

The Human Eye and the Colourful World

CLASS-10TH CHAPTER-11TH

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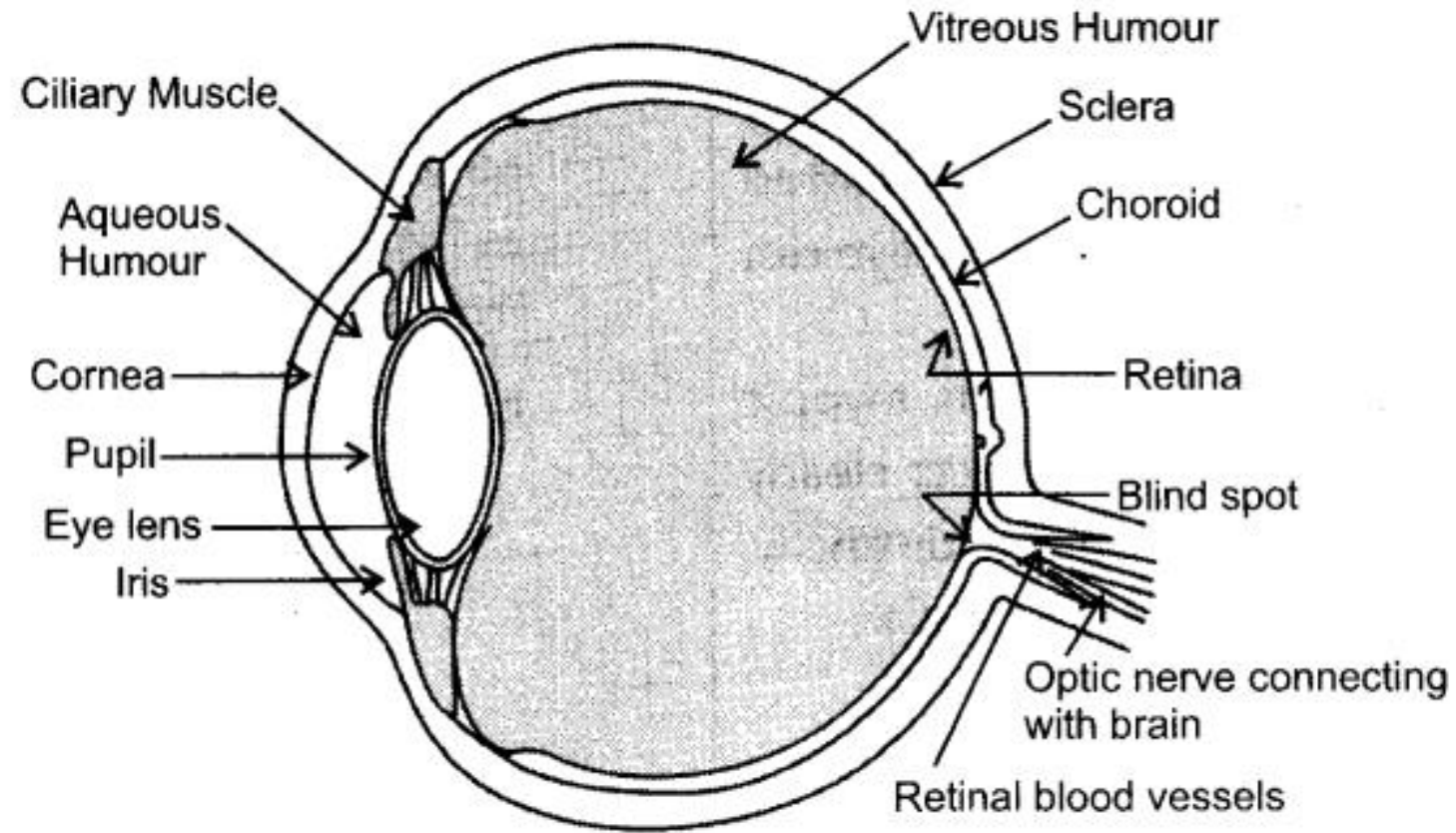
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- You have studied in the previous chapter about refraction of light by lenses. You also studied the nature, position and relative size of images formed by lenses.
- How can these ideas help us in the study of the human eye? The human eye uses light and enables us to see objects around us.
- It has a lens in its structure. What is the function of the lens in a human eye? How do the lenses used in spectacles correct defects of vision? Let us consider these questions in this chapter.
- We have learnt in the previous chapter about light and some of its properties. In this chapter, we shall use these ideas to study some of the optical phenomena in nature.
- We shall also discuss about rainbow formation, splitting of white light and blue color of the sky.

THE HUMAN EYE

- The human eye is one of the most valuable and sensitive sense organs. It enables us to see the wonderful world and the colors around us.
- On closing the eyes, we can identify objects to some extent by their smell, taste, sound they make or by touch.
- It is, however, impossible to identify colors while closing the eyes.
- Thus, of all the sense organs, the human eye is the most significant one as it enables us to see the beautiful, colourful world around us.
- The human eye is like a camera. Its lens system forms an image on a light-sensitive screen called the retina. Light enters the eye through a thin membrane called the cornea.
- It forms the transparent bulge on the front surface of the eyeball. The eyeball is approximately spherical in shape with a diameter of about 2.3 cm



HUMAN EYE

- Most of the refraction for the light rays entering the eye occurs at the outer surface of the cornea.
- The crystalline lens merely provides the finer adjustment of focal length required to focus objects at different distances on the retina.
- We find a structure called *iris* behind the cornea. Iris is a dark muscular diaphragm that controls the size of the pupil.
- The pupil regulates and controls the amount of light entering the eye.
- The eye lens forms an inverted real image of the object on the retina. The retina is a delicate membrane having enormous number of light-sensitive cells.
- The light-sensitive cells get activated upon illumination and generate electrical signals. These signals are sent to the brain via the optic nerves.

- The brain interprets these signals, and finally, processes the information so that we perceive objects as they are.

DO YOU KNOW?

Damage to or malfunction of any part of the visual system can lead to significant loss of visual functioning. For example, if any of the structures involved in the transmission of light, like the cornea, pupil, eye lens, aqueous humor and vitreous humor or those responsible for conversion of light to electrical impulse, like the retina or even the optic nerve that transmits these impulses to the brain, is damaged, it will result in visual impairment . You might have experienced that you are not able to see objects clearly for some time when you enter from bright light to a room with dim light. After sometime, however, you may be able to see things in the dim-lit room. The pupil of an eye acts like a variable aperture whose size can be varied with the help of the iris. When the light is very bright, the iris contracts the pupil to allow less light to enter the eye. However, in dim light the iris expands the pupil to allow more light to enter the eye. Thus, the pupil opens completely through the relaxation of the iris.

Power of Accommodation

- The eye lens is composed of a fibrous, jelly-like material. Its curvature can be modified to some extent by the ciliary muscles.
- The change in the curvature of the eye lens can thus change its focal length. When the muscles are relaxed, the lens becomes thin.
- Thus, its focal length increases. This enables us to see distant objects clearly. When you are looking at objects closer to the eye, the ciliary muscles contract.
- This increases the curvature of the eye lens. The eye lens then becomes thicker.
- Consequently, the focal length of the eye lens decreases. This enables us to see nearby objects clearly.

- The ability of the eye lens to adjust its focal length is called accommodation.
- However, the focal length of the eye lens cannot be decreased below a certain minimum limit. Try to read a printed page by holding it very close to your eyes.
- You may see the image being blurred or feel strain in the eye. To see an object comfortably and distinctly, you must hold it at about 25 cm from the eyes.
- The minimum distance, at which objects can be seen most distinctly without strain, is called the least distance of distinct vision. It is also called the near point of the eye.
- For a young adult with normal vision, the near point is about 25 cm. The farthest point upto which the eye can see objects clearly is called the far point of the eye.
- It is infinity for a normal eye. You may note here a normal eye can see objects clearly that are between 25 cm and infinity.

