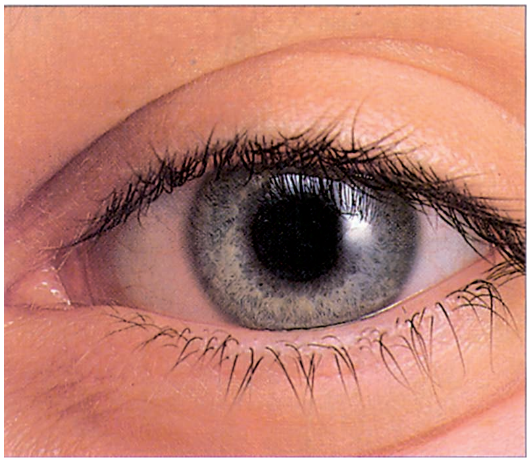
CHAPTER

6



The Human Eye And The Colourful World

In the previous Chapter we have studied the refraction of light by lenses (convex lenses and concave lenses). The optical instruments such as cameras, microscopes, telescopes, film projectors and spectacles, etc., work on the refraction of light through various types of artificial lenses (man-made lenses) made of transparent glass. **The human eye works on the refraction of light through a natural convex lens made of transparent living material and enables us to see things around us**. Our eye is the most important optical instrument gifted to us by the God. Without eye, all other optical instruments would have no value at all. In this chapter we will study the structure and working of the human eye. We will also describe the common defects of eye (or defects of vision) and how they are corrected by using various types of lenses (in the form of spectacles). And finally, we will discuss the refraction of light through a glass prism, atmospheric refraction and scattering of light by atmosphere. Let us start with the human eye.

THE HUMAN EYE

The main parts of the human eye are : Cornea, Iris, Pupil, Ciliary muscles, Eye lens, Retina and Optic nerve (see Figure 1). The eye-ball is approximately spherical in shape having a diameter of about 2.5 cm. We will now describe the construction and working of the eye.

Construction of the Eye

The front part of the eye is called cornea. It is made of a transparent substance and it is bulging outwards. The outer surface of cornea is convex in shape. The light coming from objects enters the eye through cornea. Just behind the cornea is the iris (or coloured diaphragm). Iris is a flat, coloured, ring-shaped membrane behind the cornea of the eye. There is a hole in the middle of the iris which is called pupil of the eye. Thus, *pupil is a hole in the middle of the iris.* The pupil appears black because no light is reflected from it.

The eye-lens is a convex lens made of a transparent, soft and flexible material like a jelly made of proteins. Being flexible, the eye-lens can change its shape (it can become thin or thick) to focus light on to the retina. The eye-lens is held in position by suspensory ligaments. One end of suspensory ligaments is attached to the eye-lens and their other end is attached to ciliary muscles (see Figure 1). Ciliary muscles change the thickness of eye-lens while focusing. In other words, the focal length of eye-lens (and hence its converging power) can be changed by changing its shape by the action of ciliary muscles. In this respect an eye differs from a camera. The focal length of the convex lens used in a camera is fixed and cannot be changed but the focal length of the convex lens present inside the eye can be changed by the action of ciliary muscles.

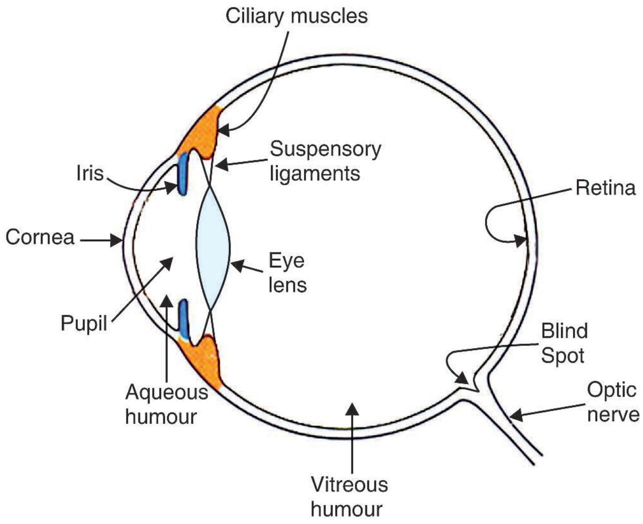


Figure 1. The structure of human eye.

The screen on which the image is formed in the eye is called retina. The retina is behind the eye-lens and at the back part of the eye. The retina of an eye is just like the film in a camera. The retina is a delicate membrane having a large number of light sensitive cells called 'rods' and 'cones' which respond to the 'intensity of light' and 'colour of objects' respectively, by generating electrical signals. At the junction of optic nerve and retina in the eye, there are no light sensitive cells (no rods or cones) due to which no vision is possible at that spot. This is called blind spot. Thus, **blind spot is a small area of the retina insensitive to light where the optic nerve leaves the eye** (see Figure 1). When the image of an object falls on the blind spot, it cannot be seen by the eye. It should be noted that there is an eye-lid in front of the eye which is just like the shutter in a camera. When eye-lid is open, light can enter the eye but when eye-lid is closed, no light enters the eye. The space between cornea and eye-lens is filled with a watery liquid called 'aqueous humour'. And the space between eye-lens and retina is filled with a transparent jelly like substance called 'vitreous humour' which supports the back of the eye.

Working of the Eye

The light rays coming from the object kept in front of us enter through the cornea of the eye, pass through the pupil of the eye and fall on the eye-lens. The eye-lens is a convex lens, so it converges the light rays and produces a real and inverted image of the object on the retina. (Actually, the outer surface of cornea also acts as a convex lens due to which cornea converges most of the light rays entering the eye. Only the final convergence of light rays is done by the eye-lens to focus the image of an object exactly on the retina). The image formed on the retina is conveyed to the brain by the optic nerve and gives rise to the sensation of vision. Actually, the retina has a large number of light-sensitive cells. When the image falls on the retina then these light-sensitive cells get activated and generate electrical signals. The retina sends these electrical signals to the brain through the optic nerve and gives rise to the sensation of vision. Although the image formed on the retina is inverted, our mind interprets the image as that of an erect object. **As far as physics is concerned, the eye consists of a convex lens (called eye-lens) and a screen (called retina). The eye-lens forms a real image of the objects on the retina of the eye and we are able to see the objects.**

The human eye is like a camera. In the eye, a convex lens (called eye-lens) forms a real and inverted image of an object on the light-sensitive screen called retina whereas in a camera, the convex lens (called camera-lens) forms a real and inverted image of an object on the light sensitive photographic film.

The Function of Iris and Pupil

The iris controls the amount of light entering the eyes. The iris automatically adjusts the size of the pupil according to the intensity of light received by the eye. **If the amount of light received by the eye is large (as during the day time), then the iris contracts the pupil (makes the pupil small) and reduces the amount of light entering the eye** (see Figure 2). On the other hand, **if the amount of light received by the**

eye is small (as in a dark room or during night), the iris expands the pupil (makes the pupil large) so that more light may enter the eyes (see Figure 3). Thus, the iris regulates (or controls) the amount of light entering the eye by changing the size of the pupil. The iris makes the pupil 'expand' or 'contract' according to the intensity of light around the eye. If the intensity of the outside light is low, then the pupil expands to allow more light to enter the eye. On the other hand, if outside intensity of light is high, then the pupil contracts so that less light enters the eye.

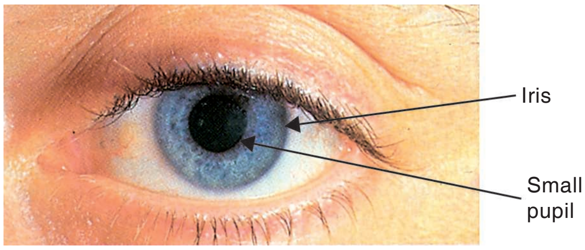


Figure 2. When outside light is bright, pupil becomes small, so that less light goes into the eye.

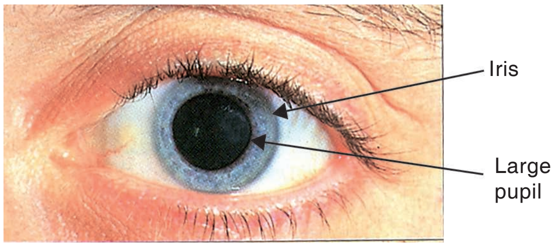


Figure 3. When outside light is dim, pupil becomes large, so that more light enters the eye.

It should be noted that **the adjustment of the size of the pupil takes some time**. For example, when we go from a bright light to a darkened cinema hall, at first we cannot see our surroundings clearly. After a short time our vision improves, and we can see the persons sitting around us. This is due to the fact that in bright sunlight the pupil of our eye is small. So, when we enter the darkened cinema hall, very little light enters our eye and we cannot see properly. After a short time, the pupil of our eye expands and becomes large. More light then enters our eye and we can see clearly. On the other hand, if we go from a dark room into bright sunlight or switch on a bright lamp, then we feel the glare in our eyes. This is due to the fact that in a dark room, the pupil of our eye is large. So, when we go out from a dark room into bright sunlight or switch on a bright lamp, a large amount of light enters our eyes and we feel the glare. Gradually, the pupil of our eye contracts. Less light then enters our eye and we can see clearly. In this way, the iris also protects our eyes from the glare of bright lights.

Rods and Cones

The retina of our eye has a large number of light-sensitive cells. There are two kinds of light-sensitive cells on the retina : rods and cones.

(*i*) Rods are the rod-shaped cells present in the retina of an eye which are sensitive to dim light. Rods are the most important for vision in dim light (as during the night). We can see things to some extent in a dark room or in the darkness of night due to the presence of rod cells in the retina of our eyes. Nocturnal animals (animals which sleep during the day and come out at night) like the owl have a large number of rod cells in their retina which help them see properly during the night when there is not much light (see Figure 4). In fact, our night vision is relatively poor as compared to the night vision of an owl due to the presence of relatively smaller number of rod cells in the retinas of our eyes. Rod cells of the retina, however, do not provide information about the colour of the object.

Figure 4. An owl has very large number of 'rod' cells in the retina of its eyes. These help the owl to see properly even in dim light during the night.

Figure 5. We can see the various colours in this picture due to the presence of 'cone' cells in the retina of our eyes.

(*ii*) Cones are the cone-shaped cells present in the retina of an eye which are sensitive to bright light (or normal light). The cone cells of our retina also respond to colours. In other words, **cone cells cause the sensation of colour of objects in our eyes**. The cone-shaped cells of the retina make us see colours and also make us distinguish between various colours (see Figure 5). Cone cells of the retina function only in bright light. **The cones do not function in dim light**. This is why when it is getting dark at night, it becomes impossible to see colours of cars on the road.

An Important Discussion

A normal eye can see the *distant* objects as well as the *nearby* objects clearly due to its power of accommodation. Before we discuss the power of accommodation of the eye, we should know the difference between the *distant* objects and *nearby* objects from the point of view of light rays received from them. This is described below.

