Chapter
14

Refraction of Light

Study Points:

14.1 Refraction of light
14.2 Phenomena based on refraction
14.3 Lens
14.4 Use of Lens and Optical instruments
14.5 Human eye
14.6 Colour dispersion of light

You know that light seems to move in straight-line in transparent medium. When it strikes on opaque object during propagation in straight-line in transparent medium then it does not move forward and a shadow of object appears behind the object. Similarly, when light strikes on bright opaque object (mirror) during propagation in straight-line in transparent medium then it returns to same medium. But, what happen, when light enters from one transparent medium to another transparent medium? Does it also move in straight-line or changes its direction? You might have seen in daily life experiences that the bottom of water filled container or pond or well seems to raised . Similarly, when a thick glass slab is kept on alphabet of any book or newspaper then the word seems to be raised . Why this happen? Let us know about it.

14.1 Refraction of light

Activity -1

Take a white paper sheet and fix it on drawing board with drawing pins. Put a rectangular glass slab at the middle of sheet. Draw the perimeter of rectangular glass slab with pencil. Mark PQRS on it and remove the slab. Now, draw a normal MON at point 'O' and draw a line AB making an angle i (30o) with the normal with the help of protector. Insert two pins vertically at point 'A' and 'B' as shown in fig. 14.1.

Now, put again the glass slab on same perimeter PQRS and see from the opposite face of glass slab the images of pins 'A' and 'B'. Now put another pin 'C' with viewing the pin 'A" and 'B' in such a way that image of 'C' is also form on straight-line on which images of pins 'A' and 'B' formed. Put one more pin 'D' in

similar fashion so that pin 'D' and 'C' , and pins 'A' and 'B' are on same straight-line. Remove all the pins and glass slab. Denote a mark on the positions of pin 'D' and 'C' and draw a line CD and extend it to a point O'. Draw the normal O'N' at point O' on surface SR.

Now, join the point O and O' and extend the line AB also as shown in fig with dotted line.

You see that light moves along the line AB in air and enters into glass slab after striking on glass surface. At point O , the light ray AB in air (rarer medium) bends towards the normal during entrance in glass (denser medium).

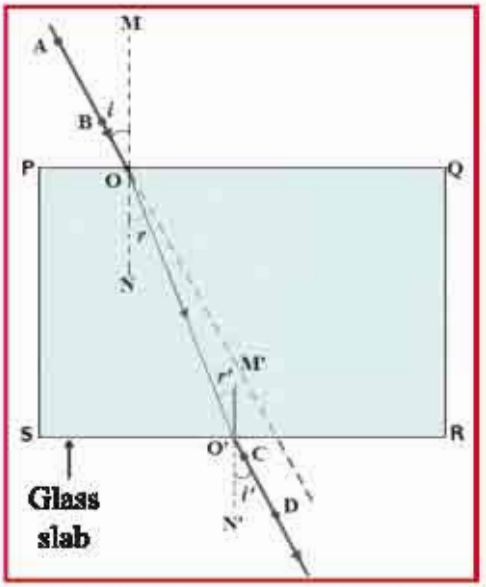

Fig. 14.1 Refraction from glass slab

Similarly, at point O' on surface SR, the light ray from glass (denser medium) comes out in air (rarer medium) then it bends away from the normal.

So we can say that -

1. When a light ray enters in denser medium from rarer medium then it bends towards the normal.
2. When a light ray enters in rarer medium from denser medium then it bends away from the normal. i.e.

> "When a light ray passes from one medium to another medium then it deviates from its original path. This phenomenon is called refraction of light."

Why refraction occurs:

The speed of light is less in denser medium compared to rarer medium. So, it is clear that when light enters into denser medium from rarer medium then its speed reduces. When light enters into rarer medium from denser medium its speed increases. The refraction occurs due to change in speed of when it passes from one medium to another.

Coefficient of Refraction (Refractive Index) : Coefficient of Refraction is the ratio of speed of light in two mediums. It is a constant and dimension less quantity.

$$\text{Refraction coefficient } (\mu) = \frac{\text{Speed of light in first medium}}{\text{Speed of light in second medium}}$$

$$\mu = \frac{v_1}{v_2}$$

In daily life we observe many phenomenon and effects due to refraction. Here we will discuss few of them by different activities.

