u}$$

* Power of a lens

ability of a lens to converage or diverge the rays of light.

$$P = \frac{1}{f(m)}$$

$$P = \frac{100}{f(cm)}$$

SI unit of power: dioptre

* magnification

'm' is +ve for virtual image

* 'm' is −ve for real image.

* Define one dioptre

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

if $f = 1m$, $P = 1D$

one dioptre is the power of lens when its focal length is 1m.

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

$$P = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

* uses of combined lenses

1, To make final image erect

2, To increase magnification

3, To reduce aberration

* Expression for power and magnification of combined lenses.

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

$$P = P_1 + P_2$$

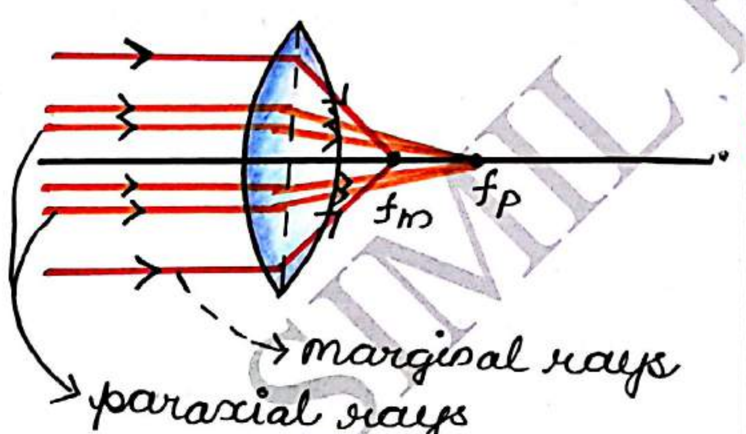
$$m = m_1 \times m_2$$

Spherical aberration or achromatic aberration

The inability of a lens of large aperture to bring all the rays in a wide beam to focus at a single point is called spherical aberration.

* **cause for spherical aberration**

→ marginal rays focussed closer to optic centre compared to paraxial rays.

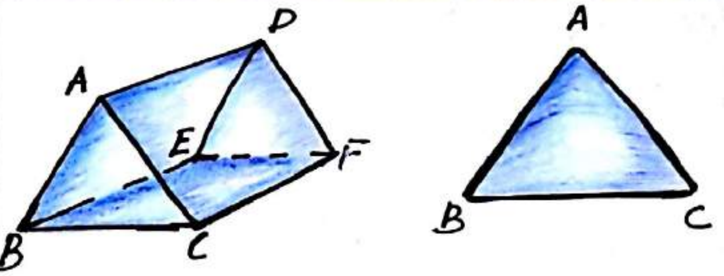


* **How to minimise spherical Aberration**

→ By using stops - slits
1, It'll allow either marginal or paraxial rays

→ 2, By using combined lenses.

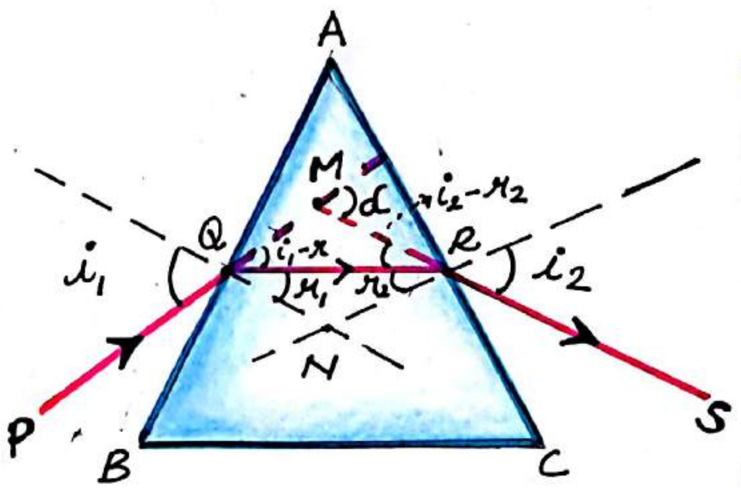
PRISM



A prism is a portion of a transparent refracting medium bounded by two plane faces inclined to each other at a certain angle.

* The two plane faces ABED and ACFD are called refracting faces.
* angle between them is called angle of prism (A)

Derive $n = \dfrac{\sin\left(\frac{A+D}{2}\right)}{\sin\left(\frac{A}{2}\right)}$



Let ABC be a principal section of a prism with angle of prism A.

