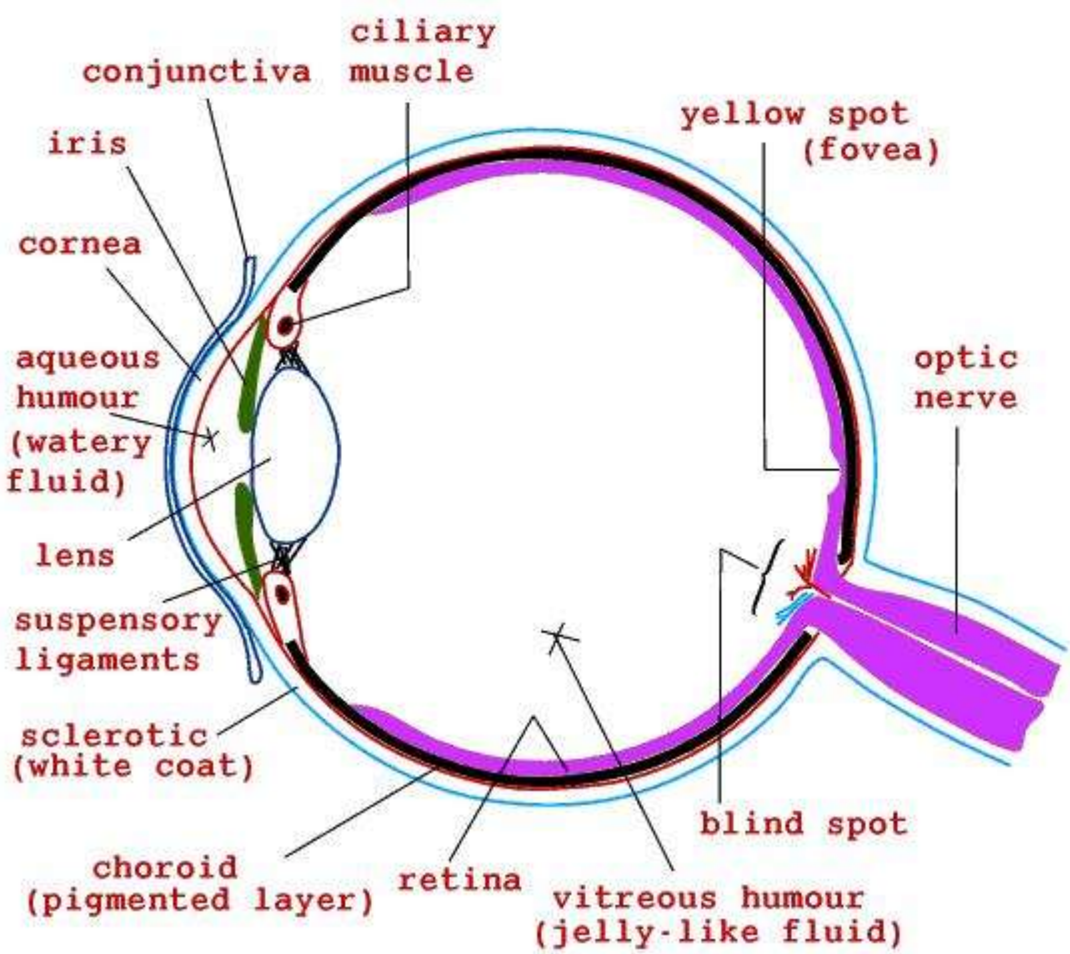
THE HUMAN EYE & THE COLOURFUL WORLD

THE HUMAN EYE

- The human eye is a natural optical device which enables us to see the surrounding object objects. **It is like a camera.** Its lens system forms a real inverted image of an object on a light sensitive surface called retina.
- Of all the sense organs, the human eye is most significant one as it enables us to see the beautiful coloured world around us.



