3 The World of Colours and Vision

Have you ever thought about the reason why flowers appear in different colours, though they are all illuminated by the same light?

Refraction through a Glass Prism

Pass a beam of light from a laser torch through a prism as shown in figure 3.1.

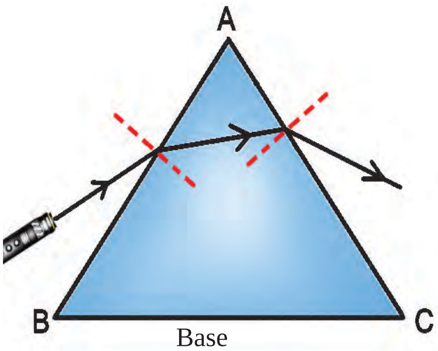


Fig.3.1

Have you observed the deviation in the path of light?

- What is the reason for this deviation?
- Identify the faces on which the light ray undergoes deviation. Depict the path of light ray in your science diary.
- Towards which part of the prism does the light ray deviate when it enters into the prism from air?
- What about when the light ray passes from the prism into air?

When light ray enters and leaves a prism, it deviates towards the base of the prism due to refraction.

Dispersion of Light

Let's pass sunlight through a prism instead of laser light.

Using a plane mirror, reflect sunlight onto a white wall. Place a narrow slit in the path of the sunlight so that only a thin beam of light passes through it.

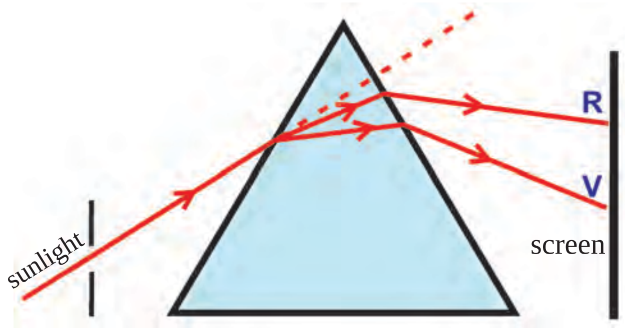


Fig. 3.2

Now you can see a white patch of light on the wall.

Arrange a prism in the path of this beam so that it falls obliquely on one of its sides (Fig. 3.2).

- What do you observe?
- Instead of white light, don't you see different colours as in a rainbow on the wall?

You have seen that sunlight splits into different colours. Record in the science diary the colours in the decreasing order of deviation. Can't you see the component colours in the order violet, indigo, blue, green, yellow, orange and red (VIBGYOR)? This orderly arrangement of the component colours in white light is called the spectrum.

Fig. 3.3

Why does sunlight split into its component colours when it passes through a prism?

Observe the splitting of sunlight into its component colours when it passes through a prism as shown in figure 3.4.

- What could be the reason for the deviation of the light ray?

When light ray passes through a prism, it deviates at the two faces due to refraction.

- Is this deviation the same for all the colours?

Let's see how this is related to the wavelength of different colours of light.

Compare the wavelengths of the colours given in table 3.1.

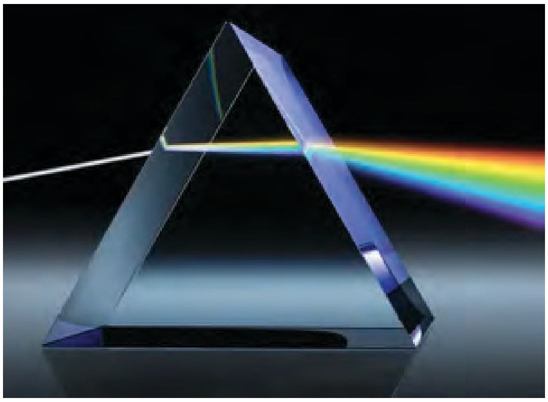


Fig. 3.4

Colour	Approximate wavelength (nanometre) nm
Violet (V)	380 - 440
Indigo (I)	440 - 460
Blue (B)	460 - 500
Green (G)	500 - 570
Yellow (Y)	570 - 590
Orange (O)	590 - 620
Red (R)	620 - 750

Table 3.1

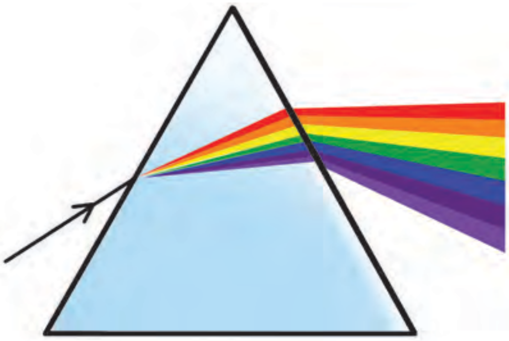


Fig. 3.5

- Which colour of light has the shortest wavelength? Which has the longest?
- Which colour deviates the most as it passes through a prism? Which has the least deviation?
- What is the reason for the changes observed in the deviation of colours?