- Sometimes, the crystalline lens of people at old age becomes milky and cloudy. This condition is called cataract. This causes partial or complete loss of vision. It is possible to restore vision through a cataract surgery.

Do You Know

Why do we have two eyes for vision and not just one?

There are several advantages of our having two eyes instead of one. It gives a wider field of view. A human being has a horizontal field of view of about 150° with one eye and of about 180° with two eyes. The ability to detect faint objects is, of course, enhanced with two detectors instead of one. Some animals, usually prey animals, have their two eyes positioned on opposite sides of their heads to give the widest possible field of view. But our two eyes are positioned on the front of our heads, and it thus reduces our field of view in favour of what is called stereopsis. Shut one eye and the world looks flat – two-dimensional. Keep both eyes open and the world takes on the third dimension of depth. Because our eyes are separated by a few centimetres, each eye sees a slightly different image. Our brain combines the two images into one, using the extra information to tell us how close or far away things are.

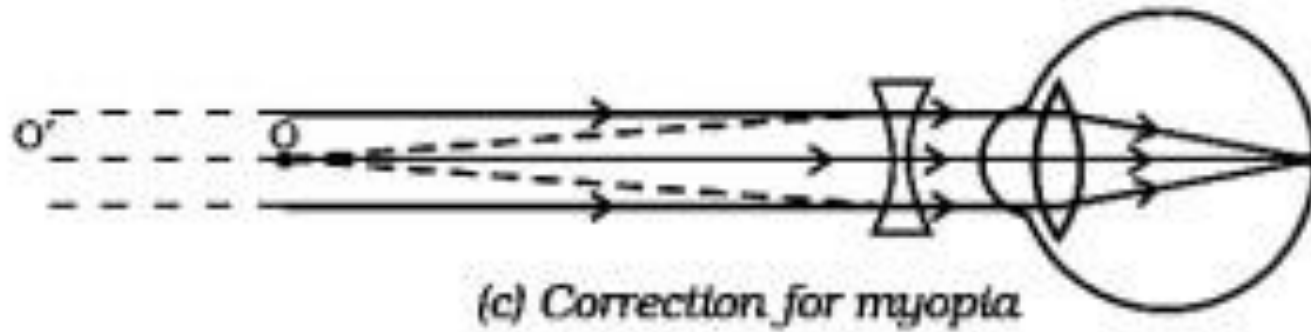
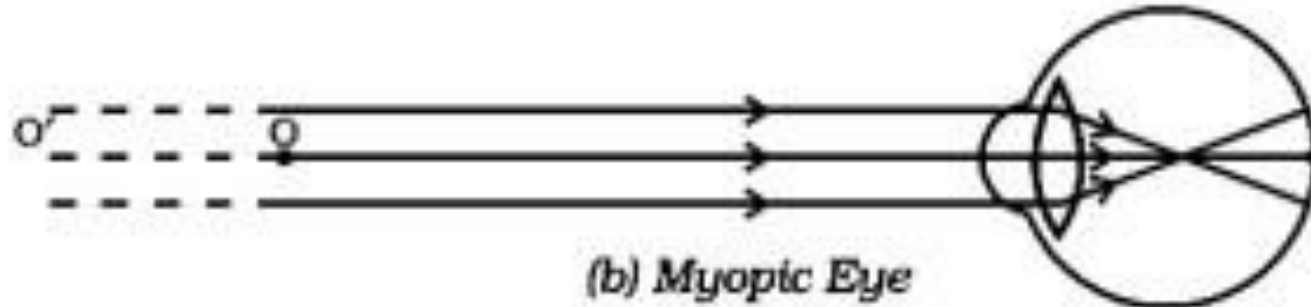
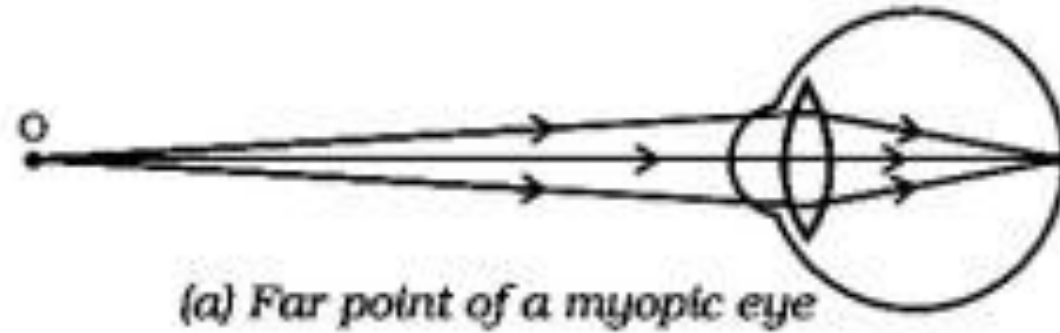
DEFECTS OF VISION AND THEIR CORRECTION

- Sometimes, the eye may gradually lose its power of accommodation. In such conditions, the person cannot see the objects distinctly and comfortably.
- The vision becomes blurred due to the refractive defects of the eye.
- There are mainly three common refractive defects of vision.
- These are (i) myopia or near-sightedness, (ii) Hypermetropia or farsightedness, and (iii) Presbyopia. These defects can be corrected by the use of suitable spherical lenses.

We discuss below these defects and their correction.

