Light – Reflection and Refraction

CLASS-10TH CHAPTER-10TH

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- We see a variety of objects in the world around us. However, we are unable to see anything in a dark room.
- On lighting up the room, things become visible. What makes things visible? During the day, the sunlight helps us to see objects. An object reflects light that falls on it.
- This reflected light, when received by our eyes, enables us to see things. We are able to see through a transparent medium as light is transmitted through it.
- There are a number of common wonderful phenomena associated with light such as image formation by mirrors, the twinkling of stars, the beautiful colors of a rainbow, bending of light by a medium and so on.
- A study of the properties of light helps us to explore them. By observing the common optical phenomena around us, we may conclude that light seems to travel in straight lines.

- The fact that a small source of light casts a *sharp* shadow of an opaque object points to this straight-line path of light, usually indicated as a ray of light.

- In this Chapter, we shall study the phenomena of reflection and refraction of light using the straight-line propagation of light.

- These basic concepts will help us in the study of some of the optical phenomena in nature.

- We shall try to understand in this Chapter the reflection of light by spherical mirrors and refraction of light and their application in real life situations.

REFLECTION OF LIGHT

- A highly polished surface, such as a mirror, reflects most of the light falling on it. You are already familiar with the laws of reflection of light.

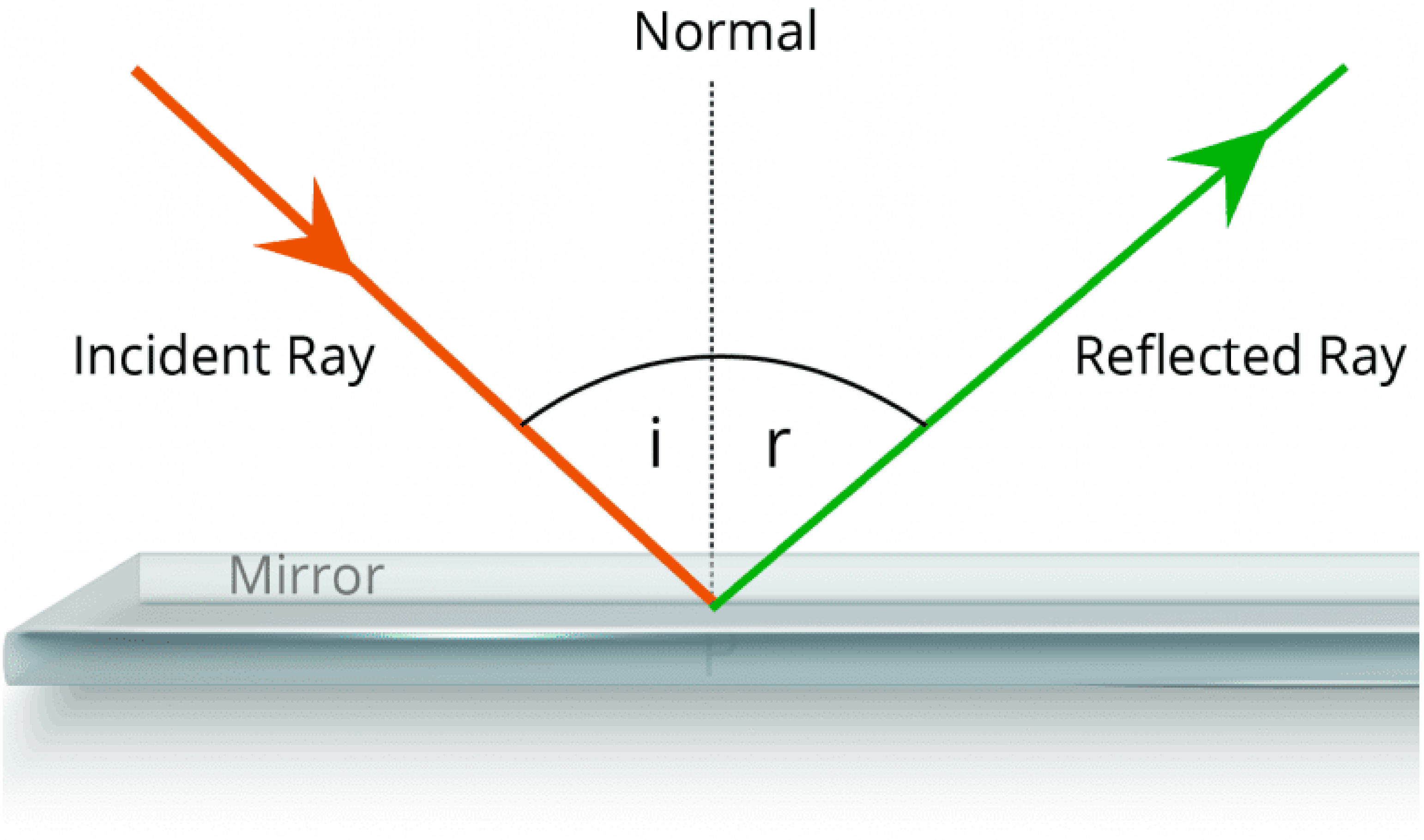
- Let us recall these laws –
- (i) The angle of incidence is equal to the angle of reflection, and
- (ii) The incident ray, the normal to the mirror at the point of incidence and the reflected ray, all lie in the same plane.
- These laws of reflection are applicable to all types of reflecting surfaces including spherical surfaces.

- You are familiar with the formation of image by a plane mirror. What are the properties of the image?

aabhasi aur sidha

- Image formed by a plane mirror is always virtual and erect. The size of the image is equal to that of the object.

Reflection Of Light



- The image formed is as far behind the mirror as the object is in front of it. Further, the image is laterally inverted.
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- The curved surface of a shining spoon could be considered as a curved mirror. The most commonly used type of curved mirror is the spherical mirror.

- The reflecting surface of such mirrors can be considered to form a part of the surface of a sphere. Such mirrors, whose reflecting surfaces are spherical, are called spherical mirrors.

SPHERICAL MIRRORS

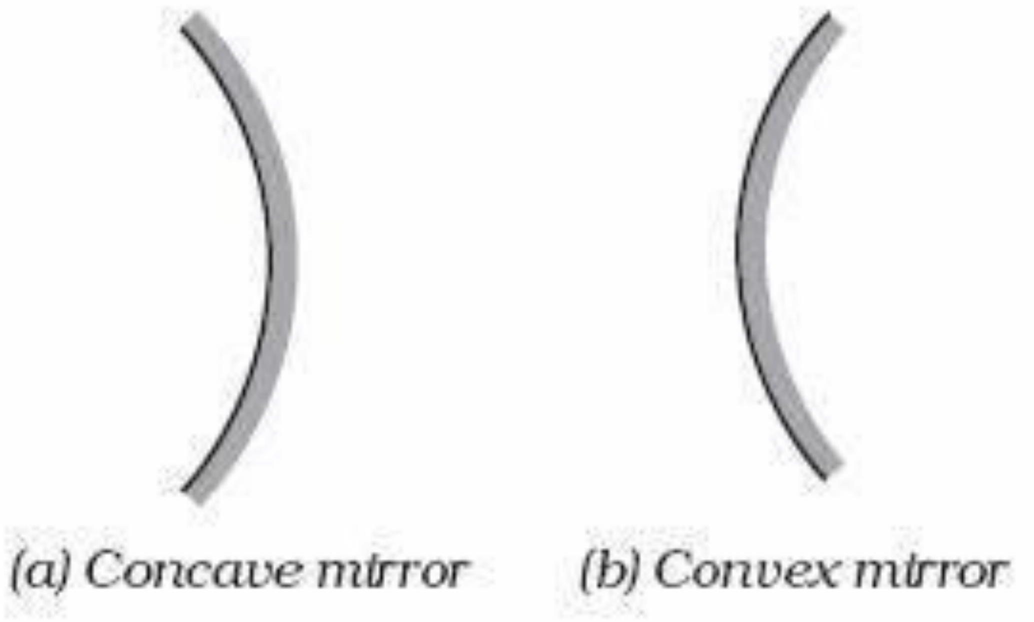
- The reflecting surface of a spherical mirror may be curved inwards or outwards.

- A spherical mirror, whose reflecting surface is curved inwards, that is, faces towards the center of the sphere, is called a concave mirror.

- A spherical mirror whose reflecting surface is curved outwards, is called a convex mirror. The schematic representation of these mirrors.

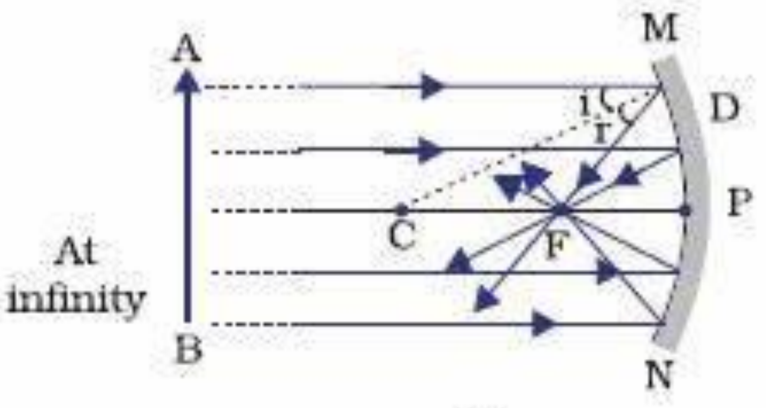
- You may now understand that the surface of the spoon curved inwards can be approximated to a concave mirror and the surface of the spoon bulged outwards can be approximated to a convex mirror.

- Before we move further on spherical mirrors, we need to recognize and understand the meaning of a few terms.

