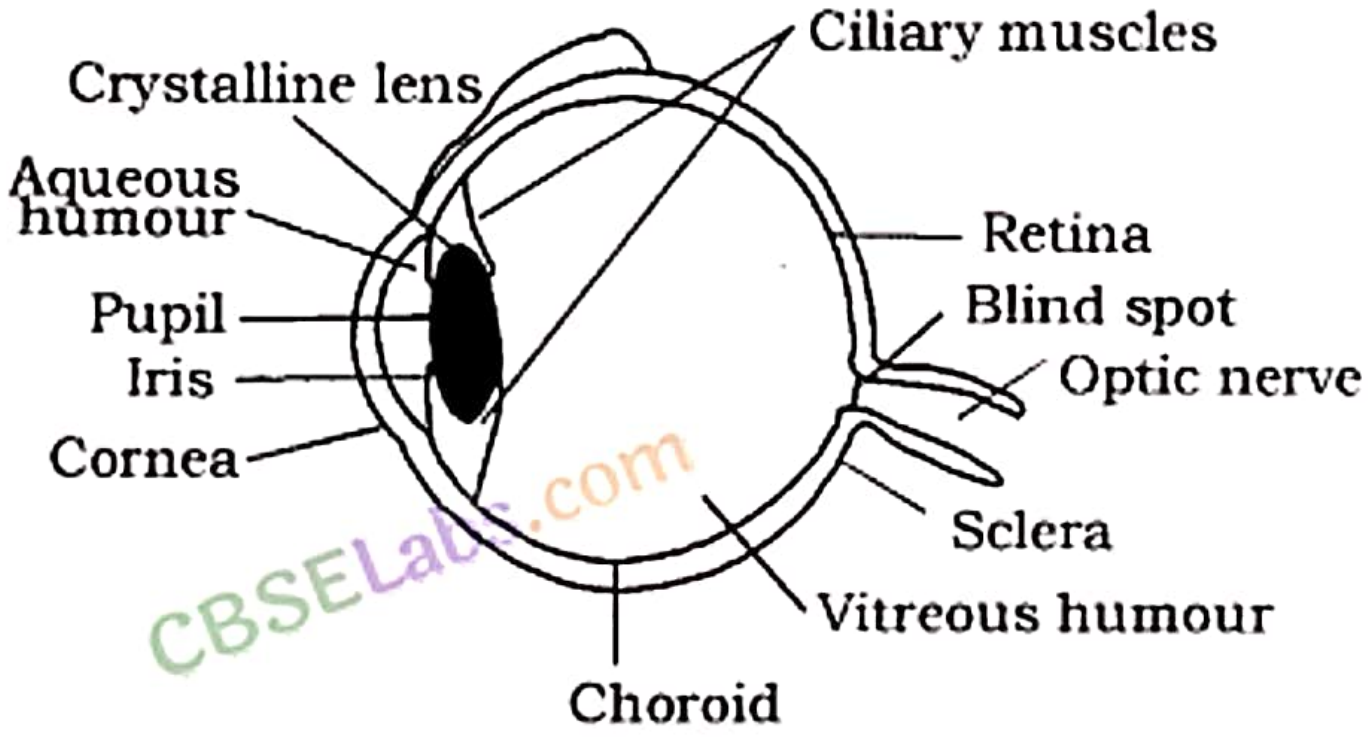
Human Eye: working of human eye, Persistence of vision, Power of accommodation of human eye, Defects of vision.

The Human Eye: It is a natural optical instrument which is used to see the objects by human beings. It is like a camera which has a lens and screen system.

Structure of the Human Eye



- *Retina: It is a light sensitive screen inside the eye on which image is formed. It contains rods and cones.*
- *Cornea: It is a thin membrane which covers the eye trail. It acts like a lens which refracts the light entering the eye.*
- *Aqueous humour: It is fluid which fills the space between cornea and eye lens.*
- *Eye lens: It is a convex lens made of transparent and flexible jelly like material. Its curvature can be adjusted with the help of ciliary muscles.*
- *Pupil: It is a hole in the middle of iris through which light enters the eye. It appears black because light falling on it goes into the eye and does not come back.*

- Ciliary muscles: These are the muscles which are attached to eye lens and can modify the shape of eye lens which leads to the variation in focal lengths.
- Iris: It controls the amount of light entering the eye by changing the size of the pupil.
- Optical nerve: These are the nerves which take the image to the brain in the form of electrical signals.

