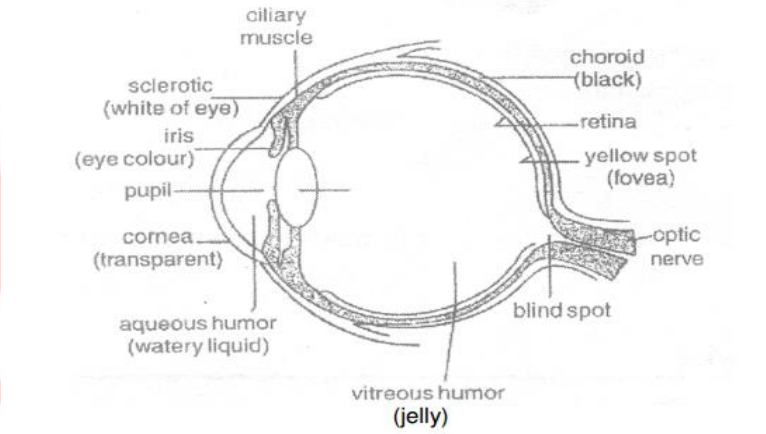
Chapter-11

HUMAN EYE AND THE COLORFUL WORLD

STUDY NOTES

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



1) **Cornea:** It is the transparent spherical membrane covering the front of the eye. Light enters the eye through this membrane. Most of the refraction occurs at the outer surface of the cornea.
2) **Iris:** It is a dark muscular diaphragm between the cornea and the lens. It controls the size of the pupil.
3) **Pupil:** It is a small hole between the iris through which light enters the eye. In dim light it expands and in bright light it contracts.
4) **Crystalline Lens:** The eye lens is a convex lens made of a transparent, soft and flexible material like a jelly made of proteins
5) **Ciliary Muscles: They** hold the lens in position and help in modifying the curvature of the lens.
6) **Retina:** It is the light sensitive surface of the eye on which the image is formed. It contains **Rods and Cones**. Rod cells respond to intensity of light and cone cells respond to colors. These cells generate signals which are transmitted to the brain through the optic nerve.
7) **Optic Nerve:** It transmits visual information from the retina to the brain.

8) **Sclera:** It is an opaque, fibrous, protective outer layer of an eye containing collagen and elastic of the fiber. It is also called as the white of the eye.
9) **Blind Spot: It** is the point at which the optic nerve leaves the eye. It contains no rods and cones. So an image formed at this point is not sent to the brain.
10) **Aqueous humour:** Between the cornea and the eye lens, we have a space filled with a transparent liquid called the aqueous humour. It maintains the intraocular pressure.
11) **Vitreous humour:** The space between the eye lens and retina is filled with another liquid called vitreous humour.

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

Accommodation: It is the ability of the eye lens to focus both near and distant objects by adjusting its focal length.

Near point: The minimum distance at which an object can be seen most distinctly without any strain is called **the least distance of distinct vision.**

- It is **25 cm** for normal eye of an adult.
- It is also called near point of the eye.

Far point: it is the farthest point up to which the eye can see clearly.

- It is infinity for normal eye.

Persistence of vision: The time for which sensation of an object continues in the eye is called persistence of vision.

- It is about $1/16^{th}$ of a second.

Power of accommodation: It is the maximum variation in power of eye lens for focusing nearby or far objects.

- For young adults, with normal vision, the power of accommodation is about 4D.

Defects of vision:

The defects due to which a person cannot see the objects distinctly and comfortably are called defects of vision.

The three main defects are:

