Human Eye and The Colourful World

10^{th} Class

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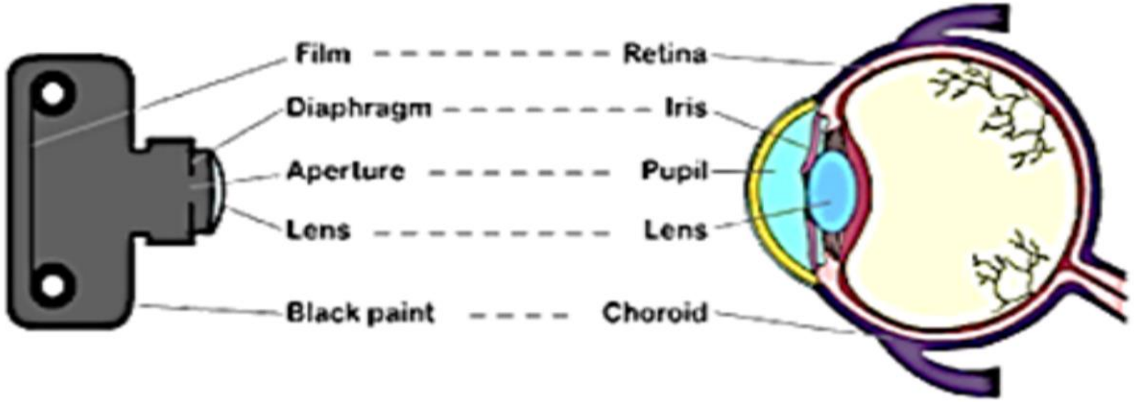
THE HUMAN EYE

- The **eyeball** is nearly spherical with a diameter of **2.3 cm.**
- Eye is like a **camera.**
- It has the following main parts:

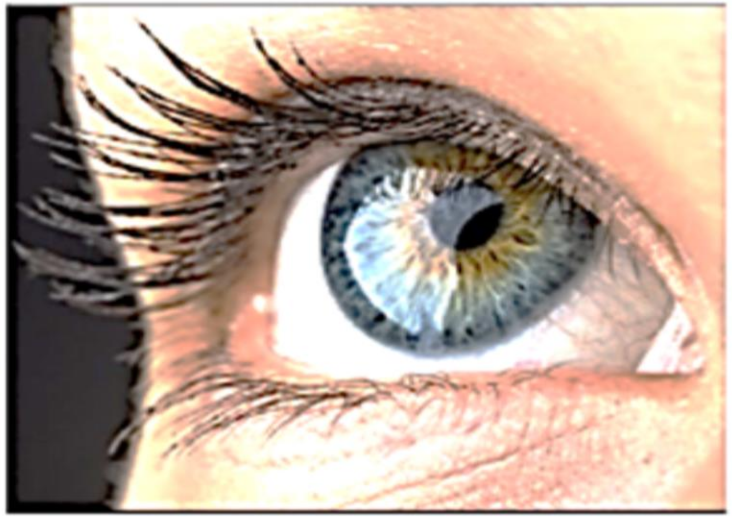


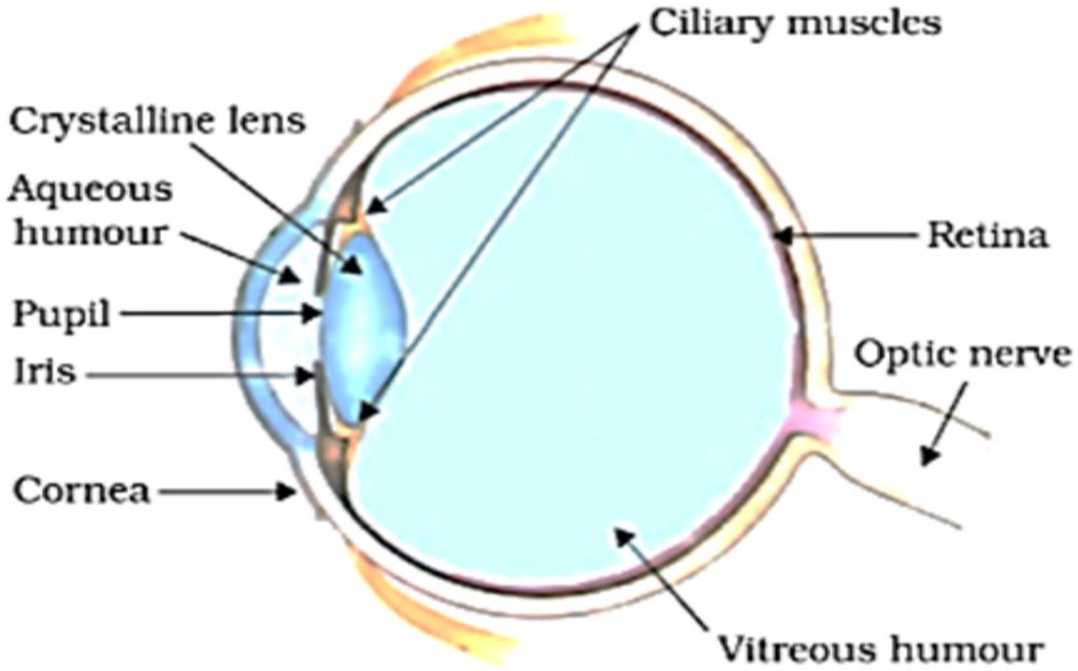
Cornea

Iris

Lens

Retina





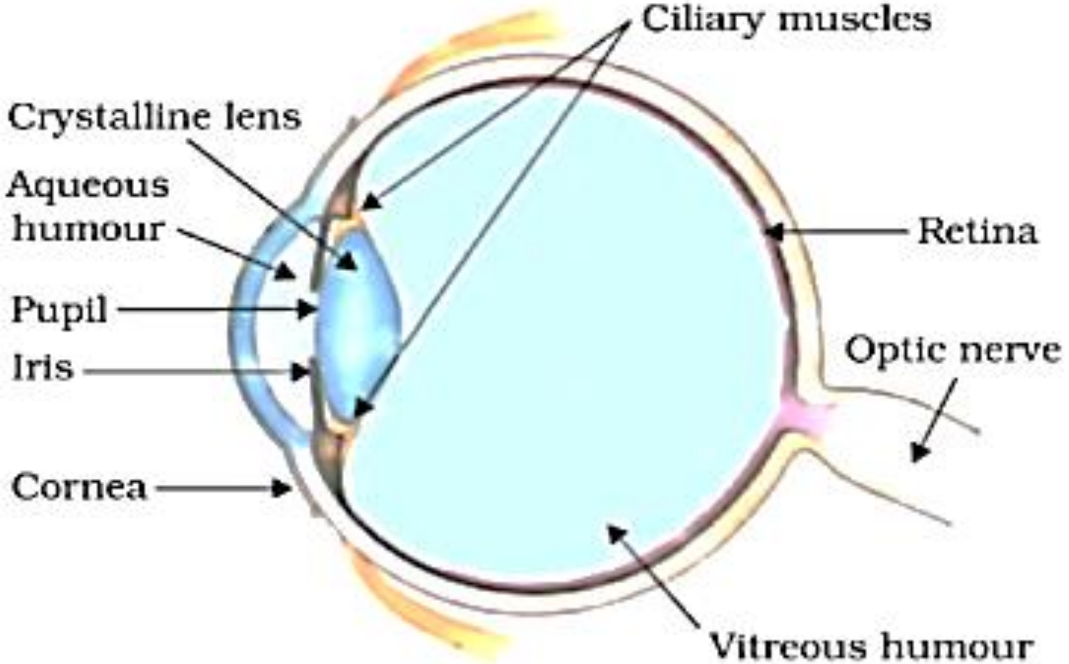
THE HUMAN EYE

Cornea

- A thin transparent bulged membrane on the front of eyeball.
- Light enters the eye through the cornea. Most of the refraction for light rays occurs at the outer surface of the cornea.

Iris

- A dark **muscular diaphragm** behind the cornea.
- It controls the size of the **pupil.**
- Pupil is an aperture to regulate the amount of light entering the eye.