The human eye is roughly spherical in shape with a diameter of about 2.3 cm. It consists of a convex lens made up of living tissues. Hence, human lenses are living organs contrary to the simple optical lenses. The following table lists the main parts of the human eye and their respective functions.

Human Eye Part	Functions
Pupil	Opens and closes in order to regulate and control the amount of light.
Iris	Controls light level similar to the aperture of a camera.
Sclera	Protects the outer coat.
Cornea	A thin membrane which provides 67% of the eye's focusing power.

5.	Crystalline lens	Helps to focus light into the retina.
6.	Conjunctive	Covers the outer surface (visible part) of the eye.
7.	Aqueous humour	Provides power to the cornea.
8.	Vitreous humour	Provides the eye with its form and shape.
9.	Retina	Captures the light rays focussed by the lens and sends impulses to the brain via the optic

		nerve.
10.	Optic nerve	Transmits electrical signals to the brain.
11.	Ciliary muscles	Contracts and extends in order to change the lens shape for focusing.

How Pupil Works?

For Example, You would have observed that when you come out of the cinema hall after watching the movie in the bright sunlight, your eyes get closed. And when you entered the hall from the bright light, you won't be able to see and after some time you would be able to see. Here, the pupil of an eye provides a variable aperture, whose size is controlled by iris.

(a) When the light is bright: Iris contracts the pupil, so that less light enters the eye.
(b) When the light is dim: Iris expands the pupil, so that more light enters the eye.
Pupil opens completely when iris is relaxed.

Persistence of Vision: It is the time for which the sensation of an object continue in the eye. It is about 1/16th of a second

Power of Accommodation: The ability of the eye lens to adjust its focal length accordingly as the distances is called power of accommodation.

Ciliary muscles

Relaxed	Contract
1. Eye lens become thin.	1. Eye lens become thick.
2. Increases the focal length.	2. Decreases the focal length.
3. Enable us to see distant object clearly.	3. Enable us to see nearby object clearly.

Near point of the Eye	Far point of the Eye
It is 25 cm for normal eye. The minimum distance at which object can be seen most distinctly without strain.	It is infinity for normal eye. It is the farthest point upto which the eye can see object clearly.

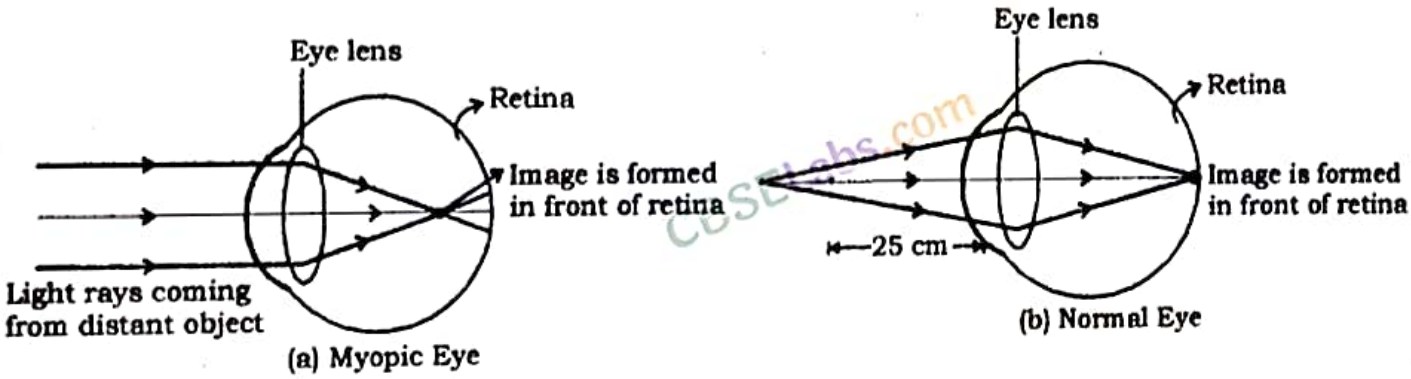
Colour Blindness: A person having defective cone cells is not able to distinguish between the different colours. This defect is known as Colour Blindness.

