THE HUMAN EYE AND THE COLOURFUL WORLD

THE HUMAN EYE – The human eye is one of the most valuable and sensitive organ which helps us to see things around us. It is like a camera, It refracts light through a natural convex lens and forms a image so that we can see the object. It has following parts –

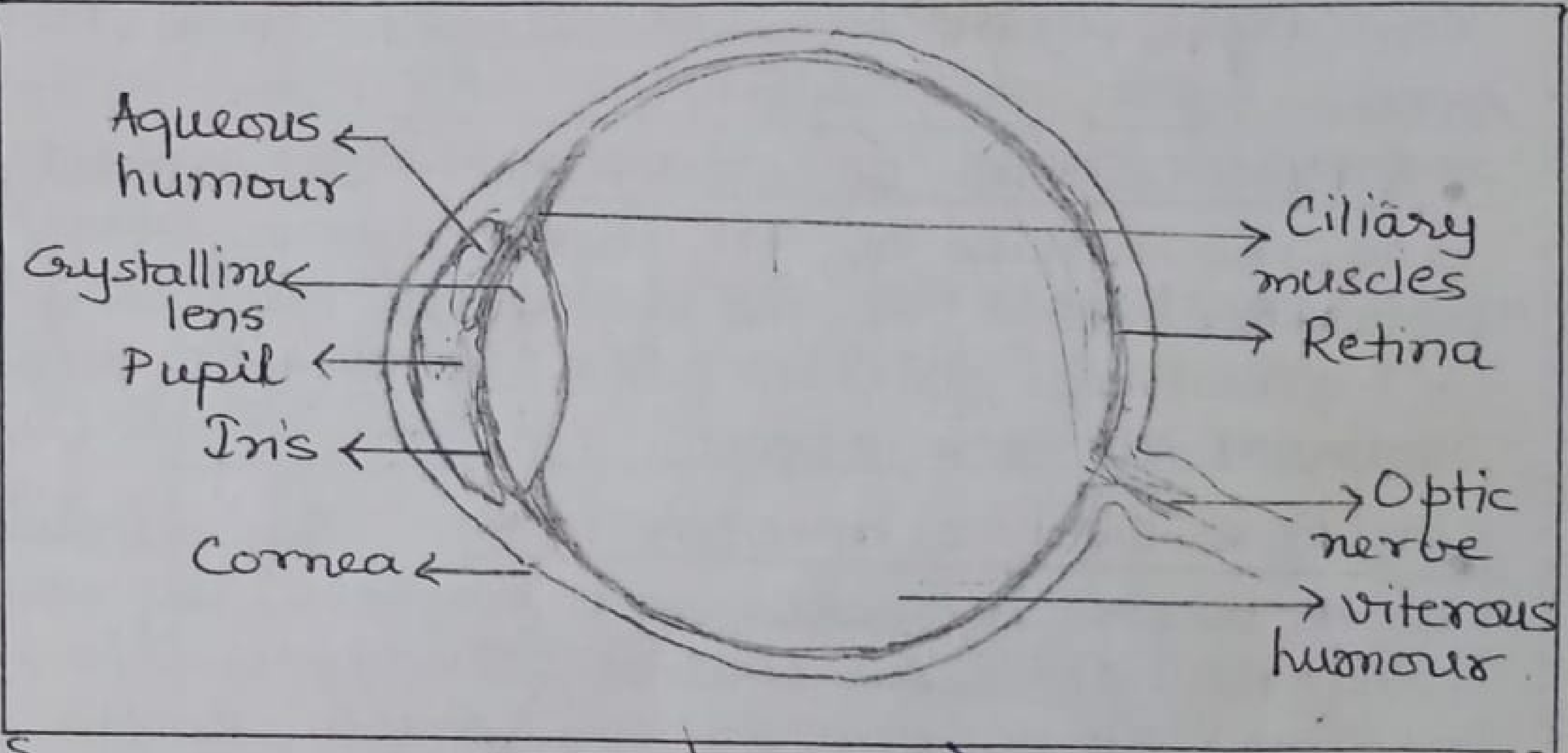
(i) **Eyeball** – is approximately spherical in shape with a diamter of about 2.3 cm.

(ii) **Cornea** – is a thin, transparent membrane on the front surface of the eyeball through which light enters the eye. It forms the transparent bulge on the front surface of the eyeball. Most of the refraction for the light rays entering the eye occurs at the outer surface of cornea.

(iii) **Pupil** – regulates and controls the amount of light entering the eye.

(iv) **Iris** – is a dark circular muscular diaphragm located behind the cornea. It controls the size of the pupil and forms the variable aperture system of the eye.

(v) **Lens** – The eye lens is a convex lens made of a transparent, fibrous jelly like flexible material (mainly protein in nature) It forms an inverted real image of the object on retina. The crystalline lens is held in position by ciliary muscles. It provides the finer adjustment of focal length required to focus objects at different distances on the retina.



(vi) **Retina** – is a delicate membrane having large number of light sensitive cells called "rods" and "cones." which respond to "intensity of light" and "colour of objects" respectively.

(vii) **Aqueous humour and viterous humour** – The space between cornea and eye lens is filled with a viscous liquid called aqueous humour and the space between eyelens is filled with another liquid called vitreous humour. The fluid helps in maintaining the shape of eye ball.

WORKING OF THE EYE – The light rays coming from the object kept in front of us enter the pupil of eye and fall on the eye lens. The eyelens is a convex lens so it produces a real and inverted image of the object on the retina. The light sensitive cells of the retina gets activated upon illumination and generate electric signals. These signals are transmitted to the brain through the optic nerve and give rise to sensation of vision. The brain interprets these signals and finally processes the information so that we perceive objects as they are. A small region of the retina where the optic nerve enters the eye ball is insensitive to light and it is called BLIND SPOT.

- FUNCTIONING OF PUPIL – We are not able to see objects clearly for some time on entering from bright light to a room with dim light (or vice versa). However, after some time we are able to see things in dim light. The pupil of an eye acts like a variable aperture whose size can be varied with the help of iris. When the light is very bright, the iris contracts the pupil to allow less light to enter the eye. When we enter in a dim light room, very little light enters our eyes and we cannot see properly. After a short time, the pupil of our eye expands and become large. More light then enters our eye and we can see clearly. On the other hand, if we go from a dark room into bright sunligth we feel the glare in our eyes. This is due to the fact that in the dark room, the pupil of our eye is large. So, when we go out in a bright sunlight, a large amount of light enters our eyes and we feel the glare. Gradually, the pupil of our eye contracts. Less light then enters our eyes and we can see clearly.

- PERSISTENCE OF VISION – The ability of eye to continue to see the image of an object for a very short duration even after removal of the object is called persitence of vision. In human eye, vision persists for $1/16^{th}$ of a second after the removal of the object.

