Chapter 10

LENSES

STUDENTS' LEARNING OUTCOMES

After studying this chapter, students will be able to:

- ☑ Define lenses.
- ☑ Differentiate between different types of lenses.
- ☑ Describe the image formation using a lens by ray diagram.
- ☑ Compare and contrast the working of human eye with the lens camera.
- ☑ Explain how eye focuses by altering the thickness of the eye lens.
- ☑ Investigate how eyes get used to darkness after sometime.
- ☑ Explain how lenses are used to correct short sightedness and long sightedness.
- ☑ Identify the types of lenses used for various purposes in daily life.

You have already studied the refraction of light in the previous class. Light, when enters from a lighter medium (e.g., air) to a denser medium (e.g., glass), it bends towards the normal. Conversely, when light enters from a denser medium (e.g., glass) to a lighter medium (e.g., air), it bends away from the normal. The main application of refraction is the image formation through lenses. In this chapter, we will learn about the types of lenses, image formation by lenses and uses of lenses.

10.1 Lenses

Lenses are widely used in our life. Many eyesight defects are corrected by the use of lenses. Lenses are commonly used in spectacles, cameras, microscopes, telescopes, binoculars, projectors and many other instruments for different purposes. Contact lenses are also becoming very popular these days. These can be placed in eyes and removed easily when needed.

A lens is a piece of any transparent material (like glass) with two faces, of which at least one is curved. Each surface of a lens is a part of a sphere. The centre of such a sphere is called **centre of curvature** (C). The centre of the lens is called **optical centre** (O). The line passing through the optical centre and centre of curvature of the faces of the lens is called **principal axis** or **optical axis** (Figure 10.1).

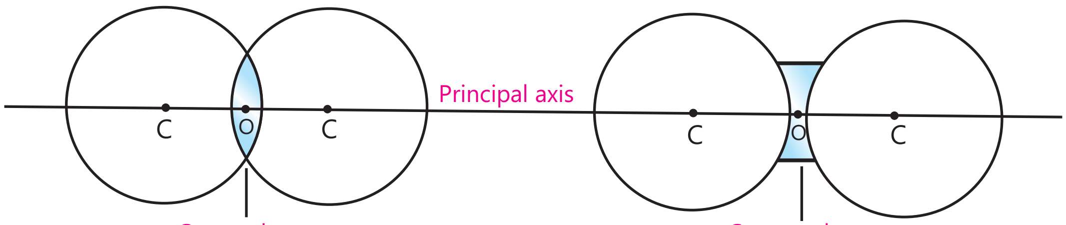


Figure 10.1: Centre of curvature and principal axis of the lenses

10.2 Types of Lenses

There are two types of lenses; **convex lens** or converging lens and **concave lens** or diverging lens (Figure 10.2). A convex lens is thicker in the middle and thinner at the edges. A concave lens is thinner in the middle and thicker at the edges.

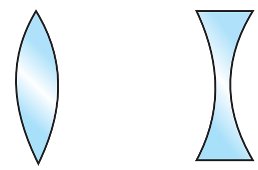
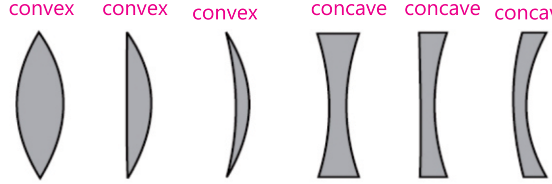


Figure 10.2: Convex and concave lenses

For your information

There are different types of converging and diverging lenses such as double convex lens, plano-convex lens, concavo convex, double concave lens, plano-concave lens, convexo-concave.