IMPORTANT PARTS OF HUMAN EYE

- **Eye ball**: It is nearly spherical in shape of about 2.3 cm diameter. Its outermost coating is made up of tough and opaque while substance (called sclerotic), which preserves the shape of the eye as well as protects the eyes against any injury.
- **Cornea:** The front transparent part of the eye that is bulged outwards is called as cornea. It acts as the window of the eyes as light enters the eye through the cornea. **The cornea**

and aqueous humour acts as a lens and provides most of the refraction for the light rays entering the eyes.

- **Iris and Pupil**: Behind the cornea is the iris with a hole in the middle called pupil. The iris is a dark muscular diaphragm that controls the size of the pupil. Hence it **controls the amount of light entering the eye** by means of an involuntary muscle control. In dim light, the iris expands the pupil to allow more light to enter, and in bright light, the iris contracts the pupil to allow less light to enter the eye.

- **Crystalline lens:** It is a converging lens located just behind the iris. It is made up of fibrous, jelly like crystalline protein. It is held in position by ciliary muscles. The crystalline lens with the help of ciliary muscles merely **provides the finer adjustment of focal length** required to focus objects at different distances on the retina.

- **Aqueous Humour and Vitreous Humour**: The space between cornea and eye lens filled with a viscous liquid called aqueous humour. Along with cornea it acts as main lens and provides maximum refraction of light entering the eye.

  The space between eye lens and retina contains a transparent jelly called as vitreous humour. It gives shape to the eye.

- **Retina:** It is a delicate membrane behind the eye lens and at the back part of the eyeball, having enormous light sensitive cells called as rods and cones. **Rods cells** respond to intensity of light while **cone cells** respond to colour of light. These cells get activated upon illumination and generate electrical signals or nerve impulses which are sent to the brain via the **optic nerve**. The brain interprets these signals and finally processes the information and we perceive objects as they are.

POWER OF ACCOMMODATION

- With the help of ciliary muscles the focal length of the eye lens can be changed by changing its curvature.

- When we see distant object less bending of light rays is required to focus the rays on retina. At this time the ciliary muscles are relaxed, the lens becomes thin (less curvature). Thus its focal length increases and light bending ability of the lens decreases and image is focused sharply on retina.

- When we see near object more bending of light rays is required to focus the rays on retina. At this time the ciliary muscles are contracts, the lens becomes thick (more curvature). Thus its focal length decreases and light bending ability of the lens increases and image is focused sharply on retina.

- **Accommodation is the ability of eye by which it changes the focal length of the eye lens such that a sharp image is always formed on the retina.**

- Although the power of accommodation of the eye is amazing, it has certain limitations. The focal length of the eye cannot adjust enough to form a sharp images of objects kept beyond a certain point and closer than a certain point.
- The farthest point up to which the eye can see properly is called **far point of the eye**. For the normal eye, the far point is **infinity**. When looking an object at the far point, the ciliary muscles are in their most relaxed state and lens is in flattest possible shape. Thus eye lens has maximum focal length when looking at an object at the far point.
- As an object is brought closer to the eye, the ciliary muscles contact to decrease the focal length of the eye lens such that the sharp image is formed on the retina. The minimum distance at which the object can be seen most distinctly without strain is called **least distance of distinct vision**. It is also called the **near point**. For normal eye, the near point is **25 cm**.
- Thus a normal eye can see objects clearly that are between 25 cm and infinity.
- **The maximum variation in the power of the eye lens can be achieved by the eye of a person is called its power of accommodation. For normal eye, the power of accommodation is about 4 dioptres.**
- Sometimes, the crystalline lens of people at old age becomes milky or cloudy. This condition is called **cataract.** This causes partial or complete loss of vision. Normal vision can be restored through a cataract surgery.

