Ray Optics

Light

Light is a form of energy which produces the sensation of sight on our eyes.

Sources of light are of three types-thermal sources, gas discharge sources and luminescent sources.

Photometry is a branch of ray optics which deals with the measurement of light energy.

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.

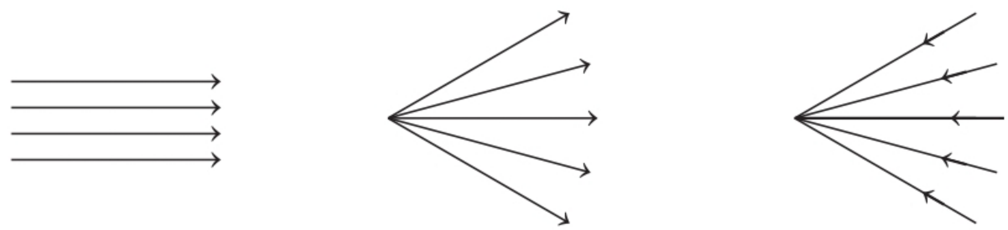
Important Terms

(i) **Luminous Objects** The objects which emits its own light are called luminous objects, *e.g.* sun, other stars, an oil lamp etc.

(ii) **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, *e.g.* moon, table, chair, trees etc.

(iii) **Ray of Light** A straight line drawn in the direction of propagation of light is called a ray of light.

(iv) **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

(v) **Image** If light ray coming from an object meets or appear to meet at a point after reflection or refraction, then this point is called image of the object.

(vi) **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.

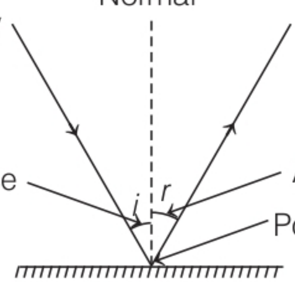
(vii) **Virtual Image** The image obtained when light rays are not really meeting but appears to meet only, is called a virtual image.

Reflection of Light

The rebouncing back of light rays into the same medium on striking a highly polished surface such as a mirror is called reflection of light.

Laws of Reflection

There are two laws of reflection

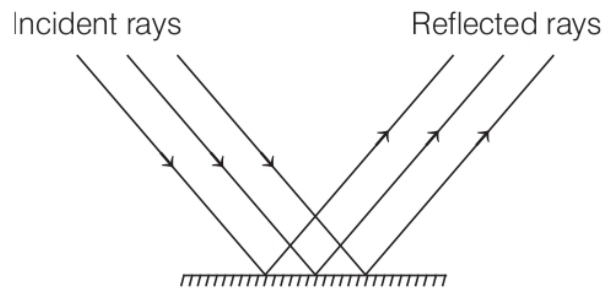


(i) The incident ray, the reflected ray and the normal at the point of incidence all three lie in the same plane.

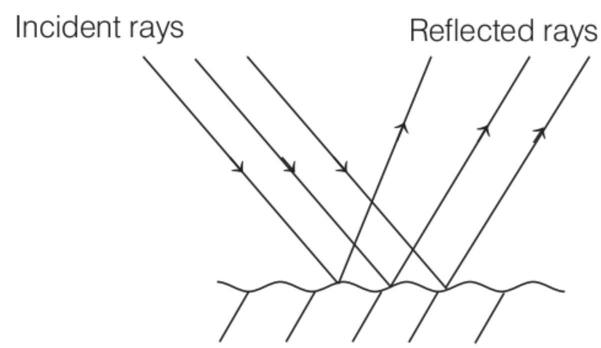
(ii) The angle of incidence (i) is always equal to the angle of reflection (r).

Types of Reflection

(i) **Regular Reflection** When a parallel beam of reflected light rays is obtained from a parallel beam of incident light rays after reflection from a plane reflecting surface, then such type of reflection is called regular reflection.



(ii) **Irregular or Diffused Reflection** When a non-parallel beam of reflected light rays is obtained from a parallel beam of incident light rays after reflection from a surface, then such type of reflection is called irregular or diffused reflection.



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 may see his full image in a mirror of half height of man.

- When two plane mirror are held at an angle θ, the number of images of an object placed between them is given as below

(a) $n = \left(\frac{360°}{\theta} - 1\right)$, if $\frac{360°}{\theta}$ is an even integer.

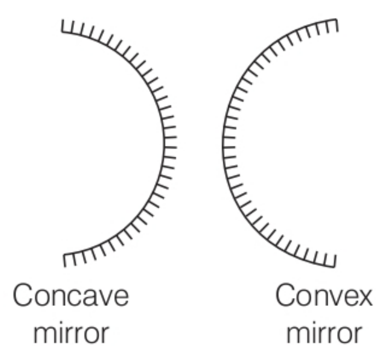
(b) $n =$ integral part of $\frac{360°}{\theta}$, when $\frac{360°}{\theta}$ is an odd integer.

- If keeping an object fixed, a plane mirror is rotated in its plane by an angle θ, then the reflected ray rotates in the same direction by an angle 2θ.
- Focal length as well as radius of curvature of a plane mirror is infinity. Power of a plane mirror is zero.
- In the image formed by a plane mirror, the right side of the object appears as left side and *vice-versa*. This phenomena is called **lateral inversion**.

(ii) **Spherical Mirror** A highly polished curved surface whose reflecting surface is a cut part of a hollow glass sphere is called a spherical mirror. Spherical mirrors are of two types

(a) **Concave Mirror** A spherical mirror whose bent in surface is reflecting surface, is called a concave mirror.

(b) **Convex Mirror** A spherical mirror whose buldging out surface is reflecting surface, is called a convex mirror.



Some Terms Related to Spherical Mirrors are Given Below

(i) **Centre of Curvature** (C) It is the centre of the sphere of which the mirror is a part.

(ii) **Radius of Curvature** (R) The radius of the hollow sphere of which the mirror is a part is called radius of curvature.

(iii) **Pole** (P) The central point of the spherical mirror is called its pole (P).

(iv) **Focus** (F) When a parallel beam of light rays is incident on a spherical mirror, then after reflection it meets or appears to meet at a point on principal axis which is called focus of the spherical mirror.

