9 OPTICAL PHENOMENA

This beautiful scene in the sky might have raised questions in your mind too. What is this phenomenon? How is it formed? Why does it appear like a bow?

Try an activity. Place a triangular glass prism on a paper as shown in the figure and draw its outline. Pass a beam of light from a laser torch obliquely through one side of it in the plane of the paper. Mark the direction of the beam of light and the point of incidence P on the prism. Also mark the direction of the emergent beam and the point of emergence Q on the other side of the prism. Remove the prism and join the points. Compare the figure you have drawn with Fig. 9.1.

- What is the change in the direction of the ray of light through the prism when it is incident obliquely from air into the prism?

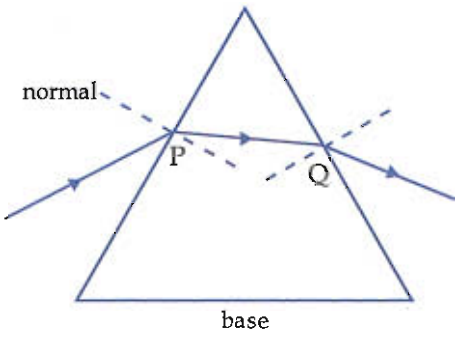
  -

- What is the reason for it?

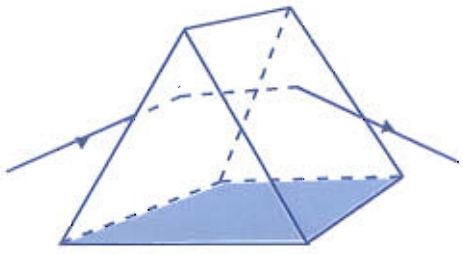
  -

- And when the light ray emerged from glass to air?

  -



(a)



(b)

Fig. 9.1

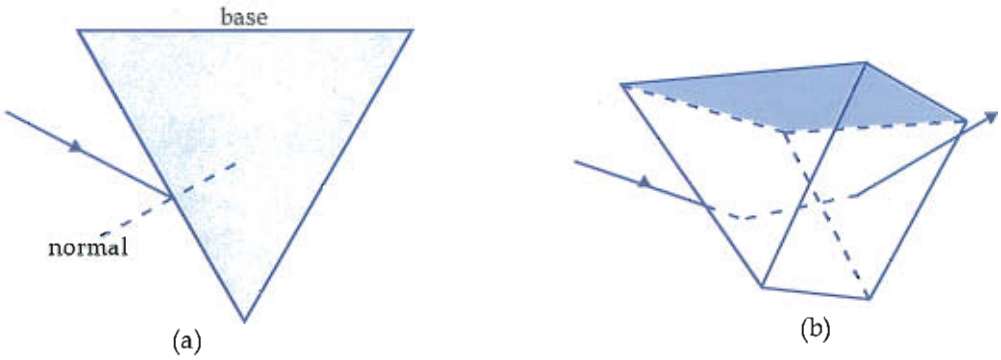


Fig. 9.2

Complete Fig. 9.2 (a) by repeating the experiment with the triangular prism reversed.

By comparing Fig. 9.1 with 9.2, discuss and note the conclusion in your science diary about the side of the prism to which the light will deviate when it passes through the prism

Dispersion of light

Now shall we conduct the experiment using sunlight instead of the laser beam?

Allow sunlight to fall on a wall of the classroom using a plane mirror and a slit.

Place a triangular prism in the path of the light from the plane mirror as shown in figure such that the light is incident on one face of the prism. Sketch the findings in the science diary. Compare your sketch with Fig. 9.3.