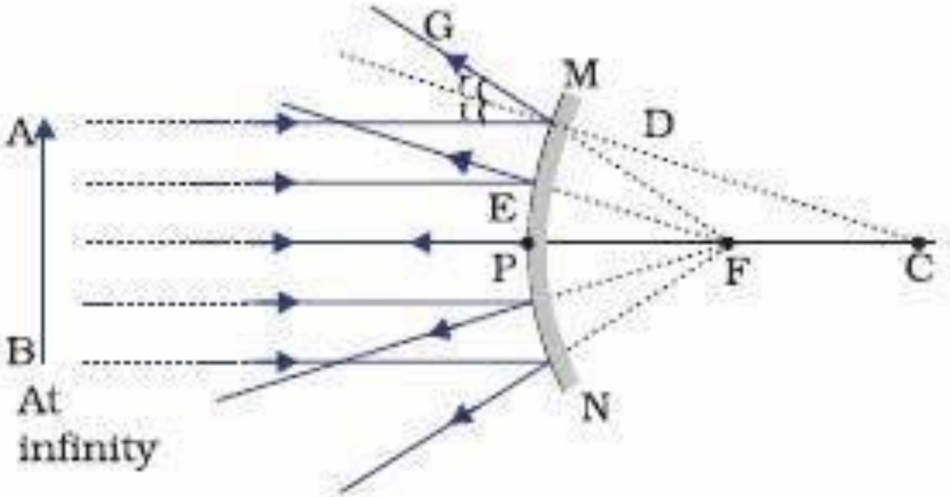


Schematic representation of spherical mirrors; the shaded side is non-reflecting

- These terms are commonly used in discussions about spherical mirrors. The center of the reflecting surface of a spherical mirror is a point called the pole.
- It lies on the surface of the mirror. The pole is usually represented by the letter P.
- The reflecting surface of a spherical mirror forms a part of a sphere. This sphere has a centre. This point is called the centre of curvature of the spherical mirror.
- It is represented by the letter C. Please note that the center of curvature is not a part of the mirror. It lies outside its reflecting surface.
- The center of curvature of a concave mirror lies in front of it. However, it lies behind the mirror in case of a convex mirror.
- The radius of the sphere of which the reflecting surface of a spherical mirror forms a part, is called the radius of curvature of the mirror.



(a)



(b)

(a) Concave mirror (b) Convex mirror

- It is represented by the letter *R*. You may note that the distance PC is equal to the radius of curvature.
- Imagine a straight line passing through the pole and the center of curvature of a spherical mirror.
- This line is called the principal axis. Remember that principal axis is normal to the mirror at its pole.
- The paper at first begins to burn producing smoke. Eventually it may even catch fire. Why does it burn?
- The light from the Sun is converged at a point, as a sharp, bright spot by the mirror. In fact, this spot of light is the image of the Sun on the sheet of paper.
- This point is the focus of the concave mirror. The heat produced due to the concentration of sunlight ignites the paper.

- The distance of this image from the position of the mirror gives the approximate value of focal length of the mirror.

- A number of rays parallel to the principal axis are falling on a concave mirror. Observe the reflected rays.

- They are all meeting/intersecting at a point on the principal axis of the mirror. This point is called the principal focus of the concave mirror.

- How are the rays parallel to the principal axis, reflected by a convex mirror? The reflected rays appear to come from a point on the principal axis.

- This point is called the principal focus of the convex mirror. The principal focus is represented by the letter F.

- The distance between the pole and the principal focus of a spherical mirror is called the focal length. It is represented by the letter f.

- The reflecting surface of a spherical mirror is by-and-large spherical. The surface, then, has a circular outline.

- The diameter of the reflecting surface of spherical mirror is called its aperture. In Fig.10.2, distance MN represents the aperture.

- We shall consider in our discussion only such spherical mirrors whose aperture is much smaller than its radius of curvature.

- Is there a relationship between the radius of curvature *R,* and focal length *f,* of a spherical mirror?

- For spherical mirrors of small apertures, the radius of curvature is found to be equal to twice the focal length.

- We put this as $R = 2f$. This implies that the principal focus of a spherical mirror lies midway between the pole and center of curvature.

Image Formation by Spherical Mirrors

- You have studied about the image formation by plane mirrors. You also know the nature, position and relative size of the images formed by them.

- How about the images formed by spherical mirrors? How can we locate the image formed by a concave mirror for different positions of the object? Are the images real or virtual? Are they enlarged, diminished or have the same size?

- You will see in the above Activity that the nature, position and size of the image formed by a concave mirror depends on the position of the object in relation to points P, F and C. The image formed is real for some positions of the object.

- It is found to be a virtual image for a certain other position. The image is either magnified, reduced or has the same size, depending on the position of the object.

Image formation by a concave mirror for different positions of the object

Image formation by a concave mirror for different positions of the 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

Representation of Images Formed by Spherical Mirrors Using Ray Diagrams

We can also study the formation of images by spherical mirrors by drawing ray diagrams.

Consider an extended object, of finite size, placed in front of a spherical mirror. Each small portion of the extended object acts like a point source.

An infinite number of rays originate from each of these points. To construct the ray diagrams, in order to locate them image of an object, an arbitrarily large number of rays emanating from a point could be considered.

However, it is more convenient to consider only two rays, for the sake of clarity of the ray diagram.

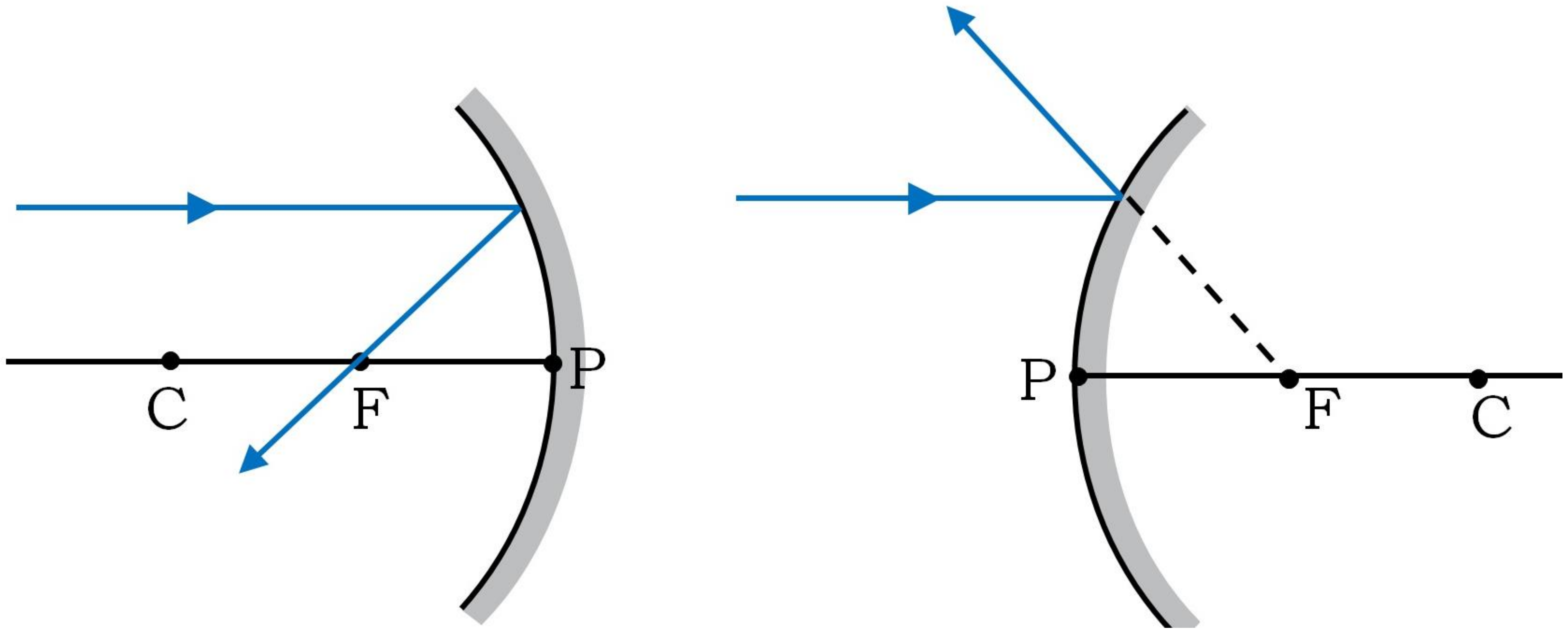
These rays are so chosen that it is easy to know their directions after reflection from the mirror.

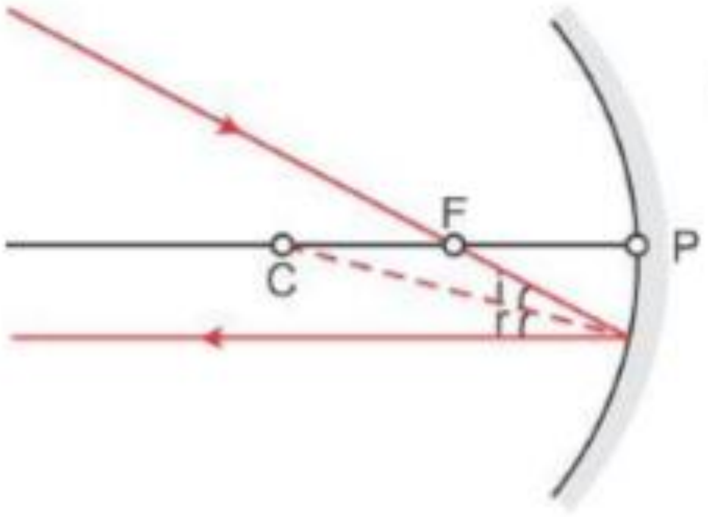
- The intersection of at least two reflected rays give the position of image of the point object.

