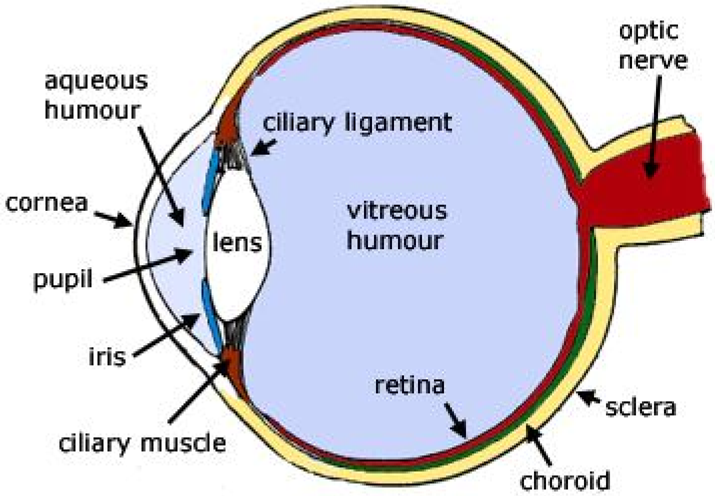
CHAPTER - 11

THE HUMAN EYE AND THE COLOURFUL WORLD

THE HUMAN EYE

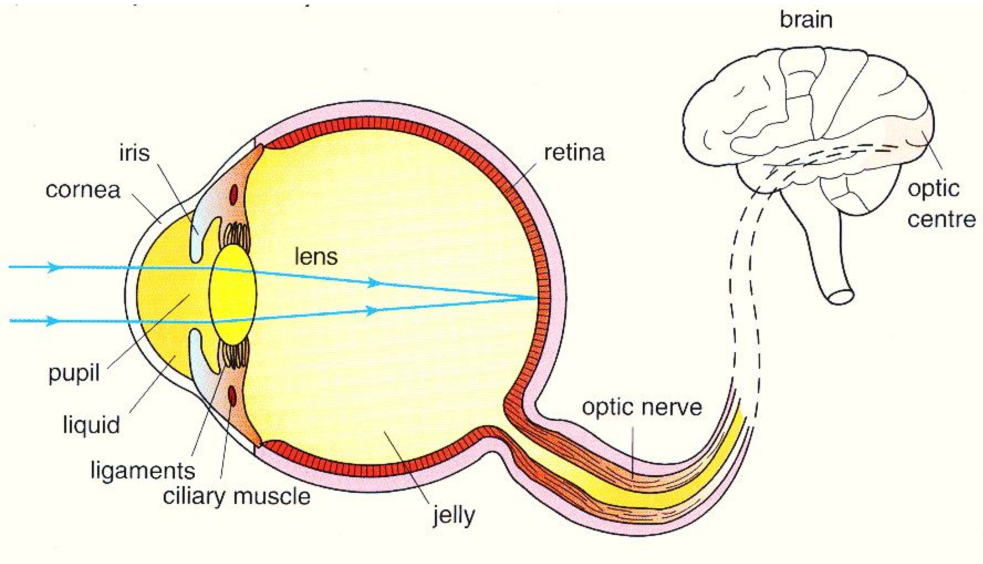
The human eye is one of the most valuable and sensitive sense organs. It enables us to see the wonderful world and the colours around us

The main parts of the human eye include:
Cornea: transparent tissue covering the front of the eye that lets light travel through
Iris: a ring of muscles in the colored part of the eye that controls the size of the pupil
Pupil: an opening in the center of the iris that changes size to control how much light is entering the eye.
Sclera: the white part of the eye that is composed of fibrous tissue that protects the inner workings of the eye
Lens: located directly behind the pupil, it focuses light rays onto the retina
Retina: membrane at the back of the eye that changes light into nerve signals
Optic Nerve: a bundle of nerve fibers that carries messages from the eyes to the brain
Macula: a small and highly sensitive part of the retina responsible for central vision, which allows a person to see shapes, colors, and details clearly and sharply.
Choroid: The choroid is a layer of blood vessels between the retina and sclera; it supplies blood to the retina.
Ciliary muscle: it changes the shape of the lens - (this is called accommodation). It relaxes to flatten the lens for distance vision; for close work it contracts rounding out the lens.
Aqueous homour: A water like fluid, produced by the ciliary body, it fills the front of the eye between the lens and cornea and provides the cornea and lens with oxygen and nutrients. It drains back into the blood stream through the canals of schlemm.
Vitreous homour: The space between the lens and retina filled with the gel like Vitreous Humor.



WORKING OF HUMAN EYE

Light enters the eye through a thin membrane called the cornea. It forms the transparent bulge on the front surface of the eyeball as shown in below figure. 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 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, i.e. without inversion.