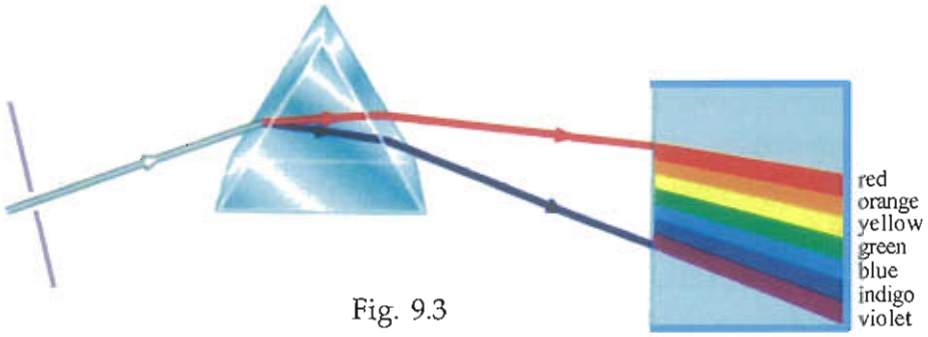
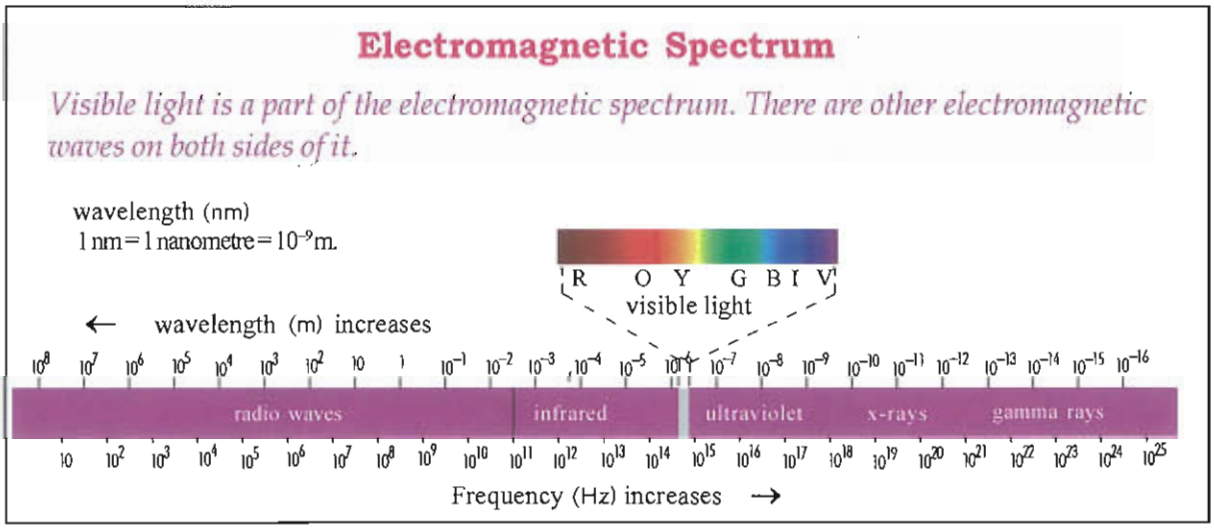


Fig. 9.3



★ Which are the colours formed on the wall?

- -

★ Can you see the colours distinctly?

- -

★ Which colour is seen near the base of the prism?

- -

★ What is the order of their distribution from the base?

Colour	Wavelength nanometre (nm)
Violet	400-440
Indigo	440-460
Blue	460-500
Green	500-570
Yellow	570-590
Orange	590-620
Red	620-700

★ Which colour among these has the lowest wavelength?

- -

★ And the highest wavelength?

- -

★ Which colour has the maximum deviation in the prism?

- -

★ Which colour has the minimum deviation?

- -

★ How are the wavelength and deviation of the constituent colours related to each other?

- -

The phenomenon of splitting of visible light into its constituent colours is dispersion. An array of constituent colours formed as a result of dispersion is the spectrum.

Based on your findings, discuss the reason for dispersion with your friends and note it down in the science diary.

Repeat the experiment using different sources of light such as torch, candle flame etc. Note the differences in the spectrum in the science diary.

Does dispersion of light occur only in glass? Let's see.

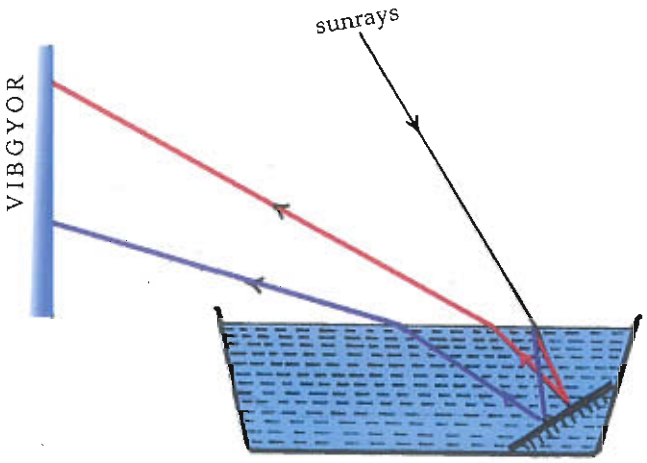


Fig. 9.4

Arrange a plane mirror in a vessel as shown in Fig. 9.4. Using another plane mirror let sunlight fall on the mirror in the glass vessel. Adjust the vessel and the mirror in it such that the reflected rays fall on a wall or a screen.