(i) *A ray parallel to the principal axis*, after reflection, will pass through the principal focus in case of a concave mirror or appear to diverge from the principal focus in case of a convex mirror.(1)

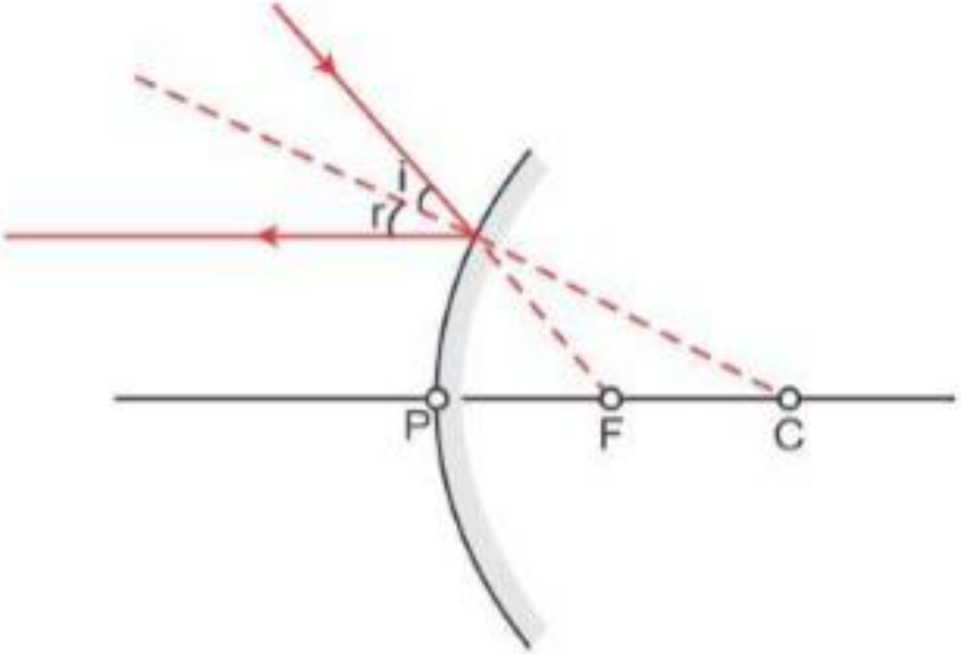
(ii) *A ray passing through the principal focus* of a concave mirror or *a ray which is directed towards the principal focus of* a convex mirror, after reflection, will emerge parallel to the principal axis.(2)

(iii) *A ray passing through the centre of curvature* of a concave mirror or directed in the direction of the centre of curvature of a convex mirror, after reflection, is reflected back along the same path. The light rays come back along the same path because the incident ray fall on the mirror along the normal to the reflecting surface.(3)

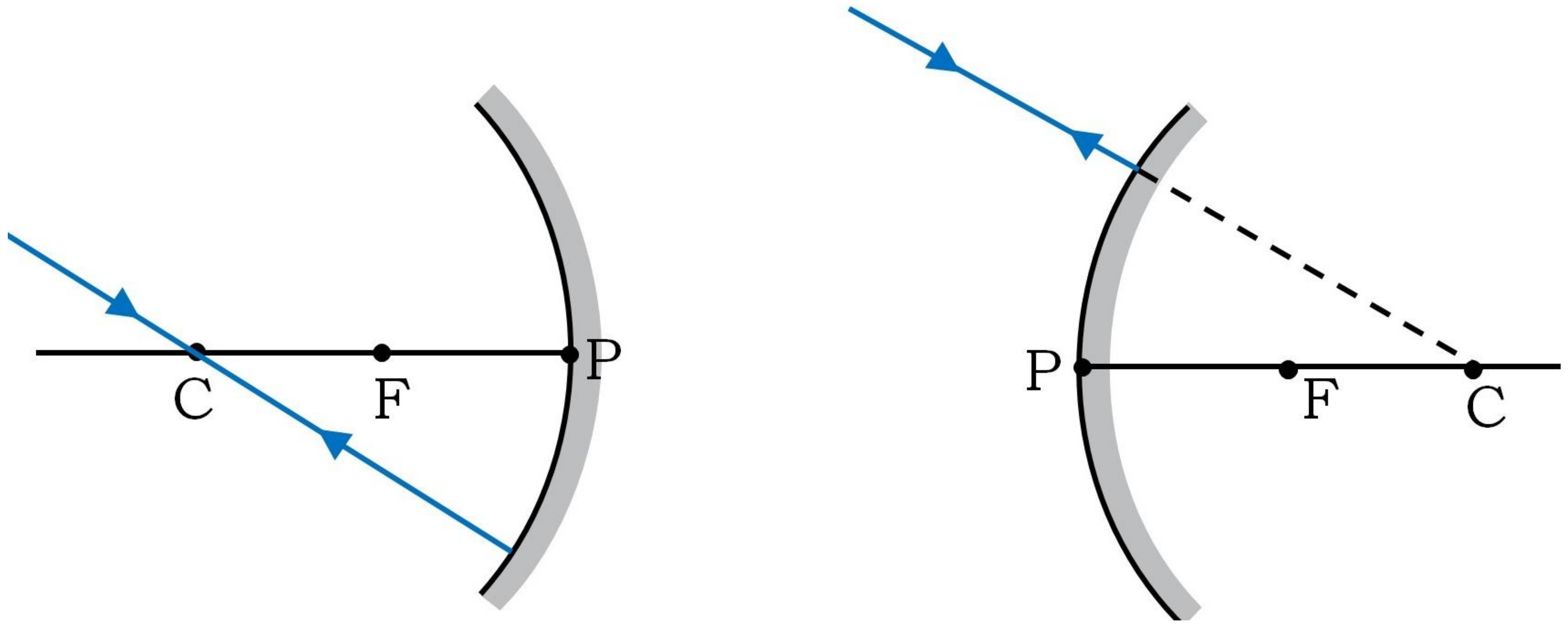

C
F
P
P
F
C



Concave Mirror



Convex Mirror



C
F
P
P
F
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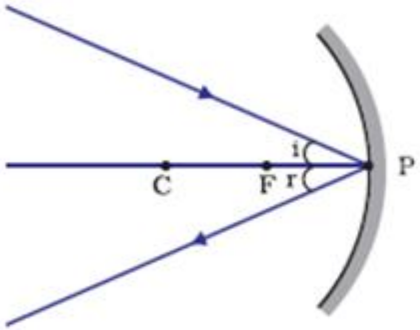
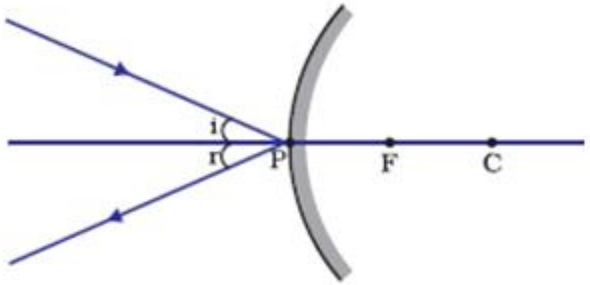


(a) concave mirror

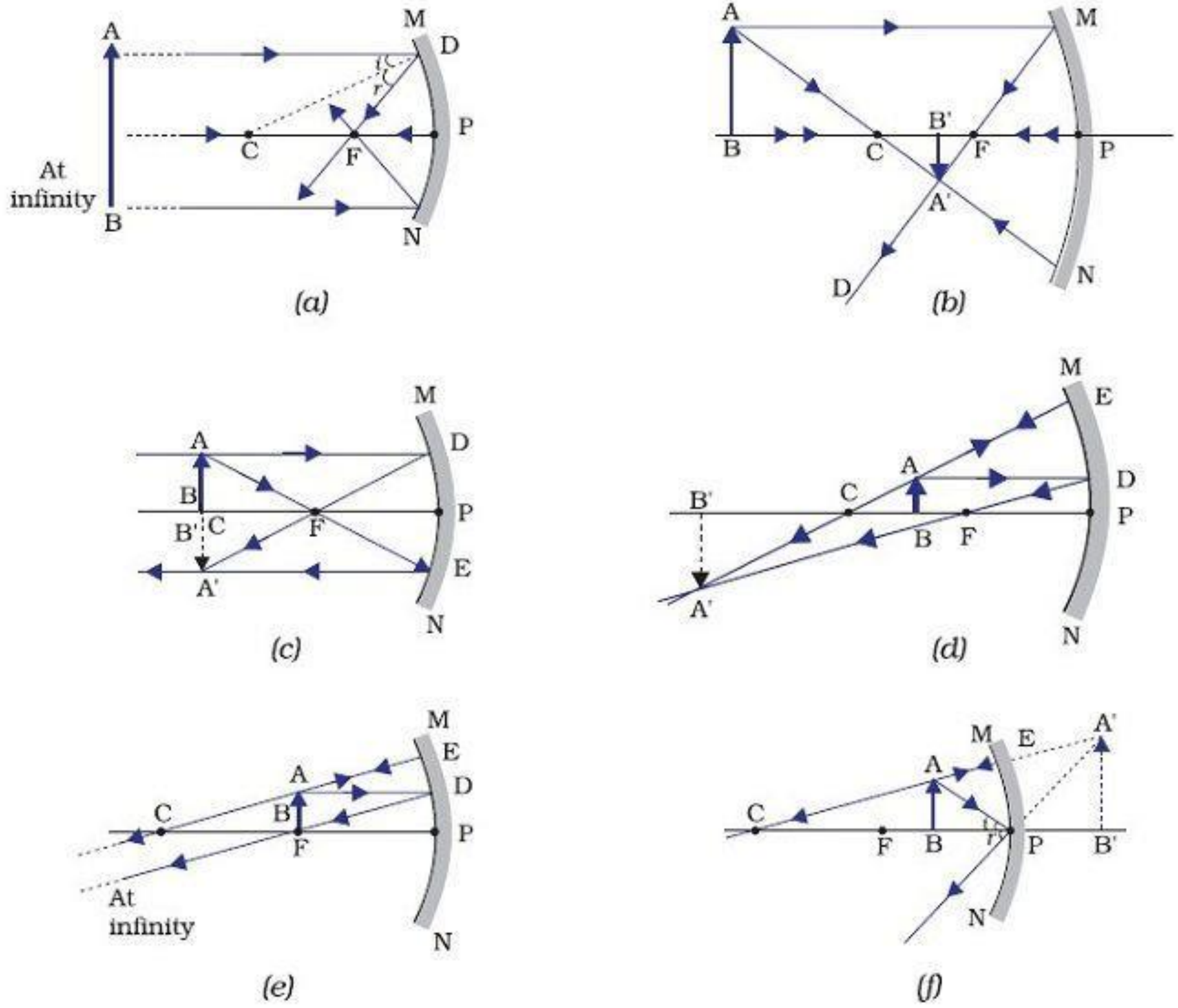


(b) convex mirror

(iv) *A ray incident obliquely to the principal axis*, towards a point P (pole of the mirror), on the concave mirror Is reflected obliquely. The incident and reflected rays follow the laws of reflection at the point of incidence (point P), making equal angles with the principal axis.

