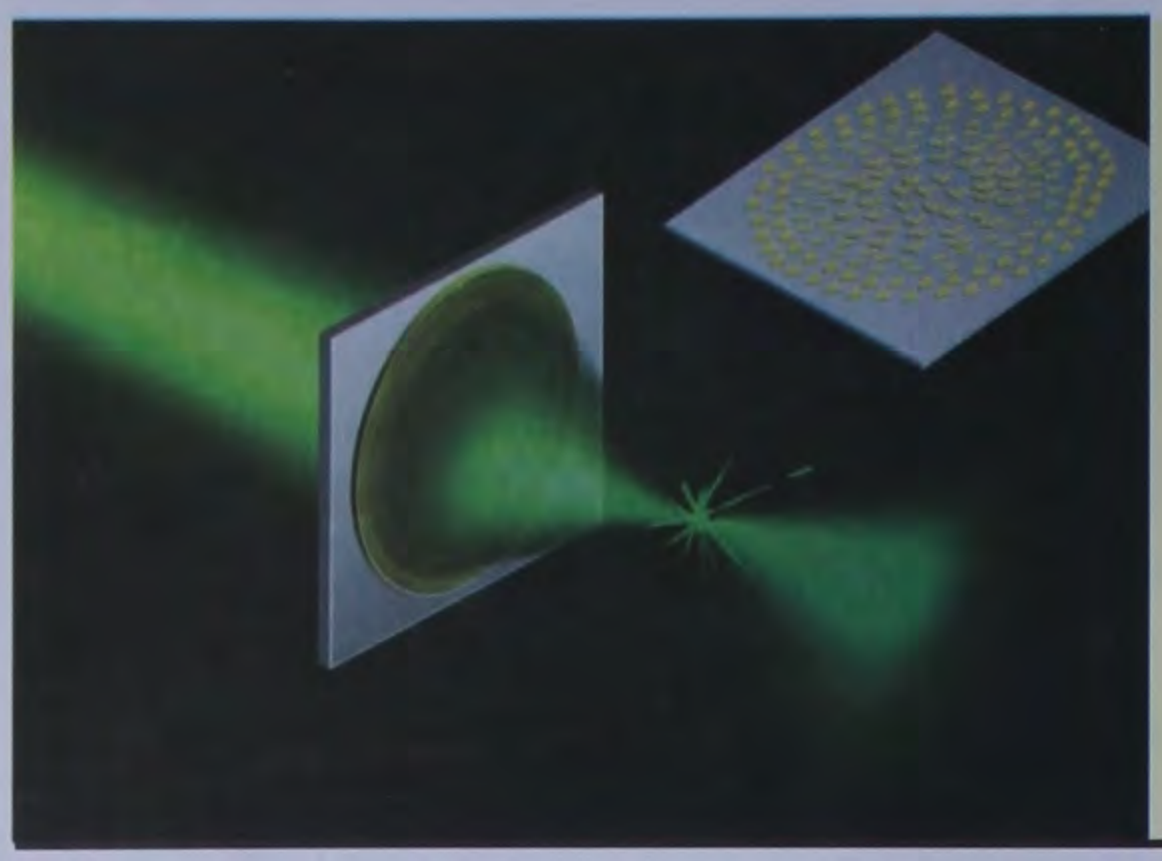


3 Lenses

LENS

A lens is a transparent medium, usually made up of glass or plastic. Generally, both of its sides are curved so as to achieve the required bending of rays of light.

Convex Lens (Converging lens)

A convex lens converges a beam of parallel rays of light after refraction through it. Such a lens is thickest at the middle and gradually becomes thinner towards its edges. There are three types of convex lenses.

(a) Biconvex or double convex lens or, simply, a convex lens which has both the surfaces convex.

(b) Plano-convex lens which has one surface convex and the other plane.

(c) Concavo-convex lens which has one surface convex and the other concave.

(a) *Double convex or Convex or Biconvex lens*

(b) *Plano convex lens*

(c) *Concavo convex lens*

Fig. 3.1 : Three types of convex lenses

Concave lens (Diverging lens)

A concave lens diverges a beam of parallel rays of light after refraction through it. Such a lens is thinnest at the middle and gradually becomes thicker towards its edges. There are three types of concave lenses.

(a) Biconcave or double concave lens or simply concave lens which has both the surfaces concave.

(b) Plano-concave lens which has one surface concave and the other plane.

(c) Convexo-concave which has one surface concave and the other convex.

