Chapter 11 - The Human Eye and Colourful world

Introduction

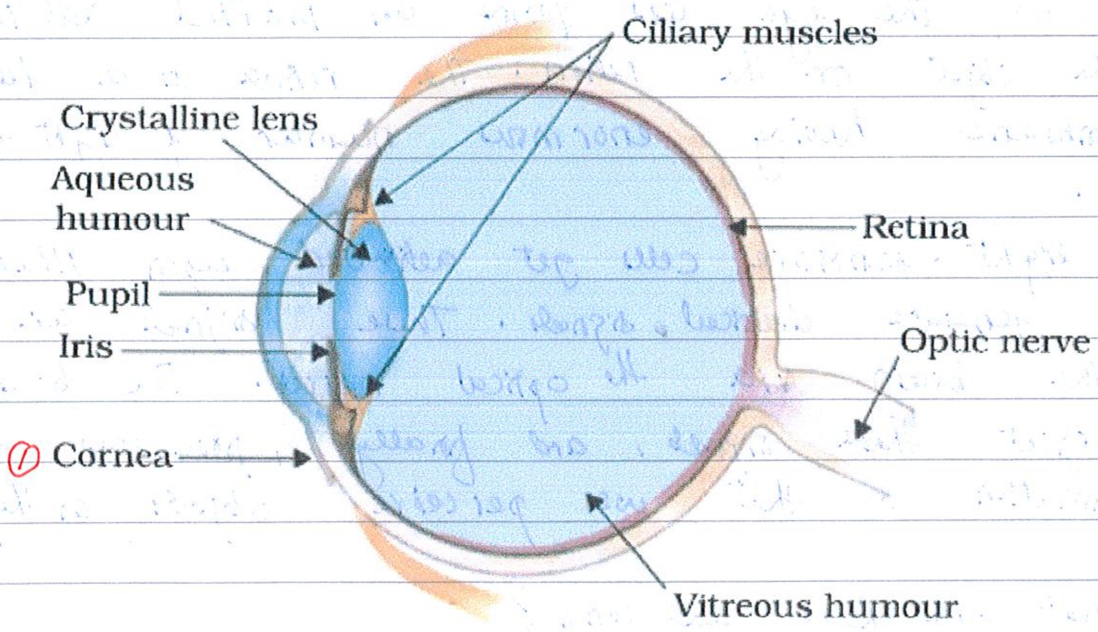
The human eye uses light and enables us to see objects around us. It has a lens in its structure. It is a natural optical device using which man could see objects around him. It forms an inverted, real image on a light sensitive surface called retina.

The Human Eye

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

The human eye is like a camera. Its lens system forms an image on a light sensitive screen called the retina.

Parts of Human Eye



(1) **Cornea:** Light enters the eye through a thin membrane called the cornea. It form 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.

(2) Lens : The crystalline lens merely provides the fine adjustment of focal length required to focus objects at different distances on the retina. It is composed of a fibrous, jelly like material. Provides the focused real and inverted image of the object on the retina. This is a convex lens that converges light at retina.

(3) IRIS : A structure called iris behind the cornea. Iris is a dark muscular diaphragm that controls the size of the pupil.

(4) Pupil : The pupil regulates and controls the amount of light entering the eye. It is the window of the eye. It is the central aperture in iris. It regulates and control the amount of light entering the eye.

(5) Retina : 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 optical nerves. The brain interpret these signals, and finally, processes the information so that we perceive objects as they are.

What are Rods and Cones?

Rods and cones are light sensitive cells present in retina. Rods control the intensity of light, while cones control the colour perception.

Power of Accommodation

Q.) How is a normal eye able to see distinctly distant as well as nearer objects? What is the distance of distinct vision?

Ans) (i) The eye lens is composed of a fibrous, jelly-like material. Its curvature can be modified to some extent by the ciliary muscle.

ii) The change in the curvature of the eye lens can thus change its focal length.

iii) When the muscles are relaxed, the lens become thin. Thus, its focal length increases. This enables us to see distant objects clearly.

(iv) When you are looking at objects closer to the eye, the ciliary muscles contract. This increases the curvature of the eye lens. The eye lens then become thicker. Consequently, the focal length of the lens decreases. This enables us to see nearby objects clearly.

The minimum distance at which objects can be seen distinctly is called distance of distinct vision. It is 25 cm.

Q.) Define power of accomodation.

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

However, the focal length of the eye lens cannot be decreased below a certain minimum limit.

Distance of distinct vision

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 near point is about 25 cm.

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.

A normal eye can see objects clearly that are between 25 cm and infinity.

(Q) When a person is said to have developed cataract? How is the vision of such a person restored?