- Remember that in all the above cases the laws of reflection are followed. At the point of incidence, the incident ray is reflected in such a way that the angle of reflection equals the angle of incidence.

(a) Image formation by Concave Mirror the ray diagrams for the formation of image by a concave mirror for various positions of the object.



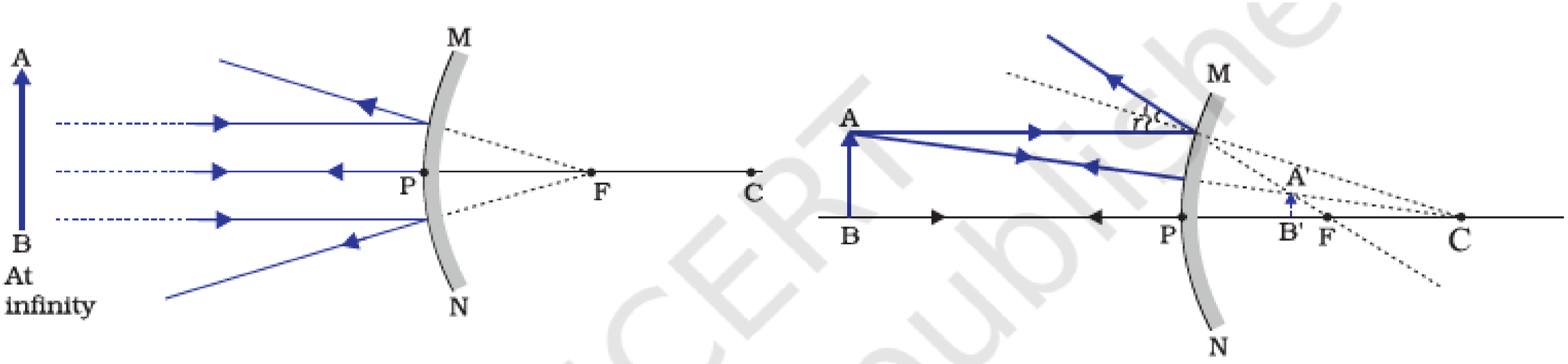
Ray diagrams for the image formation by a concave mirror

Uses of concave mirrors

Concave mirrors are commonly used in torches, search-lights and vehicles headlights to get powerful parallel beams of light. They are often used as shaving mirrors to see a larger image of the face. The dentists use concave mirrors to see large images of the teeth of patients. Large concave mirrors are used to concentrate sunlight to produce heat in solar furnaces.

(b) Image formation by a Convex Mirror We studied the image formation by a concave mirror. Now we shall study the formation of image by a convex mirror.

We consider two positions of the object for studying the image formed by a convex mirror. First is when the object is at infinity and the second position is when the object is at a finite distance from the mirror. The ray diagrams for the formation of image by a convex mirror for these two positions of the object



(a) (b)

Formation of image by a convex mirror

You can see a full-length image of a tall building/tree in a small convex mirror. One such mirror is fitted in a wall of Agra Fort facing Taj Mahal. If you visit the Agra Fort, try to observe the full image of Taj Mahal. To view distinctly, you should stand suitably at the terrace adjoining the wall.

Uses of convex mirrors

- Convex mirrors are commonly used as rear-view (wing) mirrors in vehicles.

- These mirrors are fitted on the sides of the vehicle, enabling the driver to see traffic behind him/her to facilitate safe driving.

- Convex mirrors are preferred because they always give an erect, though diminished, image. Also, they have a wider field of view as they are curved outwards.

- Thus, convex mirrors enable the driver to view much larger area than would be possible with a plane mirror

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

- The New Cartesian Sign Convention These sign conventions are applied to obtain the mirror formula and solve related numerical problems.

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

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

- This formula is valid in all situations for all spherical mirrors for all positions of the object. You must use the New Cartesian Sign Convention while substituting numerical values for *u, v, f*, and *R* in the mirror formula for solving problems.

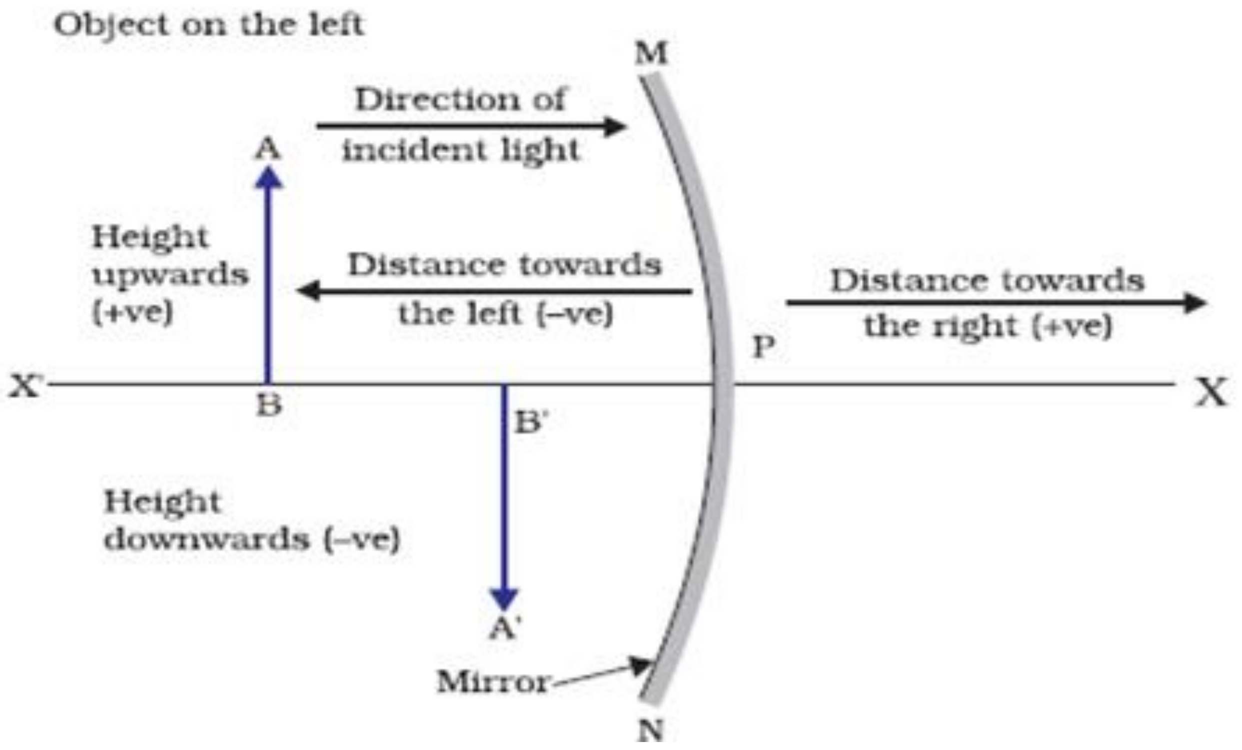
Magnification

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

$$m = \frac{\text{Height of the image ( )}}{\text{Height of the object ( )}}$$



The New Cartesian Sign Convention for spherical mirrors

$$M = \frac{h'}{h}$$

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

$$\text{Magnification } (m) = \frac{h'}{h} = \frac{-v}{h}$$

- You may note that the height of the object is taken to be positive as the object is usually placed above the principal axis.

- The height of the image should be taken as positive for virtual images. However, it is to be taken as negative for real images.

- A negative sign in the value of the magnification indicates that the image is real. A positive sign in the value of the magnification indicates that the image is virtual.

REFRACTION OF LIGHT

Light seems to travel along straight-line paths in a transparent medium. What happens when light enters from one transparent medium to another?