14.2 Phenomenon based on refraction

1. Bottom of the bucket filled with water seems higher

Activity-2

Put a coin at the bottom of bucket filled with water. Try to lift the coin in a single attempt by keeping your eye just above water. Are you succeeding to lift the coin in single attempt? Repeat the process again. Why are you not successful in lifting the coin in single attempt? Ask your friends to do similar activity. Compare your experience with your friend's experience.

Activity-3

Put a coin at bottom of a pot of glass or plastic or stainless steel. Keeping eyes on the coin move away slowly from pot till coin disappears. Now, ask your friends to pour water carefully and slowly into pot (as fig. 14.2 (a)), ensure that the coin should not displace from its position. Are you able to see the coin again, now? You did not change your position, then, how it becomes possible to see the coin?

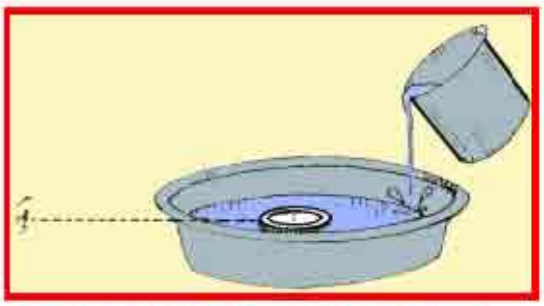

Fig.14. 2 (a) Coin in tub filled with water

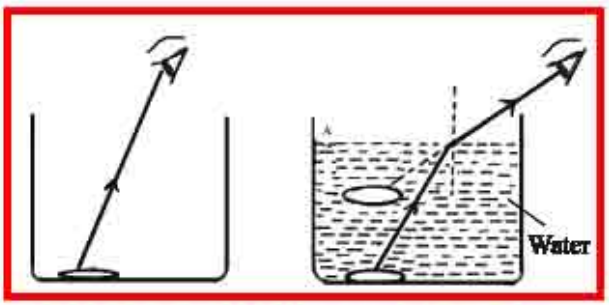

Fig.14. 2 (b) Coin seems lifted in glass beaker.

It is due to refraction of light. According to fig. 14.2 (b) when light rays from coin passes from water (denser medium) to air (rarer medium) then it bends away from the normal to the surface. When these refracted rays enter in our eyes, the coin appears raised.

Similarly, the bottom of container, pond, well, swimming pool filled with water seems raised.

Do it also.

Put a white paper on table. Draw a thick line on the white paper. Put a glass slab on the thick line in such a way that its one end makes any angle with the line. Now, see from the side the portion of line which is under the glass road. What do you see? Is the line near the edge beneath the glass slab seems to be bend? Put the glass slab perpendicular to line. Now what do you see. Is the portion of line beneath the rod seems to be bend?

2. Twinkling of stars

The layers of atmosphere have different densities. So have different coefficients of refraction. The light coming from stars deviates continuously after passing through these different atmospheric layers. That is why, the stars seem twinkling.

3. Bending of pencil in water

Activity-4

Take a glass. Fill it with water and put a pencil in such a way that it is partly immersed and held obliquely to the surface. It appears to be bent at the point (at the upper surface of water level) where it enters water. It is due to refraction of light. The light ray coming from the immersed portion of pencil bends and moves away from the normal to the water surface. That is why the pencil partly immersed in water appears to be bent at the water surface.