(a) *Double concave or Concave or Biconcave lens*

(b) *Plano concave lens*

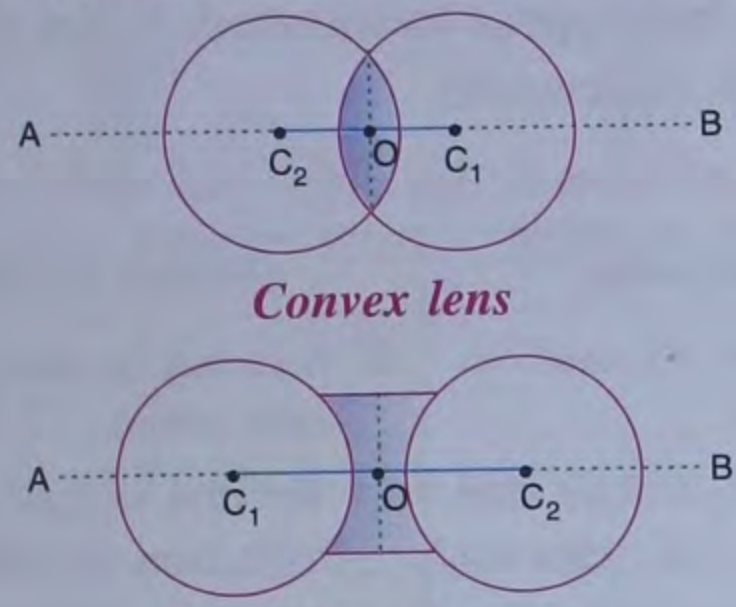
(c) *Convexo concave lens*

Fig. 3.2 Three types of concave lenses

SOME TERMS RELATED TO LENSES

Each of a convex (double convex or converging) lens and a concave (double

concave or diverging) lens has both of its surfaces spherical as shown below :



Convex lens

Fig. 3.3 Concave lens

1. **Centre of curvature (C) :** It is the centre of the sphere of which the surface of the lens is a part. In a lens, there are two spherical surfaces, therefore there are two centres of curvature of a lens. In Fig. 3.3, C_1 and C_2 are the centres of curvature.
2. **Radius of curvature (R) :** It is the radius of the sphere of which the surface of the lens is a part. Since there are two spherical surfaces of the lens, we get two radii of curvature. In Fig. 3.3, OC_1 and OC_2 are the two radii of curvature. These radii of curvature of a lens may or may not be equal; but in this chapter, we shall consider both the radii to be equal.
3. **Principal Axis :** It is a straight line passing through the two centres of curvature of the lens. In Fig. 3.3, the straight line AB is the principal axis. Any ray passing through the lens along the principal axis remains undeviated.
4. **Optical Centre (O) :** It is the point on the principal axis inside the lens, through which when a ray of light passes does not deviate. In Fig. 3.3, point O is the optical centre of the lens. Any ray passing through the optical centre of the lens remains undeviated.
5. **Principal Focus (F) :** In case of a convex lens, the rays of light incident parallel to the principal axis meet after refraction, at a point on the other side of the lens, on the principal axis. This point is called the principal focus and is denoted by letter F. A convex lens has two principal foci F_1 and F_2 as rays can be refracted from either side.

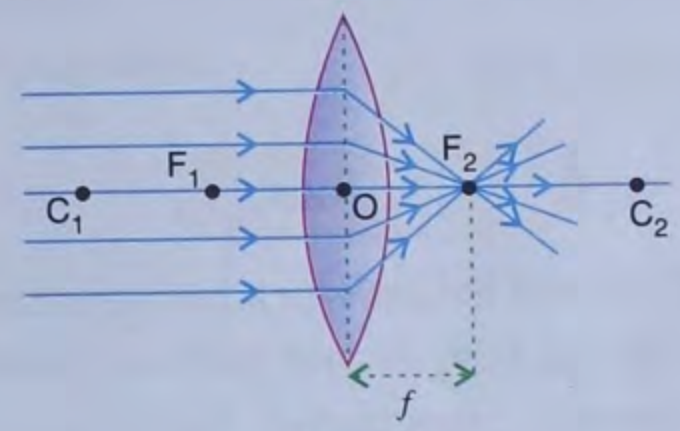


Fig. 3.4

It is dangerous to look through a convex lens at the sun or a bright light. You should also be careful not to focus sunlight with a convex lens on any part of your body.

In case of a concave lens, the rays of light incident parallel to the principal axis appear to diverge, after refraction, from a point on the same side of the lens on the principal axis. This point is called the principal focus and is denoted by letter F. A concave lens also has two principal foci F_1 and F_2.

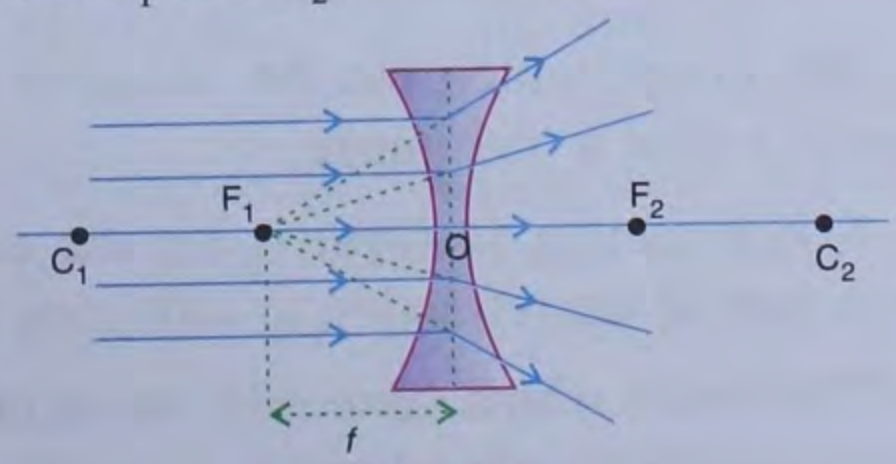


Fig. 3.5

6. **Focal length (*f*) :** The focal length of a lens is the distance between its optical centre and its principal focus.

