HOLY FAITH PRESENTATION SCHOOL

RAWALPORA SRINAGAR KASHMIR

Chapter 2 Human Eye and the Colourful World *(CLASS 10TH-PHYSICS)*

Introduction :- God has gifted us with two eyes which are of great value. All other optical instruments have no value at all with out an eye. Let us describe the structure, working and defects of human eye.

Structure of Human Eye:- The human eye is more or less like a photographic camera. The essential parts of human eye are Cornea, Iris, Pupil, Eye lens, Ciliary muscles, retina and optic nerve.

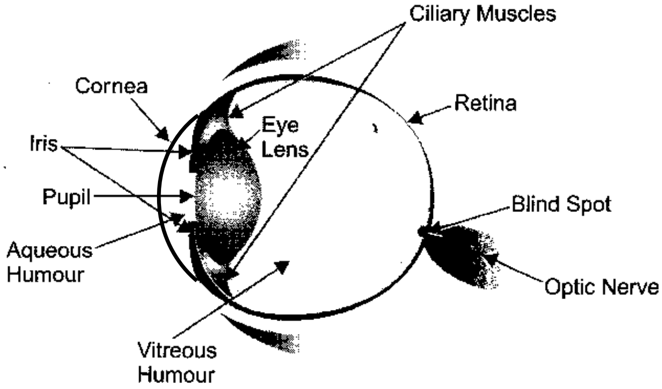
Cornea: The front transparent part of the eye is called cornea which is bulged outwards. The light coming from the objects enter the eye through cornea, thus it serves as a window of the eye.

Iris:_ The coloured diaphragm behind the cornea is called as iris.

Pupil: A small hole in the centre of iris is called as pupil. It appears black as no light is reflected from it.

Eye lens: A double convex lens which is a transparent and flexible material like a jelly made of proteins.

Ciliary muscles: The special type of muscles which hold the eye lens in a proper position. The focal length of the eye lens is varied and regulated with the help of ciliary muscles.



Retina: A screen behind the eye lens and at the back of the eye ball, on which the image of the object is formed. It is a delicate membrane consisting of a large number of light sensitive cells in the form of rods and cones. The rods respond to the intensity of light and the cones respond to the colour of objects by generating electric pulses.

Optic nerve: The optic nerve receives the electric pulses form retina and passes to the brain where the information is processed and we perceive the objects as they are.

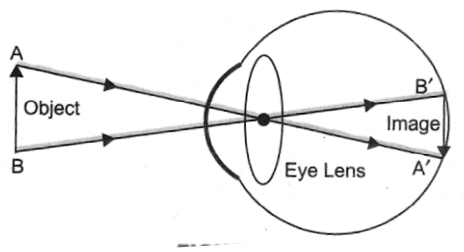
Aqueous humour: The space between the cornea and the eye lens is filled with a viscous liquid called aqueous humour.

Vitreous humour: The space between the eye lens and the retina is filled with a specific fluid called as vitreous humour.

Blind spot: It is the least sensitive spot on the retina through which the optic enters the retina.

Diameter of eye ball: The whole eye ball is a sphere of diameter about 2.3cm.

Working of human eye:- Light rays coming from an object to be seen enter the eye through Cornea and fall on the eye lens through the pupil of the eye. The eye-lens, being convex, converges the rays of light, forming a real and virtual Image of the object on the retina. The large number of rod and cone shaped cells of the retina get activated by the light falling on them, they generate electric signals which are sent to the brain via optic nerve. The brain process this message and it gives rise to the sensation of vision. Although the image formed on the retina is inverted, our mind interprets the image as that of an erect object.



Persistence of vision:- One of the important characteristics of human eye is that the image formed on the retina of an object is neither permanent nor it fades away instantly . But actually the image of any object seen persists on the retina for $^{1}/_{16}{}^{th}$ of a second even after the removal of object. This ability of an eye to continue to see the image of an object for a very short duration, even after the removal of the object, is called persistence of vision. This property of persistence is used in cinematography i.e. in projection of motion pictures.

HOLY FAITH PRESENTATION SCHOOL

RAWALPORA SRINAGAR KASHMIR

Chapter 2 Human Eye and the Colourful World *(CLASS 10TH-PHYSICS)*

How do we see different colours:-

The retina of our eye contains a large number of rod and cone shaped cells which are light sensitive. The rod shaped cells respond to the intensity i.e. brightness of light and the cone shaped cells respond to colours. In other words the cone shaped cells enable us to distinguish between different colours. It is interesting to note that a chicken wakes up in the morning with the rising sun and goes to sleep by sunset because the retina of chicken's eye contains very few rod shaped cells which respond to the intensity of light. Due to the lack of the rod shaped cells in its retina, a chicken needs bright light to see. Similarly a bee has some cone shaped cells in its retina which are sensitive to ultraviolet light while as human eye can not see ultraviolet so humans are said to be ultraviolet blind.

