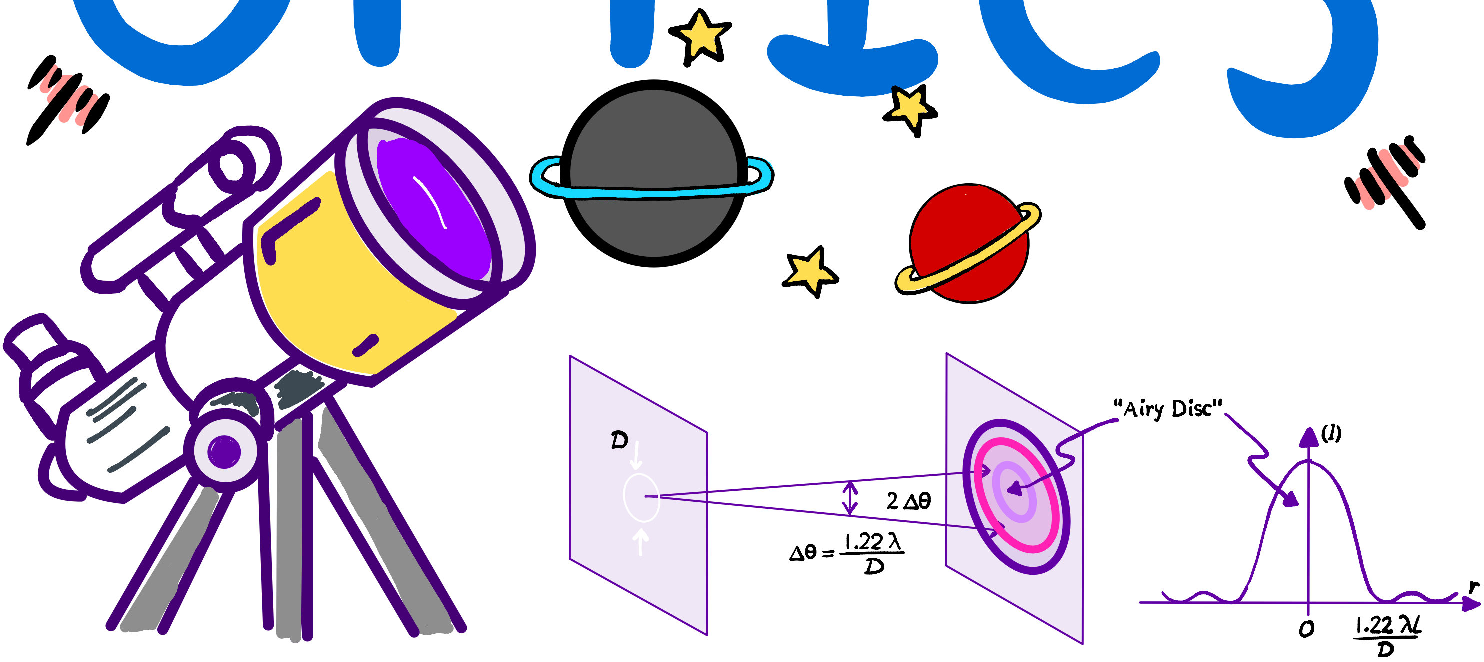
RAY OPTICS



CLASS 12 | New Notes | PHYSICS

Made With ❤

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Light: Light is a form of energy which produces sensation of vision to our eyes and makes objects visible.

Optics

The branch of physics which deals with the study of nature of light, its properties, effects and propagation is known as optics.

Optics

Ray or geometrical Optics

This branch of optics deals with propagation of light in terms of rays which are valid, if sizes of obstacles are large in comparison with wavelength of light (in nm range).

Wave or Physical optics

This branch of optics deals with wave phenomenon like interference, diffraction and polarisation.

Characteristics of light

- Light waves are electromagnetic waves, whose nature is transverse.
- The speed of light in vacuum is 3×10^8 m/s but it is different in different media.
- The speed and wavelength of light change when it travels from one medium to another but its frequency remains unchanged.

Important Terms

1). Luminous Objects

The objects which emits its own light are called luminous objects, eg sun, other stars, an oil lamp etc.

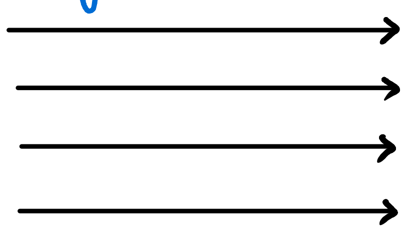
2). Non-luminous objects

The objects which do not emit its own light but become visible due to the reflection of light falling on them are called non-luminous objects.

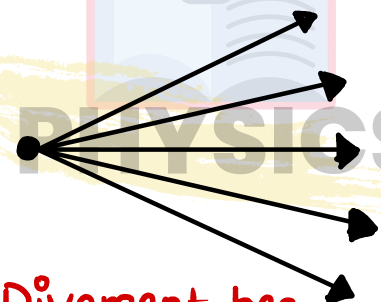
eg moon, table, chair, trees etc.

3). Beam of light

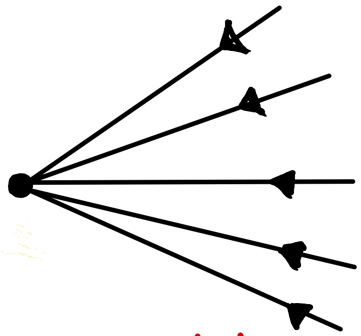
A bundle of the adjacent light rays is called a beam of light.



Parallel beam of light



Divergent beam of light



Convergent beam of light.

4). Real Image

The image obtained by the real meeting of light rays is called a real image.

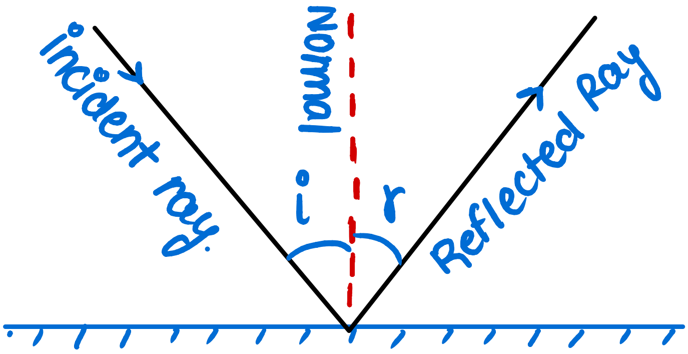
- Real image can be obtained on a screen.
- Real image is inverted.

5). Virtual Image

The image obtained when light rays are not really meeting but appears to meet only, is called a virtual image.

o Reflection of Light

When light strikes the Surface of an object, some of the light is returned into the same medium. This phenomena is called reflection.



$\angle i$ = angle of incidence
$\angle r$ = angle of reflection

Laws of Reflection:

i) The angle of incidence is equal to the angle of reflection.

ii). The incident ray, the normal to the mirror at the point of incidence and reflected ray lie in the same plane.

Mirror

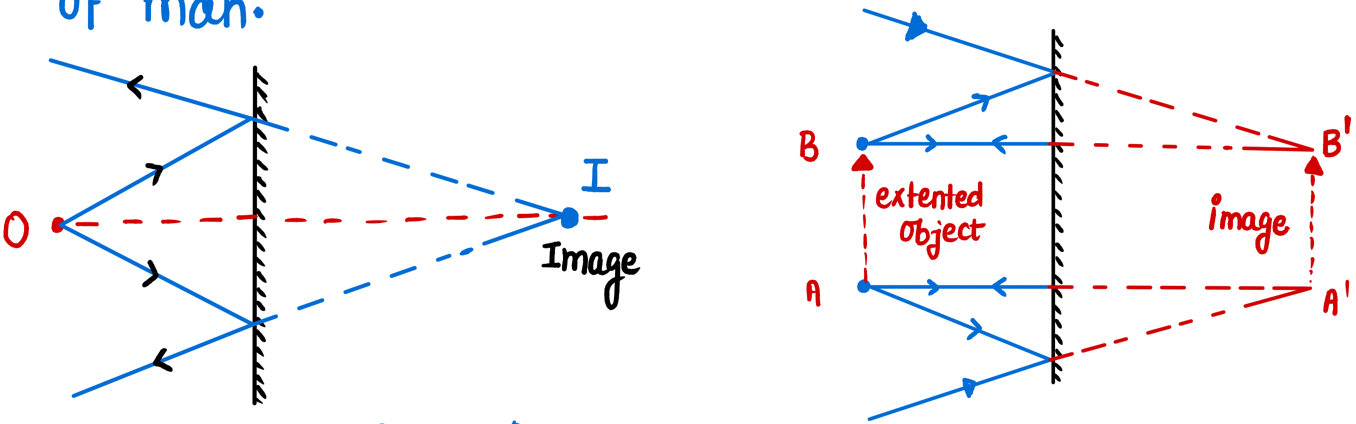
A Smooth and highly polished reflecting surface is Called a mirror.

i). **Plane Mirror** A highly polished plane surface is Called a plane mirror.

