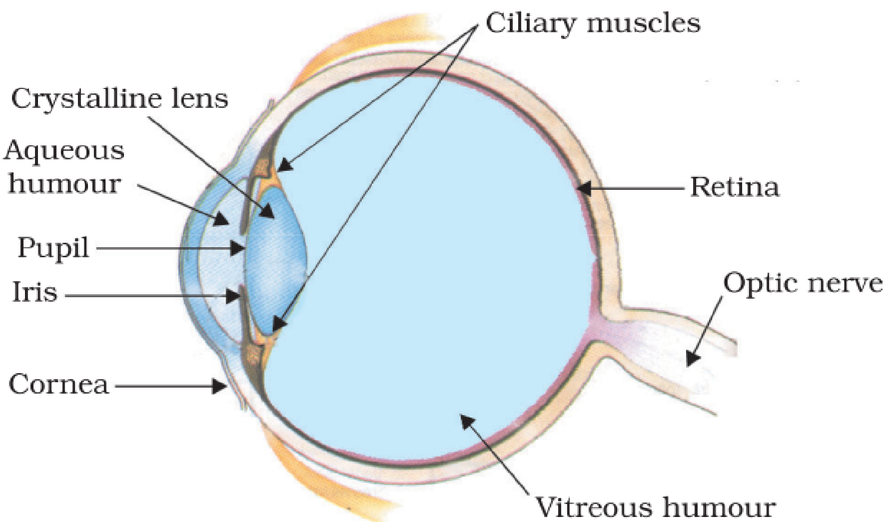
THE HUMAN EYE AND THE COLOURFUL WORLD

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.



The various parts of eye and their functions :

i. Cornea: It is a thin membrane which covers the eye trail. It acts like a lens which refracts the light entering the eye.

ii. Aqueous humour: It is fluid which fills the space between cornea and eye lens.Provides power to the cornea.

iii. Iris: It is a coloured flexible muscle which controls the amount of light entering the eye by changing the size of the pupil.

iv. 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.

(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.

v. Eye lens: It is a crystalline convex lens made of transparent and flexible jelly like material. Its curvature can be adjusted with the help of ciliary muscles.
vii. Ciliary muscles: These are the muscles which are attached to eye lens and can modify the shape of eye lens by contracting and extending which leads to the variation in focal lengths.
(a) While looking at distant objects : Ciliary muscles relax which increases focal length of eye lens and enables the eye to see distant objects distinctly .
(b) While looking at near objects : Ciliary muscles contract which decreases the focal length of eye lens and enables the eye to see near objects distinctly.

viii. Vitrous Humour: It is fluid which fills the space inside the eyeball to maintain the pressure. Provides the eye with its form and shape.

ix. Retina: It is a light sensitive screen inside the eye on which image is formed.The retina is a delicate membrane having enormous number of light-sensitive cells called rods and cones.
(a)Cone photoreceptors: Cones are cone-shaped cells enable vision in bright light.They make it possible to see multiple colors.
(b)Rodes photoreceptors: Rods are cylindrical-shaped cells which help with night vision.They do not help with color visualization.

x. Optical nerve: These are the nerves which take the image to the brain in the form of electrical signals.

Near Point of Eye : The minimum distance at which object can be seen most distinctly without strain. It is 25 cm for normal eye.

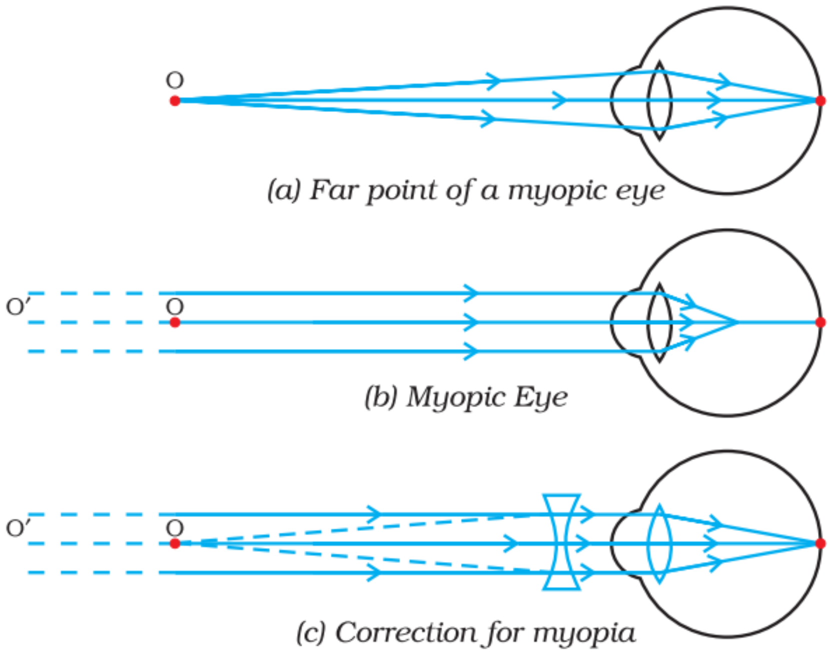
Far Point of Eye : The maximum disance at which object can be seen most distinctly without strain. It is infinity for normal eye.