Colour Blindness:- Colour blindness is said to be occur when a person can not distinguish between different colours , though his vision may otherwise be normal. This is because the retina of the eye of such a person does not posses some cone cells. E.g. a person who is blind to red-green colour may be deficient in cone shaped cells having red and green pigment in the retina of his eyes. It is genetic disorder which occurs by inheritance. It has not been cured so far.

Power of Accommodation:-(Q:What is meant by power of accommodation of the eye?) A normal can see near by objects clearly as well as the distant objects. The ability of an eye to focus the distant objects as well as the near by objects on the retina by changing the focal length of its lens is called accommodation or power of accommodation of eye. This is done by the action of ciliary muscles. When the object is at infinity, the ciliary muscles are relaxed and the eye lens becomes very thin and possesses maximum focal length and maximum converging power. The image of the distant object is formed on the retina. Thus in this case the eye is relaxed and is called to be **unaccommodated.** For observing nearby objects the ciliary muscles contract which increase the thickness of the eye lens decreasing its focal length and increases its converging power. Thus the image of the nearby objects is formed on the retina. In this case the eye is in a state of tension and is said to be **accommodated**. The maximum accommodation is reached when the object is at a distance of 25cm from the eye.

Far point of eye:- The most distant point at which an object is seen clearly by an eye is called far point (F) of the eye. It lies at infinity.

Near point of eye:- The point at the closest distance, at which an object is seen clearly by an eye is called Near point (N) of the eye. The distance between the Near point and the eye is called least distance of distinct vision. It is denoted by "d" For normal eye its value is 25cm. The distance between the Near point and the Far point of the eye is called range of vision.

Functions of Iris and pupil:- The iris automatically adjust the size of the pupil according to the intensity of light received by the eye. If the amount of light received by the eye is great (during daytime) the pupil contracts i.e. becomes small and reduces the amount of light entering the eye. On the other hand, if the amount of light received by the eye is small (during the night), the pupil expands i.e. becomes bigger and increases the amount of light entering the eye. Thus we can say that iris regulates the amount of light entering the eye by adjusting the size of the pupil. This adjustment takes some time e.g. when we go from a bright light to a darkened cinema hall, at first we can not see our surroundings clearly. After a short time, our vision improves and we can see the surroundings clearly. This is because in the bright light, the pupil is very small, so entering in the cinema hall, a small amount of light reaches our eye lens and we can not see properly, but after a short time, the pupil expands and more light then enters our eye and we can see clearly. This is why we can not see our surroundings clearly when we enter a darkened cinema hall from a bright sun shine.

Defects of vision

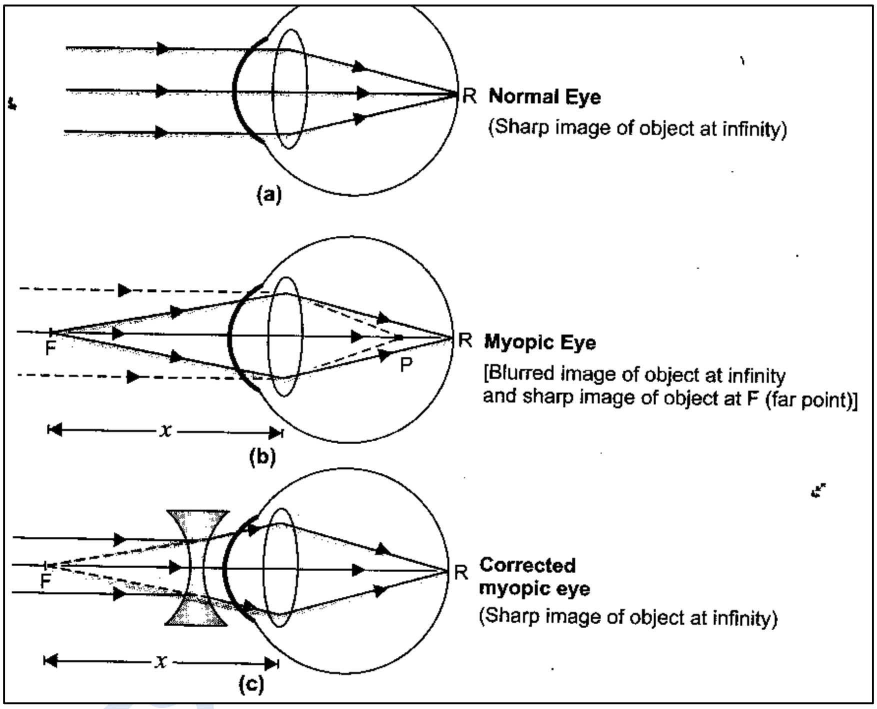
There are four defects of vision or defects of eye which can be corrected by using suitable spectacles. These are:

1. Myopia and short sightedness

2. .Hypermetropia or long sightedness.
3. Presbyopia
4. Astigmation.

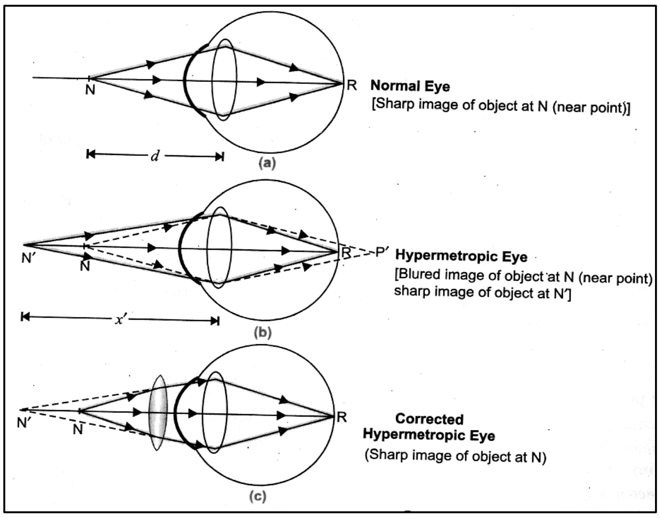
Out of these four defects the first two are most common.

1. **Myopia:-** It is that defect due to which an eye can see nearby objects clearly but can not see the distant objects clearly. This defect is caused either (i) Due to the high converging power of the eye lens or (ii) due to the eyeball being too long. The far point of an eye suffering from this defect is less than infinity. In some cases, in an eye suffering from myopia, the ciliary muscles attached to the eye lens do not relax completely to make the eye lens thinner to reduce its converging power. So due to the greater converging power of the eye lens; the image of the distant object is formed in front of the retina and hence the eye can not see it clearly. In some other cases, in an eye suffering from this defect, the eyeball is too long due to which the retina is at longer distance from the eye lens. This also leads to the formation of image of distant object in front of retina. This is shown in the following fig. (b). this defect can be corrected by using spectacles containing concave lenses of suitable focal lengths as shown in fig (c).



Parallel rays of light from infinity first diverge on passing through concave lens and appear to come from F, then the rays are converged by the eye lens and the image is formed on the retina and hence the eye can see it clearly.

2. **Hypermetropia or long sightedness:-** It is that defect of eye due to which an eye can see the distant objects clearly but can not see the nearby objects clearly. The near point of a hypermetropic eye is more than 25cm away so a person suffering from this defect can not read or write easily. It is caused either. (i) due to the low converging power of the eye lens or (ii) due to the eye-ball being too short. Thus the image of a nearby object in a hypermetropic eye is formed behind the retina instead of retina as shown in the following fig.(b) . This defect can be corrected by using spectacles containing Due to the combined converging action, of this lense and eye lens the image is formed on the retina and the eye can see the nearby object clearly.



HOLY FAITH PRESENTATION SCHOOL

RAWALPORA SRINAGAR KASHMIR

Chapter 2 Human Eye and the Colourful World ***(CLASS 10TH-PHYSICS)***

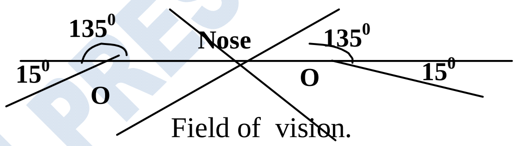
3. **Presbyopia:-** It is that defect of eye due to which an old man can not read comfortably and clearly without spectacles. That is why it is called old sight. This defect occurs in the old age due to the gradual weakening of the ciliary muscles and diminishing flexibility of the eye lens. Obviously Presbyopia is a sort of hypermetropia where near point of eye recedes to a distance more than 25cm from the eye. It is corrected in the same way as hypermetropia by using spectacles of convex lenses of suitable focal lengths. When a person suffers from both myopia and hypermetropia his spectacles for correction have bifocal lenses. The upper half is a concave lens for distant vision and lower half is a convex lens for reading.

