Light: Reflection And Refraction

Laws of Reflection:

(i) The angle of incidence is equal to the angle of reflection, and

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

These laws of reflection are applicable to all types of reflecting surfaces including spherical surfaces.

Plane Mirror:

Image formed by a plane mirror is always virtual and erect. The size of the image is equal to that of the object. The image formed is as far behind the mirror as the object is in front of it. Further, the image is laterally inverted.

Spherical Mirror:

1. Concave Mirror: A spherical mirror, whose reflecting surface is curved inwards, that is, faces towards the centre of the sphere, is called a concave mirror.

2. Convex Mirror: A spherical mirror whose reflecting surface is curved outwards, is called a convex mirror.

Key Terminologies:

1. Pole: The centre of the reflecting surface of a spherical mirror is called the pole. It is represented by 'P'.

2. Centre of Curvature: The centre of the sphere is called the centre of curvature. The spherical mirror is part of a big sphere. The centre of curvature lies outside the mirror. In case of concave mirror it lies in front of the reflective surface. In case of convex mirror it lies behind the reflective surface.

3. Radius of Curvature: The radius of the sphere is called the radius of curvature. It is represented by 'R'.

4. Principal Axis: The line joining the pole and the center of curvature is called the principal axis.

5. Principal Focus: In mirrors with small aperture (diameter) roughly half of the radius of curvature is equal to the focus point. At focus point all the light coming from infinity converge, in case of concave mirrors. The light seem to diverge from f, in case of convex mirrors.

Image Formed by Concave Mirror: (S here stands for distance between object and mirror.)

Watch Video

1. When S < F, the image is: Virtual, Upright , Magnified (larger)

2. When S = F, the image is formed at infinity. In this case the reflected light rays are parallel and do not meet the others. In this way, no image is formed or more properly the image is formed at infinity.

3. When F < S < 2F, the image is: Real, Inverted (vertically), Magnified (larger)

4. When S = 2F, the image is: Real, Inverted (vertically), Same size

5. When S > 2F, the im5. When S > 2F, the image is: Real, Inverted (vertically), Diminished (smaller) j

Use of Concave Mirrors: They are used in torches, searchlights, to reflect a beam of light to great distance. Doctors use concave mirrors to throw beam of light inside ears and mouth to examine patients. Headlights of automobiles use concave mirrors for better visibility.

Image Formed By Convex Mirror: The image is always virtual (rays haven't actually passed though the image), diminished (smaller), and upright . These features make convex mirrors very useful: everything appears smaller in the mirror, so they cover a wider field of view than a normal plane mirror does as the image is "compressed".

Watch Video

Use of Convex Mirrors: Rear-view mirrors of automobiles are convex mirrors. They enable the driver to see through a wider vision field without craning his neck. At hairpin bends on hilly roads convex mirrors are installed for motorists to see the traffic on the other side of the bend.

Sign Convention for Reflection by Spherical Mirrors

While dealing with the reflection of light by spherical mirrors, we shall follow a set of sign conventions called the New Cartesian Sign Convention. In this convention, the pole (P) of the mirror is taken as the origin. The principal axis of the mirror is taken as the x-axis (X'X) of the coordinate system. The conventions are as follows:

(i) The object is always placed to the left of the mirror. This implies that the light from the object falls on the mirror from the left-hand side.

(ii) All distances parallel to the principal axis are measured from the pole of the mirror.

(iii) All the distances measured to the right of the origin (along + x-axis) are taken as positive while those measured to the left of the origin (along – x-axis) are taken as negative.

(iv) Distances measured perpendicular to and above the principal axis (along + y-axis) are taken as positive.

(v) Distances measured(v) Distances measured perpendicular to and below the principal axis (along –y-axis) are taken as negative.