Defects of Vision and their Correction

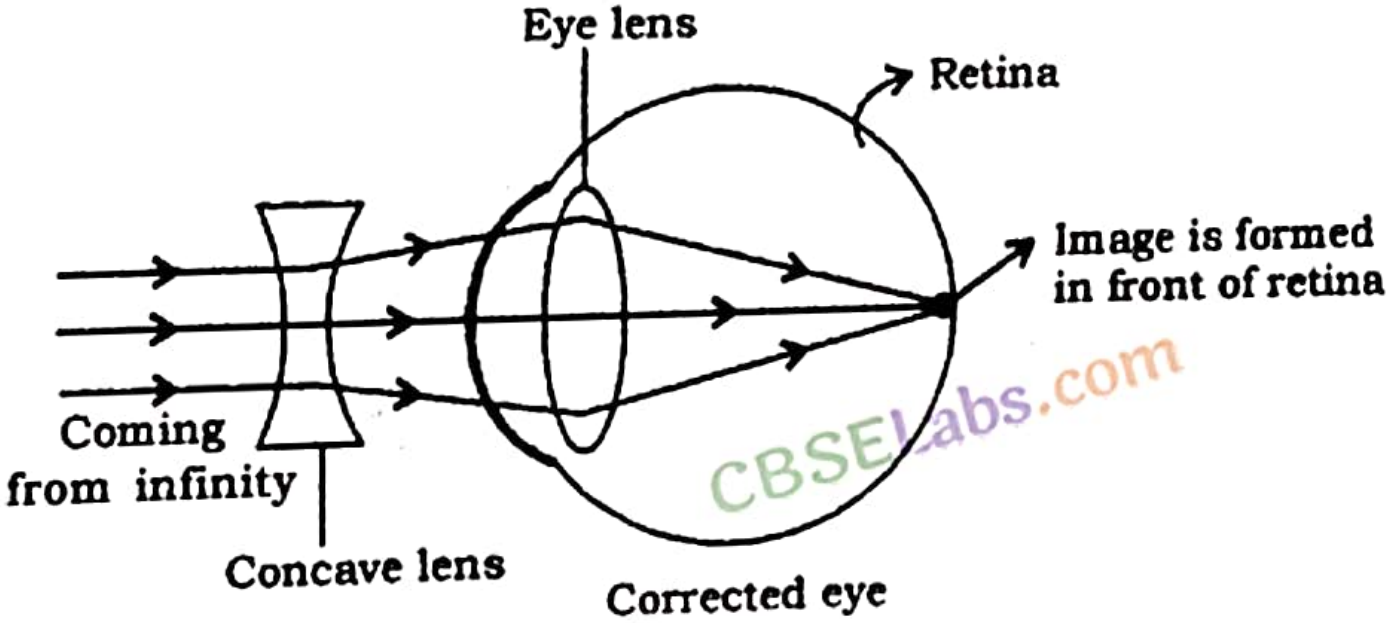
Myopia (Short-sightedness): It is a kind of defect in the human eye due to which a person can see near objects clearly but he cannot see the distant objects clearly. Myopia is due to

(i) excessive curvature of the cornea.

(ii) elongation of eyeball.


Eye lens
Retina
Image is formed
in front of retina
Light rays coming
from distant object
(a) Myopic Eye
Eye lens
Retina
Image is formed
in front of retina
25 cm
(b) Normal Eye

Correction: Since a concave lens has an ability to diverge incoming rays, it is used to correct this defect of vision. The image is allowed to format the retina by using a concave lens of suitable power as shown in the given figure.

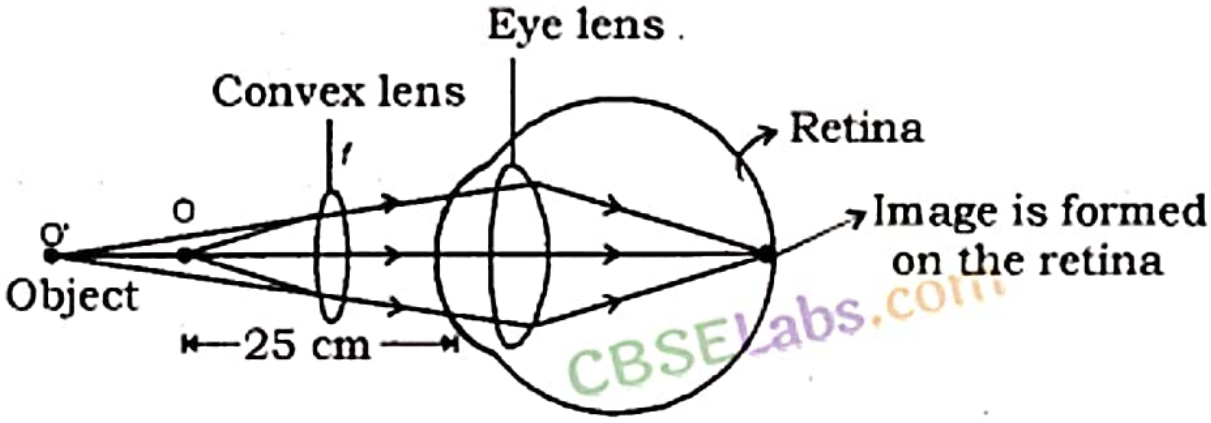


Hypermetropia (Long-sightedness): It is a kind of defect in the human eye due to which, a person can see distant objects properly but cannot see the nearby objects clearly. It happens due to