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

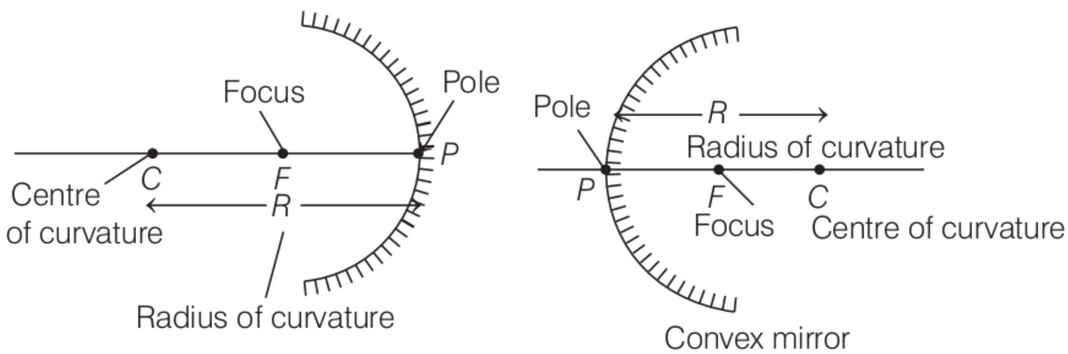
Relation between focal length and radius of curvature is given by

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

The power of a mirror is given as $P = \frac{1}{f}$ (metre)

(vi) **Mirror formula** $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$

where, f = focal length of the mirror, u = distance of the object and v = distance of the image.



Newton's formula for a concave mirror,

$$f = \sqrt{x_1 x_2}$$

$$\Rightarrow \qquad f^2 = x_1 x_2$$

where, x_1 and x_2 are the distances of object and image from the focus.

Linear Magnification

The ratio of height of image (I) formed by a mirror to the height of the object (O) is called linear magnification (m).

Linear magnification $(m) = \frac{I}{O} = -\frac{v}{u}$

Areal and Axial Magnification

The ratio of area of image to the area of object is called areal magnification.

Areal magnification $= m^2 = \frac{\text{Area of image}}{\text{Area of object}} = \frac{v^2}{u^2}$

When a small sized object is placed linearly along the principle axis, then its longitudinal or axial magnification is given by

Axial magnification $= -\frac{dv}{du} = \left(\frac{v}{u}\right)^2 = \left(\frac{f}{f-u}\right)^2 = \left(\frac{f-v}{f}\right)^2$

Sign Convention for Spherical Mirrors

(i) All distances are measured from the pole of the mirror.

(ii) Distances measured in the direction of incident light rays are taken as positive.

(iii) Distances measured in opposite direction to the incident light rays are taken as negative.

(iv) Distances measured above the principal axis are positive.

(v) Distances measured below the principal axis are negative.

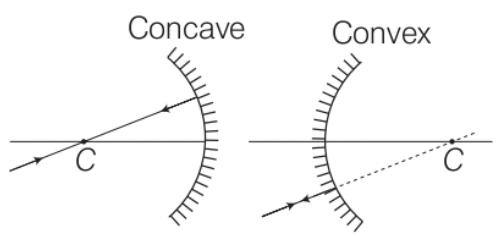
Note The focal length of concave mirror is taken negative and for a convex mirror taken as positive.

Rules for Image Formation in Spherical Mirrors

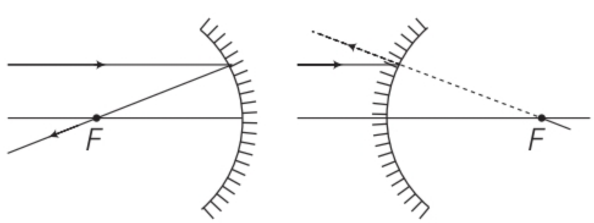
In ray optics, to locate the image of an object, tracing of a ray as it reflects is very important.

Following four types of rays are used for image formation

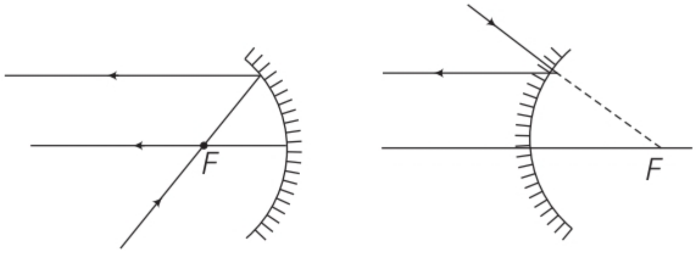
Ray 1. A ray through the centre of curvature which strikes the mirror normally and is reflected back along the same path.



Ray 2. A ray parallel to principal axis after reflection either actually passes through the principal focus F or appears to diverge from it.



Ray 3. A ray passing through the principal focus F or a ray which appears to converge at F is reflected parallel to the principal axis.



Ray 4. A ray striking at pole P is reflected symmetrically back in the opposite side.

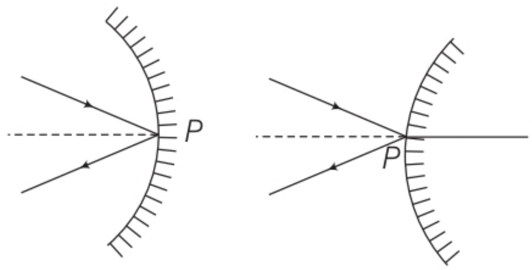
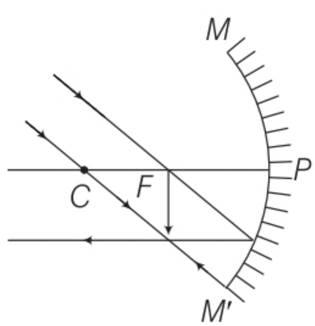
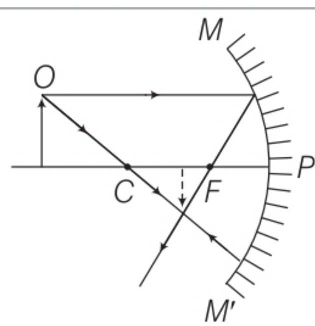


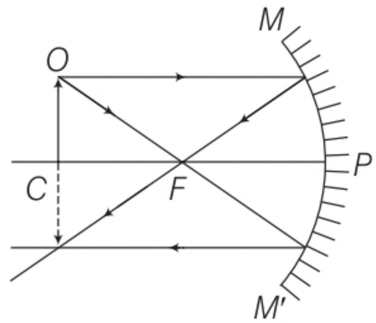
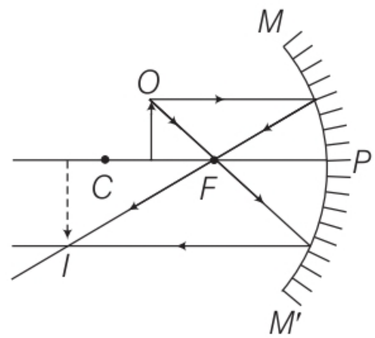
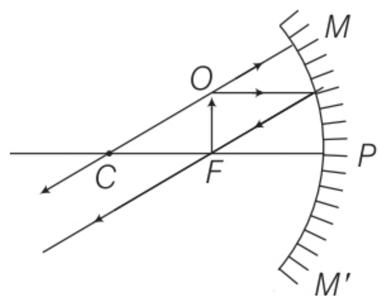
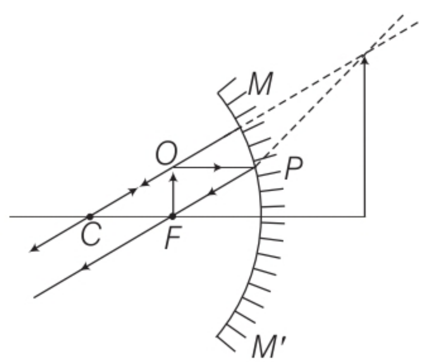
Image Formation by Spherical Mirrors

1. Image formation by concave mirror

In case of a concave mirror, the image is erect and virtual when the object is placed between F and P. In all other positions of object, the image is real and inverted as shown in the table given below.