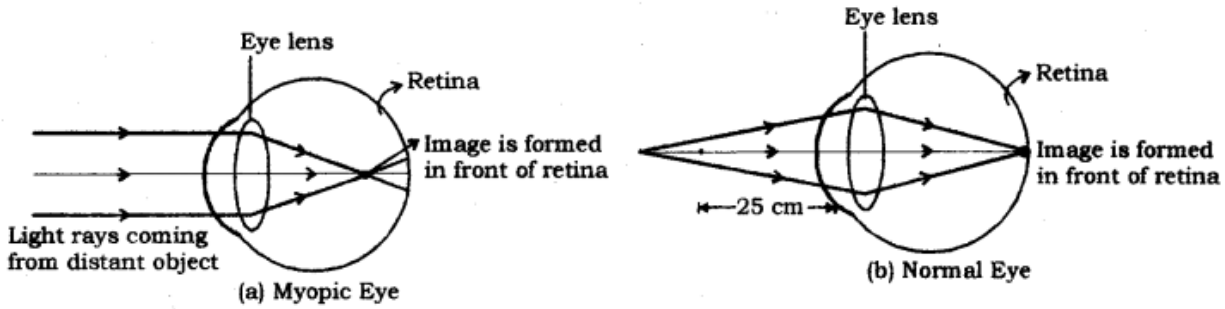
1) Myopia or short sightedness
2) Hypermetropia or long sightedness
3) Presbyopia

4) Astigmatism

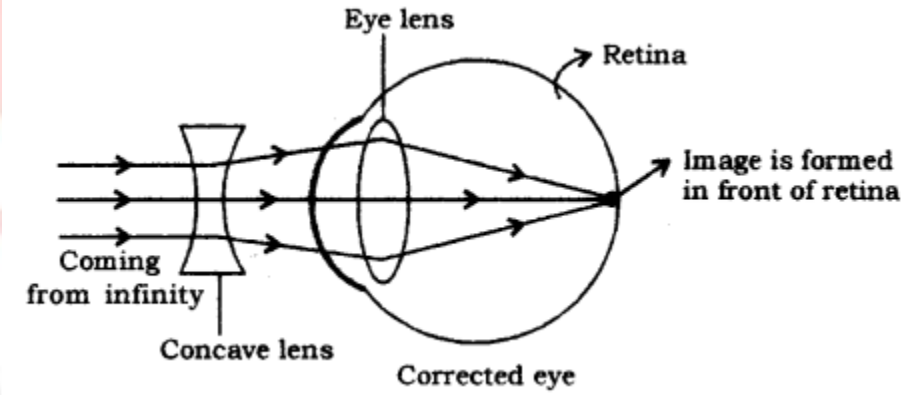
5) Cataract

1. Myopia: 1. the defect in which a person can see nearby objects distinctly but cannot see distant objects clearly is called myopia.

2. In this case, the image is formed before retina.
3. **Causes**: I. Excessive curvature of eye lens.
II. Elongation of eye ball.



Remedy: This defect can be corrected by using **concave lens** of appropriate power

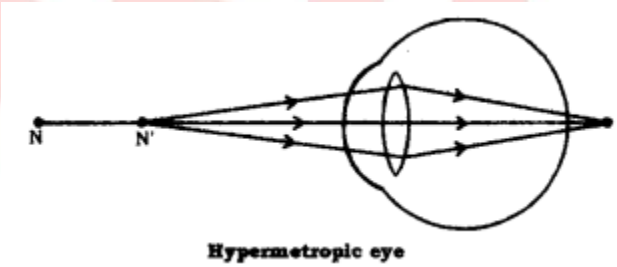


2. Hypermetropia: : 1. The defect in which a person can see distant objects distinctly but cannot see nearby objects clearly is called hypermetropia.

2. In this case, the image is formed after retina.

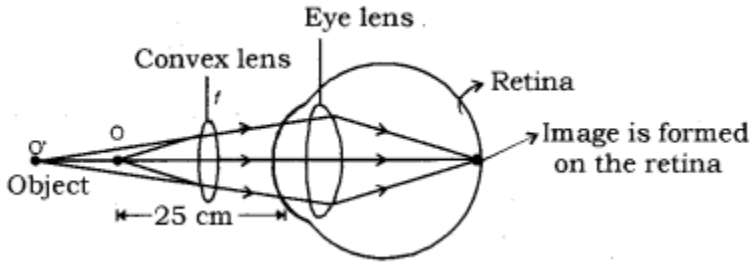
Causes:

- Focal length of eye lens becomes large.
- Eye ball becomes too short.



Hypermetropic eye

Remedy: This defect can be corrected by using **convex lens** of appropriate power.



3. Presbyopia: It is found in old people.

- For most people the near point recedes away with age.
- Sometimes people may suffer from both myopia and hypermetropia.

Causes:

- Weakness of ciliary muscles.
- Hardening or loss of elasticity of eye lens.