(i) decrease in the power of eye lens i.e., increase

Hypermetropic eye

Correction: Since a convex lens has the ability to converge incoming rays, it can be used to correct this defect of vision, as you already have seen in the animation. The ray diagram for the corrective measure for a hypermetropic eye is shown in the given figure.



Power of the correcting convex lens:

The Lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ can be used to calculate the focal length and hence, the power of the myopia correcting lens.

In this case,

Object distance, u = ∞

Image distance, v =

person's far point Focal length, f =?

Hence, lens formula becomes

$$\frac{1}{\text{far point}} - \frac{1}{\infty} = \frac{1}{\text{focal length}}$$

Power of the correcting convex lens:

The Lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ can be used to calculate the focal length and hence, the power of the myopia correcting lens.

In this case,

Object distance, u = ∞

Image distance, v =

person's far point Focal length, f =?

Hence, lens formula becomes

$$\frac{1}{\text{far point}} - \frac{1}{\infty} = \frac{1}{\text{focal length}}$$

$$\frac{1}{\text{far point}} - 0 = \frac{1}{\text{focal length}}$$

In case of a concave lens, the image is formed in front of the lens i.e., on the same side of the object.

Focal length = -Far point

Now, power of the required lens (P) = $\frac{1}{f(inm)}$

Power of the correcting convex lens: Lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ can be used to calculate focal length f and hence, power P of the correcting convex lens, where,

Object distance, u = -25 cm, normal near point

Image distance, v = defective near point

Hence, the lens formula is reduced to

$\frac{1}{v} + \frac{1}{25} = \frac{1}{f}$

Presbyopia: It is a kind of defect in human eye which occurs due to ageing. It happens due to the following reasons

(i) decrease in flexibility of eye lens.

(ii) gradual weakening of ciliary muscles.

In this, a person may suffer from both myopia and hypermetropia.

Correction: By using a bifocal lens with appropriate power. Bifocal lenses consist of both concave and convex lens, upper position consists of the concave lens and lower portion consists of a convex lens.

Astigmatism: It is a kind of defect in human eye due to which a person cannot see (focus) simultaneously horizontal and vertical lines both.

Correction: By using a cylindrical lens.

Cataract: Due to the membrane growth over eye lens, the eye lens becomes hazy or even opaque. This leads to a decrease or loss of vision. This problem is called a cataract. It can be corrected only by surgery.

Refraction of light through a prism, Dispersion of white light by a glass prism, Composition of white light, Recombination of spectrum colours, Rainbow.

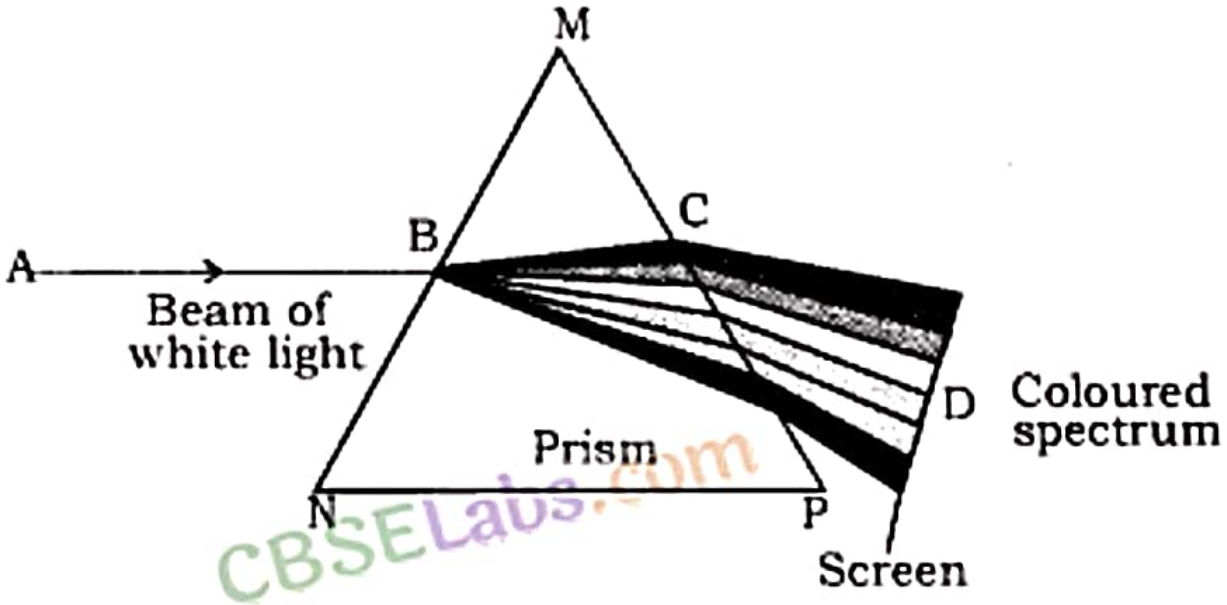
Refraction of light through a prism: When a ray of light is incident on a rectangular glass slab, after refracting through the slab, it gets displaced laterally. As a result, the emergent ray comes out parallel to the incident ray.
Unlike a rectangular slab, the side of a glass prism are inclined at an angle called the angle of prism.