(*i*) The rays of light coming from a distant object (at infinity) are parallel to one another when they reach the eye [see Figure 6(*a*)]. Actually, the rays of light given out by the distant object are diverging in the beginning but they become parallel when they reach the eye after travelling a large distance. The parallel rays of light coming from a distant object need a convex eye-lens of *low converging power* to converge them or focus them to form an image on the retina of the eye. The convex eye-lens of low converging power is the one having a *large* focal length and it is quite *thin.*

(*a*) The light rays coming from a distant object are parallel

(*b*) The light rays coming from a nearby object are diverging

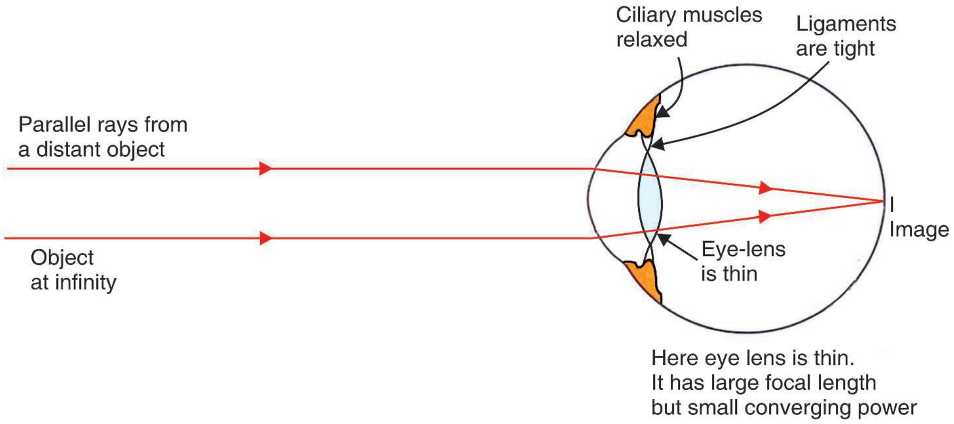
Figure 6.

(*ii*) The rays of light coming from a nearby object are diverging (or spreading out) when they reach the eye [see Figure 6(*b*)]. The diverging rays coming from a nearby object need a convex eye-lens of *high converging power* to converge them or focus them to form an image on the retina of the eye. The convex eye-lens of high converging power is the one having a *short* focal length and it is quite *thick.* Keeping these points in mind, it will now be easy for us to understand the power of accommodation of the eye.

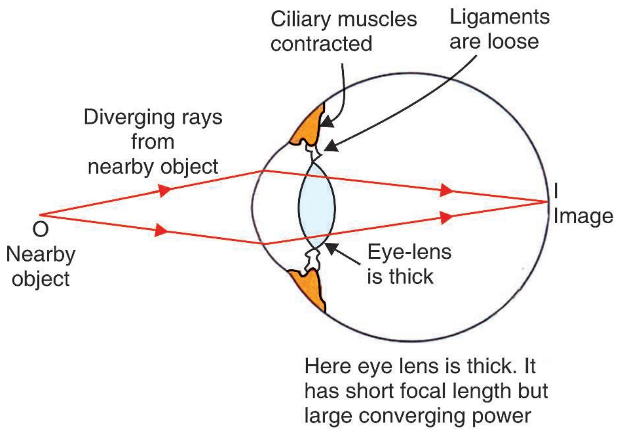
Accommodation

A normal eye can see the *distant* objects as well as the *nearby* objects clearly. We will now discuss how the eye is able to focus the objects lying at various distances. **An eye can focus the images of the distant objects as well as the nearby objects on its retina by changing the focal length (or converging power) of its lens.** The focal length of the eye-lens is changed by the action of ciliary muscles. The ciliary muscles can change the thickness of the soft and flexible eye-lens and hence its focal length which, in turn, changes the converging power of the eye-lens. Let us see how it happens.

When the eye is looking at a distant object (at infinity), then the ciliary muscles of the eye are fully relaxed. The relaxed ciliary muscles of the eye pull the suspensory ligaments attached to the eye-lens tightly. The suspensory ligaments, in turn, pull the eye-lens due to which the eye-lens gets stretched and becomes thin (or less convex) [see Figure 7 (*a*)]. The thin eye-lens has large focal length but its converging power is small. The small converging power of thin eye-lens is sufficient to converge the parallel rays of light coming from a distant object to form an image on the retina of the eye [see Figure 7(*a*)]. When the eye is looking at a distant object, the eye is said to be *unaccommodated* because it is the relaxed state of the eye.



(*a*) An eye focused on a distant object (at infinity).



(*b*) An eye focused on a nearby object

Figure 7. Diagrams to show how an eye can focus the distant objects as well as nearby objects by changing the thickness (or converging power) of its lens.

The thin eye-lens is not powerful enough to converge the diverging light rays coming from the nearby objects onto the retina. So, to look at the nearby objects, the eye-lens has to change its shape and become thick (or more convex) to increase its converging power. This happens as follows :

When the same eye has to look at a nearby object, the ciliary muscles of the eyes contract. The contracted ciliary muscles make the suspensory ligaments loose. When the suspensory ligaments become loose, they stop pulling the eye-lens. The eye-lens bulges under its own elasticity and becomes thick (or more convex) [see Figure 7(*b*)]. The thick eye-lens has small focal length but its converging power is large. Since the converging power of eye-lens increases, the thick eye-lens can converge the diverging light rays coming from the nearby object to form an image on the retina of the eye. This is shown in Figure 7(*b*) in which an object *O* is near to the eye. It has been focused by the thick eye-lens to form an image *I* on the retina. *When the eye-lens becomes more convex to focus the nearby objects, the eye is said to be 'accommodated'*. We can now say that : **The ability of an eye to focus the distant objects as well as the nearby objects on the retina by changing the focal length (or converging power) of its lens is called accommodation.**

The maximum "accommodation" of a normal eye is reached when the object is at a distance of about 25 cm from the eye. After this the ciliary muscles cannot make the eye-lens more thick (or more convex). So, an object placed at a distance of less than 25 cm cannot be seen clearly by a normal eye because all the power of accommodation of the eye has already been exhausted. Thus, **a normal eye has a power of accommodation which enables objects as far as infinity and as close as 25 cm to be focused on the retina.** The power of accommodation of the eye for a person having normal vision (normal eyesight) is about 4 dioptres.

Range of Vision of a Normal Human Eye

We will first understand the meaning of far point and near point of an eye. **The farthest point from the eye at which an object can be seen clearly is known as the "far point" of the eye.** The far point of a normal human eye is at **infinity** (see Figure 8). This means that the far point of a normal human eye is at a very large distance. **The nearest point up to which the eye can see an object clearly without any strain, is called the "near point" of the eye.** The near point of a normal human eye is at a distance of **25 centimetres** from the eye.

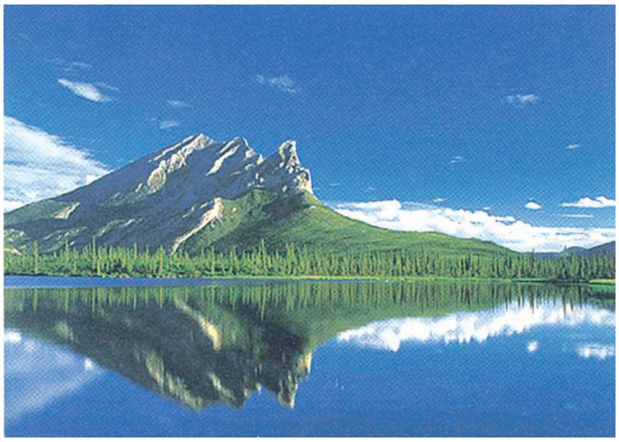


Figure 8. We can see the distant mountains, clouds and sky because the far point of our eye is at infinity.

The near point of an eye is also known by another name as the least distance of distinct vision. **The minimum distance at which an object must be placed so that a normal eye may see it clearly without any strain, is called the least distance of distinct vision.** The least distance of distinct vision for a normal human eye is about **25 centimetres.** For example, to read a book clearly and comfortably without putting a strain on the eyes, it must be held at a distance of 25 centimetres from our eyes. If we try to read a book by holding it very close to our eyes, we will feel a lot of strain on the eyes and the image of printed matter of the book will also look blurred.

From the above discussion we conclude that **the range of vision of a normal human eye is from infinity to about 25 centimetres.** That is, a normal human eye can see the objects clearly which are lying anywhere between infinity to about 25 centimetres. Let us answer one question now.

Sample Problem. What happens to the image distance in the eye when we increase the distance of an object from the eye ? **(NCERT Book Question)**

Answer. In the eye, the image distance (distance between eye-lens and retina) is fixed by the God which cannot be changed. So, when we increase the distance of an object from the eye, there is no change in the image distance inside the eye.

Before we go further and study the common defects of vision, **please answer the following questions :**

Very Short Answer Type Questions

1. What kind of lens is present in the human eye ?
2. Name two parts of the eye which refract light rays (or bend light rays).
3. Name the part of the eye :
(*a*) which controls the amount of light entering the eye.
(*b*) on which the image is formed.
(*c*) which changes the focal length of eye-lens.
4. What is the name of :
(*a*) the curved, transparent front surface of the eye ?
(*b*) the light-sensitive layer in the eye ?
5. Where is the image formed in a human eye ?
6. What is the function of the lens in the human eye ?
7. What job does the pupil of the eye do ?
8. How does the eye adjust to take account of an increase in brightness ?
9. Name that part of the eye which is equivalent to the photographic film in a camera.
10. Name the part of the retina which is insensitive to light.
11. Which part of the eye contains cells which are sensitive to light ?
12. Name two types of cells in the retina of an eye which respond to light.

13. Out of rods and cones in the retina of your eye :
(*a*) which detect colour ?
(*b*) which work in dim light ?

14. State whether the following statement is true or false :
The image formed on our retina is upside-down

15. What is the principal function of the eye-lens ?

16. Where does the greatest degree of refraction of light occur in the eye ?

17. What changes the shape of lens in the eye ?

18. What do the ciliary muscles do when you are focusing on a nearby object ?

19. What is the least distance of distinct vision for a normal human eye ?

20. What is the :
(*a*) far point of a normal human eye ?
(*b*) near point of a normal human eye ?

21. What is the range of vision of a normal human eye ?

22. Name the part of our eyes which helps us to focus near and distant objects in quick succession.

23. Define the term "power of accommodation" of human eye.

24. Give the scientific names of the following parts of the eye :
(*a*) carries signals from an eye to the brain.
(*b*) muscles which change the shape of the eye-lens.
(*c*) a hole in the middle of the iris.
(*d*) a clear window at the front of the eye.
(*e*) changes shape to focus a picture on the retina.

25. Fill in the following blanks with suitable words :
(*a*) Most of the refraction of light rays entering the eye occurs at the outer surface of the............
(*b*) The part of eye sensitive to light is..................
(*c*) The part of eye which alters the size of the pupil is..............
(*d*) When light is dim, the pupil becomes...............
(*e*) The iris controls the amount of..................entering the eye.
(*f*) The ciliary muscles control the shape of the ....
(*g*) To bring light from a distant object to a focus on the retina of the eye, the convex eye-lens needs to be made..........
(*h*) To bring light from a near object to a focus on the retina of the eye, the convex eye-lens needs to be made.......