A ray of light PQ incident on the face AB at an angle of incidence i_1 and refracted along QR at an angle of refraction r_1.

The ray QR strikes the face AC at an angle r_2 and gets refracted along RS at an angle i_2.

The angle between the direction of incident ray and emergent ray is called angle of deviation 'd'.

* $\angle d$ depends upon
  (i) Angle of prism (A)
  (ii) Material of prism
  (iii) Angle of incidence (i)

figure.
ABC – section of a prism
PQ – Incident ray
QR – Refracted ray
RS – Emergent ray
QN, RN – Normals
A – angle to prism.
d – Angle of deviation.

In Quadrilateral AQNR

$\angle A + \angle N = 180^\circ$ ..... (1)

In Δ QNR

$r_1 + r_2 + \angle N = 180^\circ$ ... (2)

compare (1) and (2)

$\boxed{\angle A = r_1 + r_2}$ ... (3)

In Δ QMR

sum of interior angles = Exterior angle.

$i_1 - r_1 + i_2 - r_2 = d$

$i_1 + i_2 = d + (r_1 + r_2)$

$\boxed{i_1 + i_2 = d + A}$ .... (4)

At minimum deviation position (D)

$i_1 = i_2$ and $r_1 = r_2$ and $d = D$

Equation (3) becomes

$2r = A$

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

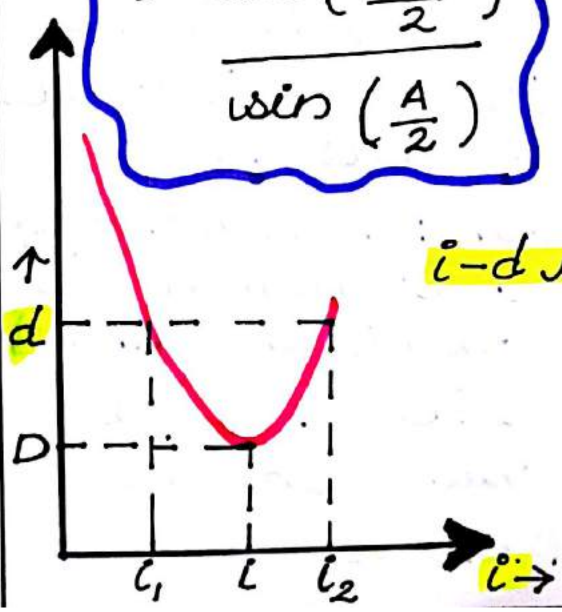
Equation (4) becomes

$2i = D + A$

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

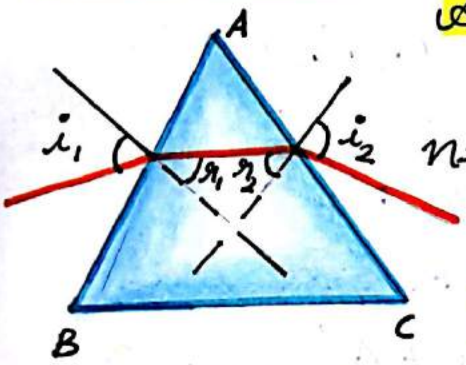
As $\mu = \frac{\sin i}{\sin r}$,

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



i–d curve.

Angle of deviation for a small angled prism.



At face AB

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

$$i_1 = n r_1$$

At face AC

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

$$i_2 = r_2 n$$

$$i_2 = n r_2$$

$$i_1 + i_2 = A + d$$

sub i_1 and i_2

$$n r_1 + n r_2 = A + d$$

$$n(r_1 + r_2) = A + d$$

$$nA = A + d$$

$$d = nA - A$$

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

Dispersion of Light

splitting up of white light into constituent colours.