Representation of lens as a combination of different sections of prism

A lens may be considered to be made up of a combination of different sections of prism.

Converging lens *Diverging lens*

Do You Know ?

— Concave lenses work to make something look smaller, so they're not quite as common as convex lenses. Spectacles have one convex surface and one concave surface. It can bend the light just the right amount before it gets to your eyes.

— Lenses have "aberrations", which means that they don't focus light of different colours or light passing through different portions of a lens at one point. A combination of a convex lens and a concave lens of different materials can approximately get rid of the "chromatic aberration" or the problem of focusing light of different colours differently. Thus concave - convex combinations are used in many high quality telescopes and binoculars so that the colour defect of images can be eliminated.

REAL AND VIRTUAL IMAGES

The image which can be obtained on a screen is called a real image.

A real image is formed by the actual intersection of the refracting or reflecting rays.

The image which cannot be taken on the screen, is called a virtual image.

A virtual image is formed when the refracting or reflecting rays do not actually intersect but appear to intersect when they are produced backwards.

Difference between real image and virtual image

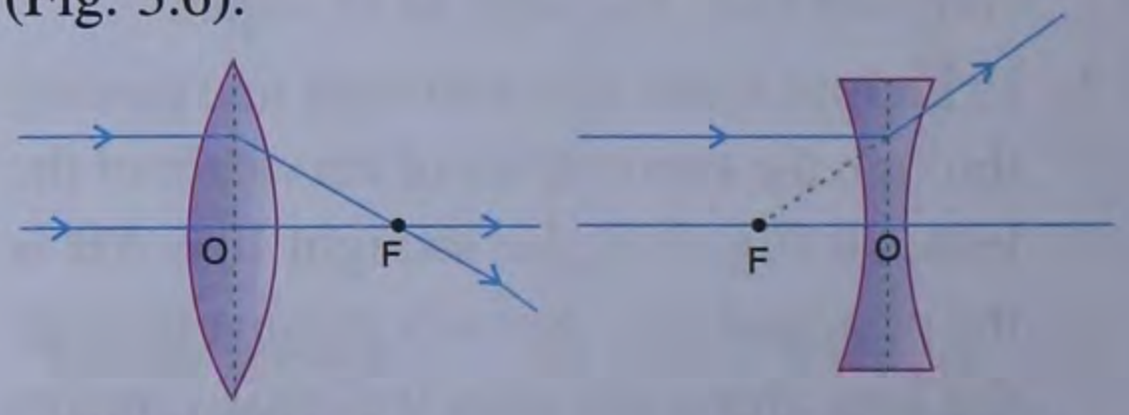
Real image	Virtual image
1. It can be obtained on a screen.	1. It cannot be obtained on a screen.
2. The rays of light after reflection or refraction meet at a point.	2. The rays of light after reflection or refraction appear to meet at a point.
3. It is always inverted.	3. It is always erect.

IMAGE FORMED BY LENSES

To find out the position, nature, size and whether the image is erect or inverted, we need to draw at least two rays starting from the object and travelling through the lens. While drawing the ray diagrams, we must keep in mind the following important rules :

Rule 1 :

A light ray incident parallel to the principal axis converges at the focal point in case of convex lens and appears to diverge from the focal point in case of a concave lens (Fig. 3.6).

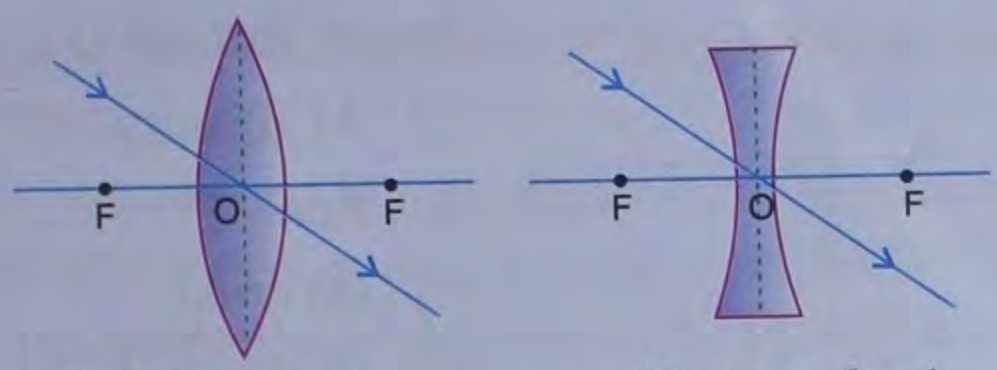


(Convex Lens) *(Concave lens)*

Fig. 3.6

Rule 2 :

A ray passing through the optical centre of a lens remains undeviated irrespective of its inclination on the principal axis (Fig. 3.7).