DEFECTS OF VISION AND THEIR CORRECTION

- On loosing the power of accommodation the eye of a person cannot see the object distinctly and comfortably without strain on his eyes. The vision becomes blurred or defective due to the refractive defects of the eye.
- There are mainly three common refractive defects of vision. These are:
  1. Myopia or near-sightedness or near-sightedness,
  2. Hypermetropia or far-sightedness,
  3. Presbyopia.

MYOPIA OR NEAR-SIGHTEDNESS

- Myopia or near-sightedness is that defect of human eye due to which a person can see clearly objects lying at short distances from it, but cannot see far off objects clearly.
- A person with this defect has the far point nearer than infinity. Such a person may see clearly upto a distance of few metres.

- **It is caused due to:**
  - Elongation of the eye ball.
  - Excessive curvature of the eye lens.
  - Derease in focal length of the eye lens in the relaxed state.
- Due to this, the image of an object beyond a specific far off point falls before the retina hence cannot be seen clearly.

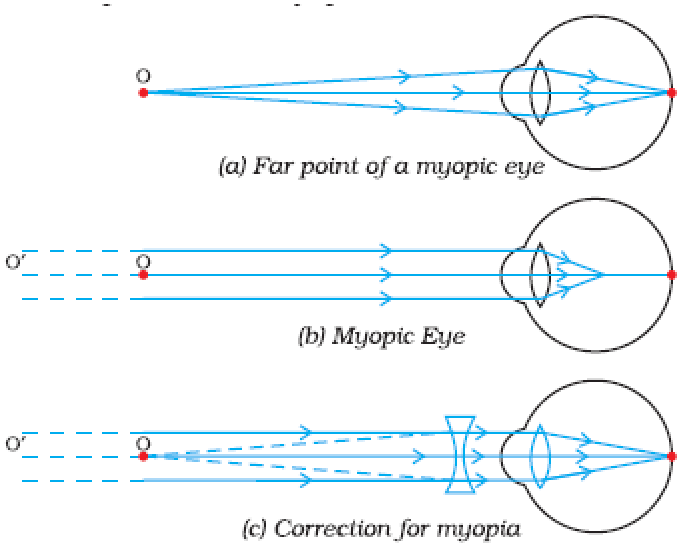


Figure 11.2
(a), (b) The myopic eye, and (c) correction for myopia with a concave lens

- **Correction:** Myopia can be correction by using spectacles of **concave lens** of suitable focal length, which diverges and shifts the image to the retina.

HYPERMETROPIA OR LONG-SIGHTEDNESS.

- It is the defect of human eye in which a person can see clearly objects at large distances from it, but cannot see nearby objects clearly.
- 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.
- **It is caused due to:**
  - Shortening of the eyeball.
  - Increase in focal length of the eye lens in the relaxed state.
- Due to this, the image of nearby objects is formed beyond the retina.

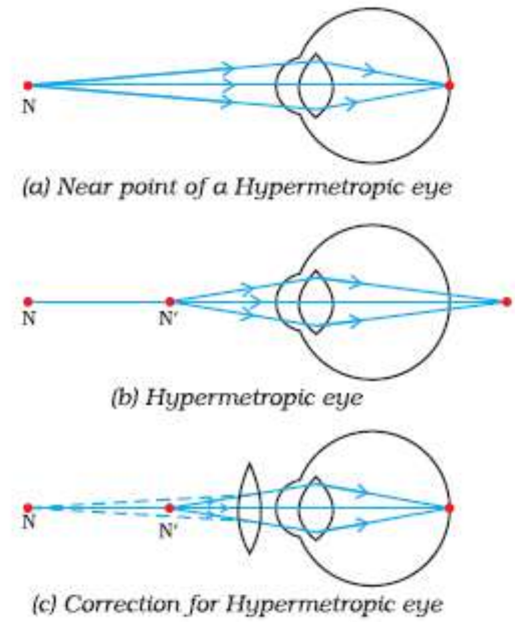


Figure 11.3
(a), (b) The hypermetropic eye, and (c) correction for hypermetropia

- **Correction:** It is corrected by using spectacles having **convex lens**, which converges and shifts the image to retina from beyond.