spectrum: The band of colours so formed is called spectrum (VIBGYOR)

violet ray bends more than red ray

$n_V > n_r$

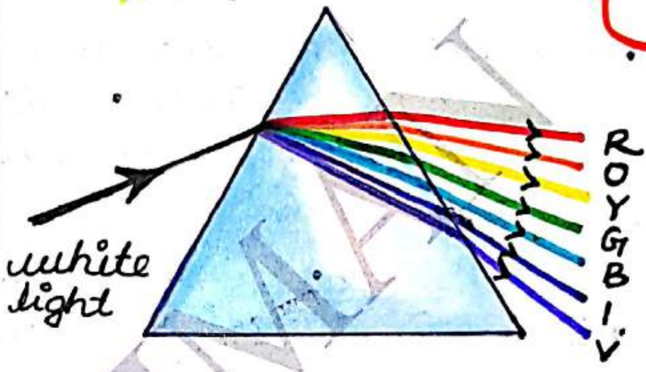
$\lambda_V < \lambda_r$

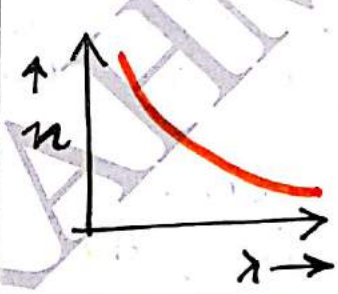
Velocity of violet < Velocity of Red

$$\delta_{violet} > \delta_{red}$$

$$\mu = \frac{c}{v}$$

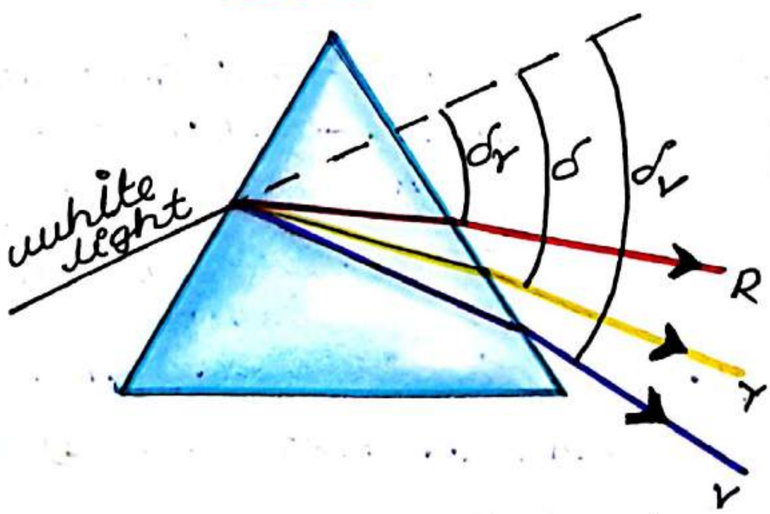
$$n \propto \frac{1}{v}$$





Derivation – Dispersive power

$$\omega = \frac{n_V - n_r}{n-1}$$



when white light is passed through a prism, it gets dispersed.

If d_v – deviation of violet colour

d_r – deviation of red colour

δ – deviation of mean light (yellow)

Angular dispersion

$(\delta_v - \delta_r)$

The difference in angles of deviation of two extreme colours i.e. violet and red colours, is called angular dispersion

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

$$\delta_v = (n_v - 1)A$$

$$\delta_r = (n_r - 1)A$$

$$\delta_v - \delta_r = (n_v - 1)A - (n_r - 1)A$$

$$= n_vA - A - n_rA + A$$

$$\boxed{\delta_v - \delta_r = (n_v - n_r)A}$$

Angular dispersion depends on

(i) angle of prism

(ii) Nature of material of prism

Dispersive Power

Ratio between angular dispersion and mean deviation

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

$$\omega = \frac{\delta_v - \delta_r}{\delta}$$

$$\omega = \frac{(n_v - n_r)A}{(n-1)A}$$

$$\boxed{\omega = \frac{\delta_v - \delta_r}{\delta} = \frac{n_v - n_r}{n-1}}$$

* Dispersive power depends only on nature of material of prism.

Scattering of Light

Rayleigh's scattering law

The intensity of scattered light is inversely proportional to the fourth power of incident light wavelength

$$I \propto \frac{1}{\lambda^4}$$

* shorter waves are scattered more than longer waves.

condition for scattering

size of particle should be in order of λ of light.

Blue colour of Sky

According to Rayleigh's scattering law $I \propto \frac{1}{\lambda^4}$

If λ decreases I Increases. As blue colour has a shorter wavelength, it gets scattered more by molecules present in atmosphere. So sky appears blue.

Why does sun appear reddish at the time of sunset and sunrise?

* At the time of sunset and sunrise, the sun is near the horizon.
* sun light has to travel longer distance.
* most of blue colour scattered away.
* Only the least scattered red light reaches the observer.