Image Formation by Concave Mirror

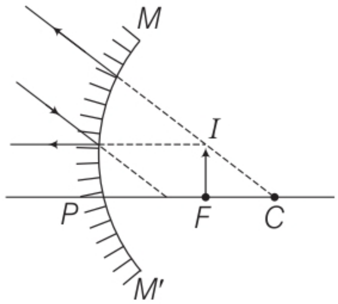
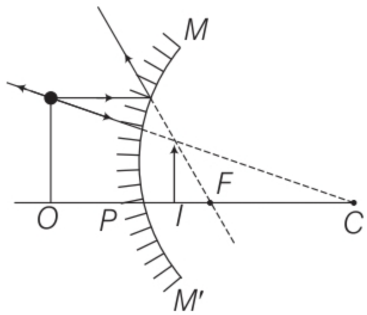
S.No.	Position of Object	Ray Diagram	Properties of Image
1.	At infinity		Real, inverted, very small at F
2.	Between infinity and C		Real, inverted, diminished between F and C

S.No.	Position of Object	Ray Diagram	Properties of Image
3.	At C		Real, inverted, equal in size at C
4.	Between F and C		Real, inverted and very large between 2 F and infinity
5.	At F		Real, inverted, very large at infinity
6.	Between F and P		Virtual, erect, large in size behind the mirror

2. Image formation by convex mirror

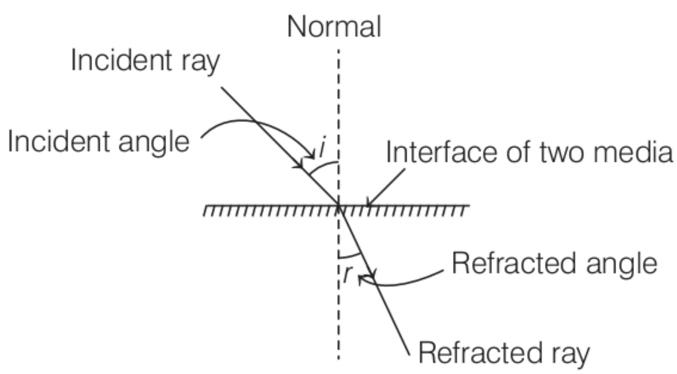
Image formed by convex mirror is always virtual, erect and diminished no matter where the object is. All the images formed by this mirror will be between pole and focus as shown in the table given below.

Image Formation by Convex Mirror

S.No.	Position of Object	Ray Diagram	Details of Image
1.	At infinity		Virtual, erect, very small in size at *F*
2.	In front of mirror		Virtual, erect, diminished between *P* and *F*

Refraction of Light

The deviation of light rays from its path when it travels from one transparent medium to another transparent medium is called refraction of light.



- When a ray of light goes from a rarer medium to a denser medium, it bends towards the normal.
- When a ray of light goes from a denser medium to a rarer medium, it bends away from the normal.

Cause of Refraction

The speed of light is different in different media.

Laws of Refraction

(i) The incident ray, the refracted ray and the normal at the point of incidence, all three lies in the same plane.

(ii) The ratio of sine of angle of incidence to the sine of angle of refraction is constant for a pair of two media,

i.e. $$\frac{\sin i}{\sin r} = \text{constant } ({}_1\mu_2)$$

where ${}_1\mu_2$ is called **refractive index** of second medium with respect to first medium. This law is also called **Snell's law.**

Refractive Index

The ratio of speed of light in vacuum (c) to the speed of light in any medium (v) is called refractive index of the medium.

Refractive index of a medium, $\mu = \frac{c}{v}$

Refractive index of water $= \frac{4}{3} = 1.33$

Refractive index of glass $= \frac{3}{2} = 1.50$

When light is reflected by a denser medium, phase difference of π radian or path difference of $\frac{\lambda}{2}$ or time difference $\frac{T}{2}$ is produced. This is known as Stoke's law. Distance x travelled by light in a medium of refractive index μ is equal to distance (μx) travelled in vacuum.

Time taken by light to transverse a thickness $x = \frac{\mu x}{c}$
where $c =$ velocity of light in vacuum.

Relative Refractive Index

The refractive index of second medium with respect to first medium

$${}_1\mu_2 = \frac{v_1}{v_2}$$

where, v_1 is the speed of light in medium 1 and v_2 is the speed of light in medium 2.

Cauchy's Formula

Refractive index of a medium, $\mu = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4} + \ldots\ldots$

where, $\lambda =$ wavelength of light and A, B, C ..... are constants.

$\therefore$ Refractive index, $\mu \propto \frac{1}{\lambda^2}$

Refraction through a Glass Slab

When a glass slab is placed in the path of a light ray it produces a shift in the position of object when viewed through it, which is $= \left(1 - \frac{1}{n}\right)t$.

When object is in denser medium and seen from rarer medium normally through the plane surface, then apparent depth of object $= \left(1 - \frac{1}{n}\right) \times$ actual depth of object in denser medium.

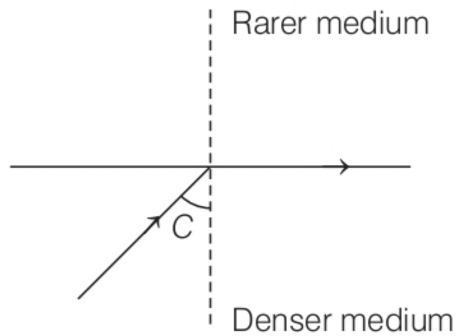
Critical Angle

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

Critical angle for diamond = 24°

Critical angle for glass = 42°

Critical angle for water = 48°



Refractive index of denser medium,

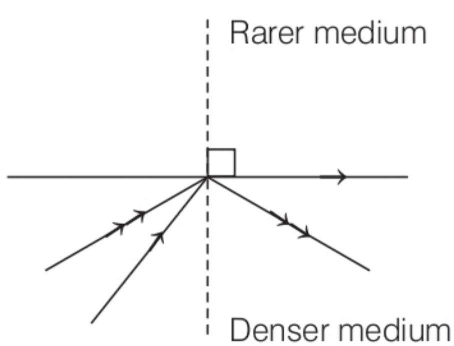
$$\mu = \frac{1}{\sin C}$$

Critical angle increases with temperature.