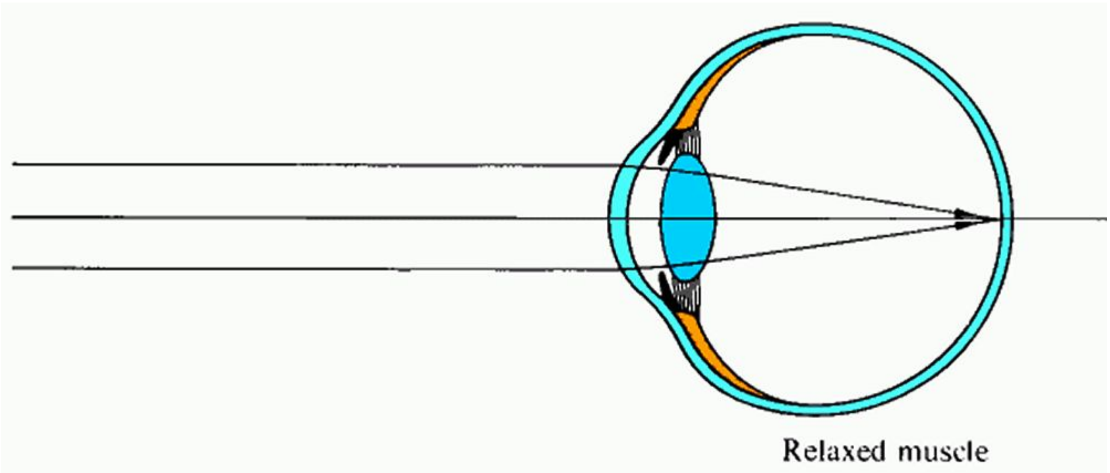


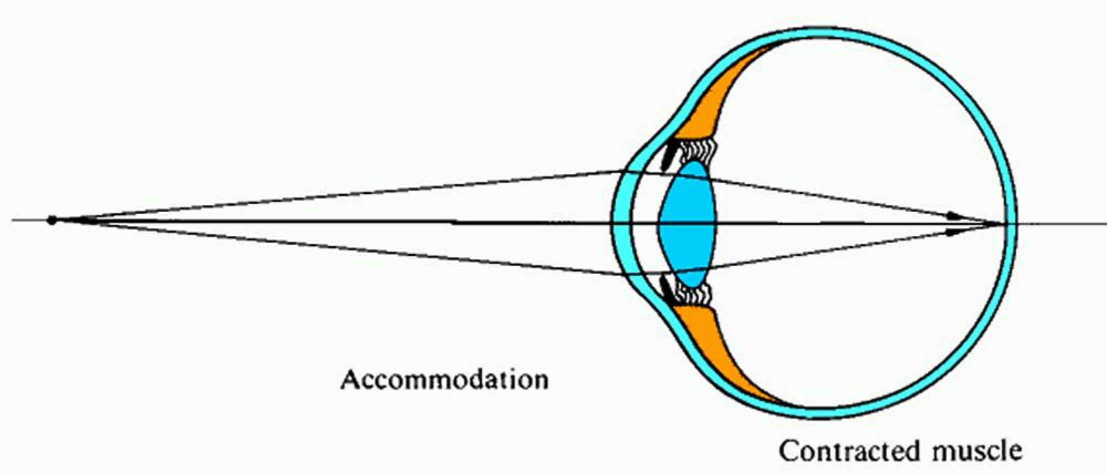
POWER OF ACCOMMODATION

The process by which the ciliary muscles change the focal length of an eye lens to focus distant or near objects clearly on the retina is called the accommodation of the eye.

How Does an Eye Focus Objects at Varying Distances?

To focus on distant objects the ciliary muscles relax making the eye lens thin. As a result the focal length of the eye lens increases and we see the distant objects. But to focus on nearby objects the ciliary muscles contract making the eye lens thick. As a result the focal length of the eye lens decreases and we see the nearby objects. In short it is the adjustment of the focal length of the eye lens which enables us to focus on objects situated at different distances.





Near point or Least Distance of Distinct Vision

Near point or least distance of distinct vision is the point nearest to the eye at which an object is visible distinctly. For a normal eye the least distance of distinct vision is about 25 centimetres. However, it varies with age of the person. For example, for infants it is only 5 to 8 cm.

Far Point

Far point of the eye is the maximum distance up to which the normal eye can see things clearly. It is infinity for a normal eye.

Range of Vision

The distance between the near point and the far point is called the range of vision.

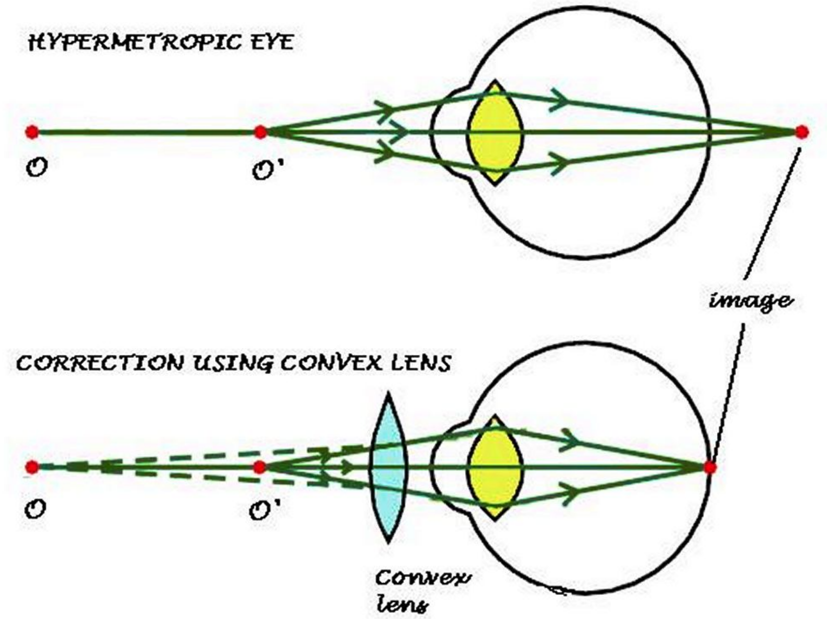
DEFECTS OF VISION

A normal eye can see all objects over a wide range of distances i.e., from 25 cm to infinity. But due to certain abnormalities the eye is not able see objects over such a wide range of distances and such an eye is said to be defective. Some of the defects of vision are