Prism: A prism has two triangular bases and three

Angle of Prism: Angle between two lateral faces is

Angle of Deviation: The angle between the incident deviation.

Dispersion of white light by a glass prism: The phenomenon of splitting of white light into its seven constituent colours when it passes through a glass prism is called dispersion of white light. The various colours seen are Violet, Indigo, Blue, Green, Yellow, Orange and Red. The sequence of colours remembers as VIBGYOR. The band of seven colours is called the spectrum. The different component colour of light bends at a different angle with respect to the incident angle. The violet light bends the least while the red bends most.



Composition of white light: White light consists of seven colours i.e., violet, indigo, blue, green, yellow, orange and red.

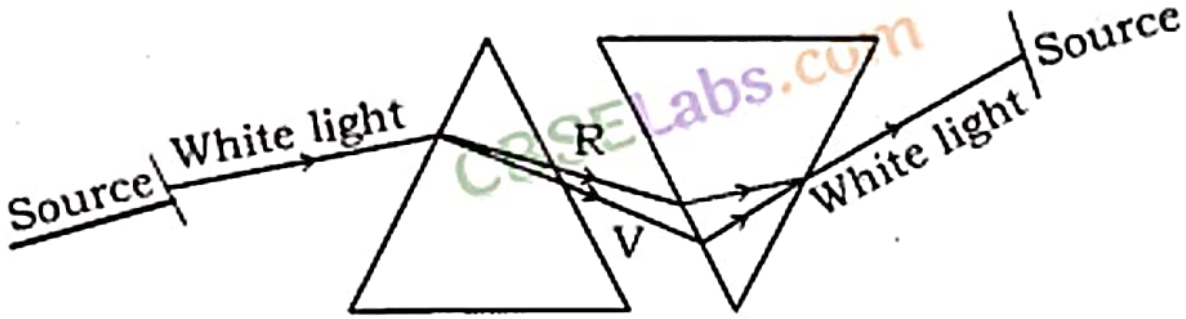
Monochromatic light: Light consisting of single colour or wavelength is called monochromatic light, example; sodium light.

Polychromatic light: Light consisting of more than two colours or wavelengths is called polychromatic light, example; white light.

Recombination of white light: Newton found that when an inverted prism is placed in the path of dispersed light then after passing through the prism, they recombine to form white light.

Issac Newton: He was the first, who obtained spectrum of sunlight by using glass prism. He tried to split the spectrum of white light more by using another similar prism, but he could not get any more colours.

He repeated the experiment using second prism in inverted position with respect to the first prism. It allowed all the colours of spectrum to pass through second prism. He found white light emerges on the other side of second prism.



Dispersion is caused by prism P_1

He concluded that Sun is made up of seven visible colour VIBGYOR.

Rainbow: It is the spectrum of sunlight in nature. It is formed due to the dispersion of sunlight by the tiny water droplet, present in the atmosphere.

Formation of the rainbow: The water droplets act like small prism. 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 colours reach the observer's eye.