The refractive index is maximum for violet colour of light and minimum for red colour of light, *i.e.* $\mu_V > \mu_R$, therefore critical angle is maximum for red colour of light and minimum for violet colour of light, *i.e.* $C_V < C_R$.

Total Internal Reflection (TIR)

When a light ray travelling from a denser medium towards a rarer medium is incident at the interface at an angle of incidence greater than critical angle, then light rays are totally reflected back in to the denser medium. This phenomena is called TIR.



For total internal reflection to take place following set conditions must be obeyed

(i) The ray must travel from denser medium to rarer medium.

(ii) The angle of incidence ($\angle i$) must be greater than critical angle ($\angle C$).

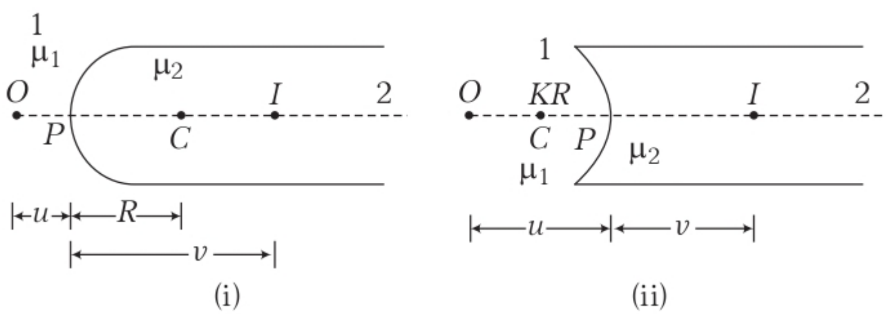
Mirage is an optical illusion observed in deserts and roads on a hot day which is an application of TIR.

Optical Fibres

Optical fibres are also based on the phenomenon of total internal reflection. Optical fibres consist of several thousands of very long fine quality fibres of glass or quartz. The diameter of each fibre is of the order of 10^{-4} cm with refractive index of material being of the order of 1.5. These fibres are fabricated in such a way that light reflected at one side of the inner surface strikes the other at an angle larger than critical angle. Even, if fibre is bent, light can easily travel along the length. Thus, these are used in transmission and reception of electrical signals by converting them first into light signals.

Refraction at Spherical surfaces

When two transparent media are separated by a spherical surface, light incident on the surface from one side get refracted into the medium on the other side. Spherical surfaces are of two types as shown in figure.



Spherical surface (i) convex (ii) concave

For both surfaces refraction formula is given by

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

where, μ = refractive index, u = distance of object, v = distance of image and R = radius of curvature of the spherical surface.

Lens

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

Convex Lens

A lens which is thinner at edges and thicker at middle is called a convex or converging lens.

Concave Lens

A lens which is thicker at edges and thinner at middle is called a concave or diverging lens.

Lens Formula

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

where, f = focal length of the lens, u = distance of object and v = distance of image.

Lens Maker's formula

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

where, μ = refractive index of the material of the lens and R_1 and R_2 are radii of curvature of the lens.

Power of a Lens

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

$$\text{Power of a lens, } (P) = \frac{1}{f\,(\text{metre})}$$

Its unit is diopter (D).

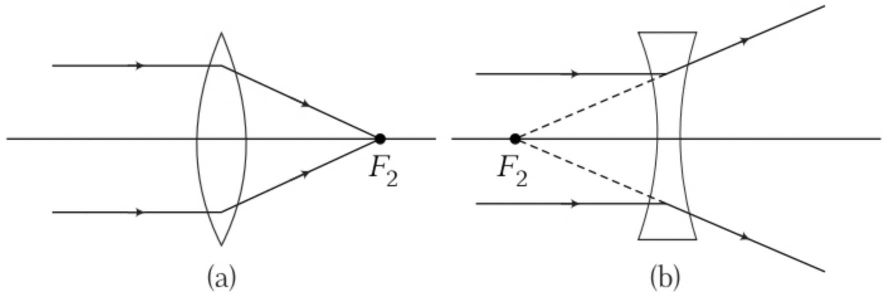
The power of a convex (converging) lens is positive and for a concave (diverging) lens it is negative.

Laws of Formation of Images by Lens

The position and nature of the image by lens, in any case can be obtained either from a ray diagram or by calculation.

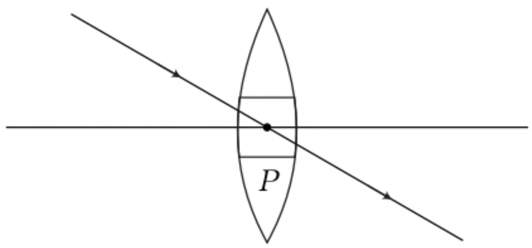
To construct the image of a small object perpendicular to the axis of a lens, two of the following three rays are drawn from the top of the object.

(i) A ray parallel to the principal axis after refraction passes through the principal focus or appears to diverge from it.



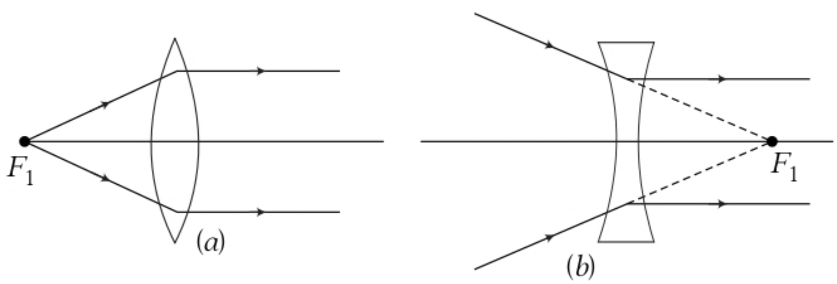
Path of incident ray parallel to principal axis for
(a) convex lens (b) concave lens

(ii) A ray through, the optical centre P passes undeviated because the middle of the lens acts like a thin parallel-sided slab.



Path of incident ray passing through centre for convex lens

(iii) A ray passing through, the first focus F_1 become parallel to the principal axis after refraction.



