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Chapter – 10

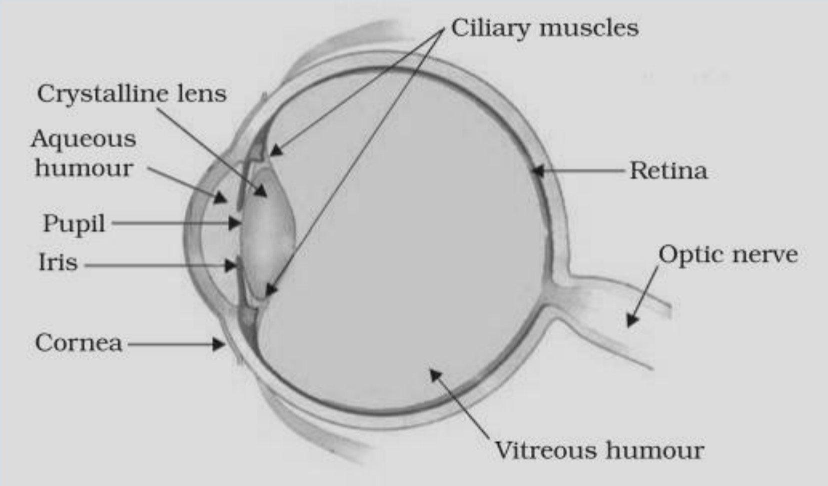
The Human Eye

And

The Colourful World

THE HUMAN EYE

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. 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.

Power of Accommodation

An eye can focus the images of the distant objects as well as the nearby objects on its retina by changing the focal length (or converging power) of its lens. The focal length of the eye-lens is changed by the action of ciliary muscles. The ciliary muscles can change the thickness of the soft and flexible eye-lens and hence its focal length which, in turn, changes the converging power of the eye-lens

The ability of the eye lens to adjust its focal length is called accommodation. 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.

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.

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 far - sightedness, and
(iii) Presbyopia.

These defects can be corrected by the use of suitable spherical lenses.

Myopia

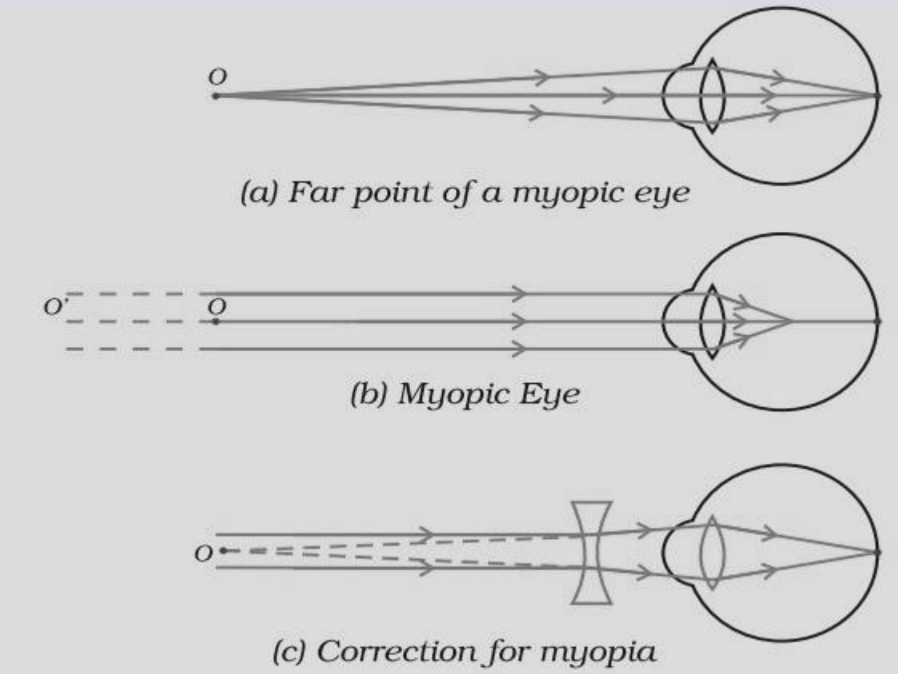
Myopia is also known as near-sightedness. A person with myopia can see nearby objects clearly but cannot see distant objects distinctly.

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

<u>**Hypermetropia**</u>

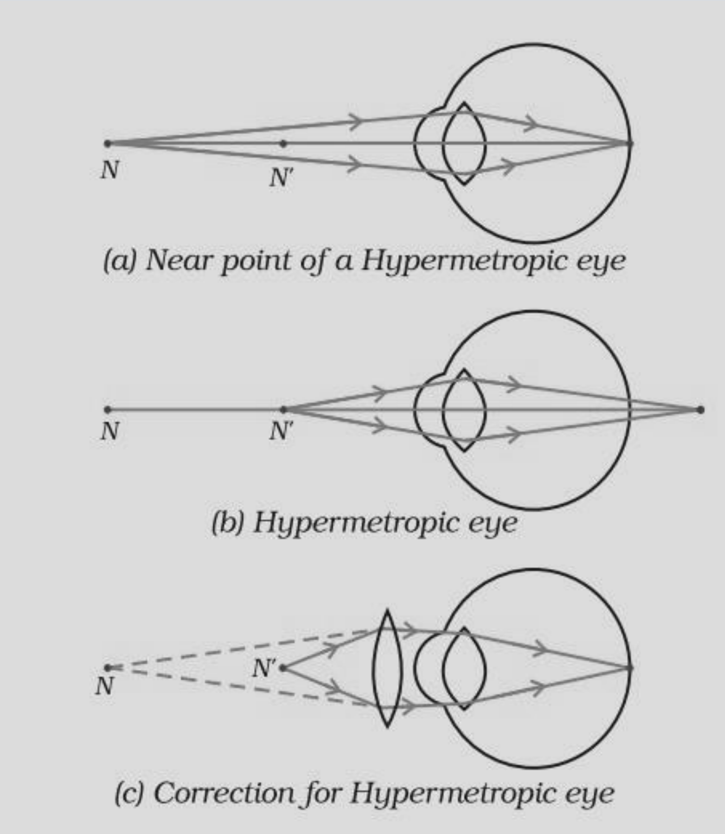
Hypermetropia is also known as far-sightedness. A person with hypermetropia can see distant objects clearly but cannot see nearby objects distinctly. The near point, for the person, is farther away from the normal near point.