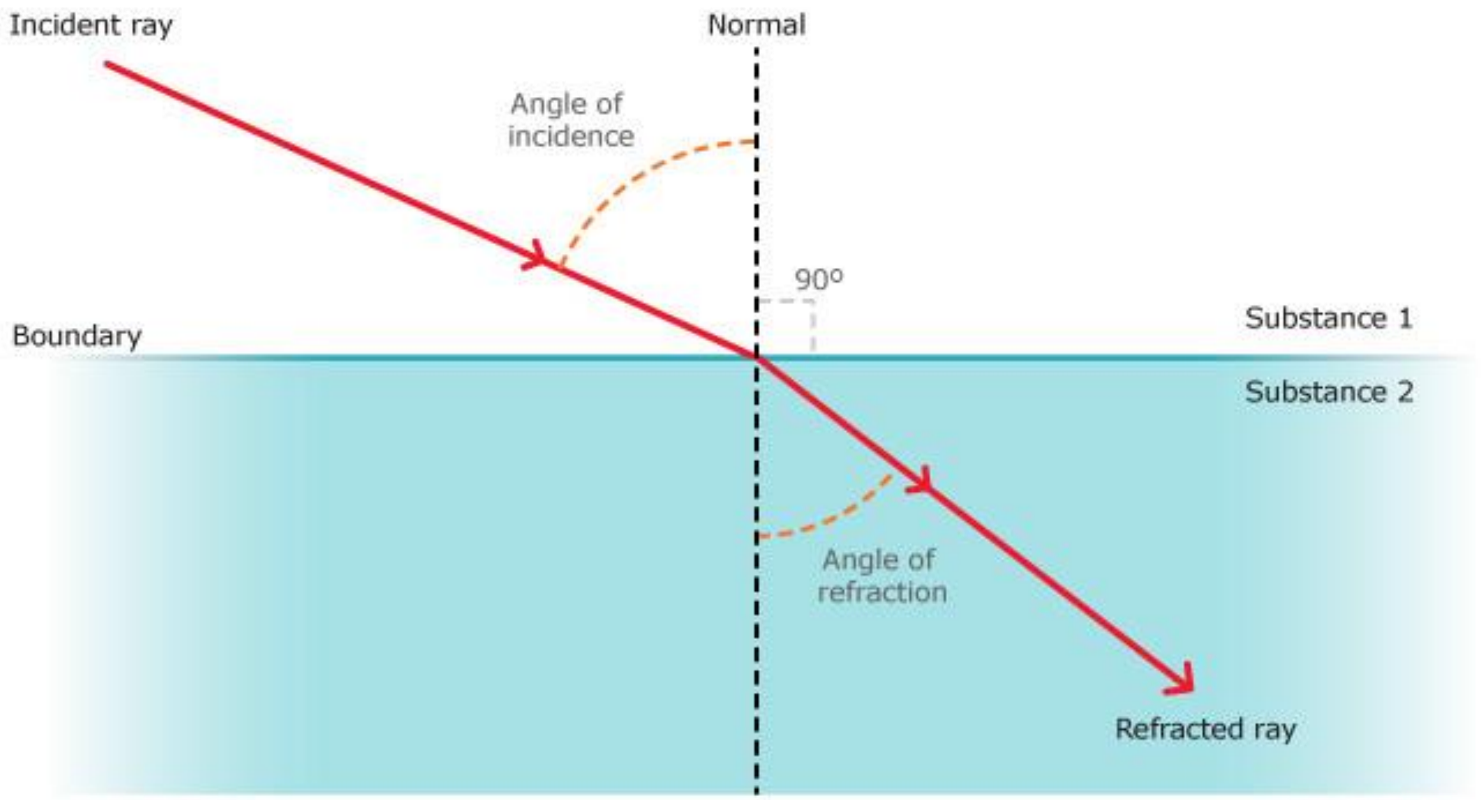
Does it still move along a straight-line path or change its direction? We shall recall some of our day-to-day experiences.

You might have observed that the bottom of a tank or a pond containing water appears to be raised.

Similarly, when a thick glass slab is placed over some printed matter, the letters appear raised when viewed through the glass slab.

Why does it happen? Have you seen a pencil partly immersed in water in a glass tumbler? It appears to be displaced at the interface of air and water.

Refraction of light



You might have observed that a lemon kept in water in a glass tumbler appears to be bigger than its actual size, when viewed from the sides. How can you account for such experiences?

Let us consider the case of the apparent displacement of a pencil, partly immersed in water. The light reaching you from the portion of the pencil inside water seems to come from a different direction, compared to the part above water.

This makes the pencil appear to be displaced at the interface. For similar reasons, the letters appear to be raised, when seen through a glass slab placed over it.

Does a pencil appear to be displaced to the same extent, if instead of water, we use liquids like kerosene or turpentine? Will the letters appear to rise to the same height if we replace a glass slab with a transparent plastic slab?

- You will find that the extent of the effect is different for different pair of media. These observations indicate that 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.

- Let us understand this phenomenon further by doing a few activities.

- The coin becomes visible again on pouring water into the bowl. The coin appears slightly raised above its actual position due to refraction of light.

Refraction through a Rectangular Glass Slab

- To understand the phenomenon of refraction of light through a glass slab In this Activity, you will note, the light ray has changed its direction at points O and O¢.

- Note that both the points O and O¢ lie on surfaces separating two transparent media. Draw a perpendicular NN’ to AB at O and another perpendicular MM¢ to CD at O¢.

- The light ray at point O has entered from a rarer medium to a denser medium, that is, from air to glass. Note that the light ray has bent towards the normal.

- At O¢, the light ray has entered from glass to air, that is, from a denser medium to a rarer medium.

- The light here has bent away from the normal. Compare the angle of incidence with the angle of refraction at both refracting surfaces AB and CD.

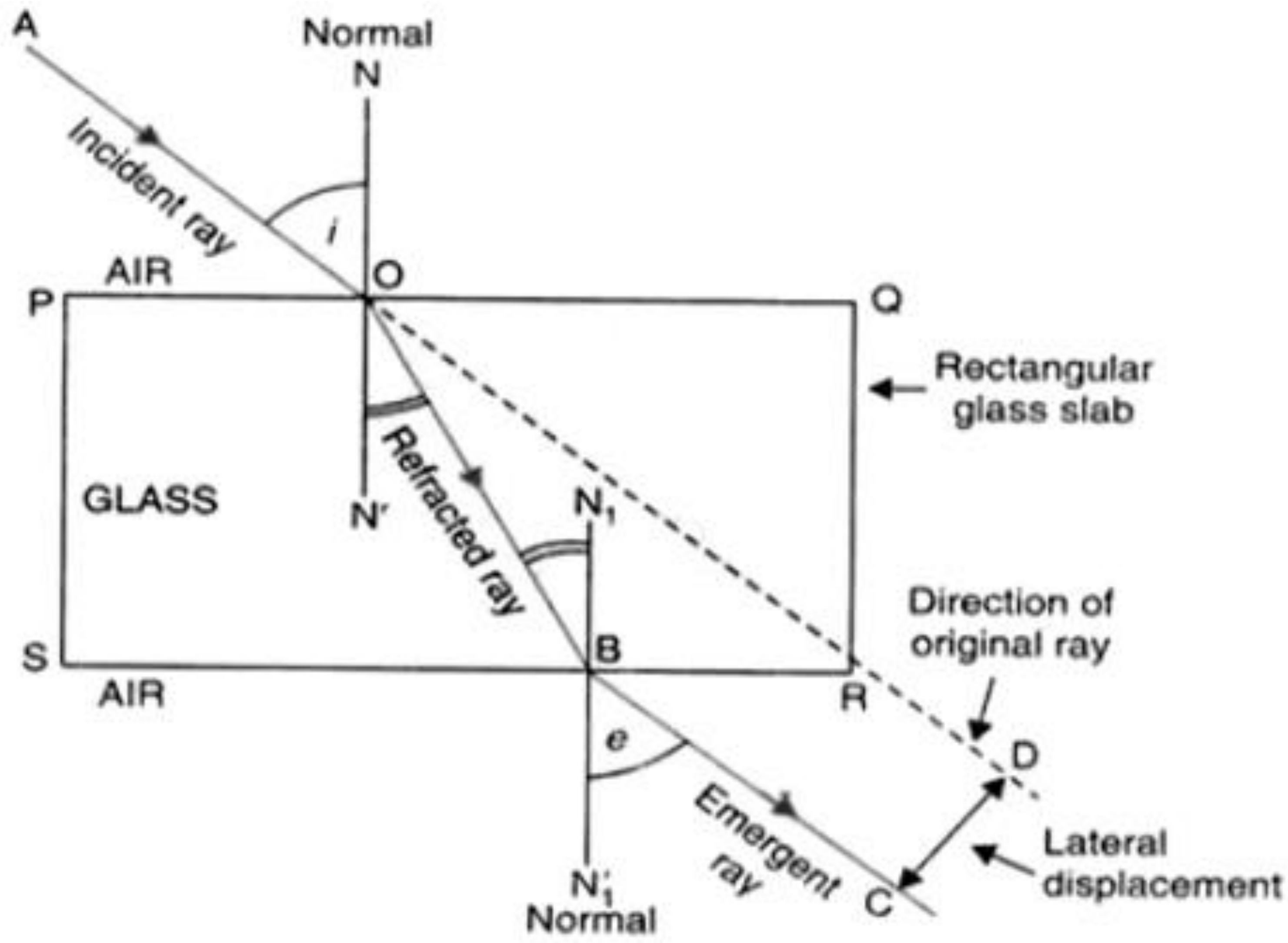
A ray EO is obliquely incident on surface AB, called incident ray. OO¢ is the refracted ray and O¢ H is the emergent ray.

You may observe that the emergent ray is parallel to the direction of the incident ray. Why does it happen so?

The extent of bending of the ray of light at the opposite parallel faces AB (air-glass interface) and CD (glass-air interface) of the rectangular glass slab is equal and opposite.

This is why the ray emerges parallel to the incident ray. However, the light ray is shifted sideward slightly.

What happens when a light ray is incident normally to the interface of two media? Try and find out.


A
Normal
N
Incident ray
i
AIR
O
P
Q
Rectangular
glass slab
GLASS
N′
Refracted ray
N$_1$
Direction of
original ray
S
B
AIR
R
e
D
Emergent
ray
Lateral
displacement
N$_1'$
Normal
C

Now you are familiar with the refraction of light. Refraction is due to change in the speed of light as it enters from one transparent medium to another. Experiments show that refraction of light occurs according to certain laws.

The following are the 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 color and for the given pair of media.

This law is also known as Snell’s law of refraction. (This is true for angle 0 < i < 90o)
If i is the angle of incidence and r is the angle of refraction, then,

$$\frac{\text{Sin } t}{\textit{Sin } r} = \textit{constant}$$

- This constant value is called the refractive index of the second medium with respect to the first.

The Refractive Index

You have already studied that 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 may be expressed in terms of the refractive index, the “constant” appearing on the right-hand side.

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 fastest in vacuum with speed of 3×108 m s–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.

- Consider a ray of light travelling from medium 1 into medium 2.

- Let *v*1 be the speed of light in medium 1 and *v*2 be the speed of light in medium 2. The refractive index of medium 2 with respect to medium 1 is given by the ratio of the speed of light in medium 1 and the speed of light in medium 2. This is usually represented by the symbol *n*21. This can be expressed in an equation form as

$$N21 = \frac{\text{Speed of light in medium 1}}{\text{Speed of light in medium 2}} = \frac{v1}{v2}$$

- By the same argument, the refractive index of medium 1 with respect to medium 2 is represented as *n12*. It is given by

$$n_{12} = \frac{\text{Speed of light in medium 2}}{\text{Speed of light in medium 1}} = \frac{v2}{v1}$$

- If medium 1 is vacuum or air, then the refractive index of medium 2 is considered with respect to vacuum.