Why does clouds appear white?

As water droplets size is much greater than λ ($a >>> \lambda$), all wavelength scattered equally. so cloud appears white.

RainBow

The formation of rainbow is due to the dispersion of white light from the sun due to refraction and total Internal reflection from the water droplets suspended in air.

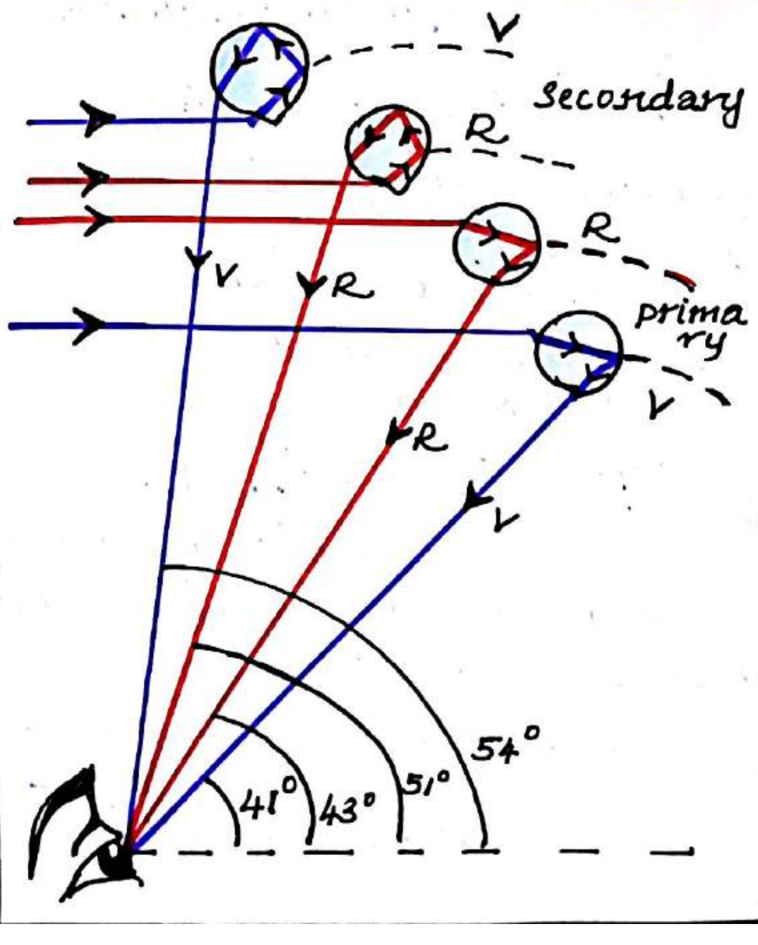
* Always formed opposite to sun.

rainbows
- Primary Rainbow [brighter one]
- secondary Rainbow [fainter one]

Primary Rainbow

Formed due to refraction one total Internal reflection and dispersion in a droplet.

* outer arc is red and inner arc is violet.
* Red emerges at 42° and violet at 40°



Secondary Rainbow

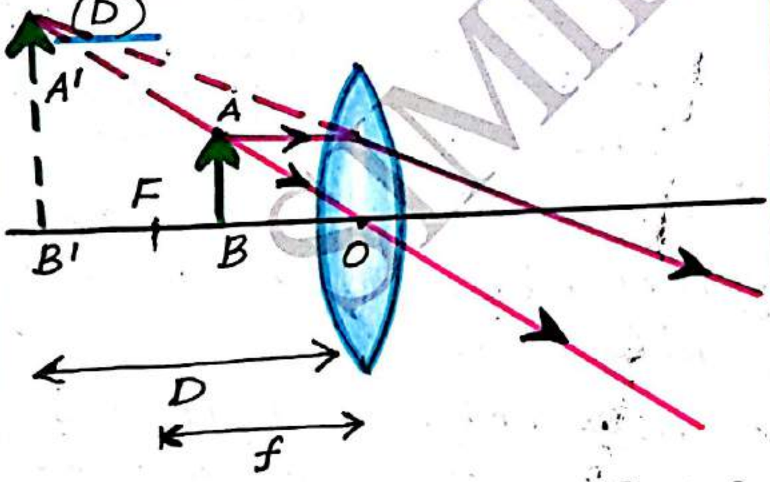
* Formed due to refraction, dispersion and two total Internal Reflection within a drop
* outer arc is violet & inner arc is red
* Red emerges at 50° and violet at 53°.
* It is fainter than primary rainbow.