Myopia

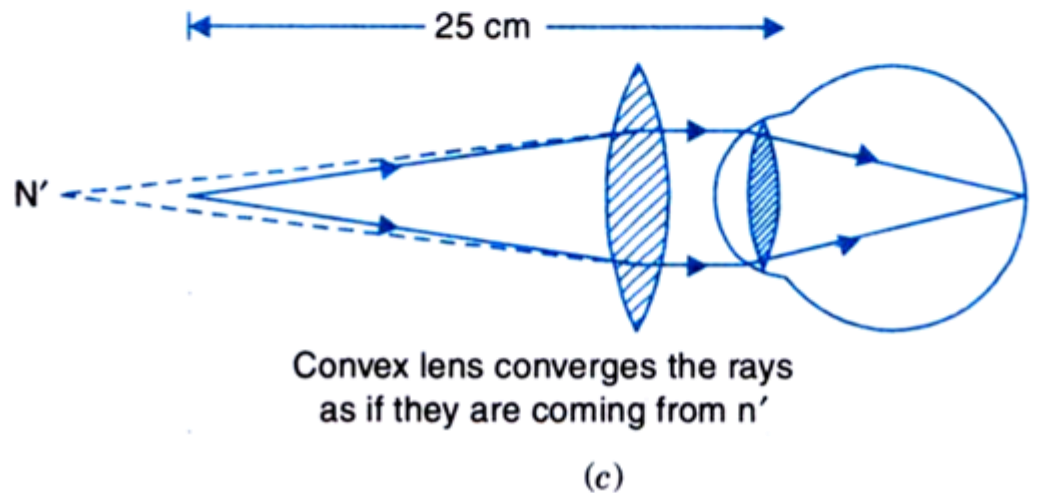
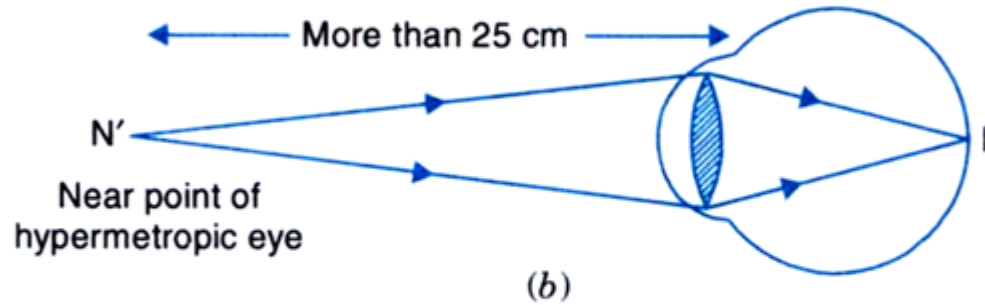
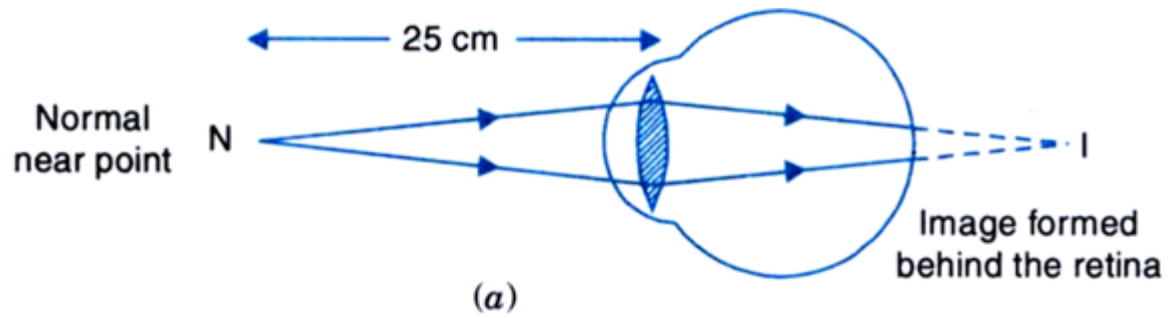
- Myopia is also known as near-sightedness. A person with myopia can see nearby objects clearly but cannot see distant objects distinctly.
- A person with this defect has the far point nearer than infinity. Such a person may see clearly upto a distance of a few metres.
- In a myopic eye, the image of a distant object is formed in front of the retina and not at the retina itself.
- This defect may arise due to (i) excessive curvature of the eye lens, or (ii) elongation of the eyeball.
- This defect can be corrected by using a concave lens of suitable power. A concave lens of suitable power will bring the image back on to the retina and thus the defect is corrected.



(a), (b) The myopic eye, and (c) correction for myopia with a concave lens

(b) Hypermetropia

- Hypermetropia is also known as far-sightedness. A person with hypermetropia can see distant objects clearly but cannot see nearby objects distinctly.
- The near point, for the person, is farther away from the normal near point (25 cm).
- Such a person has to keep a reading material much beyond 25 cm from the eye for comfortable reading.
- This is because the light rays from a close by object are focused at a point behind the retina .
- This defect arises either because (i) the focal length of the eye lens is too long, or (ii) the eyeball has become too small. This defect can be corrected by using a convex lens of appropriate power.
- Eye-glasses with converging lenses provide the additional focusing power required for forming the image on the retina.

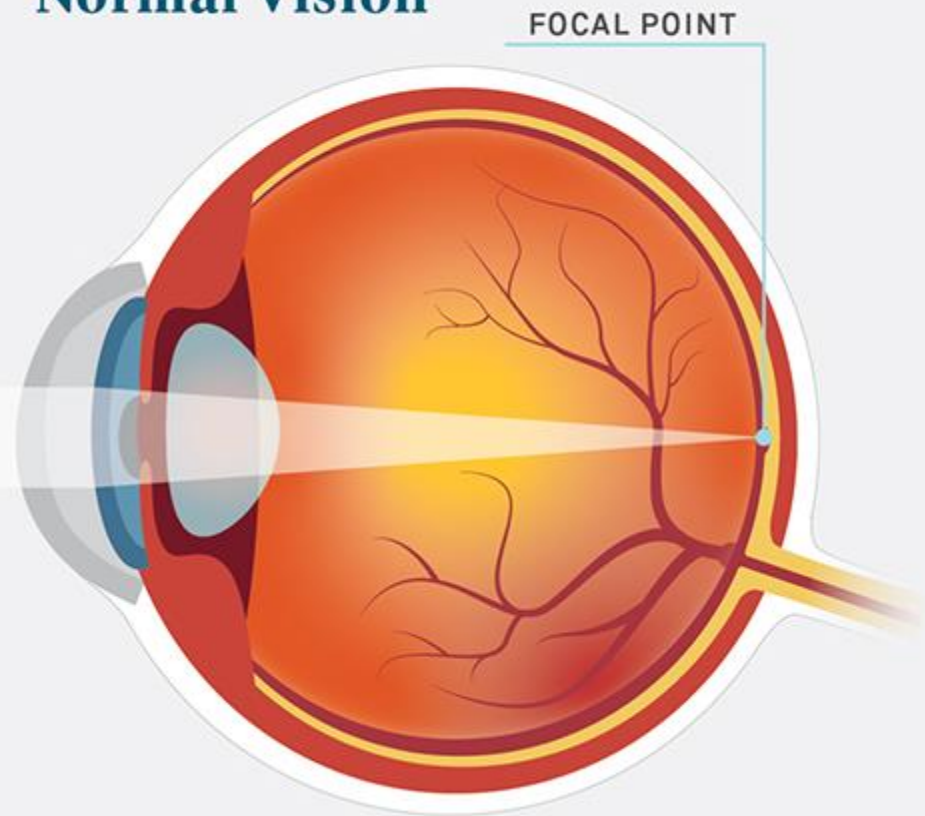


(a), (b) The hypermetropic eye, and (c) correction for hypermetropia
N = Near point of a hypermetropic eye.
N' = Near point of a normal eye.