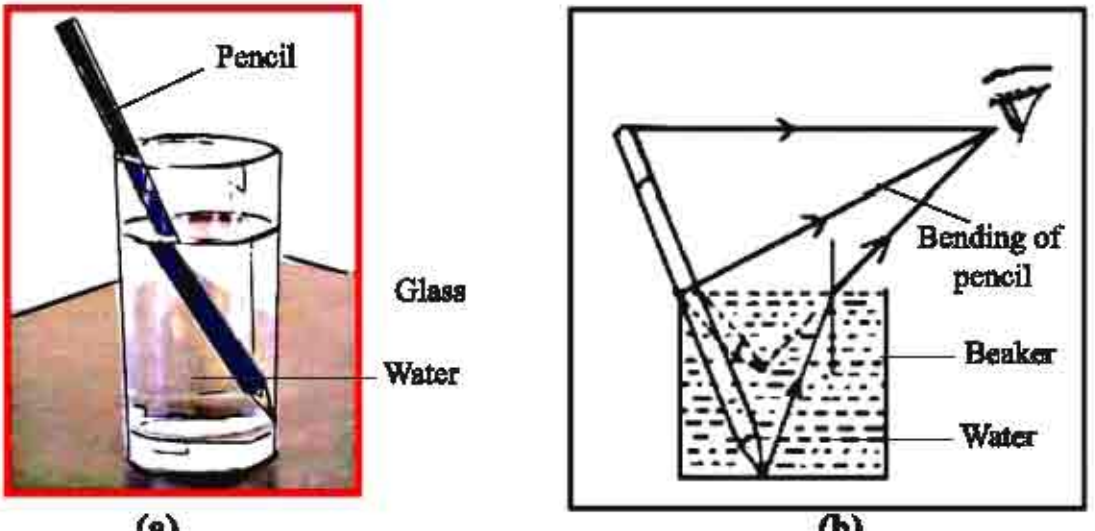

Fig. 14. 3 Pencil immersed into water seems bend.

4. Appearance of sun before sunrise and after sunset

At the time of sunrise in morning, the light ray coming from sun gets refracted (bends) by different layers of atmosphere and reaches to our eyes. Because of this atmospheric refraction, the sun appears to be raised above the horizon. There for the sun can be seen two minutes before actual sunrise.

Similarly at the time of sunset sun can be seen two minutes after the actual sunset. Thus the day time increases by four minute.

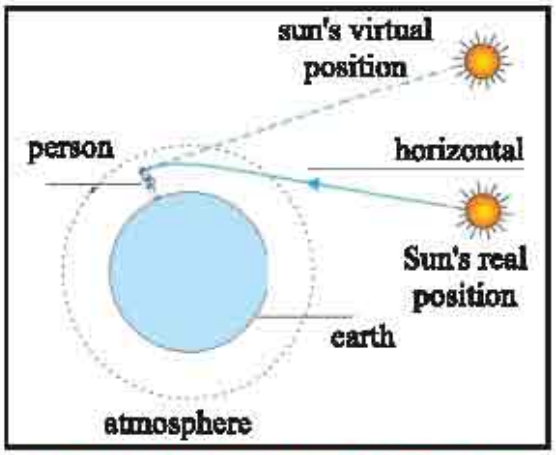

Fig.14. 4 Sun is seen before sun rising and after sun set.

14.3 Lens

You have seen many people wearing eye-glass and also few students do not able to see clearly words written on black board. These children are advised to wear spectacles. Did you thought ever? What is the different in spectacles, so visibility become clear? Spectacles have lenses.

" The transparent medium covered by the two curved surfaces is called lens.."

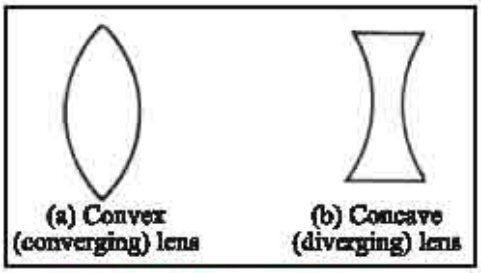

Fig. 14.5 Type of lenses.

Types of lens:

Mainly there are two types of lens-

1. Convex (converging) lens
2. Concave (diverging) lens

1. Convex (converging) lens

Activity-5

Take a convex and a concave lens and see its shape by touching.

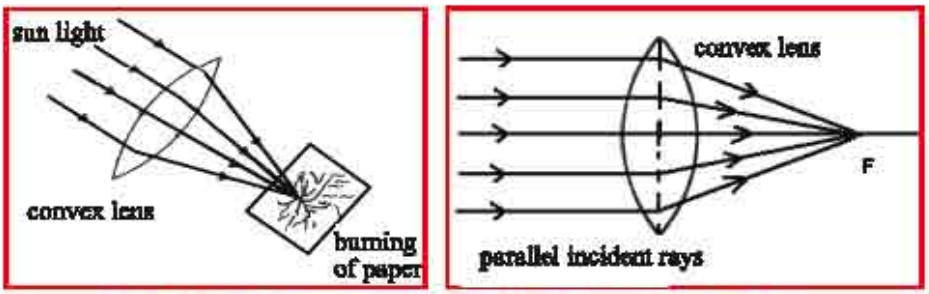

Fig. 14. 6 Conversing nature of convex lens.