Principal Focus (F) and Focal Length (*f*) of the Lenses

In case of convex lens the light rays parallel to the principal axis after refraction through the lens meet at a point. This point is called **principal focus** (F) or focus point of convex lens (Figure 10.3). As the light rays actually meet at the focus point after refraction through the convex

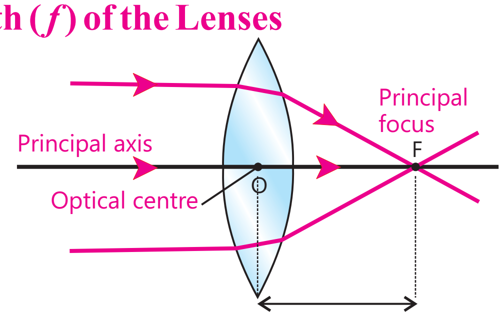


Fig. 10.3: Light rays passing through a convex lens

lens, so the focus point is 'real'. The distance between the optical centre (O) and focus point (F) of the lens is called **focal length** (*f*). Focal length of a convex lens is taken as positive. Since a convex lens actually converges light at principal focus (F), that is why, it is also known as converging lens. Because of this property, convex lens makes real image on the screen placed on the other side of the lens.

In case of concave lens, light rays parallel to the principal axis after passing through the lens bend in such a way that they do not meet at one point. They diverge out and appear to be coming from one point which is called principal focus. The principal focus of a concave lens is 'virtual'. The focal length of a concave lens is taken as negative. The image is not formed on the screen by a concave lens (Figure 10.4).

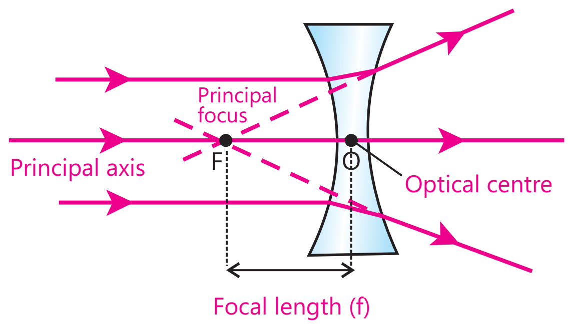
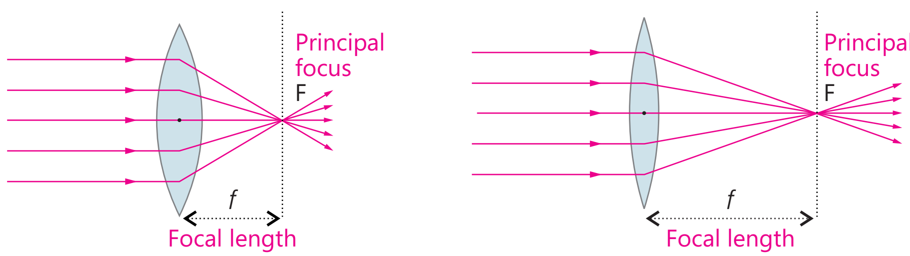


Fig. 10.4: Light rays passing through a concave lens

For your information

The focal length of a thick convex lens is shorter than that of a thin convex lens.



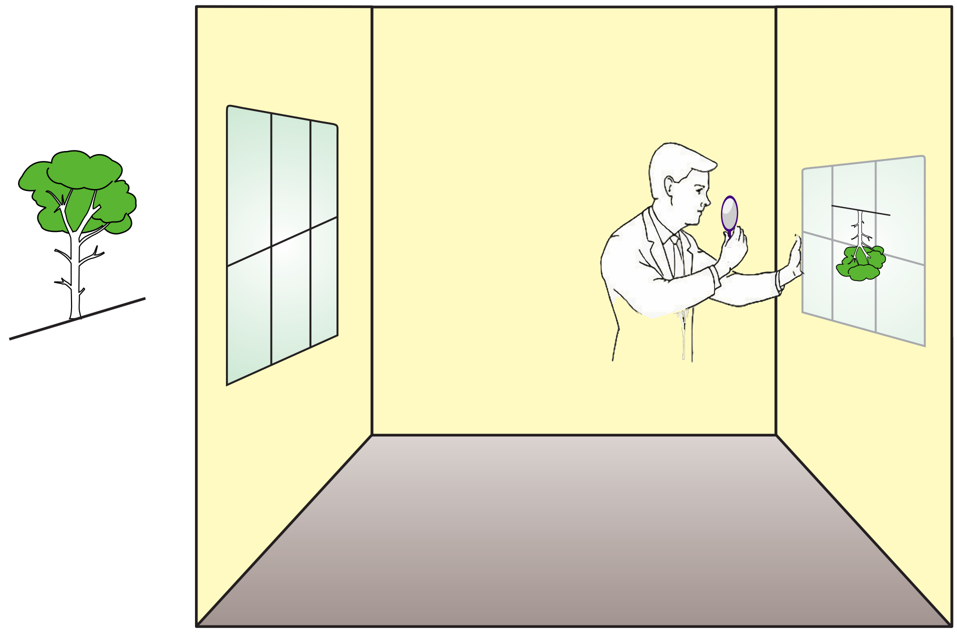
How to Find out Focal Length (f) of a Lens?