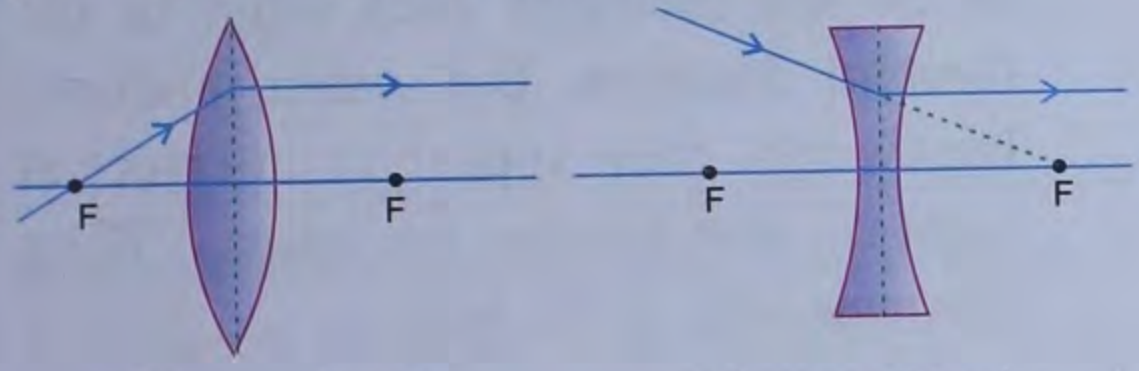


(Convex Lens) *(Concave lens)*

Fig. 3.7

Rule 3 :

A ray of light which comes through focus (in case of convex lens) or appears to come towards focus (in case of a concave lens) becomes parallel to the principal axis after passing through the lens (Fig. 3.8).



(Convex Lens) *(Concave lens)*

Fig. 3.8

ACTIVITY 1

Take a convex lens and fix it vertical on a stand. Place it on a table. Place a lighted candle at a distance of about 50 cm from the lens. Try to obtain the image of the candle on a paper screen placed on the other side of the lens. You may have to move the screen towards or away from the lens to get a sharp image of the flame. What kind of image did you get ? Is it upright or inverted ? Is it magnified or diminished ?

Now vary the distance of the candle from the lens. Try to obtain the image of the candle flame every time on the paper screen by moving it. Record your observations. Did you see for any position of the object an image was erect and magnified. Could this image be obtained on a screen ? Is the image real or virtual ? This is how a convex lens is used as a magnifying glass.

In a similar fashion study the images formed by a concave lens. You will find that the image formed by a concave lens is always virtual, erect and smaller in size than the object. It cannot be obtained on a screen.

FORMATION OF IMAGE BY A CONVEX LENS

We now draw the ray diagrams to get the position, size and nature of the image formed by a convex lens for various positions of the object.

1. **Object at infinity.** Rays coming from an object at infinity, can be taken parallel to each other. These rays, after refraction form an image at focus as shown below.

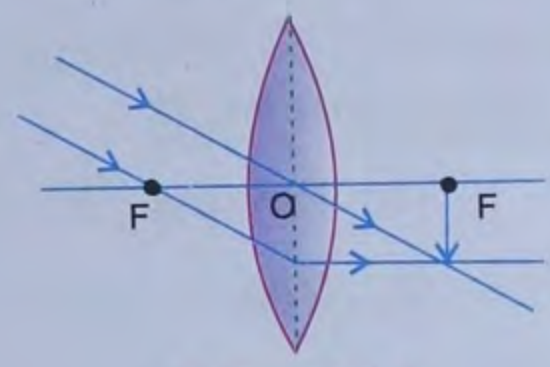


Fig. 3.9 (a)

Image formed is :

(a) at F

(b) Real

(c) Inverted

(d) Highly diminished

2. **Object beyond 2F.** One ray from the object AB can be taken parallel to the principal axis and the other through the optical centre. The two rays, after refraction, intersect to form image between F and 2F on the other side of the lens as shown below.

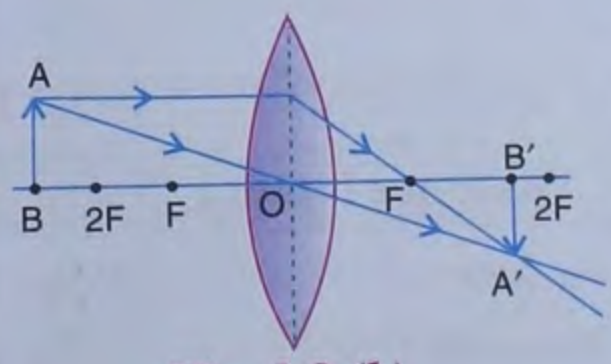


Fig. 3.9 (b)

Image formed is :

(a) Between F and 2F

(b) Real

(c) Inverted

(d) Smaller (or diminished)

3. **Object at 2F.** One ray from the object AB can be taken parallel to the principal axis and the other through the optical centre. The two rays, after refraction intersect to form image at 2F on the other

side of the lens as shown below.