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.

Defects of Vision and their Correction:

1. Myopia (Short/near-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.

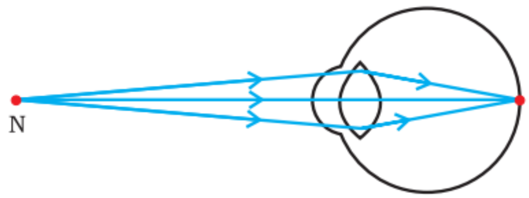


(a) Far point of a myopic eye
(b) Myopic Eye
(c) Correction for myopia

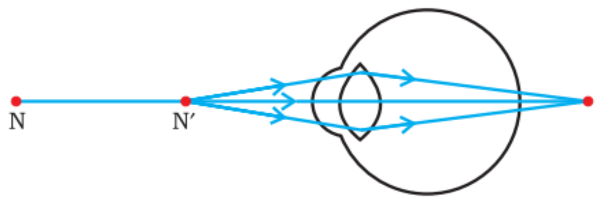
Correction: Since a concave lens has an ability to diverge incoming rays, it is used to correct this defect of vision.
* Concave lens diverge the incident light and helps to form the image at retina by convering again by power of eye lens.
* Concave lens brings the object to the far point of the myopic eye(i.e., near to the eye) by forming an image at far point(O) of the object at (O') as shown in figure.

2. Hypermetropia (Long/far-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 in focal length of eye lens.
(ii) shortening of eyeball.

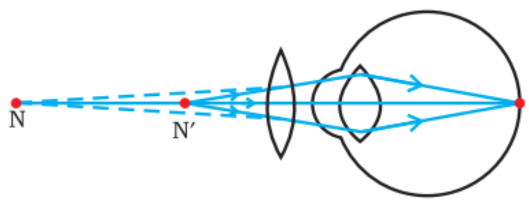
A hypermetropic eye has its least distance of distinct vision(near point) greater than 25 cm.



(a) Near point of a Hypermetropic eye



(b) Hypermetropic eye



(c) Correction for Hypermetropic eye

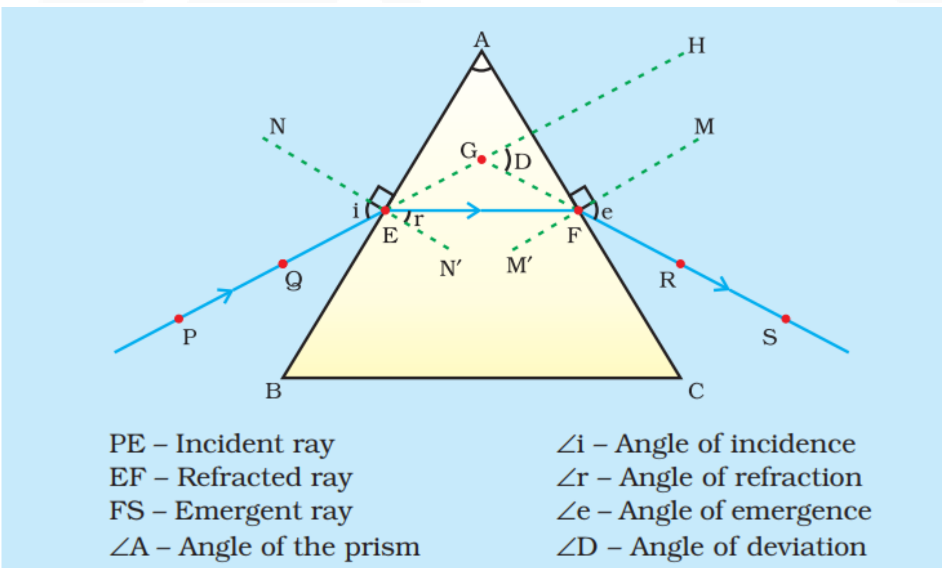
Correction: Since a convex lens has the ability to converge incoming rays,so it can be used to correct this defect of vision.
* Convex lens converge the incident light and helps to form the image at retina by convering again by power of eye lens.
* Concave lens brings the object to the near point of the hypermetropic eye (i.e., far from the eye) by forming an image at near point(N) of the object at (N') as shown in figure.