Remedy: The defect can be corrected by using bifocal lenses which contains both concave lens and convex lens.

Power of the correcting convex lens:

The Lens formula, 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) =1/f (in m)

Power of the correcting convex lens: Lens formula, 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

1/v +1/25 = 1/f.

Astigmatism:

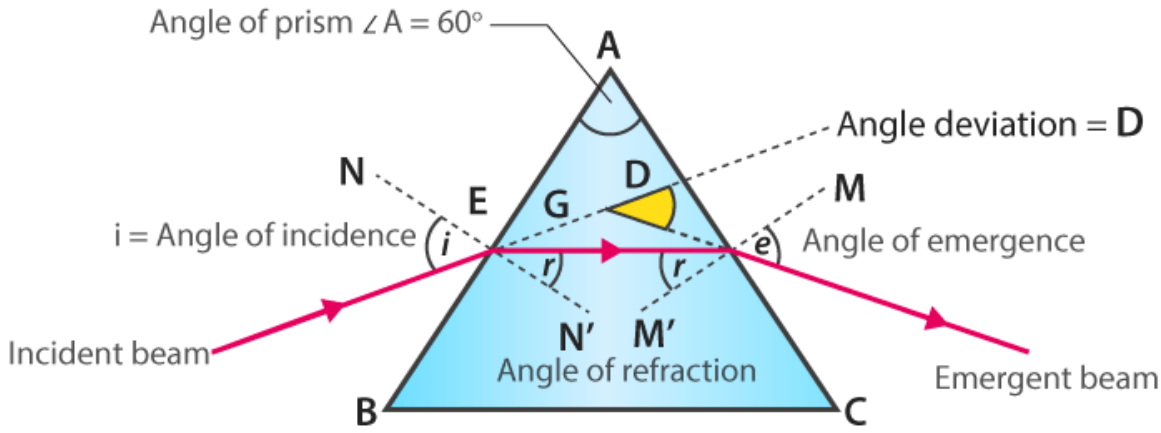
- It is a kind of defect in human eye due to which a person cannot see (focus) simultaneously **horizontal and vertical lines** both.
- **Correction**: By using a **cylindrical lens**.

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:** 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 is inclined at an angle called the angle of prism.

Prism: A prism has two triangular bases and three rectangular bases.

- **Angle of Prism**: Angle between two lateral faces is
- **Angle of Deviation**: The angle between the incident ray and the emergent ray.

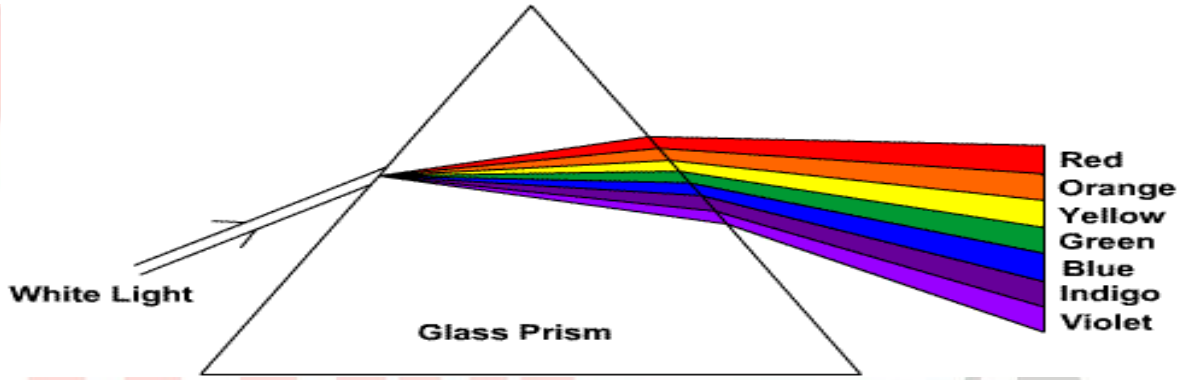


Tracing the path of light ray through prism

Dispersion of light through a glass prism:

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

https://youtu.be/Wx0GIDvyMIY



- **Composition of white light**: White light consists of seven colors i.e., violet, indigo, blue, green, yellow, orange and red.
- **Monochromatic light**: Light consisting of single color or wavelength is called monochromatic light, example; sodium light.
- **Polychromatic light**: Light consisting of more than two colors 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.