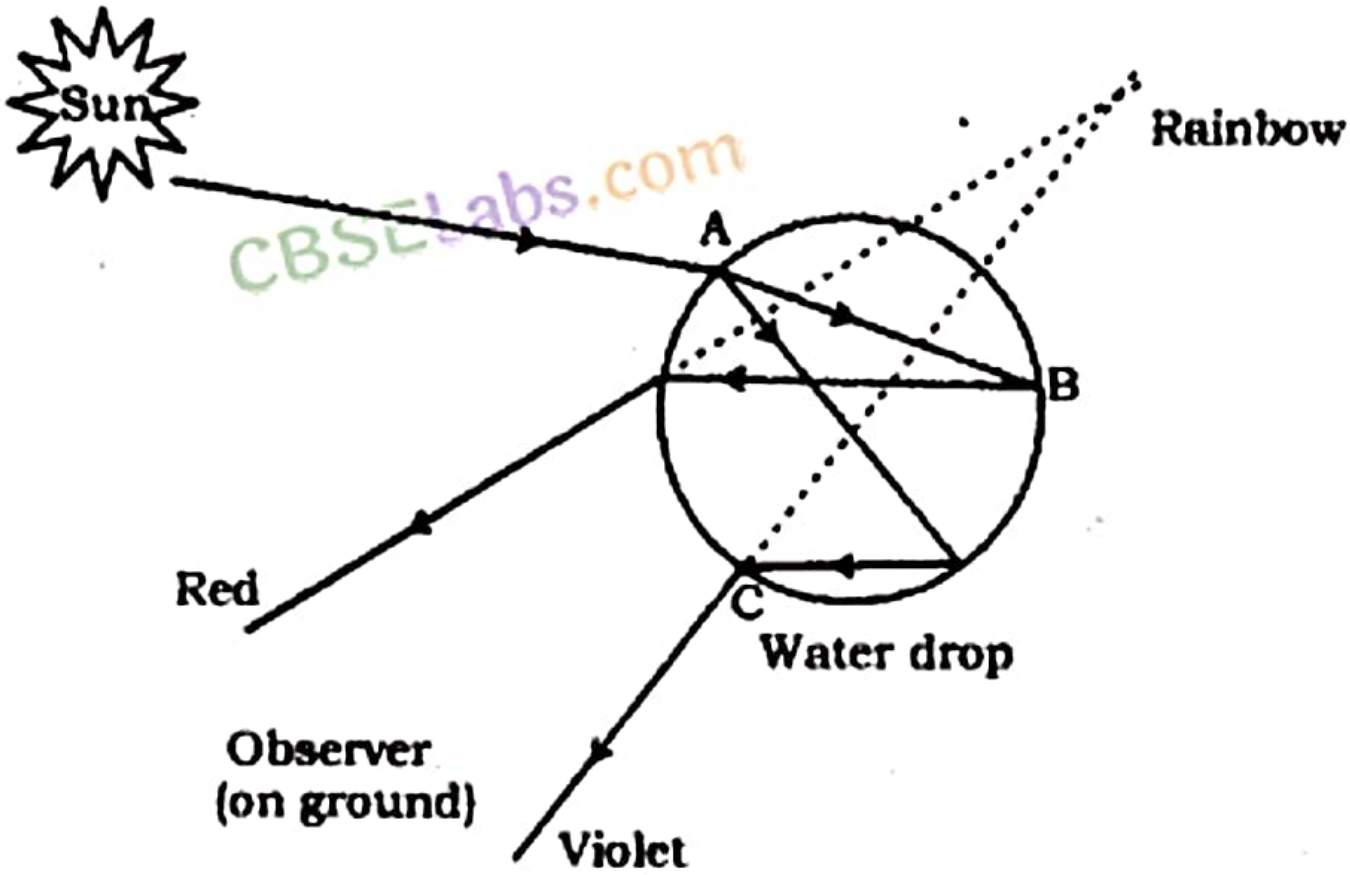
Red colour appears on top and violet at the bottom of rainbow.

A rainbow is always formed in a direction opposite to that of Sun.

At 'A' – Refraction and dispersion take place.

At 'B' – Internal reflection takes place.

At 'C' – Refraction and dispersion take place.