- Hypermetropia or long sightedness
- Myopia or short sightedness and
- Presbyopia
- Astigmatism

HYPERMETROPIA

Hypermetropia is also known as far-sightedness. Hypermetropia or hyperopia is the defect of the eye due to which the eye is not able to see clearly the nearby objects though it can see the distant 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. This is because the light rays from a closeby object are focussed at a point behind the retina as shown in below figure. 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. This is illustrated in below figure. Eye-glasses with converging lenses provide the additional focusing power required for forming the image on the retina.



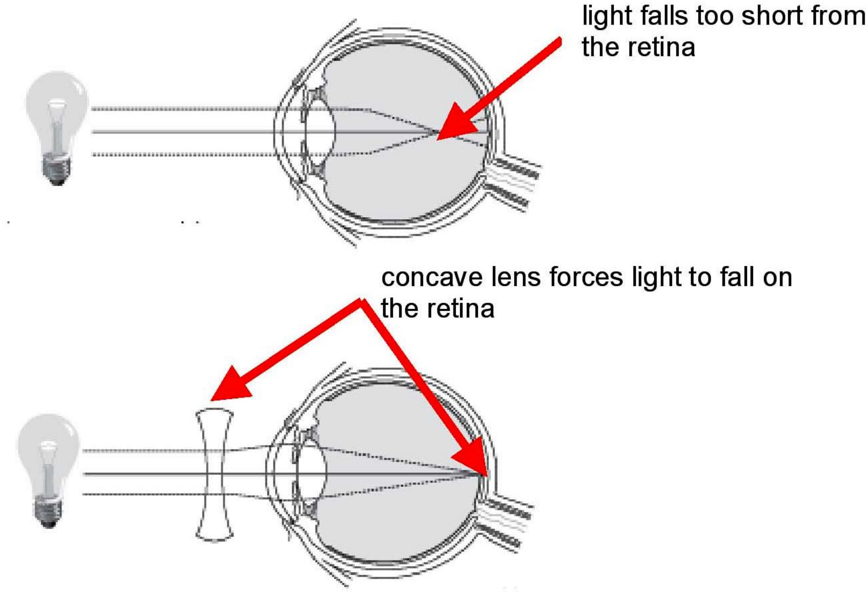
MYOPIA

Myopia is also known as near-sightedness. A myopic person cannot see distant objects clearly because the far point of his eye is less than infinity. Myopia is the defect of the eye due to which the eye is not able to see the distant objects clearly.

Myopia is due to:

- the elongation of the eye ball, that is, the distance between the retina and eye lens is increased.
- decrease in focal length of the eye lens.

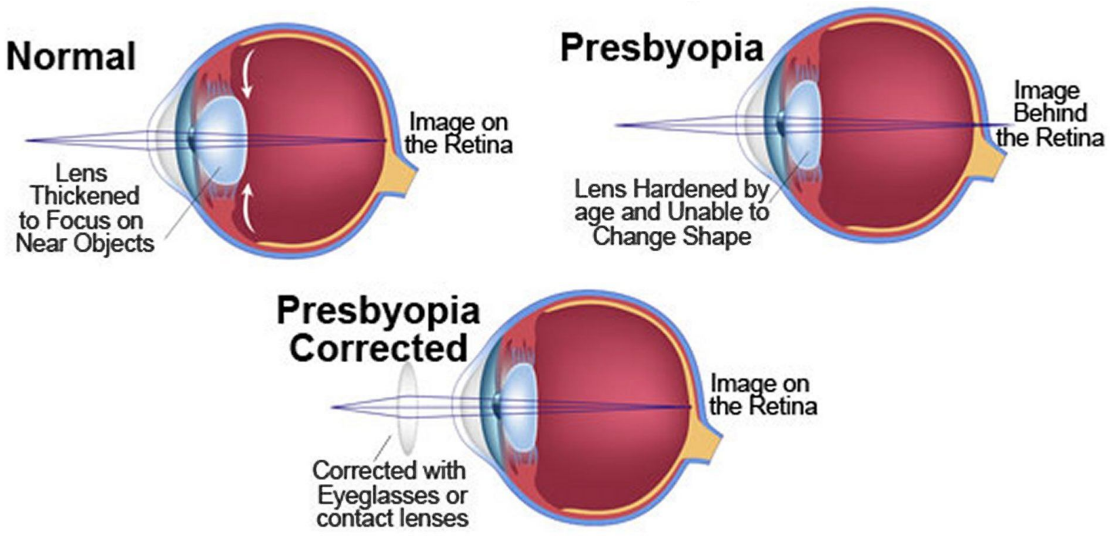
In a myopic eye, the image of a distant object is formed in front of the retina and not at the retina itself. This defect may arise due to (i) excessive curvature of the eye lens, or (ii) elongation of the eyeball. This defect can be corrected by using a concave lens of suitable power. This is illustrated in below figure. A concave lens of suitable power will bring the image back on to the retina and thus the defect is corrected.