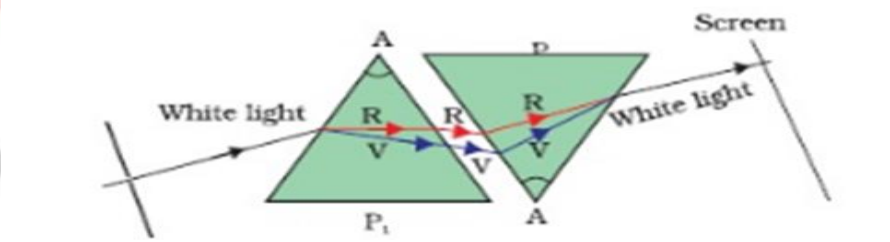


Figure 11.6 Recombination of the spectrum of white light

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.

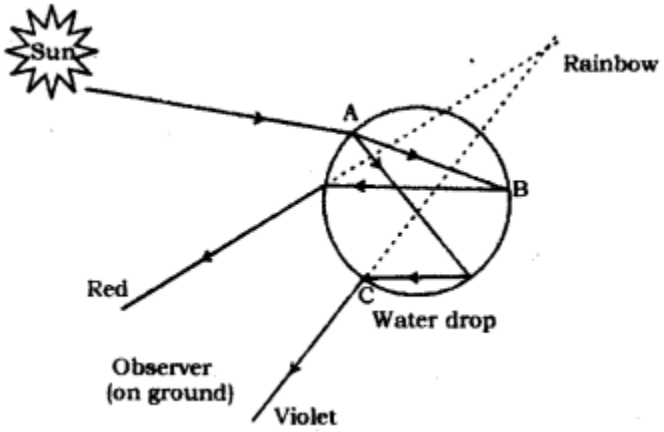
- **Formation of the rainbow**: The water droplets act like small prism. They refract and disperse the incident sunlight, then reflect it internally, and finally refract it again when it comes out of the raindrop.
- Due to the dispersion of light and internal reflection, different colors reach the observer's eye.
  Red color appears on top and violet at the bottom of rainbow.

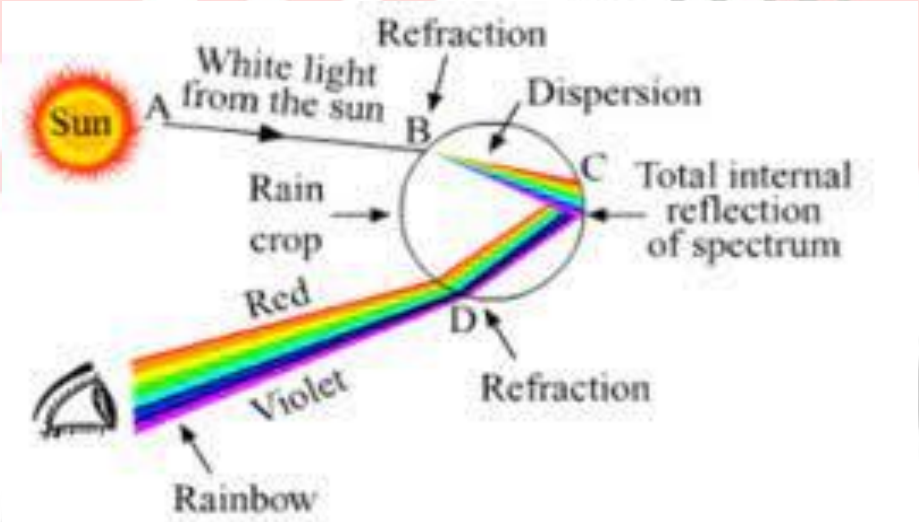
- A rainbow is always formed in a direction opposite to that of Sun.

  At 'A' – Refraction and dispersion take place.

  At 'B' – Internal reflection takes place.

  At 'C' – Refraction and dispersion take place.