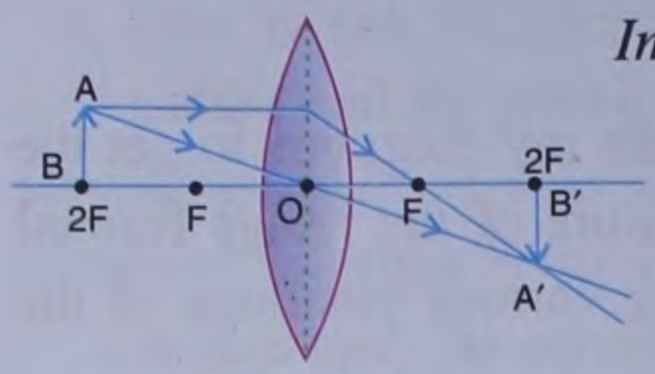


Fig. 3.9 (c)

Image formed is :

(a) at 2F

(b) Real

(c) Inverted

(d) Same size

4. Object between F & 2F. One ray from the object AB can be taken parallel to the principal axis and the other through the optical centre. The two rays intersect each other to form an image beyond 2F on the other side of the lens as shown below.

Image formed is :

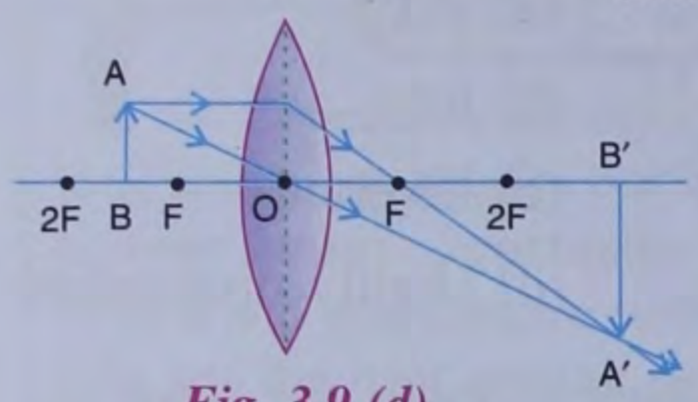


Fig. 3.9 (d)

(a) Beyond 2F

(b) Real

(c) Inverted

(d) Larger (or magnified)

5. Object at F. One ray from the object AB can be taken parallel to the principal axis and the other through the optical centre. The two rays, after refraction, are parallel to each other and so appear to intersect at infinity.

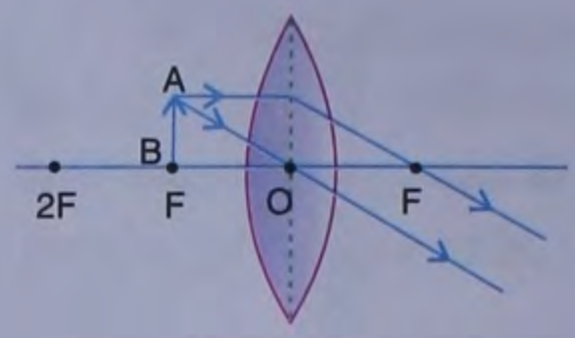


Fig. 3.9 (e)

Image formed is :

(a) At infinity

(b) Real

(c) Inverted

(d) Highly enlarged

6. Object between F and O *i.e.* object within focus.

One ray, from object AB, is taken parallel to the principal axis and the other through the optical centre. The two rays, after refraction, go away from each other and so do not intersect each other in the forward direction. But, when produced backwards, they appear to intersect at point A′, thus forming the image A′B′ on the same side of the lens.

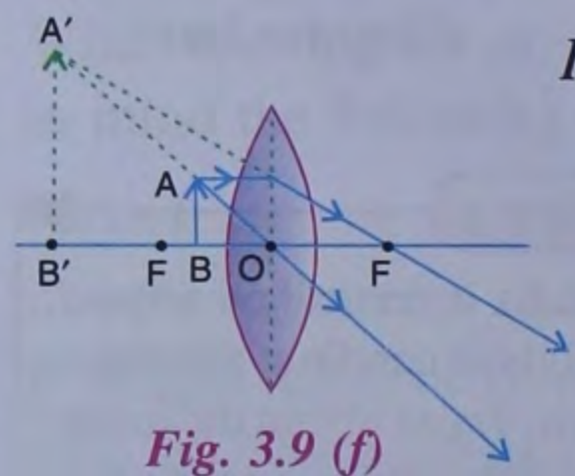


Fig. 3.9 (f)

Image formed is :

(a) On the same side

(b) Virtual

(c) Erect

(d) Enlarged

IMAGE FORMED BY A CONVEX LENS FOR DIFFERENT POSITIONS OF OBJECT

Position of object	Position of image	Nature/Size of image	Use
1. Infinity	At focus	Real, inverted & highly diminished	Burning glass
2. Beyond 2F	Between F & 2F	Real, inverted and small	Camera
3. At 2F	At 2F	Real, inverted and of same size	Xerox machine
4. Between F & 2F	Beyond 2F	Real, inverted & enlarged	Projectors, objective of microscope
5. At F (focus)	At infinity	Real, inverted & highly magnified	Searchlight, collimator
6. Between F & O	On the same side and behind the object	Virtual, erect & enlarged	Magnifying glass.