Short Answer Type Questions

26. Why is a normal eye not able to see clearly the objects placed closer than 25 cm ?

27. What changes take place in the shape of eye-lens :
(*a*) when the eye is focused on a near object ?
(*b*) when the eye is focused on a distant object ?

28. The eyes of a person are focused (*i*) on a nearby object, and (*ii*) on a distant object, turn by turn. In which case :
(*a*) the focal length of eye-lens will be the maximum ?
(*b*) the converging power of eye-lens will be the maximum ?

29. What change is made in the eye to enable it to focus on objects situated at different distances ? Illustrate your answer with the help of diagrams.

30. How is the amount of light entering the eye controlled ?

31. What happens to the eye when you enter a darkened cinema hall from bright sunshine ? Give reason for your answer.

32. Why does it take some time to see objects in a dim room when you enter the room from bright sunshine outside ?

33. A person walking in a dark corridor enters into a brightly lit room :
(*a*) State the effect on the pupil of the eye.
(*b*) How does this affect the amount of light entering the eye ?

34. Ciliary muscles of human eye can contract or relax. How does it help in the normal functioning of the eye ?

35. Describe and explain, how a normal eye can see objects lying at various distances clearly.

36. There are two types of light-sensitive cells in the human eye :
(*a*) Where are they found ?
(*b*) What is each type called ?
(*c*) To what is each type of cell sensitive ?

37. What are rods and cones in the retina of an eye ? Why is our night vision relatively poor compared to the night vision of an owl ?

38. (*a*) How does the convex eye-lens differ from the ordinary convex lens made of glass ?
(*b*) List, in order, the parts of the eye through which light passes to reach the retina.

39. (*a*) What happens to the size of pupil of our eye (*i*) in dim light (*ii*) in bright light ?
(*b*) Name the cells on the retina of an eye which are sensitive to (*i*) bright light (*ii*) dim light (*iii*) sensation of colour.

Long Answer Type Questions

40. (*a*) Draw a simple diagram of the human eye and label clearly the cornea, iris, pupil, ciliary muscles, eye-lens, retina, optic nerve and blind spot.
(*b*) Describe the working of the human eye with the help of the above diagram.
(*c*) How does the eye adjust itself to deal with light of varying intensity ?

41. (*a*) Explain the functions of the following parts of the eye :
(*a*) cornea (*b*) iris (*c*) pupil (*d*) ciliary muscles (*e*) eye-lens
(*f*) retina (*g*) optic nerve
(*b*) If you walk from a dark room into sunlight and back again into dark room, how would your pupils alter in size ? What makes this happen ?
(*c*) Explain why, we cannot see our seats first when we enter a darkened cinema hall from bright light but gradually they become visible.

Multiple Choice Questions (MCQs)

42. The human eye forms the image of an object at its :
(*a*) cornea (*b*) iris (*c*) pupil (*d*) retina

43. The change in focal length of an eye-lens is caused by the action of the :
(*a*) pupil (*b*) retina (*c*) ciliary muscles (*d*) iris

44. The least distance of distinct vision for a young adult with normal vision is about :
(*a*) 25 m (*b*) 2.5 cm (*c*) 25 cm (*d*) 2.5 m

45. Refraction of light in the eye occurs at :
(*a*) the lens only (*b*) the cornea only (*c*) both the cornea and the lens (*d*) the pupil

46. To focus the image of a nearby object on the retina of an eye :
(*a*) the distance between eye-lens and retina is increased
(*b*) the distance between eye-lens and retina is decreased
(*c*) the thickness of eye-lens is decreased
(*d*) the thickness of eye-lens is increased

47. The term "accommodation" as applied to the eye, refers to its ability to :
(*a*) control the light intensity falling on the retina
(*b*) erect the inverted image formed on the retina
(*c*) vary the focal length of the lens
(*d*) vary the distance between the lens and retina

48. Which of the following controls the amount of light entering the eye ?
(*a*) ciliary muscles (*b*) lens (*c*) iris (*d*) cornea

49. The human eye possesses the power of accommodation. This is the power to :
(*a*) alter the diameter of the pupil as the intensity of light changes
(*b*) distinguish between lights of different colours
(*c*) focus on objects at different distances
(*d*) decide which of the two objects is closer.

50. How does the eye change in order to focus on near or distant objects ?
(*a*) The lens moves in or out (*b*) The retina moves in or out
(*c*) The lens becomes thicker or thinner (*d*) The pupil gets larger or smaller

51. Which of the following changes occur when you walk out of bright sunshine into a poorly lit room ?
(*a*) the pupil becomes larger (*b*) the lens becomes thicker
(*c*) the ciliary muscle relaxes (*d*) the pupil becomes smaller

52. The size of the pupil of the eye is adjusted by :
(*a*) cornea (*b*) ciliary muscles (*c*) optic nerve (*d*) iris

Questions Based on High Order Thinking Skills (HOTS)

53. The descriptions of five kinds of images are given below :
(*a*) diminished and virtual (*b*) enlarged and real
(*c*) enlarged and erect (*d*) real and inverted
(*e*) virtual and the same size
Which one of these describes the image formed :
(*i*) on the retina of the eye ? (*ii*) by a magnifying glass ?
(*iii*) by a convex driving mirror on a car ? (*iv*) by a plane mirror ?
(*v*) on the screen of a slide projector ?

54. What shape are your eye-lenses :
(*a*) when you look at your hand ?
(*b*) when you look at a distant tree ?

55. Suggest how your irises help to protect the retinas of your eyes from damage by bright light.

56. (*a*) Which parts of the eye cause rays of light to converge on the retina ?
(*b*) Which part causes the greatest convergence ?
(*c*) Which part brings the image into sharp focus on the retina ? How does it do this ?

57. An object is moved closer to an eye. What changes must take place in the eye in order to keep the image in sharp focus ?

58. Why does the eye-lens not have to do all the work of converging incoming light rays ?

59. Explain why, when it is getting dark at night, it is impossible to make out the colour of cars on the road.

60. Nocturnal animals (animals which sleep during the day and come out at night) tend to have wide pupils and lot of rods in their retinas. Suggest reasons for this.

ANSWERS

2. Cornea and Eye-lens **3.** (*a*) Iris (*b*) Retina (*c*) Ciliary muscles **4.** (*a*) Cornea (*b*) Retina **10.** Blind spot **11.** Retina **14.** True **16.** At cornea **17.** Ciliary muscles **18.** Make the eye-lens thicker (more converging) **22.** Ciliary muscles **24.** (*a*) Optic nerve (*b*) Ciliary muscles (*c*) Pupil (*d*) Cornea (*e*) Eye-lens **25.** (*a*) cornea (*b*) retina (*c*) iris (*d*) large (*e*) light (*f*) eye-lens (*g*) thinner (*h*) thicker **27.** (*a*) Eye-lens becomes thicker (more convex) (*b*) Eye-lens becomes thinner (less convex) **28.** (*a*) When the eye is focused on a distant object (*b*) When the eye is focused on a nearby object **33.** (*a*) Pupil becomes smaller (*b*) Amount of light entering the eye is reduced **39.** (*i*) Becomes large (*ii*) Becomes small (*b*) (*i*) Cones (*ii*) Rods (*iii*) Cones **42.** (*d*) **43.** (*c*) **44.** (*c*) **45.** (*c*) **46.** (*d*) **47.** (*c*) **48.** (*c*) **49.** (*c*) **50.** (*c*) **51.** (*a*) **52.** (*d*) **53.** (*i*) *d* (*ii*) *c* (*iii*) *a* (*iv*) *e* (*v*) *b* **54.** (*a*) Thick (more convex) (*b*) Thin (less convex) **56.** (*a*) Cornea and Eye-lens (*b*) Cornea (*c*) Eye-lens ; By changing its thickness and hence converging power **57.** Ciliary muscles should change the shape of eye-lens to make it thicker and increase its converging power **58.** Because cornea of the eye also converges light rays entering the eye **59.** The colour detecting cells of the retina of eye called 'cones' do not work well in dim light **60.** Wide pupils allow more light to enter the eye during night ; Rod cells in the retina are sensitive to dim light and hence help in seeing properly at night.

DEFECTS OF VISION AND THEIR CORRECTION

The ability to see is called vision. It is also called eyesight. Vision is known as *'drishti'* in Hindi. Sometimes the eye of a person cannot focus the image of an object on the retina properly. In such cases the vision of a person becomes blurred and he cannot see either the distant objects or nearby objects (or both) clearly and comfortably. The person is said to have a *defect* of vision. The defects of vision are also known as defects of eye. There are three common defects of vision (or defects of eye). These are :

1. **Myopia** (Short-sightedness or Near-sightedness)
2. **Hypermetropia** (Long-sightedness or Far-sightedness), and
3. **Presbyopia.**

Figure 9. If the lenses in our eyes don't focus properly, wearing spectacles with appropriate lenses helps us see clearly.

These are the *refractive* defects of vision because they are caused by the incorrect refraction of light rays by the eye-lens. These defects of vision can be corrected by using suitable spherical lenses (convex lenses or concave lenses). These lenses are usually used in the form of eye-glasses or spectacles (see Figure 9). We will now describe all these defects of vision and their correction, one by one. Let us start with myopia.

1. Myopia (Short-sightedness or Near-sightedness)

A short-sighted person means that the short sight of the person (to see nearby objects) is normal but his long-sight (to see distant objects) is defective. **Myopia (or short-sightedness) is that defect of vision due to which a person cannot see the distant objects clearly (though he can see the nearby objects clearly).** For example, a child having the defect called myopia (or short-sightedness) and sitting on the back benches in the class cannot read the writing on blackboard clearly though he can read his book comfortably. **The far point of an eye suffering from myopia is less than infinity.** Such a person can see clearly only up to a distance of few metres (or even less).

Figure 10. This girl is having the eye-defect called myopia (short-sightedness). She cannot see the distant ship clearly.

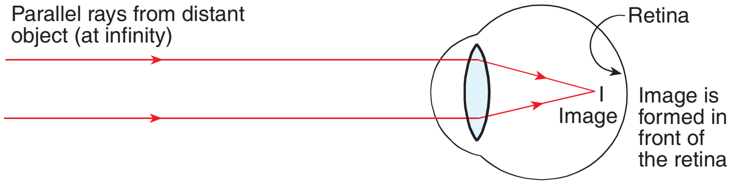
The defect of eye called myopia (or short-sightedness) is caused :

(*i*) due to *high* converging power of eye-lens (because of its *short* focal length), or

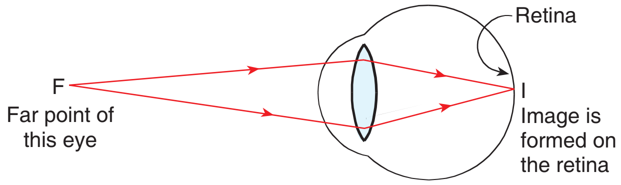
(*ii*) due to eye-ball being too *long*.

