Chapter 11
The Human Eye and The Colourful World

The human eye is a **sense organ** that allows us to see the colourful world around us.
With a diameter of about 2.3cm, the **eye ball** is almost spherical in shape.

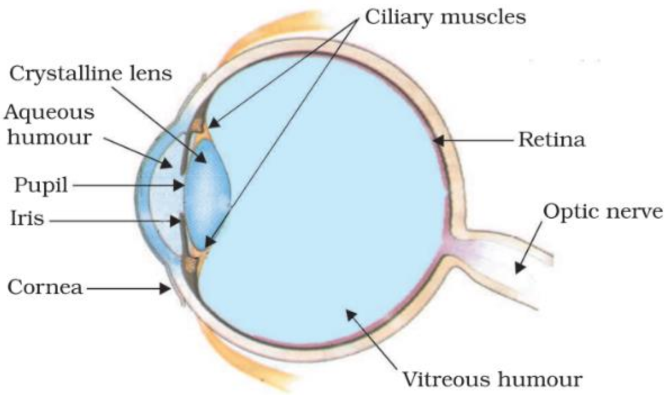
Parts of the Human Eye

- **Cornea**: It is the outermost transparent part of eye and allows the light to enter in the eye.
- **Lens**: The eye lens is a convex lens and made of transparent and flexible tissues. It is behind the pupil and held by the muscles called **ciliary muscles**. It focuses the images of objects on the retina of the eye.
- **Ciliary muscles**: These muscles hold the eye lens in position and control the focal length of the eye lens.
- **Iris**: A dark muscular diaphragm that controls the size of the pupil.
- **Pupil**: It regulates and controls the amount of light that enters the eye.
- **Retina**: It acts as a screen to where the image of the object is formed. It contains of **rod cells** and **cone cells**. Rod shaped cells respond to the **brightness or intensity** of light. Cone shaped cells respond to the **colour** of light.
- **Optic nerve**: It carries the image formed on the retina to the brain in the form of electrical signals. The brain interprets these signals and we are able to see the object.

Working of Human Eye

When we look towards an object, light from the object enters the **pupil** of the eye and falls on the **eye lens**. The eye lens creates a real and inverted image of the object on the **retina**. The **light-sensitive cells** in the retina then generate **electrical signals**, which are carried to the brain by the **optic nerves**. The **brain** interprets these signals and we are able to see the object.

- **Far point:** The maximum distance at which object can be seen clearly is far point of the eye. For a normal adult eye, its value is **infinity**.
- **Near point**: The minimum distance at which objects can be seen most clearly without strain. For a normal adult eye, its value is **25 cm**.
- **Power of accommodation**: The ability of the eye lens to adjust its focal length is called accommodation. When **ciliary muscles** relax, the lens becomes **thin** and focal length **increases**. When **ciliary muscles** contract, the lens becomes **thick** and focal length **decreases**.

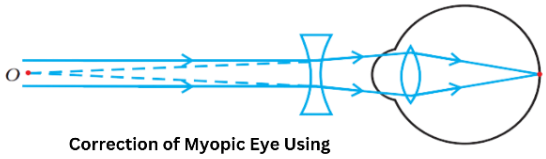


Defects of Vision and their correction

1. **Myopia (Near sightedness):** A human eye is myopic if it can see the nearby objects clearly but cannot see distant objects clearly. Image of a distant object is formed in front of retina.
   Causes of Myopia:
   1) Excessive curvature of eye lens
   2) Elongation of the eye ball

Correction of Myopia: Myopia can be corrected by using a concave lens of suitable power.

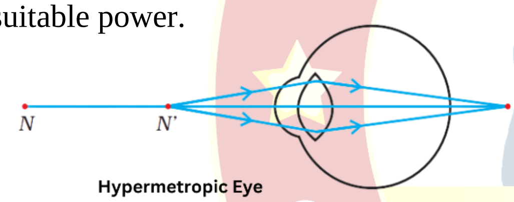
Myopic Eye



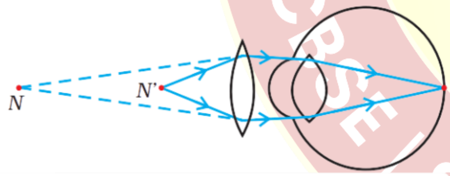
Correction of Myopic Eye Using Concave Lens

2. **Hypermetropia (Far sightedness):** Hypermetropia is a condition in which a person's eye can see distant or far-off objects clearly but not see nearby objects clearly.
   Causes of Hypermetropia:
   1) The focal length of the eye lens is too long
   2) The eyeball has become too small

Correction of Hypermetropia: Hypermetropia can be corrected by using a convex lens of suitable power.