PRESBYOPIA

Presbyopia occurs at the age of 40 years and its main symptom is reduced near vision. Difficulty in reading without glasses at 35-40 cm and fatigue after a short period of close work are present. Normally the lens is flexible enough to change its shape when focusing at close objects. Loss of its flexibility and elasticity known as loss of the eye's adjustment mechanism results in presbyopia.

Presbyopia (which literally means "aging eye") is an age-related eye condition that makes it more difficult to see very close.
At the young age, the lens in your eye is soft and flexible. The lens of the eye changes its shape easily, allowing you to focus on objects both close and far away. After the age of 40, the lens becomes more rigid. Because the lens can't change shape as easily as it once did, it is more difficult to read at close range. This normal condition is called presbyopia. Since nearly everyone develops presbyopia, if a person also has myopia (nearsightedness), hyperopia (farsightedness) or astigmatism, the conditions will combine. People with myopia may have fewer problems with presbyopia.



ASTIGMATISM

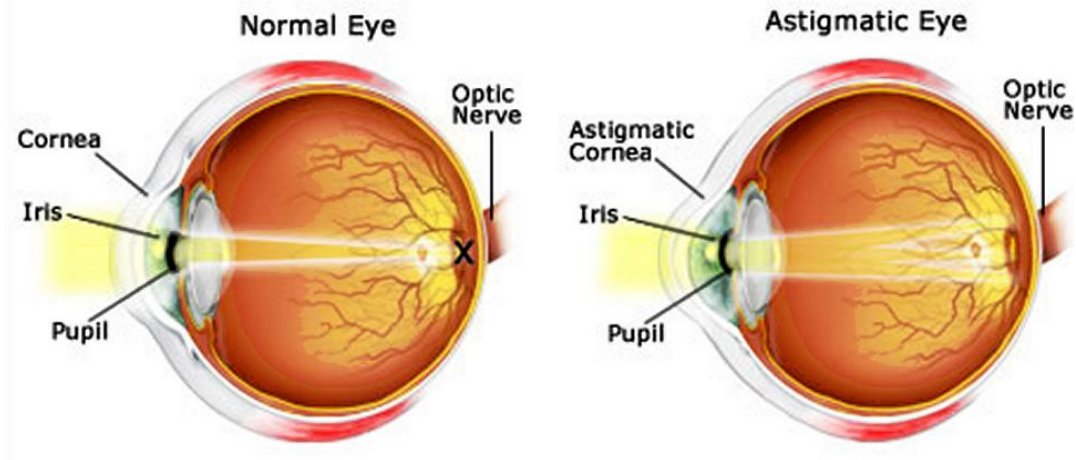
Astigmatism is an eye condition with blurred vision as its main symptom. The front surface of the eye (cornea) of a person with astigmatism is not curved properly - the curve is irregular - usually one half is flatter than the other - sometimes one area is steeper than it should be.

When light rays enter the eye they do not focus correctly on the retina, resulting in a blurred image. Astigmatism may also be caused by an irregularly shaped lens, which is located behind the cornea.

Astigmatism is a type of refractive error. A refractive error means that the shape of the eye does not bend light properly, resulting in a blurred image. Light has to be bent (refracted) by the lens and the cornea correctly before it reaches the retina in order to see things clearly.

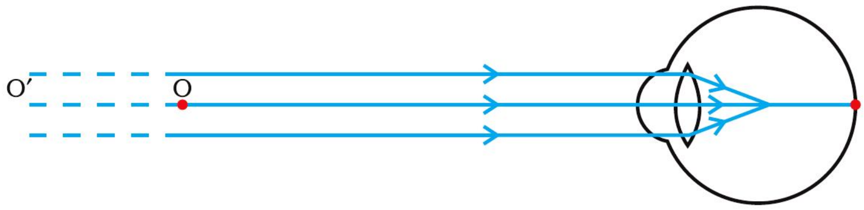
The two most common types of astigmatism are:
Corneal astigmatism - the cornea has an irregular shape
Lenticular astigmatism - the lens has an irregular shape

In astigmatism, images focus in front of and beyond the retina, causing both close and distant objects to appear blurry (see below figure).

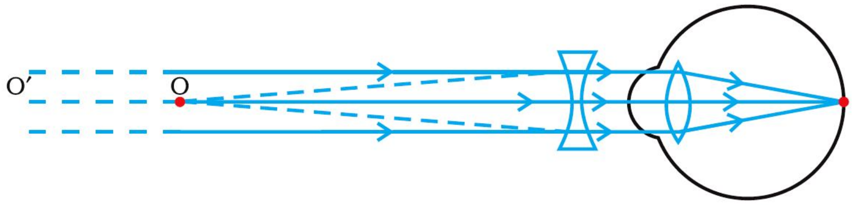


INTEXT QUESTIONS PAGE No. 190

1. **What is meant by power of accommodation of the eye? Ans:**
When the ciliary muscles are relaxed, the eye lens becomes thin, the focal length increases, and the distant objects are clearly visible to the eyes. To see the nearby objects clearly, the ciliary muscles contract making the eye lens thicker. Thus, the focal length of the eye lens decreases and the nearby objects become visible to the eyes. Hence, the human eye lens is able to adjust its focal length to view both distant and nearby objects on the retina. This ability is called the power of accommodation of the eyes.
2. **A person with a myopic eye cannot see objects beyond 1.2 m distinctly. What should be the type of the corrective lens used to restore proper vision?**
Ans:
The person is able to see nearby objects clearly, but he is unable to see objects beyond 1.2 m. This happens because the image of an object beyond 1.2 m is formed in front of the retina and not at the retina, as shown in the given figure.