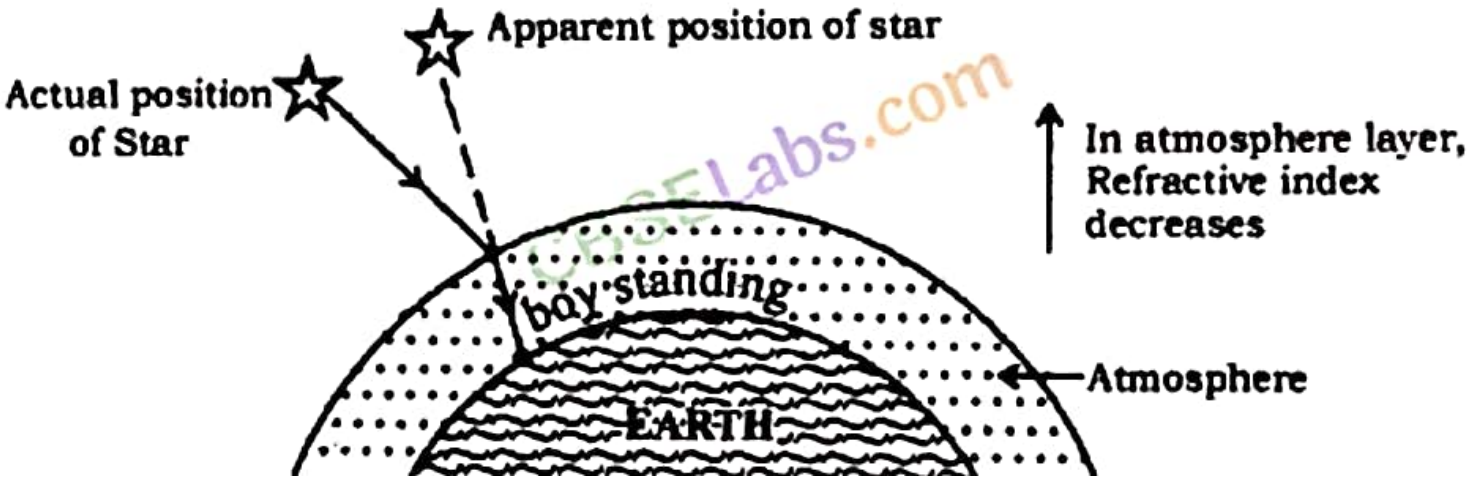
Atmospheric Refraction: The refraction of light caused by the Earth's atmosphere (having air layers of varying optical densities) is called Atmospheric Refraction.

atmospheric refraction of star light.

The temperature and density of different layer of atmosphere keeps varying. Hence, we have different medium.

Distant star act as point source of light. When the starlight enter the Earth's atmosphere, it undergoes refraction continuously, due to changing refractive index i.e. from Rarer to denser. It bends towards the normal.

Due to this, the apparent position of the star is different from actual position. The star appear higher than its actual position.



Twinkling of Star: It is also due to atmospheric refraction.

Distant star act like a point source of light. As the beam of starlight keeps deviating from its path, the apparent position of star keeps on changing because physical condition of earth's atmosphere is not stationary.

Hence, the amount of light enters our eyes fluctuate sometimes bright and sometime dim. This is the "Twinkling effect of star".

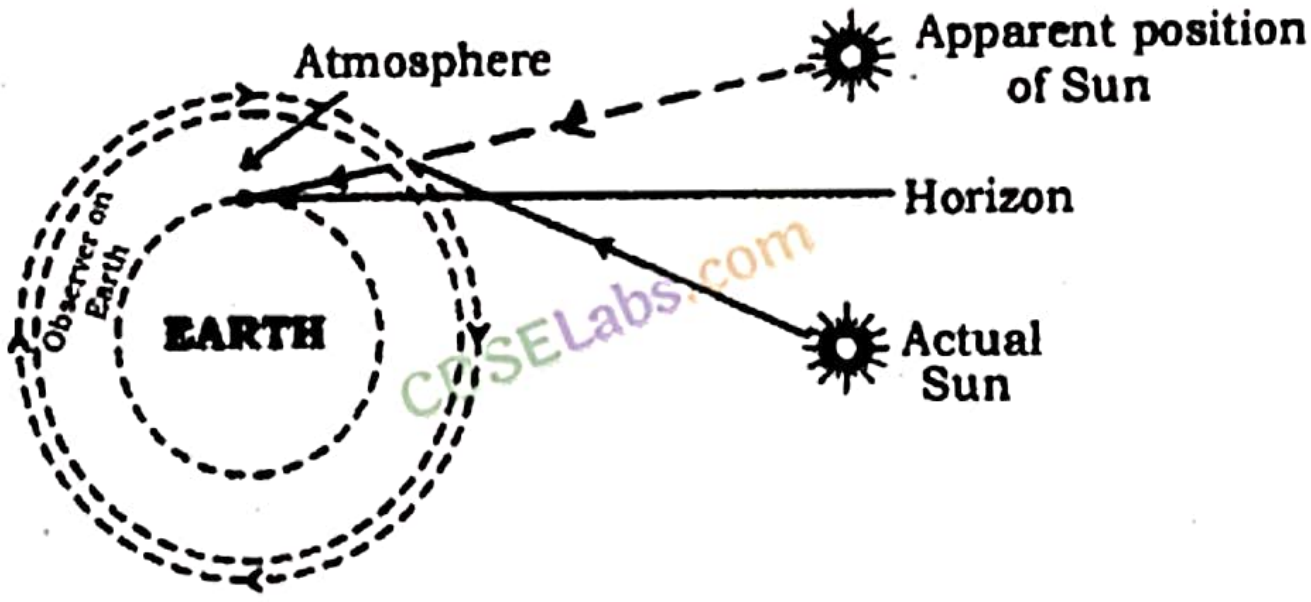
Why planets do not twinkle ?