- POWER OF ACCOMODATION – The ability of an eye to focus both near and distant objects by changing the focal length of lens is called accomodation. A normal eye has a power of accomodation which enables object as far as infinity and as close as 25 cm to be focussed on the retina.
  - The ciliary muscles play an important role in accomodation. They change the curvature of eye lens which result in change in focal length of eyelens. When muscles are relaxed, the lens becomes thin. Thus its focal length increases and a person can see distant objects clearly. To focus or to see the near objects clearly, the ciliary muscles contract. This increase the curvature of eye lens (or decreases the focal length) and the lens becomes thicker.
  - The focal length of eye lens cannot be decreased below a certain minimum limit. If we keep the object very close to our eyes (or at a distance less than 25 cm), we cannot see it clearly as the ciliary muscles cannot make the eye lens more to focus the object.

- RANGE OF VISION OF A NORMAL HUMAN EYE – The range of vision of a normal human eye is from infinity to about 25 cm.
  - The farthest point from the eye which can be seen clearly is known as the "FAR POINT" of the eye. The far point of a normal eye lies at infinity.

- The smallest distance at which the eye can see the objects clearly without strain is called the "NEAR POINT OF THE EYE OR LEAST DISTANCE OF DISTINCT VISION". For a young adult with normal vision, it is about 25 cm.

WHY DO WE HAVE TWO EYES FOR VISION AND NOT JUST ONE – (i) it gives a wider field of view :- A human being has a horizontal field of view of about 150° with one eye and of about 180° with two eyes.

(ii) The ability to detect faint objects with two eyes is enhanced instead of one.

(iii) Because our eyes are separated by a few centimeters, each eye sees a slightly different image. Our brain combines the two images into one and thus provides three-dimensional perception of the objects.

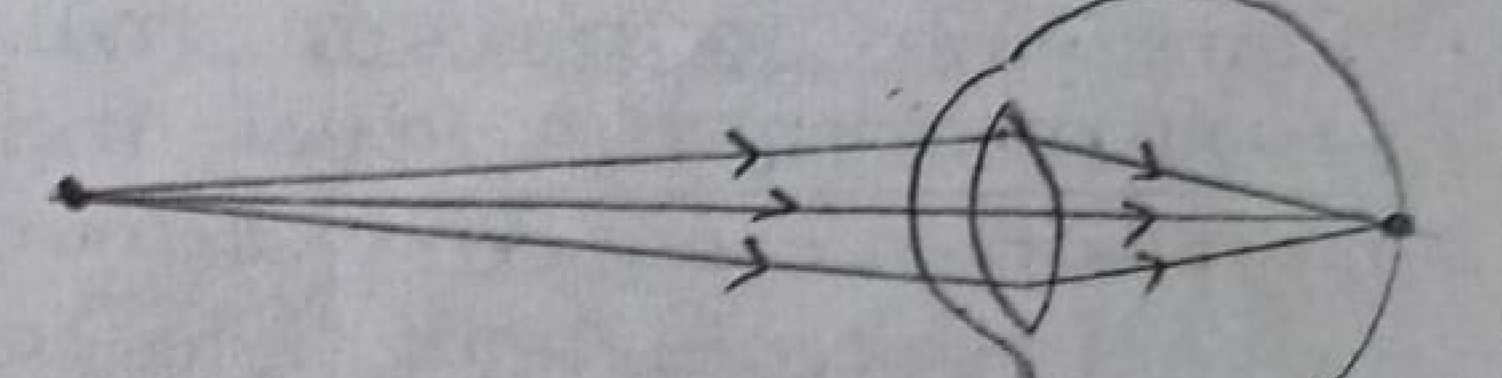
WHY DO SOME ANIMALS HAVE THEIR TWO EYES POSITIONED ON OPPOSITE SIDES OF THEIR HEADS – to give the widest possible field of view.

DEFECTS OF VISION AND THEIR CORRECTION – Some common defects of the eye are –

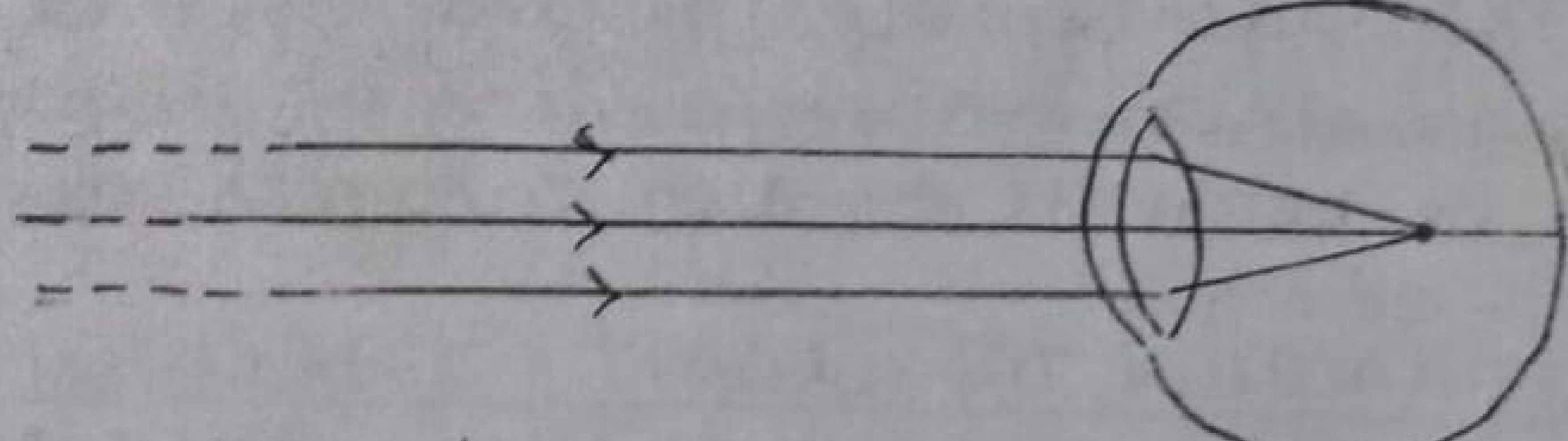
1. **MYOPIA (SHORT-SIGHTEDNESS OR NEAR SIGHTEDNESS)** – A person with myopia can see nearby objects clearly but cannot see distant objects distinctly.
   - A person with this defect has the far point nearer than infinity.
   - The image of the distant object is formed in front of the retina and not on the retina itself.

Cause – (i) due to excessive curvature of the eye lens.
(ii) due to elongation of eye-ball.