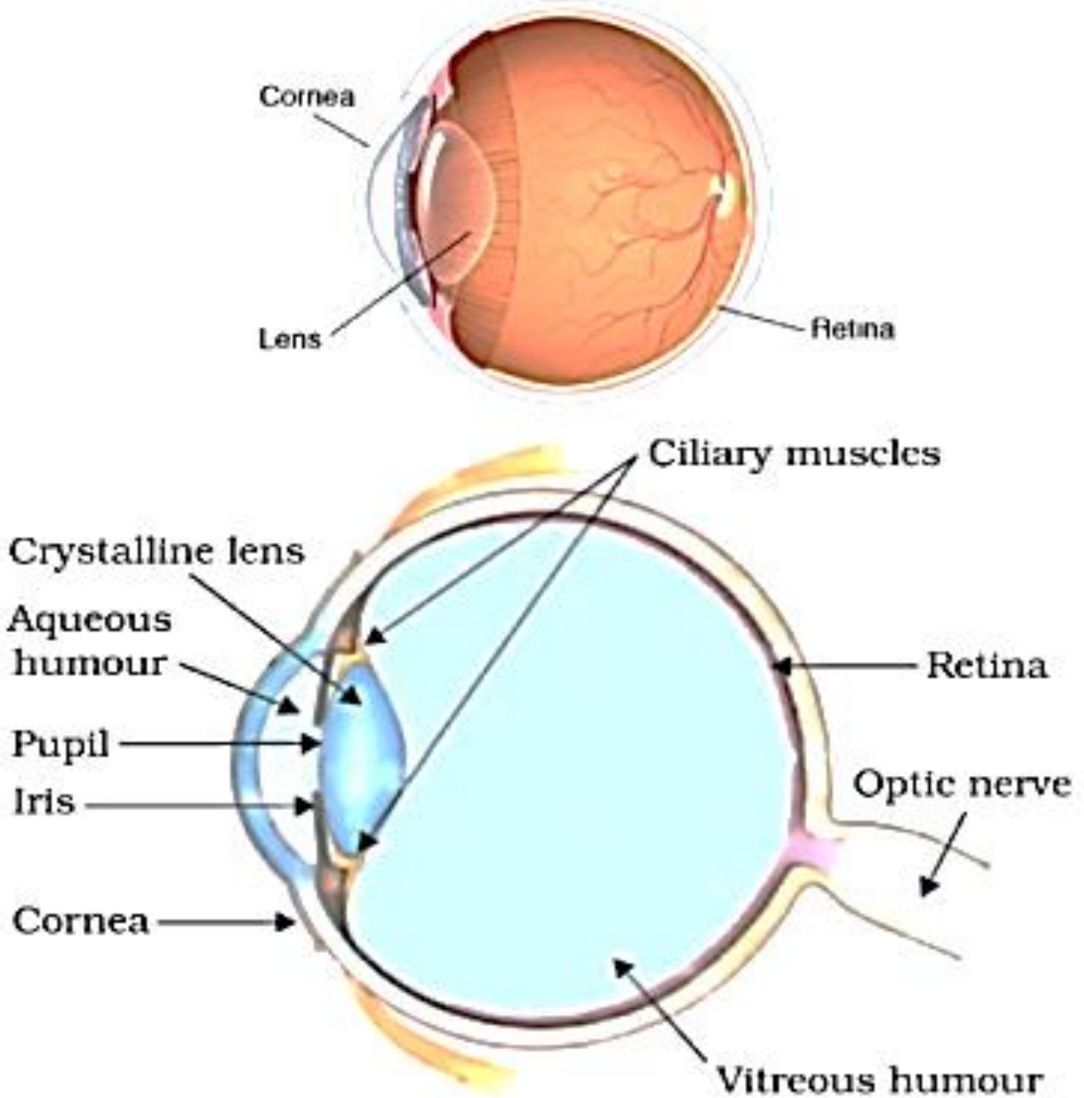
THE HUMAN EYE

Lens

- It is composed of a **fibrous, jelly-like** material.
- It forms an **inverted real image** of the object on retina. It can adjust the focal length to focus objects at different distances on the retina.

Retina

- A delicate membrane with many light-sensitive cells.
- They get activated upon illumination and generate **electrical signals (impulse).**
- Signals are sent to the brain via optic nerves. Brain interprets the signals to perceive objects.



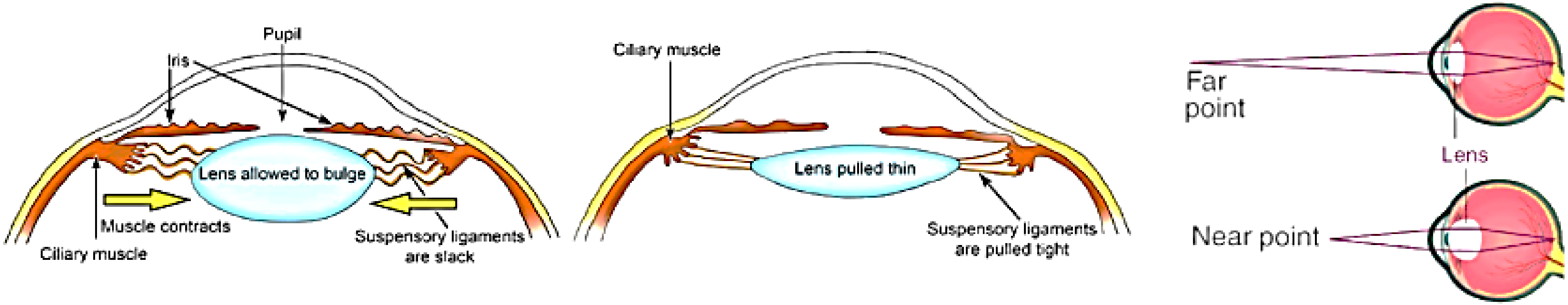
THE HUMAN EYE

When we enter from **bright light to a dim light room,** we cannot see objects clearly for some time. Then it becomes clear. In bright light, **iris contracts the pupil** so that less light enters the eye. In dim light, **iris relaxes to expand the pupil** so that more light enters.

THE HUMAN EYE

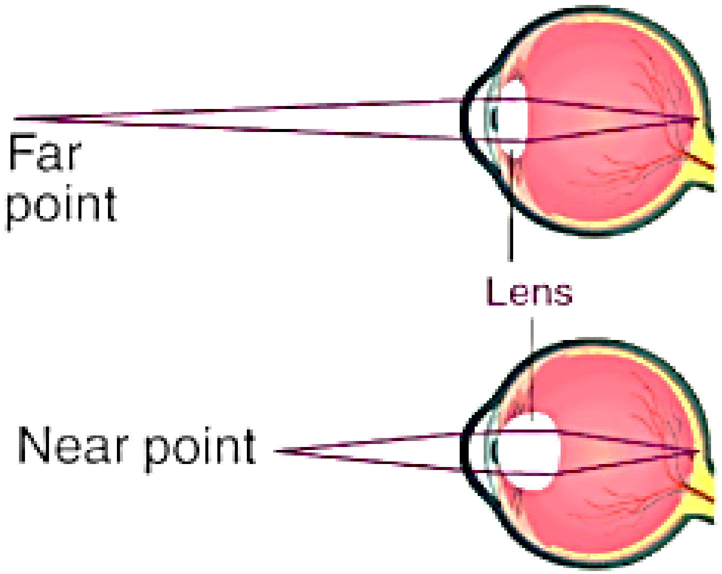
Power of Accommodation

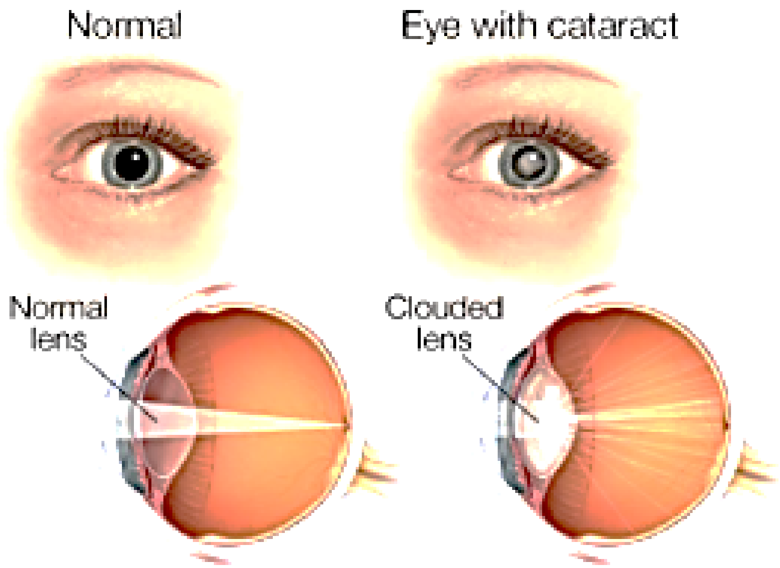
- It is the ability of the **eye lens** to adjust its **focal length** by changing its **curvature.**
- When **ciliary muscles relax,** lens becomes thin and its **focal length increases.** It enables **distant vision.**
- When **ciliary muscles contract,** curvature of the lens increases (lens becomes thicker). So its **focal length decreases.** This enables **nearby vision.**
- However, focal length of the lens cannot be decreased below a minimum limit. That's why we cannot clearly read or see an image held very close to eyes.