PRESBYOPIA

- With growing age, a person is unable to read and write comfortably because the power of accommodation of the eye usually decreases with ageing. And near point gradually recedes away.
- **It is caused due to**
  - Weakening of ciliary muscles,
  - Diminishing flexibility of the eye ball.
- **Correction:** A person suffering from presbyopia should wear **convex lens** of suitable focal length.

NOTE:

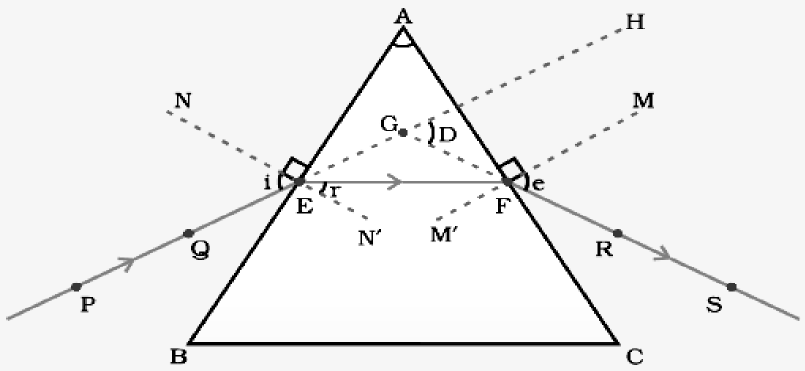
- Sometime, a person may suffer from both myopia and hypermetropia. Such people often required bi-focal lenses. A common type of bi-focal lenses consists of both concave and convex lenses. The upper portion consists of a concave lens. It facilitates distant vision. The lower part is a convex lens. It facilitates near vision.
- Contact lenses and surgical intervention are also used as corrective measure for refractive defects.

REFRACTION OF LIGHT THROUGH A PRISM

- When the light passes through a rectangular glass slab, it undergoes refraction and the emergent ray is parallel to incident ray but slightly displaced sideways. This is because of two parallel refractive surfaces of the of the glass slab.
- Light rays behave in some different ways after refraction when the two refractive surfaces inclined to each other at an angle. As in case of prism.
- A medium bounded by two plain refractive surfaces at an angle to each other is called a **Prism**. This angle is called the **angle of prism** and is denoted by A.
- The surface opposite to the angle A is the **base of the prism**. The line along which the refracting surface meets is known as the refracting edge of the prism.
- So a prism has two triangular bases and rectangular lateral surfaces. A section of prism cut by a plane at right angles to the refracting edge of the prism is called **principal section of the prism.**

- **Activity : 11.1**

- Fix a sheet of white paper on a drawing board using drawing pins.
- Place a glass prism on it in such a way that it rests on its triangular base. Trace the outline of the prism using a pencil.
- Draw a straight line PE inclined to one of the refracting surfaces, say AB, of the prism.
- Fix two pins, say at points P and Q, on the line PE as shown in Fig. 11.4.
- Look for the images of the pins, fixed at P and Q, through the other face AC.
- Fix two more pins, at points R and S, such that the pins at R and S and the images of the pins at P and Q lie on the same straight line.
- Remove the pins and the glass prism.
- The line PE meets the boundary of the prism at point E (see Fig. 11.4). Similarly, join and produce the points R and S. Let these lines meet the boundary of the prism at E and F, respectively. Join E and F.
- Draw perpendiculars to the refracting surfaces AB and AC of the prism at points E and F, respectively.
- Mark the angle of incidence (∠i), the angle of refraction (∠r) and the angle of emergence (∠e) as shown in Fig. 11.4.