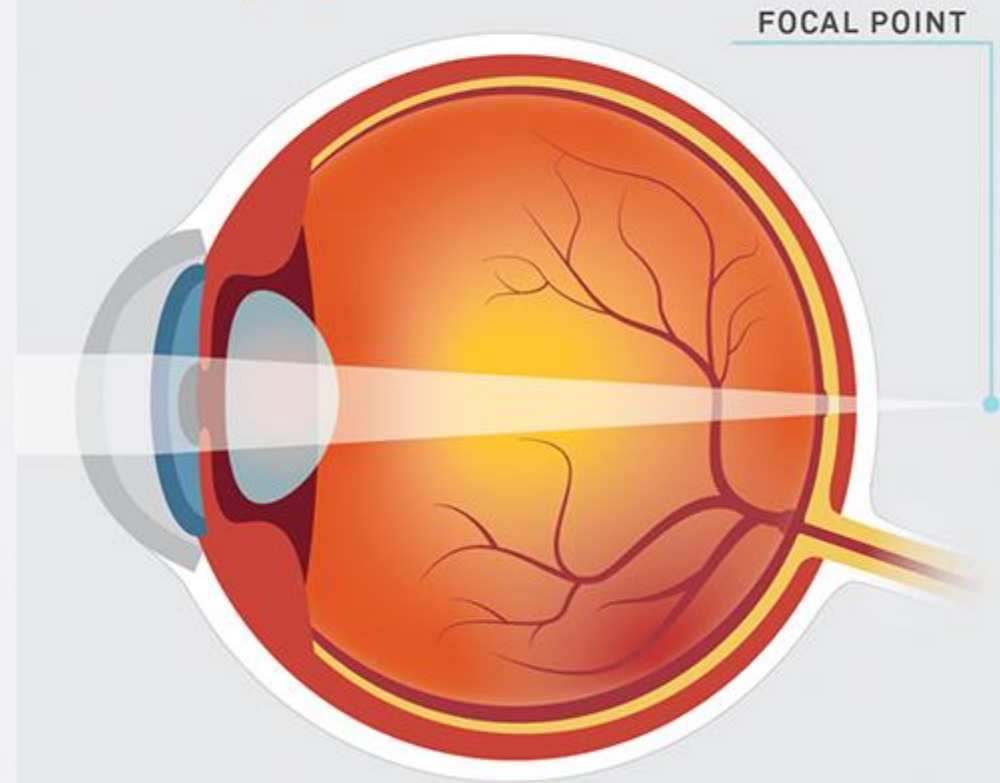
(c) Presbyopia

- The power of accommodation of the eye usually decreases with ageing. For most people, the near point gradually recedes away.
- They find it difficult to see nearby objects comfortably and distinctly without corrective eye-glasses.
- This defect is called Presbyopia. It arises due to the gradual weakening of the ciliary muscles and diminishing flexibility of the eye lens.
- Sometimes, a person may suffer from both myopia and hypermetropia. Such people often require bi-focal lenses.
- A common type of bi-focal lenses consists of both concave and convex lenses. The upper portion consists of a concave lens.

Normal Vision



Presbyopia



- It facilitates distant vision. The lower part is a convex lens. It facilitates near vision.
- These days, it is possible to correct the refractive defects with contact lenses or through surgical interventions

REFRACTION OF LIGHT THROUGH A PRISM

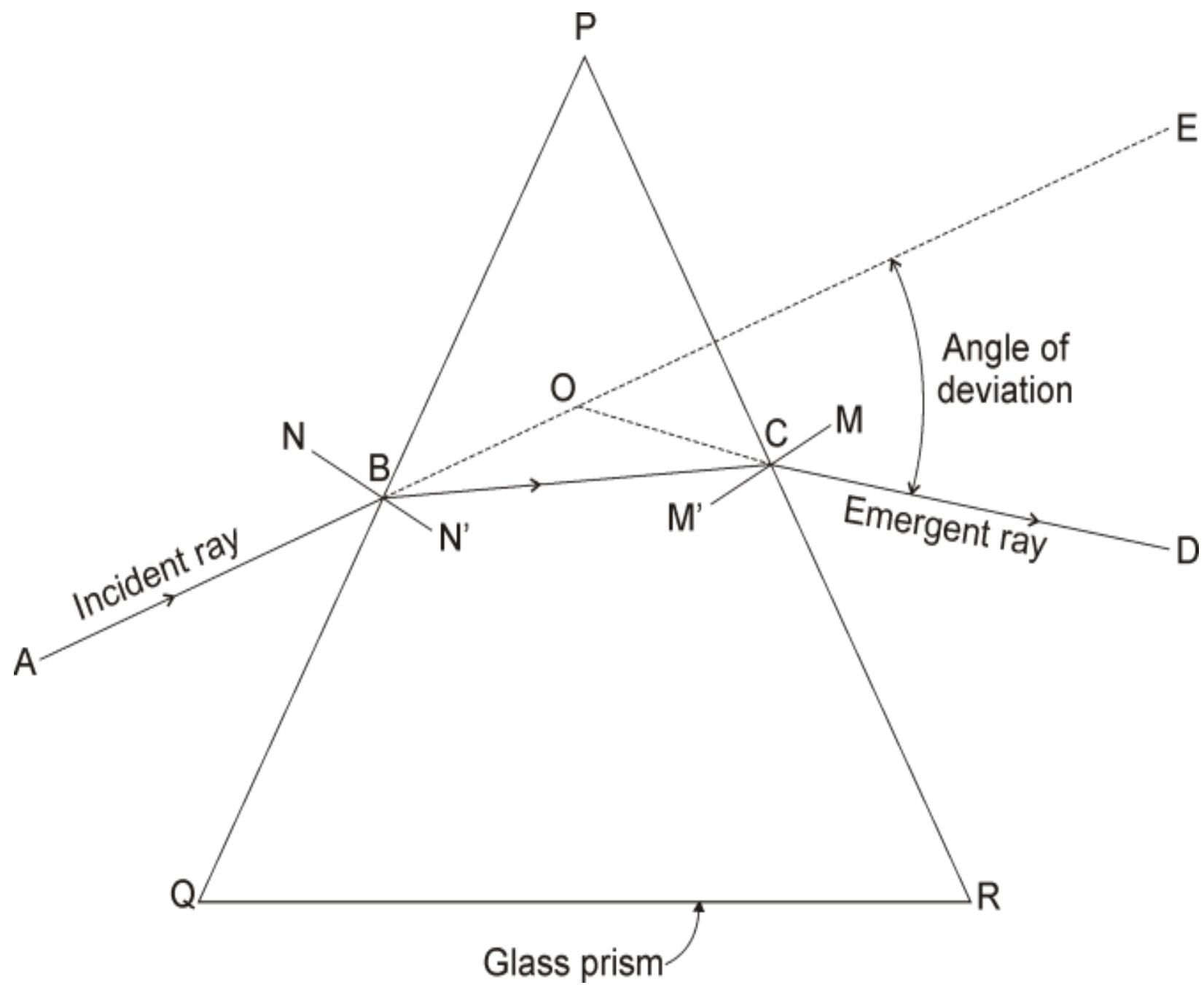
You have learnt how light gets refracted through a rectangular glass slab.

For parallel refracting surfaces, as in a glass slab, the emergent ray is parallel to the incident ray. However, it is slightly displaced laterally.

How would light get refracted through a transparent prism? Consider a triangular glass prism. It has two triangular bases and three rectangular lateral surfaces.

These surfaces are inclined to each other. The angle between its two lateral faces is called the angle of the prism.

Let us now do an activity to study the refraction of light through a triangular glass prism.



- Here PE is the incident ray, EF is the refracted ray and FS is the emergent ray. You may note that a ray of light is entering from air to glass at the first surface AB.
- The light ray on refraction has bent towards the normal. At the second surface AC, the light ray has entered from glass to air. Hence it has bent away from normal.
- Compare the angle of incidence and the angle of refraction at each refracting surface of the prism. Is this similar to the kind of bending that occurs in a glass slab?
- The peculiar shape of the prism makes the emergent ray bend at an angle to the direction of the incident ray.
- This angle is called the angle of deviation. In this case $\angle D$ is the angle of deviation. Mark the angle of deviation in the above activity and measure it.