The lens which is thinner at the edges and thick in the middle portion is called **Convex lens.**

Take a Convex lens and a paper. Pass the sun light rays through the convex lens in such a way that it gathered at a single point on the paper. Now hold this position till, paper does not start to burn.

The parallel rays passing through Convex lens converge (meets) at a single point. That is why it is called **Converging lens.**

The incident rays parallel to principal axis gets focused at a point on principal axis after refraction from Convex lens. The point is called (F) the focal point of convex lens.

Precautions:

To see the sun or any bright light through the convex lens is dangerous. It may damage your eyes. You should not focus the sun light on any part of body. It can burn your skin.

2. Concave (diverging) lens

The lens which has thicker edges and thiner in the middle portion is called concave lens. It spreads the incident parallel rays (diverge it). That is why this type of lens is called diverging lens.

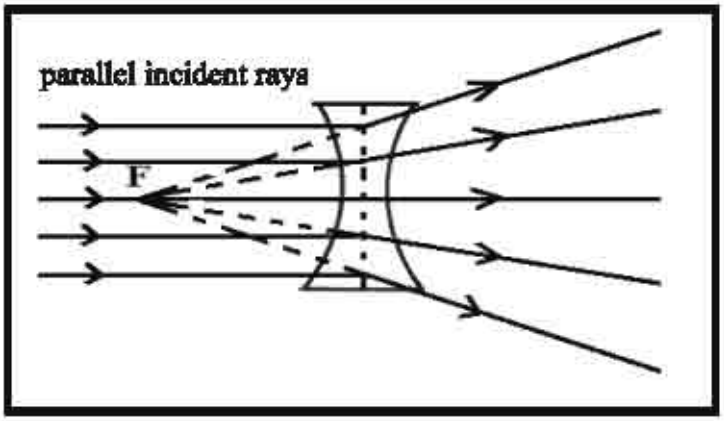

Fig. 14. 7 Diverging nature of concave lens.

The light rays passing through lens deviates from their path. So, we can say that the lens refract the light rays.

Some definitions related to lens:

Principle axis: The line passing through the centres of curvature (C1 and C2) is called principle axis.

Optical centre: The point on the

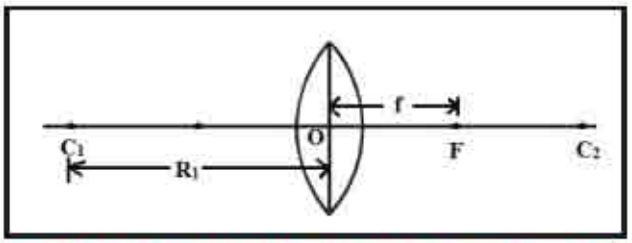

Fig. 14. 8 Some definitions related to lens

principal axis inside lens, through which a light ray passes without any deviation, is called optical centre (O) of the lens.

Focal point:

1. Incident light rays parallel to the principal axis converge at a point on principal axis after refraction from the convex lens. This point is called Focal point (F) of convex lens.
2. Incident light rays parallel to the principal axis appear to diverge from a point on principal axis after passing through the concave lens. This point is called focal point (F) of concave lens.

Focal length: The distance between the focal point and optical centre of lens is called focal length (f).

Formation of image by convex lens:

Activity - 6

Take a convex or magnifying lens and a paper. Pass the sun light through convex lens and focus it at a point on a paper sheet. Hold the lens till paper does not start to burn. You see that convex lens converge the incident parallel sun rays at a point. The point is called the focal point of lens. We can find the approximate focal length by measuring the distance of the image from the optical centre of lens. This point is the infinitesimal small image of sun. The image can be obtained on screen. Thus it is a real image. The real images are always inverted. Thus we can say that -

"When the object is at infinity then image formed by the convex lens is real, invert and infinitesimal small at focal point."

Activity - 7

Draw a line on table by the chock and mark a point at the mid of it. Put the convex lens on this point in such a way that the optical point O of lens lies on it. Mark a point F' on left side of optical point O at a distance equal to focal length (f) and mark another point 2F' at the distance equal to f from the point F' (fig. 14.9 (a)).