Ans) Sometimes, the crystalline lens of people at old age becomes milky and cloudy. This condition is called cataract. This causes partial or complete loss of vision.
It is possible to restore vision through a cataract surgery.

Do you know? Why do we have two eyes for vision and not just one?

Defects of vision and their correction

Sometimes, the eye may gradually lose its power of accomodation. In such condition, the person cannot see the objects distinctly and comfortably. The vision becomes blurred due to the refractive defects of the eye.

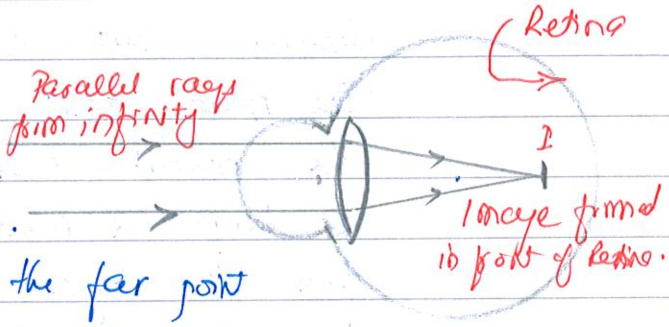
There are mainly three common refractive defects of vision. These are :

(i) Myopia or near-sightedness : Distant objects are not visible. It is corrected by using concave lens.

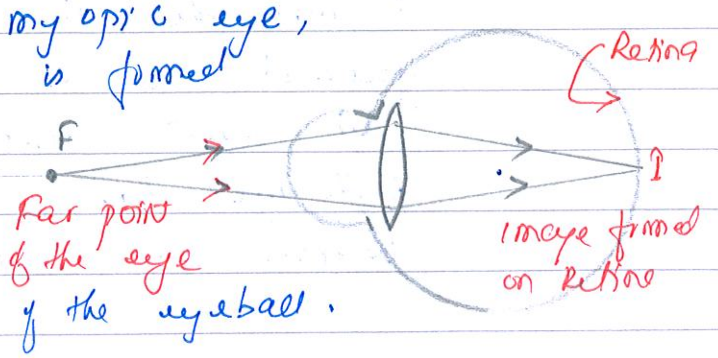
(ii) Hypermetropia or far-sightedness : Affected person can see far objects clearly but cannot see nearby objects clearly. Use of convex lens of suitable power can correct the defect.

iii) Presbyopia (Old age Hypermetropia) : It is the defect of vision due to which an old person cannot see the nearby objects clearly due to less power of accomodation of the eye.

(a). Myopia

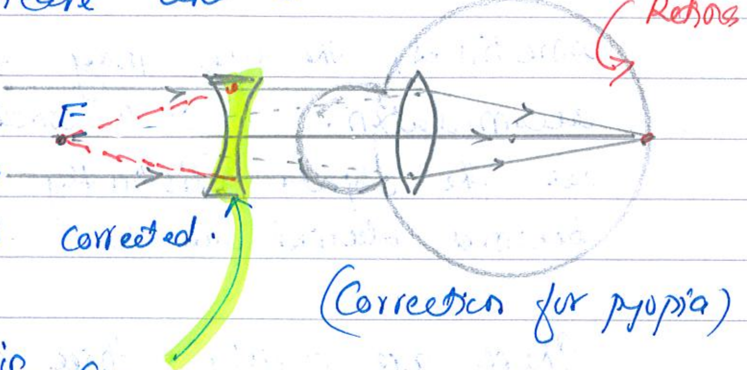


Myopia is also known as near sightedness. A person with myopia can see nearby objects distinctly. A person with this defect has the far point nearer than infinity. In myopic eye, the image of a distant object is formed in front of the retina.



This defect may arise due to (i) excessive curvature of eye 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.



(Correction for myopia)

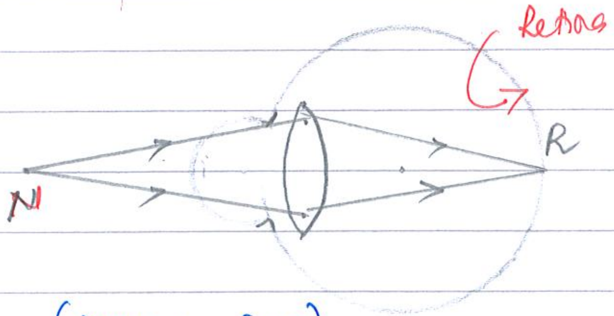
The concave lens placed in front of the eye forms a virtual image of distant object at far point (F) of myopic eye.