Optical Instruments

simple microscope

It is a convex lens of small focal length used to get magnified images.

(a) Image at near point (D)



when object is placed within the focus, image is adjusted to form at least distance of distinct vision D

($D = 25cm$)

Linear magnification (m)

$$m = \frac{v}{u} = v\left(\frac{1}{u}\right) = v\left(\frac{1}{v} - \frac{1}{f}\right)$$

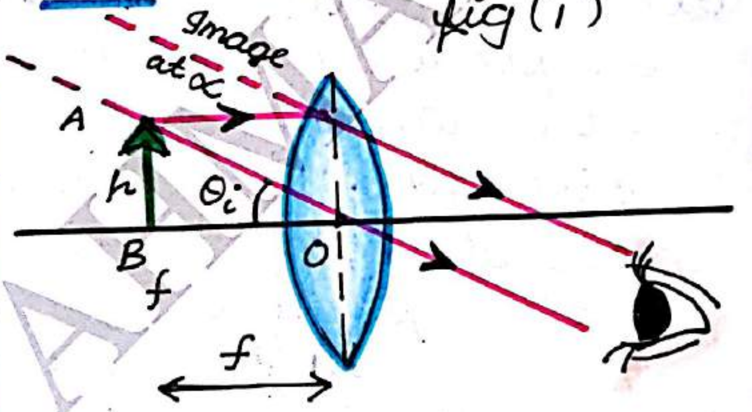
$$m = 1 - \frac{v}{f} \quad \ldots (1)$$

since $v = -D$

$$(1) \Rightarrow m = 1 + \frac{D}{f}$$

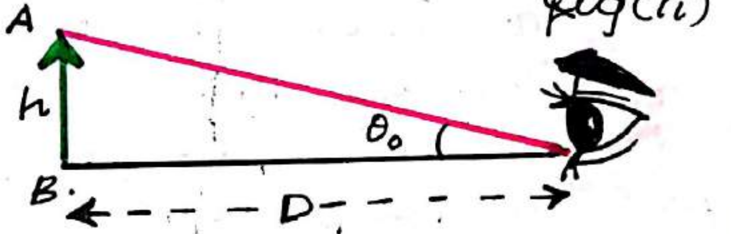
(b) when image at infinite

fig(1)



Angular magnification

fig(ii)



The maximum angle the object can substend (θ_0), when object is placed at near point D. (without convex lens)

$$\tan\theta_0 = \frac{h}{D} = \theta_0$$

angle substended by image (from fig 1)

$$\tan\theta_i = \frac{h}{f} = \theta_i$$

Scanned by CamScanner

$$m = \frac{\theta_i}{\theta_o} = \frac{h/f}{h/D} = \frac{D}{f}$$

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

Compound Microscope

It has two lenses.

Objective lens (O) - very small focal length and short aperture.

Eye piece lens (E) - moderate focal length and large aperture.

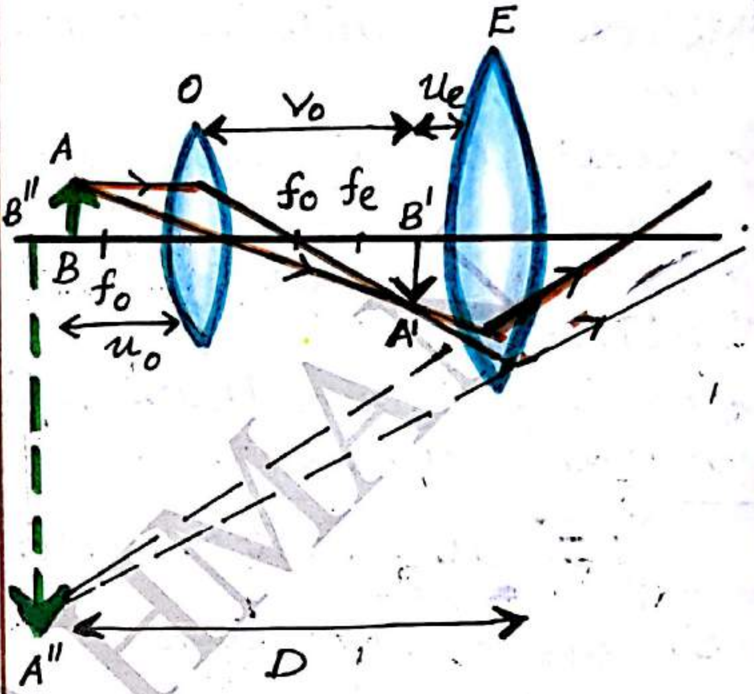
Place an object AB beyond (f_o) of objective lens. It forms a real inverted enlarged image A'B'. It acts as an object for eye piece, whose position is so adjusted that A'B' lies between optic centre C_e of eye piece and principal focus f_e of eye piece.