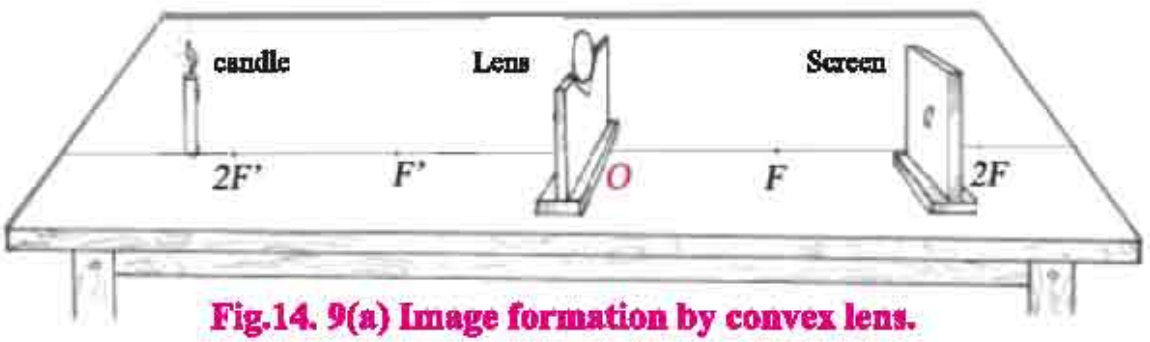

Fig.14. 9(a) Image formation by convex lens.

Similarly, denote two points F' and 2F' on right side of lens. Now put a burning candle little away from 2F' towards left side. Paste a white paper on the 15 cm long and 10 cm wide cardboard. It will work as screen. Put it on right side of lens and adjust the position to get sharp and bright image of candle's flam. See the image carefully. It is inverted and small. It can be obtained on screen. It is real and positioned between F and 2F.

Repeat the same experiment for different positions of candle. Write the observations and compare it with the data given in next table.

Activity-8

When the object is between lens and F, you will not be able to get the image. To find the position of image, remove the lens from the stand and put near the printed alphabets of a book and see its virtual and erect image in lens. Do you see the enlarged alphabets? In this situation, object is (alphabets) between optical centre O and focal point F of the lens. You will see virtual, erect and enlarged image (Fig. 14.9(B)).

Fig. 14.9(b) Big, erect and virtual image formation through convex lens.

Table 14.1 Image formation by convex lens

Sr. No.	Object's Position	Position of Image	Size of image	Nature of image
1	At infinity	At F	Infinitesimal small and inverted	real
2	At some distance away from 2F'	Between F' and 2F	Small and inverted	real
3	At 2F'	At 2F	Equal and inverted	real
4	Between F' and 2F'	away from 2F'	large and inverted	real
5	At F'	At infinity	Very large and inverted	real
6	Between Lens and F'	Between infinity and lens	large and erect	virtual

Image formation by concave lens

Now, put concave lens in place of convex lens and repeat the activity. You will find that the image is not formed on screen by the concave lens. Its image is always erect, virtual and small which can be seen by putting eyes in front of concave lens.

Fig. 14. 10 small, erect and virtual image formation by concave lens.

14.4 Uses of Lens and Optical instruments

1. In correction of defects of vision

Both types of lenses are used in spectacles. Those who cannot see clearly the distant objects have nearsightedness eye defect. Such people use the concave lens spectacles. Those who cannot see clearly the near objects are suffering with farsightedness of eye defect. Such people use the convex lens spectacles.

2. Simple microscope

In previous activity, we have seen that the convex lens is used as magnifying lens. (fig. 14.9 (b)) to see enlarged letters. In this way it is used to read very small letters. Clock repairer uses the convex lens to see small elements of clock. This single lens device is called simple microscope. The low focal length lens is used in simple microscope. With the help of microscope we can see small objects in enlarged form.

3. Compound microscope

Observe the compound microscope available in your school. This consists of two convex lenses inserted into a metal tube. The lens towards object is called objective lens. The lens towards our eye through which we see is called the eye-piece or eye lens.