To correct this defect of vision, he must use a concave lens. The concave lens will bring the image back to the retina as shown in the given figure.



3. **What is the far point and near point of the human eye with normal vision?**
Ans:
The near point of the eye is the minimum distance of the object from the eye, which can be seen distinctly without strain. For a normal human eye, this distance is 25 cm.

The far point of the eye is the maximum distance to which the eye can see the objects clearly. The far point of the normal human eye is infinity.

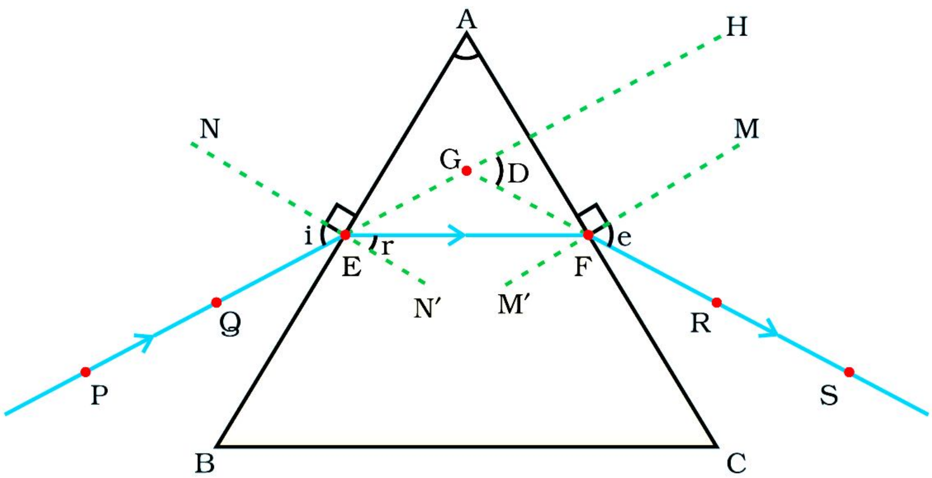
4. A student has difficulty reading the blackboard while sitting in the last row. What could be the defect the child is suffering from? How can it be corrected?

Ans:

A student has difficulty in reading the blackboard while sitting in the last row. It shows that he is unable to see distant objects clearly. He is suffering from myopia. This defect can be corrected by using a concave lens.

REFRACTION OF LIGHT THROUGH A PRISM

Prism is a transparent optical element, which refracts light. An optical object to be defined as prism must have at least two faces with an angle between them. A triangular glass prism 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

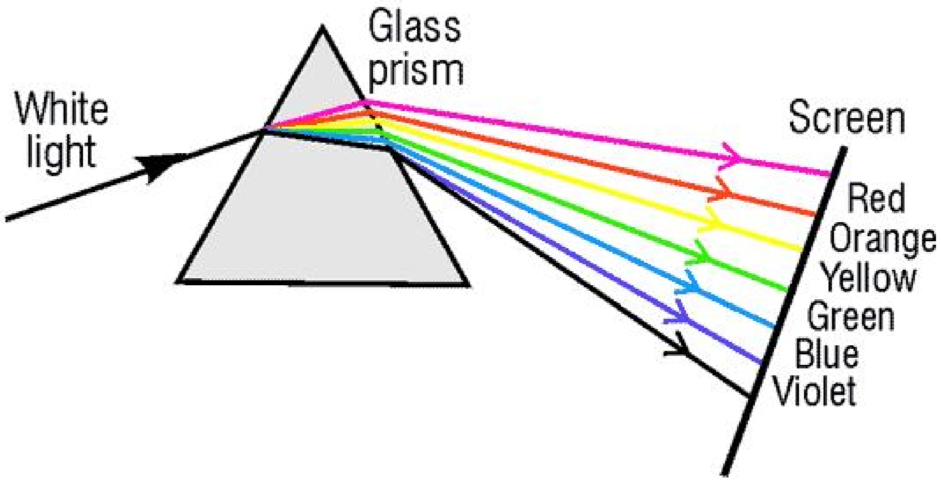


PE – Incident ray
EF – Refracted ray
FS – Emergent ray
∠A – Angle of the prism
∠i – Angle of incidence
∠r – Angle of refraction
∠e – Angle of emergence
∠D – Angle of deviation

PE is the incident ray, EF is the refracted ray and FS is the emergent ray. A ray of light is entering from air to glass at the first surface AB. So, 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. 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.