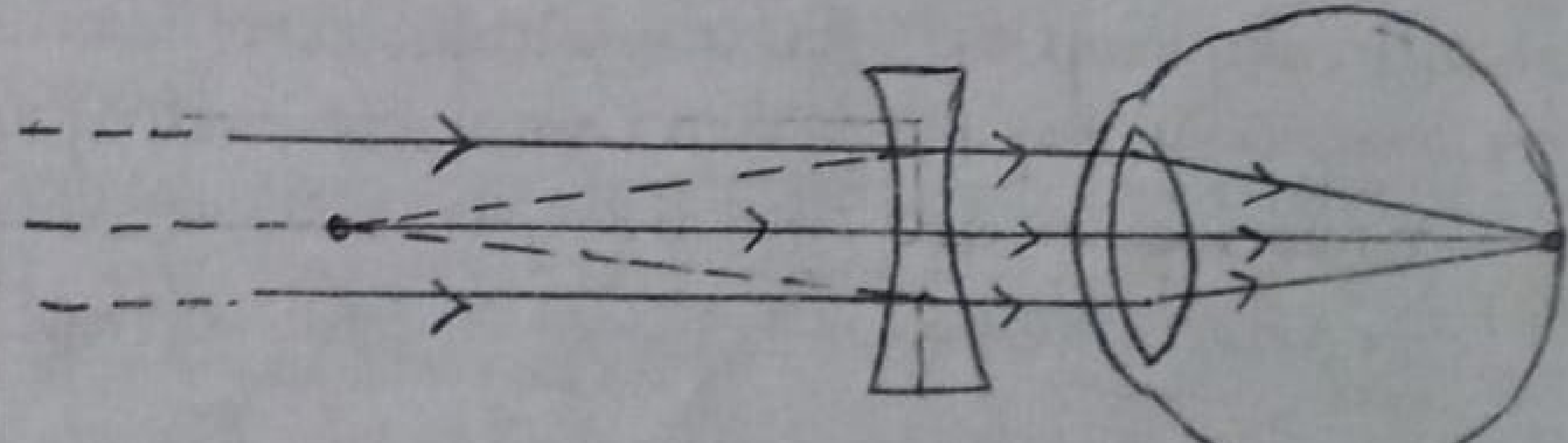
Correction – This defect is corrected by using a concave lens of suitable power.



Far point of a myopic eye



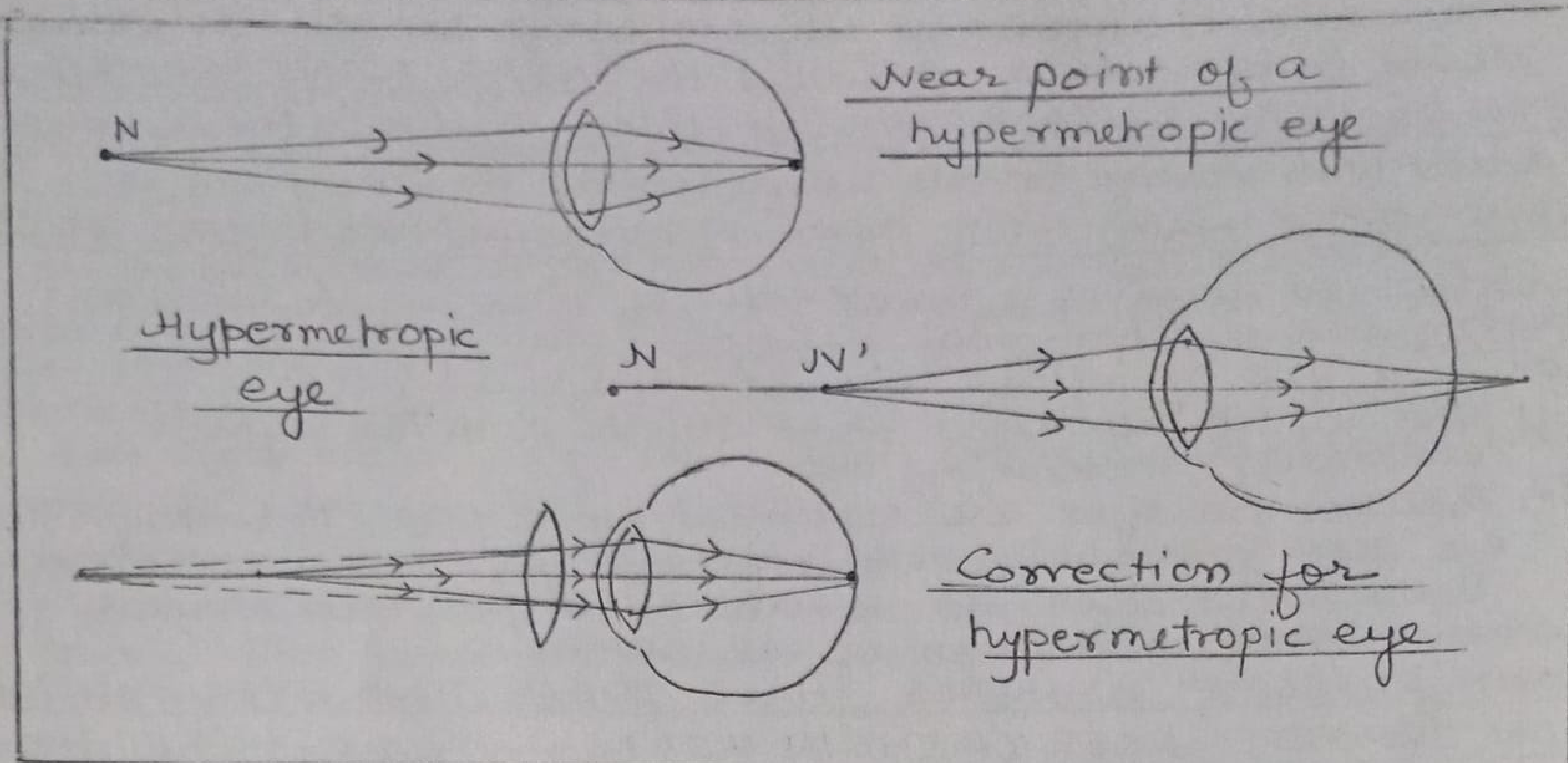
Myopic eye



Correction for myopia

2. **HYPERMETROPIA OR FAR-SIGHTEDNESS** – A person can see distant objects clearly but cannot see nearby objects distinctly.
   - A person with this defect has near point more than 25 cm.

Cause – (i) due to low converging power of eye lens (because of its large focal length).
(ii) the eyeball has become too small.



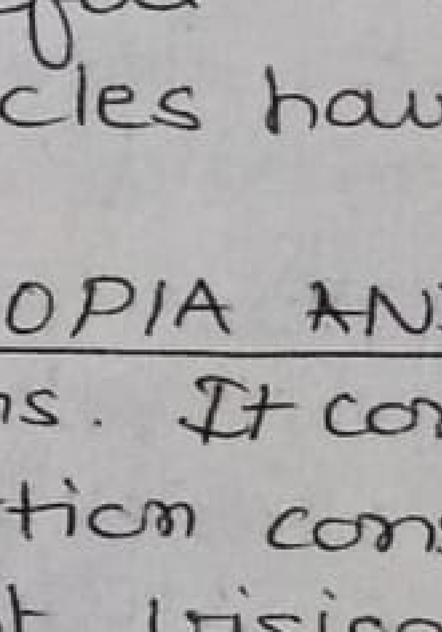
Correction - This is done by using a convex lens of suitable power which provides the additional focussing power required to form image on retina.