Planets are closer to earth and are seen as extended source of light i.e. the collection of large number of point sized sources of light. Therefore the total amount of light entering our eyes from all individual point source will nullify the twinkling effect.

Why, the duration of day becomes 4 minutes shorter if there is no atmosphere on earth: Actual sun rise happens when it is below the horizon in the morning. The rays of light from the sun below the horizon reach our eyes because of refraction of light. Similarly, the sun can be seen about few minutes after the actual sun set. Thus the duration of, day time will increase by 4 minutes.

This is due to atmospheric refraction. Because of this sun is visible about 2 minutes earlier than actual sunrise and about 2 minutes after the actual sun set.

Apparent flattering of the Sun's disc at sunset and sunrise is due to atmospheric refraction.



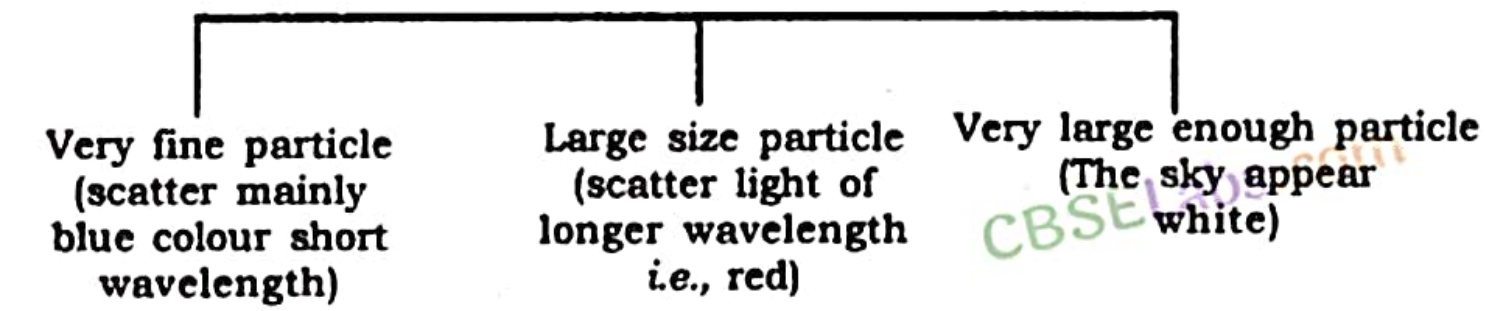
Scattering of light: According to Rayleigh' Law of Scattering, the amount of scattered light $\propto \frac{1}{\lambda^4}$ (λ = wavelength)

Scattering of light decreases with increase in wavelength.

Tyndall Effect: When a beam of light strikes, the minute particle of earth's atmosphere, suspended particles of dust and molecule of air the path of beam become visible. The phenomenon of scattering of light by the colloidal particle gives rise to Tyndall Effect.

It can be observed when sunlight passes through a canopy of a dense forest.

The colour of the scattered light depends on the size of the scattering particles.



Colour of Sunrise and Sunset: While sunset and sunrise, the colour of the sun and its surroundihg appear red. During sunset and sunrise, the sun is near to horizon, and therefore, the sunlight has to travel larger distance in atmosphere. Due to this, most of the blue light (shorter wavelength) is scattered away by the particles. The light of longer wavelength (red colour) reaches our eye. This is why sun appear red in colour.

Why the danger signal or sign is made of red colour?
Red colour scatteres the most when strikes the small particle of fog and smoke because it has the maximum wavelength (visible spectrum). Hence, from large distance also, we can see the red colour clearly.

At noon sun appears white: At noon, the sun is overhead and sunlight would travel shorter distance relatively through the atmosphere. Hence, at noon, the sun appear white as only little of the blue and violet colours are scattered.