We use lenses of different focal lengths for different purposes. For the correct use of a lens, its focal length should be known. Let us perform a simple activity to find the focal length of convex lens.

Activity

- Take a convex lens and position yourself near the wall opposite to the window.
- Direct the lens towards the window in such a way that an image of a distant object such as a tree is formed on the wall.
- Move the lens slowly towards or away from the wall so that the image on the wall becomes sharp.
- At this position, note the distance between the lens and the wall. This distance is called focal length of lens.
- Measure this length and note it.
- Now take a concave lens and try to obtain the image of the same object on the wall.

- You will come to know that no image is formed on the wall by the concave lens.



10.3 Image Formation by the Lenses

Where and how an image is formed by a lens, it can be known by drawing a ray diagram. A ray diagram is a drawing showing the path of light rays. Therefore, the location and nature of image formed by a lens can be found very easily through a ray diagram. In this method, two or three light rays emerging from an object and passing through a lens are used. The image of the object is formed at the point where all the refracted rays meet after passing through the lens. In a ray diagram, light rays are represented by straight lines with arrow heads. The arrow heads show the direction of light ray. The following properties are used in drawing the ray diagrams:

1. A ray parallel to the principal axis after refraction from a convex lens passes through its principal focus (F). In case of concave lens, the refracted ray appears to come from the principal focus (F) (Figure 10.5).

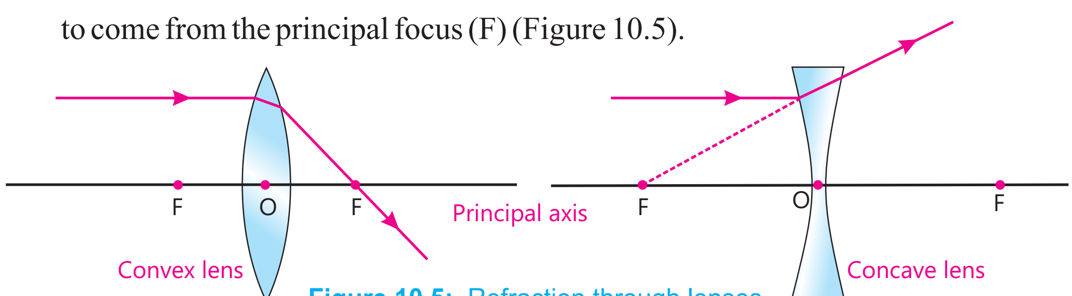


Figure 10.5: Refraction through lenses

2. A ray incident on the convex lens after passing through its principal focus (F) becomes parallel to the principal axis after refraction. In case of a concave lens, the ray pointing towards the principal focus appears to come from the principal focus after refraction (Figure 10.6).