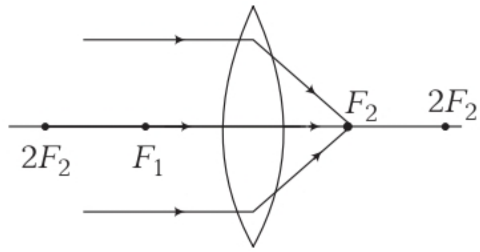
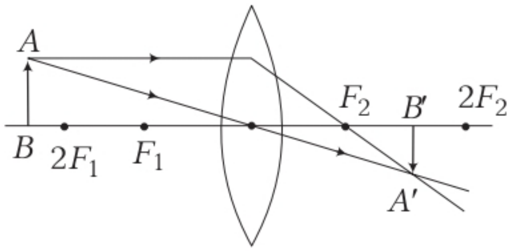
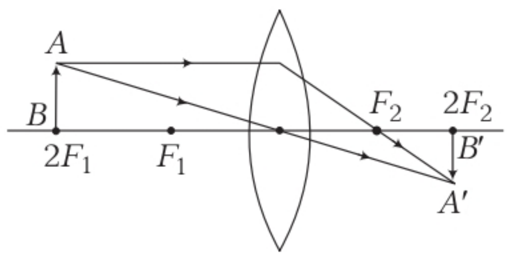
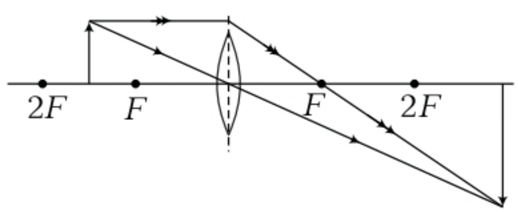
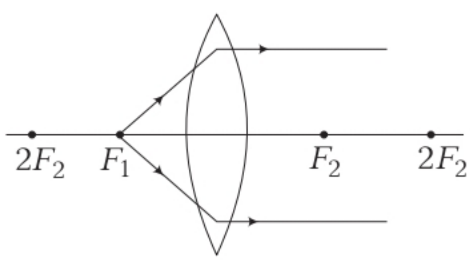
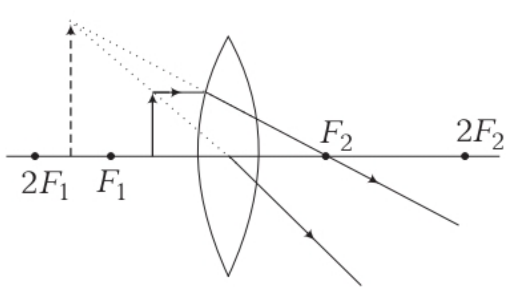
Path incident ray passing through the focus for
(a) convex lens (b) concave lens

Image Formation by Lens

1. Image Formation by Convex lens

The image formed by convex lens depends on the position of object. Formation of image by convex lens for different positions of object is shown in the table given below.

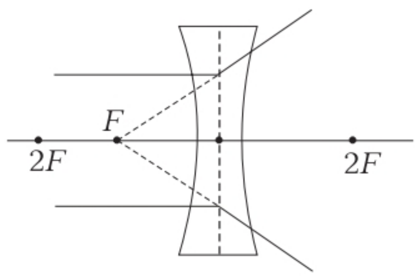
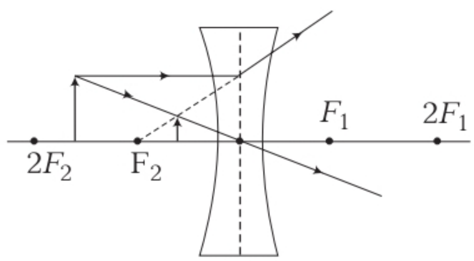
Formation of Image by Convex Lenses

S.No.	Position of Object	Ray Diagram	Position of Image	Nature and Size of Image
1.	At infinity		At the principal focus (F_2) or in the focal plane	Real, inverted and extremely diminished
2.	Beyond $2F_1$		Between F_2 and 2 F_2	Real, inverted and diminished
3.	At $2F_1$		At 2 F_2	Real, inverted and of same size as the object
4.	Between F_1 and $2F_1$		Beyond 2 F_2	Real, inverted and highly magnified
5.	At F_1		At infinity	Real, inverted and highly magnified
6.	Between F_1 and optical centre		On the same side as the object	Virtual, erect and magnified

2. Image Formation by Concave lens

The image formed by a concave lens is always virtual, erect and diminished (like a convex mirror). The image formation by concave lens for different positions of object is shown in the table given below.

Formation of Image by Convex Lenses

S. No.	Position of object	Ray diagram	Position of image	Nature and size of image
1.	At infinity		At the focus	Virtual erect and point size
2.	Anywhere except on the principal axis		Between the lens and F_2	Virtual, erect, diminished

Focal Length of a Lens Combination

(i) When lenses are in contact

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

Power of the combination, $P = P_1 + P_2$

(ii) When lenses are separated by a distance d

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

Power of the combination, $P = P_1 + P_2 - dP_1P_2$

Linear Magnification

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

For a small sized object placed linearly along the principal axis, its axial (longitudinal) magnification is given by

$$\text{Axial magnification} = \frac{dv}{du} = \left(\frac{v}{u}\right)^2 = \left(\frac{f}{f+u}\right)^2 = \left(\frac{f-u}{f}\right)^2$$

Focal Length of a Convex Lens by Displacement Method

Focal length of the convex lens

$$f = \frac{a^2 - d^2}{4a}$$

where, a = distance between the image pin and object pin

and d = distance between two positions of lens.

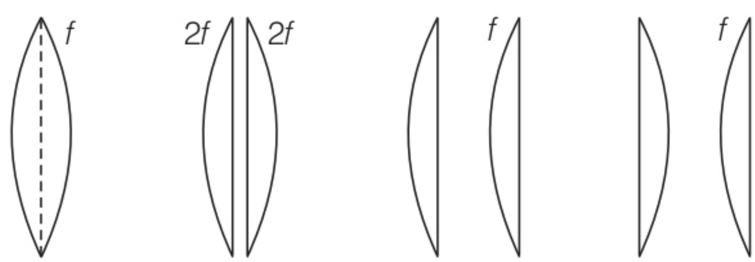
The distance between the two pins should be greater than four times the focal length of the convex lens, *i.e.* $a > 4f$.

Height of the object, $O = \sqrt{I_1 I_2}$.

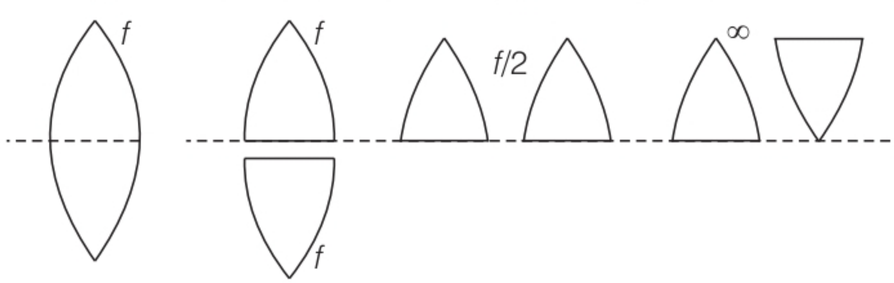
Cutting of a Lens

(i) If a symmetrical convex lens of focal length f is cut into two parts along its optic axis, then focal length of each part (a plano-convex lens) is $2f$.