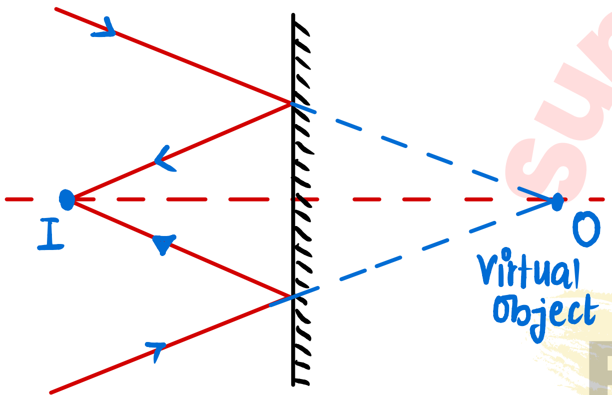
Different properties of image formed by plane mirror are given below

- size of image = size of object
  magnification = Unity
- Distance of image from the mirror = Distance of object from the mirror.

- A plane mirror may form a virtual as well as real image.
- A man see his full image in a mirror of half height of man.

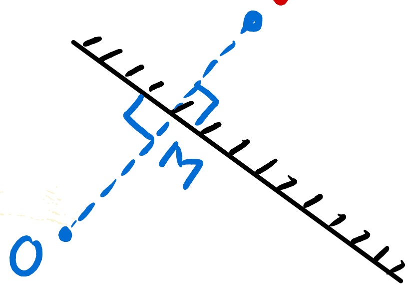


Formation of images by a Plane Mirror.

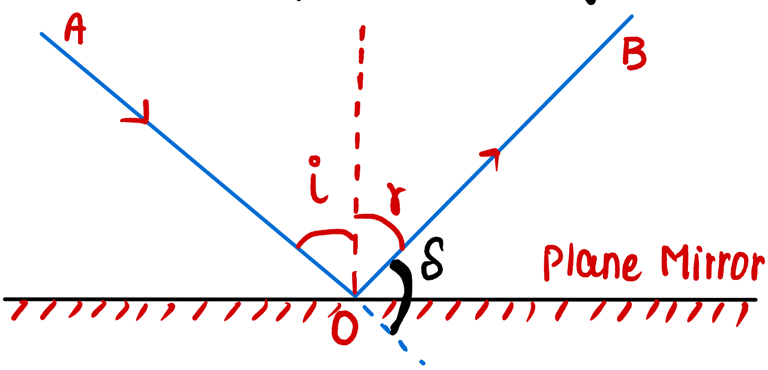


formation of image by plane mirror of a virtual object.

Note: To find the location of image of an object from an inclined plane mirror, you have to see the perpendicular distance of object from the mirror.



Deviation produced by plane Mirror by Single Reflection



$$\delta = 180^\circ - (i+r)$$

$$\delta = 180^\circ - 2i$$

or

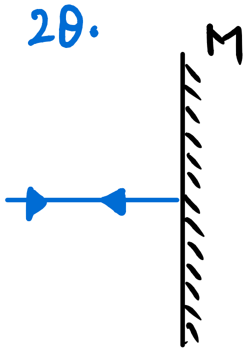
$$\delta = 180^\circ - 2r$$

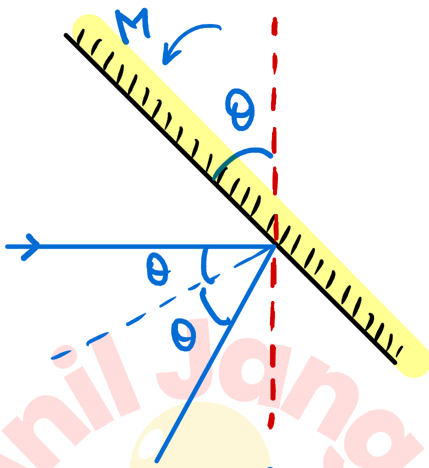
The deviation produced by reflection at two Mirrors inclined to each other at an angle θ is

$$\boxed{\delta = 360^\circ - 2\theta}$$

Rotation produced in reflected ray due to rotation of a plane mirror

i). For a given fixed incident ray, the the plane Mirror is rotated through an angle θ in the plane of incidence, the reflected ray turns through an angle 2θ.





ii). if a plane Mirror is rotated in its own plane, the incident ray and the reflected ray remain at same positions.

Multiple Images in Plane Mirrors

Number of images formed

$$n = \frac{360^\circ}{\theta} - 1 \quad \text{if } \frac{360^\circ}{\theta} = \text{even}$$

$$n = \frac{360^\circ}{\theta} \quad \text{if } \frac{360^\circ}{\theta} = \text{odd.}$$

NOTE

if two plane mirrors are parallel to each other, then infinite number of images will be formed.

• Spherical Mirrors

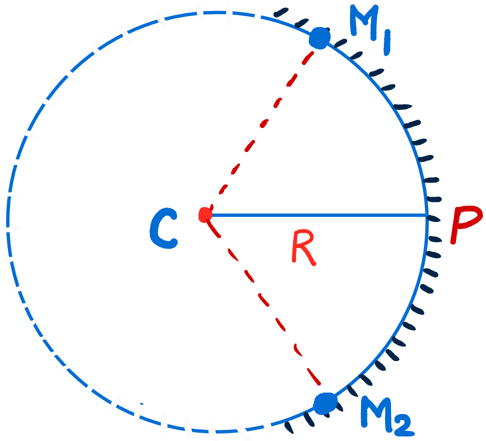
A spherical mirror is a part of a hollow sphere, whose one side is reflecting and other side is opaque.

Two types of spherical mirrors

- Concave Mirror (Converging Mirror)
- Convex Mirror (Diverging Mirror)

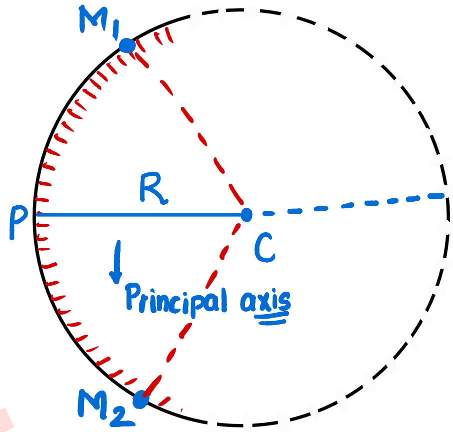
- **Concave Mirror (Converging Mirror)**

whose reflecting surface is towards the centre of the Sphere of which the Mirror is a part



- **Convex Mirror (Diverging Mirror)**

whose reflecting surface is away from the centre of the sphere of which the mirror is a part.



Some Definitions

1). **Pole** : The middle point or centre of the spherical mirror is called vertex or pole of the mirror. It is represented by P.

2). **Centre of Curvature** : The centre of curvature of spherical mirror is the centre of the sphere of which the mirror forms a part. It is represented by C.

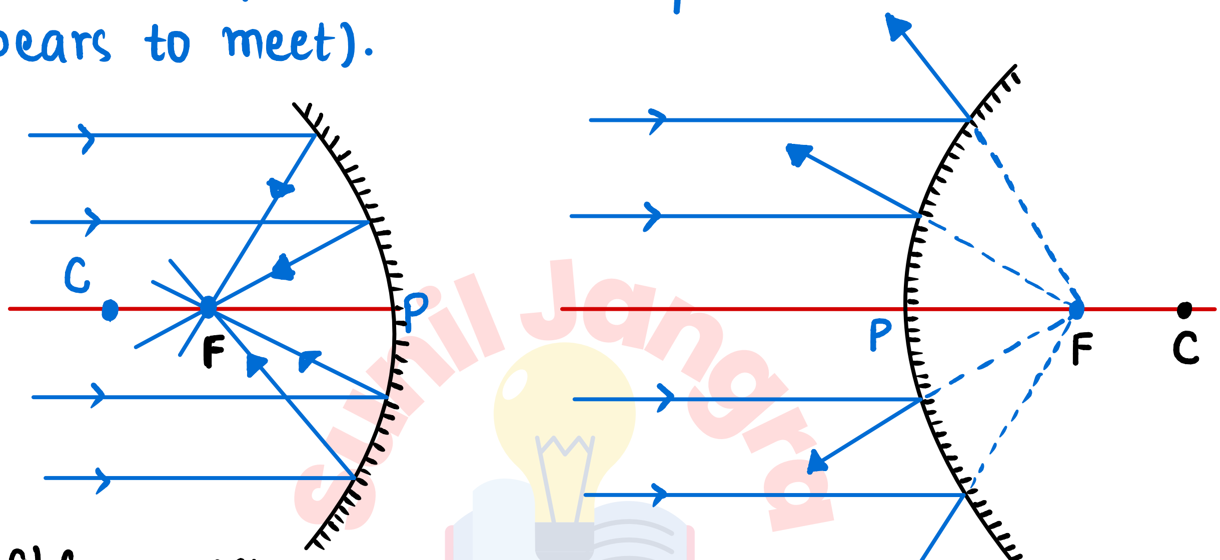
3). **Radius of Curvature**: Radius of curvature of a spherical mirror is the radius of the sphere of which the mirror forms a part. It is represented by R.