- This is called the absolute refractive index of the medium. It is simply represented as *n*2.

- If *c* is the speed of light in air and *v* is the speed of light in the medium, then, the refractive index of the medium n*m* is given by

$$Nm = \frac{\text{Speed of light in air}}{\text{Speed of light in the medium}} = \frac{c}{v}$$

Refractive index and speed of light

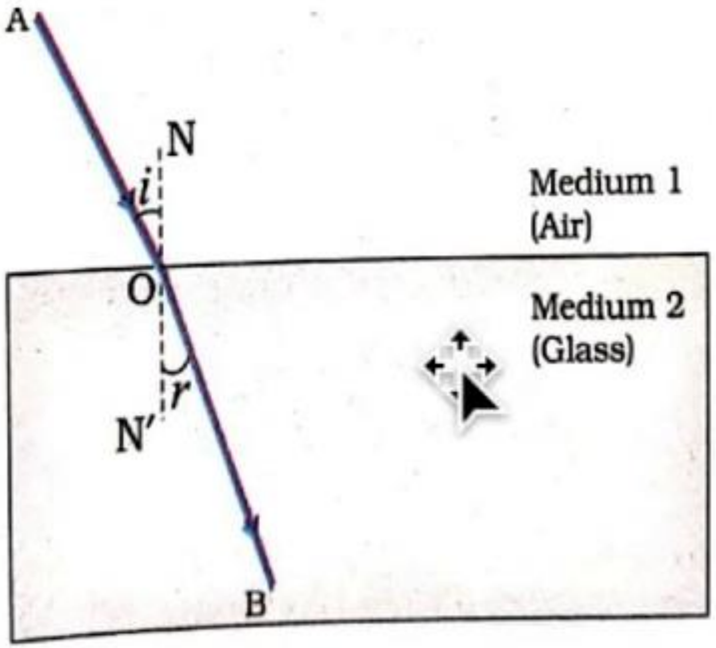


Figure 10.11

Relative refractive index

$$n_{21} = \frac{\text{speed of light in medium 1}}{\text{speed of light in medium 2}} = \frac{v1}{v2}$$

$$n_{12} = \frac{\text{speed of light in medium 2}}{\text{speed of light in medium 1}} = \frac{v2}{v1}$$

Absolute refractive index $= \dfrac{c}{v}$

e.g $n_w = 1.33$

the ratio of the speed of light in air to that of speed of light in water is equal to 1.33.

- The absolute refractive index of a medium is simply called its refractive index.
- From the Table you can know that the refractive index of water, nw = 1.33. This means that the ratio of the speed of light in air and the speed of light in water is equal to 1.33.
- Similarly, the refractive index of crown glass, ng =1.52. Such data are helpful in many places. However, you need not memories the data.

Material medium	Refractive index	Material medium	Refractive index
Air	1.0003	Canada Balsam	1.53
Ice	1.31		
Water	1.33	Rock salt	1.54
Alcohol	1.36		
Kerosene	1.44	Carbon disulphide	1.63
Fused quartz	1.46	Dense flint glass	1.65
Turpentine oil	1.47	Ruby	1.71
Benzene	1.50	Sapphire	1.77
Crown glass	1.52	Diamond	2.42

- Note from Table that an optically denser medium may not possess greater mass density.

- For example, kerosene having higher refractive index, is optically denser than water, although its mass density is less than water.

MORE TO KNOW

The ability of a medium to refract light is also expressed in terms of its optical density. Optical density has a definite connotation. It is not the same as mass density. We have been using the terms ‘rarer medium’ and ‘denser medium’ in this Chapter. It actually means ‘optically rarer medium’ and ‘optically denser medium’, respectively. When can we say that a medium is optically denser than the other? In comparing two media, the one with the larger refractive index is optically denser medium than the other. The other medium of lower refractive index is optically rarer. 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.

Refraction by Spherical Lenses

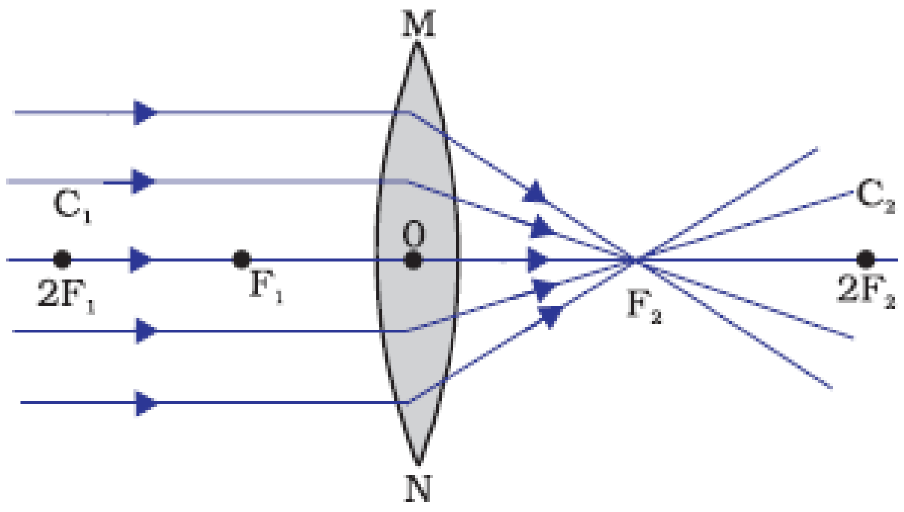
You might have seen watchmakers using a small magnifying glass to see tiny parts.

Have you ever touched the surface of a magnifying glass with your hand? Is it plane surface or curved? Is it thicker in the middle or at the edges? The glasses used in spectacles and that by a watchmaker are examples of lenses. What is a lens? How does it bend light rays? We shall discuss these in this section.

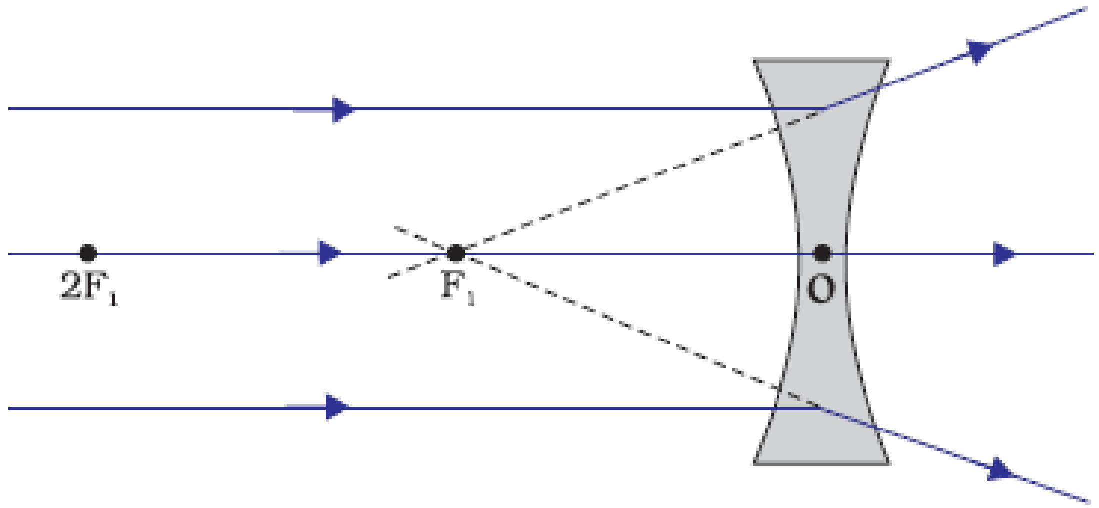
A transparent material bound by two surfaces, of which one or both surfaces are spherical, forms a lens.

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.



(a) Converging action of convex lens



(b) Diverging action of concave lens

- It is simply called a convex lens. It is thicker at the middle as compared to the edges.
- Hence convex lenses are also 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 Such lenses are also 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. The centre of curvature of a lens is usually represented by the letter C.

- Since there are two centers of curvature, we may represent them as C1 and C2. An imaginary straight line passing through the two centers of curvature of a lens is called its principal axis. The central point of a lens is its optical center.

- It is usually represented by the letter O. A ray of light through the optical centre of a lens passes without suffering any deviation.

- The effective diameter of the circular outline of a spherical lens is called its aperture.

- We shall confine our discussion in this Chapter to such lenses whose aperture is much less than its radius of curvature and the two centers of curvatures are equidistant from the optical center O.

- Such lenses are called thin lenses with small apertures. What happens when parallel rays of light are incident on a lens? Let us do an Activity to understand this.

- The paper begins to burn producing smoke. It may even catch fire after a while. Why does this happen?

- The light from the Sun constitutes parallel rays of light. These rays were converged by the lens at the sharp bright spot formed on the paper.

- In fact, the bright spot you got on the paper is a real image of the Sun. The concentration of the sunlight at a point generated heat. This caused the paper to burn.

- Now, we shall consider rays of light parallel to the principal axis of a lens. What happens when you pass such rays of light through a lens?

- Several rays of light parallel to the principal axis are falling on a convex lens.

- These rays, after refraction from the lens, are converging to a point on the principal axis. This point on the principal axis is called the principal focus of the lens.

- Let us see now the action of a concave lens Several rays of light parallel to the principal axis are falling on a concave lens.

- These rays, after refraction from the lens, are appearing to diverge from a point on the principal axis.

- This point on the principal axis is called the principal focus of the concave lens.

- If you pass parallel rays from the opposite surface of the lens, you get another principal focus on the opposite side.
- Letter F is usually used to represent principal focus. However, a lens has two principal foci. They are represented by F1 and F2.
- The distance of the principal focus from the optical center of a lens is called its focal length. The letter *f* is used to represent the focal length.
- How can you find the focal length of a convex lens? In this Activity, the distance between the position of the lens and the position of the image of the Sun gives the approximate focal length of the lens.