In some cases, in an eye suffering from myopia, the ciliary muscles attached to the eye-lens do not relax sufficiently to make the eye-lens thinner to reduce its converging power. So, due to the greater converging power of the eye-lens in myopic eye, the image of a distant object is formed in *front* of the retina and hence the eye cannot see it clearly. In other cases, in the eye suffering from myopia, the eye-ball is too long due to which the retina is at a larger distance from the eye-lens. This condition also results in the formation of the image of a distant object in *front* of the retina (even though the eye-lens may have correct converging power).

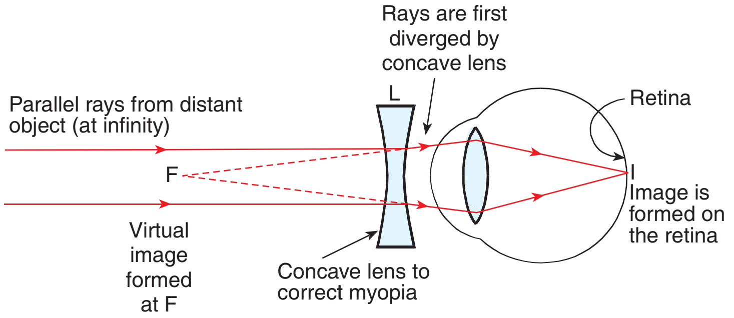
Figure 11(*a*) shows an eye having the defect called myopia (or short-sightedness). In this case, the parallel rays of light coming from the distant object *O* (at infinity) are converged to form an image *I* in front of the retina due to which the eye cannot see the distant object clearly [see Figure 11(*a*)] (The object is at a large distance called infinity from the eye, so it has not been shown in this Figure). The image is formed in front of the retina either due to *high* converging power of eye-lens or due to eye-ball being too *long*.



(*a*) In a myopic eye, image of distant object is formed in front of the retina (and not on the retina)



(*b*) The far point (*F*) of a myopic eye is less than infinity



(*c*) *Correction of myopia*. The concave lens placed in front of the eye forms a virtual image of distant object at far point (*F*) of the myopic eye

Figure 11. Myopia and its correction by using concave lens.

The far point of eye having myopia (or short-sightedness) is at point *F* which is less than infinity [see Figure 11(*b*)]. Please note that the rays of light coming from the person's far point *F* can just be focused by his eye on the retina as shown in Figure 11(*b*). This means that if the distant object can be made to appear as if it were at the far point *F* of this eye, then the eye can see it clearly. This is done by putting a concave lens in front of the eye (as described below).

Myopia (short-sightedness or near-sightedness) is corrected by using spectacles containing concave lenses. When a concave lens (diverging lens) *L* of suitable power is placed in front of the myopic eye as shown in Figure 11(*c*), then the parallel rays of light coming from the distant object (at infinity) are first diverged by the concave lens. Due to this the concave lens forms a virtual image of the distant object at the far point *F* of this myopic eye [see Figure 11(*c*)]. Since the rays of light now appear to be coming from the eye's far point (*F*), they can be easily focused by the eye-lens to form an image on the retina [see Figure 11(*c*)]. **Please note that the concave lens used for correcting myopia should be of such a focal length (or power) that it produces a virtual image of the distant object (lying at infinity) at the far point of the myopic eye.**

It should also be noted that **the whole purpose of using a concave lens here is to reduce the converging power of the eye-lens.** The concave lens used here decreases the converging power of the eye-lens and helps in forming the image of distant object on the retina of the myopic eye.

Calculation of Power of Concave Lens to Correct Myopia. The focal length of concave lens needed to correct myopia (or short-sightedness) in a person is calculated by using the lens formula $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$. In this formula, the object distance u is to be taken as infinity (∞), and the image distance v will be the distance of person's far point (which is different for different persons). Knowing the focal length of the concave lens, we can calculate its power. This will become more clear from the following example.

Sample Problem. The far point of a myopic person is 80 cm in front of the eye. What is the nature and power of the lens required to correct the defect ? **(NCERT Book Question)**

Solution. The defect called myopia is corrected by using a concave lens. So, the person requires concave lens spectacles. We will now calculate the focal length of the concave lens required in this case. The far point of the myopic person is 80 cm. This means that this person can see the distant object (kept at infinity) clearly if the image of this distant object is formed at his far point (which is 80 cm here). So, in this case :

Object distance, $u = \infty$ (Infinity)

Image distance, $v = -80$ cm (Far point, in front of lens)

And, Focal length, $f = ?$ (To be calculated)

Putting these values in the lens formula :

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

we get

$$\frac{1}{-80}-\frac{1}{\infty}=\frac{1}{f}$$

or

$$-\frac{1}{80}-0=\frac{1}{f} \qquad \left(\text{Because } \frac{1}{\infty}=0\right)$$

$$-\frac{1}{80}=\frac{1}{f}$$

$$f = -80 \text{ cm}$$

Thus, the focal length of the required concave lens is 80 cm. We will now calculate its power. Please note that the focal length of, – 80 cm is equal to $\frac{-80}{100}$ m or – 0.8 m. Now,

$$\text{Power, } P = \frac{1}{f\,(\text{in metres})}$$

$$= \frac{1}{-0.8}$$

$$= -\frac{10}{8}$$

$$= -1.25 \text{ D}$$

So, the power of concave lens required is, –1.25 dioptres.

2. Hypermetropia (Long-sightedness or Far-sightedness)

A long-sighted person means that the long-sight of the person (to see distant objects) is normal but his short-sight (to see nearby objects) is defective. **Hypermetropia (or long-sightedness) is that defect of vision due to which a person cannot see the nearby objects clearly (though he can see the distant objects clearly).** For example, a person having the defect hypermetropia cannot read a book clearly and comfortably though he can read the number of a distant bus clearly. **The near-point of a hypermetropic eye is more than 25 centimetres away.** Such a person has to hold the reading material (like a book or newspaper) at an arm's length, much beyond 25 cm from the eye for comfortable reading. Please note that **hypermetropia is just the opposite of myopia.**

The defect of eye called hypermetropia (or long-sightedness) is caused :

(*i*) due to *low* converging power of eye-lens (because of its *large* focal length), or

(*ii*) due to eye-ball being too *short*.

In some cases, the ciliary muscles attached to the eye-lens become weak and cannot make the eye-lens thicker to increase its converging power. So, due to the low converging power of eye-lens in an eye suffering from hypermetropia, the image of nearby object is formed *behind* the retina and hence the eye cannot see it clearly. In other cases, in an eye suffering from hypermetropia, the eye-ball is too short due to which the retina is at a smaller distance from the eye-lens. This condition also results in the formation of the image of a nearby object *behind* the retina (even though the eye-lens may have correct converging power).

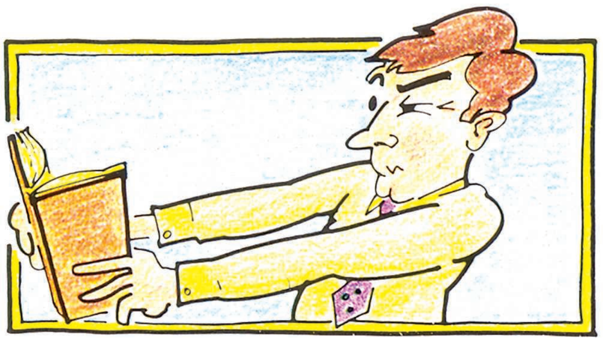
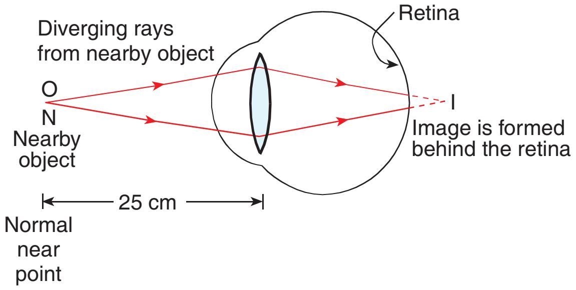
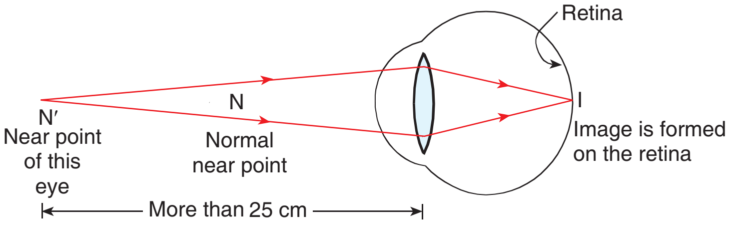


Figure 12. This man is having the eye-defect called hypermetropia (long-sightedness). He cannot read a book clearly by holding it at the normal distance of 25 cm. He has to hold the book at a much larger distance (at arm's length) to be able to read it.

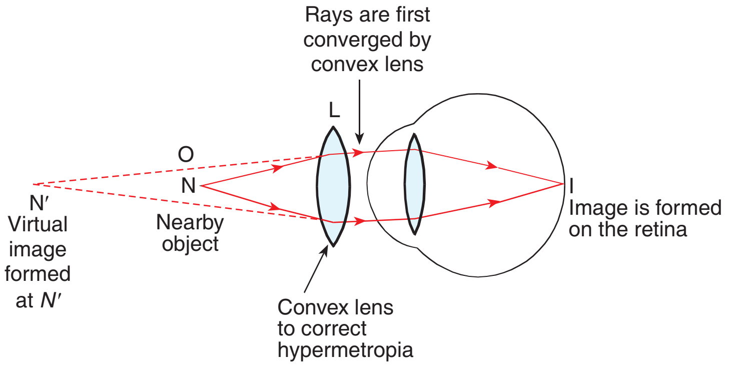
Figure 13(*a*) shows an eye having the defect called hypermetropia (or long-sightedness). In this case the



(*a*) In a hypermetropic eye, the image of nearby object lying at normal near point *N* (at 25 cm) is formed behind the retina.



(*b*) The near point *N′* of hypermetropic eye is farther away from the normal near point *N*



(*c*) *Correction of hypermetropia*. The convex lens forms a virtual image of the object (lying at normal near point *N*) at the near point *N′* of this eye.

Figure 13. Hypermetropia and its correction by using convex lens.

diverging rays of light coming from a nearby object *O* placed at the normal near point *N* (25 cm from the eye) are converged to form an image *I* behind the retina due to which the eye cannot see the nearby object clearly [see Figure 13(*a*)]. The image is formed behind the retina either due to *low* converging power of eye-lens or because of eye-ball being too *short*.

The near-point of an eye having hypermetropia (or long-sightedness) is at point *N*′ which is more than 25 centrimetres away [see Figure 13(*b*)]. The diverging rays of light coming from a hypermetropic person's near point can just be focused by his eye on the retina as shown in Figure 13(*b*). This means that if the object placed at the normal near point *N* (25 cm) can be made to appear as if it were placed at this eye's near point *N*′, then the eye will be able to see it clearly. This can be done by putting a convex lens in front of the eye.