4). **Principal Axis** : It is a straight line joining the pole (P) and the centre of curvature (C) extended on both sides.

5). **Linear Aperture**: The diameter M_1M_2 of the spherical mirror is called the aperture or linear aperture of the mirror.

6). **Angular Aperture:** The angle M_1CM_2, subtented at C by the diameter of the spherical mirror is called the angular aperture of the mirror.

7). **Principal focus:** Principal focus is a point on the principal axis of the mirror at which the light rays coming parallel to principal axis actually meet after reflection (or appears to meet).



a). Concave Mirror (Converging Mirror)

b). Convex Mirror (diverging Mirror)

8). **Focal length (f):** The distance between the pole and focus is called focal length (f).

Sign Conventions

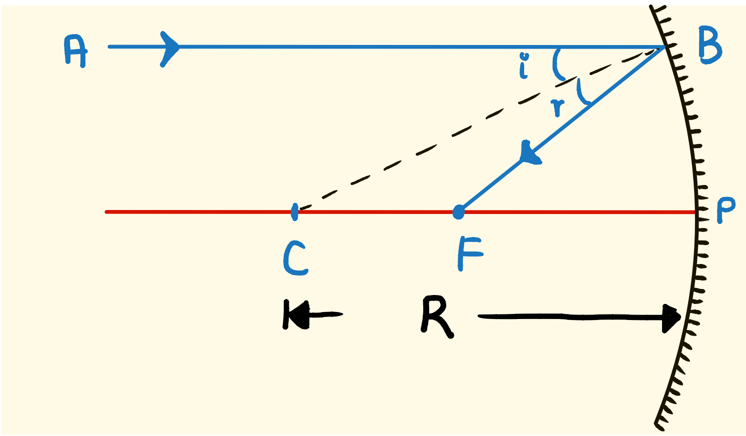
1). All distances have to be measured from the pole of the mirror.

2). Distances measured in the direction of incident light are positive, and those measured in opposite direction are taken as positive.

3). Heights measured upwards and normal to the principal axis of the mirror are taken as positive, while those measured downwards are taken as negative.

• Relation between focal length (f) and Radius of Curvature (R).

Consider a concave mirror of small aperture with pole at P, Principal focus at F and centre of Curvature at C. Then by definition $PC = R$ and $PF = f$



From figure

$\angle ABC = i \quad \angle CBF = r$

alternate angle

$\angle ABC = \angle CBF$

Since $i = r$ $\quad \angle BCF = \angle FBC$ $\quad \therefore$ Triangle CBF is isosceles

So that $CF = FB$

Since the aperture of the mirror is small, point B is close to Point P and hence $FB = PF$

$\therefore \; CF = PF$, This means that F is the midpoint of CP.

$\therefore \quad PF = \frac{1}{2} PC \quad$ or $\quad f = \frac{R}{2}$

Image formation in concave mirror for different positions of object

Position of the object	Position of the image	Size of the image	Nature of the image
At infinity	At the focus *F*	Highly diminished, point sized	Real and inverted
Beyond *C*	Between *F* and *C*	Diminished	Real and inverted
At *C*	At *C*	Same size	Real and inverted
Between *C* and *F*	Beyond *C*	Enlarged	Real and inverted
At *F*	At infinity	Highly Enlarged	Real and inverted
Between *P* and *F*	Behind the mirror	Enlarged	Virtual and erect

Image formation in convex mirror for different positions of object

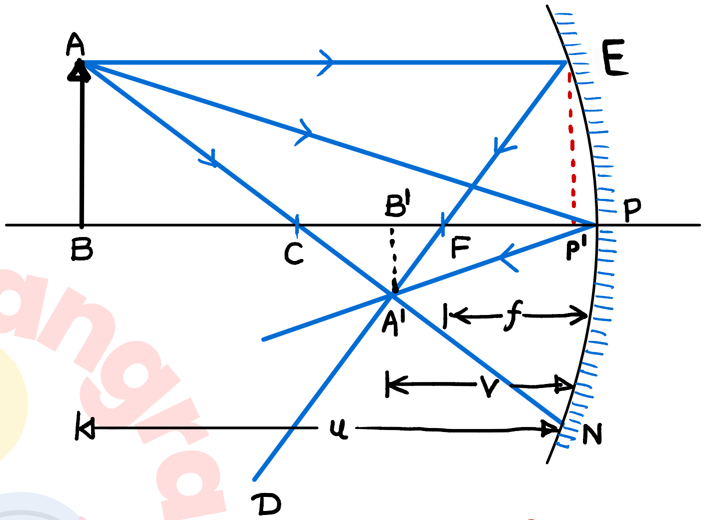
Position of the object	Position of the image	Size of the image	Nature of the image
At infinity	At the focus *F*, behind the mirror	Highly diminished point sized	Virtual and Erect
Between infinity and the pole *P* of the mirror	Between *P* and *F*, behind the mirror	Diminished	Virtual and Erect

Mirror Formula : Simple Relation between the distance u of the object from the mirror, the distance v of the image from the mirror and focal length f of the mirror.

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

- This is known as Mirror Formula.
- Valid for both Concave & Convex Mirror.

Derivation



Ray diagram for image formation of Concave mirror.

From pair of similar Triangles ABC and A'B'C.

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

from another pair of similar triangles A'B'F and EP'F.

$$\frac{P'E}{A'B'} = \frac{P'F}{B'F}$$

But $AE \parallel BP'$

$\therefore P'E = AB$ $\quad \therefore \dfrac{AB}{A'B'} = \dfrac{P'F}{B'F} \quad \text{---} (2)$

Comparing eq (1) & (2)

$$\frac{CB}{CB'} = \frac{P'F}{B'F} \Rightarrow \frac{PB - PC}{PC - PB'} = \frac{PF}{PB' - PF}$$

using sign convention.

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

on solving the equation

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

Note:

Focal length
↙ Convex ⇓ Positive
↘ Concave ⇓ Negative

Linear Magnification: The linear magnification of a spherical mirror is the ratio of height of image (I) formed by the mirror to the height of the object (O).

i.e linear Magnification

$$m = \frac{I}{O}$$

In similar triangles ABP & A'B'P

$$\frac{A'B'}{AB} = \frac{B'P}{BP} \Rightarrow \frac{-I}{O} = \frac{-v}{-u}$$

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

Refraction: It is the phenomena of bending of ray of light, when they pass from one transparent medium to another medium depending on their optical densities.

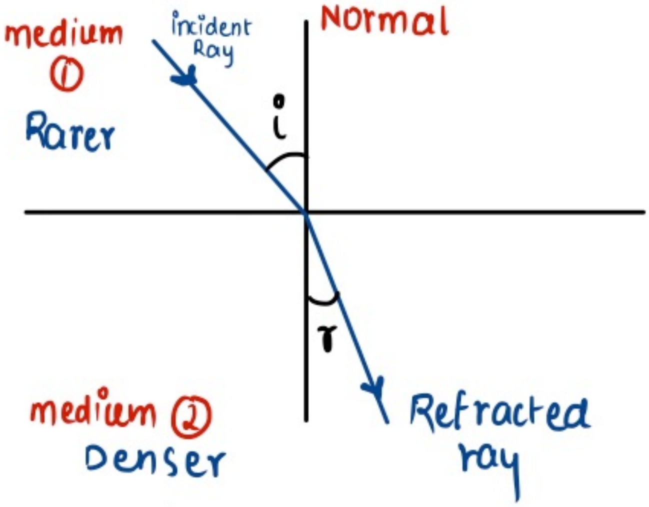
Laws of Refraction: i). The incident ray, the refracted ray and the normal to the interface at the point of incidence all lies in same plane.

ii). The ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant. This constant is called as Refractive index of medium.

$\boxed{\frac{\sin i}{\sin r} = \text{constant}}$ [Refractive index]. i.e $\boxed{n_{21} = \frac{\sin i}{\sin r}}$

n_{21} = Refractive index of medium 2 w.r.t medium 1

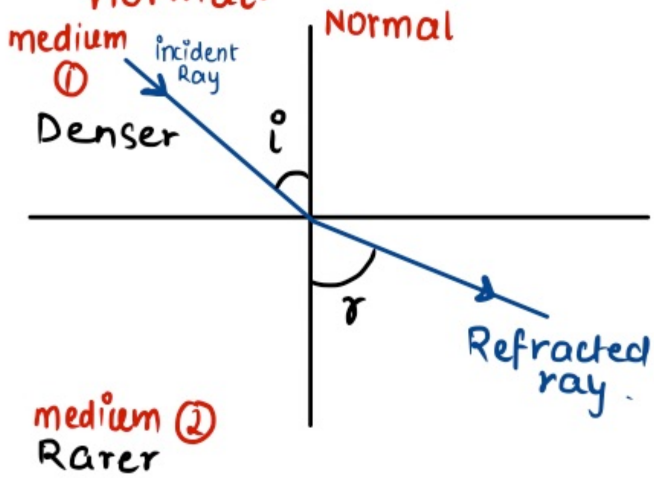
if $n_{21} > 1$ i.e $r < i$
ray bends toward normal



Note $i > r$ $v_2 < v_1$ (Speed)

$\mu_2 > \mu_1$ $\lambda_2 < \lambda_1$

if $n_{21} < 1$ i.e $r > i$
ray bends away from normal.