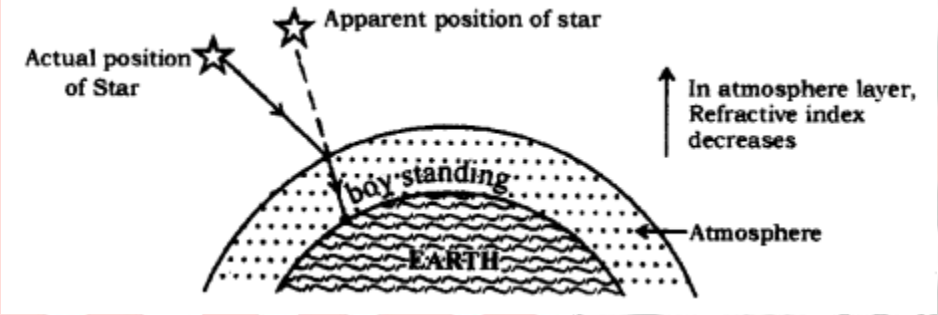




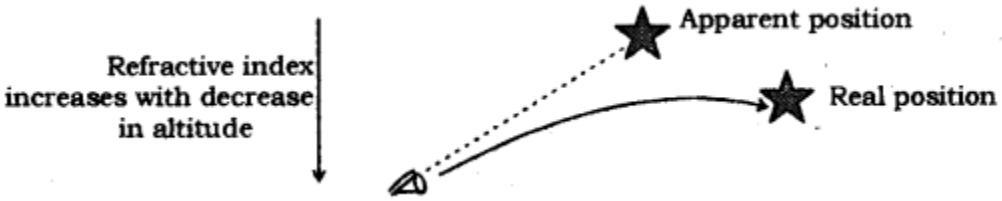
Atmospheric Refraction: The refraction of light caused by the Earth's atmosphere (having air layers of varying optical densities) is called Atmospheric Refraction.

1. Appearance of Star Position:
   - It is due to 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 enters 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 appears higher than its actual position.



2. **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".

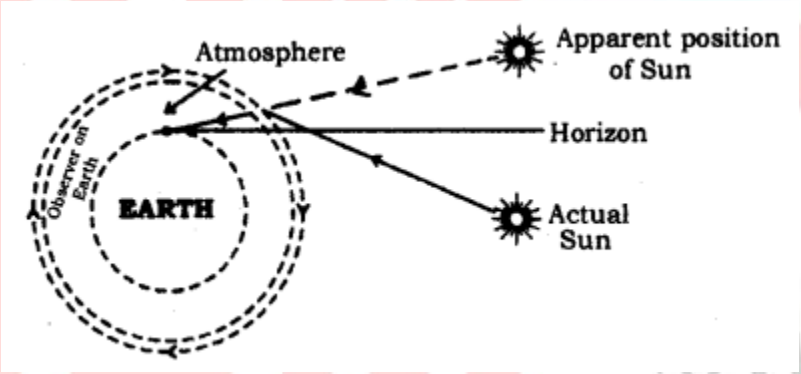


3. Planets do not twinkle.

- 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.

4. Advance sunrise and delayed sunset:

- The sun is visible to us about two minutes before the actual sun rise and about two minutes after the actual sun set because of atmospheric refraction.
- When the sun is slightly below the horizon, the sun light come from less dense to denser air.
- So it is refracted downwards, due to this sun appears to be raised above the horizon and we can see it before the sun rise.



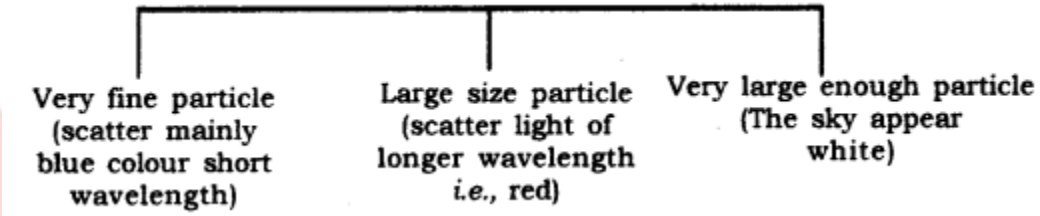
Scattering of light:

- According to Rayleigh' Law of Scattering, the amount of scattered light ∝ 1λ4 (λ = wavelength)
- Scattering of light decreases with increase in wavelength.