Compare the deviation of colours with their wavelengths.

- How does the deviation of colours change with the increase in the wavelength as it passes through a prism?
- What are the factors on which the deviation of a ray of light depend?
  - ➢ Refractive index of the medium
  - ➢ Wavelength of the colour of light

When light passes through a glass prism, it undergoes refraction at the two refracting faces of the prism. The extent of deviation depends on the wavelength of light. Red deviates the least because of its longer wavelength. What about violet, which has a shorter wavelength? What about the other colours? The wavelength of other colours lie in between red and violet. Hence their deviation occurs proportionally and is arranged between red and violet.

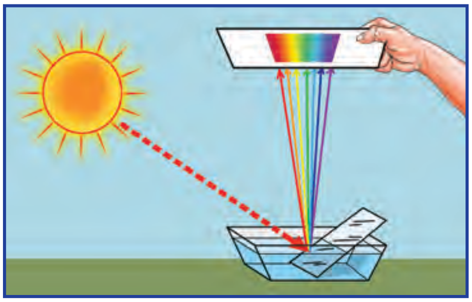


Fig. 3.6

Place a small plane mirror slightly inclined in a tray of water as shown in the figure. Adjust its position so as to reflect sunlight onto a screen. What do you observe? Explain based on the dispersion of light.

From the experiments we have done, we can understand that sunlight is composed of different colours.

Light composed of different colours is a composite light.

Dispersion of light is the phenomenon of splitting up of a composite light into its component colours.

Is the rainbow seen in the sky formed by dispersion?

Rainbow

Have you observed a rainbow? Can we create a rainbow artificially?

Fig. 3.7

Spray fine droplets of water into the air when the sun is shining behind you. What do you observe? Haven't you created an artificial rainbow? Compare the spectrum obtained now with the colours of the natural rainbow. Identify the colours you have observed. Note them down in the science diary. Now spray fine droplets of water towards the sun. A rainbow is not formed, is it? A rainbow is always formed in a direction opposite to the sun. Where will the Sun be when a rainbow is seen in the east? What about the position of the Sun when a rainbow is seen in the west?

How is a rainbow formed in the sky?

Observe figure 3.8.

- When passing through water droplets where do light rays undergo refraction?
- What happens to the refracted light rays inside the water droplets?

A ray of sunlight passing through a water droplet undergoes refraction twice and internal reflection once. This is a natural phenomenon. A rainbow is formed as a result of the combined effect of refraction, dispersion, and internal reflection.

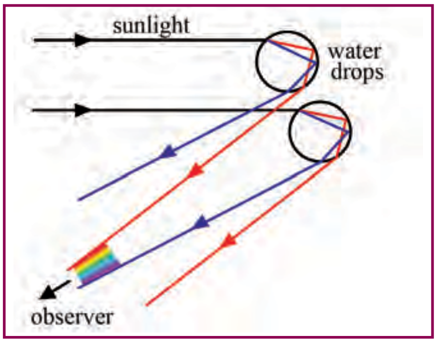


Fig. 3.8

Recombination of Colours of Light

We get dispersed light from the prism in the experiment as shown in figure 3.2. In the path of the dispersed light arrange an identical prism as shown in figure 3.9.

- What kind of light is obtained on the wall? (coloured light / white light)
- What could be the reason for this?

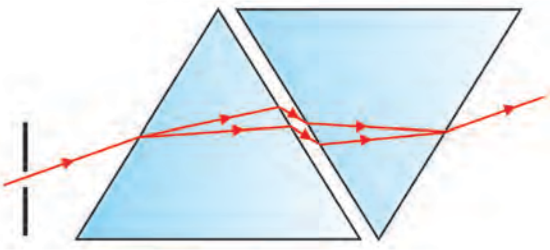


Fig. 3.9

The rays of different colours from the first prism undergo a deviation in the opposite direction by the second prism. This results in the recombination of colours to produce white light on the wall.

Are there any other components in sunlight besides visible light?

Electromagnetic Spectrum

We feel hot when sunlight falls on our body. Sunlight is beneficial to our body. But do you know that excessive exposure to sunlight is harmful? What could be the reason for this?