Note $i < r$
$v_2 > v_1$
$\mu_2 < \mu_1$
$\lambda_2 > \lambda_1$

Cause of Refraction The Speed of Light is different in different media.

Note: As a ray of light moves from medium 1 to medium 2, its wavelength changes but its frequency remains constant.

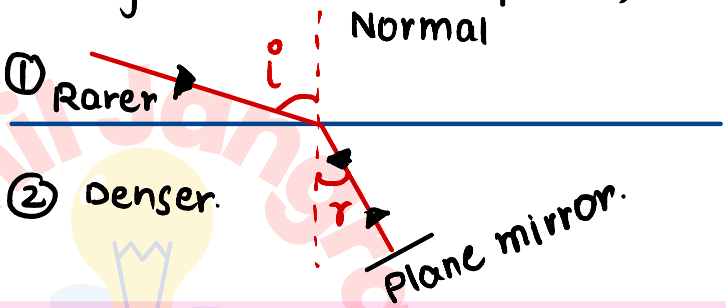
Absolute Refractive index.

$$\mu = \frac{\text{Speed of Light in vacuum}}{\text{Speed of Light in medium}} \qquad \boxed{\mu = \frac{c}{v}}$$

Principle of reversibility of Light States that when final path of a ray of Light after suffering any number of reflections & refractions is reversed, the ray retraces its path, exactly.

$$\boxed{n_{21} \times n_{12} = 1}$$

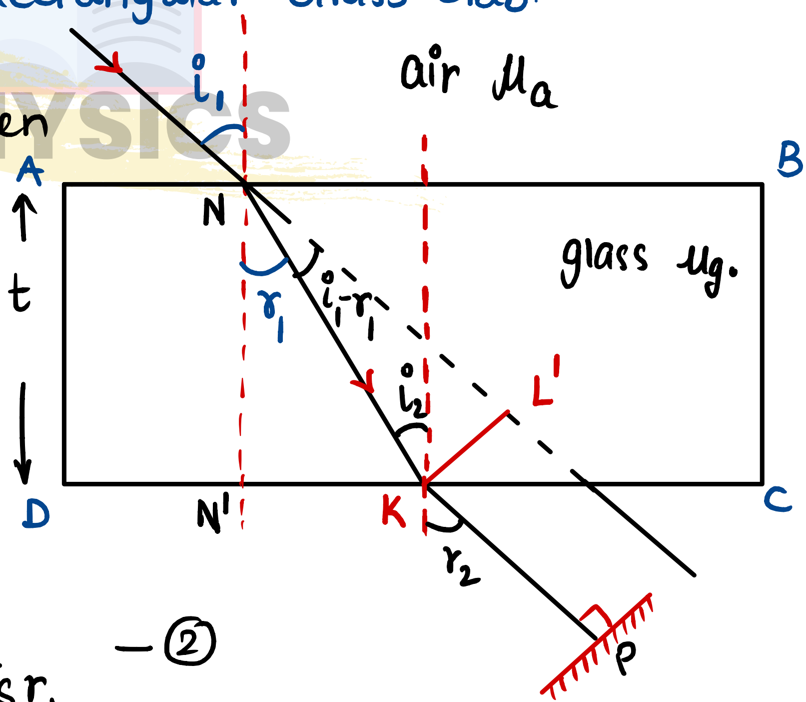
$$\boxed{n_{21} = \frac{1}{n_{12}}}$$



Refraction of Light Through a Rectangular Glass Slab.

Lateral displacement

Perpendicular distance between incident ray and emergent ray is called as Lateral displacement.



Here we have to find KL'.

In $\Delta NKL'$

$$\sin(i_1 - r_1) = \frac{KL'}{NK} \quad \text{—①}$$

To find NK using $\Delta NN'K$.

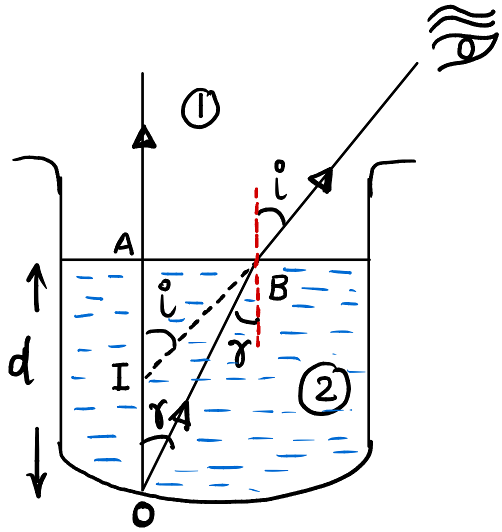
$$\cos r_1 = \frac{NN'}{NK} \Rightarrow NK = \frac{t}{\cos r_1} \quad \text{—②}$$

using ① and ② $\quad KL' = NK \sin(i_1 - r_1)$

$$\boxed{KL' = \frac{t \sin(i_1 - r_1)}{\cos r_1}}$$

Apparent Depth and Normal Shift :

When an object is in denser medium and observer is in rarer medium, then object appears to be at lesser depth than its actual depth.



Acc to Snell's Law.

$n_{21} = \frac{\sin i}{\sin r}$ $\sin i \simeq \tan i = \frac{AB}{AI}$

& $\sin r \simeq \tan r = \frac{AB}{AO}$

$n_{21} = n = \frac{\cancel{AB}}{AI} \times \frac{AO}{\cancel{AB}} \Rightarrow n = \frac{AO}{AI}$

AO = Actual depth
AI = Apparent depth

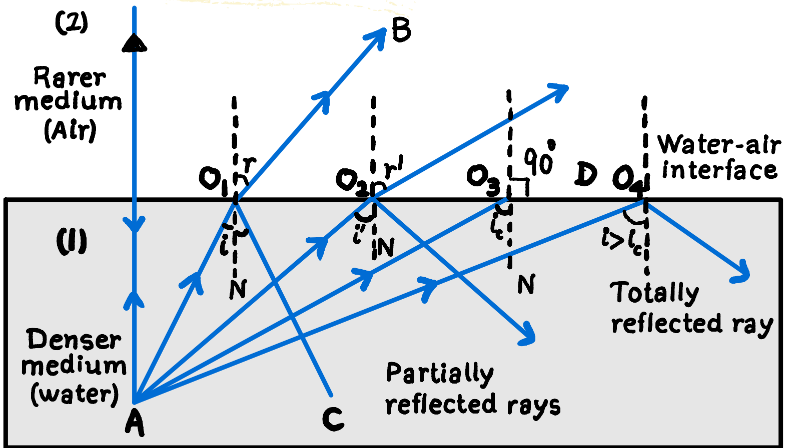
$AI = \frac{AO}{n} \Rightarrow \boxed{AI = \frac{d}{n}}$

$\boxed{\text{Normal Shift} = AO - AI \Rightarrow d\left(1 - \frac{1}{n}\right)}$

Total internal Reflection: When a light ray travelling from denser medium towards a rarer medium is incident at the interface at an angle of incidence greater than critical angle, then light ray totally reflected back into the dense medium. This phenomena is called TIR.

Critical Angle

The angle of incidence in a denser medium for which the angle of refraction in rarer medium becomes 90° is called critical angle.



i.e $i = C$ when $r = 90°$

$\frac{\sin C}{\sin 90} = \frac{\mu_{rarer}}{\mu_{denser}} = \frac{\mu_r}{\mu_d} = \sin C$

$\mu_r = \text{air} = 1$
& $\mu_d = \mu$

$C = \sin^{-1}\left(\frac{1}{\mu}\right)$

Condition must be obeyed for TIR

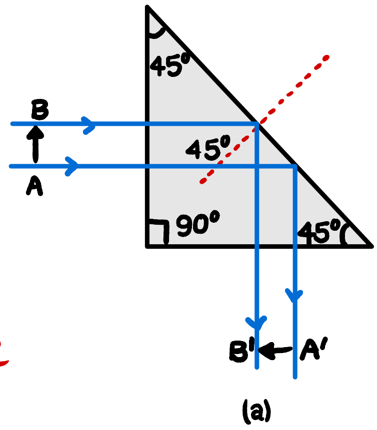
1). The ray must travel from denser medium to Rarer medium
2). The angle of incidence must be greater than critical angle.

Substance medium	Refractive index	Critical angle
Water	1.33	48.75
Crown glass	1.52	41.14
Dense flint glass	1.62	37.31
Diamond	2.42	24.41

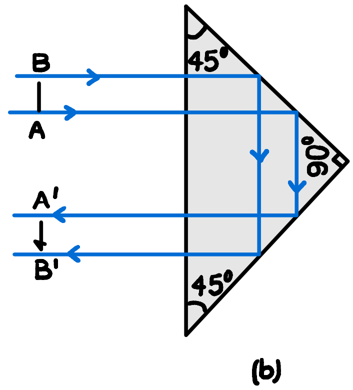
Application of TIR

1). Totally reflecting prism.