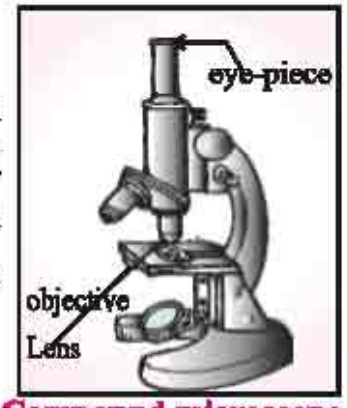

Fig. 14. 11 Compound microscope.

let us do it also

Prepare a slide of onion with help of your teacher. Now see it through simple microscope and compound microscope one-by-one. What difference you observe in size? You will find that the compound microscope enlarge the object many times, in comparison to simple microscope.

4. Telescope

The telescope is used to see the distant objects. It has also two convex lens one is called objective lens and another is called eye-piece.

14.5 Human eye

In our eye there is flexible convex lens made up of muscular tissues. The image of object is formed at retina and we see the objects.

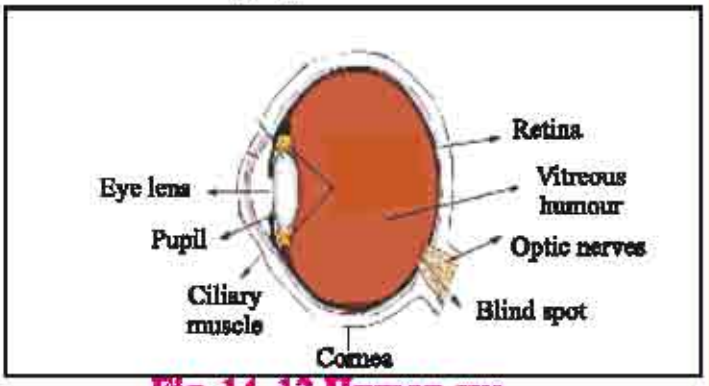

Fig. 14. 12 Human eye.

The shape of eye is spherical. Outer coat of eye is white. Its front transparent part is called cornea. Behind the cornea, there is dark muscular structure is called Iris. Small hole in Iris is called pupil. The size of pupil is controlled by iris and iris also controls an amount of light entering into eye. In the case of more light the aperture of pupil reduces and in low light the aperture of pupil increases. Eye lens is situated behind the pupil. The position of lens is held by muscular tissues. A space between cornea and eye lens is filled with transparent liquid material which is called eye fluid.

The inverted image is formed on retina. Retina is light sensitive transparent membrane which contains lot of light sensitive neurons. It is connected to brain. When these neurons send the signals generated by formation of image on retina to brain. Then brain converts images into erect and we see the object.

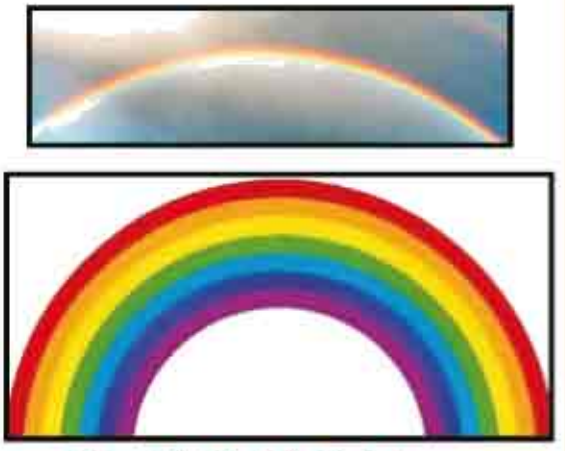

Fig. 14. 13 (a) Rainbow.

The liquid filled between the retina and lens is called vitreous humour.

14.6 Dispersion of light

In rainy season you might have seen the seven colour arc shape strips in sky when the sun is at your back. The group of these seven colours strips is called rainbow.

Have you ever think about it. Why does it happen?

Let us learn by doing.

Take a prism and put one face in front of sun light. Rotate the prism slowly in such way that the refracted light rays fall on a wall under shadow. Observe the refracted light on wall. What do you see? We see a group of seven colours strips on the wall. This is called as "Spectrum of light".