Pour water in the vessel slowly. Observe the light incident on the wall when the mirror in the vessel is completely immersed in water.

★ What happened to the white light incident on the wall when the mirror is immersed in water?

- -

★ What is the similarity in the spectrum formed on the wall and that formed by the prism?

- -

Now isn't it clear that dispersion of light can occur in water also?

Let's do another experiment for the dispersion of light in water.

Rainbow

In the morning or evening, spray water filled in your mouth in a direction opposite to the sun. What do you observe? Isn't it due to the dispersion of light in water?

Haven't you seen a rainbow?

★ Where is the rainbow seen in the morning?

- -

★ And in the evening?

- -

★ If the rainbow is to be seen, should the position of the sun be behind or in front of us?

- -

Repeat the experiment of spraying water filled in your mouth, find the important colours and the order in which they occur and note in your science diary .

Isn't it due to the dispersion of light in the water droplets that the spectrum is produced? Try to draw a diagram of dispersion of light in a water droplet, in the science diary. Compare your figure with Fig. 9.5.

★ How many times did the light ray undergo refraction in the water drop?

- -

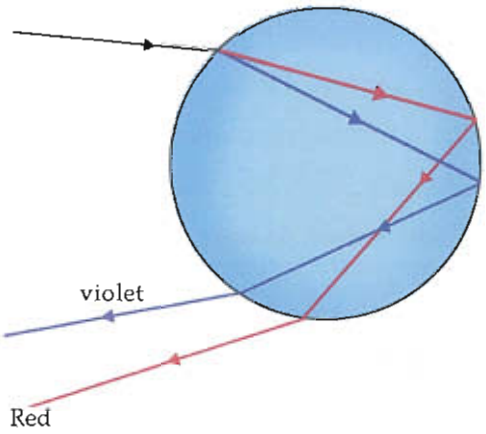


Fig. 9.5

★ How many times did total internal reflection occur?

- -

★ Which colour is seen at the top of the spectrum of light emerging from the water drop?

- -

★ And at the bottom ?

- -

Dispersion of sunlight by small water drops present in the atmosphere is responsible for the spectrum. It is this spectrum that we see as a rainbow.

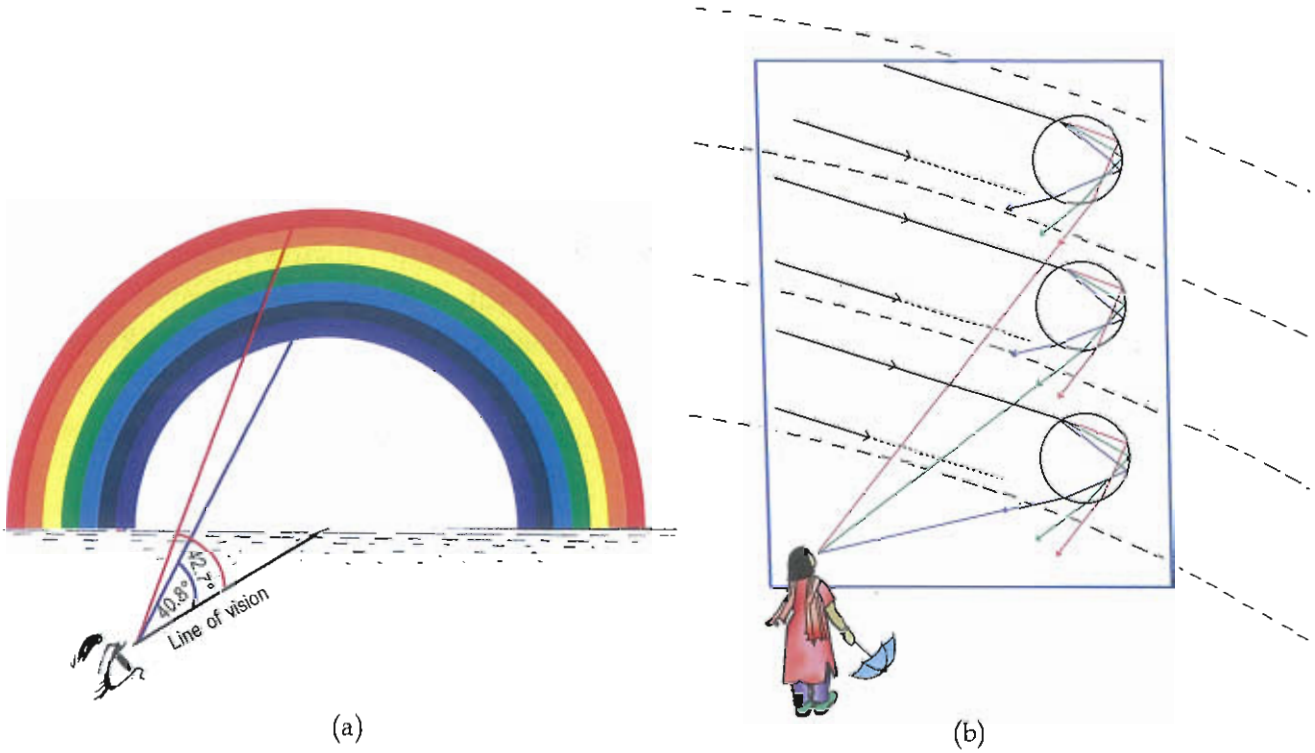
The line joining the centre of the rainbow and the observer is the line of vision . The incident rays on water drops must be parallel to the line of vision. Each coloured ray makes a definite angle with the line of vision. All water droplets appearing in the same colour make the same angle with the line of vision.