Hypermetropia (long-sightedness or far-sightedness) is corrected by using spectacles containing convex lenses. When a convex lens (converging lens) *L* of suitable power is placed in front of the hypermetropic eye as shown in Figure 13(*c*), then the diverging rays of light coming from the nearby object (at 25 cm) are first converged by this convex lens. Due to this, the convex lens forms a virtual image of the nearby object (which is lying at the normal near point *N*) at the near point *N*′ of the hypermetropic eye [see Figure 13(*c*)]. Since the rays of light now appear to be coming from this eye's near point *N*′, they can be easily focused by the eye-lens to form an image on the retina [see Figure 13(*c*)]. **Please note that the convex lens used for correcting hypermetropia (or long-sightedness) should be of such a focal length (or power) that it forms a virtual image of the object (placed at the normal near point *N* of 25 cm), at the near point *N*′ of the hypermetropic eye.**

It should also be noted that **the whole purpose of using a convex lens here is to increase the converging power of the eye-lens.** The convex lens used in spectacles increases the converging power of eye-lens and helps in forming the image of a nearby object on the retina of the eye.

Calculation of the Power of Convex Lens to Correct Hypermetropia. The focal length of convex lens needed to correct hypermetropia (or long-sightedness) can be calculated by using the lens formula $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$. In this formula, the object distance *u* is to be taken as the normal near point of the eye (which is 25 cm) and the image distance *v* will be the distance of the near point of the hypermetropic eye. Knowing the focal length of the convex lens, its power can be calculated. This will become more clear from the following example.

Sample Problem. The near point of a hypermetropic eye is 1 m. What is the nature and power of the lens required to correct this defect ? (Assume that the near point of the normal eye is 25 cm).

(NCERT Book Question)

Solution. The eye defect called hypermetropia is corrected by using a convex lens. So, the person requires convex lens spectacles. We will first calculate the focal length of the convex lens required in this case. This hypermetropic eye can see the nearby object kept at 25 cm (at near point of normal eye) clearly if the image of this object is formed at its own near point which is 1 metre here. So, in this case :

Object distance, u = –25 cm (Normal near point)
Image distance, v = –1 m (Near point of this defective eye)
= –100 cm
And, Focal length, f = ? (To be calculated)

Putting these values in the lens formula,

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

We get :

$$\frac{1}{-100} - \frac{1}{-25} = \frac{1}{f}$$

or

$$-\frac{1}{100} + \frac{1}{25} = \frac{1}{f}$$

$$\frac{-1+4}{100} = \frac{1}{f}$$

$$\frac{3}{100} = \frac{1}{f}$$

$$f = \frac{100}{3}$$

$$f = 33.3 \text{ cm}$$

Thus, the focal length of the convex lens required is +33.3 cm. We will now calculate the power. Please note that 33.3 cm is equal to $\frac{33.3}{100}$ m or 0.33 m. Now,

$$\text{Power,} \quad P = \frac{1}{f \text{ (in metres)}}$$

$$= \frac{1}{+0.33}$$

$$= +\frac{100}{33}$$

$$= +3.0 \text{ D}$$

So, the power of convex lens required is +3.0 dioptres.

Myopia and hypermetropia are the two most common defects of vision (or defects of eye). We will now study another defect of vision which occurs in old age. It is called presbyopia.

3. Presbyopia

In old age, due to ciliary muscles becoming weak and the eye-lens becoming inflexible (or rigid), the eye loses its power of accommodation. Because of this an old person cannot see the nearby objects clearly. This leads to the defect called presbyopia. **Presbyopia is that defect of vision due to which an old person cannot see the nearby objects clearly due to loss of power of accommodation of the eye**. For example, an old person having presbyopia cannot read a book or newspaper comfortably and clearly without spectacles. Presbyopia occurs in old age due to the gradual weakening of the ciliary muscles and diminishing flexibility of the eye-lens. **The near-point of the old person having presbyopia gradually recedes and becomes much more than 25 centimetres away.** Actually, presbyopia is a special kind of hypermetropia. We can call it old age hypermetropia. Presbyopia is the hypermetropia (or long-sightedness) caused by the loss of power of accommodation of the eye due to old age. **Presbyopia defect is corrected in the same way as hypermetropia by using spectacles having convex lenses** (see Figure 13).

It is also possible that the same person has both the defects of vision – myopia as well as hypermetropia. A person suffering from myopia as well as hypermetropia uses spectacles having bifocal lenses in which upper part consists of a concave lens (to correct myopia) used for distant vision and the lower part consists of a convex lens (to correct hypermetropia) used for reading purposes (see Figure 14).

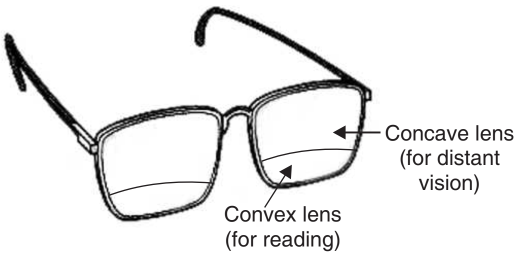


Figure 14. Spectacles having bifocal lenses.

These days it is possible to correct the refractive defects of the eye (such as myopia and hypermetropia) by using contact lenses or by undergoing surgical procedures. Then there is no need to wear spectacles.

Cataract

A yet another defect of the eye which usually comes in old age is the cataract. **The medical condition in which the lens of the eye of a person becomes progressively cloudy resulting in blurred vision is**

called cataract. Cataract develops when the eye-lens of a person becomes cloudy (or even opaque) due to the formation of a membrane over it. Cataract decreases the vision of the eye gradually. It can even lead to total loss of vision of the eye. The vision of the person can be restored after getting **surgery** done on the eye having cataract. The opaque lens is removed from the eye of the person by surgical operation and a new artificial lens is inserted in its place. Please note that the eye-defect called 'cataract' cannot be corrected by any type of spectacle lenses. We are now in a position to **answer the following questions :**

Very Short Answer Type Questions

1. Name one of the common defects of vision and the type of lens used to remove it.

2. Name the defect of vision in a person :
(*a*) whose near point is more than 25 cm away.
(*b*) whose far point is less than infinity

3. Which defect of vision can be rectified :
(*a*) by using a concave lens ?
(*b*) by using a convex lens ?

4. What type of lens is used to correct (*a*) hypermetropia (*b*) myopia ?

5. What is the other name for (*a*) myopia (*b*) hypermetropia ?

6. What is the scientific name of (*a*) short-sightedness, and (*b*) long-sightedness ?

7. What kind of lens is used to correct (*a*) short-sightedness (*b*) long-sightedness ?

8. State whether the following statement is true or false :
Short-sightedness can be cured by using a concave lens.

9. Name the defect of vision in which the eye-lens loses its power of accommodation due to old age.

10. Name the defect of vision which makes the eye-lens cloudy resulting in blurred vision.

11. What is the other name of old age hypermetropia ?

12. Name any two defects of vision which can be corrected by using spectacles.

13. Name one defect of vision (or eye) which cannot be corrected by any type of spectacle lenses.

14. Name the body part with which the terms myopia and hypermetropia are connected.

15. What is the far point of a person suffering from myopia (or short-sightedness) ?

16. Where is the near point of a person suffering from hypermetropia (or long-sightedness) ?

17. Your friend can read a book perfectly well but cannot read the writing on blackboard unless she sits on the front row in class.
(*a*) Is she short-sighted or long-sighted ?
(*b*) What type of lenses–converging or diverging–would an optician prescribe for her ?

18. A man can read the number of a distant bus clearly but he finds difficulty in reading a book.
(*a*) From which defect of the eye is he suffering ?
(*b*) What type of spectacle lens should he use to correct the defect ?

19. A student sitting in the last row of the class-room is not able to read clearly the writing on the blackboard.
(*a*) Name the type of defect he is suffering from.
(*b*) How can this defect by corrected ?

20. Complete the following sentences :
(*a*) A short-sighted person cannot see .... objects clearly. Short-sightedness can be corrected by using ....lenses.
(*b*) A long-sighted person cannot see .... objects clearly. Long-sightedness can be corrected by using .... lenses.

Short Answer Type Questions

21. What are the two most common defects of vision (or defects of eye) ? How are they corrected ?

22. Differentiate between myopia and hypermetropia. What type of spectacles should be worn by a person having the defects of myopia as well as hypermetropia ? How does it help ?

23. Name the defect of vision which can be corrected by a converging lens. Show clearly by a ray diagram how the lens corrects the defect.

24. Name the defect of vision which can be corrected by a diverging lens. Show clearly by a ray diagram how the lens corrects the defect.

25. Explain with the help of labelled ray diagram, the defect of vision called myopia and how it is corrected by a lens.

26. Explain with the help of labelled ray-diagram, the defect of vision called hypermetropia, and how it is corrected by a lens.

27. A person suffering from the eye-defect myopia (short-sightedness) can see clearly only up to a distance of 2 metres. What is the nature and power of lens required to rectify this defect ?

28. The near-point of a person suffering from hypermetropia is at 50 cm from his eye. What is the nature and power of the lens needed to correct this defect ? (Assume that the near-point of the normal eye is 25 cm).

29. A person needs a lens of power, – 5.5 dioptres for correcting his distant vision. For correcting his near vision, he needs a lens of power, +1.5 dioptres. What is the focal length of the lens required for correcting (*i*) distant vision, and (*ii*) near vision ?

30. What is presbyopia ? Write two causes of this defect. Name the type of lens which can be used to correct presbyopia.

31. When is a person said to have developed cataract in his eye ? How is the vision of a person having cataract restored ?

32. Fill in the following blanks with suitable words :

A person is short-sighted if his eyeball is too................Spectacles with a ....lens are needed. A person is long-sighted if his eyeball is too................Spectacles with a ....lens are needed. These focus light rays exactly on to the.............

Long Answer Type Questions

33. (*a*) What is short-sightedness ? State the two causes of short-sightedness (or myopia). With the help of ray diagrams, show :

(*i*) the eye-defect short-sightedness.

(*ii*) correction of short-sightedness by using a lens.

(*b*) A person having short-sight cannot see objects clearly beyond a distance of 1.5 m. What would be the nature and power of the corrective lens to restore proper vision ?

34. (*a*) What is long-sightedness ? State the two causes of long-sightedness (or hypermetropia). With the help of ray diagrams, show :

(*i*) the eye-defect long-sightedness.

(*ii*) correction of long-sightedness by using a lens.

(*b*) An eye has a near point distance of 0.75 m. What sort of lens in spectacles would be needed to reduce the near point distance to 0.25 m ? Also calculate the power of lens required. Is this eye long-sighted or short-sighted ?

(*c*) An eye has a far point of 2 m. What type of lens in spectacles would be needed to increase the far point to infinity ? Also calculate the power of lens required. Is this eye long-sighted or short-sighted ?