FORMATION OF IMAGE BY A CONCAVE LENS

An object AB is placed on the principal axis of a concave lens. Two rays are taken from it (the object), one parallel to the principal axis which after refraction appears to diverge from the focus F and the other through the optical centre O. This is refracted by the concave lens without any deviation.

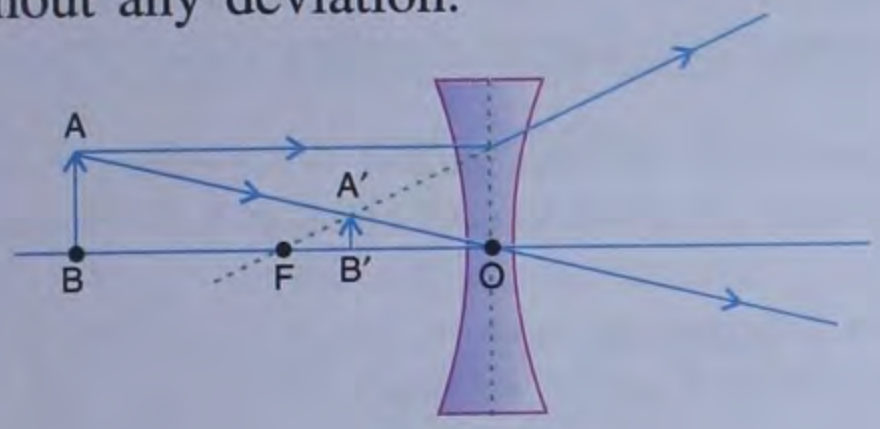


Fig. 3.10

The two rays after refraction travel away from each other and appear to come from point A′ between the object and the lens. Thus the image A′B′ is formed.

The characteristics of the images formed by a concave lens are :

1. The images are virtual.
2. The images are formed on the same side as that of object between focus and optical centre.
3. The image is always erect and diminished.

To find the focal length of a convex lens

Make a screen of a white blank paper on a piece of smooth cardboard. Stand the screen verticals near a window. Adjust the position of a convex lens in front of the screen by moving it to and fro until a sharp inverted image of any distant building or a tree is formed on the screen.

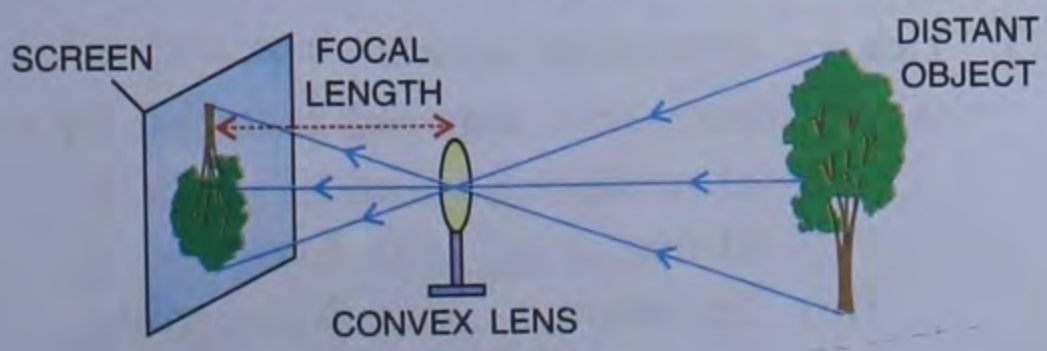


Fig. 3.11

Now measure the distance between the screen and the lens when a sharp image of the object is formed on the screen. This distance is equal to the focal length of the lens used.

Uses of a Convex Lens

(i) It is used in a number of optical instruments like camera, picture projector, telescope, microscope, *etc*.

(ii) It is used as a reading lens and as a magnifying glass.

(iii) It is used in spectacles for the correction of long sightedness (hypermetropia) of the eyes.

Uses of a Concave Lens

(i) It is used in telescopes to see far off objects.

(ii) It is used in spectacles for the correction of short sightedness (myopia) of the eyes.

Differences between convex lens and concave lens

Convex lens	Concave lens
1. Convex lenses are thicker in the middle than at the edges. OR Convex lens will be bulged at centre and narrow at edges.	1. Concave lenses are thinner in the middle than at the edges. OR Concave lens will be narrow at centre and bulged at edges.
2. Convex lens converge parallel rays of light.	2. Concave lens diverge parallel rays of light.
3. If the object is at focus or beyond it, the image formed is real and inverted, whereas, if the object is between focus and optical centre, the image is a virtual, erect and magnified image.	3. It forms a virtual, erect and diminished image.