However, if the two parts are joined as shown in figure, the focal length of combination is again f.



(ii) If a symmetrical convex lens of focal length f is cut into two parts along the principal axis, then focal length of each part remains unchanged as f. If these two parts are joined with curved ends on one side, focal length of the combination is $\frac{f}{2}$. But on joining two parts in opposite sense, the net focal length becomes ∞.



Aberration of Lenses

The image formed by the lens suffer from following two main drawbacks

(i) **Spherical Aberration** Aberration of the lens due to which all the rays passes through the lens are not focussed at a single point and the image of a point object placed on the axis is blurred is called spherical aberration. It can be reduced by using

(a) lens of large focal lengths (b) plano-convex lenses

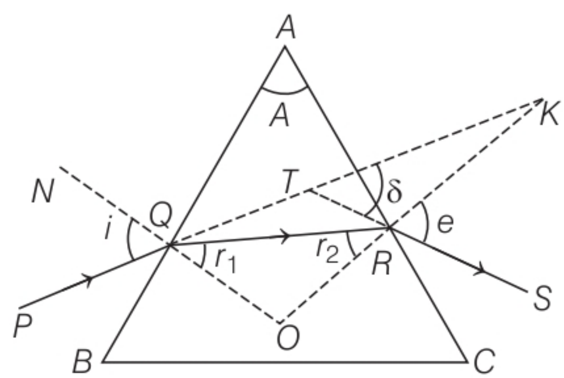
(c) crossed lenses

(d) combining convex and concave lens

(ii) **Chromatic Aberration** Image of a white object formed by lens is usually coloured and blurred. This defect of the image produced by lens is called chromatic aberration.

Prism

Prism is uniform transparent medium bounded between two refracting surfaces inclined at an angle.



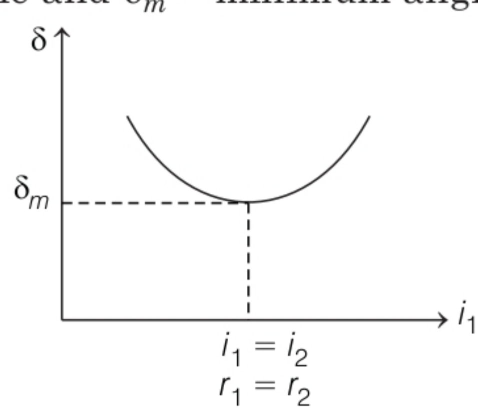
Angle of Deviation

The angle subtended between the direction of incident light ray and emergent light ray from a prism is called angle of deviation (δ).

Prism Formula

The refractive index of material of prism, $\mu = \dfrac{\sin\left(\dfrac{A+\delta_m}{2}\right)}{\sin\left(\dfrac{A}{2}\right)}$

where, A = prism angle and δ_m = minimum angle of deviation.



For very small angle prism

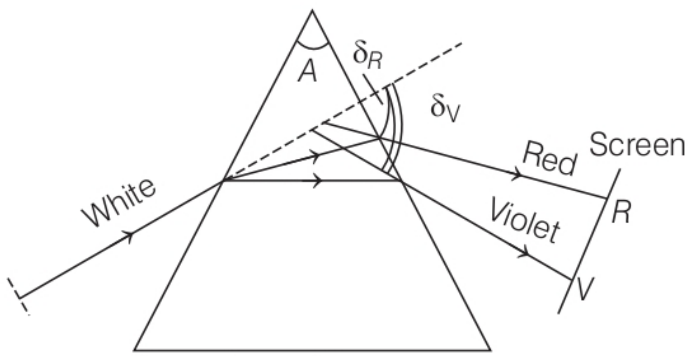
$$\delta_m = (\mu - 1) A$$

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

Dispersion of Light

The splitting of white light into its constituent colours in the sequence of VIBGYOR, on passing through a prism is called dispersion of light.

The refractive index $\mu_V > \mu_R$, therefore violet colour deviates most and red colour deviates least, *i.e.* $\delta_V > \delta_R$.



Angular Dispersion

The angle subtended between the direction of emergent violet and red rays of light from a prism is called angular dispersion.

$$\text{Angular dispersion } (\theta) = \delta_V - \delta_R = (\mu_V - \mu_R) A$$

where, δ_V and δ_R are angle of deviation.

Dispersive Power

$$w = \frac{\theta}{\delta_Y} = \frac{(\mu_V - \mu_R)}{(\mu_Y - 1)}$$

where, $\mu_Y = \frac{\mu_V + \mu_R}{2}$ is mean refractive index.

Scattering of Light

When light passes through a medium in which particles are suspended whose size is of the order of wavelength of light, then light on striking these particles, deviated in different directions. These phenomena is called scattering of light.

According to the Lord Rayleigh, the intensity of scattered light

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

Therefore, red colour of light is scattered least and violet colour of light is scattered most.

Daily Life Examples of Scattering of Light

(i) Blue colour of sky.

(ii) Red colour of signals of danger.

(iii) Black colour of sky in the absence of atmosphere.

(iv) Red colour of sky at the time of sun rise and sun set.

(v) The human eye is most sensitive to yellow colour.

Human Eye

Human eye is an optical instrument which forms real image of the objects on retina.

A human eye has the following main parts

Cornea It is the transparent spherical membrane covering the front of the eye. Light enters the eye through this membrane.

Crystalline lens The eye lens is a convex lens made of a transparent, soft and flexible material like a jelly made of proteins.

Iris It is a dark muscular diaphragm between the **cornea** and the **lens**. It controls the size of the **pupil**.

Pupil It is a small hole between the **iris** through which light enters the eye.