4. **Astigmatism:-** It is that defect of eye due to which a person can not focus on both horizontal and virtul lines simultaneously. This defect arises due to the irregularities in the surface of the cornea. The cornea surface of a normal eye is a part of the surface of a perfect sphere. A person suffering from this defect has its cornea having different curvatures in different directions in horizontal and vertical planes. Due to this eye can focus the object well in one direction while those in the perpendicular direction to it are not well focused. That is, if the eye can focus well on horizontal lines, it can not focus well on vertical lines at the same time and vice-versa. This defect can be corrected by super imposing cylindrical lenses upon the spherical shape of spectacle lenses.

5. **Cataract:-** yet another defect of eye that comes usually in old age is cataract. Cataract develops when the eye lens of a person becomes cloudy (or even opaque) due to the formation of a membrane over it. It decreases the vision gradually leading some times to total loss of vision. This problem is solved by cataract surgery i.e. removal of the eye lens and its replacement by a lens of suitable focal length.

Advantages of having two eyes instead of one:-

1. Having two eyes gives a wider field of view. The field of view is only 150^0 with one eye open but the field of view becomes 210^0 with two eyes open. Thus a larger area in front of us can be viewed with two eyes.
2. Having two eyes enables us to judge distances more accurately. Two eyes form different images from the same object and the brain recombines them to build a three-dimensional picture of the object more accurately.

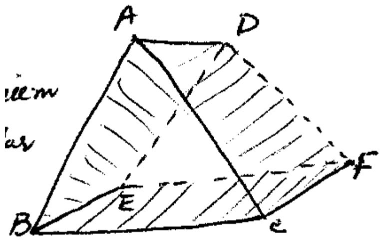


Field of vision.

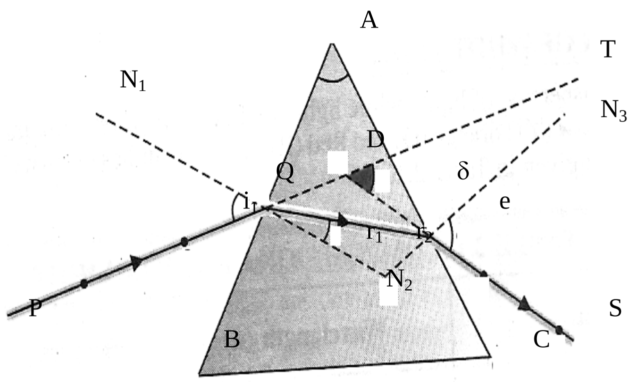
Gift of Vision:-

There are millions of blind people in the world Their eyesight can be restored if they are given the eyes donated by others after their death. Thus our eyes can live even after our death. These are some important points to be noted about the donation of eyes.

1. Any person male or female can donate eyes but he or she must not have any communicable disease. The person having diabetes, hypertension, asthma, can donate their eyes but those having Aids, Lepalitis, Leukaemia, Tetanus, Cholera, meningitis can not donate eyes.



Glass Prism:- A Prism is a transparent glass medium bounded by two triangular and three rectangular faces as shown in the figure. One of three rectangular faces is called the base and the other two are called as refracting faces.The line joining the two triangular faces is called the edge of the prism and the angle made by two opposite faces is called angle of the prism. The refraction through a prism is different from that through a glass slab in the sense that the emergent ray in case of prism is not parallel to the incident ray so we called it as deviated ray. Thus light after passing through a prism is deviated from its original path.



Refraction through a glass prism: Consider ABC as the prism with its base BC and AB and AC being its refracting faces. Let a ray of light PQ incident on face AB after refraction at Q it is refracted through QR and it emerges out as RS. Draw N_1O and N_2O normal at point Q and R.