THE HUMAN EYE — Power of Accommodation

- **Least distance of distinct vision (near point of the eye):** It is the minimum distance at which objects can be seen most distinctly without strain. It is **25 cm.**
- **Far point of the eye:** It is the farthest point up to which eye can see objects clearly. It is **infinity.**
- A normal eye can clearly see objects **b/w 25 cm & infinity.**
- The lens of some people at old age becomes milky and cloudy causing partial or complete loss of vision. This is called **cataract.** It can be rectified by **cataract surgery.**





DEFECTS OF VISION AND THEIR CORRECTION

Defects of vision (refractive defects) are caused due to gradual **loss of power of accommodation.**

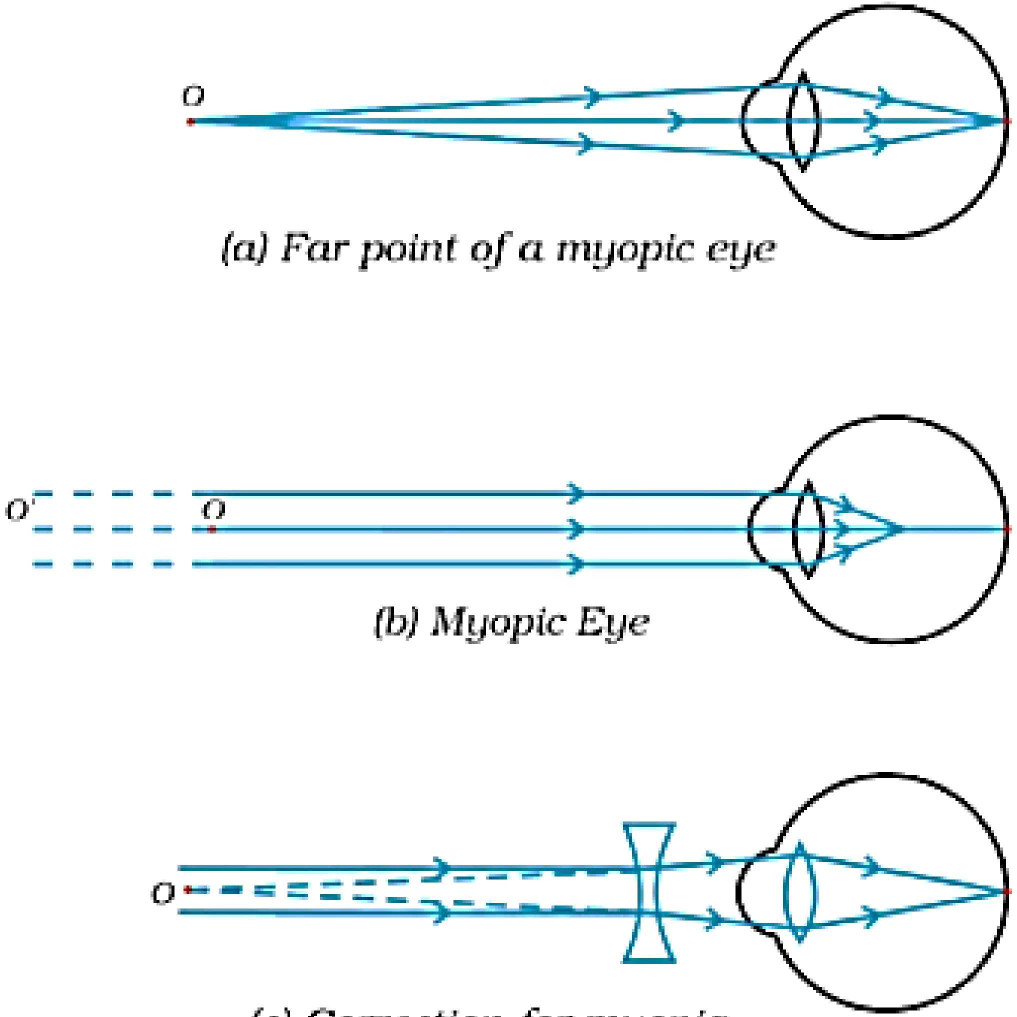
3 types of defects of vision

- Myopia
- Hypermetropia
- Presbyopia

DEFECTS OF VISION AND THEIR CORRECTION

(a) Myopia (near-sightedness)

- Here, a person can see nearby objects clearly but **cannot see distant objects** distinctly.
- A myopic person has the far point nearer than infinity.
- This is caused due to the formation image of a distant object in front of the retina.



(a) Far point of a myopic eye

(b) Myopic Eye

(c) Correction for myopia

Reasons

1. Excessive curvature of the lens.
2. Elongation of the eyeball.

Correction

Use a **concave lens** of suitable power. It brings the image back on to the retina.

DEFECTS OF VISION AND THEIR CORRECTION

(b) Hypermetropia (far-sightedness)

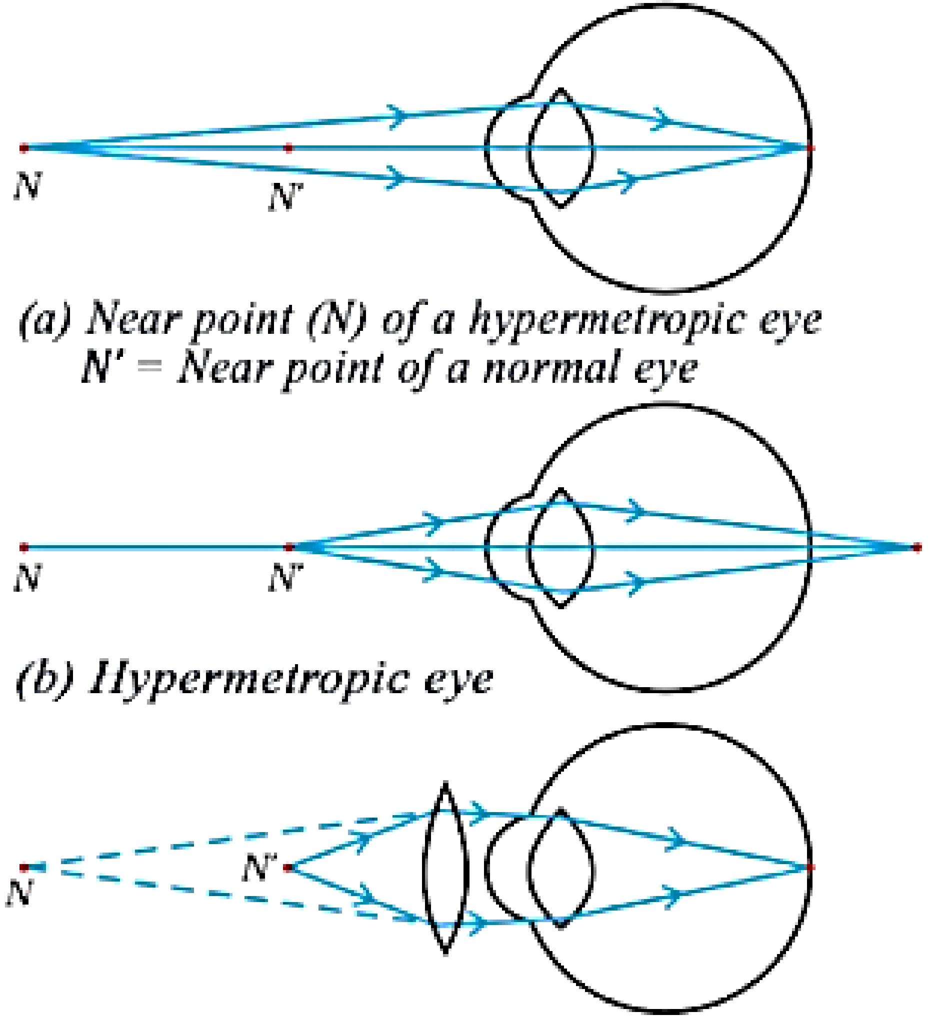
- Here, a person can see distant objects clearly but **cannot see nearby objects** distinctly.
- The near point is farther away from the normal near point (25 cm). Such a person must keep a reading material beyond 25 cm from the eye.
- This is because the light rays from a close object are focussed at a point behind the retina.

Reasons

1. Focal length of the eye lens is too long.
2. Eyeball becomes too small.

Correction

Use **convex lens (converging lenses)** of suitable power. It provides additional focussing to form the image on the retina.