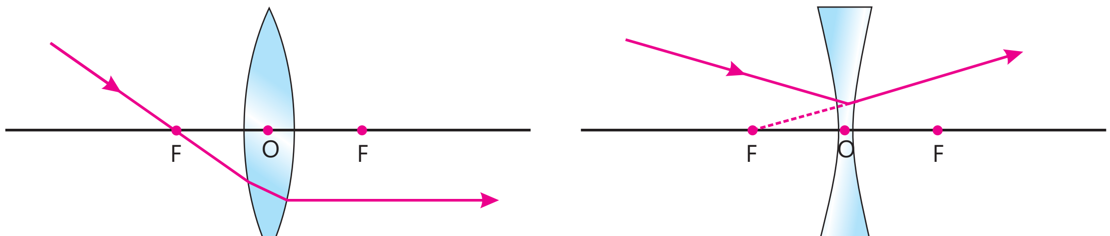


Figure 10.6: Path of ray through lenses

3. A ray passing through the optical centre of the lens goes straight without changing its direction (Figure 10.7).

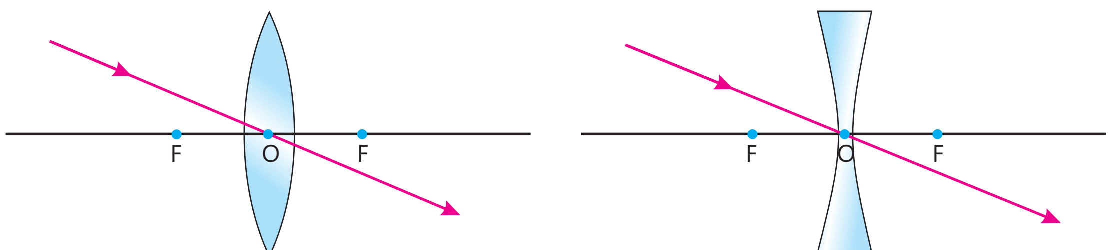


Figure 10.7: Path of ray through lenses

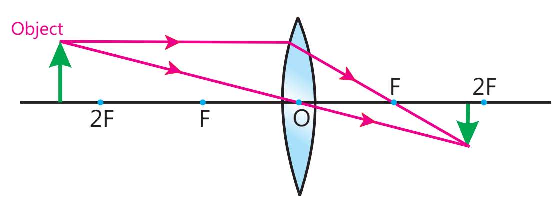
Image Formation Using a Lens by Ray Diagram

To find the position and nature of the image of an object by ray diagram method, follow the following steps:

1. Draw the positions of the object, lens and focal points on the principal axis.
2. Draw any two rays out of the three from the top of the object. In case of a convex lens, the point at which these rays cross each other after refraction is the top of the image.

Let us draw the ray diagrams to locate the image of an object placed at different positions in front of the convex lens (Figure 10.8).

a. When the object is placed beyond 2F, the image is formed on the other side of the lens between F and 2F. The image is real, inverted and smaller in size than the object.



b. When the object is at 2F, the image is also formed at 2F on the other side of the lens. The image is real, inverted and equal in size to the object.

c. When the object is between F and 2F, the image of the object is formed beyond 2F on the other side of the lens. The image is real, inverted and larger in size than the object.

d. When the object is at F, the image of the object is formed at infinity. It cannot be shown in the diagram because rays become parallel after refraction.

e. When the object is between O and F, rays after refraction diverge out and do not actually meet on the other side of the lens. A virtual image will be formed at a point where the rays meet when extended backward. These rays will appear to come from the image. The image will be magnified and erect.