3. PRESBYOPIA - In old age, due to ciliary muscles becoming weak and eye lens becoming inflexible (or rigid), the eye loses its power of accomodation. This lead to the defect called presbyopia. It is corrected by using spectacles having convex lenses.

4. Sometimes, a person may suffer from BOTH MYOPIA AND HYPERMETROPIA and may require bifocal lens. It consists of both concave and convex lenses. The upper portion consists of a concave lens (to correct myopia) for distant vision while the lower portion consists of convex lens (to correct hypermetropia) to facilitate near vision.

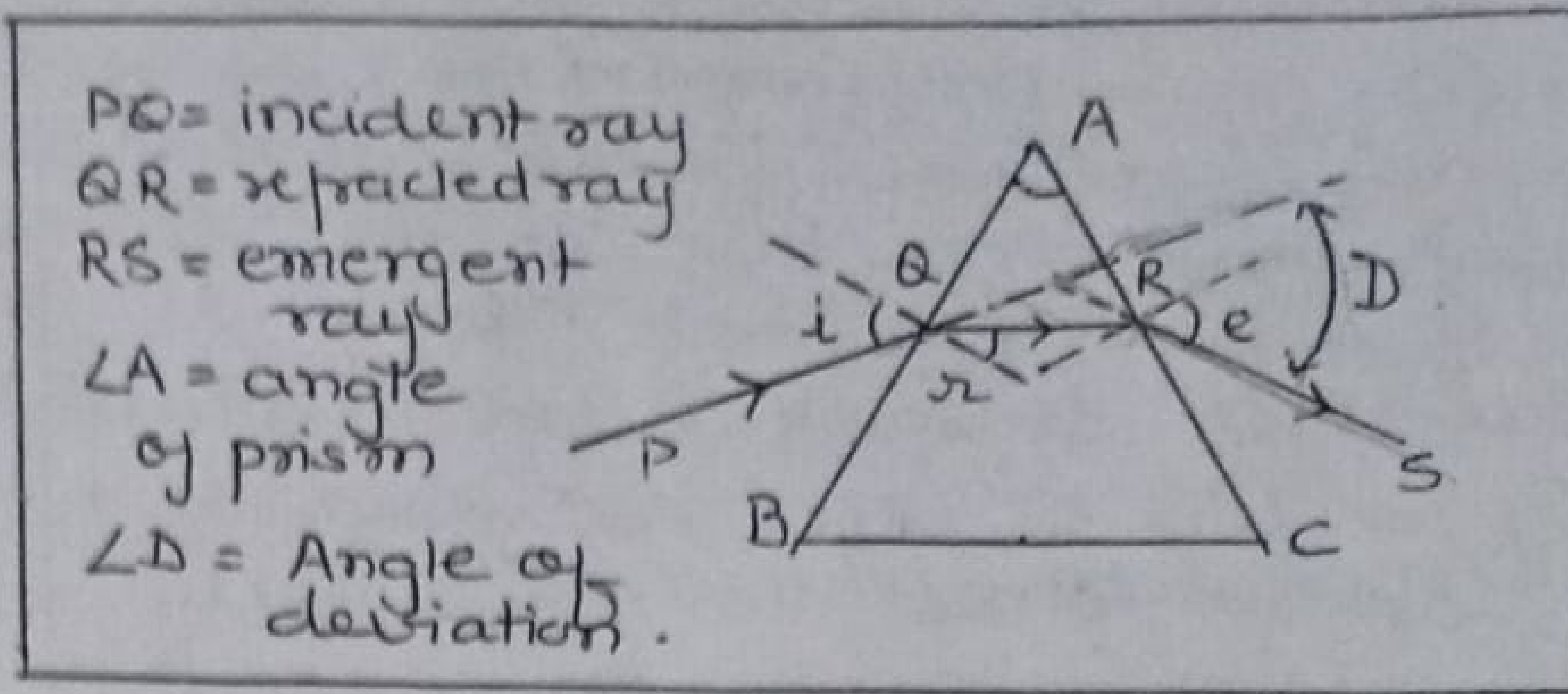
5. CATARACT. - in this the crystalline lens of a person at old age becomes milky and cloudy which results in partial or complete loss of vision. The vision of the person can be restored through cataract surgery.

• REFRACTION OF LIGHT THROUGH A PRISM - A triangular glass prism has two triangular faces and three rectangular lateral surfaces which are inclined to each other. The two rectangular faces through which refraction takes place are called the refracting faces and the third face is known as the base of the prism. The angle between two lateral faces is called the angle of the prism.