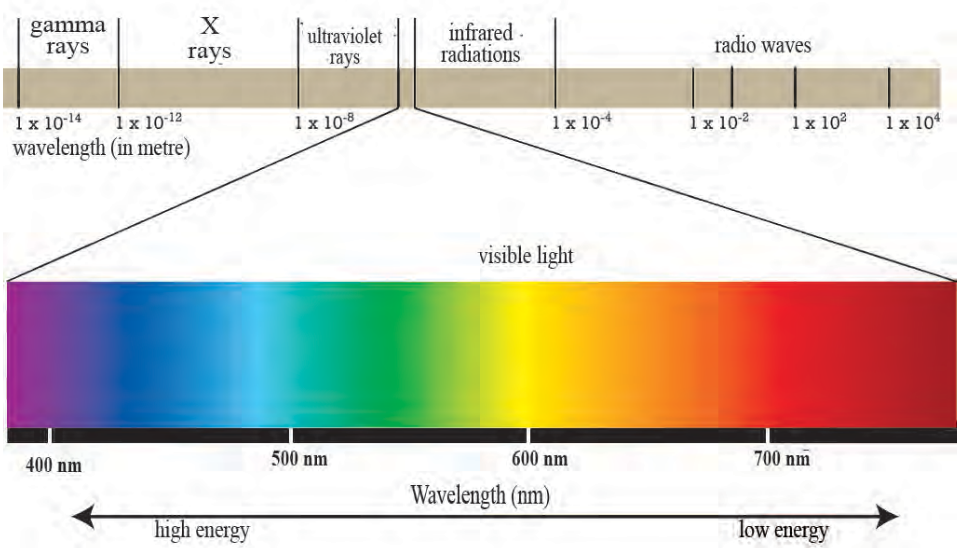
Sunlight contains infrared and ultraviolet radiations in addition to visible light. The infrared radiation in the sunlight is the main reason for the heat in the Sun's rays.

In the activity shown in figure 2.2 (b) (burning paper using a lens), the paper burns because of the convergence of infrared radiation on the paper. Ultraviolet radiation helps to produce vitamin D in our body.

Solar radiations reach the earth's atmosphere after travelling an average distance of 150 million kilometre through air and vacuum. The distance it travels through the air is negligibly small compared to that in vacuum. Solar radiations contain visible light, infrared radiation, ultraviolet radiation, etc. They do not require a medium to travel. They travel through vacuum at a speed of 300,000 kilometre per second (3×10^8 m/s). Such radiations are electromagnetic radiations.

The orderly distribution of electromagnetic radiations is known as the electromagnetic spectrum.

Observe figure 3.10. Name the radiations that constitute the electromagnetic spectrum. List them in the ascending order of wavelength.



Electromagnetic spectrum

Fig.3.10

Is white light produced only when all the colours of visible light are combined?

Primary Colours and Secondary Colours

Arrange LEDs emitting red, green, and blue light at an angle of 120° on a circular disc. Pass the light from the LEDs through a PVC pipe and project it onto a screen. Set the position of the PVC pipe such that the red, green, and blue colours overlap.

What do you observe? Based on your observations, complete table 3.2.

Overlapping colours	Resulting colours on overlapping
Red + Green	Yellow
Red + Blue	
Blue + Green	
Red + Green + Blue	

Table 3.2

Fig. 3.11

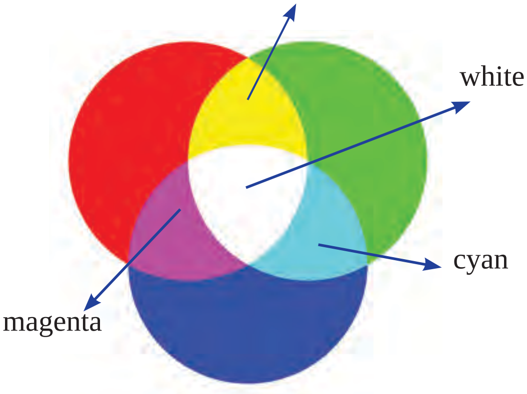


Fig. 3.12

In the region where red, green, and blue colours of the same intensity are combined, we see white light. The region where red and green combine appears as yellow, the part where green and blue combine appears as cyan, and the part where red and blue combine appears as magenta.

Not only white light, but all other coloured lights can also be created using red, green, and blue lights. Therefore, these colours are called the primary colours of light. The coloured light formed by combining any two primary colours is a secondary colour of light.

Find the secondary colours from figure 3.12 and write them down.

- What are the primary colours in yellow light?
- Which primary colour is not present in yellow light?
- Which colour will be obtained when yellow light is combined with the primary colour that is not present in yellow?

The yellow light from a sodium vapour lamp is not a composite light. Hence, red and green objects appear dark in this light.

Colours and Dyes

Red, green and blue (RGB) are primary colours while considering colours of light. But in the case of dyes, cyan, magenta and yellow (CMY) are taken as primary colours. The combination of primary colours of the same intensity and primary dyes are given in the table.

Colours of Light	Colour obtained
Blue+ Green + Red	White
Blue + Green	Cyan
Green + Red	Yellow
Blue + Red	Magenta

Dyes	Dye obtained
Cyan + Yellow + Magenta	Dark
Cyan + Yellow	Green
Cyan + Magenta	Blue
Yellow + Magenta	Red

Primary dyes are used in painting and printing. In printing, black dye is also used.