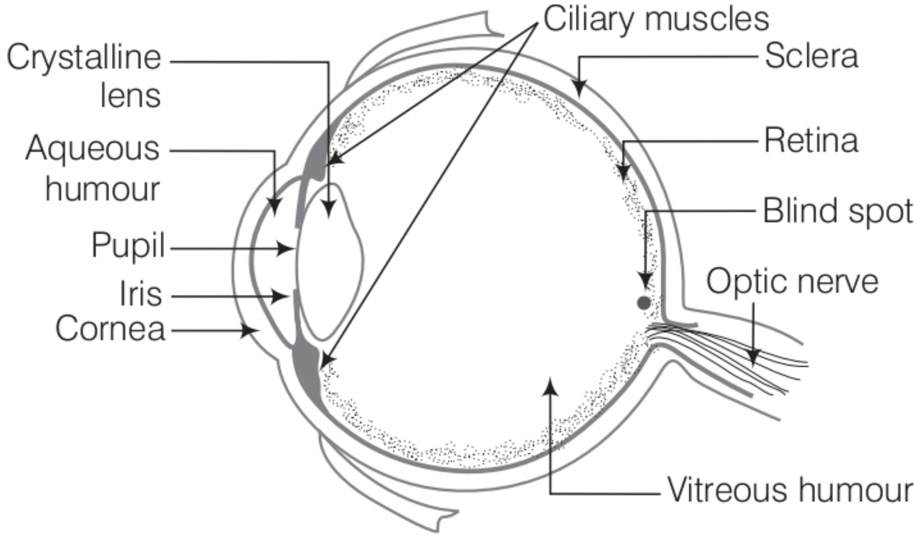
Ciliary muscles They hold the lens in position and help in modifying the curvature of the lens.

Retina It is the light sensitive surface of eye on which the image is formed. It contains light sensitive cells **rods** and **cones.**

Optic nerve It transmits visual information from the **retina** to the **brain**.

Sclera It is an opaque, fibrous, protective, outer layer of an eye containing **collagen** and **elastic fibre.** It is also known as **white of the eye.**

Blind spot It is the point at which the optic nerve leaves the eye. It contains no rods and cones, so an image formed at this point is not sent to the brain.



Aqueous humour Behind the cornea, we have a space filled with a transparent liquid called the aqueous humour.

Vitreous humour The space between eye lens and retina is filled with another liquid called vitreous humour.

Accommodation of eye It is the ability of eye lens, to change its focal length to form sharp images of objects at different positions from the eye on the retina of the eye.

Range of vision It is the distance between near point and the far point of an eye. For normal eye, the range of vision is 25 cm to infinity.

Near point It is the nearest position of an object from human eye, so that its sharp images is formed on the retina.

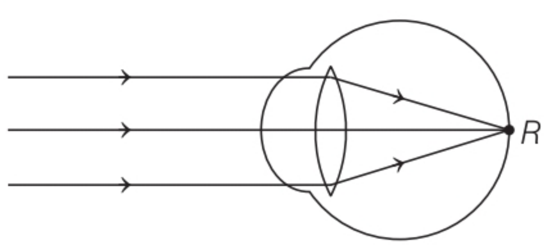
Different defects of vision of human eye are described below

(i) **Myopia or Short-Sightedness** It is a defect of eye due to which a person can see near by objects clearly but cannot see far away objects clearly.

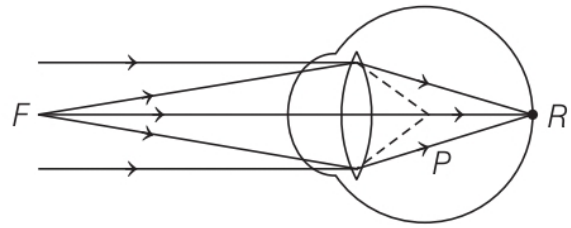
In this defect, the far point of eye shifts from infinity to a nearer distance.

This defect can be removed by using a concave lens of appropriate power.

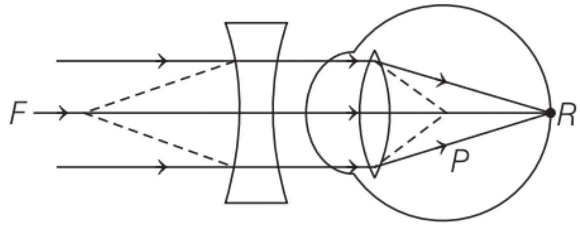
(a)



Normal eye

(b) 

Myopic eye

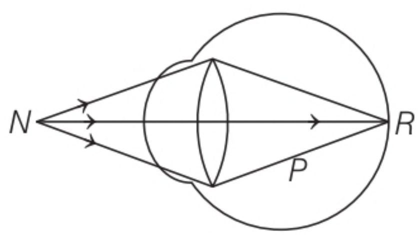
(c) 

Corrected eye

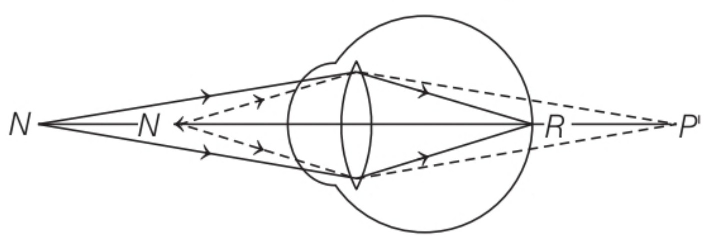
(ii) **Hypermetropia or Long-Sightedness** In this defect, a person can see far away objects clearly but cannot see near by objects clearly.

In this defect, the near point of eye shifts away from the eye.

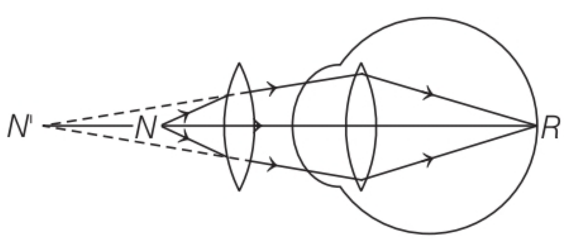
This defect can be removed by using a convex lens of appropriate power.

(a) 

Normal eye

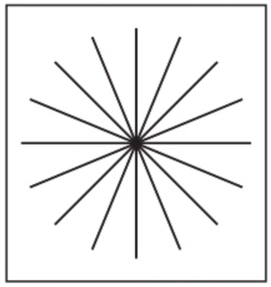
(b) 

Hypermetropic eye

(c) 

Corrected eye

(iii) **Astigmatism** In this defect, a person cannot focus on horizontal and vertical lines at the same distance at the same time.



This defect can be removed by using suitable cylindrical lenses.

(iv) **Colour Blindness** In this defect, a person is unable to distinguish between few colours.

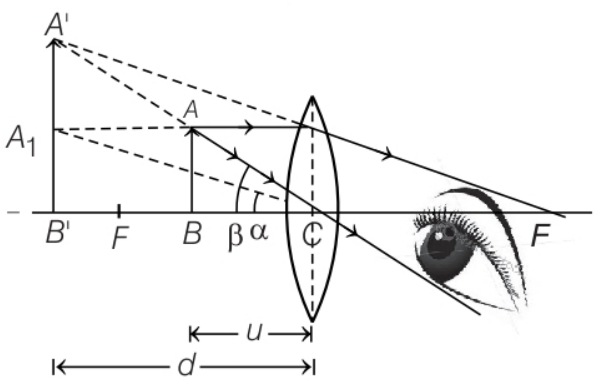
The reason of this defect is the absence of cone cells sensitive for few colours.