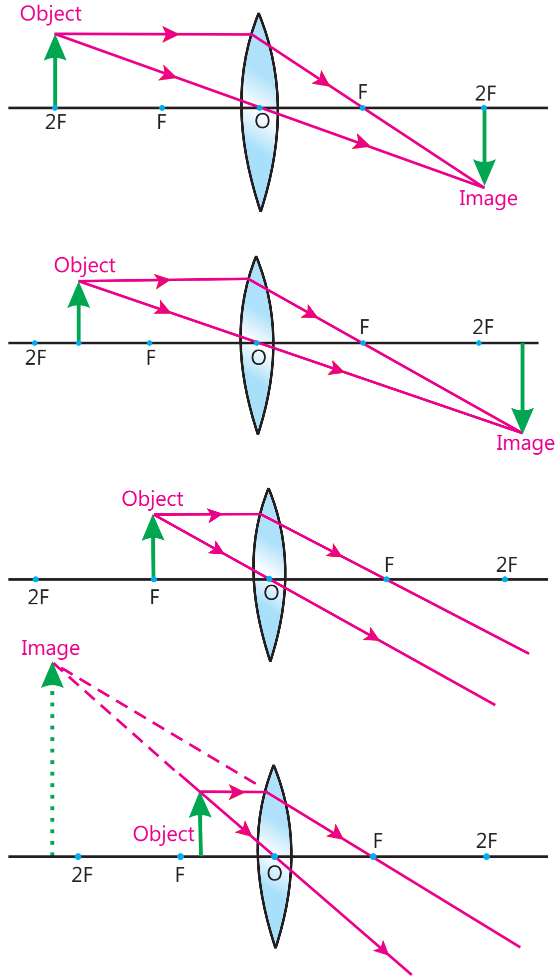


Figure 10.8: Position, nature and size of images formed through convex lens

- In case of concave lens, draw ray diagram by placing the object at different positions. Is real image formed on the other side of the lens? You will come to know that rays diverge out and do not meet on the other side of the lens after refraction. Therefore, real image is not formed on the other side. In fact, a virtual image is formed on extending the rays backward. This image is always virtual, erect and smaller in size (Figure 10.9).

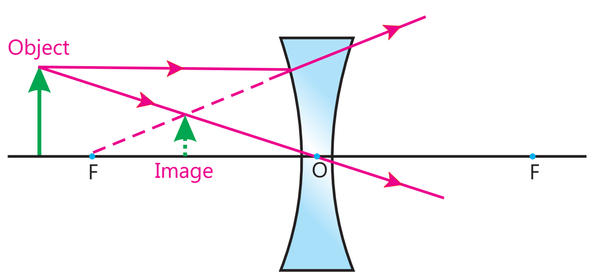


Figure 10.9: Position, nature and size of image formed through concave lens

10.4 Image Formation in Simple Camera and Human Eye

We know that if an object is lying at a distance more than the focal length of a convex lens, its real and inverted image is formed on the other side of the lens. The image through the eye and camera is formed in the same way. Let us compare the structure and function of both of them.

Camera

Camera is a kind of box to which a convex lens is mounted on the front side (Figure 10.10). The lens forms a real and inverted image of an object on the sensitive film placed behind it. A system is provided in the camera to move the lens back and forth so that sharp image is obtained on the film. There is shutter behind the lens that remains close normally. When the button is pressed, the shutter opens for a while. Light coming from the object enters the camera during this interval and image is formed on the film. The amount of light entering into the camera depends upon the size of aperture. Aperture is an opening in the diaphragm behind the lens. This can be made smaller or larger as required. The picture is obtained by developing the image on the film.

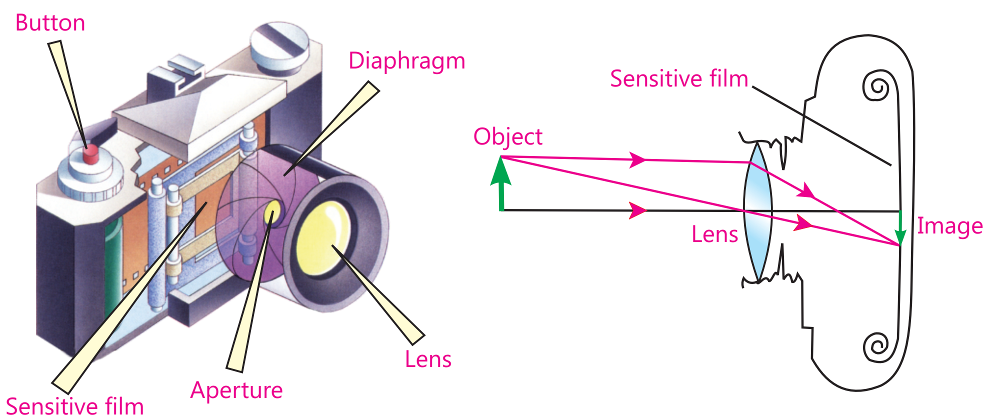


Figure 10.10: Image formation in camera

Human Eye

The human eye also works like a camera. Different parts of eye are shown in Figure10.11.