Producing PQ forwards and RS backwards, the two lines meet at D giving rise to an angle δ called as the angle of deviation:
It is defined as the deviation occurred to the incident light due to a prism placed in the path of incident light.
From the figure;
$i = \angle\delta_1 + r_1 \Rightarrow \angle\delta_1 = i - r_1$
$\|$y $e = \angle\delta_1 + r_2 \Rightarrow \angle\delta_1 = e - r_2$
Now $\delta = \delta_1 + \delta_1$ (ext. ∟ is equal to sum of int. opp. ∠s)
⇨ $\delta = i - r_1 + e - r_2$
⇨ $\delta = i + e - (r_1 + r_2)$ ____________(i)
Now AQOR is a quadrilateral in which $\angle AQO = \angle ARO = 90^0$
.: $\angle A + \angle O = 180^0$______ (ii) (sum of ∠s is of a quad. is 360^0)
But $r_1 + r_2 + \angle O = 180^0$________(iii) (Sum of ∠s of a Δ)
From (ii) and (iii) we have;
$\angle A = r_1 + r_2$ ---------- (iv)
using (iv) in (i) we have $\delta = i + e - A \Rightarrow$ $\boxed{i + e = A + \delta}$
if i and e are known the deviation angle can be measured easily
<u>**Prism Formula:**</u> $r_1 + r_2 = A$ -------------------(i)
We know that, $\delta + A = i + e$ --------- (ii)
If $\delta = \delta_m$, $i = e$ & $r_i = r_2 = r$ [Prism in minimum deviation position]
Then from ean. (i), we have , $2r = A$ or $r = A/2$ --------- (iii)
And from eqn. (ii) $\delta_m, + A = 2i$ or $i = \frac{A + \delta_m}{2}$ ------------- (iv)

According to Sncll's las $\mu = \frac{\text{Sin } i}{\text{Sin } r}$
Substituting the vale of 'i' and 'r' from (iii) and (iv) , we have

$$\boxed{\mu = \frac{\text{Sin } (A + \delta_m)/2}{\text{Sin } (A/2)}}$$

Dispersion of light:- When a beam of white light is passed through a prism it is splitted in to its constituent colours. The phenomenon of splitting of white light in to its constituent seven colours is called dispersion of light. The seven colours are violet, indigo, blue, green, yellow, orange and red. If the patch of these seven colours are obtained on a screen it is called spectrum of white light. The spectrum of white light shows the white light is made up of seven colours. It can be remembered by the word 'VIBGYOR'.

Cause of dispersion:- We know that white light has range of wave length from 3800^0A to 7800^0A. Thus when white light passes through the prism, different colours are refracted through

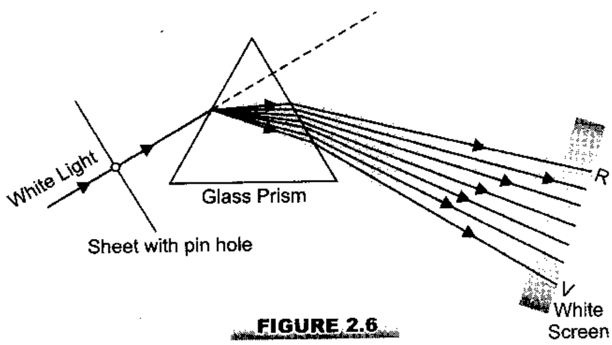


FIGURE 2.6

different angles, with the result the seven colours are spread out from a spectrum. The red colour having maximum wavelength gets deviated least and the violet having minimum wavelength gets deviated most.

Thus dispersion of white light occurs due to the refraction of different colours through different angles through a glass prism.

According to cauchy's relation $\mu = A + B/\lambda^2$ => $\mu \propto 1/\lambda^2$

Also $\lambda_{red} > \lambda_{violet}$ => $\mu_r < \mu_v$

We known that $\delta = (\mu - 1) A$

$\therefore$ $\delta_r = (\mu_r - 1) A$ and $\delta_v = (\mu_v - 1) A$

=> $\delta_r < \delta_v$

This shows that red colour deviates least and violet colour deviates most.

Q. Define angular dispersion and dispersive power of a prism.

Ans. Angular dispersion is defined as the difference in the devotions suffered by the two extreme colours (i,e red and violet colour) in passing through a prism. It is donated by θ and is given by.

$$\theta = \delta_v - \delta_r$$

Expression of θ in terms of μ and A.

Since $\delta = (\mu - 1) A$

Now angular dispersion, $\theta = \delta_v - \delta_r$

Or $\theta = (\mu_v - 1) A - (\mu_r - 1) A$

Or $\theta = (\mu_v - \mu_r) A$

Angular dispersion is measured in radians.

<u>Dispersive Power :</u> The dispersive power of a material is its ability to disperse the constituents colours of light.