Multiple Choice Questions (MCQs)

35. The human eye can focus objects at different distances by adjusting the focal length of the eye-lens. This is due to :

(*a*) presbyopia (*b*) accommodation (*c*) near-sightedness (*d*) far-sightedness

36. The defect of vision which cannot be corrected by using spectacles is :

(*a*) myopia (*b*) presbyopia (*c*) cataract (*d*) hypermetropia

37. A person cannot see the distant objects clearly (though he can see the nearby objects clearly). He is suffering from the defect of vision called :

(*a*) cataract (*b*) hypermetropia (*c*) myopia (*d*) presbyopia

38. Though a woman can see the distant objects clearly, she cannot see the nearby objects clearly. She is suffering from the defect of vision called :

(*a*) long-sight (*b*) short-sight (*c*) hind-sight (*d*) mid-sight

39. A young man has to hold a book at arm's length to be able to read it clearly. The defect of vision is :

(*a*) astigmatism (*b*) myopia (*c*) presbyopia (*d*) hypermetropia

40. After testing the eyes of a child, the optician has prescribed the following lenses for his spectacles :
Left eye : + 2.00 D Right eye : + 2.25 D
The child is suffering from the defect of vision called :
(*a*) short-sightedness (*b*) long-sightedness
(*c*) cataract (*d*) presbyopia

41. A person got his eyes tested. The optician's prescription for the spectacles reads :
Left eye : – 3.00 D Right eye : – 3.50 D
The person is having a defect of vision called :
(*a*) presbyopia (*b*) myopia (*c*) astigmatism (*d*) hypermetropia

42. A student sitting on the last bench in the class cannot read the writing on the blackboard clearly but he can read the book lying on his desk clearly. Which of the following statement is correct about the student ?
(*a*) The near point of his eyes has receded away.
(*b*) The near point of his eyes has come closer to him.
(*c*) The far point of his eyes has receded away.
(*d*) The far point of his eyes has come closer to him.

43. A man driving a car can read a distant road sign clearly but finds difficulty in reading the odometer on the dashboard of the car. Which of the following statement is correct about this man ?
(*a*) The near point of his eyes has receded away.
(*b*) The near point of his eyes has come closer to him.
(*c*) The far point of his eyes has receded away.
(*d*) The far point of his eyes has come closer to him.

44. The defect of vision in which the eye-lens of a person gets progressively cloudy resulting in blurred vision is called :
(*a*) myopia (*b*) presbyopia (*c*) colourblindness (*d*) cataract

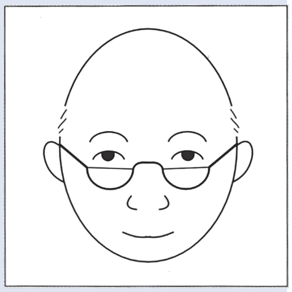
45. A person cannot see distant objects clearly. His vision can be corrected by using the spectacles containing :
(*a*) concave lenses (*b*) plane lenses (*c*) contact lenses (*d*) convex lenses

46. A person finds difficulty in seeing nearby objects clearly. His vision can be corrected by using spectacles containing :
(*a*) converging lenses (*b*) diverging lenses (*c*) prismatic lenses (*d*) chromatic lenses

Questions Based on High Order Thinking Skills (HOTS)

47. In a certain murder investigation, it was important to discover whether the victim was long-sighted or short-sighted. How could a detective decide by examining his spectacles ?

48. The picture given here shows a person wearing 'half-moon' spectacles. What sort of eye-defect do you think he has ? Why are these particular spectacles useful to him ?



49. A short-sighted person has a near point of 15 cm and a far point of 40 cm.
(*a*) Can he see clearly an object at a distance of :
(*i*) 5 cm ? (*ii*) 25 cm ? (*iii*) 50 cm ?
(*b*) To see clearly an object at infinity, what kind of spectacle lenses does he need ?

50. The near point of a long-sighted person is 50 cm from the eye.
(*a*) Can she see clearly an object at :
(*i*) a distance of 20 cm ? (*ii*) at infinity ?
(*b*) To read a book held at a distance of 25 cm, will she need converging or diverging spectacle lenses ?

51. A person can read a book clearly only if he holds it at an arm's length from him. Name the defect of vision :
(*a*) if the person is an old man (*b*) if the person is a young man

ANSWERS

2. (*a*) Hypermetropia (*b*) Myopia **8.** True **9.** Presbyopia **11.** Presbyopia **13.** Cataract **14.** Eye **17.** (*a*) Short-sighted (*b*) Diverging lenses **18.** (*a*) Hypermetropia (Long-sightedness) (*b*) Convex lens **19.** (*a*) Myopia (Short-sightedness) (*b*) Concave lens **20.** (*a*) distant ; concave

(*b*) nearby ; convex **22.** Spectacles having bifocal lenses in which upper part consists of concave lens and lower part consists of convex lens **27.** Concave lens ; – 0.5 D **28.** Convex lens; + 2 D **29.** (*i*) –18.18 cm (*ii*) + 66.6 cm **32.** long ; concave; short ; convex ; retina **33.** (*b*) Concave lenses ; – 0.67 D
34. (*b*) Convex lenses ; + 2.67 D ; Long-sighted (*c*) Concave lenses ; – 0.5 D ; Short-sighted **35.** (*b*) **36.** (*c*) **37.** (*c*) **38.** (*a*) **39.** (*d*) **40.** (*b*) **41.** (*b*) **42.** (*d*) **43.** (*a*) **44.** (*d*) **45.** (*a*) **46.** (*a*) **47.** If spectacle lenses are convex, the person was long-sighted ; If spectacle lenses are concave, then the person was short-sighted
48. Long-sightedness (Hypermetropia) ; The convex lenses of spectacles form the image of nearby object at the near point of his eye. **49.** (*a*) (*i*) No (*ii*) Yes (*iii*) No (*b*) Concave lenses **50.** (*a*) (*i*) No (*ii*) Yes (*b*) Converging lenses **51.** (*a*) Presbyopia (*b*) Hypermetropia

WHY DO WE HAVE TWO EYES FOR VISION AND NOT JUST ONE

There are many advantages of having two eyes instead of one. Some of these are given below.

1. Having Two Eyes Gives a Wider Field of View. A human being has a horizontal field of view of about 150° with one eye open but with two eyes open, the field of view becomes 180°. Thus, having two eyes gives a wider field of view. This means that with two eyes open, we can see a much larger area in front of us (than can be seen with only one eye).

Figure 15. The human beings have two eyes at the front of their head.

The human beings have two eyes at the front of their head, so their field of view is limited to about 180° (see Figure 15). Some animals, however, have their two eyes located on the opposite sides of their head. Those animals who have two eyes on the opposite sides of their head have the widest possible field of view. They can see much larger area around them than the human being can see. The animals of prey (like rabbit, deer, chicken, fish, etc.) have their two eyes on the opposite sides of their heads so that they can see their enemies (predators) in a very large area around them and try to escape from them (see Figure 16). A domestic animal having its two eyes on the opposite sides of the head is horse.

Figure 16. Rabbits are animals of prey. They have two eyes on the sides of their head.

2. Having Two Eyes Enables Us to Judge Distances More Accurately. Our two eyes are a few centimetres apart from each other (see Figure 15). Due to this, the two eyes see the same object from two slightly different angles and send two slightly different images of the same object to the brain. The brain combines these two slightly different images to build a three-dimensional picture of the object which enables us to judge the distance of the object more accurately.

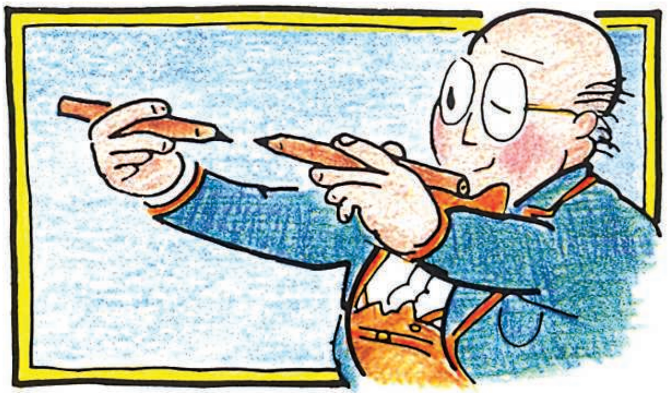


Figure 17. It is difficult to touch the tips of two pencils with one eye open (but much easier when both the eyes are open).

Figure 18. Tiger is a predator. It has two eyes at the front of its head.

This will become clear from the following example. Let us take two sharpened pencils, one in each hand. Stretch the arms forward and try touching the tips of pencils first with one eye open and then with both eyes open. We will find that it is difficult to touch the tips of two pencils with one eye open but it is much more easy when both the eyes are open (see Figure 17). This is because with both the eyes open, we can judge the distances of the pencil tips more accurately. Human beings (and all other animals having their eyes at the front of their head) are said to have *stereoscopic vision* (or *stereopsis)* which gives the perception of depth. All the predators (like tiger, lion, etc.) have their eyes at the front of head so that they can judge the distance of their prey accurately and catch them easily (see Figure 18).

The Gift of Vision

There are millions of blind people in our country who cannot see at all. The eyesight of most of these blind people can be restored if they are given the eyes donated by other persons after their death. In this way, our eyes can live even after our death. In fact, our two eyes can give eyesight to two blind persons (each getting one eye), and make them see this beautiful world.

Some of the important points to be noted about the donation of eyes are the following :

1. Any person of any age or sex (male or female) can donate eyes. People who wear spectacles or have undergone cataract operations can also donate eyes. Even the persons having ailments such as diabetes (sugar), hypertension (blood pressure) and asthma can donate eyes. But they should not have any communicable diseases. The persons who were infected with or died because of diseases such as AIDS, hepatitis B or C, rabies, leukaemia, tetanus, cholera, meningitis, or encephalitis, however, cannot donate eyes.

2. After the death of the person (who had registered for eye donation), the eye bank should be informed immediately. This is because eyes must be removed within 4 to 6 hours of a person's death.

3. The doctors of the eye bank team will remove the eyes at the home of the dead person or at the hospital. It takes only 10 to 15 minutes to remove the eyes. There is no disfigurement of the face in this process.

4. The eye bank distributes the donated eyes to various eye hospitals where these are transplanted in the blind people through surgical operation.

5. Those donated eyes which are not suitable for transplantation, are used for doing research and for teaching purposes in medical colleges.

We can, even today, make a pledge in writing, with the eye bank of our area that (God forbid) whenever we die our eyes should be removed and given to the blind persons to light up their dark world ! We should be grateful to God that he has given us the gift of vision to see this wonderful world. Let us pass on this priceless gift of vision to our less fortunate blind brothers and sisters by registering our name for eye donation. We are now in a position to **answer the following questions :**

Very Short Answer Type Questions

1. How much is our field of view :
(*a*) with one eye open ?
(*b*) with both eyes open ?

2. Which of the following have a wider field of view ?
(*a*) Animals having two eyes on the opposite sides of their head.
(*b*) Animals having two eyes at the front of their head.

3. Out of animals of prey and predators, which have their eyes :
(*i*) at the front of their head ?
(*ii*) on the opposite sides of their head ?

4. State whether the following statement is true or false :
Rabbit has eyes which look sideways.

5. Fill in the following blanks with suitable words :
(*a*) Having two eyes gives a ....field of view.
(*b*) Having two eyes enables us to judge................more accurately.