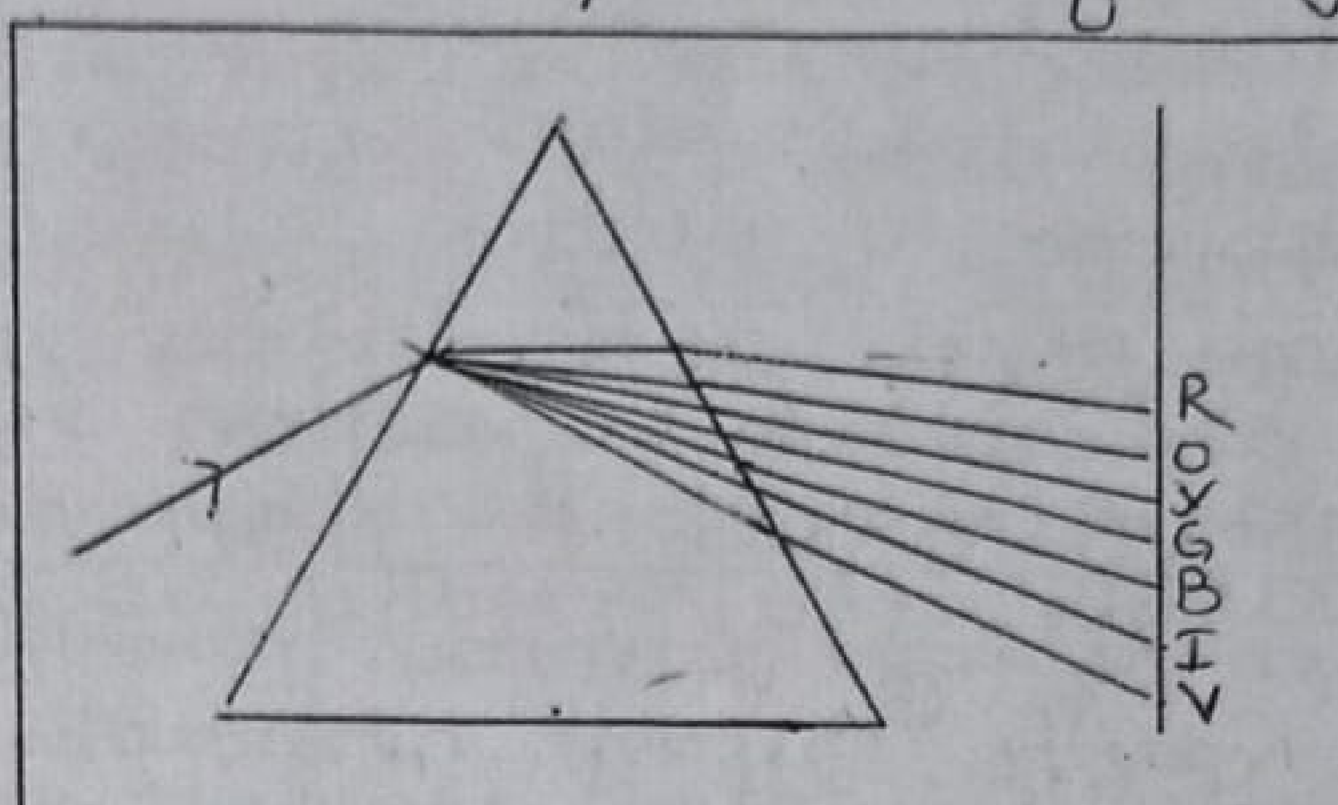


- In a rectangular glass slab (refracting surfaces are parallel), after refraction the emergent ray is parallel to incident ray, however, it is slightly laterally displaced. But in prism, after refraction, the emergent ray is deviated from its original direction since the refracting surfaces of prism are not parallel.

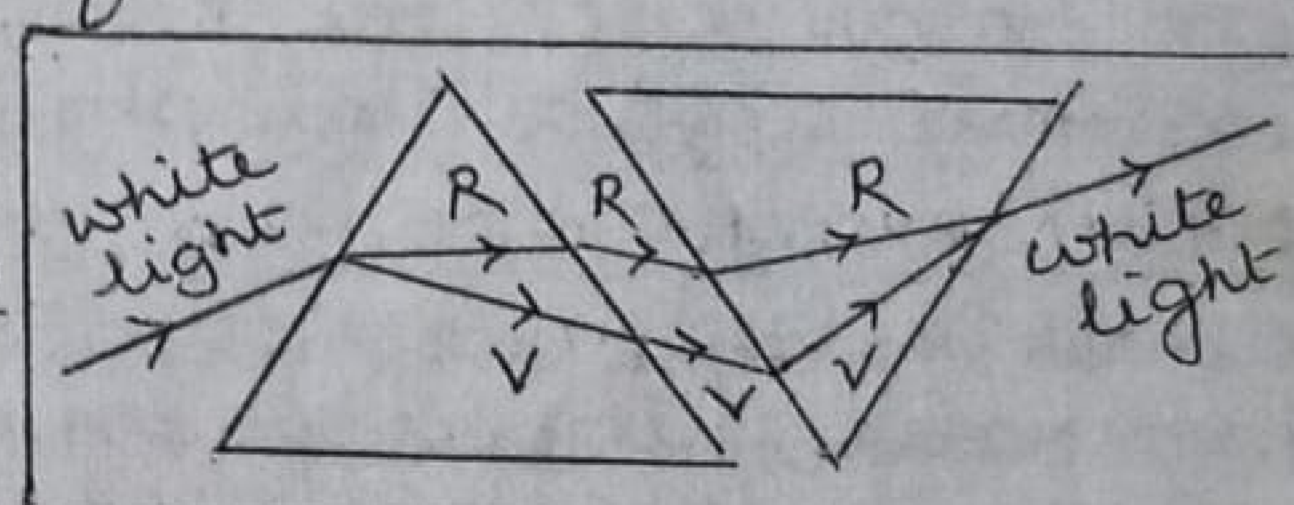
- The refraction through a glass prism is shown in the figure.
- The angle between the incident ray and emergent ray is called angle of deviation.



DISPERSION OF WHITE LIGHT BY A GLASS PRISM - The splitting of white light into seven colours (VIBGYOR) on passing through a transparent medium like a glass prism is called dispersion of light. The red light bends the least while the violet the most. This occurs due to different speed of different colours in any medium other than air. Speed of violet colour is least while red colour has maximum speed, therefore, $\mu_v > \mu_r$.

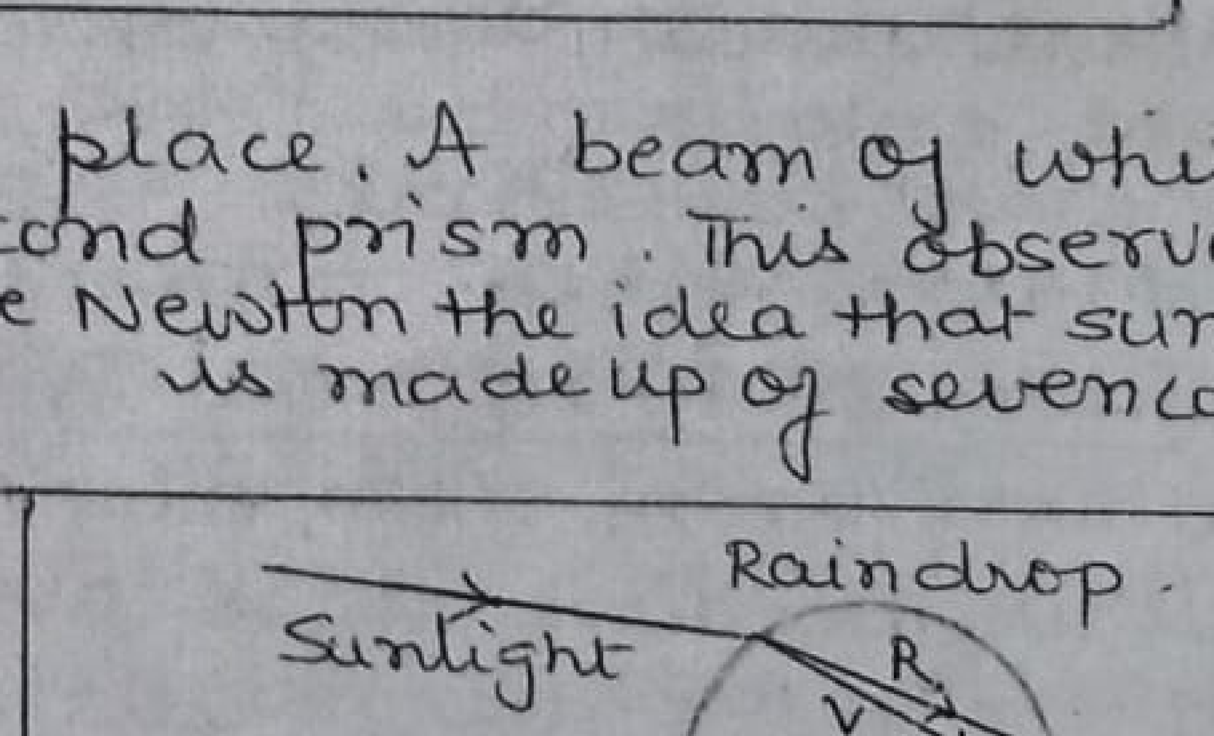


- The light does not get split when passed through a rectangular glass slab as light bends by equal angles but in opposite directions at the parallel faces of a rectangular slab. So the components of light that split at the first refraction bend back and recombine to give white light after the second refraction.
- Newton tried to split the colours of the spectrum of white light further by using another similar prism but he could not get any more colours. But, if identical prism is placed in an inverted position with respect to the first prism, recombination of the spectrum takes place. A beam of white light emerges from the other side of second prism. This observation gave Newton the idea that sunlight is made up of seven colours.