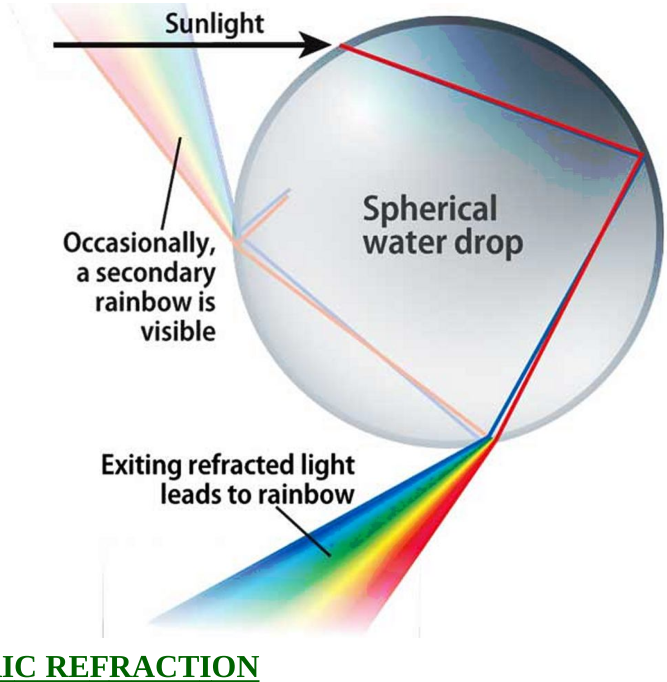
DISPERSION OF WHITE LIGHT BY A GLASS PRISM

When a ray of light enters the prism, it bends towards the normal; because light is entering from a rarer medium to a denser medium. Similarly, when the light emerges from the prism, it follows the laws of refraction of light. Due to the angle of the prism and due to different wavelengths of different components of white light; the emergent ray gets segregated into different colours. Finally, a colourful band of seven colours is obtained. This phenomenon is called dispersion of white light by the prism.



RAINBOW FORMATION

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 (see below figure). Due to the dispersion of light and internal reflection, different colours reach the observer's eye.

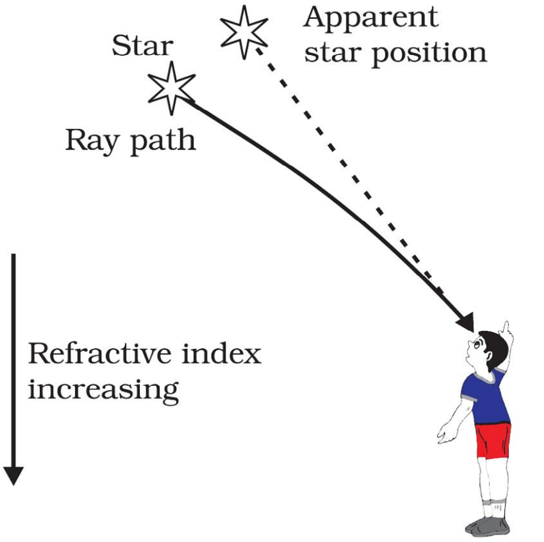


ATMOSPHERIC REFRACTION

Atmospheric refraction is the shift in apparent direction of a celestial object caused by the refraction of light rays as they pass through Earth's atmosphere.

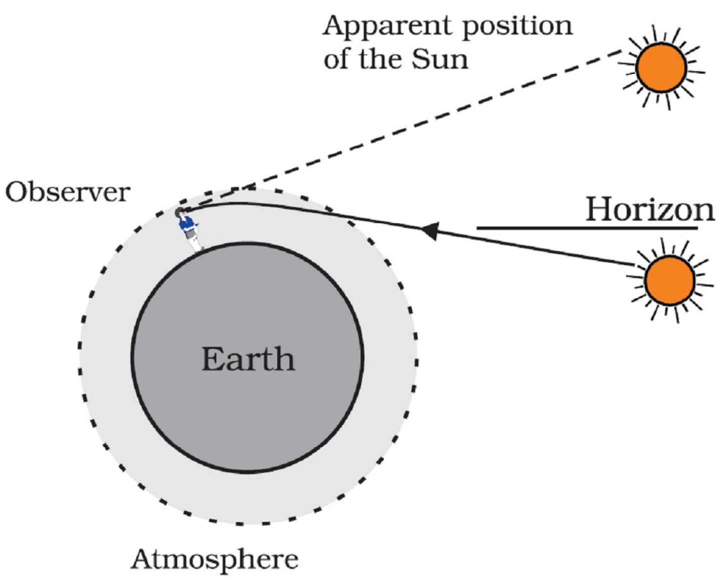
TWINKLING OF STARS

Stars emit their own light and they twinkle due to the atmospheric refraction of light. Stars are very far away from the earth. Hence, they are considered as point sources of light. When the light coming from stars enters the earth's atmosphere, it gets refracted at different levels because of the variation in the air density at different levels of the atmosphere. When the star light refracted by the atmosphere comes more towards us, it appears brighter than when it comes less towards us. Therefore, it appears as if the stars are twinkling at night.



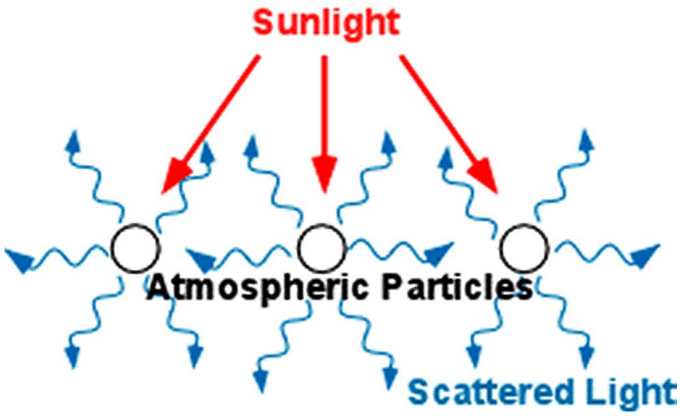
ADVANCE SUNRISE AND DELAYED SUNSET

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 below figure shows 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.