- Prism are right angled isosceles triangle which turn, the light ray by 90° or 180°. The critical angle C for material of prism must be less than 45°. True for both crown glass & dense flint glass.



(a)

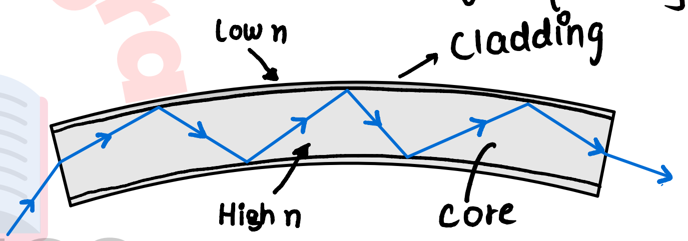


(b)

2). Diamond: The critical angle for diamond is very small, therefore once light enters a diamond, it is very likely to undergo total internal Reflection inside it. Due to this diamond shines brilliantly. Critical angle for diamond air interface is ≅ 24.4°

3). Optical fibres: These fibres are fabricated with high quality composite glass/ quartz fibres.

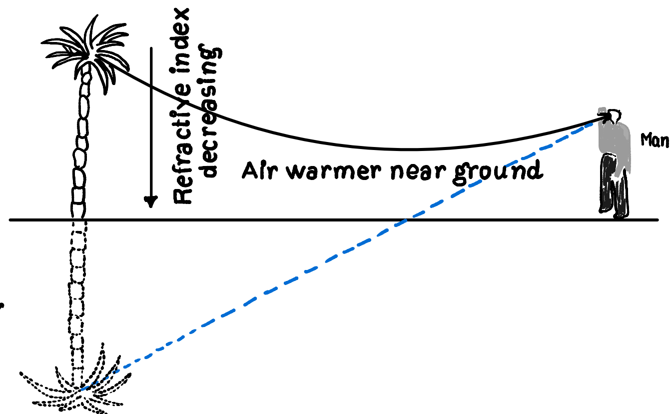
each fibre consist of a core and cladding such that refractive index of core is higher than that of the cladding.



when a signal in the form of light is directed at one end of the fibre at a suitable angle, it undergoes repeated total internal reflection along the length of the fibre and finally, comes out from other end.

Thus, these are extensively used for transmitting audio and video signals through long distances.

4). Mirage: It is the phenomena, in which an inverted image of distance tall objects cause an optical illusion of water. This type of mirage is especially common in hot deserts.



- On hot summer days, the air near the ground becomes hotter than the air at higher levels.
- Hotter air is less dense, and has smaller refractive index than the coolar air.
- The optical density at different layers of air increases with height.
- Thus light from a tall object, passes through a medium whose refractive index decreases toward ground. Thus light rays bends away from the Normal and undergoes total internal Reflection.

Refraction at spherical Surfaces

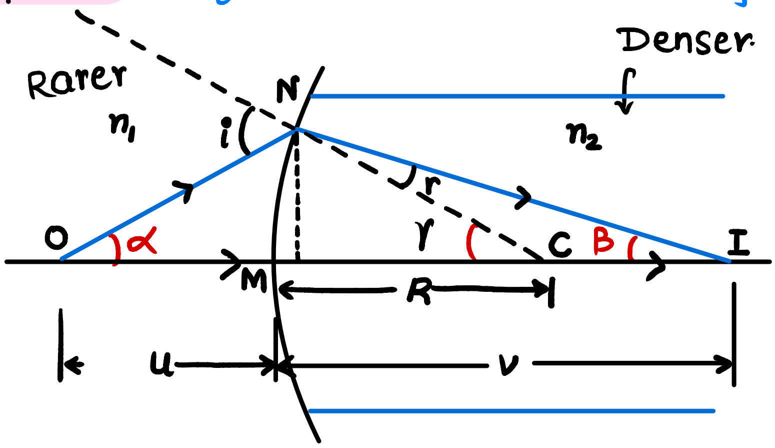
{convex Rarer to denser}

- Object is placed in rarer medium and image is formed in denser medium.

Acc to snell's law

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

$\{\sin i \simeq i \quad \sin r \simeq r\}$



Refraction at a spherical surface separating two media.

From figure

$$i = \alpha + \gamma \quad \& \quad r = \gamma - \beta$$

So $\quad \dfrac{n_2}{n_1} = \dfrac{\alpha+\gamma}{\gamma-\beta} \Rightarrow n_1(\alpha+\gamma) = n_2(\gamma-\beta)$ — (1)

from figure $\quad \alpha = \dfrac{MN}{OM} \quad \beta = \dfrac{MN}{MI} \quad \gamma = \dfrac{MN}{MC}$

using all value in eq (1) we get.

$$n_1\left[\frac{MN}{OM} + \frac{MN}{MC}\right] = n_2\left[\frac{MN}{MC} - \frac{MN}{MI}\right]$$

using sign convention $\quad OM = -u \quad MC = +R \quad MI = +v$

so we get

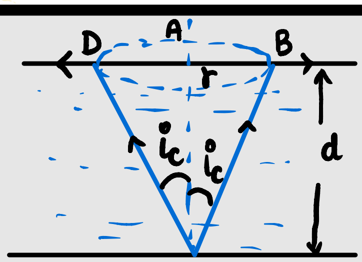
$$\boxed{-\frac{n_1}{u} + \frac{n_2}{v} = \frac{n_2 - n_1}{R}}$$

For Rarer to denser.

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

For denser to Rarer.

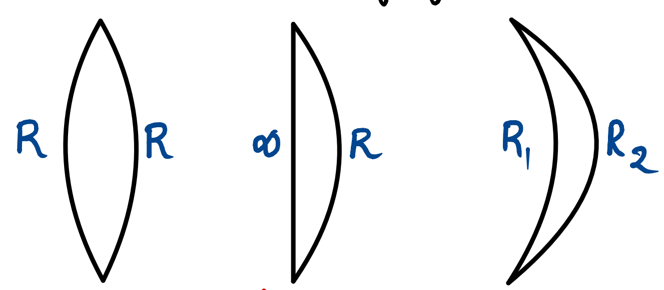
NOTE: A diver in water at a depth d sees the world outside through a horizontal Circle of radius $\quad r = d \tan i_c \quad$ Or $\quad r = \dfrac{d}{\sqrt{\mu^2 - 1}}$



LENS: A lens is a uniform transparent medium bounded between two spherical or one spherical and one plane surface.

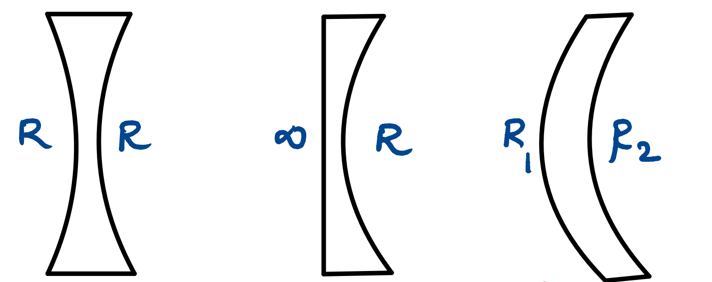
LENS

Convex or Converging lens



Double Convex lens | plano Convex lens | concavo-Convex lens

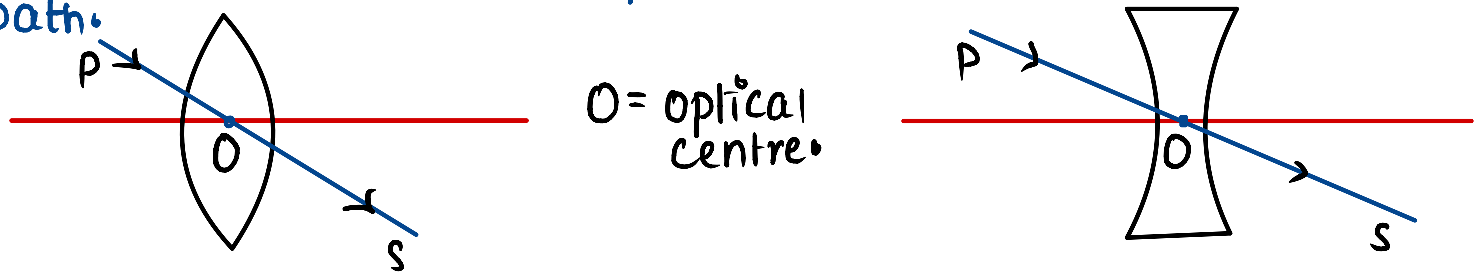
Concave or diverging lens



Double Concave lens | plano Concave lens | Convexo concave lens.