(a) Near point (N) of a hypermetropic eye
N' = Near point of a normal eye

(b) Hypermetropic eye

(c) Correction for Hypermetropic eye

DEFECTS OF VISION AND THEIR CORRECTION

(c) Presbyopia

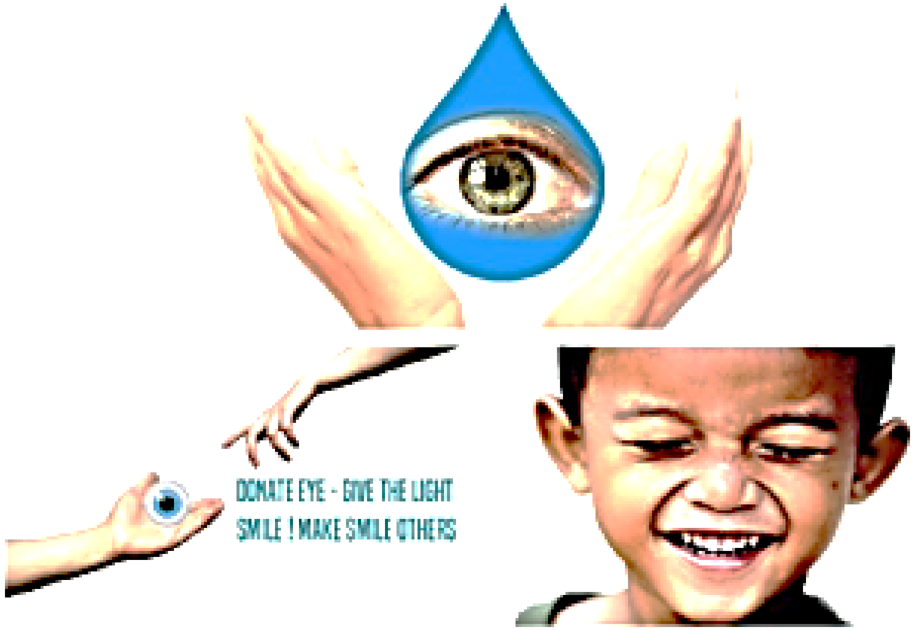
- Here, the **power of accommodation of the eye decreases with ageing.** For most people, the near point gradually recedes away. So comfortable and distinct vision of nearby objects is not possible.
- It is due to the gradual **weakening of the ciliary muscles** and **diminishing flexibility of the eye lens.**

- Some people may have both myopia & hypermetropia. They require **bi-focal lenses.** Its **upper part** is a **concave lens for distant vision.** The **lower part** is a **convex lens for near vision.**
- Refractive defects can also be corrected with **contact lenses** or through **surgery.**

DEFECTS OF VISION AND THEIR CORRECTION

- About **35 million people** in the developing world are **blind.**
- About **4.5 million** people with **corneal blindness** can be cured through **corneal transplantation.** Of these, **60% are children** below the age of 12. So, eye donation is important.

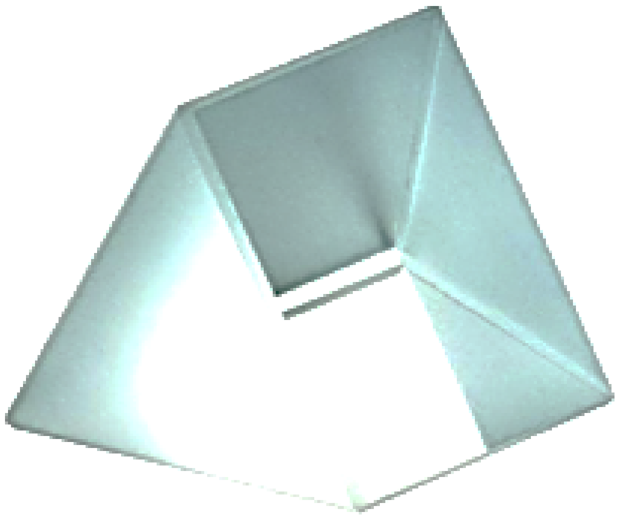
- Eye donors can belong to any age group or sex.
- Eyes must be removed within 4-6 hours after death.
- The eye bank team removes the eyes at the home of the deceased or at a hospital. It takes only 10-15 minutes without causing any disfigurement.
- Persons who were infected with or died because of AIDS, Hepatitis B or C, rabies, acute leukaemia, tetanus, cholera, meningitis or encephalitis cannot donate eyes.

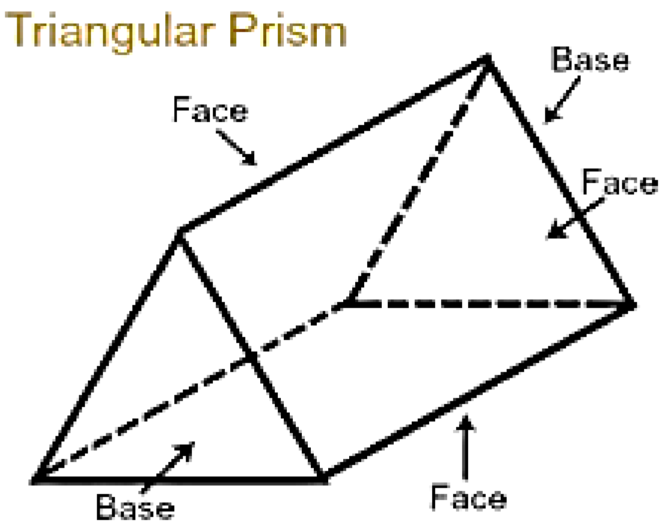


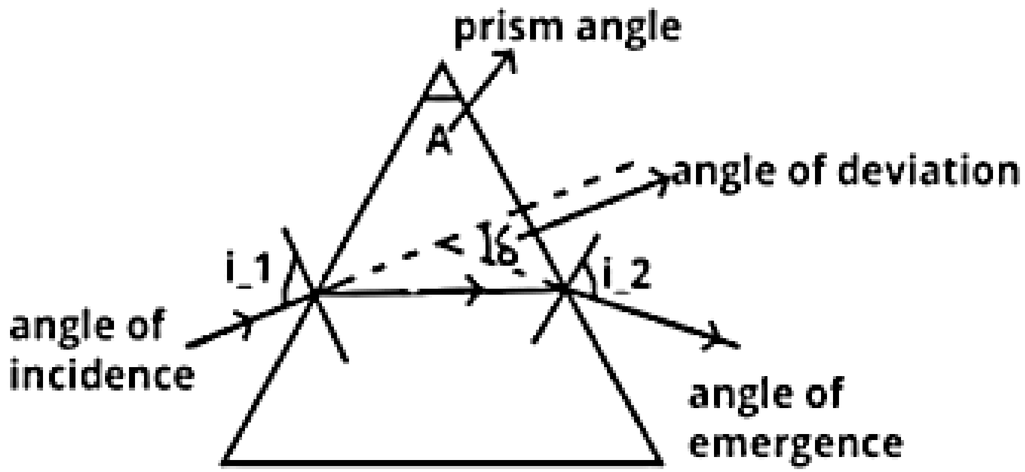
- The donated eyes unsuitable for transplantation are used for research & medical education.
- **One pair of eyes** gives vision to up to **4 corneal blind people.**

REFRACTION OF LIGHT THROUGH A PRISM

- 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.**



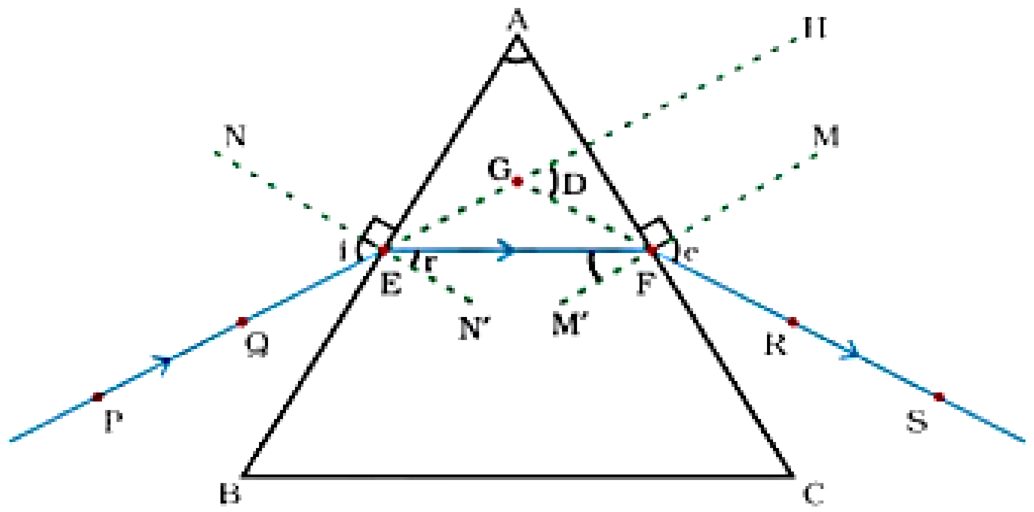




REFRACTION OF LIGHT THROUGH A PRISM

Refraction of light through a triangular glass prism

- Fix a white paper on a drawing board using drawing pins. Place a **glass prism** on it such that it rests on triangular base. Trace the outline of the prism.
- Draw a **straight-line PE** inclined to one of the **refracting surfaces (AB).**
- Fix two pins, at points P & Q on the line PE.
- Look for the images of the pins through the other face AC.
- Fix two pins, at points R & S, such that these pins and the images of the pins at P & Q lie on the same straight line.
- Remove the pins and the glass prism.