(Concave lens to correct myopia)

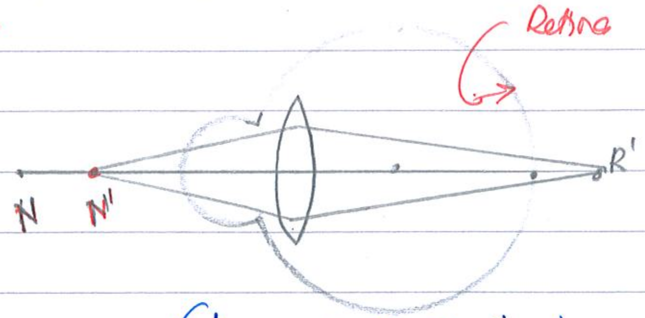
(Q) A student has difficulty reading the blackboard while sitting in the last row. What could be the defect the child suffering from? Draw ray diagram for the defect of vision. How can it be corrected? Draw ray diagram for its correction.

(b) Hypermetropia

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 (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 close-by object are focussed at a point behind the retina. This defect arises either because (i) the focal length of the eye lens is too long or (ii) the eye ball has become too small.

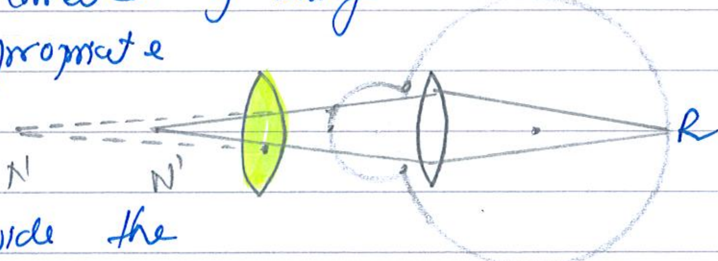


(Normal Eye)
Sharp image of object at N (near point)



(Hypermetropic Eye)
Blurred image of object at N' (Near point).
Image formed behind the retina

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.

(C) Presbyopia (Old age Hypermetropia)

The power of accomodation of the eye usually decreases with ageing. 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 gradual weaking of the ciliary muscles and diminishing flexibility of the eye lens.

Sometimes, a person may suffer from both myopia and hypermetropia. Such people often require bi-focal lenses which consist of both concave and convex lenses. The upper portion consists of a concave lens which facilitates distant vision. The lower part is convex lens for near vision.

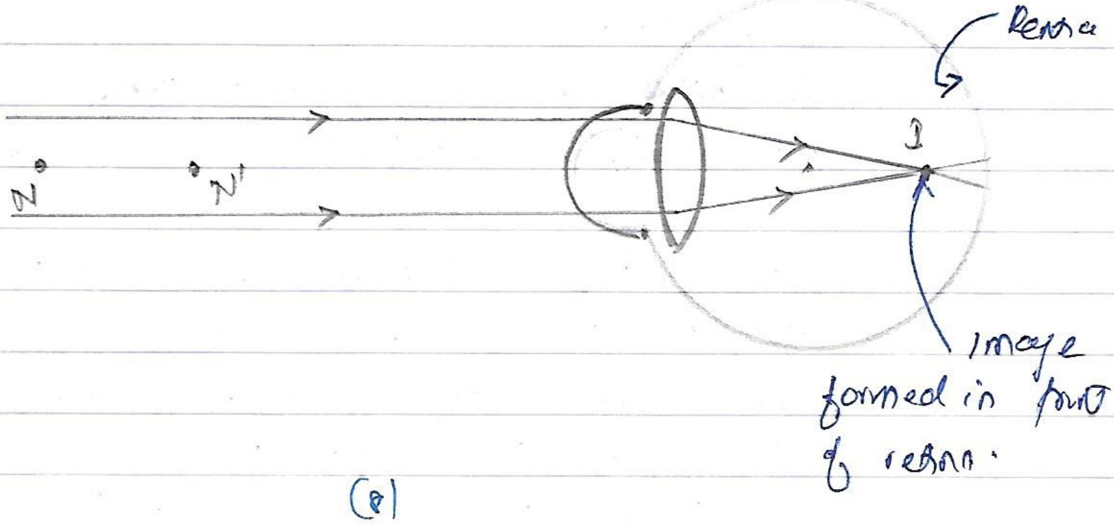
Questions (Human eye, Defects of vision and correction)

1) What is meant by power of accommodation of the eye?