FORMATION OF RAINBOW - 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 prism. They refract and disperse the incident sunlight, then reflect it internally and finally refract it again when it comes out of the raindrop. The two refractions bends the light through a large angle, keeping them separate. The lights of different colours emerging from the raindrops create a rainbow, with red at the top and violet at the bottom.



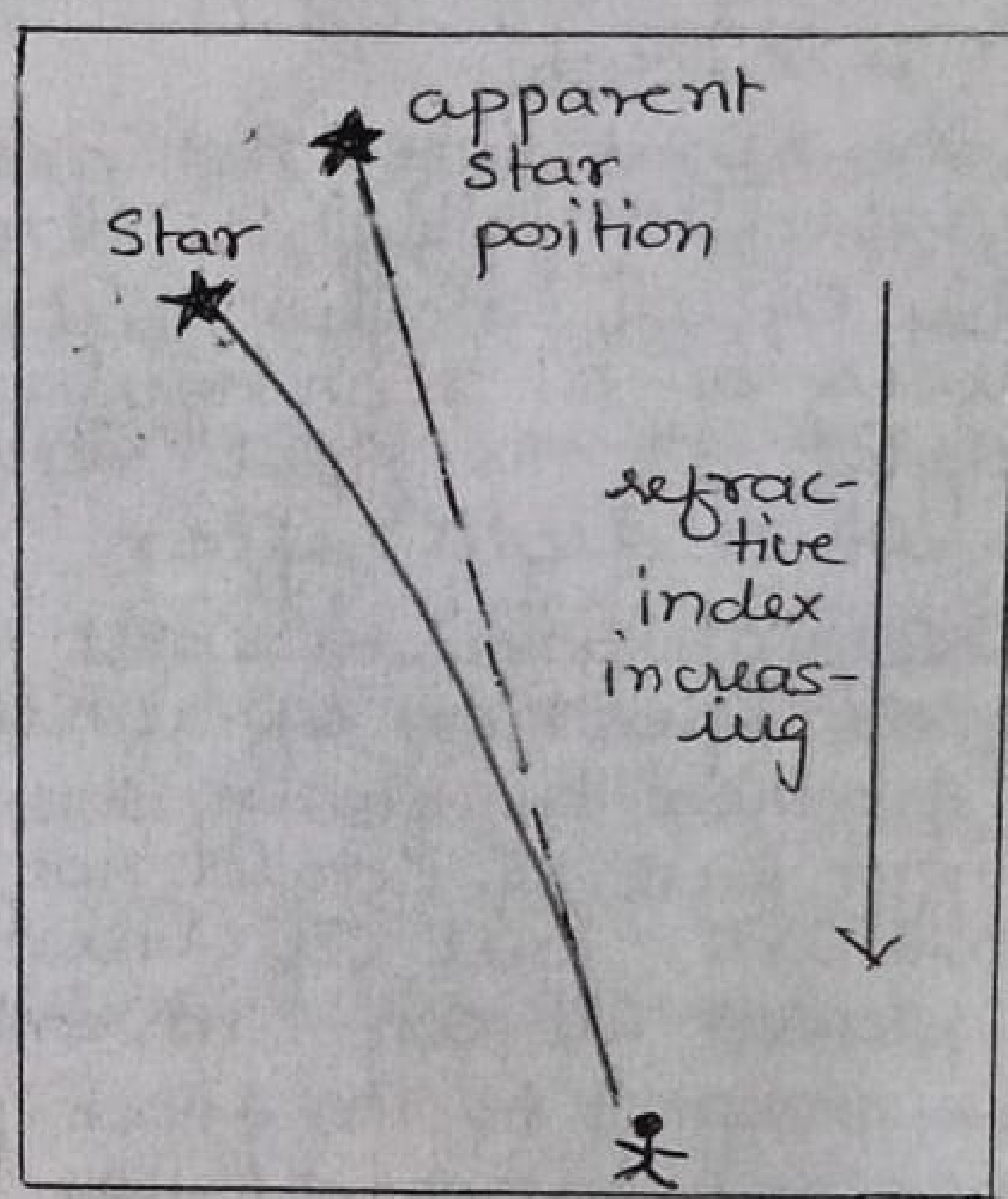
ATMOSPHERIC REFRACTION – The optical density of air in the atmosphere is not the same everywhere. In general, the density (or refractive index) is greatest at the earth's surface and goes on decreasing as we move higher. When light rays pass through the atmosphere having air layers of different optical densities, then refraction of light take place. This is called atmospheric refraction.

– If we look at objects through the hot air over a fire, the objects appear to be moving slightly. This is an example of atmospheric refraction on a small scale which can be explained as follows :– The air just above the fire becomes hotter (than the air further up). This hotter air is optically rarer. So when we see objects by the light coming from them through hot and cold air layers having different optical densities, then refraction of light takes place randomly due to which the objects appear to moving slightly.

– Some of the optical phenomenon in nature which occur due to atmospheric refraction of light are as follows –

1) THE STARS SEEN HIGHER THAN THEY ACTUALLY ARE –

When the light coming from the sun or a star travels through atmosphere, it continuously move into the regions of higher refractive index. So it continuously bends towards the normal, resulting in a path as shown in the figure. Since we see an object in the direction of the ray incident on the eye, the star appears higher than its actual position.