PE – Incident ray

EF – Refracted ray

FS – Emergent ray

∠A – Angle of the prism

∠i – angle of incidence

∠r – Angle of refraction

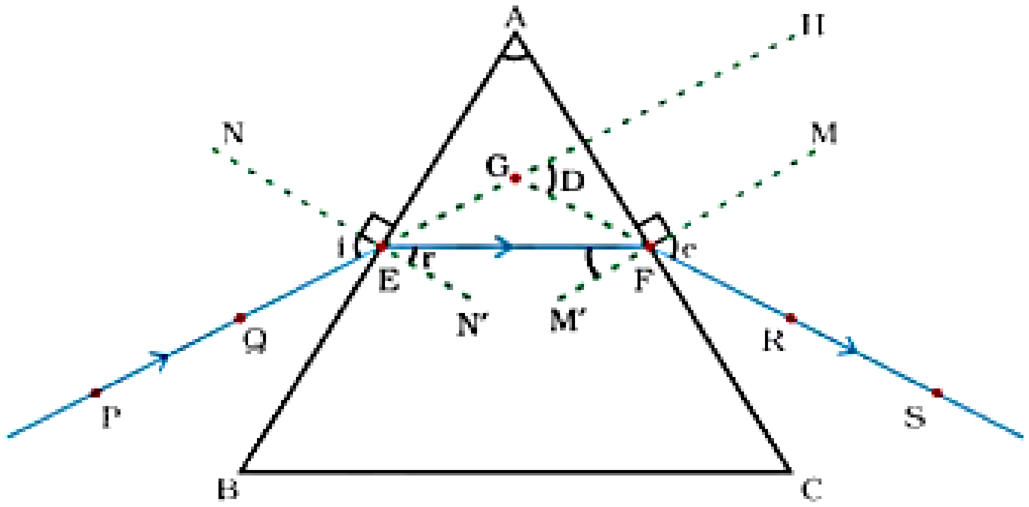
∠e – Angle of emergence

∠D – Angle of deviation

REFRACTION OF LIGHT THROUGH A PRISM

Refraction of light through a triangular glass prism

- The line PE meets the boundary of the prism at point E. Similarly, join and produce the points R and S. Let these lines meet the boundary of the prism at E and F, respectively. Join E and F.
- Draw perpendiculars to the refracting surfaces AB and AC of the prism at points E and F, respectively.
- Mark the **angle of incidence (∠i), angle of refraction (∠r)** and **angle of emergence (∠e).**



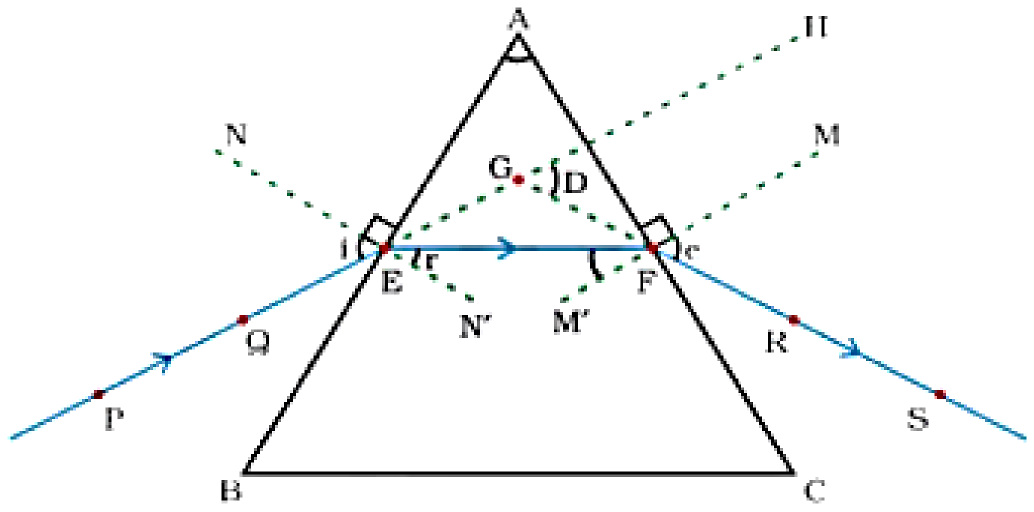
PE – Incident ray
EF – Refracted ray
FS – Emergent ray
∠A – Angle of the prism

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

REFRACTION OF LIGHT THROUGH A PRISM

Refraction of light through a triangular glass prism

- A light ray is entering from air to glass at the first surface AB. The light ray, on refraction, bends towards the normal. At the second surface AC, the light ray enters from glass to air. Hence it bends away from normal.
- Compare angle of incidence and angle of refraction at each refracting surface of the 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 (∠D).**