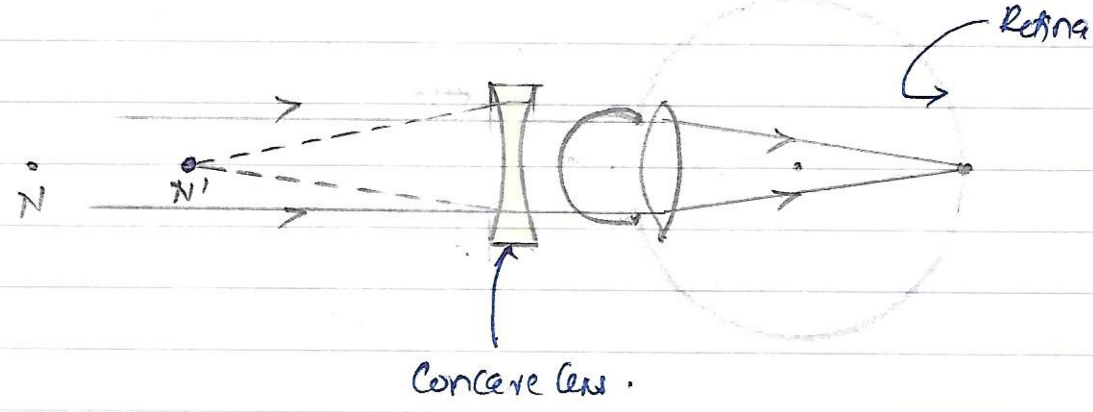
Ans) When the ciliary muscles are relaxed, the eye lens becomes thin, the focal length increases, and the distant objects are clearly visible to the eyes. To see the nearby objects clearly, the ciliary muscles contract making the eye lens thicker. Thus, the focal length of the eye decreases and nearby 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 accomodation 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.



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



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 black board 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 black board 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.

5) The human eye can focus objects at different distance by a adjusting the focal length of the eye lens. This is due to accommodation.

6) The human eye forms the image of an object at its retina.

7) The least distance of distinct vision for a young adult with normal vision is about 25 cm.

8) The change in focal length of an eye lens is caused by the action of the ciliary muscles.

9) A person needs a lens of power −5.5 dioptre 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 (ii) near vision?

ANS) The power P of a lens of focal length f is given by the relation. $P = \frac{1}{f\text{ (in metre)}}$

(i) $P = -5.5$ $\quad f = \frac{1}{-5.5} = -0.181\ m$

The focal length of the lens for correcting distant vision is $-0.181\ m$. (Concave lens ha negative)

(ii) $P = +1.5\ D$ $\quad f = \frac{1}{1.5} = +0.667\ m$

The focal length of lens for correcting near vision is $0.667\ m$ (convex lens).

10) 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) = ?

Using lens formula $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

$\frac{1}{f} = \frac{1}{-80} - \frac{1}{\infty}$, $\frac{1}{f} = \frac{1}{-80}$ $f = -80cm$

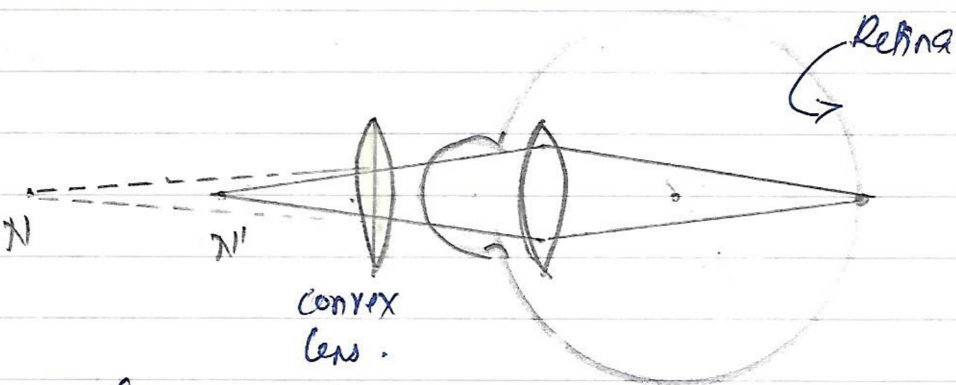
$f = -0.8 m.$

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

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

11) Make a diagram to show how hypermetropia is corrected. The near point of a hypermetropic eye is 1m. What is the power of the lens required to correct this defect? Assume near point is 25 cm

ANS) A person suffering from hypermetropia can see distinct objects 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.



(Correction for hypermetropic eye)

The convex lens actually creates a virtual image of a nearby objects (N' in 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 $= -100$ cm
Focal length $f = ?$

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

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

$$f = \frac{100}{3} = 33.3 \text{ cm} = 0.33 \text{ m}$$

$$\text{Power } P = \frac{1}{f(\text{in metre})} = \frac{1}{0.33\text{m}} = +3.0 \text{ D.}$$

A convex lens of power +3.D is required to correct the defect.

12) 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.

13) 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 eye changes in such a way that the image is always formed at the retina of the eye.

14) What is the nature of the image formed on the retina?

Ans) Real, inverted and same-sized.

15) Why does it take some time to see object in a cinema hall when we just enter the hall from bright sunlight. Explain.