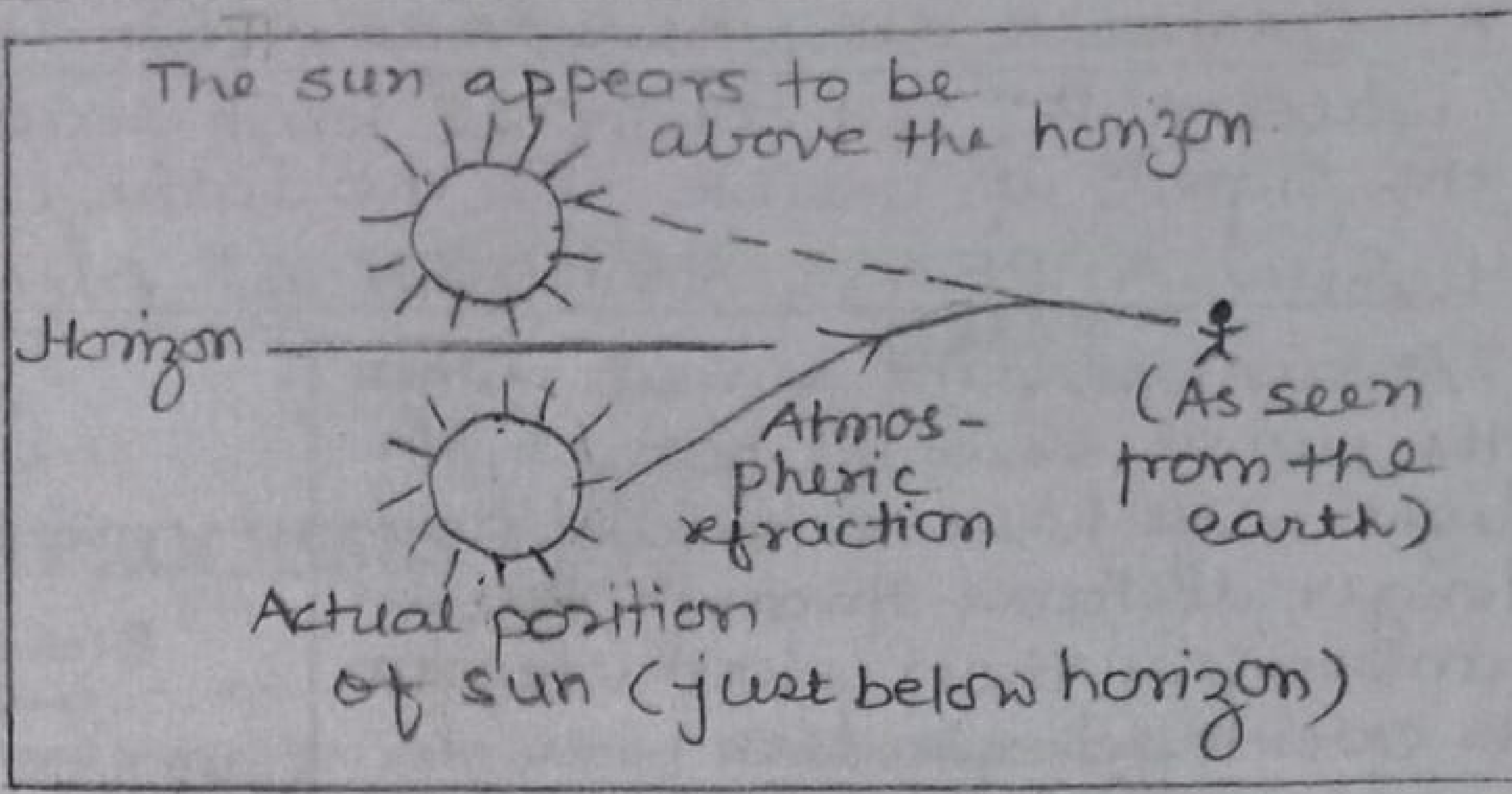


2) TWINKLING OF STARS – The physical conditions of the earth's atmosphere is not stationary, it keeps on changing continuously. Therefore, the amount of light entering the eye flickers. The star sometimes appear brighter and some other time fainter, which causes twinkling effect.

– PLANETS DO NOT TWINKLE LIKE STARS, although light coming from them also has to pass through atmosphere. This is because stars are considered as point sized source of light due to large distance from the earth. On the other hand, the planets are much closer to the earth and thus seen as extended source. If we consider a planet as a collection of a large number of point sized sources of light, the total variation in the amount of light entering our eye from all the individual point-sized sources will average out to zero, thereby nullify the twinkling effect.

3) ADVANCE SUNRISE AND DELAYED SUNSET – The sun can be seen two minutes before actual sunrise and two minutes after the actual sunset because of atmospheric refraction. Consider the situation when the sun is just below the horizon

The sunlight coming from the less dense air to more dense air refracted downward as it passes through atmosphere. Because of this atmospheric refraction, the sun appears to be raised above the horizon when actually it is slightly below the horizon. as our eye will see the sun at that position from where light enters it in the straight line.



- The apparent flattening of the sun's disc at sunrise and sunset is also due to the same phenomenon. The rays from the lower region of the sun travel a greater distance through the atmosphere than those from the upper regions, so they bend more. As a result image of the lower region gets shifted upwards more than that of upper region. This makes the sun appears like a flattened circle or oval.

<u>SCATTERING OF LIGHT</u> – The phenomenon in which a part of the light incident on a particle is redirected in different directions is called scattering of light.

<u>TYNDALL EFFECT</u> – The scattering of light by the particles in a colloidal solution is known as Tyndall effect. Some situations where Tyndall effect can be observed are –

(i) when a fine beam of sunlight enters a smoke or dust filled room through a small hole, the scattering of light make the small particles visible.

(ii) when sunlight passes through a canopy of a dense forest, tiny droplets of water in the mist scatter light.

- The colour of the scattering light depends on the size of scattering particles. Very fine particles scatter mainly blue light while particles of larger size scatter light of longer wavelengths. If the size of scattering particles is large enough, then the scattered light may even appear white.