PE – Incident ray
EF – Refracted ray
FS – Emergent ray
∠A – Angle of the prism

∠i – Angle of incidence
∠r – Angle of refraction
∠e – Angle of emergence
∠D – Angle of deviation

Figure 11.4 *Refraction of light through a triangular glass prism*

- We see that in the prism ABC, the light is refracted twice from the two surfaces AB and AC which are inclined to each other at an angle A.

- When light ray PQ falls on the first refracting surface AB, it passes from rarer medium (air) to denser medium (glass) and therefore bends towards the normal travelling along a path EF.

- This ray again gets refracted at the second surface AC. This time it is passing from denser medium to rarer medium, hence it bends away from the normal and emerges into air along the path RS.

- Here incident ray and emergent ray are not parallel to each other. The incident ray and emergent ray if produced backward intersect at G making an angle **D** known as **angle of deviation**. Through which the incident ray is deviated by the prism.
- *Thus a prism always deviates a light ray from its original direction through an angle D because of its peculiar shape and it bends the rays towards its base.*
- *After measuring angle i and angle e. some more relations comes in:*

1. *Angle i + Angle e = Angle A + Angle D*
2. *Angle of deviation is directly proportional to the angle of prism, greater the angle of prism A: greater will be the angle of deviation D.*
3. *Higher the refractive index of the prism material, greater is the angle of deviation D.*
4. *Longer the wavelength, lower the refractive index of the material of the prism. Value of RI changes with light of different wavelength.*

DISPERSION OF WHITE LIGHT BY A GLASS PRISM

- The process of splitting of white light passing through a glass prism into its seven constitute colours is called dispersion of white light.
- The band of seven colours formed on a screen due to the dispersion of white light is called spectrum of visible light or spectrum of white light (VIBGYOR).

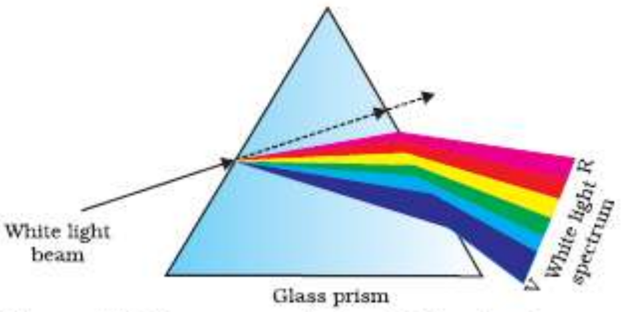


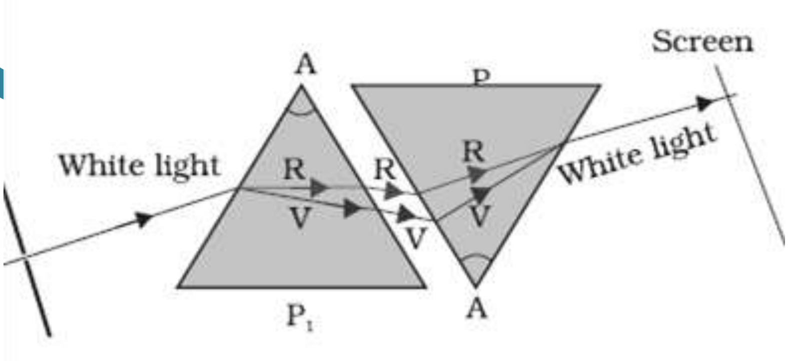
Figure 11.5 *Dispersion of white light by the glass prism*

- **Cause of Dispersion**
- White light is composed of seven different colours of light each having a different colour due to different wavelength. Red has the longest wavelength and violet the shortest.
- The frequency of light is the same for all different colours. In vacuum or air, the speed of light is same for all lights.
- But in different media, the speed of light is different of all the colours. So, each light bends to a different angle from the normal. Red light travelling fastest in any medium bends the least and violet light travelling slowest bends maximum.