Eye piece formes a virtual, erect and magnified image A''B''. It is erect w.r.t A'B'.

AB - object kept between f_o and $2f_o$

A'B' - Image formed by O
- object for eyepiece
- Real inverted

A''B'' - Image formed by eye piece at D.



Magnification by objective lens (m_o)

$$m_o = \frac{A'B'}{AB} = \frac{V_o}{u_o}$$

$u_o \simeq f_o$ (distance between objective and eye piece $= L$)

$V_o \simeq L$

$$\therefore m_o = \frac{L}{f_o}$$

Magnification by eye piece (m_e)

$$m_e = 1 + \frac{D}{f_e}$$ (proved in simple microscope)

Total magnification (m)

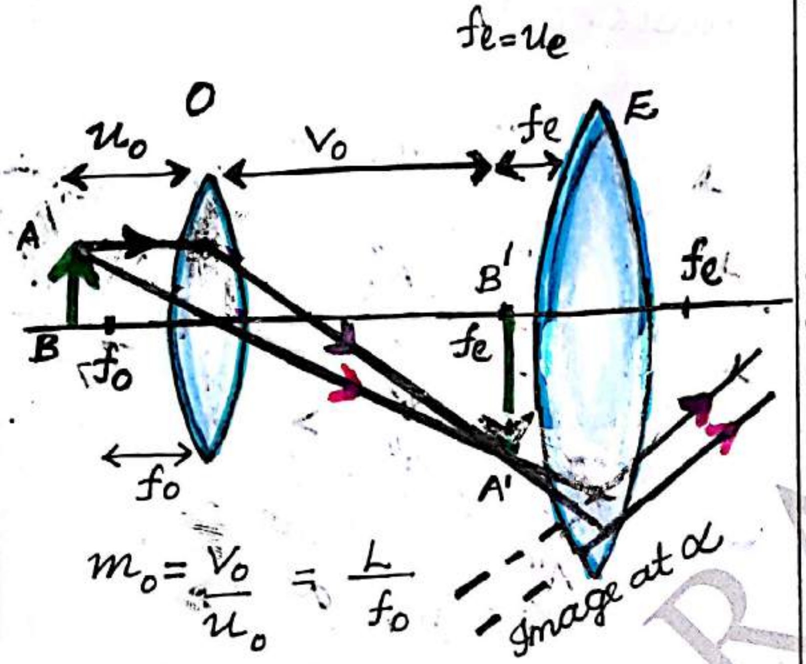
$$m = m_o m_e$$

$$m = \frac{L}{f_o}\left(1 + \frac{D}{f_e}\right)$$

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

Distance between two lenses $\boxed{L = V_o + u_e}$

Image formation at Infinity



$$m_o = \frac{V_o}{u_o} = \frac{L}{f_o}$$

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

$$m = m_o m_e$$

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

$$m = \frac{LD}{f_o f_e}$$

$$L = V_o + f_e$$

$$L = V_o + u_e$$

Telescope - Astronomical (Refracting type)