Short Answer type Questions

6. What are the advantages of having two eyes instead of just one ?
7. Explain clearly why, a person who has lost the sight of one eye is at a disadvantage compared with the normal person who has two good eyes.
8. Name two animals having eyes :
(*a*) on the sides of the head.
(*b*) at the front of the head.
9. Among animals, the predators (like lions) have their eyes facing forward at the front of their heads, whereas the animals of prey (like rabbit) usually have eyes at the sides of their head. Why is this so ?
10. Five persons A, B, C, D and E have diabetes, leukaemia, asthma, meningitis and hepatitis, respectively.
(*a*) Which of these persons can donate eyes ?
(*b*) Which of these persons cannot donate eyes ?

Multiple Choice Questions (MCQs)

11. The animal which does not have eyes that look sideways is :
(*a*) Horse (*b*) Chicken (*c*) Lion (*d*) Fish
12. With both eyes open, a person's field of view is about :
(*a*) 90° (*b*) 150° (*c*) 180° (*d*) 360°
13. Having two eyes gives a person :
(*a*) deeper field of view (*b*) coloured field of view
(*c*) rear field of view (*d*) wider field of view
14. The animals of prey have :
(*a*) two eyes at the front (*b*) two eyes at the back
(*c*) two eyes on the sides (*d*) one eye at the front and one on the side
15. The animals called predators have :
(*a*) both the eyes on the sides (*b*) one eye on the side and one at the front
(*c*) one eye on the front and one at the back (*d*) both the eyes at the front

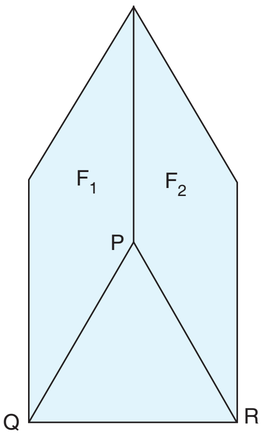
ANSWERS

1. (*a*) About 150° (*b*) About 180° **2.** (*a*) **3.** (*i*) Predators (*ii*) Animals of prey **4.** True **5.** (*a*) wider (*b*) distances **8.** (*a*) Rabbit ; Deer (*b*) Tiger ; Lion **10.** (*a*) A and C (*b*) B, D and E **11.** (*c*) **12.** (*c*) **13.** (*d*) **14.** (*c*) **15.** (*d*)

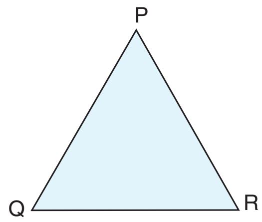
GLASS PRISM

We have already studied the refraction of light through a rectangular glass slab. In a rectangular glass slab, the emergent light rays are parallel to the incident light rays because the opposite faces of a rectangular glass slab (where refraction takes place) are parallel to one another. We will now discuss the refraction of light through a glass object whose opposite faces (where refraction takes place) are not parallel to one another. A triangular glass prism is such an object. A triangular glass prism is shown in Figure 19(*a*). The triangular glass prism is a transparent object made of glass having two triangular ends and three rectangular sides (or rectangular faces). Please note that the opposite faces of a triangular glass prism are not parallel to one another. For example, in Figure 19(*a*), the opposite faces of the glass prism F_1 and F_2 (where the refraction of light takes place) are not parallel to one another. They are inclined at an angle to one another. The angle between its opposite faces is called the angle of the prism. In Figure 19(*a*), angle QPR is the angle of this prism. Though an actual triangular glass prism looks like that shown in Figure 19(*a*), but for the sake of convenience in drawing ray-diagrams, a triangular glass prism is represented by drawing a triangle as shown in Figure 19(*b*). Please note that a 'triangular glass prism' is usually called 'glass prism' and sometimes even just 'prism'.

As we will study after a while the refraction of light on passing through a glass prism is different from that in a glass slab. This is because **in refraction through a glass slab, the emergent ray is parallel to the incident ray** but **in refraction through a glass prism, the emergent ray is not parallel to the incident ray.** *The emergent ray of light in a glass prism is not parallel to the incident ray of light because the opposite faces of the glass prism (where refraction takes place) are not parallel to one another.* Actually, in refraction through a glass prism, the emergent ray is *deviated* from its original direction by a certain angle. And we say that light rays get deviated on passing through a glass prism. We will now study the refraction of light through a glass prism in somewhat detail.



(*a*) A triangular glass prism.



(*b*) This is how a triangular glass prism is represented in ray-diagrams.

Figure 19.

REFRACTION OF LIGHT THROUGH A GLASS PRISM

When a ray of light passes through a glass prism, refraction (or bending) of light occurs both, when it enters the prism as well as when it leaves the prism. Since the refracting surfaces (*PQ* and *PR*) of the prism are *not* parallel, therefore, the emergent ray and incident ray are *not* parallel to one another (see Figure 20). In this case the ray of light is deviated on passing through the prism. Let us see how it happens.

In Figure 20, a glass prism *PQR* has been kept on its base *QR*. A ray of light *AB* is incident on the face *PQ* of the prism. The *incident* ray *AB* is going from air (rarer medium) into glass (denser medium), so it bends towards the normal *BN′* and goes along the direction *BC* inside the glass prism. Thus, *BC* is the *refracted* ray of light which bends towards the base *QR* of the prism.

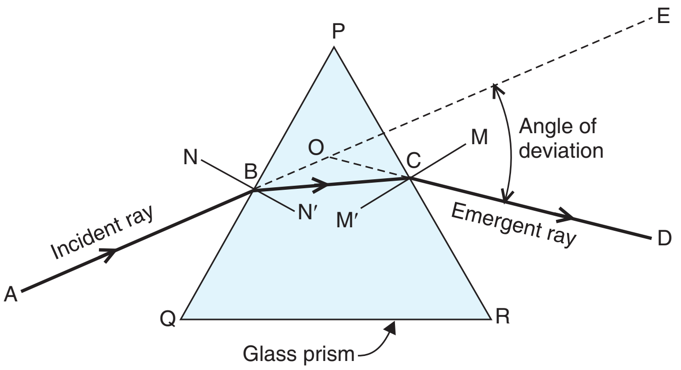


Figure 20. Refraction of light through a glass prism. Here the emergent ray *CD* is not parallel to the incident ray *AB*. It gets deviated.

When the ray of light *BC* travelling in the glass prism comes out into air at point *C*, refraction takes place again (see Figure 20). Since the ray *BC* is going from glass (denser medium) into air (rarer medium), so it bends away from the normal *MC* and goes along the direction *CD* in the form of *emergent* ray. Here also, the emergent ray of light *CD* bends towards the base *QR* of the prism. From this discussion we conclude that **when a ray of light passes through a prism, it bends towards the *base* of prism.** In other words, **when a ray of light passes through a prism, it bends towards the *thicker* part of the prism.**

If we look carefully at Figure 20, we will see that the emergent ray *CD* is not parallel to the incident ray *AB*. There has been a deviation (or change) in the path of light in passing through the prism. Let us produce the incident ray *AB* upwards towards the point *E* by a dotted line. Now, *AE* represents the original direction of the ray of light. Similarly, let us produce the emergent ray *CD* backwards by a dotted line so that it cuts the line *AE* at point *O* (see Figure 20). We can now say that the original direction of the ray of light is *AE* but after passing through the prism, it deviates from its path and goes in the direction *OD*. **The angle between incident ray and emergent ray is called angle of deviation.** In Figure 20, the angle *EOD* is the angle of deviation. Please note that *it is the peculiar shape (triangular shape) of the glass prism which makes the emergent ray bend with respect to the incident ray.*

DISPERSION OF LIGHT

In the year 1665, Newton discovered by his experiments with glass prisms that white light (like sunlight) consists of a mixture of seven colours. By saying that white light is a mixture of seven colours we mean that white light is a mixture of lights of seven colours. Newton found that if a beam of white light is passed through a triangular glass prism, the white light splits to form a band of seven colours on a white screen (see Figure 21). **The band of seven colours formed on a white screen, when a beam of white light is passed through a glass prism, is called spectrum of white light.** The seven colours of the spectrum are : Red, Orange, Yellow, Green, Blue, Indigo, and Violet. The seven colours of the spectrum can be denoted by the word *VIBGYOR* where *V* stands for Violet, *I* for Indigo, *B* for Blue, *G* for Green, *Y* for Yellow, *O* for Orange and *R* for Red.

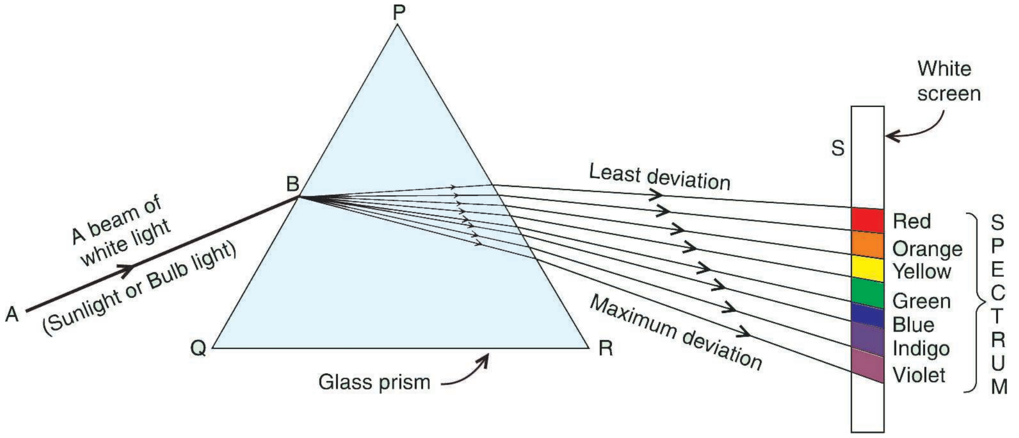


Figure 21. A glass prism splits the white light into lights of seven colours.

In Figure 21, a beam of white light *AB* is passed into a glass prism *PQR*. This beam of white light splits on entering the glass prism and forms a broad patch of seven colours on a white screen *S* placed on the other side of the prism. Please note that when the glass prism is kept on its base as shown in Figure 21, then the red colour is at the top and violet colour is at the bottom of the spectrum. **The splitting up of white light into seven colours on passing through a transparent medium like a glass prism is called dispersion of light.** The formation of spectrum of seven colours shows that white light is made up of lights of seven different colours mixed together. That is, **white light is a mixture of seven colours** (or seven coloured lights). The effect of glass prism is only to *separate* the seven colours of white light. A similar band of seven colours is produced when a beam of white light from an electric bulb falls on a triangular glass prism. We can explain the dispersion of light by a glass prism as follows.

Figure 22. It is usually not possible to distinguish all the seven colours of the spectrum easily due to the overlapping of various colours. So, the spectrum is not really seven separate colours.