1. 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 color of the scattered light depends on the size of the scattering particles.



2. Color of sun at the time of Sunrise and Sunset:

- While sunset and sunrise, the color of the sun and its surrounding appear red.

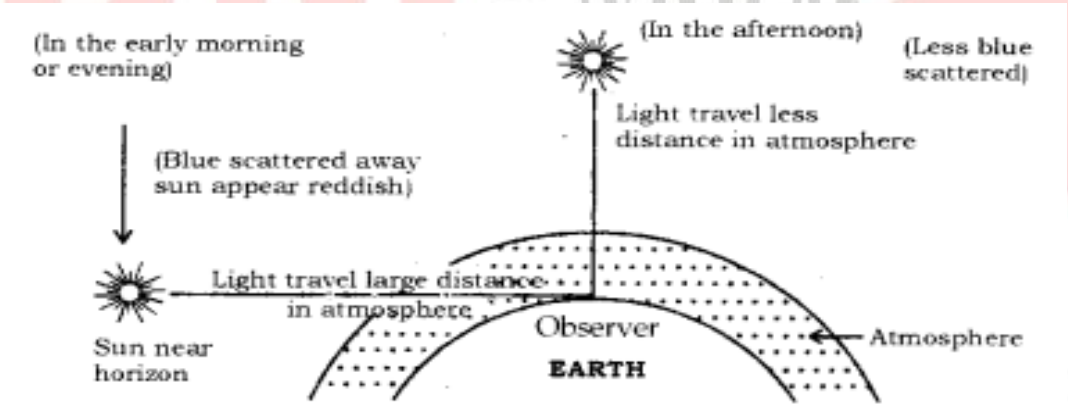
- During sunset and sunrise, the sun is near to horizon, and therefore, the sunlight has to travel larger distance in atmosphere.
- Due to this, most of the blue light (shorter wavelength) is scattered away by the particles.
- The light of longer wavelength (red color) reaches our eye. This is why sun appears red in color.

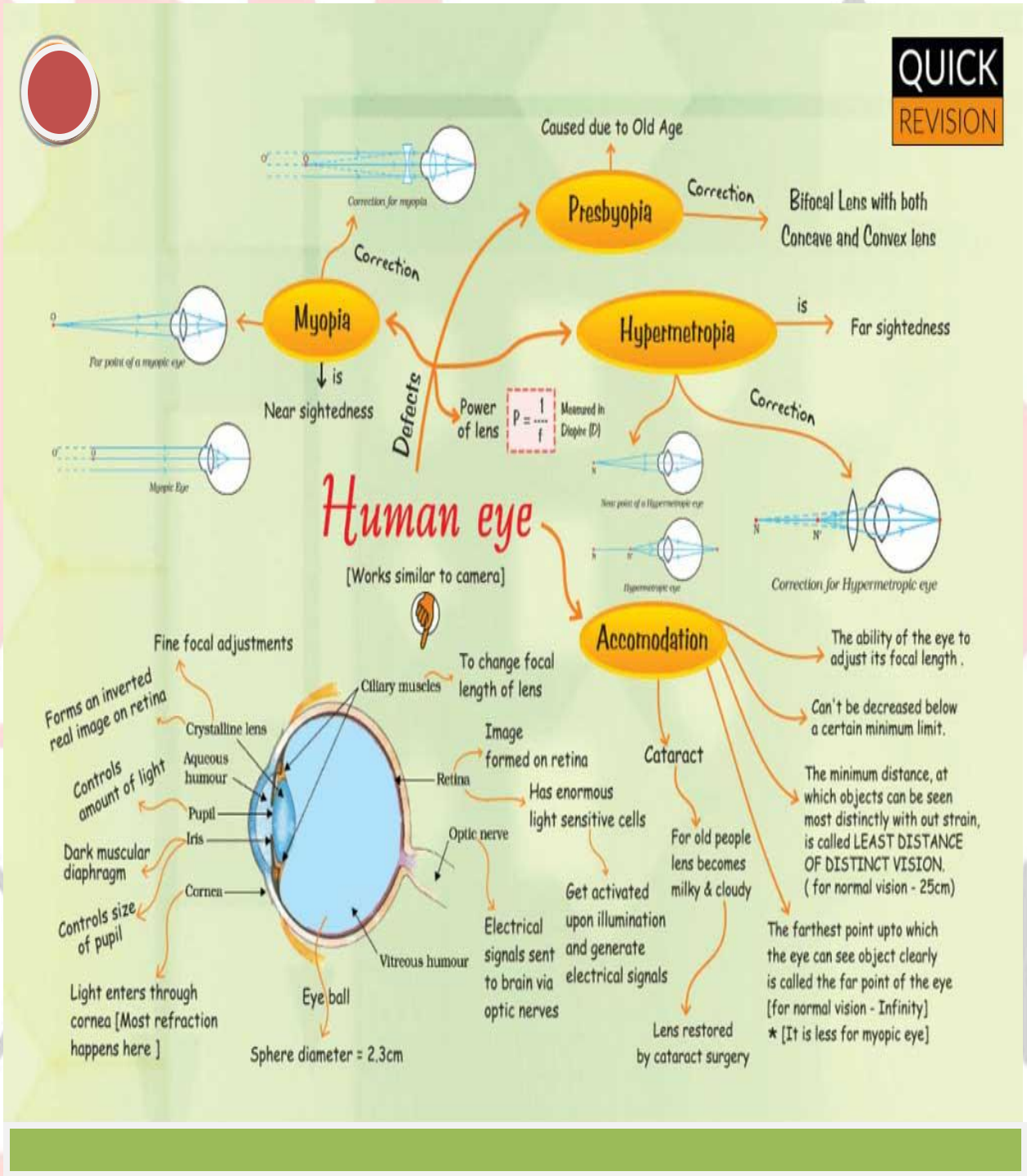
3. Why the danger signal or sign is made of red color?