Hypermetropic Eye



Correction of Hypermetropic Eye Using Convex Lens

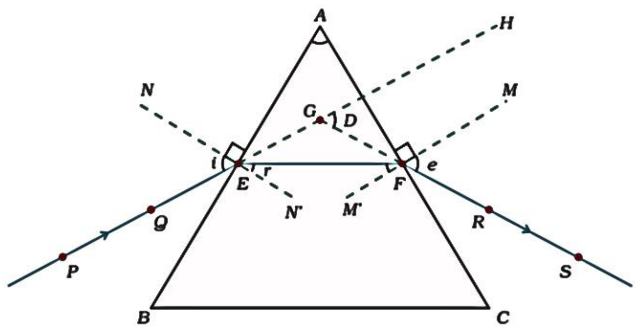
3. **Presbyopia:** Presbyopia is a condition in which a person's eye cannot see the near objects as well as far-off objects clearly. This defect arises due to the ageing of a person.
   Causes of presbyopia:
   1) Gradual weakening of ciliary muscles
   2) Diminishing flexibility of eye lens

   Correction of presbyopia: This defect can be corrected by using a **bi-focal** lenses. A bi–focal lens consists of a **concave lens** which forms the upper surface of the bi–focal lens and a **convex lens** which forms the lower surface of the bi–focal lens.

4. **Cataract:** Cataract is condition in which the crystalline lens of people at old age becomes milky and cloudy. This causes partial or complete loss of vision.
   Cause of Cataract: Cataract is caused due to the formation of an opaque membrane over the eye lens.
   Correction of cataract: Normal vision can be restored only when the affected lens has been surgically removed and replaced with an artificial lens.

Refraction Of Light Through a Prism

Prism: Prism is a pyramidal piece of glass with two triangular bases and three rectangular lateral surfaces.

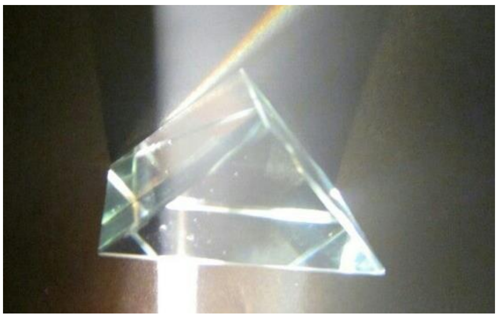


PE – Incident ray
EF – Refracted ray
FS – Emergent ray
∠A – Angle of the prism

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

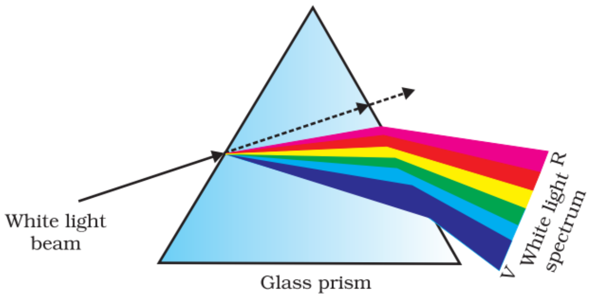
Angle of Prism(A): The angle between two non-parallel refracting surfaces is called angle of prism

Angle of deviation (D): It is the angle between incident ray and emergent ray.



Glass Prism

Dispersion Of White Light by A Glass Prism



Dispersion: The phenomenon of **splitting** white light into **seven** 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 (**VIBGYOR**).

Spectrum: The band of **seven** colours formed due to dispersion of white light is called spectrum.

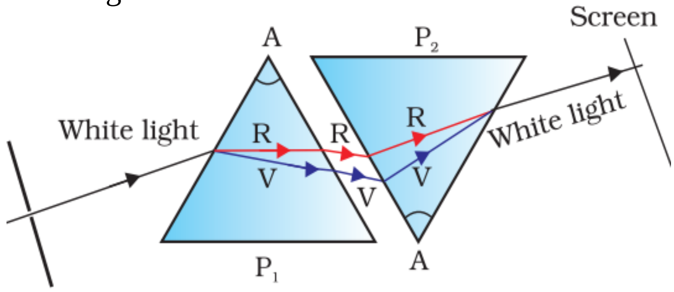
Cause of Dispersion: White light consists of seven colours: VIBGYOR. Every colour has its own wavelength. The wavelength of **red colour** is the **longest** and the wavelength of **violet colour** is **shortest**. *(Also, each colour of light travels with different speeds in a given medium. The speed of red colour in a medium is the highest and the speed of violet colour is the least*.) The red light bends the least while the violet bends the most**.** Therefore, when a white light passes through a glass prism, the different colours bend and come out of a prism at different angles. This gives rise to the dispersion of white light.