- So, when light is passed through a glass prism, each light bends to a different angle forming a spectrum of light.
- **Red colour:-**
    - ***It has maximum wavelength.***
    - *It has maximum speed in any medium.*
    - *It has maximum angle of refraction in any medium.*
    - *RI of medium is for red light is least.*
    - ***It deviates the least in any medium.***
- **Violet colour:-**
    - ***It has minimum wavelength.***
    - *It has minimum speed in any medium.*
    - *It has minimum angle of refraction in any medium.*
    - *RI of medium is for red light is minimum.*
    - ***It deviates the most in any medium.***

Recombination of the spectrum of white light

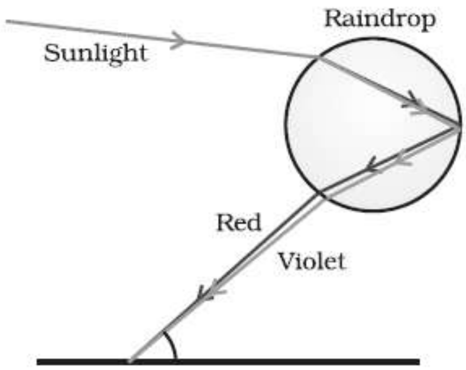
- In the year 1665, Sir Isaac Newton showed for the first time that sunlight is a mixture of seven colours which can be separated from each other by the prism. He actually obtained the spectrum of sunlight with the help of prism.



- He tried to further split up the colours of the spectrum by using similar prism. However, he could not get any more colours.
- He also showed that if a second prism (identical to the first) placed inverted in the path of the spectrum formed by the first prism, then a beam of white light emerges out from the other side of the second prism. This is called Recombination of the spectrum of white light.

- It is because the first prism dispersed the white light into seven colours and when these seven components pass through the second prism, they recombine to form white light. This observation gave Newton the idea that the sunlight is made up of seven colours.

Rainbow: A natural spectrum



- The rainbow is the spectrum of sunlight in nature. When the atmosphere is moisture laden heavily, at the time of rain, spherical water droplets acts as prism and refract the sunlight to lead to the formation of rainbow. A rainbow is always formed in the direction opposite to that of sun.
- Parallel beams of light coming from sun get dispersed at the first surface of water droplet. Inside the droplet, it suffers total internal reflection at the second inner surface and comes out into air as an emergent ray. The raindrops act as an assembly of prisms and spilt white light into its component colours.

ATMOSPHERIC REFRACTION

- Atmosphere is consists of different layers of colourless gases, having different densities at different heights. The air near the earth is denser than the air at high altitudes. Density of air gradually decreases as we move towards the higher altitude. Therefore refractive index is also decreases in the same manner.
- As light passes through atmosphere towards the earth surface, it encounters increasing optical density therefore increasing refractive indices. And light rays undergo refraction. As the light rays is keep on travelling from rarer medium to denser medium, it continuously bends towards the normal and make a smooth curved path.
- Thus refraction of light rays due to atmosphere having layers of air of different optical densities is called atmospheric refraction.

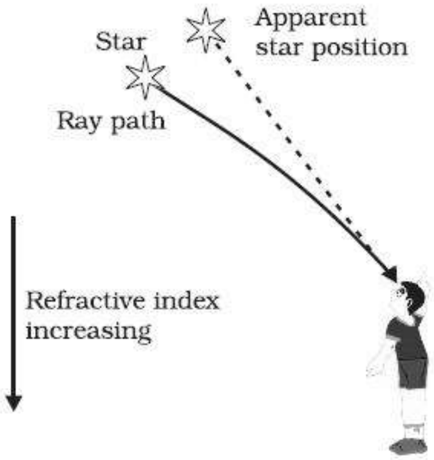
WAVERING OR FLICKERING OF OBJECTS SEEN THROUGH HOT AIR

- The air just above or around the fire or hot object is hot as compared to the air far away from fire. The hot air is less dense, therefore it is optically rarer and the cooler air is dense, therefore it is optically denser.