RECAPITULATION

- A lens is a transparent medium, in general, bounded by two spherical surfaces.
- A convex or a converging lens is thicker at the middle and thinner at the ends whereas a concave or a diverging lens is thinner at the middle and thicker at the ends.
- A convex lens is called a converging lens because it converges the incident parallel rays towards its focus whereas a concave lens is called a diverging lens because it diverges the incident parallel rays away from its focus.
- Optical centre of a lens is the point on the principal axis inside the material of lens through which if any ray passes, it gets refracted without any deviation.
- When the ray is incident parallel to the principal axis of a convex lens, after refraction, it passes through the focus of the lens. Thus, focus of a convex lens is a real point.
- When the ray is incident parallel to the principal axis of a concave lens, after refraction, it appears to come from the focus of the lens. Thus, focus of a concave lens is a virtual point.
- A ray of light passing through the focus of a convex lens, after refraction, becomes parallel to the principal axis. Whereas, a ray of light moving towards the focus of a concave lens, after refraction, becomes parallel to the principal axis.
- The image formed by a convex lens is real and inverted if the object is beyond its focus or is at its focus. But, if the object is within the focal length of the convex lens, *i.e.* the object is between F and O, the image formed is virtual and erect.
- For each position of an object, the image formed by a concave lens is always erect and virtual.
- The virtual image formed by a convex lens is always enlarged (bigger than the object), whereas the virtual image formed by a concave lens is always diminished.

TEST YOURSELF

A. Short Answer Questions

1. State, whether the following statements are ***true*** or ***false***. Rewrite the false statement correctly.
   (a) The lens which is thicker in the middle and thinner at the edges is called concave lens.
   (b) A convex lens is used as a magnifying glass.
   (c) The distance between focus and optical centre of a lens is called its focal length.
   (d) A convex lens always forms a virtual, erect and diminished image when the object is placed in front of it.
   (e) Concave lens is also called a converging lens.
   (f) Divergent lens is a double concave lens.
2. Fill in the blanks :
   (a) ..... lens is the lens which has one surface plane and the other concave.
   (b) If the object is kept at the focal point of a convex lens, the image is formed at .....
   (c) For a concave lens, the image formed is always ..... irrespective of the position of object.
   (d) ..... lens is a converging lens.
   (e) Virtual and diminished image is formed in ..... lens.
   (f) Virtual and enlarged image is formed in..... lens.
   (g) Real image is obtained only in ..... lens.
   (h) ..... lens gives ..... image of same size.
   (i) Real and diminished image is formed in ..... lens.
   (j) Convex lens is ..... at the middle and ..... at the edges.
   (k) Concave lens is ..... at the edges and ..... at the middle.
3. Tick the appropriate answer :
   (a) A transparent material bounded by two curved surfaces is called
   (i) Mirror (ii) Lens
   (iii) Telescope (iv) Microscope

(b) A real, inverted and same size image is formed when object is placed at (for convex lens)

(i) 2F (ii) F

(iii) Between F & 2F (iv) Infinity

(c) A plano-concave lens has one face as concave and other face

(i) Convex (ii) Concave

(iii) Plane (iv) None of these.

(d) Concave lens forms an image which is :

(i) always real and diminished.

(ii) real and of same size.

(iii) virtual and smaller in size.

(iv) virtual and enlarged image.

(e) Image formed in a concave lens is :

(i) real and of same size.

(ii) real and enlarged.

(iii) virtual and diminished

(iv) virtual and enlarged image.

4. Match the following :

(a) Position of image by a convex lens when object is placed at 2F	Convex lens
(b) Position of image by a convex lens when object is beyond 2F	At 2F
(c) Position of image by a concave lens when object is beyond F	Between F and 2F on the other side
(d) A projector has	Between F and O on the same side.