SCATTERING OF LIGHT

In the air, part of the sunlight is scattered. The small particles (molecules, tiny water droplets and dust particles) scatter photons the more, the shorter their wavelength is. Therefore, in the scattered light, the short wavelengths predominate, the sky appears blue, while direct sunlight is somewhat yellowish, or even reddish when the sun is very low.

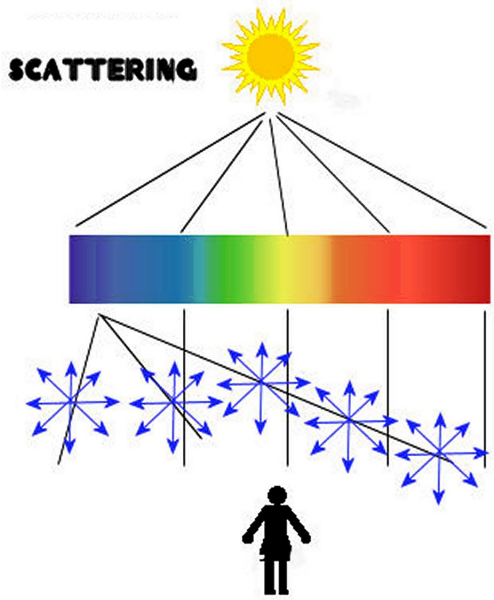


TYNDALL EFFECT

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. 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.

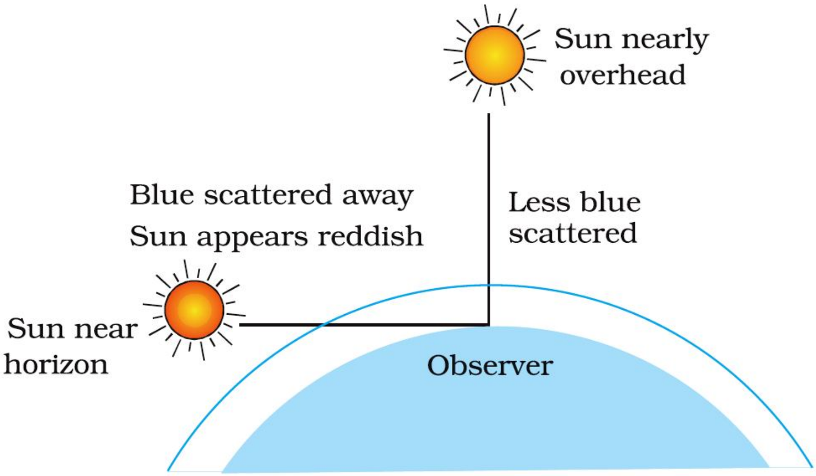
WHY IS THE COLOUR OF THE CLEAR SKY BLUE?

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



COLOUR OF THE SUN AT SUNRISE AND 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 (see below figure). 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 colours 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.



EXERCISE QUESTIONS PAGE No. 197 & 198

1. **The human eye can focus objects at different distances by adjusting the focal length of the eye lens. This is due to (a) Presbyopia (b) accommodation (c) near-sightedness (d) far-sightedness.**
   Ans:
   (b) Human eye can change the focal length of the eye lens to see the objects situated at various distances from the eye. This is possible due to the power of accommodation of the eye lens.

2. **The human eye forms the image of an object at its (a) cornea (b) iris (c) pupil (d) retina**
   Ans:
   (d) The human eye forms the image of an object at its retina.

3. **The least distance of distinct vision for a young adult with normal vision is about (a) 25 m (b) 2.5 cm (c) 25 cm (d) 2.5 m**
   Ans:
   (c) The least distance of distinct vision is the minimum distance of an object to see clear and distinct image. It is 25 cm for a young adult with normal visions.

4. **The change in focal length of an eye lens is caused by the action of the (a) pupil (b) retina (c) ciliary muscles (d) iris Ans:**
   (c) The relaxation or contraction of ciliary muscles changes the curvature of the eye lens. The change in curvature of the eye lens changes the focal length of the eyes. Hence, the change in focal length of an eye lens is caused by the action of ciliary muscles.

5. **A person needs a lens of power −5.5 dioptres for correcting his distant vision. For correcting his near vision he needs a lens of power +1.5 dioptre. What is the focal length of the lens required for correcting (i) distant vision, and (ii) near vision?**
Ans:
For distant vision = −0.181 m, for near vision = 0.667 m

The power P of a lens of focal length f is given by the relation

$$P = \frac{1}{f(in\ \ metres)}$$

(i) Power of the lens used for correcting distant vision = −5.5 D

Focal length of the required lens, $f = \frac{1}{P} = \frac{1}{-5.5} = -0.181m$

The focal length of the lens for correcting distant vision is −0.181 m.