- If we add a primary colour that is not a constituent of the secondary colour, won't we get white light?

When a secondary colour is combined with a primary colour, we get white light. Such pairs of colours are called complementary colours. Complete table 3.3 with regard to complementary colours.

Secondary Colour	Component Colours	Complementary Colour
Yellow	Red + Green	Blue
Magenta		
Cyan		

Table 3.3

Take a circular disc. Colour half of it with light yellow colour and the other half with light blue colour using crayons. Rotate this circular disc very fast. What do you observe? Why? Why does the circular disc appear white?

Persistence of Vision

When a burning incense stick is whirled very fast, a ring of fire can be seen. Why?

This is due to the peculiarity of eye called the persistence of vision.

When we quickly remove an object from our field of vision the visual experience of that object persists for about $\frac{1}{16}$ of a second. This phenomenon is the persistence of vision.

Find more examples of persistence of vision.

Newton's Colour Disc

Newton's colour disc

Fig. 3.13

The experiment (Fig. 3.9) clearly shows that white light is obtained when the seven colours of sunlight are combined. Newton’s colour disc is a circular disc painted with the colours of sunlight in the same order and proportion. What can be observed when it is rotated very fast? What is the reason?

When Newton's colour disc is rotated very fast, before the visual experience of any one colour vanishes from the eye, the rays from the succeeding colours reach the eyes in quick succession. Due to the phenomenon of persistence of vision, the combined effect of all the colours persists in our eyes and appears almost white.

Explain the following based on the persistence of vision:

- When a torch or a burning stick is rotated very fast, a ring of fire is seen.
-

Make some working models to demonstrate persistence of vision and present them in the class.

Colour of Transparent Objects

Observe figure 3.14.

- How did the children view the flowers?
- What is the colour of the filter in the spectacles they wore?

Pass white light through the filters (through transparent objects) given in figure 3.15 and project it onto a white screen.

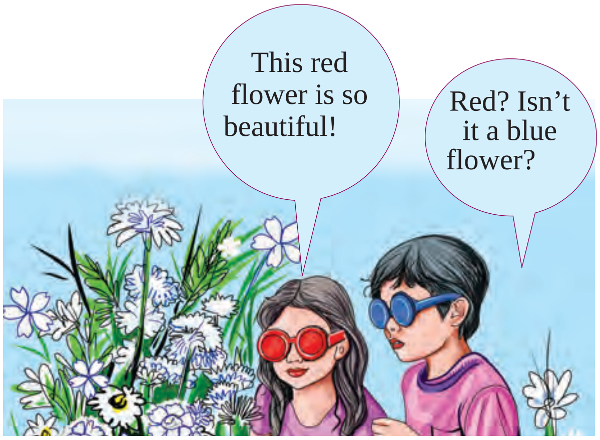


Fig. 3.14

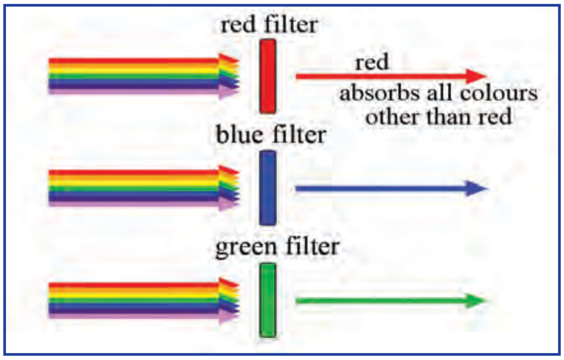


Fig. 3.15

Record the observations of each case in table 3.4.

Light falling on the filter	Colour of the filter	Colour of light passing through the filter
White light	Red	Transmits red colour in the white light
	Green	
	Blue	

Table 3.4

- Now let us pass each of the primary colours and white light through a yellow filter. What do you observe?
- Identify the components of white light transmitted through each filter.
- What happens to the other colours that fall on the filter?

Here, in each case, the filters transmit only the colour of the filter and its component colours from the white light, and block the other colours.

Complete table 3.5 related to secondary colours.

Filter	Light falling on the filter	Transmits / Does not transmit
Magenta	Red	Transmits red
	Green	
	Blue	
	Yellow	Transmits red
	White	Transmits red and blue

Table 3.5

A filter of secondary colour transmits light of its own colour and its component colours.

In a textile shop the colour of clothes are very different from their colour seen in sunlight. What is the reason for this difference?

Colour of opaque objects

We see an object in the colour of the light that is reflected from the object to our eyes.

Then, which colours will be reflected when sunlight (white light) falls on the objects given below? Complete table 3.6.