- Due to change in refractive index of air and also because the layers of air are not stationary, the apparent position of the object as seen through the hot air fluctuate due to atmospheric refraction and gives the flickering effect.

APPARENT HEIGHT OF STARS

- Atmospheric pressure keeps on decreasing considerably with height. As a result, the upper layers of atmosphere are optically rarer than lower layers. The rays of light suffer refraction at each layer of atmosphere and bends slightly towards normal. Thus, each ray of light from the star follows a curved path to reach the observer. And an observer's eye traces the straight line path and the rays appear to coming from a point higher in horizon, which gives the apparent height to star.



TWINKLING OF STARS

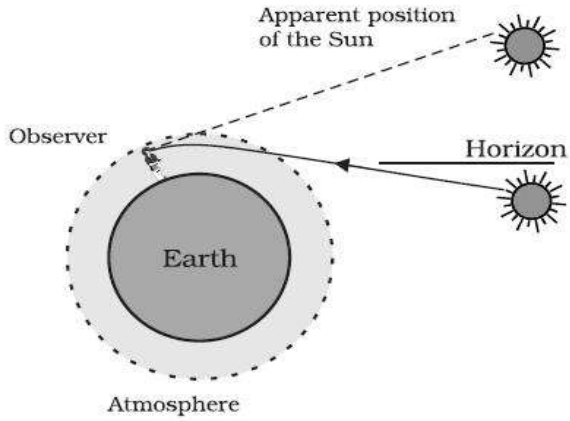
- The physical conditions of these layers of air are not stationary. So the optical densities and refractive indices go on changing continuously. Since the stars are very distant, they approximately point-sized sources of light. As a result, the final direction of the ray reaching the eye also changes, causing the image of the star to shift in random direction from its mean position. This fluctuating image of the star makes it appear as twinkling to the observer.

PLANETS DO NOT TWINKLE

- As the distance between the planet and earth is less as compared to the stars, the planets can be considered as extended object or collection of a large number of point objects. Their apparent position also changes due to variation in optical densities of different layers of atmosphere. But since the planets are nearer to the eye as compared to stars the random shift in their position cannot be observed. The twinkling effect is nullified due to its big size.

ADVANCE SUNRISE AND DELAYED SUNSET

- Air near the earth is optically denser than that at higher altitude. The sun ray, thus while travelling to reach the surface of the earth, suffer refraction at each layer travelling from a rarer to a denser medium. So due to these bent rays, the sun appears



higher in the horizon that it actually is. Therefore, the sun becomes visible about 2 minutes before its actual sunrise and remains visible for about 2 minutes after its actual sunset.

Flattening of Sun at Sunrise and Sunset

- At the time of sunrise or sunset, the sun is just near the horizon. Its lower edge is nearer than its upper edge. The ray of light from its lower edge travel greater length of atmosphere. Due to this, the lower edge appears to be raised more than the upper edge and hence sun is not seen spherical but elliptical or flat at the time of sunrise or sunset.

Scattering of Light

- When light enters a darkened room through a small hole, the dust particle present in the air scatter light and path of the light become visible.
- In a dense forest in the morning when sunlight passes through a canopy of the dense forest, the tiny water droplets present in the mist scatter the light rays.
- The path of a beam of light passing through a true solution is not visible. However, its path becomes visible though a colloidal solution where the size of the particles is relatively larger. This is due to scattering of light due to particles in colloidal solution.
- The phenomenon of scattering of light was first studied by Tyndall and is called **Tyndall effect.**
- **Tyndall effect:** The scattering of light takes place in all directions when a beam of light passes through a colloidal solution which contains fine suspended particles.
- The colour of the scattered light depends on the size of the scattered particles. Very fine particles scatter mainly blue light while particles of larger size scatter light of longer wavelengths. If the size of the scattering particle is large enough, then, the scattered light may even appear white.