<u>EFFECTS OF SCATTERING OF LIGHT</u> –

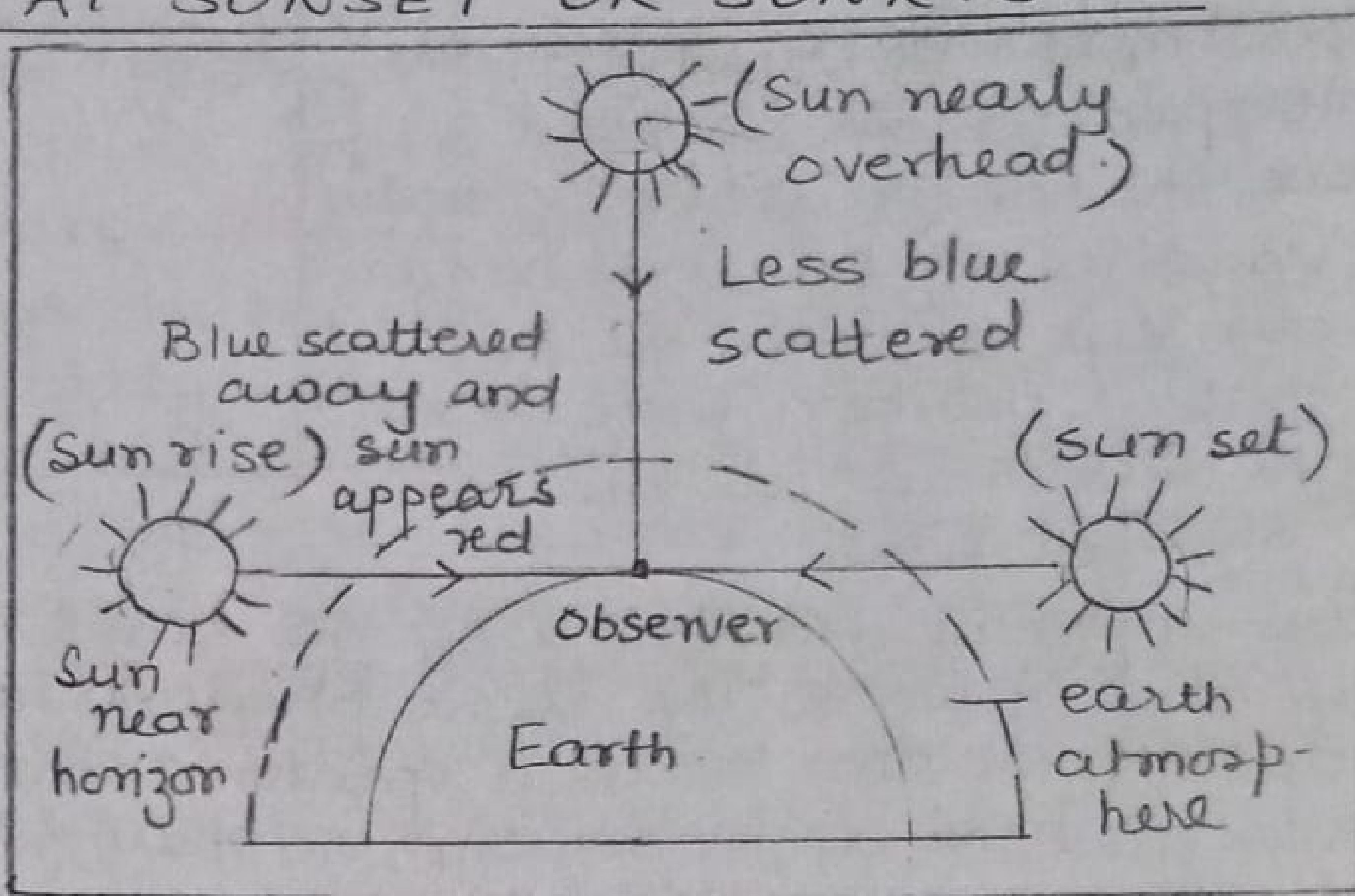
1) <u>BLUE COLOUR OF THE SKY</u> – When white light from the sun passes through the earth's atmosphere, the fine particles in air scattered the blue colour (shorter wavelength) more strongly than red as these particles have size smaller than wavelength of visible light. The scattered blue colour enters our eyes and the sky appears blue. If the earth had no atmosphere, there would have been no scattering of sun light. In that case no light from the sky would have entered our eyes and the sky would have looked dark and black to us.

2) <u>IN OUTER SPACE, THE SKY LOOKS DARK AND BLACK INSTEAD OF BLUE</u> – This is because, there is no atmosphere containing air in the outer space to scatter sunlight. Since, there is no scattered light to reach our eyes in outer space, therefore, the sky looks dark and black there.

3. DANGER SIGNALS ARE RED IN COLOUR – Due to its longer wavelength, red colour is least scattered by fog or smoke. Thus the signal is visible in the same colour from large distance

4. SUN APPEARS REDDISH AT SUNSET OR SUNRISE –.

At sunrise and sunset, when the sun is near the horizon, the light rays have to travel a longer distance through earth's atmosphere than when the sun is overhead. So less blue is scattered when sun is right overhead. As a result sun itself looks like white whereas sky around it as blue. At Sun rise or sunset, a lot of blue gets scattered away and the sun appears reddish.

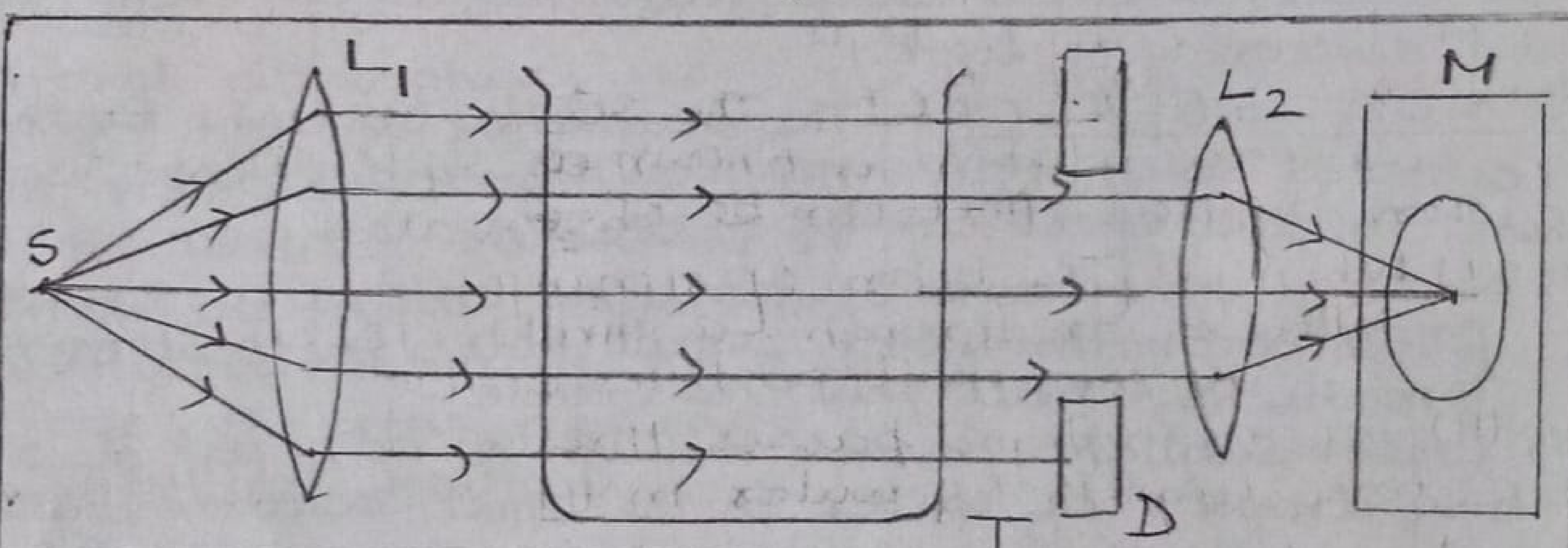


EXPERIMENT TO STUDY THE SCATTERING OF LIGHT – Set up the experiment as shown in the figure –.

S – source of white light

L_1 – convex lens.

The source S is placed at the focus of convex lens to get parallel beam of light.



T – is a transparent glass container filled with water.

D – is a cardboard disc having circular hole in the centre.

L_2 – Another convex lens. to produce image on screen M.

Switch on the source of light. A beam of light is passed through solution and we get a circular patch of white light on screen M. Now dissolve small amount of sodium thiosulphate in water and add few drops of conc. H_2SO_4. Fine particles of sulphur is formed and a colloidal solution is obtained. From the sides of glass tank, blue light can be seen. This is due to the scattering of shorter wave length blue light by sulphur particles. On the screen red coloured patch on the screen. This is because, after the scattering of blue light mainly the red colour is left