DISPERSION OF WHITE LIGHT BY A GLASS PRISM

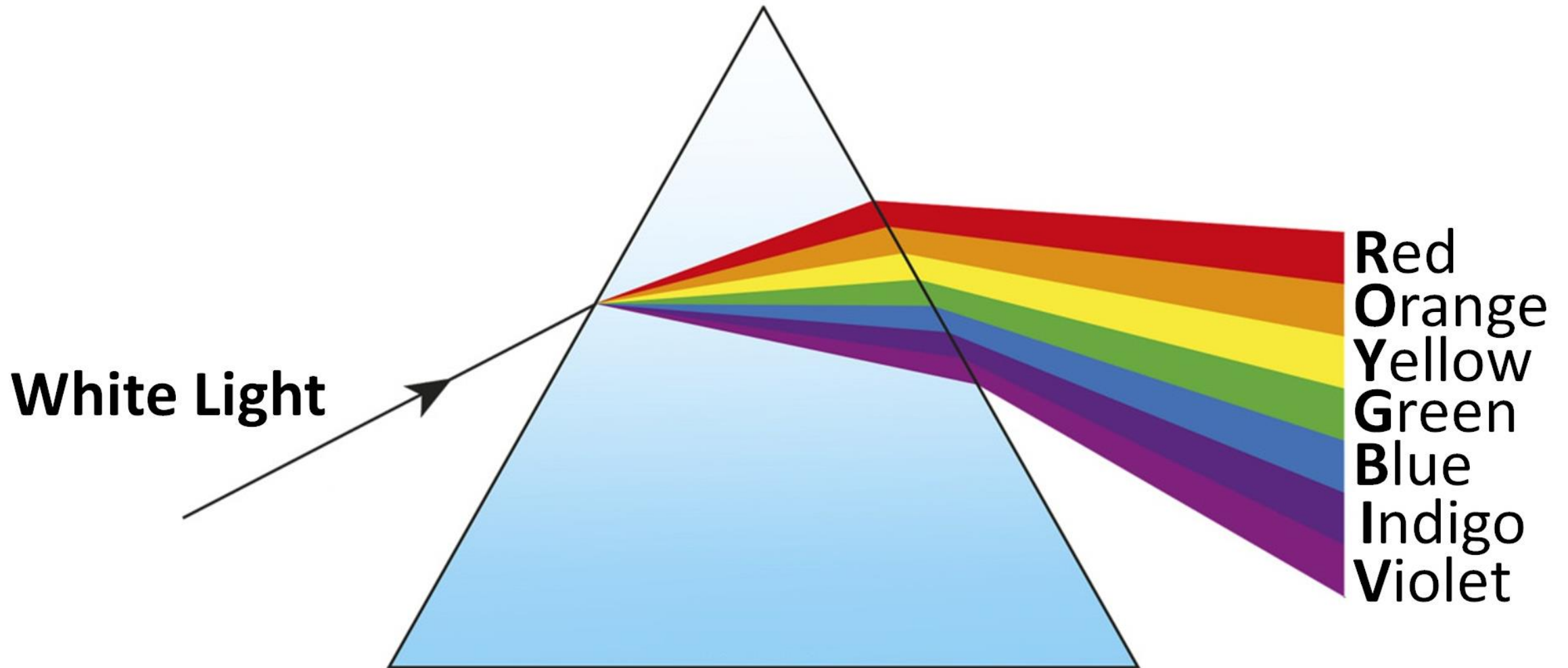
You must have seen and appreciated the spectacular colors in a rainbow. How could the white light of the Sun give us various colors of the rainbow?

Before we take up this question, we shall first go back to the refraction of light through a prism. The inclined refracting surfaces of a glass prism show exciting phenomenon.

The prism has probably split the incident white light into a band of colors. Note the colors that appear at the two ends of the color band. What is the sequence of colors that you see on the screen?

The various colors seen are Violet, Indigo, Blue, Green, Yellow, Orange and Red. The acronym VIBGYOR will help you to remember the sequence of colors.

Dispersion of White Light in a glass prism



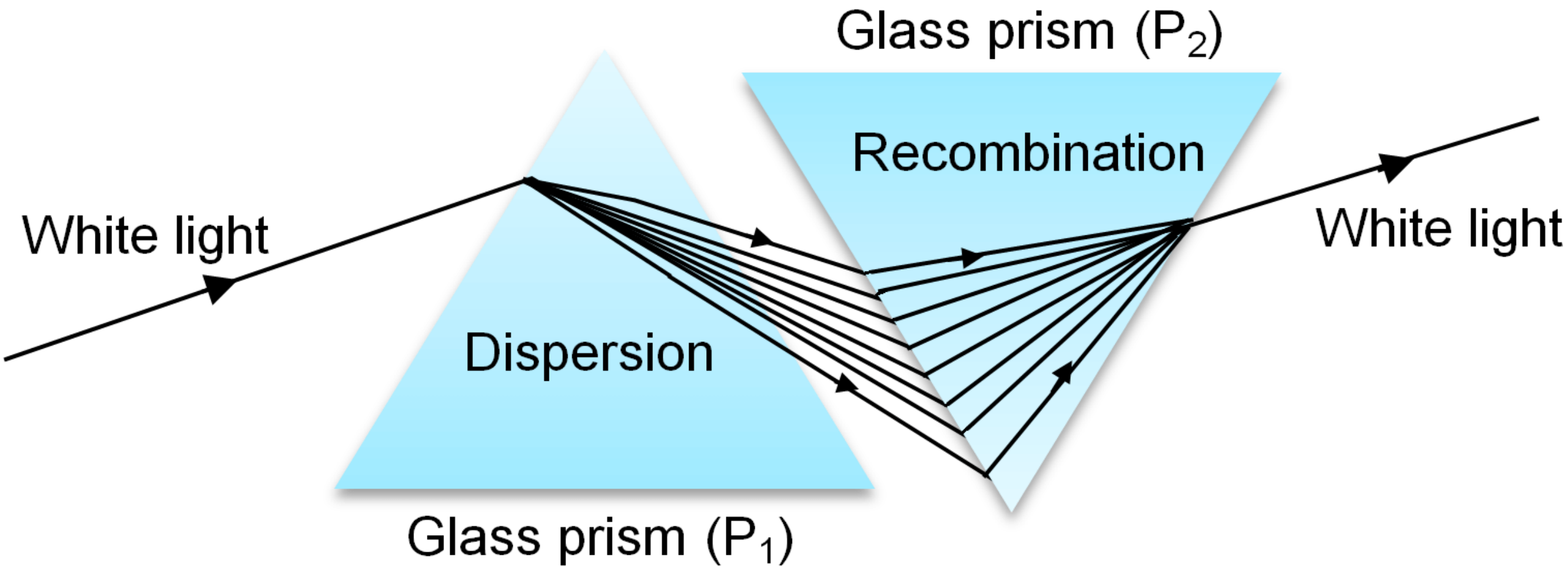
The band of the colored components of a light beam is called its spectrum.

You might not be able to see all the colors separately. Yet something makes each color distinct from the other. The splitting of light into its component colors is called dispersion.

You have seen that white light is dispersed into its seven-colour components by a prism. Why do we get these colors?

Different colors of light bend through different angles with respect to the incident ray, as they pass through a prism.

The red light bends the least while the violet the most. Thus the rays of each color emerge along different paths and thus become distinct. It is the band of distinct colors that we see in a spectrum.