Ans) (i) The pupil regulates and control the amount of light entering the eye.

(ii) In bright sunlight, the size of the pupil is small and when we enter the cinema hall, it takes some time for the pupil to expand in size due to dim light.

16) State one main function each of iris, pupil and cornea.

Ans) (i) Iris : Gives colour to eyes, controls size of pupil.

(ii) Pupil : Regulate amount of light

(iii) Cornea : Refracts most of the light into eye.

17) (i) Ravi kept a book at a distance of 10cm from the eyes of his friend. Hari is not able to read anything written in the book. Explain why?

(ii) A lens of focal length 5.0 cm is being used by a student in the laboratory as a magnifying glass. His least distance of distinct vision is 25 cm. What magnification is the student getting?

Ans) (i) Because least distance of distinct vision is 25 cm, and book is kept at a distance of 10cm.

(ii) $u = ?$ $v = -25$ cm, $f = 5$cm

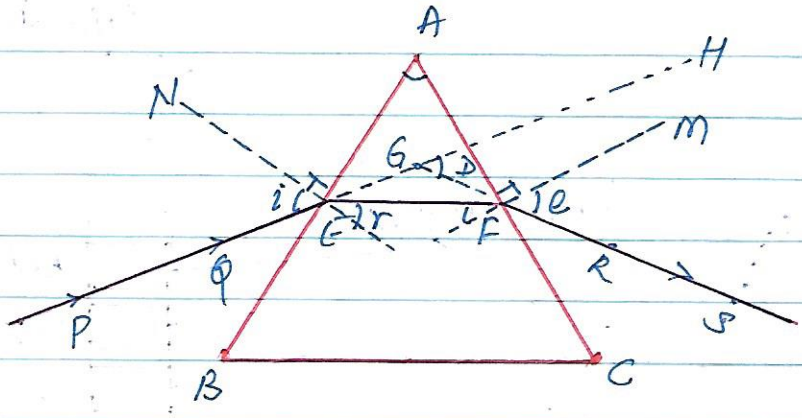
$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$, $\frac{1}{5} = \frac{1}{-25} - \frac{1}{u}$, $\frac{1}{u} = \frac{1}{-25} - \frac{1}{5}$

$u = \frac{-25}{6}$

$m = \frac{v}{u} = (-25) \times \frac{6}{-25}$, $m = 6$

Chap 11 (The Human Eye and Colourful World)
(Part - 11)

Refraction of light through a prism



PE = Incident Ray
EF = Refracted Ray
FS = Emergent Ray

∠A = Angle of Prism
∠i = Angle of incident
∠r = Angle of refraction
∠e = Angle of emergent
∠D = Angle of Deviation

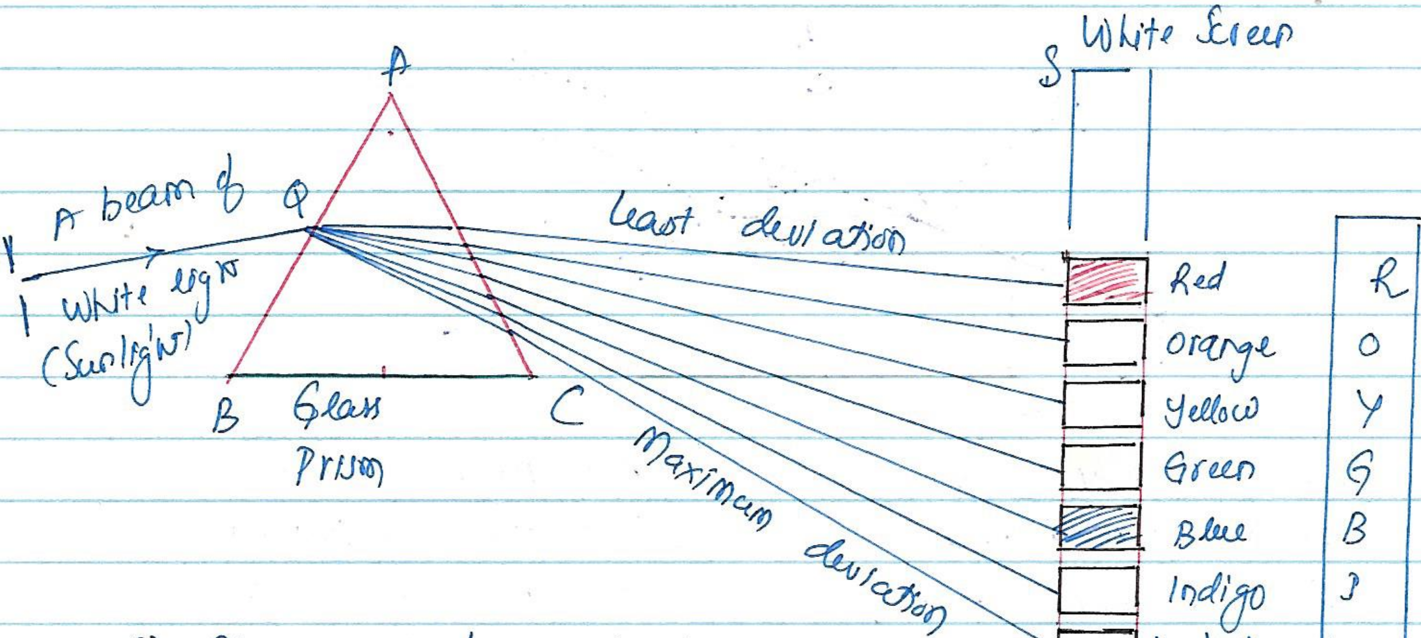
(1) A ray of light is entering from air to glass at the first surface AB..