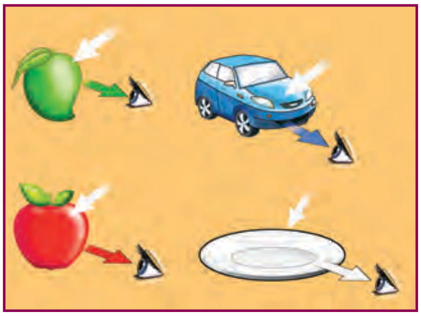


Fig. 3.16

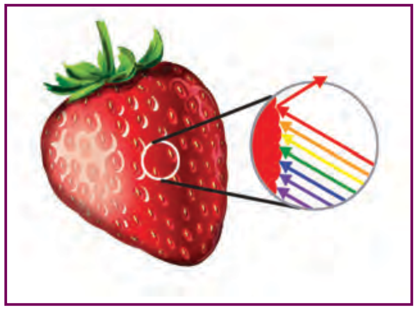


Fig. 3.17

Object	Reflected light
Blue car	Blue
Green mango	
White vessel	
Red apple	

Table 3.6

When sunlight falls on an opaque object, it reflects the colour of the object as well as the colours associated with adjacent wavelengths. It should be remembered that the colour of an object is not of a single wavelength. Similarly, there may be slight differences in colour perception depending on the light-sensitive cells (rods and cones) in the eyes of each individual. What happens to all other colours?

The object absorbs all other colours.

Write down the results obtained by observing the given objects in green, blue, and yellow lights and complete the table.

Objects	Light	Colour of the object seen
Red flower	Red	Red
	Green	Dark
	Yellow	Red
Green leaf	Red	
	Green	
	Yellow	
Yellow flower		Red
		Green
		Yellow

Table 3.7

What are the inferences obtained on analysing the table?

- What colours do a green leaf reflect? And what about a red flower?
- Can a yellow flower reflect only the yellow colour?

An opaque object of a secondary colour can reflect light of its colour and its component colours.

- In which colour will a surface appear if it reflects all colours of light falling on it? And what about a surface that absorbs all colours?

A surface that reflects all colours will appear white in white light. We know that a surface that absorbs all colours appears dark.

The beautiful colours of Peacock and Butterfly

The beautiful colours of peacock feathers and butterfly wings are primarily due to their microscopic structure rather than pigments. This is based on the arrangement of nanostructures called photonic crystals in their feathers or wings. The various light phenomena through nanostructures are responsible for the fascinating and varied colours.

In the introductory picture, the same light falls on all the flowers in the garden. But why does each appear in a different colour? Now can't it be explained? Sunlight is a composite light. It contains different colours. When sunlight falls on objects, each object reflects different colours according to its colour. Accordingly, objects are seen in different colours.

Why does the sky usually appear blue?

Scattering of Light

The schematic diagram shows the scattering of light rays due to their collision with the microscopic particles in the atmosphere (Fig.3.19).

Fig. 3.18

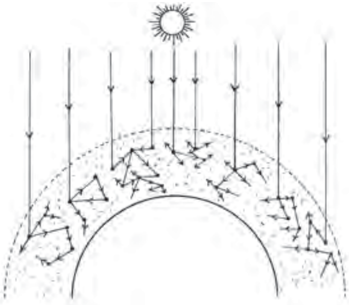


Fig. 3.19

- Which type of scattering does light undergo when it falls on microscopic particles? (regular / irregular)
- Does this type of scattering cause sunlight to spread everywhere? Discuss. The phenomenon of spreading of light in this manner is scattering.

Scattering is the irregular and partial directional deviation of light when it encounters particles in a medium.

Do all the component colours of white light undergo scattering in the same manner? Let's see. Take about three quarters of water in a rectangular glass jar. Allow light rays from a torch to pass through the water in the jar onto the screen as shown in the figure. Dissolve sodium thiosulphate in the water at a concentration of two gram per litre. Add one or two drops of hydrochloric acid to it. Observe the gradual change of light in the solution and on the screen.

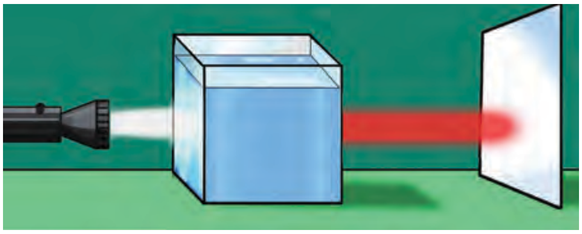


Fig. 3.20

- Which colour spreads first in the solution?
- Write down in order the colour changes seen on the screen.
- Which is the last colour to appear on the screen?

When sodium thiosulphate and hydrochloric acid react, colloidal sulphur is precipitated. The size of the particles gradually increases. Discuss the change in scattering in relation to wavelength as the size of the sulphur particles gradually increases.