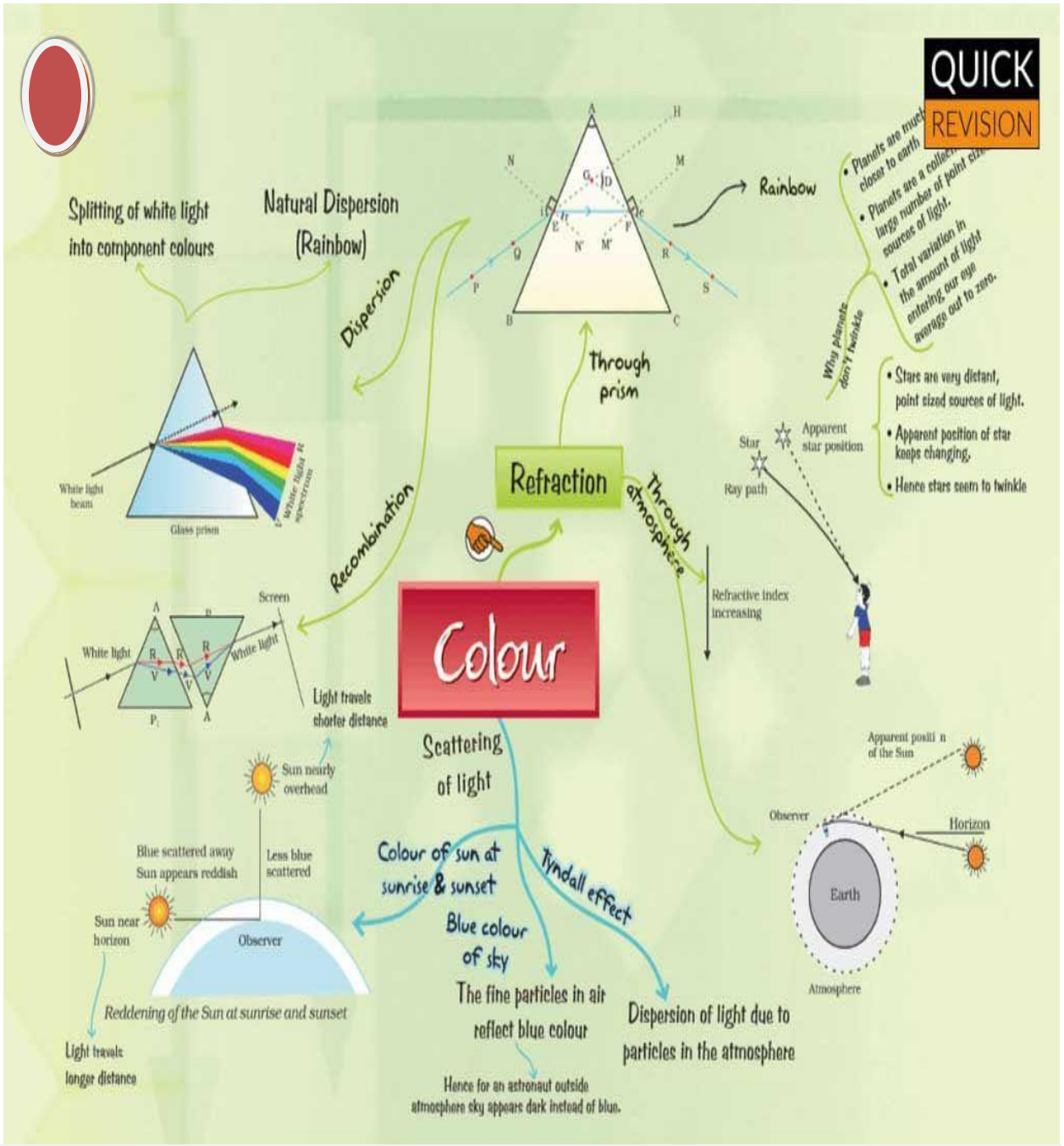
- Red color scatters the most when strikes the small particle of fog and smoke because it has the maximum wavelength (visible spectrum).
- Hence, from large distance also, we can see the red color clearly