(ii) Power of the lens used for correcting near vision = +1.5 D

Focal length of the required lens, $f = \frac{1}{P} = \frac{1}{1.5} = +0.667m$

The focal length of the lens for correcting near vision is 0.667 m.

6. **The far point of a myopic person is 80 cm in front of the eye. What is the nature and power of the lens required to correct the problem?**
Ans:
The person is suffering from an eye defect called myopia. In this defect, the image is formed in front of the retina. Hence, a concave lens is used to correct this defect of vision.
Object distance, u = infinity
Image distance, v = −80 cm
Focal length = f
According to the lens formula,

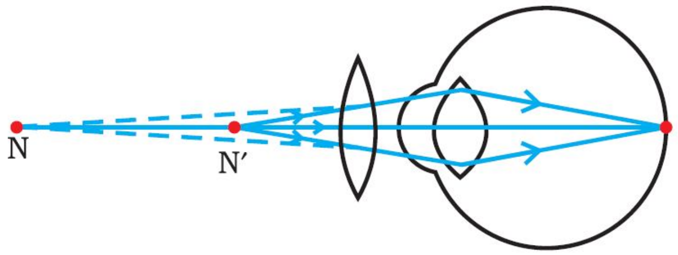
$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{-80} - \frac{1}{\infty} = \frac{1}{f}$$

$$\Rightarrow \frac{1}{f} = \frac{1}{-80} \quad \Rightarrow f = -80cm = -0.8m$$

$$P = \frac{1}{f(in\ \ metres)} = \frac{1}{-0.8} = -1.25D$$

A concave lens of power −1.25 D is required by the person to correct his defect.

7. **Make a diagram to show how hypermetropia is corrected. The near point of a hypermetropic eye is 1 m. What is the power of the lens required to correct this defect? Assume that the near point of the normal eye is 25 cm.**
Ans:
A person suffering from hypermetropia can see distinct objects clearly but faces difficulty in seeing nearby objects clearly. It happens because the eye lens focuses the incoming divergent rays beyond the retina. This defect of vision is corrected by using a convex lens. A convex lens of suitable power converges the incoming light in such a way that the image is formed on the retina, as shown in the following figure.



The convex lens actually creates a virtual image of a nearby object (N' in the figure) at the near point of vision (N) of the person suffering from hypermetropia.

The given person will be able to clearly see the object kept at 25 cm (near point of the normal eye), if the image of the object is formed at his near point, which is given as 1 m.
Object distance, u = −25 cm
Image distance, v = −1 m = −100 m
Focal length, f
Using the lens formula,

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f} \Rightarrow \frac{1}{-100}-\frac{1}{-25}=\frac{1}{f}$$

$$\Rightarrow \frac{1}{f}=\frac{1}{25}-\frac{1}{100}=\frac{4-1}{100}=\frac{3}{100}$$

$$\Rightarrow f=\frac{100}{3}cm=\frac{1}{3}m$$

Power of lens, $P=\frac{1}{f(in\ \ metres)}=\frac{1}{1/3}=+3.0D$

A convex lens of power +3.0 D is required to correct the defect.

8. Why is a normal eye not able to see clearly the objects placed closer than 25 cm?
Ans:
A normal eye is unable to clearly see the objects placed closer than 25 cm because the ciliary muscles of eyes are unable to contract beyond a certain limit.
If the object is placed at a distance less than 25 cm from the eye, then the object appears blurred and produces strain in the eyes.

9. What happens to the image distance in the eye when we increase the distance of an object from the eye?
Ans:
Since the size of eyes cannot increase or decrease, the image distance remains constant. When we increase the distance of an object from the eye, the image distance in the eye does not change. The increase in the object distance is compensated by the change in the focal length of the eye lens. The focal length of the eyes changes in such a way that the image is always formed at the retina of the eye.

10. Why do stars twinkle?
Ans:
Stars emit their own light and they twinkle due to the atmospheric refraction of light. Stars are very far away from the earth. Hence, they are considered as point sources of light. When the light coming from stars enters the earth's atmosphere, it gets refracted at different levels because of the variation in the air density at

different levels of the atmosphere. When the star light refracted by the atmosphere comes more towards us, it appears brighter than when it comes less towards us. Therefore, it appears as if the stars are twinkling at night.

11. Explain why the planets do not twinkle?
Ans:
Planets do not twinkle because they appear larger in size than the stars as they are relatively closer to earth. Planets can be considered as a collection of a large number of point-size sources of light. The different parts of these planets produce either brighter or dimmer effect in such a way that the average of brighter and dimmer effect is zero. Hence, the twinkling effects of the planets are nullified and they do not twinkle.

12. Why does the Sun appear reddish early in the morning?
Ans:
During sunrise, the light rays coming from the Sun have to travel a greater distance in the earth's atmosphere before reaching our eyes. In this journey, the shorter wavelengths of lights are scattered out and only longer wavelengths are able to reach our eyes. Since blue colour has a shorter wavelength and red colour has a longer wavelength, the red colour is able to reach our eyes after the atmospheric scattering of light. Therefore, the Sun appears reddish early in the morning.

13. Why does the sky appear dark instead of blue to an astronaut?
Ans:
The sky appears dark instead of blue to an astronaut because there is no atmosphere in the outer space that can scatter the sunlight. As the sunlight is not scattered, no scattered light reach the eyes of the astronauts and the sky appears black to them.