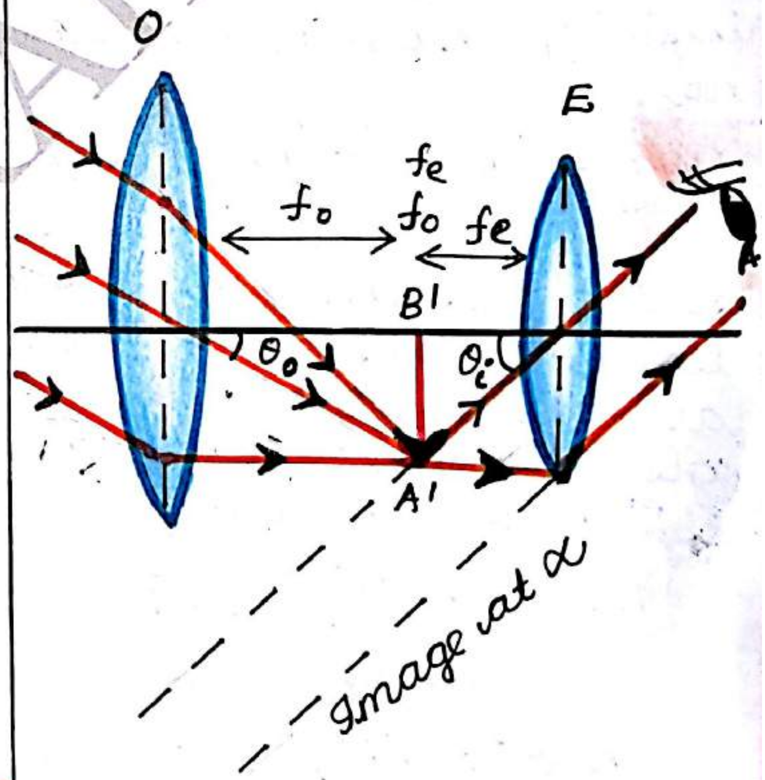
Normal adjusment position - Image formation at infinity

It is an optical Instrument used to observe very distant objects.

It consists of two lenses, the objective lens: of large focal length and large aperture

eye piece lens :- small focal length and small aperture.

They are fitted at the ends of a tube and the distance between them is adjustable.



O- objective lens of large focal length. focuses distant object.

E- Eye piece of small focal length.

$A'B'$ - Image formed by O.
- object for eye piece
- falls at f_o as well as at f_e

θ_o - Angle subtended by the object

θ_i - Angle subtended by image.

working:- light from distant object forms a real image $A'B'$ at the focal plane of the objective lens. This image is adjusted to be at the focal plane of eye piece. Final image is formed at infinity (Normal adjustment)

Magnification (m)

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

$$m = \frac{\tan \theta_i}{\tan \theta_o} \quad \ldots (1)$$

$$\tan \theta_i = A'B'/f_e$$

$$\tan \theta_o = A'B'/f_o$$

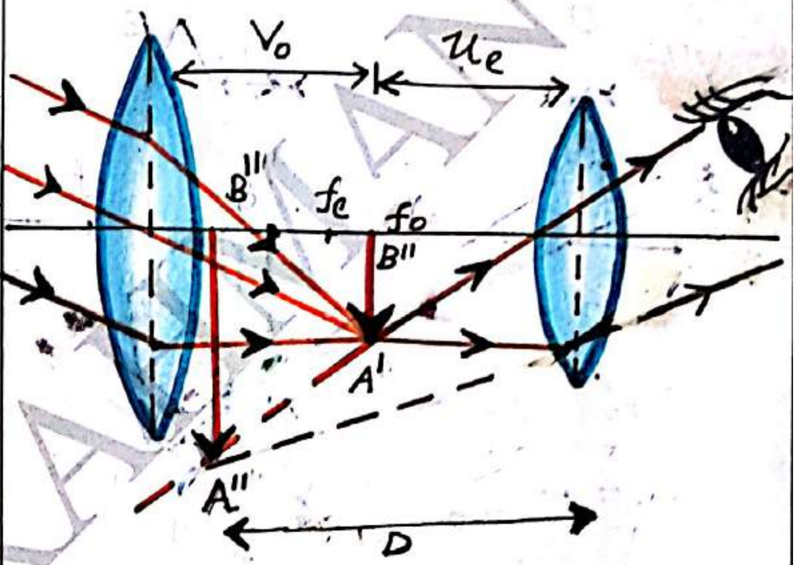
(1) ⇒

$$\therefore m = \frac{\frac{A'B'}{f_e}}{\frac{A'B'}{f_o}} = \frac{f_o}{f_e}$$

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

$$\boxed{L = f_o + f_e}$$

Image formation at near point (D) - (least distance of distinct vision)



Magnification (final image at D)