Recombination of the spectrum of white light

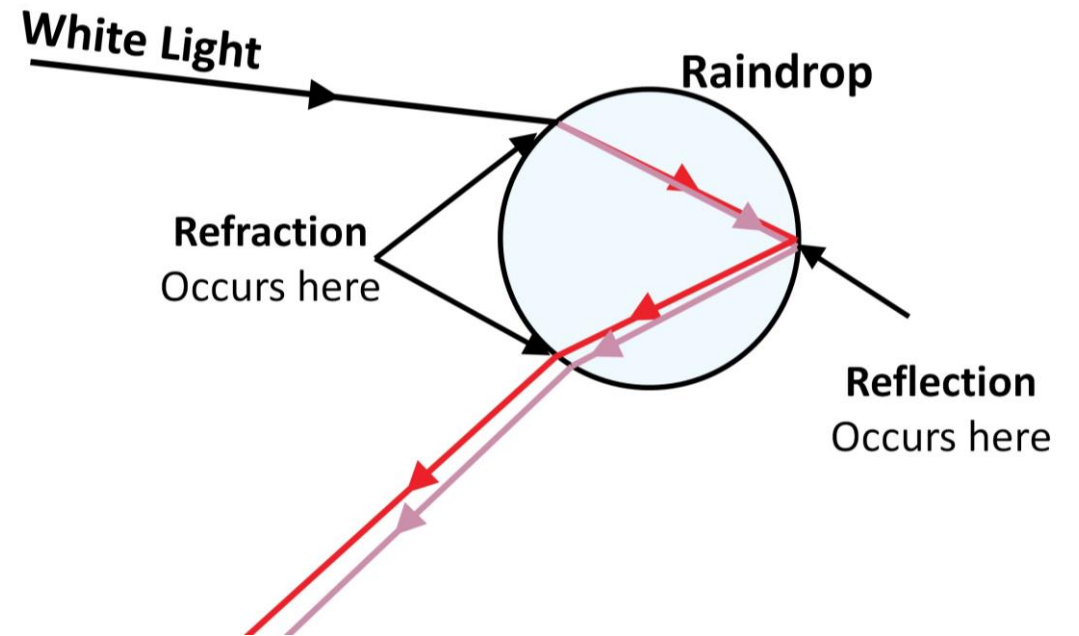
- Isaac Newton was the first to use a glass prism to obtain the spectrum of sunlight.
- He tried to split the colors of the spectrum of white light further by using another similar prism.
- However, he could not get any more colors. He then placed a second identical prism in an inverted position with respect to the first prism.
- This allowed all the colors of the spectrum to pass through the second prism. He found a beam of white light emerging from the other side of the second prism.
- This observation gave Newton the idea that the sunlight is made up of seven colors. Any light that gives a spectrum similar to that of sunlight is often referred to as white light.

- A rainbow is a natural spectrum appearing in the sky after a rain shower. It is caused by dispersion of sunlight by tiny water droplets, present in the atmosphere.
- A rainbow is always formed in a direction opposite to that of the Sun.
- The water droplets act like small prisms. They refract and disperse the incident sunlight, then reflect it internally, and finally refract it again when it comes out of the raindrop.
- Due to the dispersion of light and internal reflection, different colors reach the observer's eye.
- You can also see a rainbow on a sunny day when you look at the sky through a waterfall or through a water fountain, with the Sun behind you.



Rainbow in the sky

How is a Rainbow Formed?



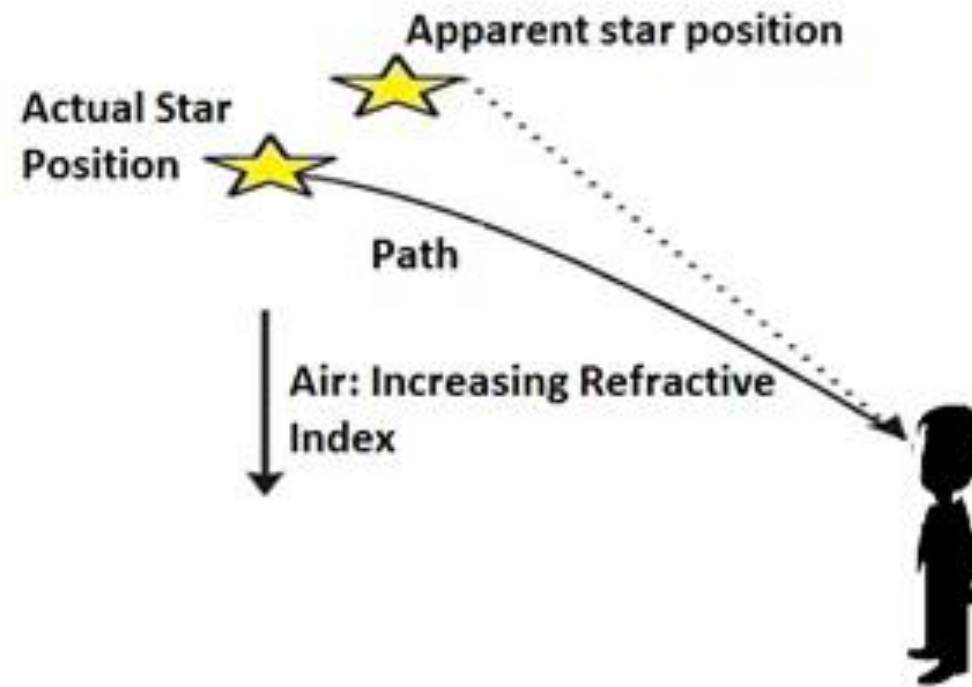
Rainbow formation

ATMOSPHERIC REFRACTION

- You might have observed the apparent random wavering or flickering of objects seen through a turbulent stream of hot air rising above a fire or a radiator.
- The air just above the fire becomes hotter than the air further up.
- The hotter air is lighter (less dense) than the cooler air above it, and has a refractive index slightly less than that of the cooler air.
- Since the physical conditions of the refracting medium (air) are not stationary, the apparent position of the object, as seen through the hot air, fluctuates.
- This wavering is thus an effect of atmospheric refraction (refraction of light by the earth's atmosphere) on a small scale in our local environment.
- The twinkling of stars is a similar phenomenon on a much larger scale. Let us see how we can explain it.

Twinkling of stars

- The twinkling of a star is due to atmospheric refraction of starlight. The starlight, on entering the earth's atmosphere, undergoes refraction continuously before it reaches the earth.
- The atmospheric refraction occurs in a medium of gradually changing refractive index.
- Since the atmosphere bends starlight towards the normal, the apparent position of the star is slightly different from its actual position.
- The star appears slightly higher (above) than its actual position when viewed near the horizon.
- Further, this apparent position of the star is not stationary, but keeps on changing slightly, since the physical conditions of the earth's atmosphere are not stationary, as was the case in the previous paragraph.