Isaac Newton activity: Issac Newton was the first person who proved that sunlight is made up of seven colours.

(i) He passed sunlight through a glass prism to form a **band of seven colours**.

(ii) He tried to split the colours further by putting **another prism** ahead of the prism forming spectrum but he failed to obtain more colours.

(iii) He formed a spectrum from sunlight and placed an identical but **inverted prism** in front of prism forming the spectrum. All the seven colours combined by the inverted prism and emerged as white light.



Critical Angle and Total Internal Reflection

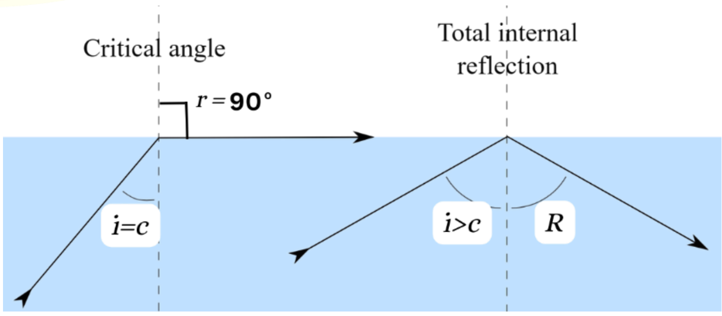
Critical Angle: Critical angle is the angle of incidence for which the angle of refraction becomes 90º.

Explanation:

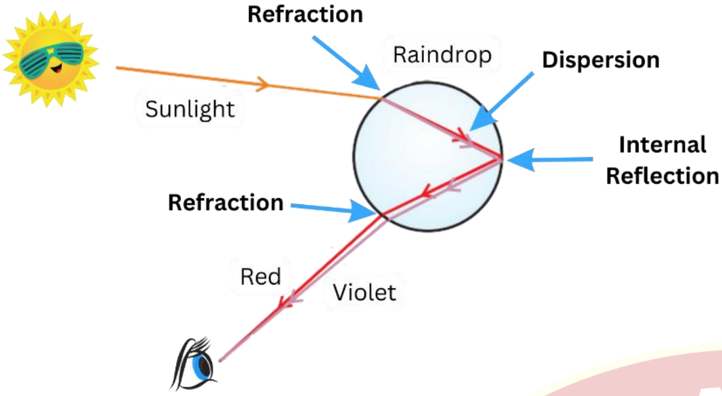
When light travels from a denser medium to a rarer medium it bends away from the normal at the boundary due to refraction. As the angle of incidence increases, the angle of refraction also increases. However, there comes a point where the angle of refraction becomes 90 degrees, and the refracted ray falls along the boundary, not actually entering the second medium.

*This angle of incidence at which this occurs is called the **critical angle**.*

Total Internal Reflection: If the angle of incidence is **larger** than the critical angle, the light gets completely reflected back into the denser medium. This phenomenon is known as total internal reflection.



Rainbow Formation



Rainbow is a natural spectrum appearing in the sky after rain showers. It is observed in the direction opposite to the sun. Rainbow is the example of dispersion of sunlight.

- Some water droplets remain suspended in air after rain. These droplets behave as glass prism.
- When light enters the rain drop, it first refracts and disperses.
- Then it reflects internally and again refracts as it come out of the drop and the seven colours reach the eye of observer in form of rainbow.
- Phenomena involved in rainbow formation:
  (i) Dispersion
  (ii) Refraction
  (iii) Internal reflection

Atmospheric Refraction

Refraction of light due to different layers of earth's atmosphere is called atmospheric refraction.

Explanation:

*In the atmosphere, the different **layers** of air have different **optical densities**. Hence different layers of air have different refractive index. Air in upper atmosphere is optically rarer and air in lower atmosphere is optically denser. So, when light rays pass through air, refraction takes place.*

Atmospheric refraction gives rise to many phenomena which are discussed ahead.

Twinkling of Stars

The twinkling of stars occurs due to **atmospheric refraction**. The optical density of air changes continuously in the different **layers** of the atmosphere.

Due to the continuous change in optical densities of air, the light is refracted **multiple times** through the atmosphere before it reaches our eyes.