4. 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 appears white as only little of the blue and violet colors are scattered.




QUICK
REVISION
Human eye
[Works similar to camera]
Defects
Myopia
is
Near sightedness
Correction
Correction for myopia
Far point of a myopic eye
Myopic Eye
Caused due to Old Age
Presbyopia
Correction
Bifocal Lens with both
Concave and Convex lens
Hypermetropia
is
Far sightedness
Correction
Correction for Hypermetropic eye
Power of lens
P = 1/f
Measured in Diopter (D)
Accomodation
The ability of the eye to adjust its focal length .
Can't be decreased below a certain minimum limit.
The minimum distance, at which objects can be seen most distinctly with out strain, is called LEAST DISTANCE OF DISTINCT VISION. (for normal vision - 25cm)
The farthest point upto which the eye can see object clearly is called the far point of the eye [for normal vision - Infinity]
★ [It is less for myopic eye]
Cataract
For old people lens becomes milky & cloudy
Lens restored by cataract surgery
Fine focal adjustments
To change focal length of lens
Ciliary muscles
Forms an inverted real image on retina
Crystalline lens
Aqueous humour
Controls amount of light
Pupil
Iris
Dark muscular diaphragm
Controls size of pupil
Cornea
Light enters through cornea [Most refraction happens here]
Eye ball
Sphere diameter = 2.3cm
Vitreous humour
Retina
Image formed on retina
Has enormous light sensitive cells
Optic nerve
Electrical signals sent to brain via optic nerves
Get activated upon illumination and generate electrical signals


QUICK
REVISION
Colour
Refraction
Through prism
Through atmosphere
Recombination
Dispersion
Splitting of white light into component colours
Natural Dispersion (Rainbow)
Rainbow
Refractive index increasing
Light travels shorter distance
Light travels longer distance
Scattering of light
Colour of sun at sunrise & sunset
Blue colour of sky
Tyndall effect
The fine particles in air reflect blue colour
Dispersion of light due to particles in the atmosphere
Hence for an astronaut outside atmosphere sky appears dark instead of blue.
Reddening of the Sun at sunrise and sunset
Blue scattered away
Sun appears reddish
Less blue scattered
Sun near horizon
Observer
Sun nearly overhead
Apparent position of the Sun
Horizon
Earth
Atmosphere
Star
Apparent star position
Ray path
Why planets don't twinkle
• Planets are much closer to earth
• Planets are a collection of large number of point sized sources of light.
• Total variation in the amount of light entering our eye average out to zero.
• Stars are very distant, point sized sources of light.
• Apparent position of star keeps changing.
• Hence stars seem to twinkle
White light beam
Glass prism
White light
Screen