★ What will be the colour on the outer edge of a rainbow?

- -

★ And on the inner edge?

- -



(a) (b)

Fig. 9.6

Various colours are distributed in accordance with the wavelength making angles from 40.8° to 42.7° with the line of vision in a rainbow.

★ What is the reason for seeing the red colour on the outer edge of the rainbow?

★ Violet is seen on the inner edge. Why?

★ Rainbow is seen as an arc. Why? Discuss and note down.

The portion of the rainbow that is visible will be less if the position of the sun is higher above the horizon. When the sun is very much higher from the horizon the rainbow disappears. The rainbow can be seen in a circular shape when viewed from an aircraft.

Haven't you understood how a rainbow is formed in the sky?

Opaque objects, Transparent objects

What might be the reason for seeing flowers, leaves, butterflies, the leopard, the tiger etc. in different colours? Have you ever thought of this?

Let's do an activity. Close the doors and windows of the science lab to create darkness. Place a red paper on the table as shown in Fig. 9.7. Hold a white paper obliquely against it. Let light fall obliquely on the red paper from a torch.

The torch should be lit in such a way that the reflected rays must fall on the white paper. Repeat the experiment using green paper, blue paper etc. instead of red paper.

★ When light fell on the red paper, in which colour did the white paper appear?

Fig. 9.7

★ How did the white paper get light?

- -

★ Which colour might have reflected from red paper?

- -

★ In what all colours did the white paper appear when green and blue papers were used? What might be the reason?

- -

★ Is there any relation between the colour of an opaque object and the colour of light reflected from it? How?

- -

★ If so, on what factor does the colour of an opaque object depend ?

- -

Repeat the experiment using opaque objects of different colours.

★ What may be the result if an object does not reflect any colour?

- -

★ Is black a colour or absence of colours?

- -

We see an opaque object when the light reflected from it is incident on our eyes.

The characteristic colour of an object is the colour of the light which is reflected by it in sunlight. We see an object in the particular colour which is reflected from the object.

★ In which colour does an opaque object appear if it reflects all colours?

- -

Objects which allow light to pass through them are transparent objects. Let's see on what factor the colour of a transparent object depends.

Take glass papers of green, red, blue and yellow colours. Observe white objects through them.

★ In which colour did the white paper appear when observed through a green glass paper?

- -

Isn't it because paper, an opaque object, reflects all the constituents of visible light that it is seen as white? The green glass paper mainly passes the green colour of visible light that comes from the white paper.

★ When the experiment is repeated using blue glass paper in which colour does the paper appear?

- -

★ What is the reason?

- -

★ Which colour passed through the glass paper here?

- -

What was the result of your observation when the experiment was repeated using colours red, yellow etc. ? If so, what does the colour of a transparent object depend on?

Observe other opaque objects using transparent objects of different colours. Note down the findings in your science diary after discussing with your friends.

Sunlight consists of different colours. Is it possible to convert these colours to white light?

In the experiment of splitting of constituent colours of sunlight (Fig. 9.3), place a second prism as shown in Fig. 9.8. The second prism is so arranged that the constituent colours pass through it. Discuss your observation with friends.