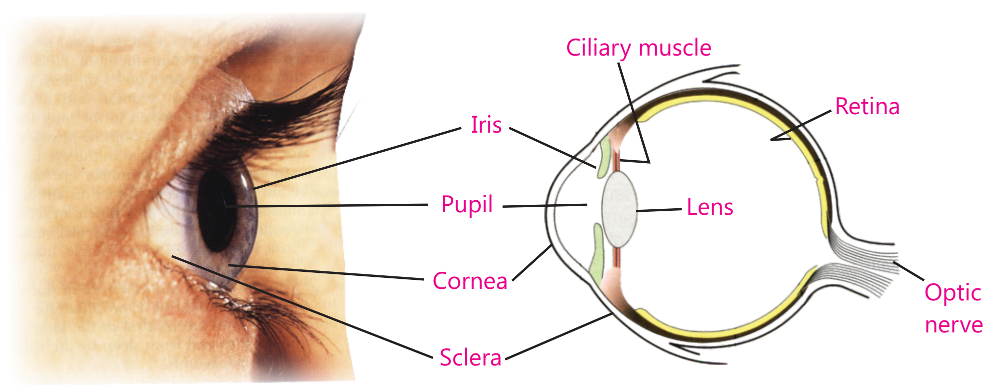


Figure 10.11: Human eye

The eye is almost a sphere of diameter about 2.5 cm. Its outer boundary called the sclera is thick and hard. At the front of the eye, there is a transparent hard skin known as cornea. Behind the cornea there is iris and after that there is convex lens. The inner layer of the back wall of eye is called retina. The retina of eye and the film of camera serve the same purpose. Like camera, the eye lens forms a real and inverted image of the object on retina. The optic nerve carries it in the form of signals to the brain. Although the image formed on the retina is inverted, but our brain interprets this correctly i.e. the right way up.

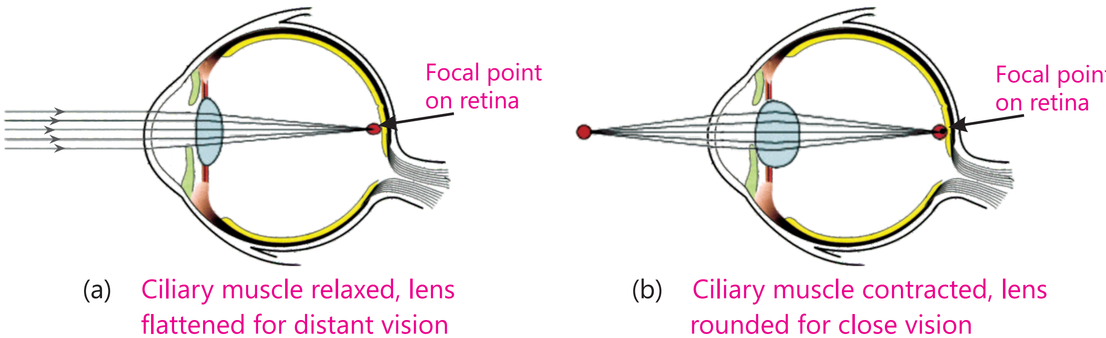


Figure 10.12: Ciliary muscles relax during distant vision (a), and contract during close vision (b).

The iris acts like the diaphragm of camera. The opening at the centre of iris is called pupil which is just like aperture of a camera. When light outside is dim, the iris contracts to make the pupil larger so that more light can enter the eye. In bright light, the iris makes the pupil smaller.

In a camera, lens is moved back and forth to focus the image on the film, but the eye lens does not move. Instead, the ciliary muscles make the lens thick or thin due to which its focal length changes (Figure 10.12). When you are looking at distant object, the ciliary muscles are in relaxed position and the image is formed on the retina. To look at something closer to the eye, these muscles make the lens thicker. This makes its focal length shorter and the image is again formed on the retina instead of forming at a point beyond it.

10.5 How Eyes Get Used to Darkness After Sometime?

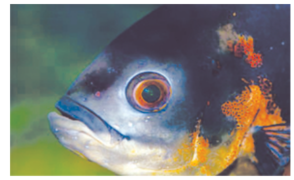
When we enter into a dimly lit room from bright sunshine, at first, we cannot see things clearly. But after sometime our eyes adjust to see in darkness. This is because, the retina of eye contains two types of vision cells. Near the centre of retina there are cone type cells.

These cells are active in bright light only and can perceive colours vision also. On the outside of retina are rod type cells which are active in dim light and only perceive object in black and white.