Image Formation by Lenses

Lenses form images by refracting light. How do lenses form images? What is their nature? Let us study this for a convex lens first.

Nature, position and relative size of the image formed by a convex lens for various positions of the object

Position of the object	Position of the image	Relative size of the image	Nature of the image
At infinity	At focus F_2	Highly diminished, point-sized	Real and inverted
Beyond $2F_1$	Between F_2 and $2F_2$	Diminished	Real and inverted
At $2F_1$	At $2F_2$	Same size	Real and inverted
Between F_1 and $2F_1$	Beyond $2F_2$	Enlarged	Real and inverted
At focus F_1	At infinity	Infinitely large or highly enlarged	Real and inverted
Between focus F_1 and optical centre O	On the same side of the lens as the object	Enlarged	Virtual and erect

- Nature, position and relative size of the image formed by a concave lens for various positions of the object

Position of the object	Position of the image	Relative size of the image	Nature of the image
At infinity	At focus F_1	Highly diminished, point-sized	Virtual and erect
Between infinity and optical centre O of the lens	Between focus F_1 and optical centre O	Diminished	Virtual and erect

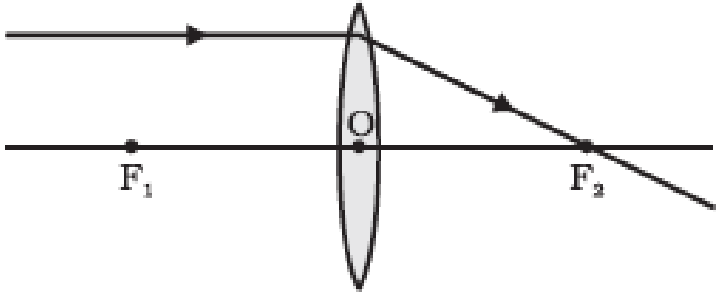
- A concave lens will always give a virtual, erect and diminished image, irrespective of the position of the object.

Image Formation in Lenses Using Ray Diagrams

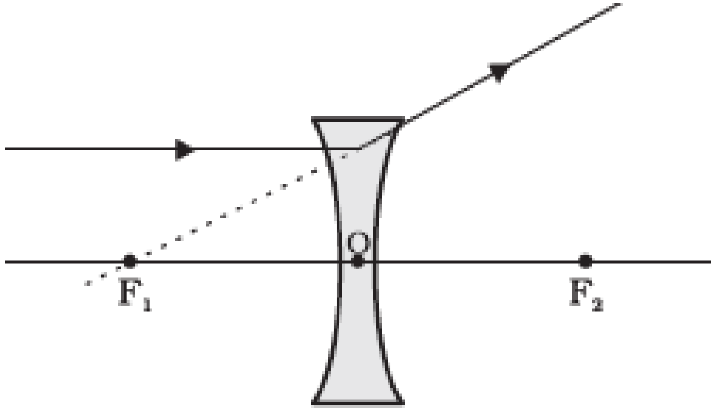
We can represent image formation by lenses using ray diagrams. Ray diagrams will also help us to study the nature, position and relative size of the image formed by lenses.

For drawing ray diagrams in lenses, alike of spherical mirrors, we consider any two of the following rays –

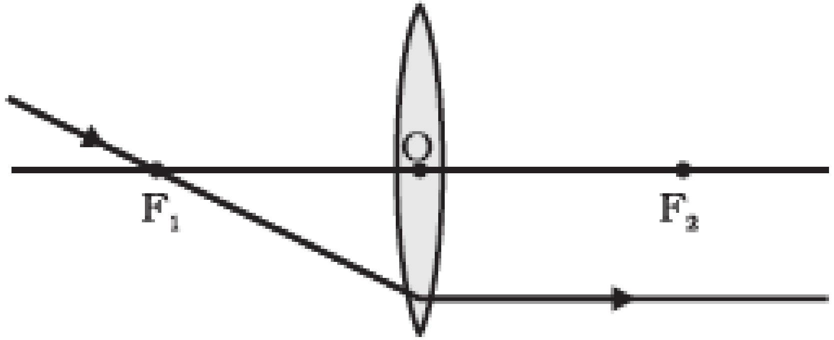
(i) A ray of light from the object, parallel to the principal axis, after refraction from a convex lens, passes through the principal focus on the other side of the lens(a). In case of a concave lens, the ray appears to diverge from the principal focus located on the same side of the lens



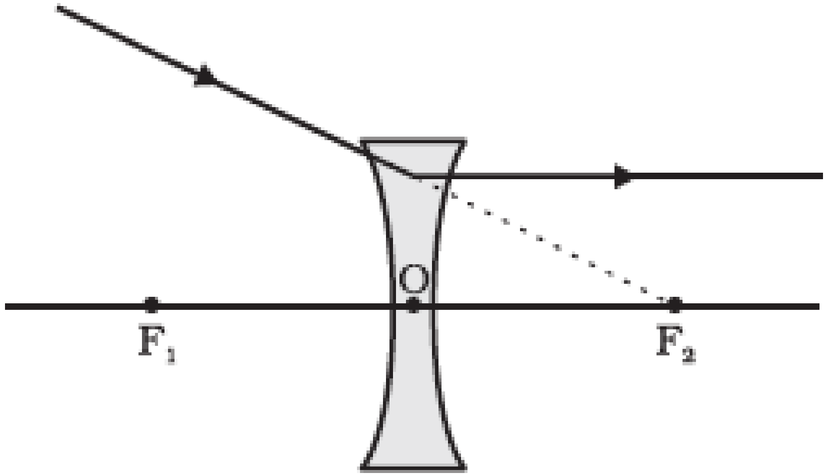
(a)



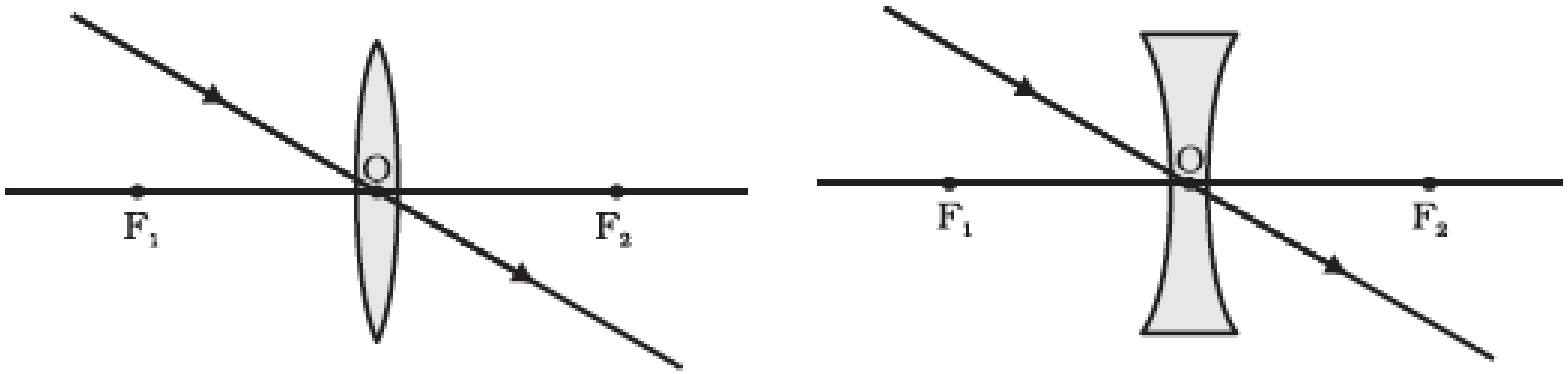
(b)



(a)



(b)



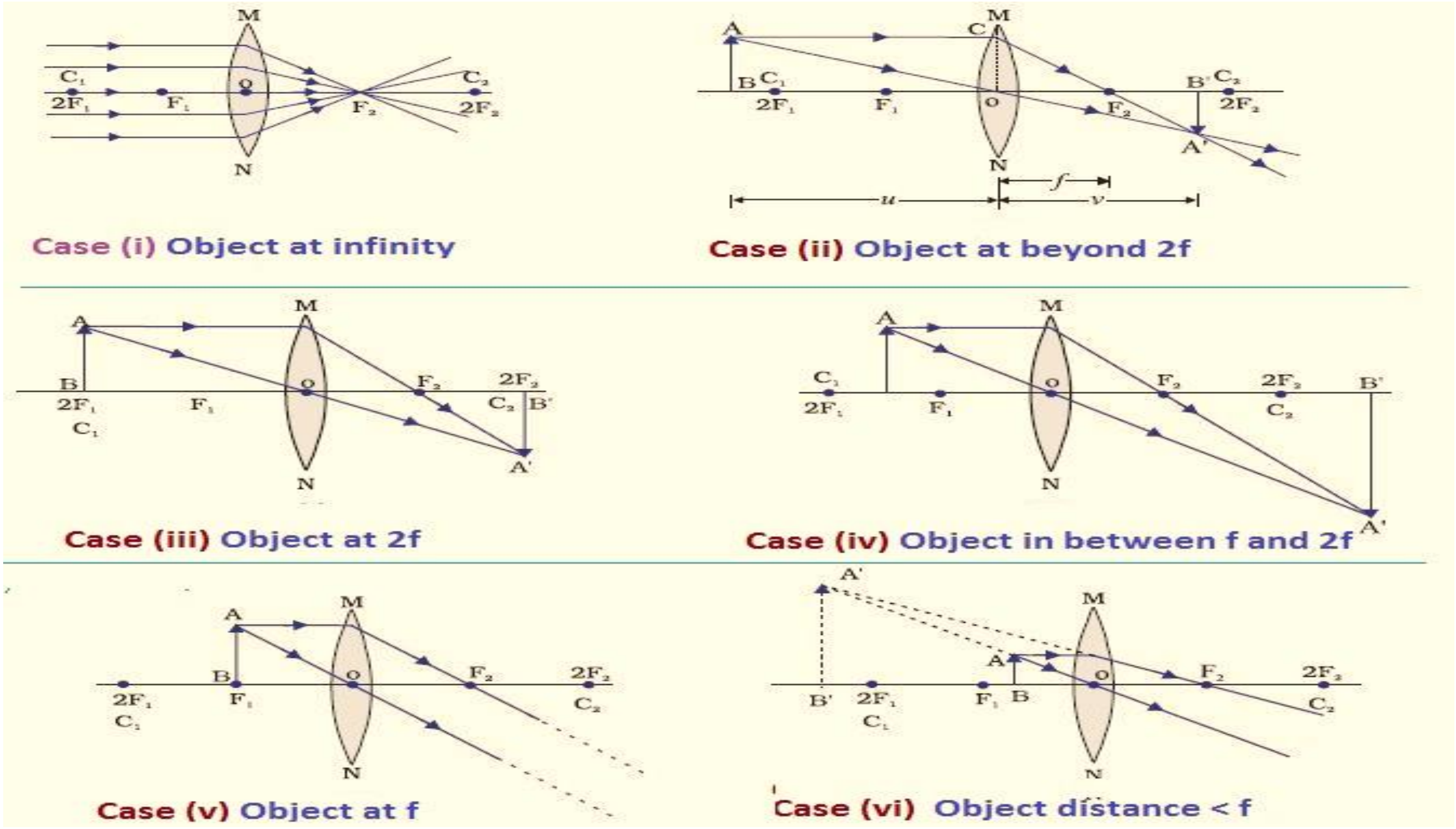
(a) (b)