Dispersive power in a prism in the ratio of angular dispersion to the mean deviation. It is denoted by ω

Thus $\omega = \dfrac{\theta}{\delta}$

Since $\theta = \delta_v - \delta_r = (\mu_v - \mu_r) A$

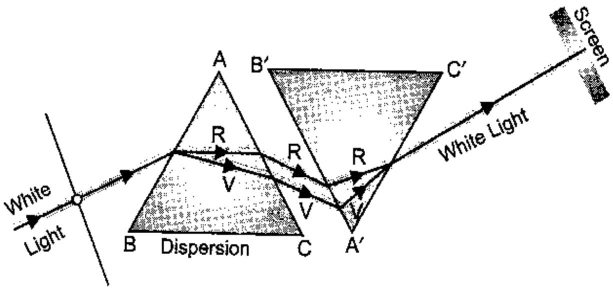
and $\delta = (\mu - 1) A$

$\therefore \omega = \dfrac{\theta}{\delta} = \dfrac{(\mu_v - \mu_r) A}{(\mu - 1) A} = \dfrac{\mu_v - \mu_r}{\mu - 1}$

=> Dispersive power depends only on the nature of the material.

<u>Recombination of spectrum colours:-</u>

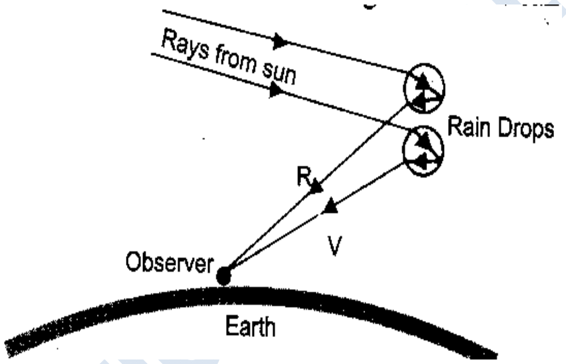
Newton was the first to obtain the spectrum of white light. It showed that white light can be dispersed into seven colours. He also observed that the reverse of it is also true i.e. seven coloured light can be recombined to give back white light. This can be done by placing two glass prisms in such a way that the first prism disperses the



white light into its constituent seven colours and all these seven coloured lights are received by the 2nd prism (which has been placed upride down) which are recombined into the original white beam of light. This recombination of seven colours is due to the fact that the second prism refracts these rays equally and oppositely to that produced by the first prism.

The Rainbow:

The rainbow is the best example of dispersion of sunlight in nature. It is an arch of seven colours visible in the sky when the sun shines on rain drops during or after the shower of rain or water. The essential condition for observing a rainbow is that the observer must stand with his back towards the



sun. During or after a shower, the rain drops suspended in air act like many small prisms. The incident sun light falling on these tiny drops is refracted and dispersed by them. It then suffers total internal refraction and finally refracted out of the rain drops to reach the observers eye. This spectrum of light having red colour at the top and violet at its bottom is observed by the eye when it makes 41^0 and 44^0 with the horizontal. This is called primary rainbow. Some times a faint rainbow along with this rainbow is also observed making 51^0 and 53^0 angle with the horizontal. That is called as secondary rainbow.

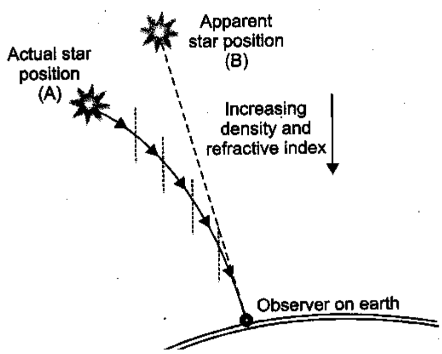
Atmospheric Refraction:-

The phenomenon of bending of light passing through different layers of atmosphere is called atmospheric refraction. We know the different layers of atmosphere are at different temperatures, they posses different optical densities. Thus the sun light or the light coming from stars on passing through these layers having different optical densities suffer multiple refractions before reaching the surface of earth. This is called atmospheric refraction. Some natural phenomena are explained on this basis.

1. **Stars appear twinkling while as planets do not :- (Q) Why do stars twinkle?**) When the light coming from a star enters the earth's atmosphere it undergoes refraction due to varying optical densities of air at various altitudes. The continuously changing atmosphere refracts the light from the stars by different amounts from one moment to the next. When the atmosphere refracts more star light towards us, the star appears to be bright and when the atmosphere refracts less star-light reaching our eyes increases and decreases continuously due to atmospheric refraction, the star appears to twinkle.

(Q: Explain why the planets do not twinkle?) The planets appear to be quit big to us because they are much nearer to the earth. So a planet can be considered to be collection of a very large number of point sources of light. The dimming effect produced by some of the point sources of light in one part of the planet is nullified by the brighter effect produced by the other point sources of light in its other part. Thus, on the whole, the brightness of a planet always remains the same and hence it does not appear to twinkle.