Activity : 11:3

- Place a strong source (S) of white light at the focus of a converging lens (L_1). This lens provides a parallel beam of light.
- Allow the light beam to pass through a transparent glass tank (T) containing clear water.
- Allow the beam of light to pass through a circular hole (c) made in a cardboard. Obtain a sharp image of the circular hole on a screen (MN) using a second converging lens (L_2), as shown in Fig. 11.11.
- Dissolve about 200 g of sodium thiosulphate (hypo) in about 2 L of clean water taken in the tank. Add about 1 to 2 mL of concentrated sulphuric acid to the water. What do you observe?

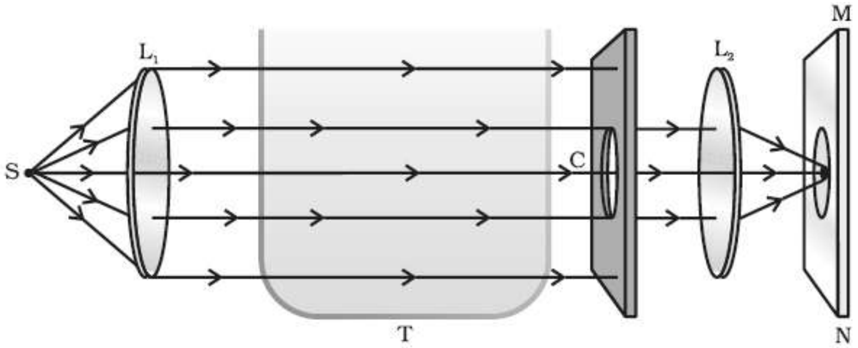


Figure 11.11
An arrangement for observing scattering of light in colloidal solution

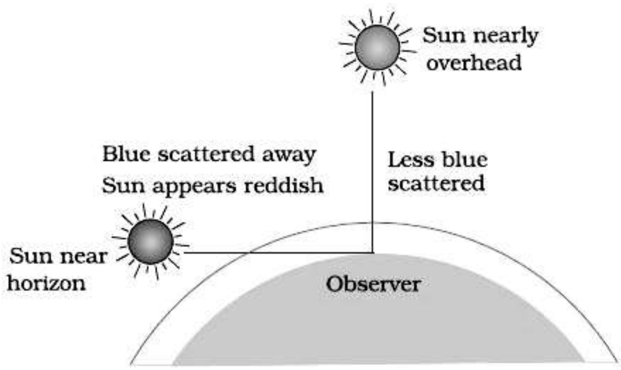
- Within 2 to 3 minutes fine microscopic sulphur particles starts precipitating and blue light coming from the three sides of the glass tank can be observed.
- On the fourth side of the glass tank facing the circular hole, first the orange red colour and then the bright crimson red colour on screen can be observed.

BLUE COLOUR OF SKY

- In white light, the blue colour has smallest wavelength and in the atmosphere the molecules of air and other fine particles have sizes smaller than the wavelength of visible light. Therefore blue light is scattered more than any other colour. That is why sky appears blue.
- If earth had no atmosphere, there would not have not been any scattering the sky would have looked dark. That is why it appears dark to the passengers flying at very high altitudes, as scattering is not prominent at such heights.

COLOUR OF THE SUN AT SUNRISE AND SUNSET

- At the time of sunset and sunrise, when the sun is near the horizon, the light rays from the sun have to travel larger thickness of atmosphere and larger distance in the earth's atmosphere than when the sun is overhead in the noon.
- The light waves of shorter wavelengths, blue and violet, get scattered by the particle near the horizon but the longer wavelengths, orange and red, are scattered least. They travel relatively undisturbed and reach the earth. So the light reaching us is dominant in red and deficient in blue and we see beautiful orange



reddish appearance of the sun.

Red Light is Used in Danger Signal

- Red light, due to its longest wavelength in visible spectrum, is least scattered. So danger signals are made red so that they can be seen from large distances.

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