Mirror Formula and Magnification

In a spherical mirror, the distance of the object from its pole is called the object distance (u). The distance of the image from the pole of the mirror is called the image distance (v). You already know that the distance of the principal focus from the pole is called the focal length (f). There is a relationship between these three quantities given by the mirror formula which is expressed as

$1/v + 1/u = 1/f$

Magnification

Magnification produced by a spherical mirror gives the relative extent to which the image of an object is magnified with respect to the object size. It is expressed as the ratio of the height of the image to the height of the object. It is usually represented by the letter m. If h is the height of the object and h ′ is the height of the image, then the magnification m produced by a spherical mirror is given by

m = Height of Image (h') / Height of Object (h) = h' / h

The magnification m is also related to the object distance (u) and image distance (v). It can be expressed as:

Magnification (m) = h'/h = -v/u

REFRACTION OF LIGHT

Light does not travel in the same direction in all media. It appears that when travelling obliquely from one medium to another, the direction of propagation of light in the second medium changes. This phenomenon is known as refraction of light.

Laws of refraction of light

(i) The incident ray, the refracted ray and the normal to the interface of two transparent media at the point of incidence, all lie in the same plane.

(ii) The ratio of sine of angle of incidence to the sine of angle of refraction is a constant, for the light of a given colour and for the given pair of media. This law is also known as **Snell's law of refraction.**

If i is the angle of incidence and r is the angle of refraction, then, sin i/ sin r = constant This constant value is called the refractive index of the second medium with respect to the first.

The Refractive Index

A ray of light that travels obliquely from one transparent medium into another will change its direction in the second medium. The extent of the change in direction that takes place in a given pair of media is expressed in terms of the refractive index.

The refractive index can be linked to an important physical quantity, the relative speed of propagation of light in different media. It turns out that light propagates with different speeds in different media. Light travels the fastest in vacuum with the highest speed of 3×10^{8} ms^{-1}. In air, the speed of light is only marginally less, compared to that in vacuum. It reduces considerably in glass or water. The value of the refractive index for a given pair of media depends upon the speed of light in the two media, as given below:

Speed of Light in Air = c

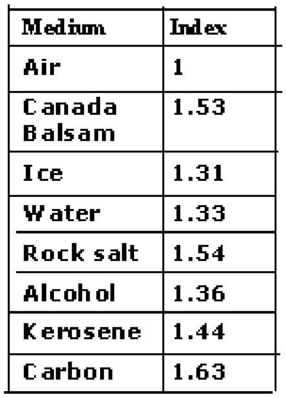
Speed of light in a medium = v

Then refractive index Then refractive index of medium

$n_m = c/v$

The speed of light is higher in a rarer medium than a denser medium. Thus, a ray of light travelling from a rarer medium to a denser medium slows down and bends towards the normal. When it travels from a denser medium to a rarer medium, it speeds up and bends away from the normal.

Refractive Index of Some Media



Medium	Index
Air	1
Canada Balsam	1.53
Ice	1.31
Water	1.33
Rock salt	1.54
Alcohol	1.36
Kerosene	1.44
Carbon	1.63