3. Presbyopia: It is a kind of defect in human eye which occurs due to ageing. It happens due to loss of power of accommodation i.e.,
(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.

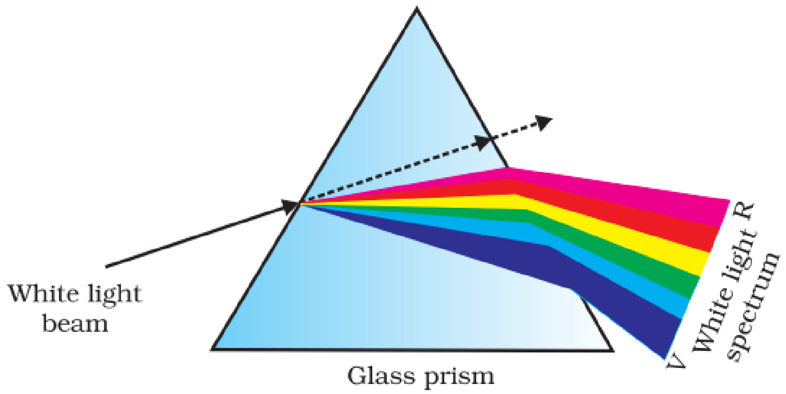
4. Cataract: Due to the (milky)membrane growth over eye lens, the eye lens becomes hazy or even opaque. This leads to a decrease or loss of vision. This problem is called a cataract.
Correction: It can be corrected only by surgery.

5. Colour Blindness: A person having defective cone cells is not able to distinguish between the different colours. This defect is known as Colour Blindness. There is no cure for this defects.

Refraction of light through a prism:
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 ∠D is the angle of deviation.



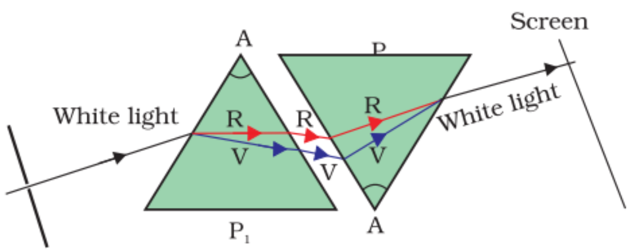
Dispersion of white light by a glass prism: The phenomenon of splitting of white light into its seven constituent colours when it passes through a glass prism is called dispersion of white light.



Dispersion of white light by the glass prism

The different component colour of light bends at a different angle with respect to the incident angle.The violet light bends the most while the red bends least.
* Different colours have different refractive index for the same medium as they intract differently with the molecules of the medium.
The band of seven colours is called the **spectrum**(VIBGYOR).

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.
He concluded by this experiment that white colour of light is made up of seven colour(VIBGYOR).

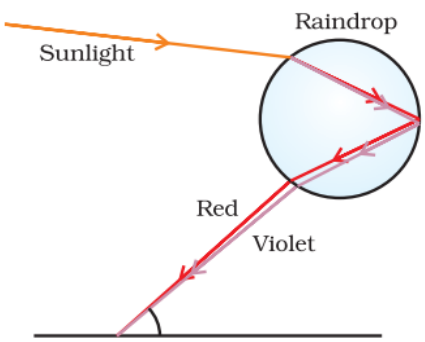


Recombination of the spectrum of white light

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.

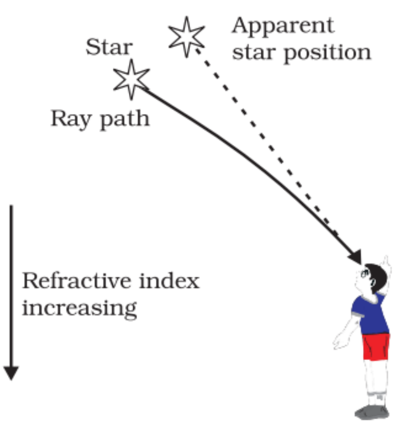
* Red colour appears on top and violet at the bottom of rainbow.
* A rainbow is always formed in a direction opposite to that of Sun.

Rainbow in the sky



ATMOSPHERIC REFRACTION

Appearance of Star Position: It is due to atmospheric refraction of star light.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.