PE – Incident ray

EF – Refracted ray

FS – Emergent ray

∠A – Angle of the prism

∠i – angle of incidence

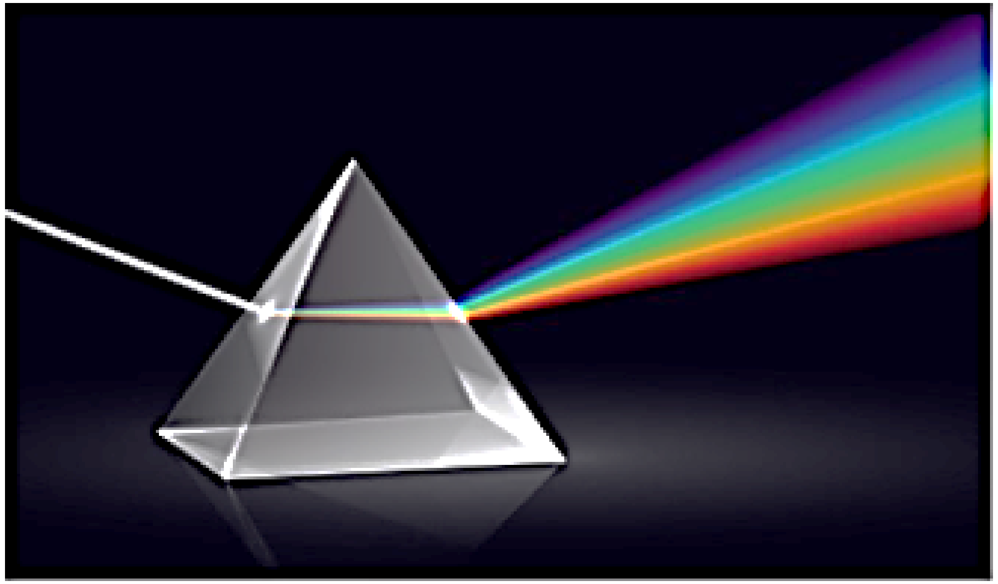
∠r – Angle of refraction

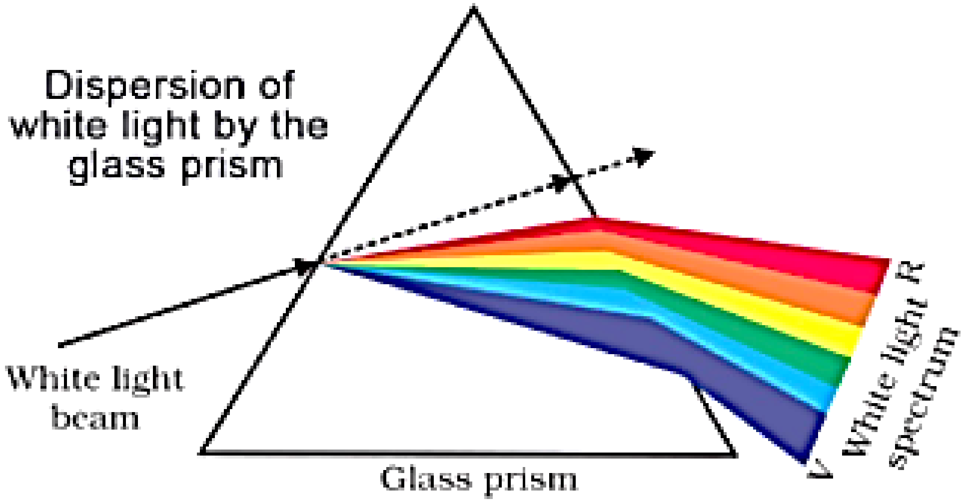
∠e – Angle of emergence

∠D – Angle of deviation

DISPERSION OF WHITE LIGHT BY A GLASS PRISM

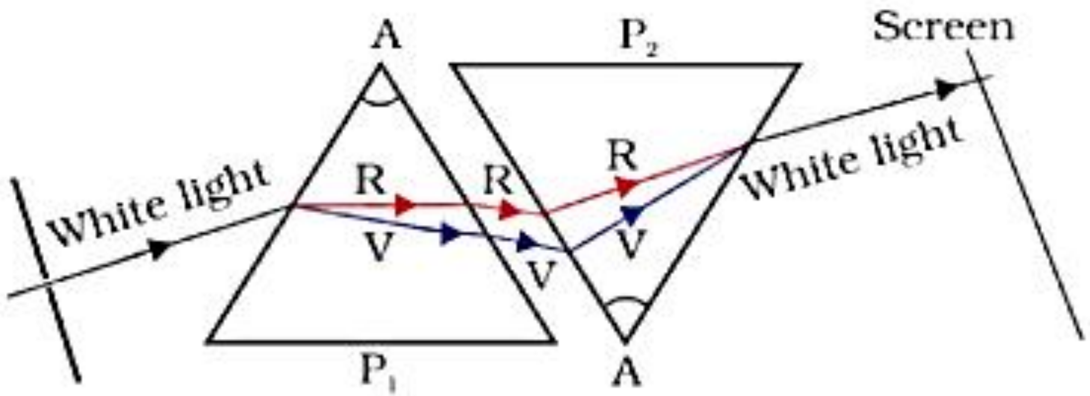
- When sunlight passes through a small hole, it gives a narrow beam of white light.
- Allow the light beam to fall on the face of a glass prism.
- The prism splits the incident white light into a band of 7 colours. They are **Violet, Indigo, Blue, Green, Yellow, Orange** and **Red (VIBGYOR).**
- The band of the coloured components of a light beam is called its **spectrum.**
- The splitting of light into its component colours is called **dispersion.**
- Different colours of light bend in different angles with respect to the incident ray. The red light bends the least while the violet the most. Thus the rays of each colour emerge along different paths and become distinct.





DISPERSION OF WHITE LIGHT BY A GLASS PRISM

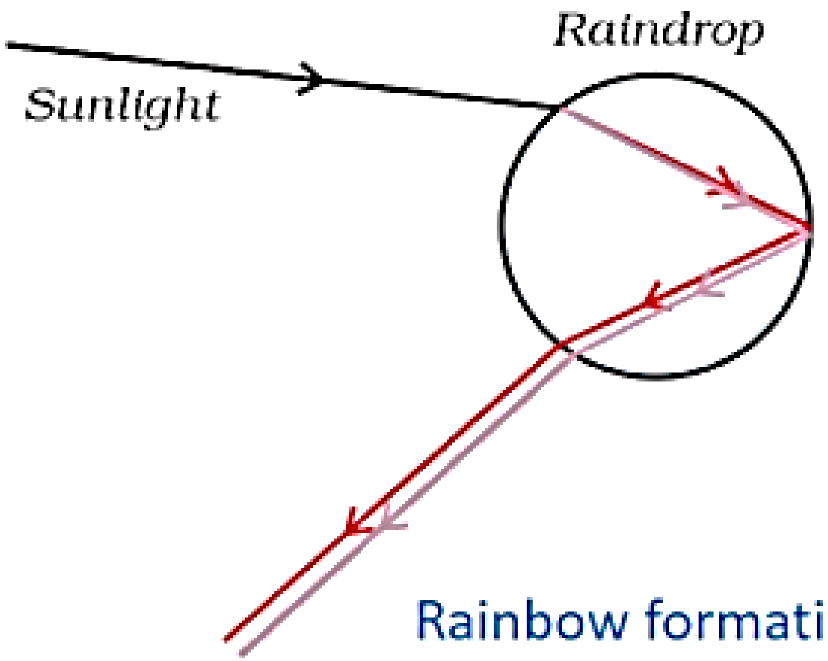
- **Isaac Newton** was the first to use a glass prism to obtain the **solar spectrum.**
- He tried to split the colours of the spectrum of white light further by using another similar prism. However, he did not get any more colours. He then placed a second identical prism in an **inverted position** with respect to the first prism. The colours of the spectrum passed through the second prism and emerged as a **beam of white light** from the other side of second prism. Thus Newton proposed the idea that the **sunlight is made up of 7 colours.**



Recombination of the spectrum of white light

DISPERSION OF WHITE LIGHT BY A GLASS PRISM

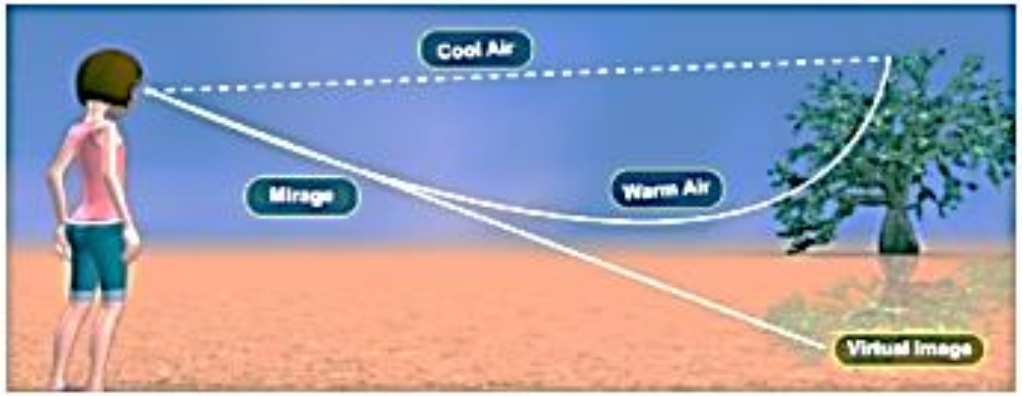
- Any light that gives a spectrum like that of sunlight is referred to as **white light.**
- A **rainbow** is a **natural spectrum.** It is always formed in a direction opposite to the Sun.
- The **rainwater droplets** in the atmosphere act like small prisms. They refract and disperse the incident sunlight, then reflect it internally. It again refracts when comes out of the raindrop. Due to dispersion and internal reflection, different colours reach the observer's eye.
- Rainbow can be also seen when look at the sky through a waterfall, with the Sun behind us.



Rainbow formation

ATMOSPHERIC REFRACTION

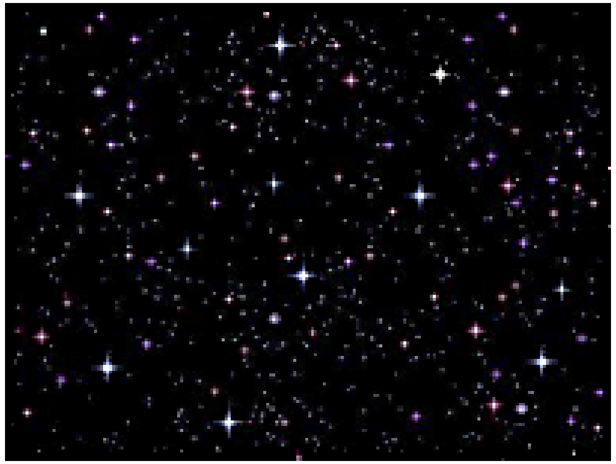
- If an object is observed through hot air above a fire or radiator, it shows **random wavering** or **flickering.**
- The **hotter air** just above the fire is **lighter (less dense)** than the **cooler air** above it. So its **refractive index** is slightly less than that of the cooler air.
- Here, the physical conditions of the refracting medium (air) are not stationary. So, the apparent position of the object fluctuates (wavering). It is an effect of **atmospheric refraction** of light.