(v) **Cataract** In this defect, an opaque white membrane is developed on cornea due to which person losts power of vision partially or completely.

This defect can be removed by removing this membrane through surgery.

Simple Microscope

It is used for observing magnified images of objects. It consists of a converging lens of small focal length.



Magnifying Power

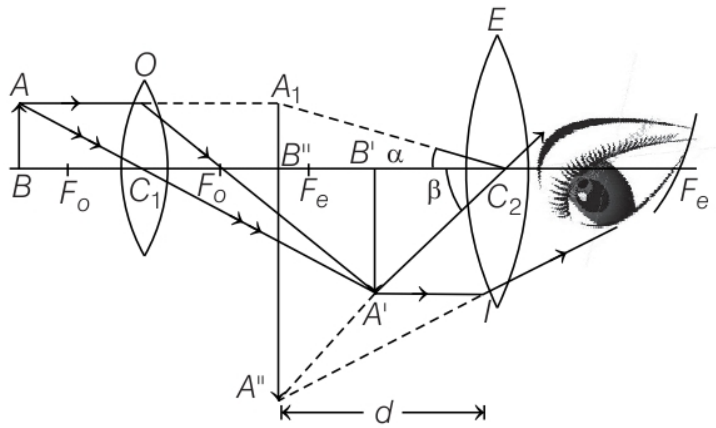
(i) When final image is formed at least distance of distinct vision (D), then $M = 1 + \frac{D}{f}$

where, f = focal length of the lens.

(ii) When final image is formed at infinity, then $M = \frac{D}{f}$.

Compound Microscope

It is a combination of two convex lenses called objective lens and eye piece separated by a distance. Both lenses are of small focal lengths but $f_o < f_e$, where f_o and f_e are focal lengths of objective lens and eye piece respectively.



Magnifying Power

(i) When final image is formed at least distance of distinct vision (D), then

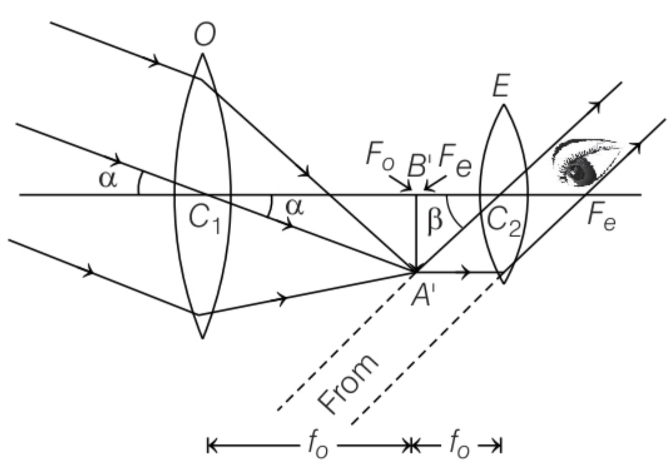
$$M = \frac{v_o}{u_o}\left(1 + \frac{D}{f_e}\right)$$

where, v_o = distance of image formed by objective lens
and u_o = distance of object from the objective.

(ii) When final image is formed at infinity, then, $M = \frac{v_o}{u_o} \cdot \frac{D}{f_e}$

Astronomical Telescope

It is also a combination of two lenses called objective lens and eyepiece, separated by a distance. It is used for observing distinct images of heavenly bodies like stars, planets etc.



Objective lens is a convex lens of large aperture and large focal length while eyepiece is a convex lens of small aperture and small focal length.

Magnifying Power

(i) When final image is formed at least distance of distinct vision (D), then $M = \frac{f_o}{f_e}\left(1 + \frac{D}{f_e}\right)$, where f_o and f_e are focal lengths of objective and eyepiece respectively.

Length of the telescope $(L) = (f_o + u_e)$

where, u_e = distance of object from the eyepiece.

(ii) When final image is formed at infinity, then $M = \frac{f_o}{f_e}$.

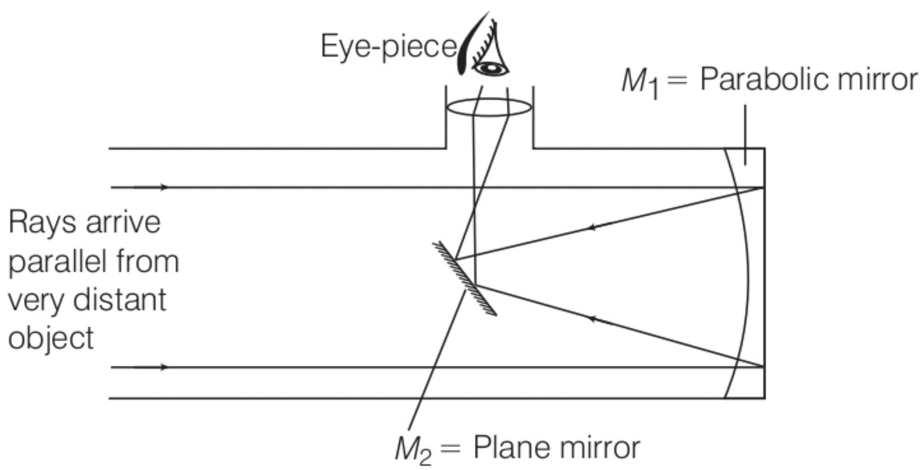
Length of the telescope, $(L) = f_o + f_e$

Note For large magnifying power of a telescope f_o should be large and f_e should be small.

For large magnifying power of a microscope $f_o < f_e$ but f_e should be small.

Reflecting Telescope

Reflecting telescope are based upon the same principle except that the formation of images takes place by reflection instead of by refraction. It consists of concave mirror of large aperture and large focal length (objective). A plane mirror is placed between the concave mirror and its focus. A small convex lens works as eye-piece.



If f_0 is focal length of the concave spherical mirror and f_e the focal length of the eye-piece, the magnifying power of the reflecting telescope is given by

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

Resolving Power

The ability of an optical instrument to produce separate and clear images of two nearby objects is called its resolving power.

Limit of Resolution

The minimum distance between two nearby objects which can be just resolved by the instrument is called its limit of resolution (d).

Resolving power of a microscope $= \dfrac{1}{d} = \dfrac{2\mu \sin\theta}{\lambda}$.

where, d = limit of resolution, λ = wavelength of light used,

μ = refractive index of the medium between the objects and objective lens

and θ = half of the cone angle.

Resolving power of a telescope $= \dfrac{1}{d\theta} = \dfrac{d}{1.22\,\lambda}$

where, $d\theta$ = limit of resolution, λ = wavelength of light used

and d = diameter of aperture of objective.