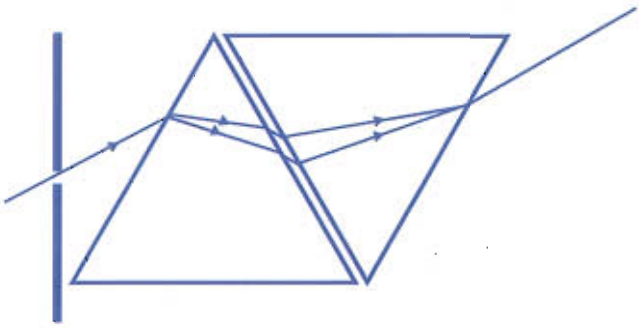


Fig. 9.8

★ What change did occur to the colours formed due to the dispersion by the first prism, when passed through the second prism?

- -

★ What is the colour of the light incident on the wall/ screen?

- -

Light composed of more than one colour is known as composite light.

Haven't you understood that a composite light can be made from constituent colours by using a suitable prism? Is there any other method for this?

Newton's colour disc

Paint on a circular metal plate the important colours of the spectrum of sunlight in the same order and the area of sectors proportional to their intensity. This is Newton's colour disc. Pass the needle of a compass or a nail through the centre of the disc and rotate it at different speeds.

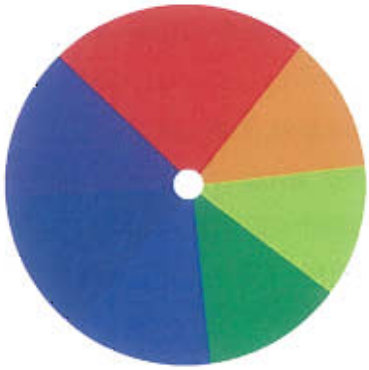


Fig. 9.9

★ When the disc is rotated slowly, in which colour does it appear?

- -

★ Rotate the disc at very high speed. In which colour does it appear now?

- -

When a person sees an object its image remains in the retina of the eye for a time interval of $\frac{1}{16}$ second. This phenomenon is persistence of vision of the eye. If more than one object is seen in $\frac{1}{16}$ second, the feeling of a resultant visual effect of all of them remains in the eye.

★ When the disc was rotated slowly, why did it not appear white?

When the Newton's colour disc was rotated at high speed it appeared white. Find the reason for it in relation to the persistence of vision of the eye and note it in the science diary.

Have you noticed the rain fall? When rain drops fall down continuously don't they appear as glass rods? Try to rotate a lit agarbathi in a circle at high speed. What do you see? Find an explanation for this on the basis of persistence of vision and note it down in your science diary.

Primary colours and secondary colours

Take a few metal discs. In one disc paint green, red and blue on three equal portions and on others paint any other three colours. Rotate each of the discs at different speeds.

Fig. 9.10

★ What difference do we see when the discs are rotated slowly and at high speed?

★ Which colours painted on the disc gave white light when it was rotated at a high speed?

You have understood that each colour painted on the disc reflects the corresponding colour.

★ Can these colours be produced using any other colours?

★ What might be the reason that the disc is seen in white colour when it is rotated at high speed?

The colours that were combined to get white light were not obtained by rotating the other discs, were they? Therefore, green, red and blue are called primary colours. The colours formed by the combination of any two primary colours are secondary colours.

Fig. 9.11

Take three circular metal discs. Paint one half of a disc green and the other half red. Similarly, paint the second disc green and blue and the third, blue and red in equal intensities. Rotate each disc at high speed. Find answers to the following questions on the basis of Fig. 9.11.

★ In which colour did the first disc appear when rotated at high speed?

★ Which colour is formed when the disc containing green and blue is rotated at high speed?

★ Which colour is formed when the third disc is rotated at high speed?

- -

★ Why are the discs seen in different colours here?

- -

It is the combination of two primary colours that form a secondary colour, isn't it? Complete Table 9.1 recording the secondary colours you have seen from this experiment.

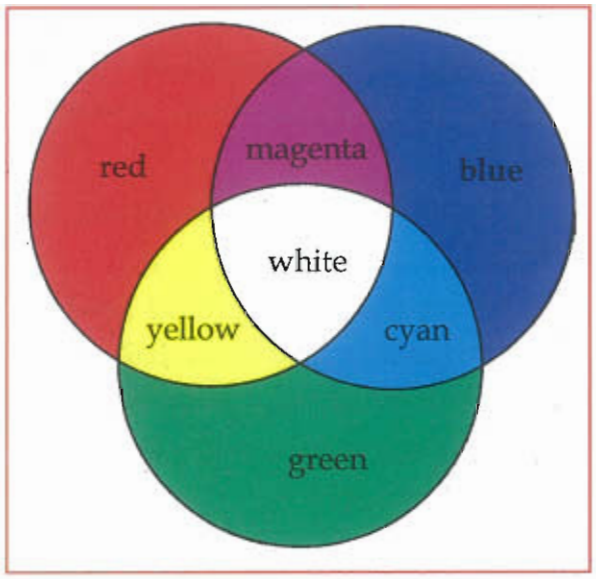


Fig. 9.12

Colours on different discs	Secondary colour *(the colour seen when the disc is rotated at high speed)*
Green + Red	
Green + Blue	
Blue + Red	

Table 9.1

Let's do another experiment using primary colours.