Violet, indigo and blue colours in sunlight, which have shorter wavelengths, undergo more scattering when they encounter particles in the atmosphere. The scattering of red, having a relatively longer wavelength, is very low. Hence red can travel a longer distance through the atmosphere.

The extent of scattering and the size of the particles are related to each other. As the size of the particles increases, so does the scattering. If the size of the particles is greater than the wavelength of light, the scattering will be the same for all colours.

Tyndall Effect

Take water mixed with chalk powder in a beaker, as shown in figure 3.21. Pass light from a torch through it.

- What do you observe?

Can you see the path of light?

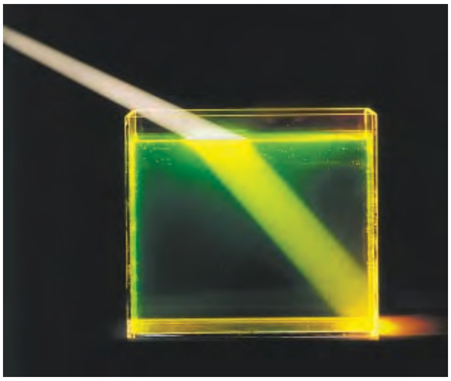


Fig. 3.21

Don't you know that water mixed with chalk powder is an example of a suspension? The path of light can be clearly seen due to the scattering of light when it passes through a suspension.

Similarly, in winter, paths of light through the gaps of the branches of trees can be seen clearly due to scattering.

When light rays pass through a colloidal liquid or suspension, they get scattered, causing tiny particles to become illuminated, making the path of light visible. This phenomenon is the Tyndall effect.

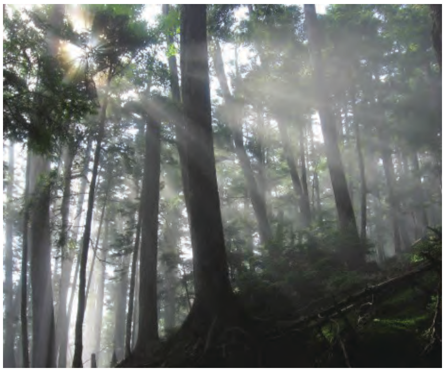


Fig. 3.22

The intensity of scattering depends on the size of the particles in the colloid. As the size of the particles increases, the intensity of scattering increases.

Let's consider some other situations related to scattering.

Blue Colour of the Sky

Why does the sky appear blue?

Observe figure 3.23.

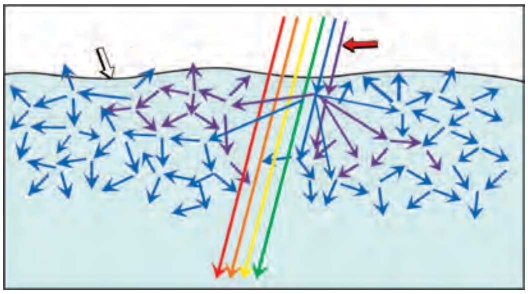


Fig. 3.23

You know that light undergoes scattering when it passes through the atmosphere.

- Which colour undergoes maximum scattering?
- Then, which colour of light spreads in the atmosphere?

When sunlight travels through the atmosphere to reach the Earth, some of its components undergo scattering as it passes through the air. Scattering occurs most for colours with shorter wavelengths such as violet, indigo and blue. This scattered light spreads in the sky. The resultant scattered light that reaches the observer's eye gives the effect of the blue colour. So the sky appears blue.

Colour of Setting and Rising Sun

Why does the sun appear red or yellow or orange during sunrise and sunset? Find out by analysing figure 3.24.

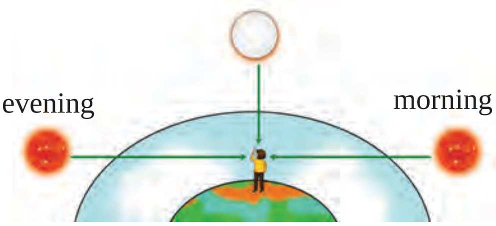


Fig. 3.24

- The distance that the sun's rays travel through the atmosphere to reach the Earth during sunrise and sunset compared to other times is
  (more / less)
- Which colours undergo the least scattering at these times?
- Which colour will be prominent in the light reaching the Earth?

If so, explain why the sun appears red, yellow, or orange during sunrise and sunset.

Eye and Vision

We can see the beautiful sights in nature with the help of our eyes.

How do eyes enable vision?

Take a convex lens of focal length10 cm. Place a burning candle at a distance of 20 cm away from the lens. Adjust the position of the screen to get a clear image of the flame.

Observe and understand the arrangements used here to form the image.

In the same way, an image of an object is formed in our eyes.

Compare the image formation in the experiment with the image formation in the eyes. Write down the similar parts which contribute to the image formation in both cases.