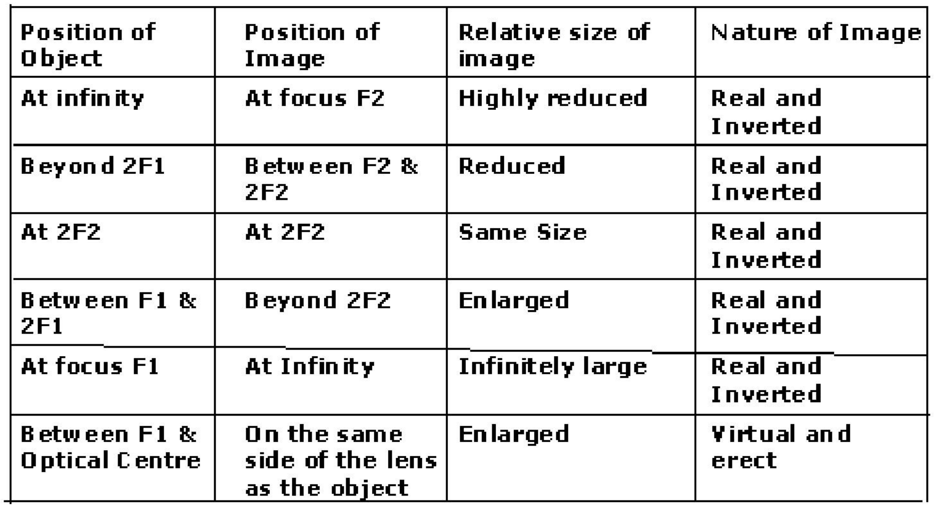
Refraction by Spherical Lenses

A transparent material bound by two surfaces, of which one or both surfaces are spherical, forms a lens. This means that a lens is bound by at least one spherical surface. In such lenses, the other surface would be plane. A lens may have two spherical surfaces, bulging outwards. Such a lens is called a double convex lens. It is simply called a convex lens. It is thicker at the middle as compared to the edges. Convex lens converges light rays, hence convex lenses are called converging lenses. Similarly, a double concave lens is bounded by two spherical surfaces, curved inwards. It is thicker at the edges than at the middle. Such lenses diverge light rays as shown and are called diverging lenses. A double concave lens is simply called a concave lens.

A lens, either a convex lens or a concave lens, has two spherical surfaces. Each of these surfaces forms a part of a sphere. The centres of these spheres are called centres of curvature of the lens.

Image formed by convex lens

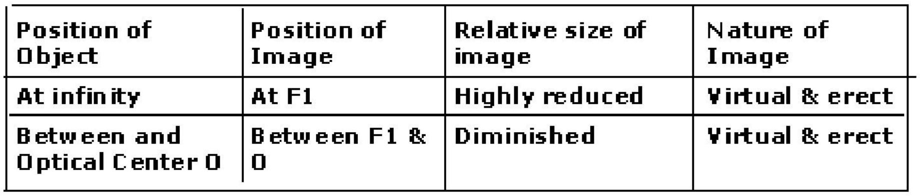
Watch Video



Position of Object	Position of Image	Relative size of image	Nature of Image
At infinity	At focus F2	Highly reduced	Real and Inverted
Beyond 2F1	Between F2 & 2F2	Reduced	Real and Inverted
At 2F2	At 2F2	Same Size	Real and Inverted
Between F1 & 2F1	Beyond 2F2	Enlarged	Real and Inverted
At focus F1	At Infinity	Infinitely large	Real and Inverted
Between F1 & Optical Centre	On the same side of the lens as the object	Enlarged	Virtual and erect

Image Formed by Concave Lens

Watch Video



Position of Object	Position of Image	Relative size of image	Nature of Image
At infinity	At F1	Highly reduced	Virtual & erect
Between and Optical Center O	Between F1 & O	Diminished	Virtual & erect

Sign Convention for Spherical Lenses

According to the convention, the focal length of a convex lens is positive and that of a concave lens is negative. Appropriate signs for the values of u, v, f, object height h and image height h′.

Lens Formula and Magnification

This formula gives the relationship between objectdistance (u), image-distance (v) and the focal length (f). The lens formula is expressed as:

$1/v – 1/u = 1/f<1/v – 1/u = 1/f$

Magnification

The magnification produced by a lens, similar to that for spherical mirrors, is defined as the ratio of the height of the image and the height of the object. It is represented by the letter m. If h is the height of the object and h ′ is the height of the image given by a lens, then the magnification produced by the lens is given by:

m =Height of the Image/Height of the object = h'/h = v/u

Where object-distance Where object-distance is u and the image-distance is v.

Power of a Lens

The degree of convergence or divergence of light rays achieved by a lens is expressed in terms of its power. The power of a lens is defined as the reciprocal of its focal length. It is represented by the letter P. The power P of a lens of focal length f is given by:

P =1/f

The SI unit of power of a lens is ‘dioptre’. It is denoted by the letter D. If f is expressed in metres, then, power is expressed in dioptres. Thus, 1 dioptre is the power of a lens whose focal length is 1 metre. 1D = 1m–1. Power of a convex lens is positive and that of a concave lens is negative. Opticians prescribe corrective lenses indicating their powers.

Let us say the lens prescribed has power equal to + 2.0 D. This means the lens prescribed is convex. The focal length of the lens is + 0.50 m. Similarly, a lens of power – 2.5 D has a focal length of – 0.40 m. The lens is concave. Many optical instruments consist of a number of lenses. They are combined to increase the magnification and sharpness of the image. The net power (P) of the lenses placed in contact is given by the algebraic sum of the individual powers P1, P2, P3, … as

P = P1 + P2 + P3 +…