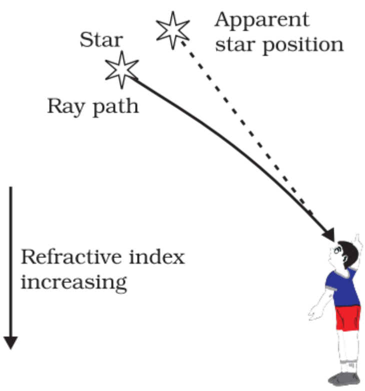
As a result, the amount of starlight entering our eye flickers (*the star sometimes appears brighter, and at some time, dim)*, this causes twinkling effect.

Why don't the planets twinkle?

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 twinkling effects of the planets are nullified and they do not twinkle.

Stars appear higher than their actual position

Due to atmospheric refraction, the stars seem to be higher in the sky than they actually are. Light from a star is refracted (bends) as it leaves space and enters the earth's atmosphere. Air in the upper sky is rarer than the lower sky (near the earth's surface). So, as the starlight comes down, the dense air bends the light more. Due to this refraction of star's light, the star appears to be at a higher position.

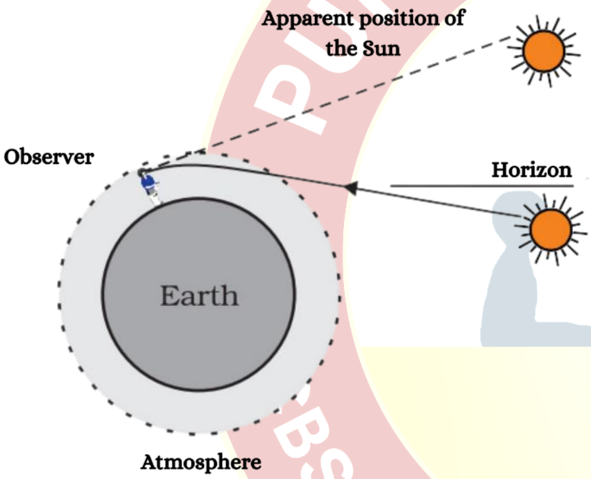


Advance sunrise and delayed sunset

Sun is visible to us about 2 minutes before the actual sunrise, and about 2 minutes after the actual sunset because of **atmospheric refraction**.

Explanation:

The rays of light from the sun below the horizon reach our eyes because of refraction of light. These rays appear to come from the apparent position of the sun which is above the horizon as shown in figure. Hence, we can see the sun for 2 minutes even after it has actually set. Similarly, the sun can be seen about 2 minutes before it actually rises. Thus, we gain 4 minutes of additional daylight each day.



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

At sunset and sunrise, the sun is near the horizon*. The rays of light from the upper and lower edge of the sun bend unequally while traveling through the atmosphere. As a result of this phenomenon, the sun appears oval or flattened

**Horizon means: the line where the earth and sky appear to meet*

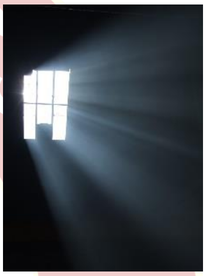
Scattering Of Light

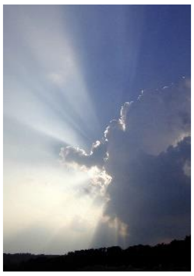
Scattering of light means spreading of light in various directions by the particles present in the atmosphere of the earth.

Tyndall Effect: The phenomenon of scattering of light by colloidal particles (*dust, smoke and water droplets*) suspended in air is known as Tyndall effect. For example:

(i) Path of light becomes visible when light enters a dark and dusty room through a slit or ventilator.

(ii) Path of light becomes visible when light passes through dense canopy of trees in a forest.





Why is the colour of the clear Sky Blue?

When sunlight enters the earth's atmosphere, the fine particles *(atoms or molecules of the gases)* present in the atmosphere scatter this light. Since **wavelength** of **red colour is larger**, so red colour is least scattered and wavelength of **blue colour** is **shorter**, so blue colour is scattered the most. (*Violet colour is scattered the most but our eye is more sensitive to the blue light than the violet light.)* Therefore, scattered light in the sky contains blue colour and hence the clear sky appears blue.

If the earth had no atmosphere there would not be any scattering of light and the sky would appear **dark**. The sky appears dark at very high altitudes. For astronauts far from the atmosphere of the earth, the sky appears dark as there is no scattering of light.

Danger signs are made in red colour because red is the least scattered colour. It is least scattered by fog and smoke and can be seen from a long distance.