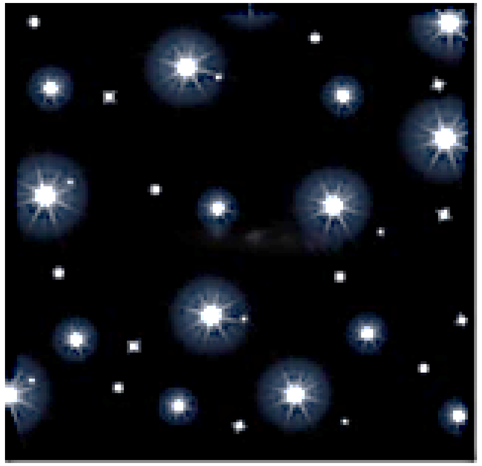


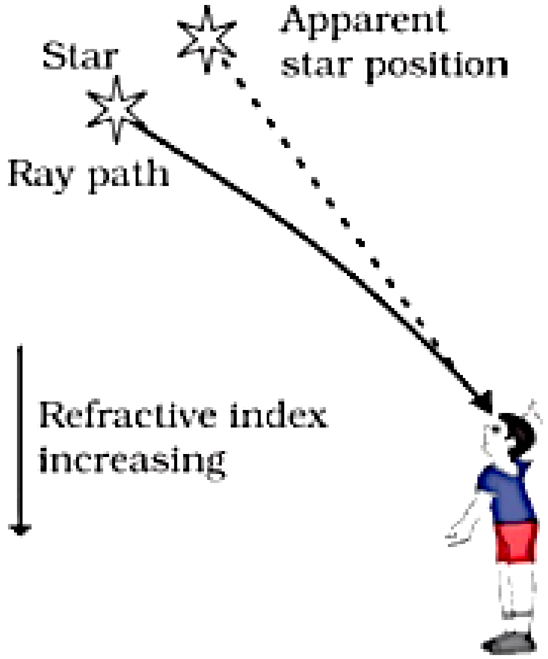
ATMOSPHERIC REFRACTION

Twinkling of stars

- It is due to **atmospheric refraction of starlight.**
- When starlight enters the atmosphere, it undergoes continuous refraction. It occurs in a medium of gradually changing **refractive index.**
- The atmosphere bends starlight towards the normal. So, the apparent position of star is slightly different from its actual position. The star appears slightly higher (above) than its actual position when viewed near the horizon.
- Apparent position of the star is not stationary. It keeps on changing slightly due to varying physical conditions of the atmosphere.





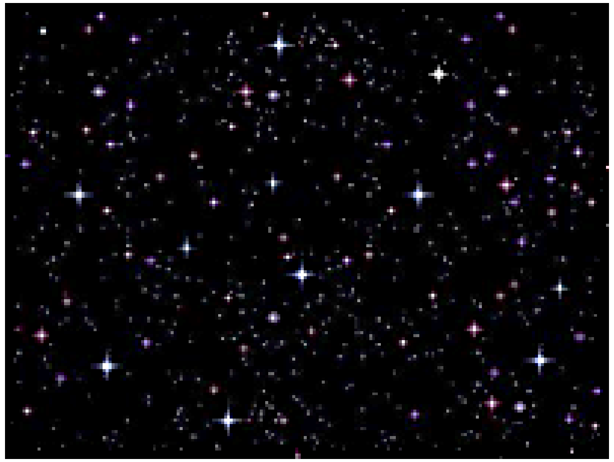


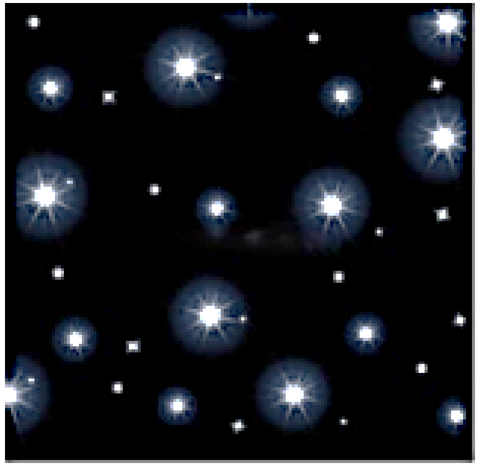
Apparent star position due to atmospheric refraction

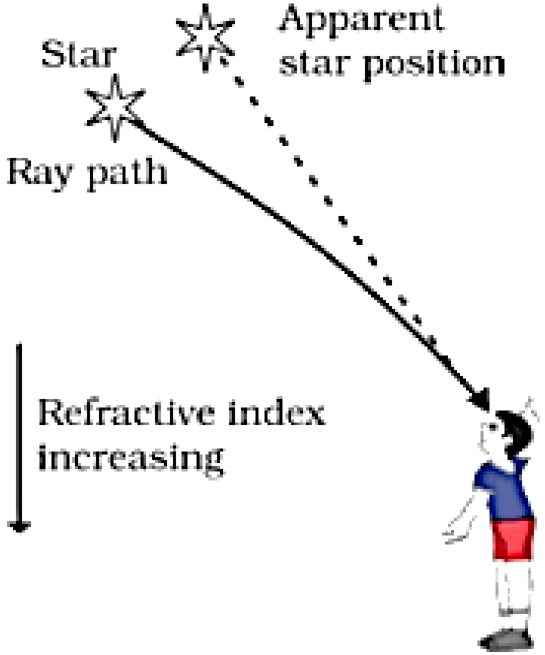
ATMOSPHERIC REFRACTION

Twinkling of stars

- The **stars are very distant.** So, they approximate point-sized sources of light. As the ray path 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 (sometimes appears brighter, some other time, fainter). It is the **twinkling effect.**
- The **planets do not twinkle** because they are **very close to the earth,** and thus seen as **extended sources.** If a planet is considered as a collection of many point-sized sources of light, the net variation of light entering the eye will be **zero.** So it nullifies twinkling effect.





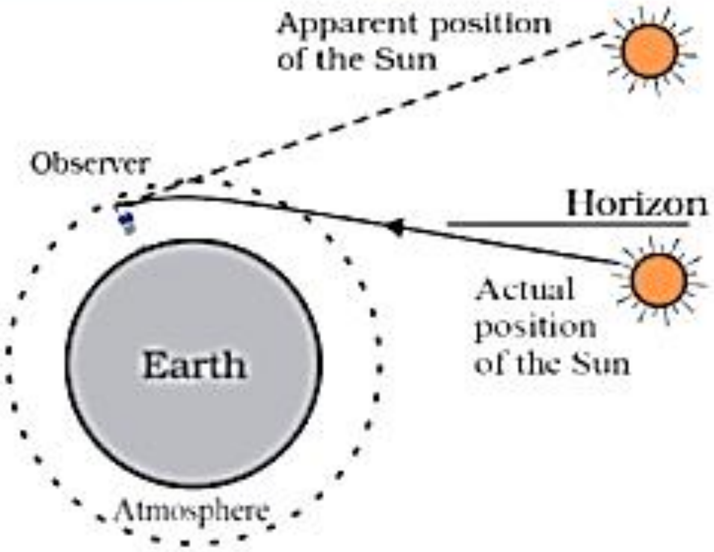


Apparent star position due to atmospheric refraction

ATMOSPHERIC REFRACTION

Advance sunrise and delayed sunset

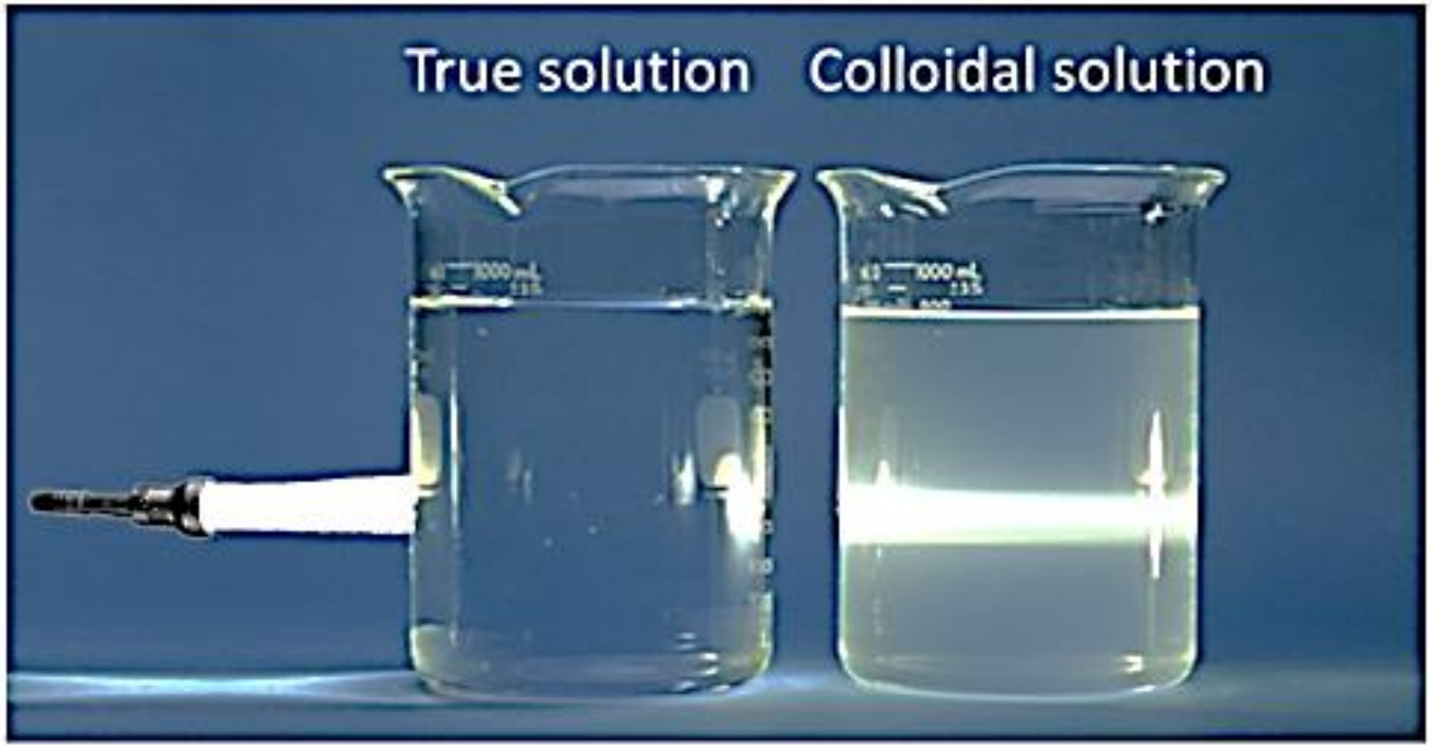
- The **Sun is visible** to us about **2 minutes before the actual sunrise,** and about **2 minutes after the actual sunset** because of atmospheric refraction. Actual sunrise means the actual crossing of the horizon by the Sun.
- The time difference between actual sunset and the apparent sunset is about 2 minutes. The apparent **flattening of the Sun's disc** at sunrise and sunset is also due to the same phenomenon.