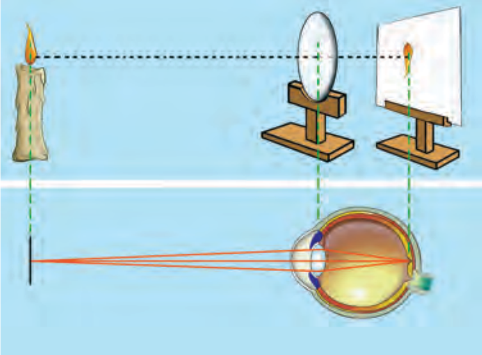


Fig. 3.25

Now try changing the position of the object to a distance 30 cm from the lens. Is a clear image formed on the screen now?

Replace the lens of focal length 10 cm with a lens of focal length 12 cm.

- What do you observe?

Isn't a clear image of the object formed on the screen?

- What could be the reason for getting a clear image now?

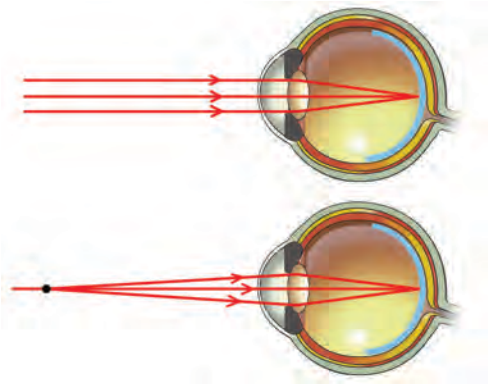


Fig. 3.26

Note that a clear image was obtained at the same position when a lens with a suitable focal length was used. When the object is placed at different positions, to get a clear image at the same position, the focal length of the lens must be adjusted accordingly.

How are images of objects at different distances formed on the retina?

This is made possible by changing the curvature of the lens in the eye with the help of the ciliary muscles by changing the focal length. When the ciliary muscles contract, the curvature of the lens increases and the focal length decreases.

- What change will occur in the curvature of the lens while looking at distant objects?
- What about the focal length when the curvature decreases?

The ability of the eye to change the curvature of the lens and adjust the focal length so that the image of the object always falls on the retina, regardless of the position of the object, is the power of accommodation of the eye.

You have understood that due to the power of accommodation of the eye, a clear image of objects at different distances is formed on the retina itself.

Will clear images be formed on the retina when objects are kept very close to the eye?

Let's do an activity.

Try reading a book by holding it close to your nose.

- Can you see the letters clearly?
- What if you move the book away?
- At what distance from the eye can you see the letters clearly?

Measure this distance. This distance is the least distance of distinct vision. The nearest point at which an object can be seen clearly is the near point. For healthy eyes, the minimum distance for clear vision is 25 cm.

- What is the maximum distance at which an object can be seen clearly?

The farthest point at which an object can be seen clearly is the far point. This distance is considered to be infinity.

- Will the near point and far point be alike for everyone?

Short sightedness / Myopia

Some people can see nearby objects clearly but cannot see distant objects. This defect of the eye is short sightedness. The schematic diagram shows the vision of a person with this defect.

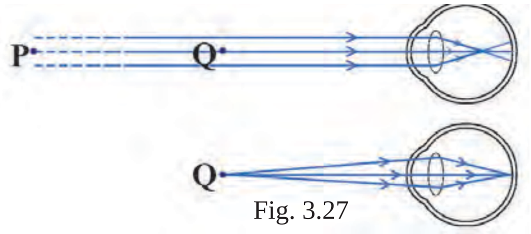


Fig. 3.27

- When an object is placed at a distant point P as shown in the figure, where will the image be formed?
- Can the object be seen clearly?
- What if the object is at Q?
- Why can't such people see distant objects clearly?

For people with this defect, the far point will not be at infinity. It will be at a certain distance from the eye.

- What could be the reason for short sightedness? Can you explain the reason based on the size of the eyeball and the power of the lens in the eye?
- The size of the eyeball is
  (larger / smaller)
- The power of the lens is
  (more / less)

Write down your conclusions in the science diary.

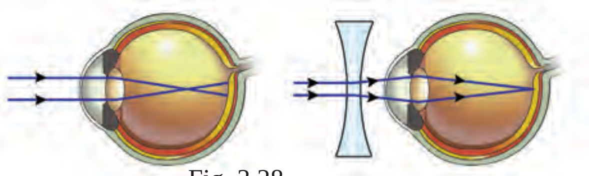


Fig. 3.28

- Observe figure 3.28 to find out how shortsightedness is rectified.