2. **Stars seen higher than they actually are:-** Light from a star is refracted as it enters the earth's atmosphere. As optical density increases towards the rare to denser medium bending every time towards the normal. On producing the final refracted ray backwards as shown in fig. the apparent star position B is higher than the actual star position A.



Advance sunrise and delayed sunset:- The sun-rise can be seen before its actual rise and it can be seen to about two minutes after the actual sunset. This is explained as follows

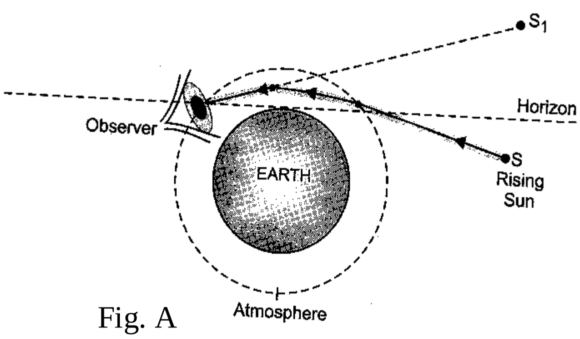


Fig. A

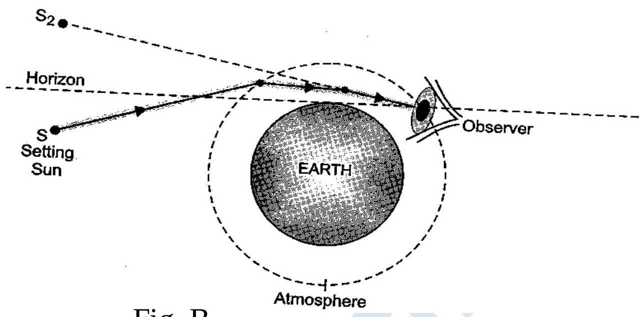


Fig. B

When the sun is below the horizon slightly, the sun light coming from less dense layers to more dense layers is refracted down wards as it passes through the atmosphere. Because of this atmosphere refraction, the sun appears to be raised above the horizon when actually it is slightly below the

horizon. The same phenomenon takes place at the time of sunset. Hence we can see the sun 2 minutes before the actual sunrise time and for 2 minutes after the actual sunset time.

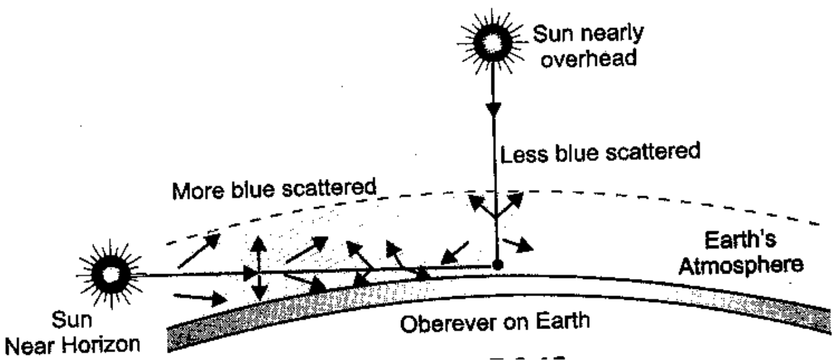
Scattering of light:- The phenomenon of spreading or throwing of light in different directions when it strikes an obstacle like atom, molecule, dust particle, water drop etc. is called as scattering of light. Lord Rayleigh studied scattering of light and he established a low called as Rayleigh's law according to which the intensity of scattered light (I_s) varies in versely as the fourth power of wavelength (λ) of incident light i.e. I_s x ${}^{1}/_{\lambda}{}^{4}$

Tyndall Effect:- The scattering of light by the particles in its path is called Tyndall effect e.g. when a fine beam of sunlight enters a smoke filled room, smoke particles become visible due to scattering of light by these particles. Similarly when sunlight passes trough the canopy of a dense forest, tiny water droplets in the mist scatter sunlight. The colour of the scattered light depends on the size of the scattering particles. If the particle size is much larger than the wavelength range of visible light, all wavelengths are scattered almost equally and the scattered light appears white. However when the particle size is very small as compared to wavelength range of visible light, the shorter wavelength region (i.e. blue light) is scattered must and the longer wavelength region (i.e. red light) is scattered least.