Some definitions Related to lens

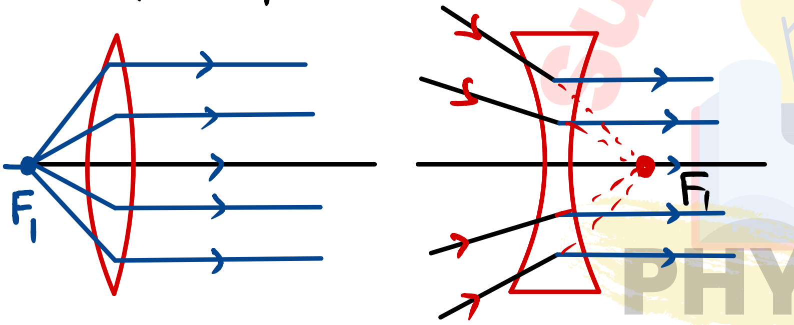
Optical Centre: The optical centre is a point within or outside the lens, at which incident rays refract without deviation in its path.



Principal focus

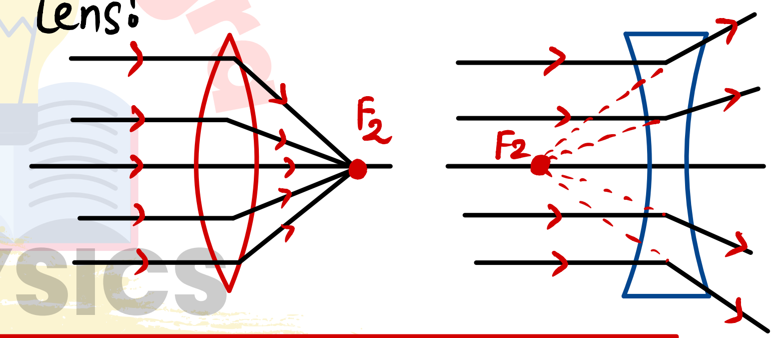
1) First Principal focus

It is a point on the principal axis of lens, the rays starting from this point in convex lens or rays directed to this point in concave lens become parallel to principal axis.



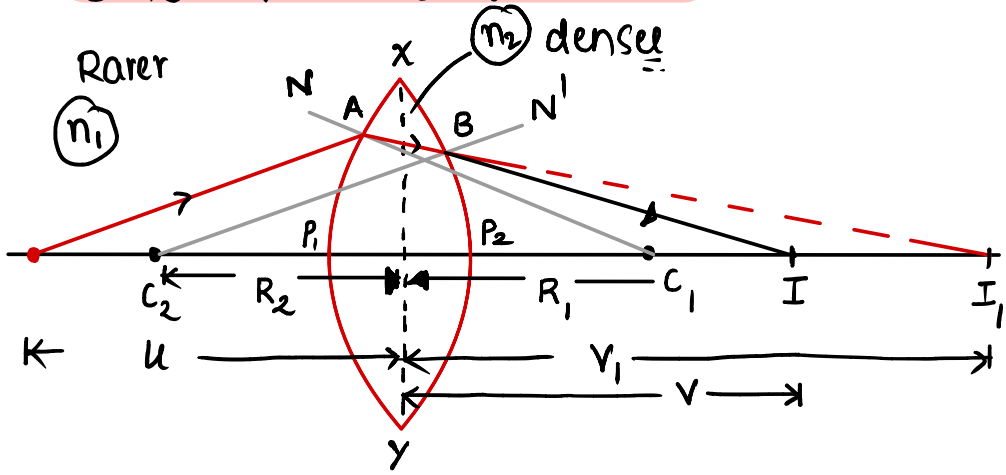
2) Second principal focus.

It is a point on the principal axis at which the rays coming parallel to the principal axis converge (convex lens) or passing through it appear to diverge (concave lens) at this point after refraction from the lens.



> **Note:** Both the focus of convex lens are real, while that of concave lens are virtual. We always uses second Principal focus.

Lens Maker's formula



Refraction at Interface XP_1Y
Rarer to denser, we get.

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

Now Refraction at interface XP_2Y.
[Denser to Rarer]
i.e (v_1 acts as object)

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

adding equation ① & ② we get.

$$-\frac{n_1}{u}+\frac{n_2}{v_1}-\frac{n_2}{v_1}+\frac{n_1}{u}=\frac{(n_2-n_1)}{R_1}-\frac{(n_2-n_1)}{R_2}$$

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

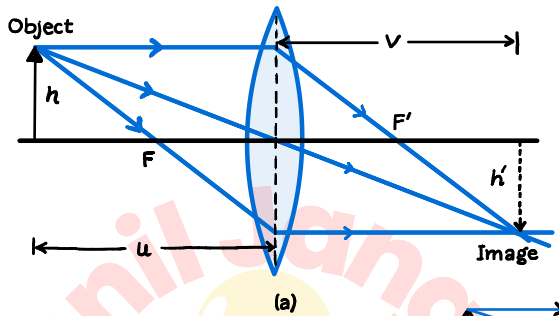
if $u=\infty$ $v=f$

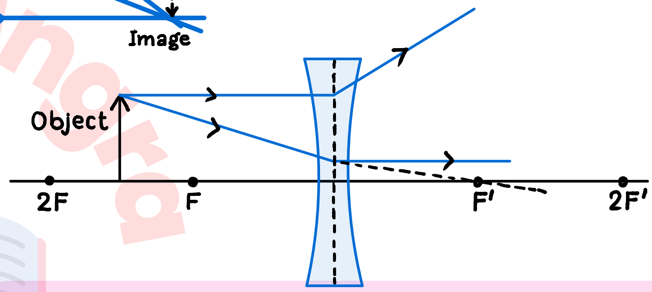
So

$$\boxed{\frac{1}{f}=(n_{21}-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)} \quad \text{or} \quad \boxed{\frac{1}{f}=(n-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)}$$

Thin lens formula

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





Magnification

$$m=\frac{\text{size of the image}}{\text{size of the object.}}$$

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

m = +ve for convex
m = −ve for concave

Power of a lens : It is the ability of the lens to deviate the path of rays passing through it. If the lens converges the rays parallel to principal axis, its power is said positive and if it diverges the rays, its power is negative.

Note:→ The reciprocal of the focal length of a lens, when it is measured in metre is called power of a lens.

Power of a lens $P=\frac{1}{f(\text{metre})}$, its unit is diopter (D).

Combination of thin lenses in contact.

The first lens produces an image at I_1. Since I_1 is real, it serves as a virtual object for the second lens B, producing final image at I.

for the image formed by the first lens A, we get.

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

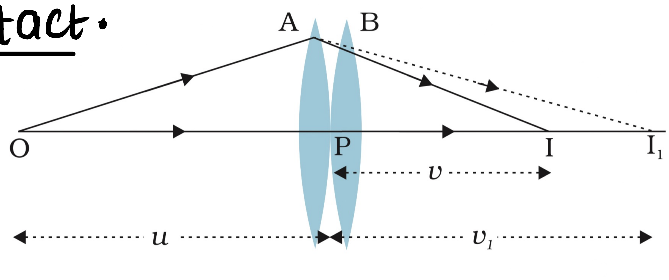


Image formation by a combination of two thin lenses in contact.

for the image formed by second lens B

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

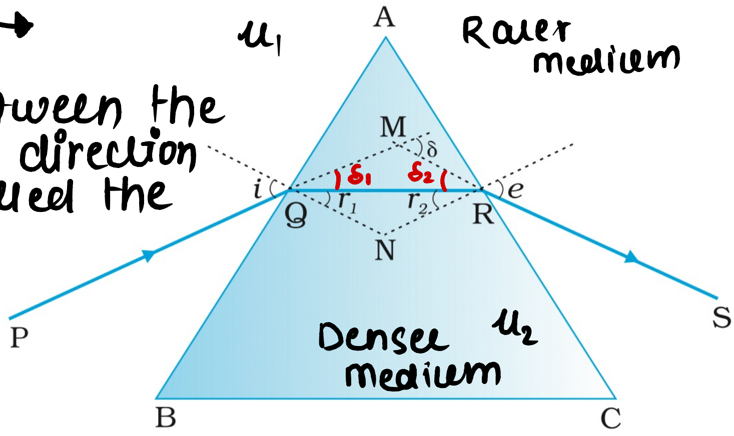
adding eq ① & ② we get $\frac{1}{v} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2}$

acc. to thin lens formula we get $\boxed{\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}}$

and Power $P = P_1 + P_2$ or $P = P_1 + P_2 + P_3 \ldots$

Total magnification m of Combination $m = m_1 \times m_2 \times m_3$

Refraction through a Prism :→



A ray of light passing through a triangular glass prism.

Angle of deviation : The angle between the emergent ray RS and the direction of the incident ray PQ is called the angle of deviation δ.

from fig $\delta = \delta_1 + \delta_2$ — ①

$i = \delta_1 + r_1 \Rightarrow \delta_1 = i - r_1$

$e = \delta_2 + r_2 \Rightarrow \delta_2 = e - r_2$

using value of δ_1 & δ_2 in eq ①. we get

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

$\delta = (i + e) - (r_1 + r_2)$ — ②

from quadrilateral AQNR.