When suddenly we move from bright light to dark area, cone cells become de-activated but rods do not immediately become activate so that we feel difficulty in seeing for sometime. Then the rod cells become active after sometime and we are able to see in darkness though cannot perceive colours.

For your information

Some animals such as fish focus images onto the retina of their eye by moving their lens backward and forward.



10.6 Defects of Human Eye

Short-sightedness and long-sightedness are the common defects of the eye.

Short-Sightedness

A person with this defect can see near objects clearly but distant objects appear blurred. This defect is caused when the eye lens becomes much thicker or eyeball becomes too long. The image of distant object is formed in front of the retina and not at the retina itself. This defect is also known as myopia and is corrected by using concave lens of suitable focal length. The concave lens diverges the light rays before they enter the eye and hence, the rays are refracted by the eye lens again to meet at the retina (Figure 10.13).

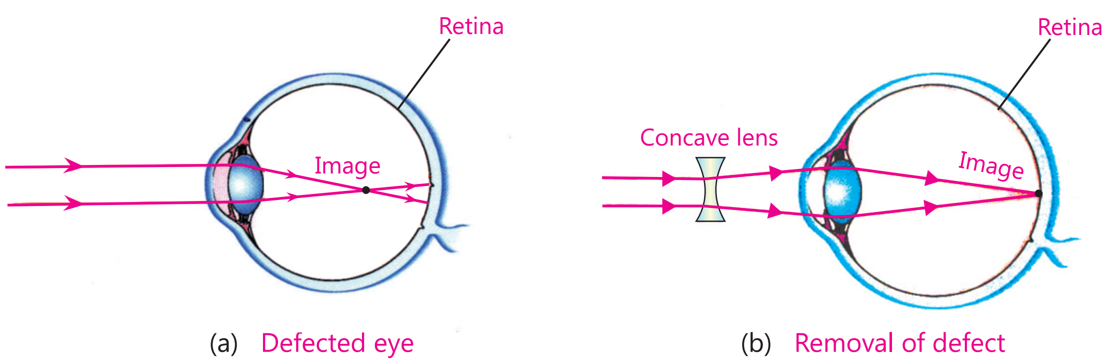
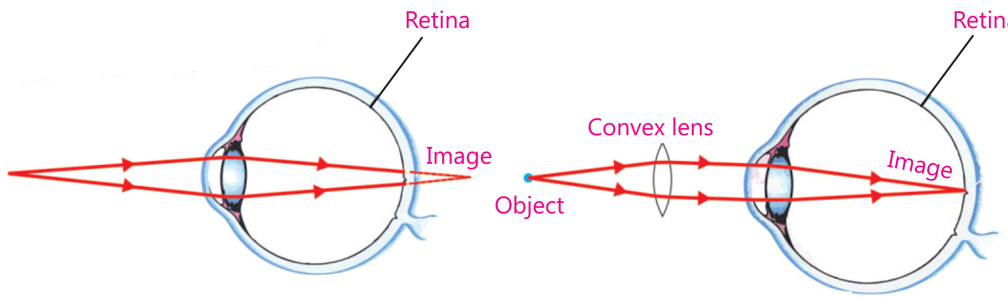


Figure 10.13: Correction of short-sightedness

Long-Sightedness

A person having this defect can see distant objects clearly but near objects appear blurred. This defect is caused when the eye lens becomes thin or the eyeball becomes too short. Due to this effect the image of the near object is formed beyond the retina. That is why the near object appears blurred in long-sightedness. This defect is known as hyperopia and is corrected by using suitable convex lens. The convex lens converges light rays before they enter the eye. After entering the eye, they are further bent by the eye lens to meet at the retina (Figure 10.14).



(a) Defected eye (b) Removal of defect

Figure 10.14: Correction of long-sightedness

10.7 Uses of Lenses

Lenses are used for various purposes in daily life. The following are their major uses:

Figure 10.15: Glass lenses in spectacles

1. Lenses are commonly used in spectacles (Figure 10.15).
2. Convex lenses are more widely used than concave lenses. Convex lenses are used to magnify images. They are used as magnifying glasses (Figure 10.16).