Atmospheric refraction effects at sunrise & sunset

SCATTERING OF LIGHT

- The path of a beam of light passing through a **true solution** is not visible. But it is visible through a **colloidal solution** due to **scattering of light.**
- When a beam of light strikes particles in the **atmosphere,** the path of the beam becomes visible. The light reaches us, after being reflected diffusely by particles.



SCATTERING OF LIGHT

Tyndall Effect

It is the phenomenon of **scattering of light by the colloidal particles** or very fine suspension. E.g.

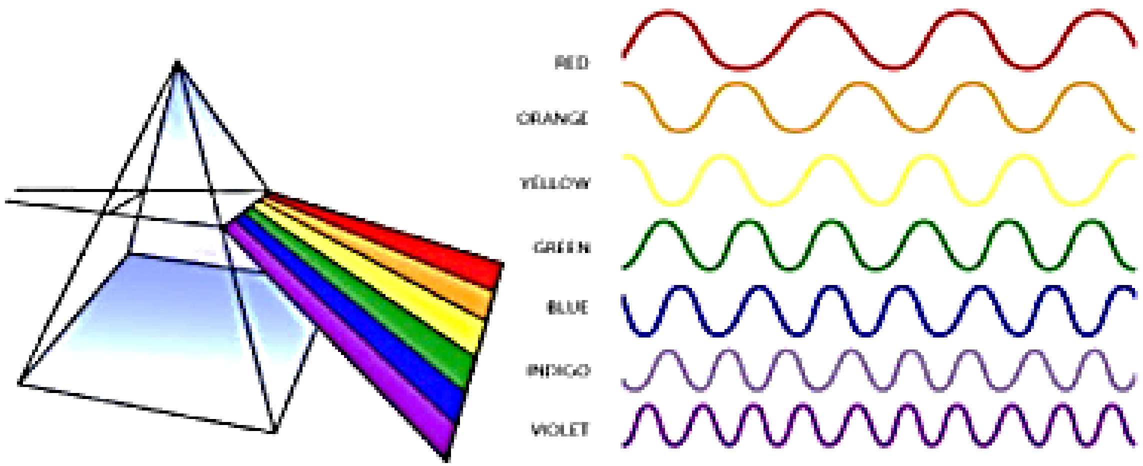
- When a beam of sunlight enters a smoke-filled room, the particles become visible due to scattering of light.
- When sunlight passes through a canopy of a dense forest, tiny water droplets in the mist scatter light.

The colour of the scattered light depends on the size of the scattering particles. **Very fine particles scatter mainly blue light** while **large sized particles scatter light of longer wavelengths.** If the size of particles is larger, the scattered light appears white.

SCATTERING OF LIGHT

Why is the colour of the clear Sky Blue?

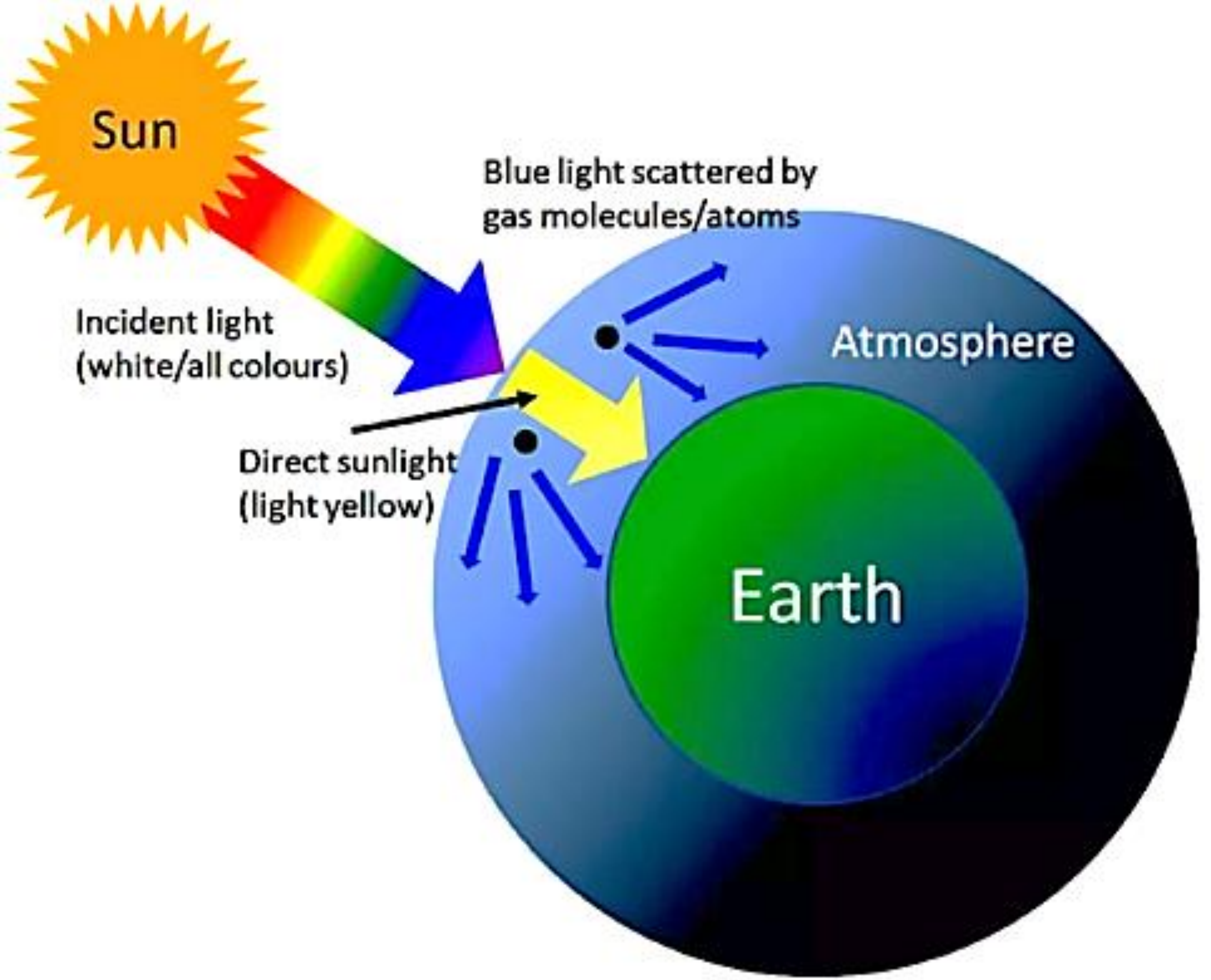
- Size of the molecules and particles in the atmosphere is generally smaller than the wavelength of visible light. So, light of **shorter wavelengths (blue end)** is more scattered than light of **longer wavelengths (red end).**
- The red light has a wavelength about **1.8 times** greater than blue light. Thus, when sunlight passes through the atmosphere, the fine particles in air **scatter the blue colour more strongly than red.** The scattered blue light enters the eyes.



SCATTERING OF LIGHT

Why is the colour of the clear Sky Blue?

- If the earth had no atmosphere, there would be no any scattering. Then, the sky would have looked dark. **The sky appears dark** to passengers flying at very high altitudes, as there is no prominent scattering.
- **Red is least scattered** by fog or smoke. So, it can be seen in the same colour at a distance. Therefore, red colour is used in **Danger signal lights.**


Sun
Blue light scattered by
gas molecules/atoms
Incident light
(white/all colours)
Atmosphere
Direct sunlight
(light yellow)
Earth

thank you