$\angle A + 90^\circ + \angle QNR + 90^\circ = 360^\circ$

$\angle A + \angle QNR = 180^\circ$ — ③

from triangle QNR

$r_1 + \angle QNR + r_2 = 180^\circ$ — ④.

equating eq 3 & 4 we get.

$A = r_1 + r_2$ so equation 2nd can be written as.

$\boxed{\delta = i + e - A}$ — ⑤

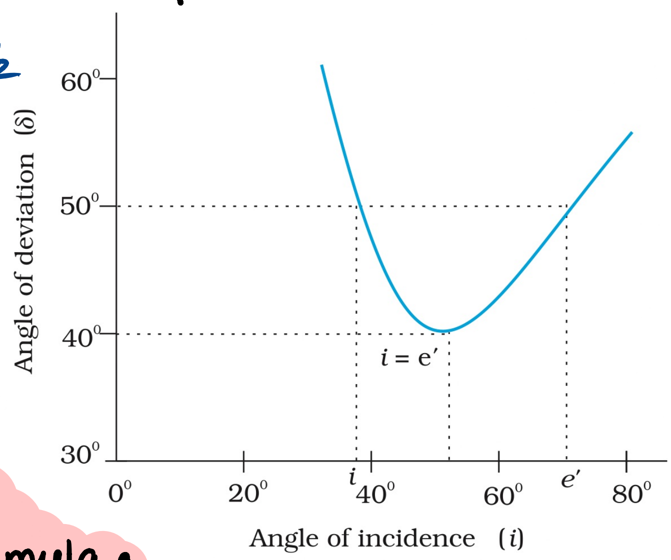
Minimum deviation : The angle of emergence of the ray from the second face equals the angle of incidence of the ray on first face then deviation produced is minimum.

i.e $\delta = D_m$, $i = e$ which implies $r_1 = r_2$

so eq 5^{th} become as.

$D_m = 2i - A \Rightarrow i = \frac{D_m + A}{2}$

& $A = r_1 + r_2 \Rightarrow r = A/2$



Acc to snell's law

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

Called as prism formula.

for small prism

D_m = minimum deviation.

$$\sin\left(\frac{A+D_m}{2}\right) \simeq \frac{A+D_m}{2} \qquad \sin\left(\frac{A}{2}\right) \simeq \frac{A}{2}$$

$$\mu = \frac{A+D_m}{2} \times \frac{2}{A} \Rightarrow \mu A = A + D_m \Rightarrow \boxed{D_m = (\mu - 1)A}$$

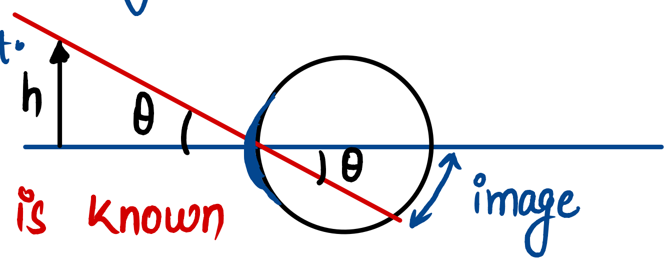
Note: Thin prism do not deviate light much.

Optical Instrument.

Power of accommodation: The ability of eye to see near object as well as far objects is called power of accommodation.

Range of vision: The minimum distance for clear vision of an object is called least distance of distinct vision (D). for normal eye this distance is generally taken to be 25 cm.

Visual Angle: The size of the image on the retina is roughly proportional to the angle subtented by the object on the eye. This angle is known as Visual Angle.



Magnifying Power is the factor by which the image on the retina can be enlarged by using the microscope or telescope.

Magnifying Power of a microscope

$$M = \frac{\text{visual angle formed by final image.}}{\text{visual angle formed by the object kept at D.}}$$

Magnifying Power of a Telescope

$$M = \frac{\text{visual angle formed by final image}}{\text{visual angle formed by the object}}$$

Optical Instrument.

Microscope

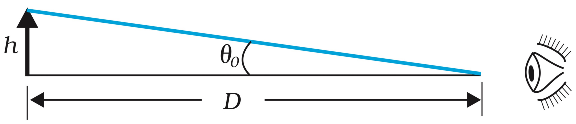
It is an instrument used to see very small object.

- Simple Microscope
- Compound Microscope.

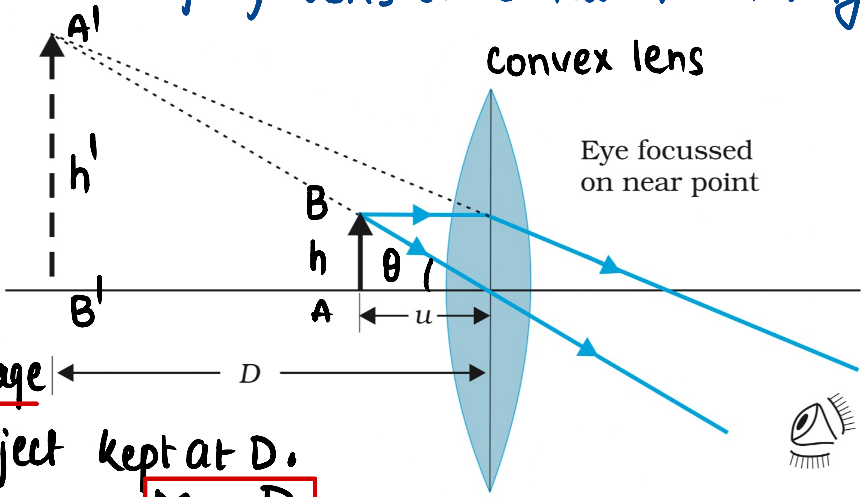
Telescope

- Refracting Telescope
- Reflecting Telescope

1). Simple Microscope it is used for observing magnified images of objects. it consists of a converging lens of small focal length.



Angle subtented by object



Magnifying Power

$$M = \frac{\text{visual angle formed by image}}{\text{visual angle formed by object kept at D.}}$$

$$M = \frac{\theta}{\theta_0} \simeq \frac{\tan\theta}{\tan\theta_0} = \frac{h}{u} \times \frac{D}{h} = \boxed{M = \frac{D}{u}}$$

Magnification

Maximum magnification

when image formed at D

$u = -u \quad v = -D \quad f = +f$

using thin lens formula.

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

$$\frac{1}{u} = \frac{1}{D} + \frac{1}{f} \quad \text{so} \quad \boxed{M = 1 + \frac{D}{f}}$$

Minimum magnification.

when image formed at ∞.

$u = -u \quad v = \infty \quad f = f$

$$\text{so} \quad -\frac{1}{-u} + \frac{1}{-\infty} = \frac{1}{f} \Rightarrow \frac{1}{u} = \frac{1}{f}$$

$$\boxed{M_\infty = \frac{D}{f}}$$

Compound Microscope: It Consists of two convex lenses coaxially separated by some distance. The lens nearer to the object is called the objective. The lens through which the final image is viewed is called the eye piece.

$$M = \frac{\tan\theta}{\tan\theta_0}$$

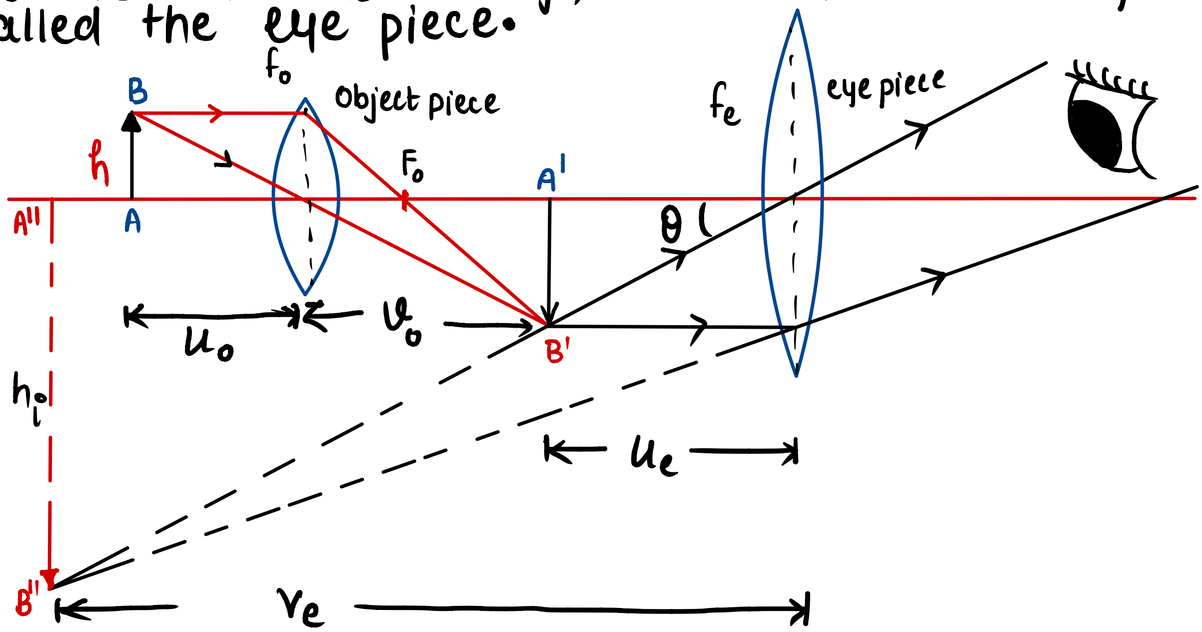
$$M = \frac{A'B'}{u_e} \times \frac{D}{AB}$$

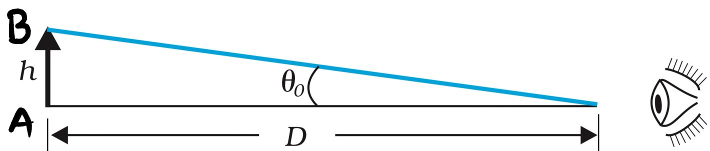
$$M = \frac{D}{u_e} \cdot \frac{A'B'}{AB}$$

From thin lens formula.

$$\frac{A'B'}{AB} = \frac{v_0}{u_0}$$

$$\text{So} \quad \boxed{M = \frac{v_0}{u_0}\left(\frac{D}{u_e}\right)}$$





Visual Angle formed by object.