(2) The light ray on refraction has bent towards the normal.

(3) At the second surface AC, the light ray has entered from glass to air. Hence it has bent away from normal.

(4) 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.

Dispersion of white light by a glass Prism



(1) The prism has probably split the incident white light into a band of colours.

White light splits into seven colours.

(2) The various colors seen are Violet, Indigo, Blue, Green, Yellow, Orange and Red. (VIBGYOR).

(3) The band of the coloured components of a light beam is called its spectrum.

(4) The splitting up of white light into its constituent colours on passing through a refracting medium like a glass prism is called dispersion of light.

(5) The dispersion of white light occurs because different colours of light bend through different angles with respect to the incident ray, as they pass through a prism.

(6) The red light bends the least while the voilet the most.

Q) A glass prism is able to produce a spectrum when white light passes through it but a glass slab does not produce any spectrum. Explain why it is so.

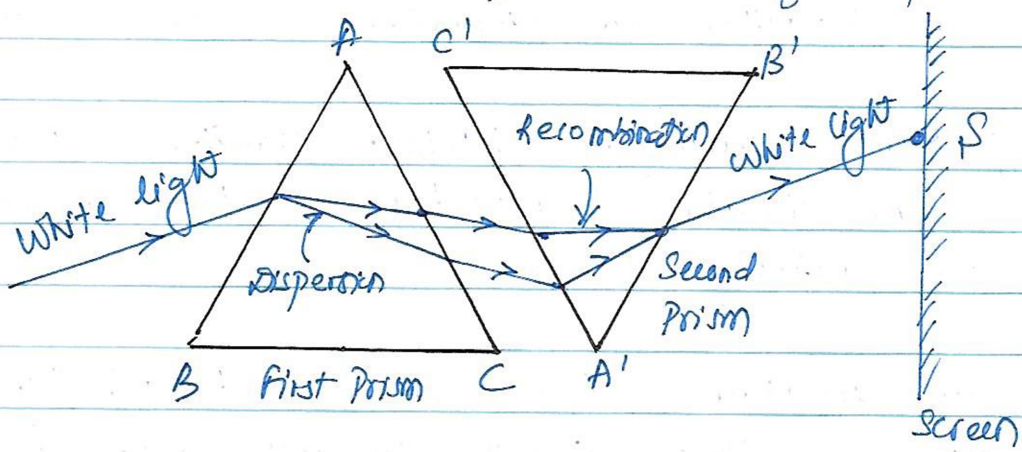
(or)

How did Newton, using two identical glass prisms, show that white light is made of seven colours?

ANS)

(a) A glass slab acts as a combination of two identical glass prisms.

(b) Newton placed a second identical prism in an inverted position with respect to the first prism.



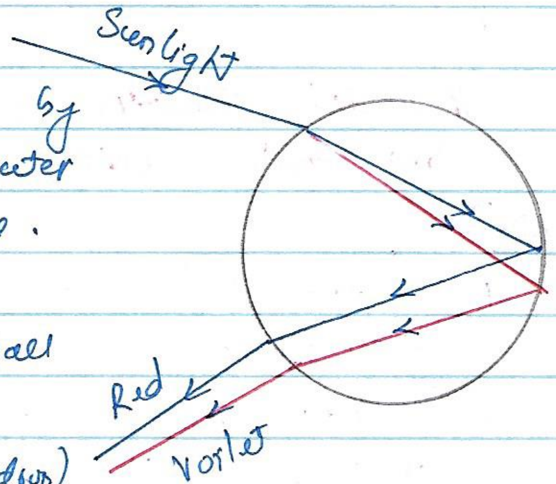
(c) The first prism splits the white light into its seven colours components. When these colour components fall on the second prism, it recombines them to form white light.