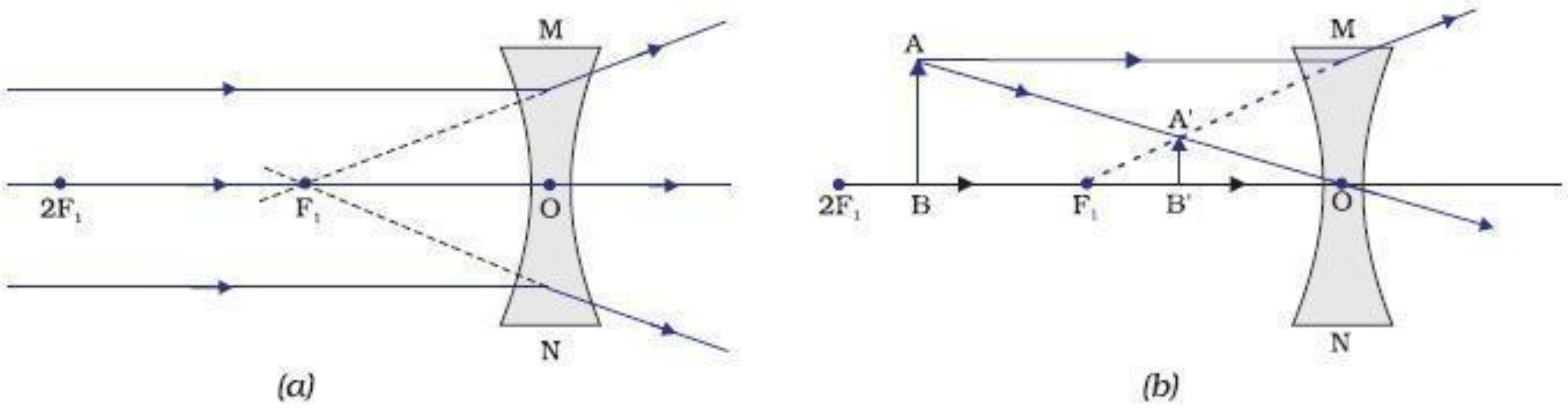
(ii) A ray of light passing through a principal focus, after refraction from a convex lens, will emerge parallel to the principal axis.A ray of light appearing to meet at the principal focus of a concave lens, after refraction, will emerge parallel to the principal axis.

(iii) A ray of light passing through the optical center of a lens will emerge without any deviation.

- The ray diagrams for the image formation in a convex lens for a few positions of the object.(FIG-A) The ray diagrams representing the image formation in a concave lens for various positions of the object.(FIG-B)

FIGURE-A *The position, size and the nature of the image formed by a convex lens for various positions of the object*





Nature, position and relative size of the image formed by a concave lens

Sign Convention for Spherical Lenses

- For lenses, we follow sign convention, similar to the one used for spherical mirrors.

- We apply the rules for signs of distances, except that all measurements are taken from the optical center of the lens.

- According to the convention, the focal length of a convex lens is positive and that of a concave lens is negative. You must take care to apply appropriate signs for the values of u, v, f, object height h and image height h¢.

Lens Formula and Magnification

- As we have a formula for spherical mirrors, we also have formula for spherical lenses.

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

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

lens formula given above is general and is valid in all situations for any spherical lens. Take proper care of the signs of different quantities, while putting numerical values for solving problems relating to lenses.

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. Magnification 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,

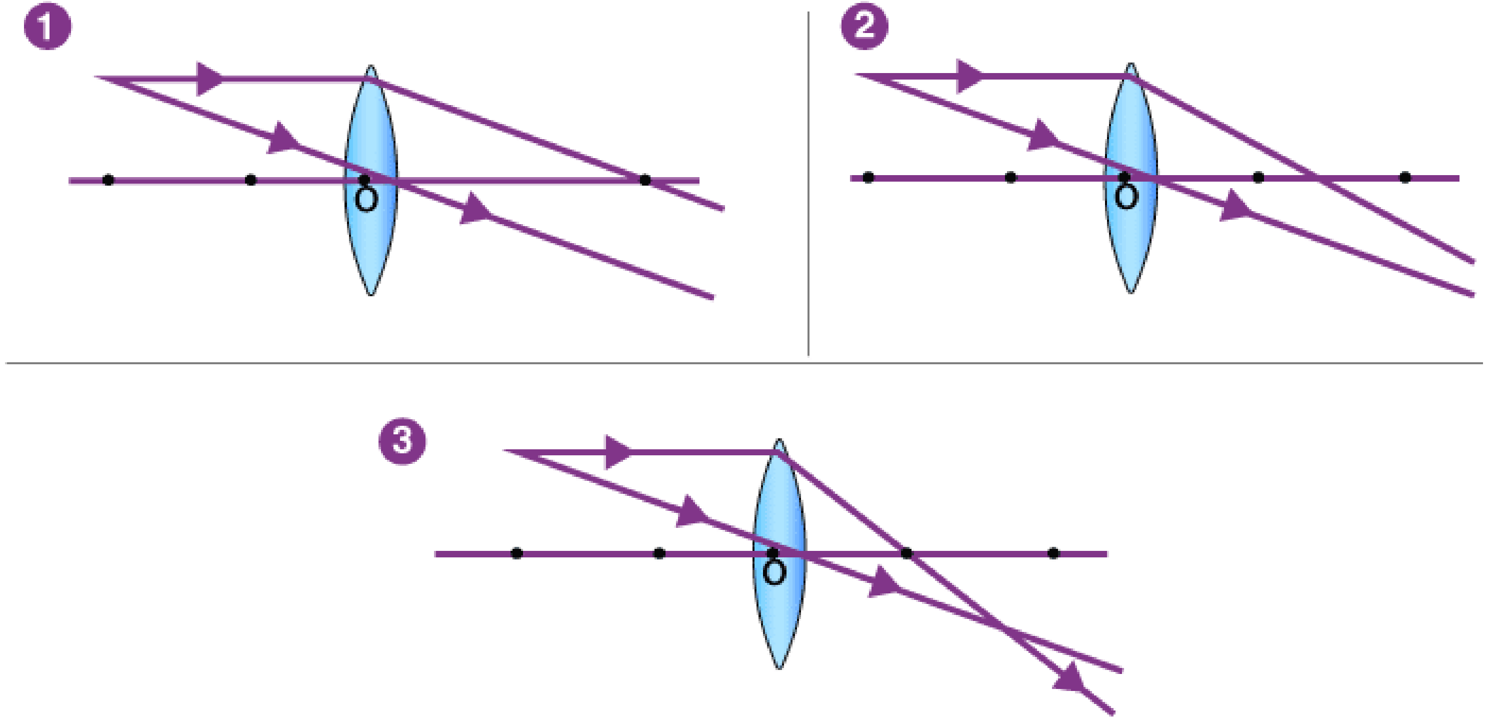
$$m = \frac{\text{Height of the Image}}{\text{Height of the object}} = \frac{h}{h}$$

Magnification produced by a lens is also related to the object-distance *u,* and the image-distance *v*. This relationship is given by

Magnification *(m*) = *h¢*/*h* = *v*/*u*

Power of a Lens

- You have already learnt that the ability of a lens to converge or diverge light rays depends on its focal length.
- For example, a convex lens of short focal length bends the light rays through large angles, by focusing them closer to the optical centre.
- Similarly, concave lens of very short focal length causes higher divergence than the one with longer focal length.
- 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


1
O
2
O
3
O

- The SI unit of power of a lens is ‘diopter’. It is denoted by the letter D. If *f* is expressed in meters, then, power is expressed in diopters.

- Thus, 1 diopter is the power of a lens whose focal length is 1 meter. 1D = 1m–1. You may note that the *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 $P = P1 + P2 + P3 + \ldots$
- The use of powers, instead of focal lengths, for lenses is quite convenient for opticians.
- During eye-testing, an optician puts several different combinations of corrective lenses of known power, in contact, inside the testing spectacles’ frame.
- The optician calculates the power of the lens required by simple algebraic addition.
- For example, a combination of two lenses of power + 2.0 D and + 0.25 D is equivalent to a single lens of power + 2.25 D.

- The simple additive property of the powers of lenses can be used to design lens systems to minimise certain defects in images produced by a single lens.

- Such a lens system, consisting of several lenses, in contact, is commonly used in the design of lenses of camera, microscopes and telescopes.

THANKYOU…