Figure 10.16: Magnifying glass

3. Contact lenses are becoming popular these days. These are very light and flexible. Contact lenses of different colours are used in eyes (Figure 10.17).

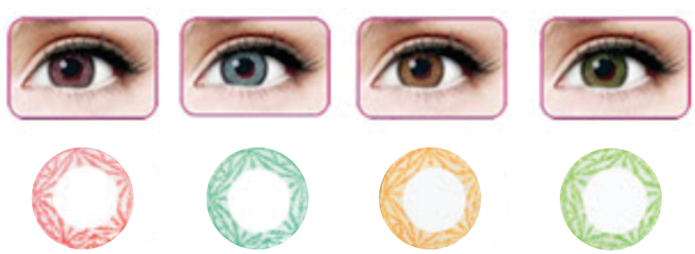


Figure 10.17: Contact lenses used in eyes

4. Special lenses are also used in high quality cameras, telescopes, and binoculars to improve the quality of images they provide (Figures 10.18, 10.19).

Figure 10.18: Lens **in camera**

Figure 10.19: Lens in binoculars

KEY POINTS

- A lens is a piece of any transparent material (like glass) with two faces, of which at least one is curved.
- A lens which is thick at the middle and thinner at the edges is called convex lens and the lens which is thin at the middle and thicker at the edges is called concave lens.
- The centre of the sphere of which any surface of the lens is a part , is known as its centre of curvature.
- Parallel rays after refraction through a convex lens converge at a point F which is called the principal focus of the lens.
- Parallel rays of light after refraction through a concave lens diverge out. They appear to come from a point F, which is called the principal focus of the lens.
- The distance between the optical centre and the principal focus is known as focal length of the lens.
- The image that can be obtained on the screen is known as real image.
- A convex lens forms real image on the screen while a concave lens always forms a virtual image.
- In short-sightedness, a person can see near objects clearly but distant objects appear blurred. This defect is corrected by using suitable concave lens.
- In long-sightedness, a person can see distant object clearly but near objects appear blurred. This defect is corrected by using convex lens of suitable focal length.

QUESTIONS

10.1 Encircle the correct option.

(i) A ray parallel to principal axis, after refraction from convex lens:

a. does not bend
b. passes through F
c. passes through C
d. passes through the middle of F and C

(ii) The centre of a lens is called:

a. optical centre
b. centre of curvature
c. principal focus
d. principal axis

(iii) The location of image of an object lying beyond 2F in front of a convex lens is:
a. between F and 2F   b. beyond 2F
c. at F   d. at 2F

(iv) The image of an object placed at C in front of a convex lens is formed:
a. at F   b. between F and C
c. at C   d. beyond C

(v) The image formed by a concave lens is:
a. virtual   b. real   c. inverted   d. larger

(vi) The point through which a ray of light passes without changing its path is the:
a. centre of curvature   b. optical centre
c. middle point of F and C   d. principal focus

(vii) Pupil is made smaller or larger by:
a. ciliary muscles   b. cornea
c. iris   d. retina

(viii) In human eye, image is formed on:
a. cornea   b. pupil   c. iris   d. retina

(ix) To obtain sharp image in a camera:
a. lens is moved back and forth   b. film is moved back and forth
c. both the lens and the film are moved   d. neither lens nor film is moved

10.2 Give short answers.

(i) Describe the paths of three rays which form image after passing through a convex lens.
(ii) Write the names of three instruments in which convex lens is used.
(iii) Define focal length.
(iv) Can image be obtained on the screen by a concave lens? Explain your answer briefly.
(v) How is the focal length affected when the lens of eye becomes thicker?
(vi) Upon what factor does the amount of light entering in a camera depend?
(vii) How long our eye takes to acquire dark adaption at its maximum?
(viii) Define short-sightedness and long-sightedness.

10.3 What is a lens? Explain the difference between convex and concave lenses.

10.4 Explain through ray diagram where the images would be formed by convex lens for different distances of object. Also discuss the nature of images.

10.5 What is a real and virtual image? Why is real image not formed by concave lens? Explain your answer by ray diagram.

10.6 Explain how eyes get used to darkness after sometime.

10.7 How do camera and human eye resemble with each other? What is the difference in their actions?