Why the sky appears blue:- When the sunlight passes through our atmosphere, the molecules of air being very small in size obey Rayleigh's scattering law and scatter blue part of the sunlight much more than they scatter red light. So when we look upwards the scattered light enters our eyes and the sky appears blue.

If the earth had no atmosphere, there would have been no scattering at all. So no light from the sky would have entered our eyes and the sky would have looked dark and black to us. This is why the astronauts who go to the outer surface find the sky to be dark and black instead of blue.

White colour of clouds:- The clouds are at much lower-height and contains large dust particles, water droplets, ice



particles etc. These are bigger in size to the wavelength of visible light and they do not obey Rayleigh's law hence all wavelengths are scattered equally by these molecules. Thus clouds generally appear white.

The sun appears red and sunrise and sunset:-

(Q: Why does the sun appear reddish early in the morning?) All the time of sunrise and sunset the sun is near the horizon, the sunlight has to travel a much larger distance through the atmosphere to reach the observer on the earth. Therefore most of the blue light is scattered away. So the light reaching us directly consists mainly of longer wavelength red colour due to which the sun appears reddish at the time of sun rise and sunset.

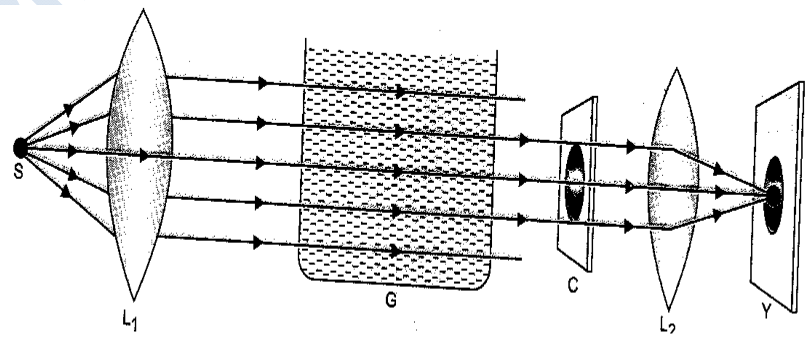
When the sun is nearly overhead (at noon), the sun light has to travel relatively shorter distance through the atmosphere to reach us. During this only a little of the blue colour remains in it. So the sun light contains almost all components colours in the right proportion, therefore the sun in the sky overhead appears white to us.

Danger signals are red:- Out of all colours of visible light, red has the largest wavelength. When sunlight travels through our atmosphere, the shorter wavelengths are scattered most and the longer wavelengths are scattered least. Thus red colour can be seen from a maximum distance. Hence danger signals are red in colour so as to detect them from a larger distance.

Experiment to study the scattering of light:- S is a strong source of white light held at the focus of a convex lens L_1. The convex lens renders the rays of light parallel. The beam of parallel rays is made to

pass through a transparent glass tank containing clear water. the beam emerging out of the tank is passed through a hole made in a cardboard. The sharp image of this hole is obtained on a screen using another convex lens L_2 as shown in fig.

Switch on the source of light. The beam of light passes through the water in the tank and a white circular patch is formed on the screen. Now dissolve about 200gm of sodium thiosulphate called as "hypo" in the water of the tank and add 2ml of conc. Sulphuric acid to the water. it will be seen that fine microscopic particles of sulphur begin to dissolve in water and a colloidal solution is obtained. Now it will be observed that blue light will be coming from the sides of the tank due to scattering of short wavelength blue light by the small sulphur particles. This is how sky looks blue. If we look at the screen on the front side of the tank containing colloidal solution, a red patch will be observed on the screen. This is how the sun looks reddish at the time of sunrise and sunset.



Textual questions

Q) What is the far point and near point of the human eye with normal vision?

Ans) For a normal human eye, the far point is at infinity and near point is at 25cm from the eye.

Q) 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) The child is suffering from myopia or short sightedness and the defect can be corrected by using spectacles with concave lens of suitable focal length.

Q) Why is a normal eye not able to see clearly the objects placed closer them 25cm?

Ans) This is because the focal length of eye can not be adjusted below a certain minimum limit.

Q) What happens to the image distance in the eye when we increase the distance of an object from the eye?

Ans) When we increase the distance of an object from the eye, the focal length of eye lens is changed due to accommodating power of the eye so as to keep image distance constant. This happens in a normal eye, because the image distance in the eye is fixed and equal to the distance of retina from the eye lens.

Q) Why does the sky appear dark instead of blue to an astronaut?

Ans) This is because at such huge heights of the astronaut, there is nothing to scatter the sunlight. Therefore, the sky appears dark.