Apparent star position due to atmospheric refraction

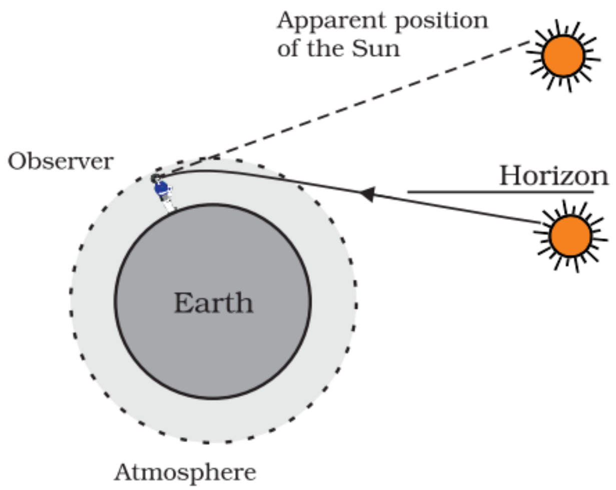
Twinkling of Star: It is also due to atmospheric refraction.
Distant star act like a point source of light. As the beam of starlight keeps deviating from its path, the apparent position of star keeps on changing because physical condition of earth's atmosphere is not stationary.
Hence, the amount of 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.

Advance Sunrise and Delayed Sunset

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.



Atmospheric refraction effects at sunrise and sunset

SCATTERING OF LIGHT

When a light beam goes through a medium, it hits the particles existing in them. Due to this phenomenon, some of the light rays get absorbed while a few get scattered in various directions. The intensity of the scattered light rays depends on the particles' size and wavelength.

According to Rayleigh' Law of Scattering, the intensity of scattered light is

$$I_{max} \propto \frac{1}{\lambda^4}$$

(λ = wavelength of light)

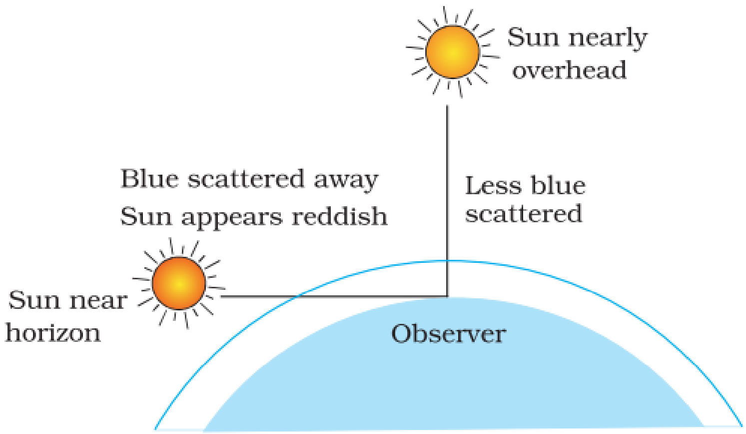
Tyndall Effect: When a beam of light strikes, the minute particle of earth's atmosphere, suspended particles of dust and molecule of air the path of beam become visible. The phenomenon of scattering of light by the colloidal particle gives rise to Tyndall Effect. It can be observed when sunlight passes through a canopy of a dense forest.
The colour of the scattered light depends on the size of the scattering particles.

Blue Colour of Clear Sky:

When sunlight passes through the atmosphere, the fine particles in air scatter the blue side colour (shorter wavelengths) more strongly than red. The scattered blue light enters our eyes and sky looks blue to us.

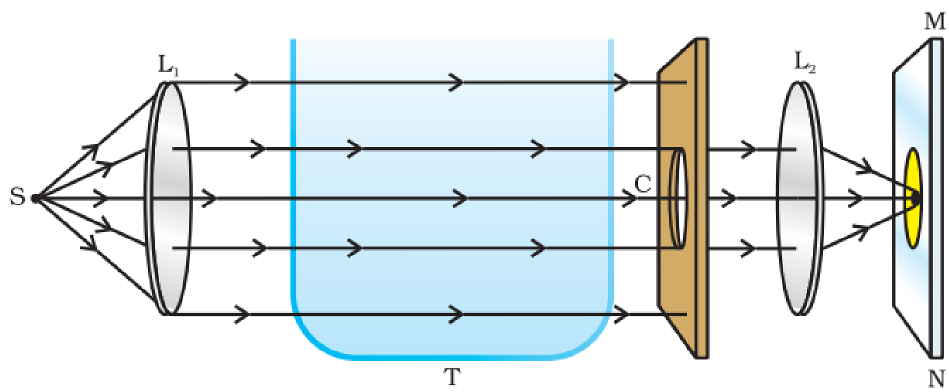
Colour of the Sun at Sunrise and Sunset:

While sunset and sunrise, the colour of the sun and its surrounding 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.



Reddening of the Sun at sunrise and sunset

Activity to show the scattering of light through colloidal solution:-



An arrangement for observing scattering of light in colloidal solution

Dissolve about 200 g of sodium thiosulphate (hypo) in about 2 L of clean water taken in the tank as shown in figure. Add about 1 to 2 mL of concentrated sulphuric acid to the water.

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.

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