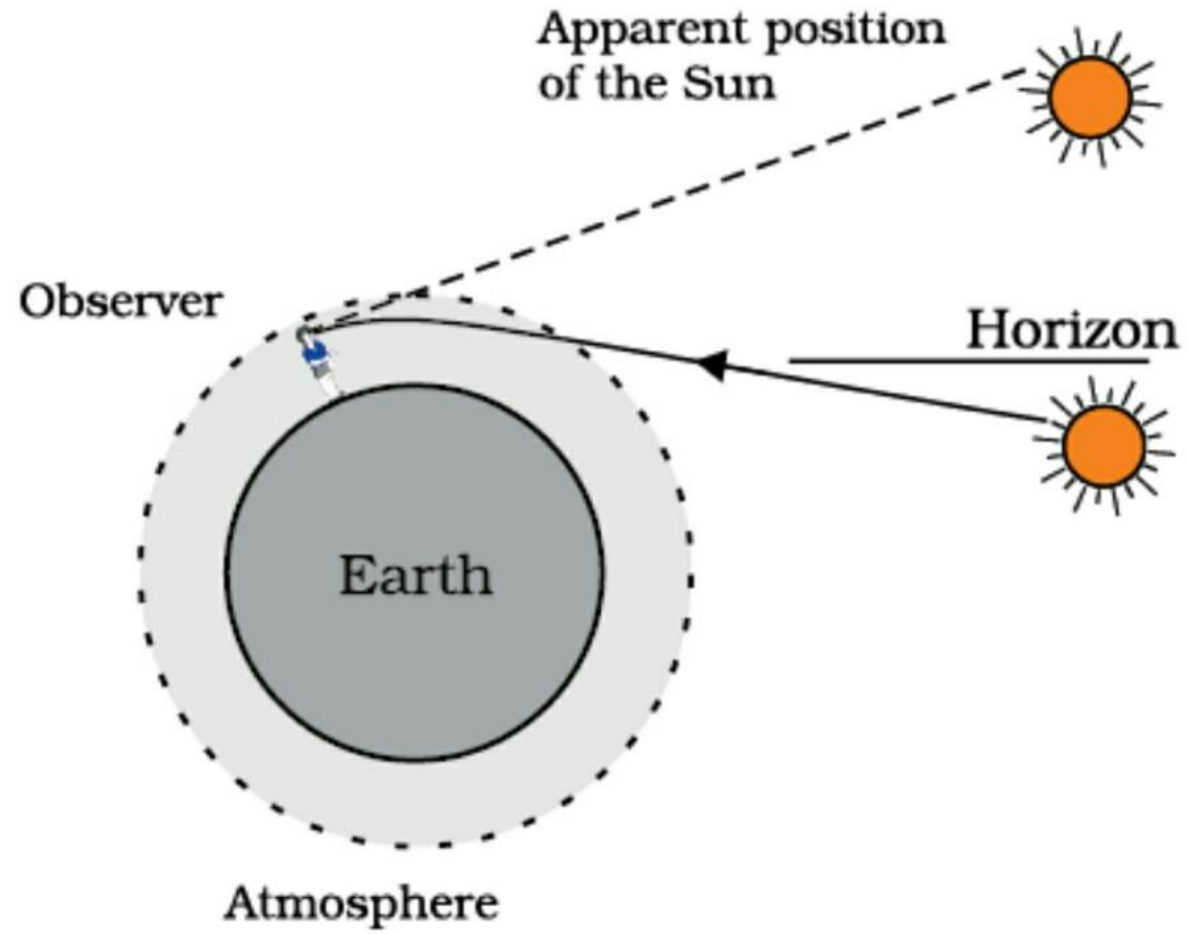


Apparent star position due to atmospheric refraction

- Since the stars are very distant, they approximate point-sized sources of light.
- As the path of rays of light coming from the star goes on varying slightly, the apparent position of the star fluctuates and the amount of starlight entering the eye flickers – the star sometimes appears brighter, and at some other time, fainter, which is the twinkling effect.
- Why don't the planets twinkle? The planets are much closer to the earth, and are thus seen as extended sources.
- If we consider a planet as a collection of a large number of point-sized sources of light, the total variation in the amount of light entering our eye from all the individual point-sized sources will average out to zero, thereby nullifying the twinkling effect.

Advance sunrise and delayed sunset

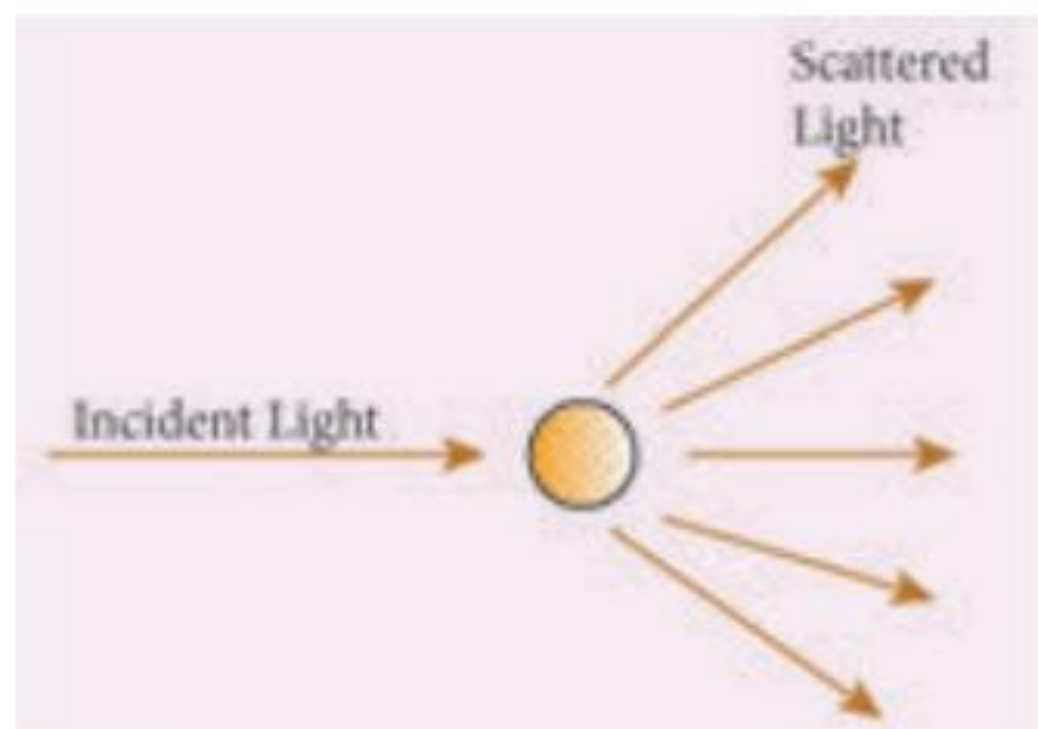
- The Sun is visible to us about 2 minutes before the actual sunrise, and about 2 minutes after the actual sunset because of atmospheric refraction.
- By actual sunrise, we mean the actual crossing of the horizon by the Sun.
- The actual and apparent positions of the Sun with respect to the horizon.
- The time difference between actual sunset and the apparent sunset is about 2 minutes.
- The apparent flattening of the Sun's disc at sunrise and sunset is also due to the same phenomenon.



Atmospheric refraction effects at sunrise and sunset

SCATTERING OF LIGHT

- The interplay of light with objects around us gives rise to several spectacular phenomena in nature.
- The blue colour of the sky, colour of water in deep sea, the reddening of the sun at sunrise and the sunset are some of the wonderful phenomena we are familiar with.
- In the previous class, you have learnt about the scattering of light by colloidal particles.
- The path of a beam of light passing through a true solution is not visible. However, its path becomes visible through a colloidal solution where the size of the particles is relatively larger.



Tyndall Effect

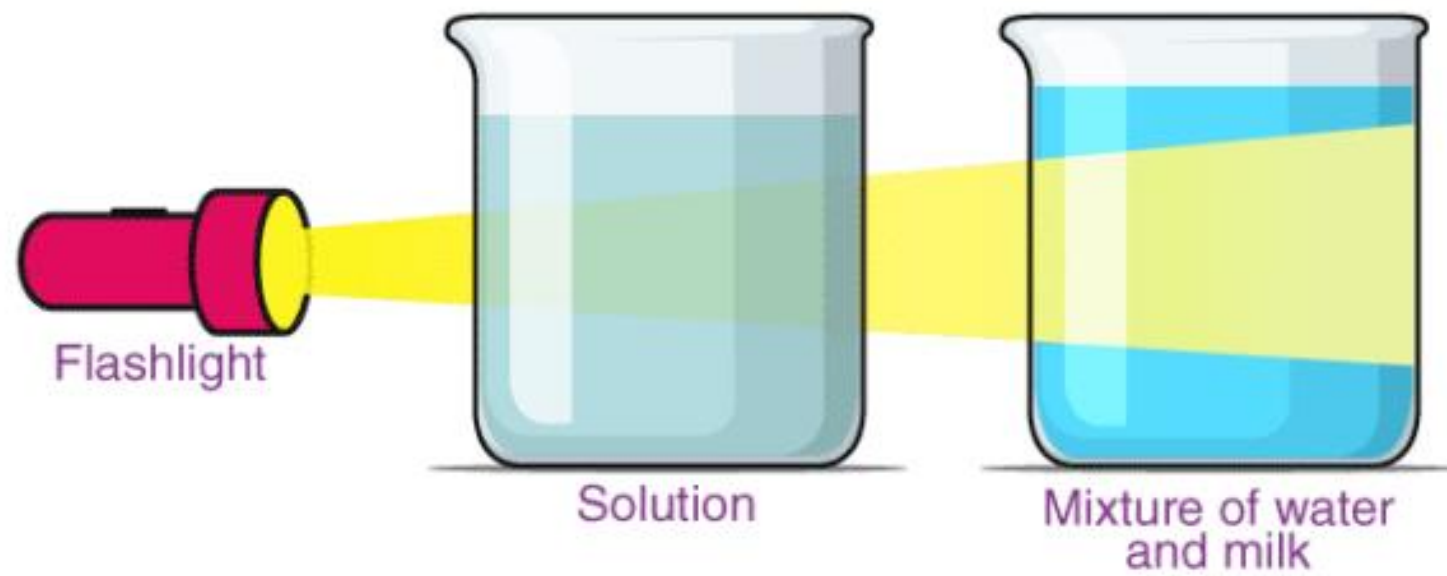
The earth's atmosphere is a heterogeneous mixture of minute particles.