(d) This observation gave Newton the idea that the sunlight is made up of seven colours.

(e) Any light that gives a spectrum similiar to that of sunlight is often referred to as white light.

Q) Describe the formation of rainbow in the sky with the help of a diagram.

Ans) A rainbow is a natural spectrum appearing in the sky after a rain. It is produced by dispersion of sunlight by tiny water droplets, present in the atmosphere.



2) The water droplets act like small prisms. When a ray of light falls on water drop (or raindrop) it undergoes refraction and dispersion to form a spectrum.

3) This spectrum undergoes internal reflection (inside the raindrop) and finally refracted again when it comes out of the raindrop.

4) After the dispersion of light and internal reflection, the band of colours reaches observer's eye in the form of a rainbow.

5) A rain is always formed in the direction opposite to that of the sun.

Atmospheric Refraction

Q) How does refraction of light take place in the atmosphere? Explain the reason why stars appear to twinkle and the planets do not twinkle.

Ans) Since the atmosphere consist of varying densities the apparent position of the object, as seen through the hot air fluctuates. This wavering of light is an effect of atmospheric refraction.

The twinkling of a star is due to atmospheric refraction of star light. The atmospheric refraction of light occurs in a medium of gradually changing refractive index.

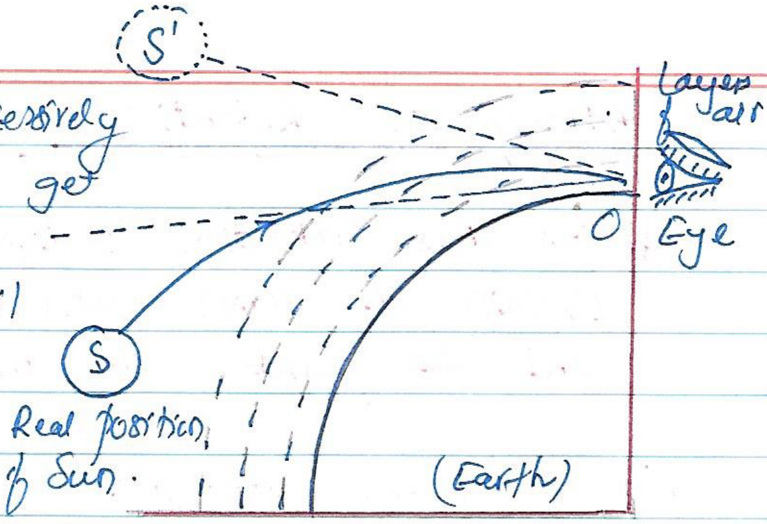
The planet are much closer to the earth and are thus seen as extended sources. A planet is considered as a collection of large number of point sized sources of light, the total variation in the amount of light entering our eye from all individual point sized source will average out to zero, thereby nullifying the twinkling effect.

Q) How does atmospheric refraction affect sunrise and sunset? (or) what is meant by advance sunrise and delayed sunset?

Ans) 1) The layers of air nearer to earth are denser than those above it.

2) At sunrise and sunset when the sun is below the horizon, the light rays starting from sun are incident on these layers.

(3) They pass through successively denser layers and thus get bent more and more towards the normal until they fall upon the eye of the observer O.



(4) To the observer O, these rays appear to come from S' which is above horizon. It is for this reason that the sun is visible to us a little before it rises above the horizon and so also till a little later it sets below the horizon.

(5) The difference of time is about 2 minutes each for early rise and late setting of the Sun.

Scattering of light :

Q) What is Tyndall effect? Explain with an example.

Ans) 1) The scattering of light by particles in its path is called Tyndall effect.

2) When beam of light enters a smoke-filled dark room through a small hole, then its path becomes visible to us. The tiny dust particles present in the air of room scatter the beam of light all around the room.

3) Thus, scattering of light makes the particles visible.

4) Tyndall effect can be observed when sunlight passes through a canopy of a dense forest. Here, tiny water droplets in the mist scatter light.

Q) Why is the colour of sky blue?