Maximum Magnification

when $v_e = -D$ $u = -u_e$ $f = f_e$

From thin lens formula.

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

$$\frac{1}{u_e} = \frac{1}{D} + \frac{1}{f_e} \quad \text{so} \quad M = \frac{v_0}{u_0}\left(1 + \frac{D}{f_e}\right)$$

Minimum Magnification

when $v_e = -\infty$ $u = -u_e$ $f = f_e$.

so

$$+\frac{1}{u_e} + \frac{1}{-\infty} = \frac{1}{f_e} \Rightarrow \frac{1}{u_e} = \frac{1}{f_e}$$

$$\boxed{M_\infty = \frac{v_0}{u_0}\left(\frac{D}{f_e}\right)}$$

Length of Compound Microscope: distance between object & eye piece

i.e $\boxed{L = v_0 + u_e}$

Telescope: To look at distant object such as a star, a planet or a distant tree etc, we use telescopes.

Telescope

- Refracting Telescope
- Reflecting Telescope

Refracting Telescope (Astronomical Telescope)

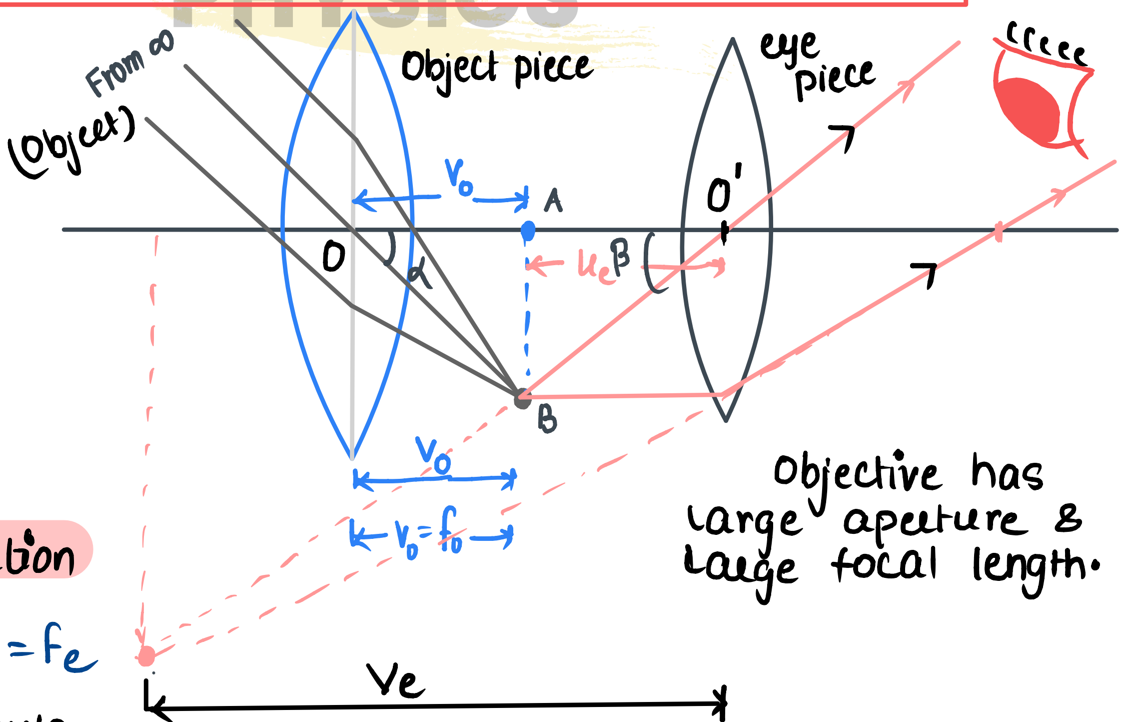
Magnifying Power (M): $\dfrac{\text{visual Angle formed by final image}}{\text{visual angle subtended by the object}}$

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

$$M = \frac{AB}{u_e} \times \frac{v_0}{AB}$$

$$M = \frac{v_0}{u_e} \qquad v_0 = f_0$$

so $\boxed{M = \frac{f_0}{u_e}}$



Objective has large apeture & Large focal length.

Maximum Magnification

$u = -u_e$ $v_e = -D$ $f = f_e$

from thin lens formula.

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

$$\frac{1}{u_e} = \frac{1}{f_e} + \frac{1}{D} \quad \text{so} \quad M = f_0\left(\frac{1}{f_e} + \frac{1}{D}\right) \Rightarrow M = \frac{f_0}{f_e}\left(1 + \frac{f_e}{D}\right)$$

for Minimum Magnification $u = -u_e \quad v = \infty \quad f = f_e$

So $\frac{1}{+u_e} + \frac{1}{-\infty} = \frac{1}{f_e} \Rightarrow \frac{1}{u_e} = \frac{1}{f_e}$ So $\boxed{M_\infty = \frac{f_o}{f_e}}$

Length of Telescope

$\boxed{L = v_o + u_e}$ when image is at D.

$\boxed{L = f_o + f_e}$ when image formed at infinity.

Disadvantages of Refracting Telescope

Aberrations : Actual image formed by an optical system is usually imperfect. The defect of images are called aberration.

Chromatic aberration. The image of an object by a lens is usually coloured and blurred. This defect of image is called chromatic aberration. This defect arises due to the fact that focal length of a lens is different for different colours.

Monochromatic aberrations: This is the defect in image due to optical system.

Note: To remove these defects we use Reflecting Telescope

Reflecting Type Telescope:

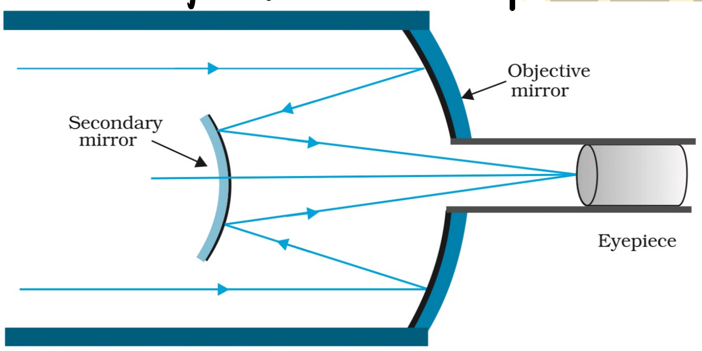
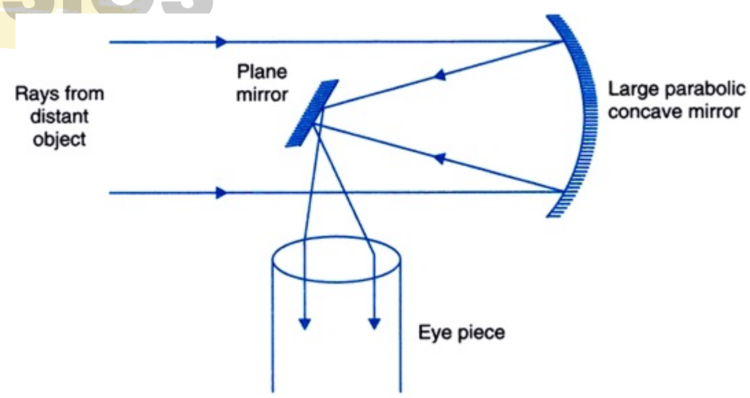


FIGURE 9.30 Schematic diagram of a reflecting telescope (Cassegrain).



Newtonian Telescope

Note: for three reason, modern Telescopes use a concave mirror rather than a lens.

- There is no aberration in mirror.
- due to parabolic reflecting surface, spherical aberration is removed.
- Mechanical Support is much less needed.

$\boxed{\text{Magnifying Power} \quad m = \frac{f_o}{f_e}}$

Thank you