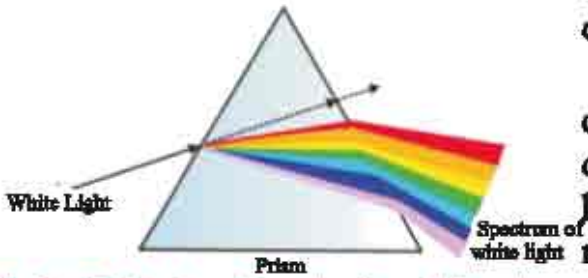

Fig. 14. 13 (b) colour dispersion through the prism.

The sun light is made up of seven colours due to which it is seen white. In denser medium, the different colours have different speed. The red colour has more speed. So, it deviates less when it passes through prism. The violet colour has less speed, so it deviates more after passing through the prism.

When white light passes through a prism it splits into seven colours- red, orange, yellow, green, blue, indigo and violet. This is called **Dispersion of light.**

When sun light passes through rain drops refraction and total internal reflection takes places and rainbow is formed.

Dr. C.V. Raman (Dr. Chandrasekhara Venkata Raman)

He was an Indian physicist. He was honored with prestigious Nobel prize in Physics in 1930 for his excellent work on scattering of light. The discovery made by him on scattering of light is known as Raman effect. He was awarded the 'Bharat Ratna' by the government of India in 1954 A.D. and also awarded Lenin Peace Prize in 1957 A.D. Chandrasekhara Venkata Raman had discovered the 'Raman effect' on 28 february, 1926.

In memory of Raman, "National science day" is celebrated each year in India.


Fig 14.14 Dr. C.V. Raman

What have you learnt

- When a light ray enters from one medium to another medium, it deviates from its path. This phenomenon is called refraction of light.
- When a light ray enters into rarer medium from denser medium then it bent away from the normal and when a light ray enters into denser medium from rarer medium then it bent towards the normal.
- The ratio of speed of light in given two medium is known as refractive index. It is a constant and dimensionless quantity.
- Lenses are made up of transparent materials which have two curved surfaces.
- Lenses are of two types - Convex lens and concave lens. Convex lens has thinner edges and thicker at the middle whereas concave lens has thicker edge and thin at the middle.
- Lenses are used in spectacles, simple microscope, compound microscope, telescope, cameras, etc.
- To remove the farsighted defects we use spectacles of convex lens whereas to remove nearsighted defect we use spectacles of concave lens.
- We have a convex lens in our eye. It forms the inverted image of an object in front of our eye and our brain converts it into erect image.
- The phenomenon of splitting of white light into its component colour is called the colour dispersion.

Exercises

Choose the correct answer.

1. Which of the following event is not related to refraction of light?

   (A) The bottom of water filled bowl appears raised.

   (B) Appearance of sun before sun rising and after sunset.

   (C) Formation of image by mirror.

   (D) Twinkling of starts ( )

2. Which is not a part of human eye?-
   (A) Retina (B) Cornea
   (C) Pupil (D) mid plane ( )
3. When a ray of light enters into rarer medium from denser medium. Then it bends -
   (A) Away from normal
   (B) Towards to normal
   (C) Move in straight-line without deviation
   (D) Non of the above ( )

Fill in the blanks with suitable words.

1. .....of eye control the amount of light enter into eye.
2. The image formation by the .....lens is awlways erect, virtual and small.
3. Light ray enters into water medium from air bends .....the normal.

Match column A and B:

	Column 'A'	Column 'B'
1.	Liquid filled in between lens and cornea.	A. vitreous humour
2.	transparent liquid filled in between lens and retina	B. Iris
3.	muscular structure of dark colour behind the cornea	C. Retina
4.	The portion of eye on which image is formed.	A. Eye fluid

Short answer questions

1. What is refraction? What is the cause of refraction?
2. Write the main difference between convex and concave lens.
3. Define the refraction coefficient?
4. What do you mean by dispersion? Write the sequence of colours in rainbow.
5. The two classmates of Meena are Raghav and Megha. Raghav is not able to see distant objects and Megha is not able to see near objects. What are eye's defects they have? To remove these defects which type of lens they should use in their spectacles?

Long answer questions:

1. Explain the refraction of light rays from glass slabe with a pictorial diagram.
2. Name the optical instruments which use lens. Describe it in brief.
3. Explain in brief the working and structure of human eye.