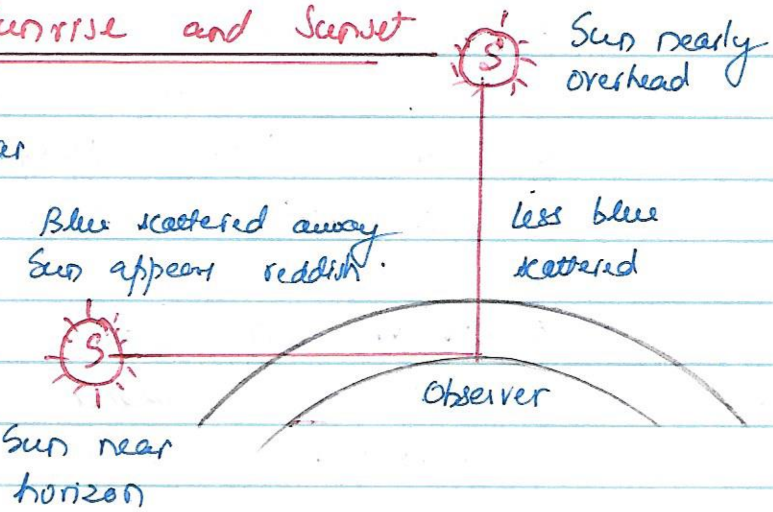
Ans) 1) The molecules of air and other fine particles in the atmosphere have smaller than the wavelength of visible light.

2) These are more effective in scattering light of shorter wavelengths at the blue end than light of longer wavelengths at the red end.

3) When sunlight passes through the atmosphere, the fine particles in air scatter the blue colour more strongly than red.

4) The scattered blue light enters our eyes. Since we see the blue light from everywhere overhead, the sky appears blue.

Colour of the Sun at Sunrise and Sunset



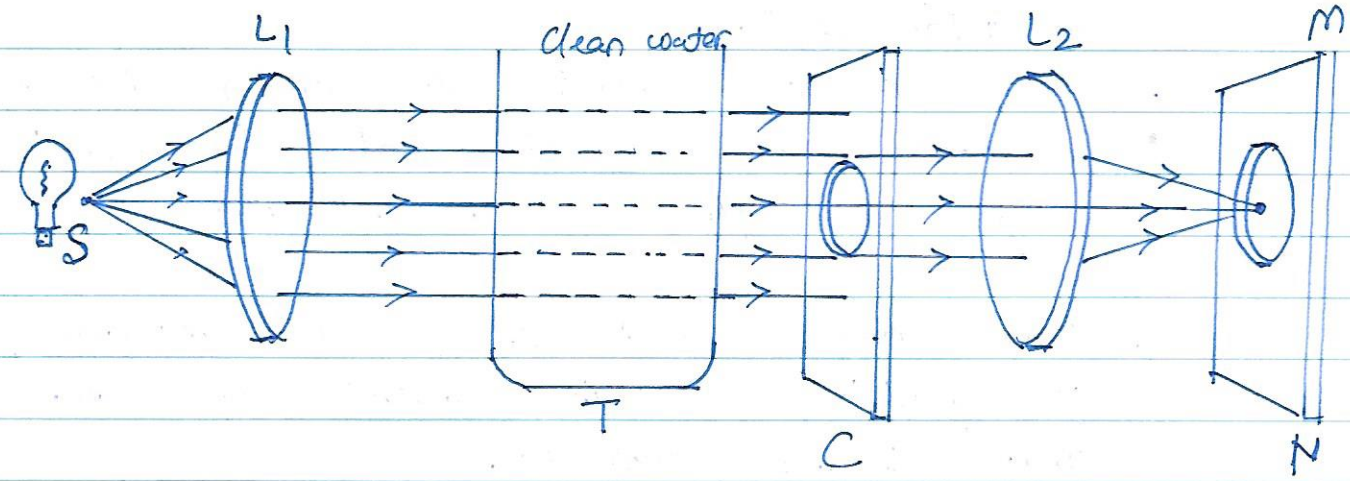
(1) Light from the Sun near the horizon passes through thicker layer of air and larger distance in the earth's atmosphere before reaching our eyes.

(2) 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.

(3) Near the horizon, most of the blue light and shorter wavelengths are scattered away by the particles.

(4) Therefore, the light reaches our eyes is of longer wavelengths. This gives rise to the reddish appearance

Q) With the help of an activity show that blue color of the sky and reddish appearance of the sun at the sunrise and sunset.



1) Place a strong soure (S) of white light at the focus of an converging lens (L_1). This lens provides a parallel beam of light.
2) Allow the light beam to pass through a transparent glass tank (T) containing clear water.
3) Allow the beam of light to pass through a circular hole (C) made in a cardboard.
4) Obtain a sharp image of the circular hole on a screen (MN) using a second converging lens (L_2).

5) Dissolve about 200 g of sodium thiosulphate (hypo) in water in the tank. Add about 1 to 2 mL of concentrated sulphuric acid to the water.

6) <u>Observation</u>: We will notice fine microscopic sulpher particles precipitating in about 2 to 3 seconds. As the sulpher particles begin to form, you can observe the blue light from the side of the tank. This is due to scattering of short wavelengths by minute colloidal sulphure particles. Observe the colour of the light patch on the screen. It is interesting to observe the change in colour of patch from orange red colour in the beginning to bright crimson red colour later on the screen.