Lights from torches emitting green, red and blue colours are allowed to fall on a wall such that they superimpose. Note your observation in the science diary.

Complementary colours

Take three circular metal discs. Paint one half of one disc yellow and the other half blue. Similarly, paint the second disc equally with magenta and green and the third with cyan and red. Rotate the discs at high speed.

Fig. 9.13

★ In which colour does each disc appear while rotating?

- -

★ What might be the reason for this? Discuss and note down.

- -

The pair of colours combined with a primary colour to get white light is called complementary colours. If so, record which are the complementary colours and complete Table 9.2.

Primary colour + Complementary colour	Light obtained
Green + Magenta	White light
Red +	White light
Blue +	White light

Table 9.2

Scattering of light

Have you asked Aravind's question ever before? Isn't there light in our homes and in places full of trees? How is light got here?

Observe Fig 9.14.

- ✶ When sunlight falls on tiny particles in the atmosphere, what happens to the rays of light?

- ✶ Do they undergo regular or irregular reflection here?

- ✶ What change is brought about in the intensity of light on repeated reflection?

Do light rays spread everywhere due to this type of irregular and repeated reflection?

This phenomenon of light is known as scattering.

Discuss with friends how light reaches inside the classroom and beneath the trees and note it down in the science diary.

Is scattering the same for all constituent colours of sunlight?

Fill three fourth of a rectangular glass vessel with water. Light from a torch is allowed to fall on the glass vessel through