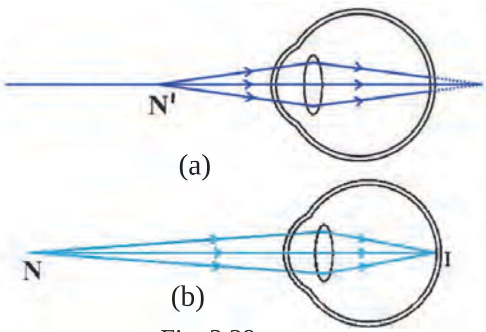
Short sightedness can be rectified using a concave lens with suitable power.

Long sightedness / Hypermetropia

Some people can see distant objects clearly but cannot see nearby objects clearly. This defect of the eye is long-sightedness.

The figures showing the image formation in the eye of a person with long sightedness are given [Fig.3.29 (a), (b)].

Didn't you observe that the distance to the near point of a person with long sightedness is different? By observing the image, you may have understood that a clear image is not formed on the retina of a person with long sightedness.



(a)

(b)

Fig. 3.29

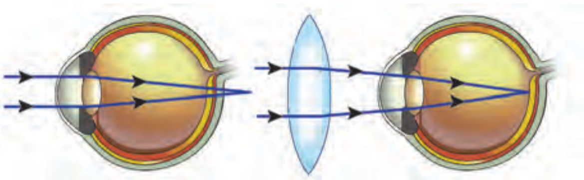


Fig. 3.30

The near point of a person with long sightedness will be more than 25 cm.

- Find the reason for this defect based on the size of the eyeball and the power of the lens in the eye.
- The size of the eyeball is

  (larger / smaller)
- The power of the lens is

  (more / less)
- How can long sightedness be rectified? Find out from figure 3.30.

Long sightedness can be rectified using a convex lens with suitable power.

Presbyopia

What is the distance to the near point for a healthy eye?

For older people, the distance to the near point may be more than 25 cm. This is because the efficiency of the ciliary muscles decreases. Such people have less power of accommodation. This is presbyopia.

Light Pollution

Although light is essential for the survival of life on Earth, artificial light harms the natural habitat of the biosphere. Light pollution refers to the creation of artificial light in excessive amounts and intensity. Artificial light adversely affects the reproduction and predation of many nocturnal animals.

Excess of artificial light adversely affects the natural activities, mental and physical health of humans. What are the other consequences of light pollution? Prepare a note on this to present in class.

- Causes difficulty during night drive.
- Makes astronomical observations difficult by obstructing the night sky.
- The light from multi-storeyed flats misleads migratory birds.
-

Photoperiodism

Certain categories of plants bloom, bear fruit and shed leaves at different times of the year. A type of protein called phytochrome found in leaves controls this biological clock. The phytochrome controls this mechanism by identifying the amount of sunlight received in each season. This phenomenon is photoperiodism. The fact that the leaves on the branches of a tree growing near a street lamp do not fall is an example of the effect of light pollution on the photoperiodism of plants.

Let's Assess

1. Find the most appropriate answer.

Name the optical phenomena taking place when light rays pass through water droplets to form a rainbow.

a) internal reflection   b) refraction

c) refraction and internal reflection   d) none of these

2. Which of the following pairs of colours can produce white light?

a) magenta, blue   b) yellow, green   c) red, green   d) magenta, green

3. When a ray of white light enters obliquely and passes through a prism

i) does not undergo refraction   ii) undergoes dispersion

iii) undergoes dispersion and deviation   iv) not subjected to any of these

Choose the correct option.

a) ii & iii   b) iv   c) i & iv   d) none of these

4. Fill in the blanks appropriately:

   a) Cyan colour + ……… $\rightarrow$ white light   b) Blue colour + ... $\rightarrow$ white light

   c) Magenta colour + green colour $\rightarrow$ ……….

   d) Magenta colour + cyan colour + yellow colour $\rightarrow$ ………..

5. Give scientific explanations based on scattering for the following:

   a) Red light is used for emergency lamps.

   b) The sky of the moon appears dark even during the day.

   c) The deep sea appears blue.

6. Complete the path of a light ray falling on the glass prism (Fig. 3.31).

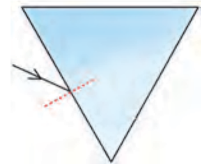


Fig. 3.31

7. What are the radiations that are seen on either side of visible light in the electromagnetic spectrum? Write one use of the radiation with a shorter wavelength than visible light.

8. The near point of a person with hypermetropia is 40 cm.

   a) Can this person read the letters in a book held 25 cm away?

   b) Can this person see an object at infinity?

   c) How can this defect of the eye be rectified?

9. Water is colourless, but it appears white in waterfalls. Why?

10. Based on the colour of illumination in the room, how can the coloured objects given in the table be seen? Complete the table.

Colour of the object	Light in the room					
	Green	Blue	Red	Magenta	Cyan	Yellow
Magenta						
Green						

Table 3.8

Extended activities

1. Prepare a note on the differences between colours of light and dyes.

2. Construct Newton's colour disc and operate.