White light is a mixture of lights of seven colours : red, orange, yellow, green, blue, indigo and violet. **The dispersion of white light occurs because colours of white light travel at different speeds through the glass prism.** The amount of refraction (or bending) depends on the speed of coloured light in glass. Now, since the different colours travel at different speeds, they are refracted (or bent) by different angles on passing through the glass prism (some colours are bent less whereas others are bent more). So, **when white light consisting of seven colours falls on a glass prism, each colour in it is refracted (or deviated) by a different angle, with the result that seven colours are spread out to form a spectrum.** The red colour has the maximum speed in glass prism, so **the red colour is deviated the least**. Due to this the red colour forms the upper part of the spectrum. On the other hand, the violet colour has the minimum speed in glass prism, so **the violet colour is deviated the maximum**. Due to this violet colour appears at the bottom of the spectrum. Please note that the seven colours of spectrum differ only in their frequencies. These colours in the order of increasing frequency (but decreasing wavelengths) are : Red, Orange, Yellow, Green, Blue, Indigo and Violet. Any light that gives spectrum similar to that of sunlight is called white light.

Re-Combination of Spectrum Colours to Give White Light

We have just seen that white light can be dispersed into its seven constituent colours. Newton showed that the reverse of this is also true. That is, **the seven coloured lights of the spectrum can be recombined to give back white light**. This can be done as follows.

A triangular glass prism *PQR* is placed on its base *QR* as shown in Figure 23, and another similar prism *P′Q′R′* is placed alongside it in the inverted position on its vertex *P′* so that its refracting surface is in the opposite direction. When a beam of white light is allowed to fall on the first prism *PQR*, then a patch of ordinary white light is obtained on a screen *S* placed behind the second prism *P′Q′R′* (see Figure 23). Newton explained these observations as follows.

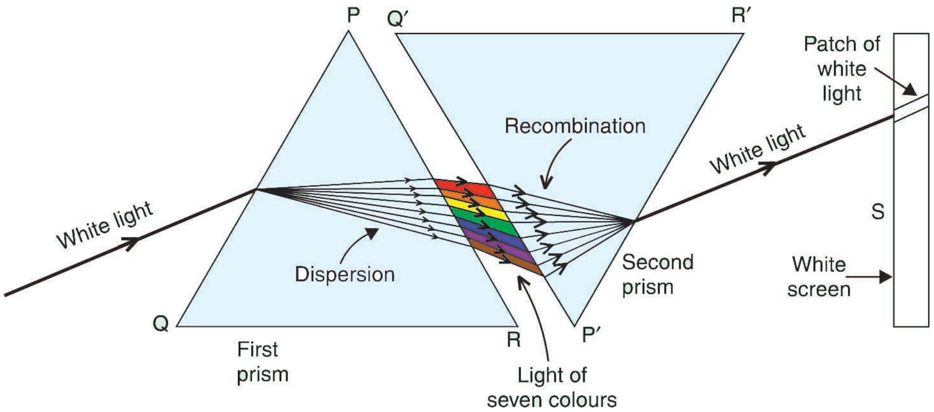


Figure 23. The first glass prism disperses (splits) white light into seven colours. The second glass prism (which has been placed upside down) recombines the seven colours of spectrum to give back white light.

The first glass prism *PQR* disperses (splits) the white light into seven coloured rays. The second glass prism *P′Q′R′* receives all the seven coloured rays from the first prism and recombines them into original white beam of light which falls on the screen *S*. The recombination of seven colours, produced by first prism, is due to the fact that the second prism has been placed in reversed position due to which the refraction produced by the second prism is equal and opposite to that produced by the first prism.

The Rainbow

One of the most beautiful examples of spectrum formed by the dispersion of sunlight is provided by nature in the form of rainbow. **The rainbow is an arch of seven colours visible in the sky which is produced by the dispersion of sun's light by raindrops in the atmosphere** (see Figure 24). The rainbow is actually a *natural spectrum* of sunlight in the sky. The rainbow is formed in the sky when the sun is *shining* and it is *raining* at the same time. We can see the rainbow if we stand with our back towards the sun and rain in front of us. A rainbow is always formed in a direction *opposite* to that of the sun. **A rainbow is produced by the dispersion of white sunlight by raindrops (or water drops) in the atmosphere. Each raindrop acts as a tiny glass**

Figure 24. A rainbow.

prism splitting the sunlight into a spectrum. This will become more clear from the following discussion.

The raindrops in the atmosphere act like many small prisms. As white sunlight enters and leaves these raindrops (or water drops), the various coloured rays present in white light are refracted by different amounts due to which an arch of seven colours called rainbow is formed in the sky. The formation of rainbow can be explained with the help of a diagram shown in Figure 25. A ray of white sunlight *AB* enters the raindrop at point *B* and undergoes refraction and dispersion to form a spectrum. This spectrum undergoes total internal reflection at point *C* within the raindrop and finally refracted out of the raindrop at point *D* (see Figure 25).

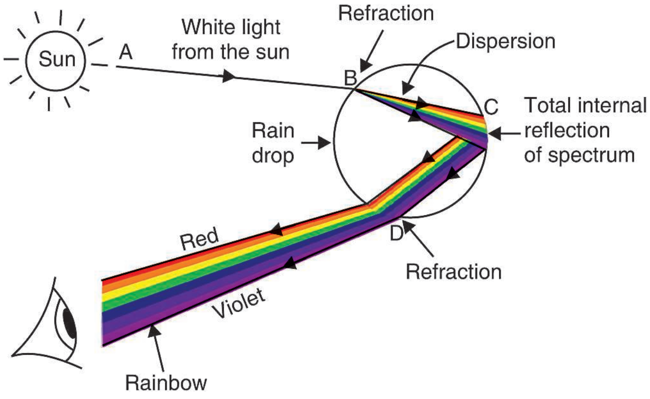


Figure 25. Formation of a rainbow.

This spectrum produced by the raindrops in the atmosphere is seen from the earth. The red colour of spectrum appears at the *top* of the rainbow whereas violet colour appears at its *bottom.*

The formation of seven-coloured rainbow in the sky shows that white sunlight consists of a mixture of seven coloured lights. We can also see a rainbow on a sunny day if we look through a spray of water from a fountain (or through a waterfall) with the sun behind us. Before we go further and discuss atmospheric refraction, **please answer the following questions :**

Very Short Answer Type Questions

1. As light rays pass from air into a glass prism, are they refracted towards or away from the normal ?
2. As light rays emerge from a glass prism into air, are they refracted towards or away from the normal ?
3. Name a natural phenomenon which is caused by the dispersion of sunlight in the sky.
4. What information do we get about sunlight from the formation of a rainbow ?
5. What did Newton demonstrate by his experiments with the prism ?
6. What colours make up white light ?
7. Give the meaning of the term VIBGYOR. With which phenomenon is it connected ?
8. In the formation of spectrum of white light by a prism :
   (*i*) which colour is deviated least ?
   (*ii*) which colour is deviated most ?
9. What colours lie on the two sides of the 'green colour' in the spectrum of white light ?
10. Name the scientist who discovered that sunlight consists of seven colours.
11. What is the order of colours in a rainbow, from the outside to the inside ?
12. Which colour of the spectrum has (*a*) longest wavelength, and (*b*) shortest wavelength ?
13. Which light has the longer wavelength : red light or blue light ?
14. Which colour of light has the shorter wavelength – red or violet ?
15. Fill in the blanks with suitable words :
    (*a*) When a ray of light enters a prism, it bends.................the normal ; as it leaves the prism, it bends .... the normal.
    (*b*) White light is composed of.............colours. The colour of white light deviated through the largest angle by a prism is..............

Short Answer Type Questions

16. (*i*) A ray of white light breaks up into its components while passing through a glass prism. Draw a ray diagram to show the path of rays.
    (*ii*) Mark the least deviated colour in your diagram.
    (*iii*) Why do different coloured rays deviate differently in a prism ?

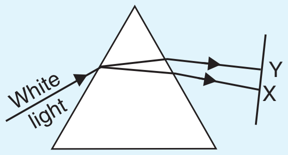
17. (*a*) What happens when a ray of ordinary light is passed through a triangular glass prism ?
(*b*) What will happen if another similar glass prism is placed upside down behind the first prism ?

18. When a beam of white light is passed through a prism, it splits to form lights of seven colours. Is it possible to recombine the lights of seven colours to obtain the white light again ? Explain your answer.

19. (*a*) What is spectrum ? What is the name of glass shape used to produce a spectrum ?
(*b*) How many colours are there in a full spectrum of white light ? Write the various colours of spectrum in the order, starting with red.

20. What is meant by dispersion of white light ? Describe the formation of rainbow in the sky with the help of a diagram.

21. In the figure given alongside, a narrow beam of white light is shown to pass through a triangular glass prism. After passing through the prism, it produces a spectrum YX on the screen.



(*a*) State the colour seen (*i*) at X, and (*ii*) at Y.
(*b*) Why do different colours of white light bend through different angles with respect to the incident beam of light ?

22. Draw a diagram to show how white light can be dispersed into a spectrum by using a glass prism. Mark the various colours of the spectrum.

23. Make two diagrams to explain refraction and dispersion.

24. Describe how you could demonstrate that white light is composed of a number of colours.

25. How could you show that the colours of the spectrum combine to give white light ?

26. Which is refracted most by a prism : red light or violet light ? Explain why ?

Long Answer Type Question

27. (*a*) Draw a diagram to show the refraction of light through a glass prism. On this diagram, mark (*i*) incident ray (*ii*) emergent ray, and (*iii*) angle of deviation.
(*b*) What is a rainbow ? What are the two conditions necessary for the formation of a rainbow in the sky ?
(*c*) What acts as tiny prisms in the formation of a rainbow ?
(*d*) Name the process which is involved in the formation of a rainbow.
(*e*) What are the seven colours seen in a rainbow ?

Multiple Choice Questions (MCQs)

28. A beam of white light is shone onto a glass prism. The light cannot be :
(*a*) deviated (*b*) dispersed (*c*) focused (*d*) refracted

29. A beam of white light falls on a glass prism. The colour of light which undergoes the least bending on passing through the glass prism is :
(*a*) violet (*b*) red (*c*) green (*d*) blue

30. The colour of white light which suffers the maximum bending (or maximum refraction) on passing through a glass prism is :
(*a*) yellow (*b*) orange (*c*) red (*d*) violet

31. Which of the following colour of white light is least deviated by the prism ?
(*a*) green (*b*) violet (*c*) indigo (*d*) yellow

32. The colour of white light which is deviated the maximum on passing through the glass prism is :
(*a*) blue (*b*) indigo (*c*) red (*d*) orange

33. The splitting up of white light into seven colours on passing through a glass prism is called :
(*a*) refraction (*b*) deflection (*c*) dispersion (*d*) scattering

34. Which of the following coloured light has the least speed in glass prism ?
(*a*) violet (*b*) yellow (*c*) red (*d*) green

35. The coloured light having the maximum speed in glass prism is :
(*a*) blue (*b*) green (*c*) violet (*d*) yellow

36. Which of the following colour of white light has the least wavelength ?
(*a*) red (*b*) orange (*c*) violet (*d*) blue