B. Long Answer Questions

1. Define in reference of a lens :

(a) centre of curvature

(b) radius of curvature

(c) principal axis

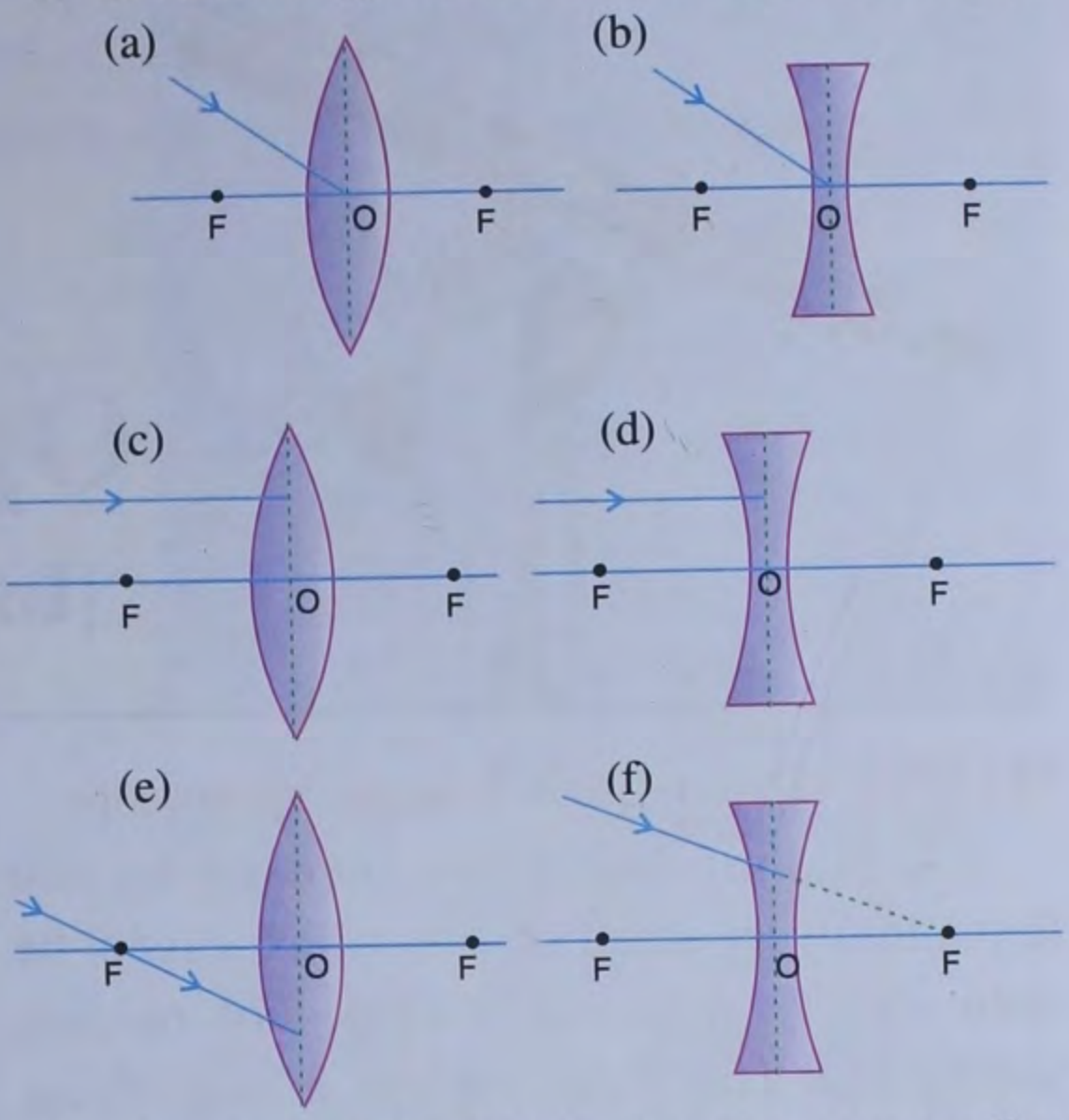
(d) optical centre

(e) focus of a convex lens

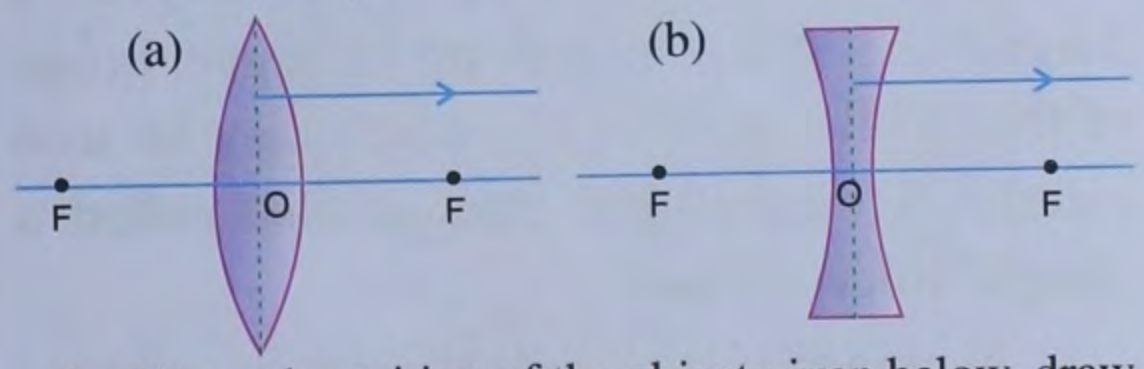
(f) focus of a concave lens

(g) focal length

2. In each case, given below, draw the refracted ray:



3. In each case given below, draw the corresponding incident ray :



4. For each position of the object given below, draw a ray diagram showing the formation of image in a convex lens when object is :

(a) beyond 2F (b) at 2F

(c) between 2F and F

(d) between F and optical centre

5. What should be the position of an object placed before a convex lens, so that the image formed is erect and enlarged ? Draw a ray diagram in support of your answer. Is the image formed virtual or real ?

6. Is there any method to find the approximate focal length of a convex lens ? Describe the method.

7. State one use of a convex lens and one use of a concave lens.

8. State two differences between a convex lens and a concave lens.