This defect arises either because

the focal length of the eye lens is too long,

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 focussing power required for forming the image on the retina



(a) Near point of a Hypermetropic eye

(b) Hypermetropic eye

(c) Correction for Hypermetropic eye

<u>Presbyopia</u>

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.

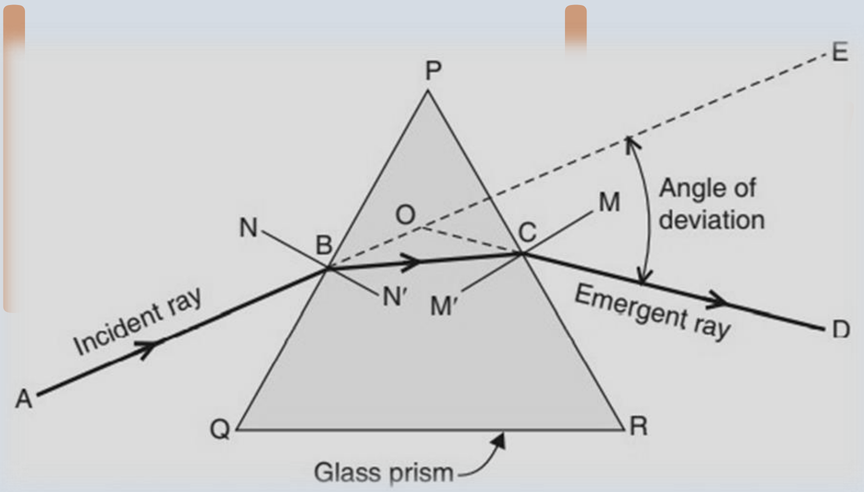
<u>REFRACTION OF LIGHT THROUGH A GLASS PRISM</u>

When a ray of light passes through a glass prism, refraction (or bending) of light occurs both, when it enters the prism as well as when it leaves the prism. Since the refracting surfaces (PQ and PR)

of the prism are not parallel, therefore, the emergent ray and incident ray are not parallel to one another

When the ray of light BC travelling in the glass prism comes out into air at point C, refraction takes place again (see Figure 20). Since the ray BC is going from glass (denser medium) into air (rarer medium), so it bends away from the normal MC and goes along the direction CD in the form of emergent ray. Here also, the emergent ray of light CD bends towards the base QR of the prism.

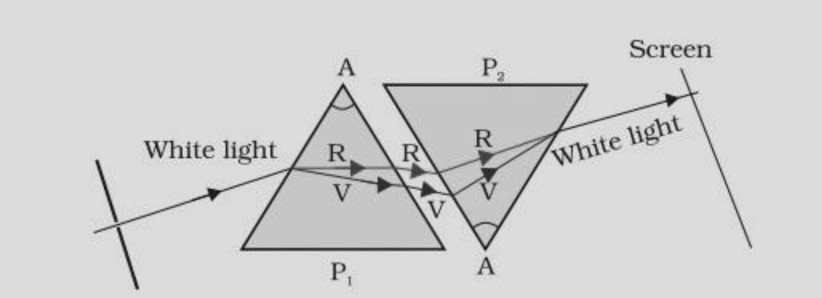
the emergent ray CD is not parallel to the incident ray AB. There has been a deviation (or change) in the path of light in passing through the prism. the incident ray AB upwards towards the point E by a dotted line. Now, AE represents the original direction of the ray of light. Similarly, let us produce the emergent ray CD backwards by a dotted line so that it cuts the line AE at point O.



The angle between incident ray and emergent ray is called angle of deviation.

DISPERSION OF LIGHT

Isaac Newton was the first to use a glass prism to obtain the spectrum of sunlight. He tried to split the colours of the spectrum of white light further by using another similar prism. However, he could not get any more colours. He then placed a second identical prism in an inverted position with respect to the first prism,



This allowed all the colours 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 colours. Any light that gives a spectrum similar to that of sunlight is often referred to as white light.

Rainbow

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 colours reach the observer's eye.

ATMOSPHERIC REFRACTION

The refraction of light caused by the earth's atmosphere (having air layers of varying optical densities) is called atmospheric refraction.

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 (Fig. 11.9). 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,

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.

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.

SCATTERING OF LIGHT

Scattering of light means to throw light in various random directions. Light is scattered when it falls on various types of suspended particles in its path. Depending on the size of particles, the scattering can be of white sunlight as such or of the coloured lights which make up the white sunlight.

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

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 the Sky is 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. The sky appears dark to passengers flying at very high altitudes, as scattering is not prominent at such heights.

Why the Sun Appears Red at Sunrise and Sunset

At the time of sunrise and sunset when the sun is near the horizon, the sunlight has to travel the greatest distance through the atmosphere to reach us. During this long journey of sunlight, most of the shorter wavelength blue-colour present in it is scattered out and away from our line of sight. So, the light reaching us directly from the rising sun or setting sun consists mainly of longer wavelength red colour due to which the sun appears red . Due to the same reason, the sky surrounding the rising sun and setting sun also appears red. Thus, at sunrise and sunset, the sun itself as well as the surrounding sky appear red.