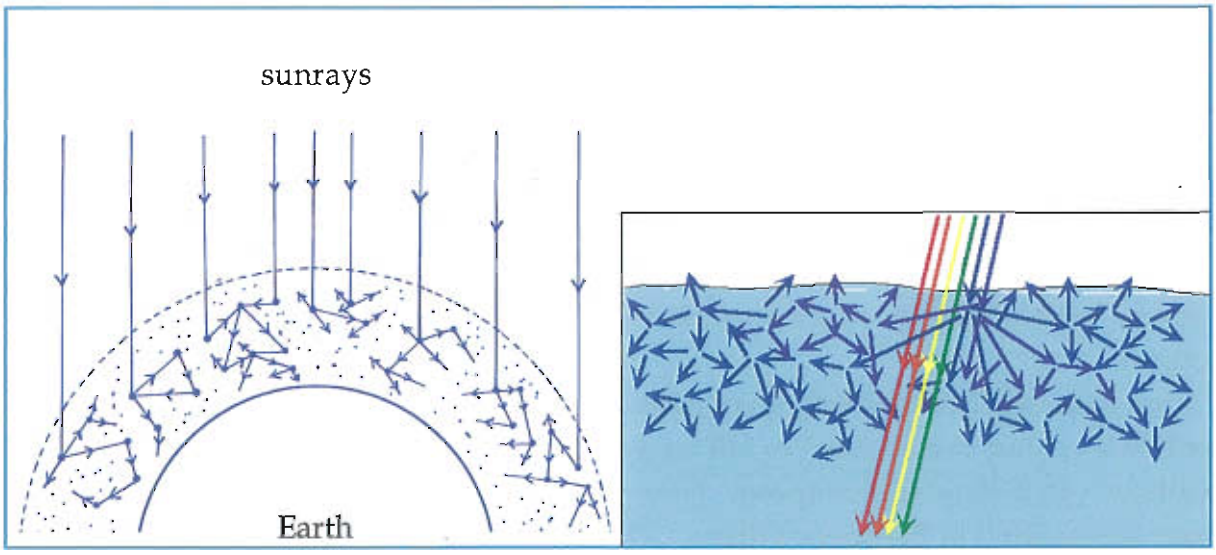


Fig. 9.14

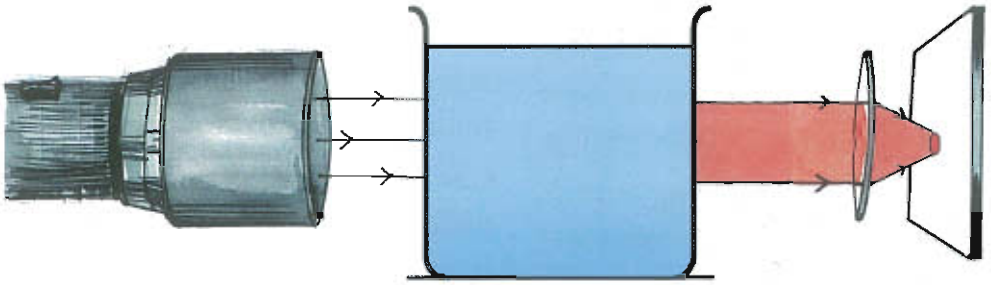


Fig. 9.15

a PVC pipe as shown in Fig. 9.15. On the other side of the tank place a screen having a circular hole and a convex lens so that the rays of light are converged. Let the converged rays fall on the screen. Dissolve sodium thiosulphate in water in the vessel at 100 g per litre. Then add one or two millilitres of concentrated sulphuric acid. Observe the reaction for two or three minutes.

Observe the sequence of changes in light inside the vessel and on the screen.

Don't you know that sulphur is precipitated when sodium thiosulphate and sulphuric acid react together?

- ✶ In the beginning which colour spreads in the glass vessel when sulphuric acid is added?

  -

- ✶ Why does this coloured light spread in the solution?

  -

- ✶ Could we see with the naked eyes the tiny particles formed in the solution on adding sulphuric acid?

  -

- ✶ In what way does the colour of light that spread in the solution differ from the colours of the light from the torch?

  -

- ✶ Which colour in white light is scattered the most by the tiny particles?

  -

- ✶ What is the order of the colours of light that emerged from the solution in the experiment?

  -

- ✶ Which is the colour that came out last?

  -

- ✶ How will the wavelength of this colour with low scattering be in comparison with that of other colours?

  -

Red colour, which has a long wavelength, can travel large distances without scattering.

The size of the particles and the rate of scattering are related to each other. As the size of particle increases, the rate of scattering also increases. If the size of particle is greater than the wavelength of light then the scattering is same for all colours.

- ✶ What was the colour of the solution some time after the end of the experiment?

  -

- ✶ What might be the reason for this?

  -

What are the phenomena that result from the scattering of light in the atmosphere?

Let's see.

The rising/setting sun and the sky

Observe Fig. 9.16. A man observes the sky in the morning, at noon and in the evening.

On the basis of experiments using sodium thiosulphate find answers to the following questions and note them down.

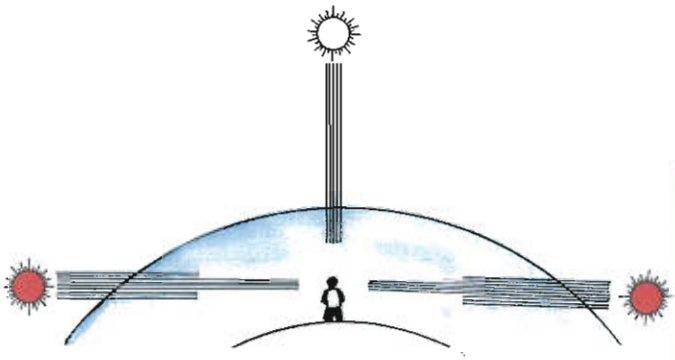


Fig. 9.16

★ For which colour is scattering the most when sunlight passes through tiny particles in the atmosphere? And the least?

In the morning and evening sunlight has to travel long distances through atmosphere to reach our eyes. Then

★ At this time which colour reaches our eyes after travelling long distances without scattering?

Note down in your science diary the reason for seeing the sun in red during sunrise and sunset.

Colour of the sky

Haven't you seen the blue sky? Why does the sky appear blue?

You have understood that more scattering takes place for the blue colour of sunlight in the atmosphere.

Colours of shorter wavelength such as violet, indigo and blue scatter more when compared to other colours of longer wavelength, and spread in the sky. The resultant colour of them makes the sky appear blue. Don't you know that the sky appears dark in the moon? What might be the reason?

Ultraviolet rays and infrared rays

Along with visible light several other electromagnetic radiations from the sun reach through the atmosphere.

★ Which are the components of the electromagnetic spectrum?

★ Among these, which radiation has the maximum wavelength ?

★ And the minimum wavelength?

★ If so, how will be their frequency?

---

* Which are the radiations on either side of the visible light? Which of these radiations travel long distances with less scattering?

In foggy weather, at night and in dim light, photographs of distant objects can be taken using radiations travelling long distances without scattering. Photographic films containing substances undergoing chemical changes when these radiations fall on them are used for this.