These particles include smoke, tiny water droplets, suspended particles of dust and molecules of air.

When a beam of light strikes such fine particles, the path of the beam becomes visible. The light reaches us, after being reflected diffusely by these particles.

The phenomenon of scattering of light by the colloidal particles gives rise to Tyndall effect which you have studied in Class IX.

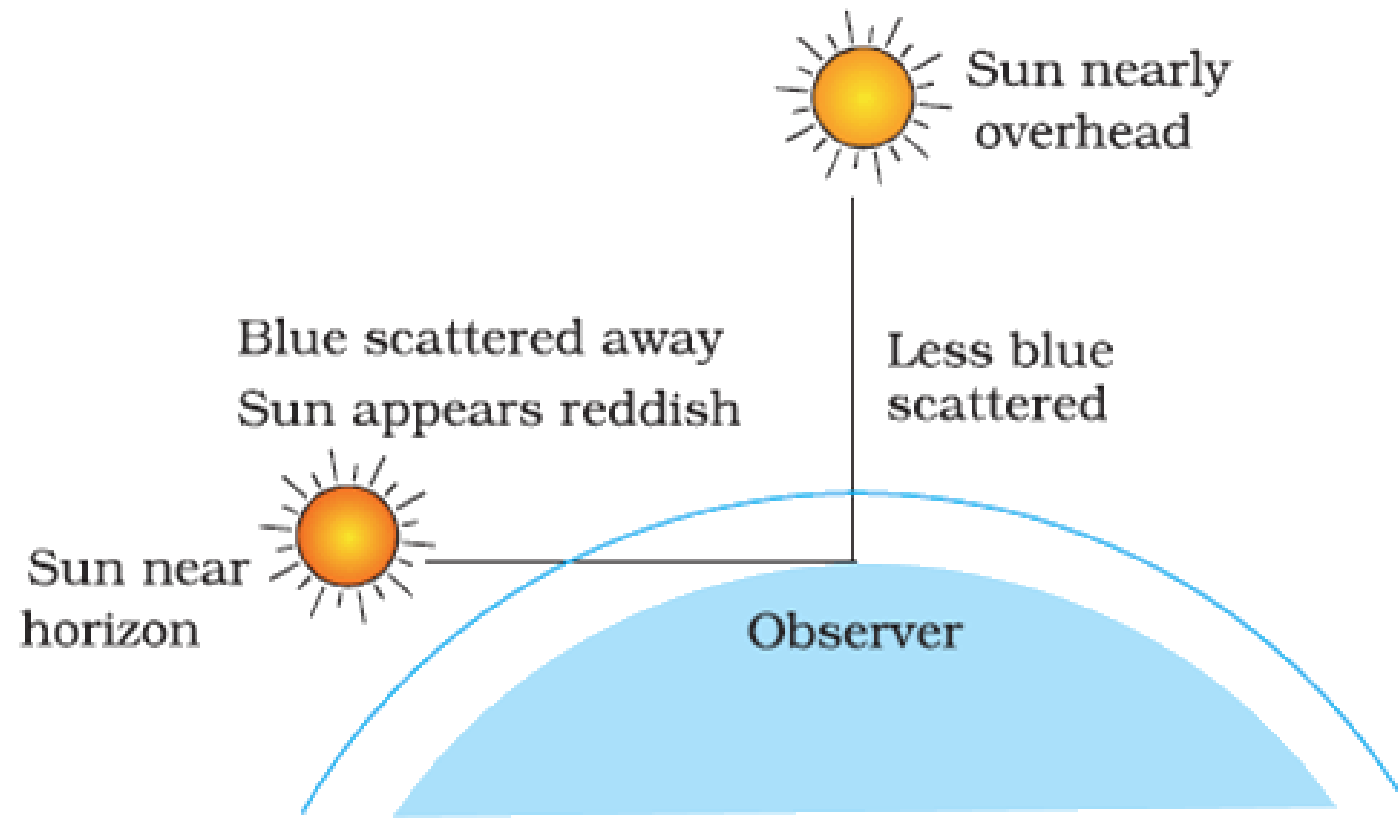
This phenomenon is seen when a fine beam of sunlight enters a smoke-filled room through a small hole.



- Thus, scattering of light makes the particles visible. Tyndall effect can also be observed when sunlight passes through a canopy of a dense forest.
- Here, tiny water droplets in the mist scatter light. The colour of the scattered light depends on the size of the scattering particles.
- Very fine particles scatter mainly blue light while particles of larger size scatter light of longer wavelengths.
- If the size of the scattering particles is large enough, then, the scattered light may even appear white.

Why is the colour of the clear Sky Blue?

- The molecules of air and other fine particles in the atmosphere have size smaller than the wavelength of visible light.
- These are more effective in scattering light of shorter wavelengths at the blue end than light of longer wavelengths at the red end.
- The red light has a wavelength about 1.8 times greater than blue light.
- Thus, when sunlight passes through the atmosphere, the fine particles in air scatter the blue colour (shorter wavelengths) more strongly than red.
- The scattered blue light enters our eyes. If the earth had no atmosphere, there would not have been any scattering. Then, the sky would have looked dark.



Reddening of the Sun at sunrise and sunset

- The sky appears dark to passengers flying at very high altitudes, as scattering is not prominent at such heights.
- You might have observed that 'danger' signal lights are red in colour. Do you know why? The red is least scattered by fog or smoke. Therefore, it can be seen in the same colour at a distance.
- Colour of the Sun at Sunrise and Sunset
- Have you seen the sky and the Sun at sunset or sunrise? Have you wondered as to why the Sun and the surrounding sky appear red?
- Let us do an activity to understand the blue colour of the sky and the reddish appearance of the Sun at the sunrise or sunset.

- You will find fine microscopic sulphur particles precipitating in about 2 to 3 minutes.
- As the sulphur particles begin to form, you can observe the blue light from the three sides of the glass tank.
- This is due to scattering of short wavelengths by minute colloidal sulphur particles.
- Observe the colour of the transmitted light from the fourth side of the glass tank facing the circular hole.
- It is interesting to observe at first the orange red colour and then bright crimson red colour on the screen.

This activity demonstrates the scattering of light that helps you to understand the bluish colour of the sky and the reddish appearance of the Sun at the sunrise or the sunset.

Light from the Sun near the horizon passes through thicker layers of air and larger distance in the earth's atmosphere before reaching our eyes .

However, light from the Sun overhead would travel relatively shorter distance. At noon, the Sun appears white as only a little of the blue and violet colors are scattered.

Near the horizon, most of the blue light and shorter wavelengths are scattered away by the particles. Therefore, the light that reaches our eyes is of longer wavelengths.

This gives rise to the reddish appearance of the Sun.

THANKYOU...