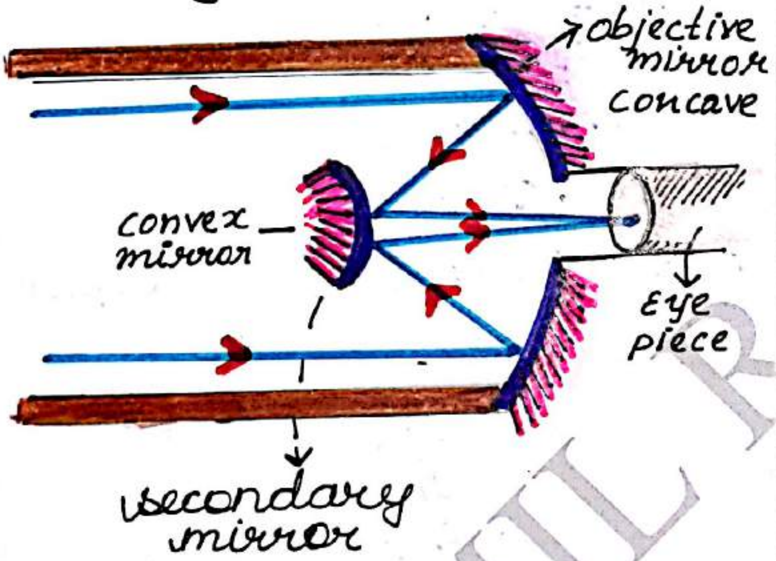
$$m = \frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right)$$

$$L = V_o + u_e$$

Astronomical Telescope Reflecting Type

It consists of a concave mirror as objective. parallel rays from distant star are focussed at the principal focus of the concave mirror. The focussed rays falls on a con vex mirror kept at the principle focus F.

* Again rays are reflected by convex mirror and focussed to eye piece.
* Image can be seen through eye piece.
* Image is Inverted, but it is not a matter for astronomical object as they are spherical.



$$m = \frac{f_o}{f_e} = \frac{R/2}{f_e}$$

R – radius of curvature of concave mirror.

Advantages of Reflecting type telescope over refracting type.

1. spherical aberration can be minimised.
2. Large gathering power.
3. Image is bright
4. less weight

SUMMARY

Formula B

Mirror

(a) $f = R/2$

(b) $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

(c) $m = \frac{h_i}{h_o} = \frac{-v}{u}$

Refraction – Snell's law

* $\frac{\sin i}{\sin r} = n_{21} = \frac{n_2}{n_1} = \text{const}$
* absolute refractive Index

$$n = \frac{c}{v}$$

* Refractive Index

$$n_{21} = \frac{n_2}{n_1} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} = \frac{1}{n_{12}}$$

→ Lateral shift

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

→ Normal shift

$$S = t\left(1 - \frac{1}{n}\right)$$

→ Total Internal reflection

$$n = \frac{1}{\sin C}$$

→ spherical surface

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

→ Lens makers formula

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

$$P = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

→ Thin lens

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

$$m = \frac{h_i}{h_o} = \frac{v}{u}$$

→ Lens combination

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

* $P = P_1 + P_2$

* $m = m_1 \times m_2$

→ Power

$$P = \frac{1}{f} = \frac{100}{f(cm)}$$

→ Refraction through prism

* $i_1 + i_2 = d + A$

$r_1 + r_2 = A$

@ D $\quad i_1 = i_2 = i, \; r_1 = r_2 = r$

$i = \frac{A+D}{2}, \quad r = A/2$

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

→ Deviation for small angled prism

$d = (n-1)A$

→ Dispersive power

$$\omega = \frac{\delta_v - \delta_r}{\delta} = \frac{n_v - n_r}{n-1}$$

→ Rayleigh's scattering law

$$I \propto \frac{1}{\lambda^4}$$

→ simple microscope

(i) Image at D

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

(ii) Image at infinity

$$m = D/f$$

→ compound microscope

(i) image at D

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

$$m = \frac{L}{f_o}\left(1 + \frac{D}{f_e}\right)$$

$$L = v_o + u_e$$

(ii) Image at infinity

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

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

$$L = v_o + f_e$$

$$L = v_o + u_e$$

→ Astronomical Telescope

(i) Image at ∞

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

$$L = f_o + f_e$$

(ii) Image at D

$$m = \frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right)$$

$$L = v_o + u_e$$

→ Telescope – Reflecting Type

$$m = \frac{f_o}{f_e} = \frac{R/2}{f_e}$$