Infrared radiations are used for taking photographs of distant objects and for controlling instruments from a distance. What might be the reason for this? Discuss your findings and note down in the science diary. Find out more situations where infrared radiations are used.

Ultraviolet is the invisible radiation that appears close to the violet of visible light. They can bring about chemical changes on silver bromide in the ordinary photographic film. Ultraviolet radiations of moderate intensity produce Vitamin D in our body. If excess ultraviolet radiations fall on the body it causes skin cancer. From certain lamps ultraviolet radiations come out along with visible light.

* How is the wavelength of ultraviolet radiations when compared to that of visible light?

---

* How is their presence detected?

---

* Why do we say that it is good to have a mild sunbath in the morning and evening?

Haven't you seen display boards shining in the light from the vehicles at night? What might be the reason for this?

Substances which absorb light of shorter wavelength and convert them to light of longer wavelength are fluorescent substances.

When ultraviolet radiations fall on fluorescent substances what change takes place in their wavelength?

Discuss your conclusions regarding fluorescence and note them down in the science diary.

Have you noticed signals indicating danger, tail lamps of vehicles, light at the top of mobile towers etc? Aren't they to be observed even from long distances? All of them are given the same colour.

* Which is the colour that emerges from them?

---

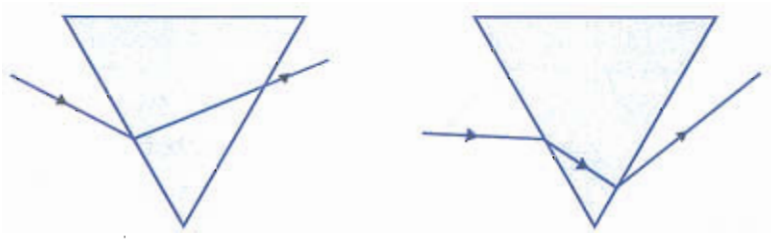
* What is the difference in its wavelength with respect to other colours?

---

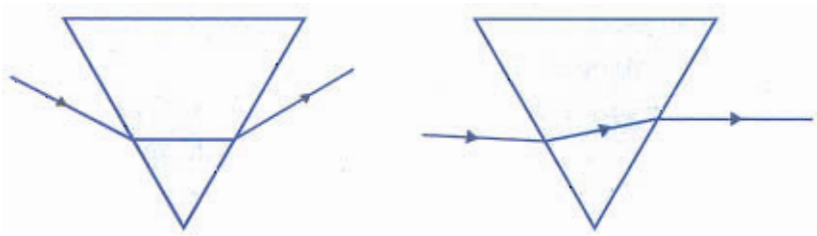
* How is its rate of scattering?

From your findings discuss the reason for using red colour in signals to be seen even from long distance and note down in the science diary.

1. The figure shows a laser beam passing through a glass prism.



(a) (b)



(c) (d)

a) Which is the correct figure here?

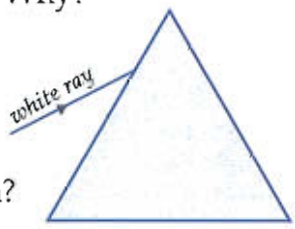
b) What is the reason?

c) Will there be any change in the direction of laser beam when the prism of the correct figure is placed in water? Why?

2. a) Complete the given figure.

b) Which are the colours formed here?

c) What is the reason for the forming of a spectrum?



3. In which colour do the given opaque objects appear when viewed in different coloured light.

Object	White Light	Green light	Red light
Red flower			
Blue flower			
Green leaf			

4. One team wears green top and red shorts in a football match between two teams. The second team wears blue top and black shorts. If the match is conducted in a stadium with sodium vapour lamps as flood light
   a) Which will be the colour of light coming out of the sodium vapour lamp?
   b) In which colour will the jersey of the first team appear?
   c) In which colour will the jersey of the second team appear? Why?
   d) In which colour will the jersey of each team appear if a mercury lamp is used instead of the sodium vapour lamp in the stadium?
5. Suresh purchased a dark coloured shirt in blue light from a shop. But in day light it appeared red.
   a) Why did the shirt appear dark inside the shop?
   b) In which colour will the shirt appear if the bulbs used in the shop were neon bulbs?
6. Haven't you made artificial rainbows?
   a) Which is the colour seen on the outer edge of the rainbow?
   b) Which is the colour on the inner edge?
   c) What is meant by line of vision?
   d) What is the reason for a rainbow appearing as an arc?