The Human Eye and the Colourful World

CHAPTER 11

EXAM DRILL

ANSWERS

1. When the image is formed on retina it remains there for 1/16th of a second, this property of eye is called persistence of vision.

OR

Yes, as size of atom/molecule is much less than wavelength of light.

2. For distance of distinct vision for a young adult with normal vision is infinity.

3. The angle between the two rectangular surface of a prism is called angle of prism.

4. Cornea : It is a transparent bulge on the front surface of eyeball which refracts most of the light rays entering the eye.

5. The lens which can correct the vision of such a person suffering from both myopia and hypermetropia is a bifocal lens.

6. The broad wavelength range of visible spectrum is 4000-8000 Å.

OR

When we enter a cinema hall, we can't see properly for a short time. This is because adjustment of size of the pupil takes some times.

7. **(a) :** On passing through a prism red colour deviates the least while the violet colour deviates the most.

8. **(b) :** When ciliary muscles expands, the focal length of the eye-lens increases.

9. **(c) :** Violet and blue lights get scattered more than lights of all other colours by the atmosphere.

OR

(d) : Scattering represents basically change in the direction of light.

10. **(c) :** Different colours of white light in vacuum/air move with the same speed.

11. **(b) :** It happens due to accommodation of eye.

OR

(a) : Figure (I) correctly indicates the path of light through prism.

12. (i) Tyndall effect.

(ii) White colour of clouds.

OR

The phenomenon of atmospheric refraction of light caused by earth's atmosphere due to the variation in optical densities of air layers.

13. Iris is a dark muscular diaphragm that controls the size of the pupil.

14. **(c) :** The red colour deviates the least while passing through a glass prism.

15. **(c) :** In myopic eye due to the increased converging power of eye lens, the image of a far off object is formed in front of the retina. Myopia can be corrected by using concave lens of suitable focal length.

16. **(d) :** Higher the refractive index of the prism material, greater is the angle of deviation.

17. **(i)** **(b) :** For a normal eye, value of least distance of distinct vision is 25 cm.

(ii) **(c) :** For a normal eye, far point lies at infinity.

(iii) **(c) :** The eye lens is a convex lens or converging lens.

(iv) **(a) :** Ciliary muscles.

(v) **(d) :** Rods and cones.

18. **(i)** **(b)**

(ii) **(b)**

(iii) **(a) :** The deviation is maximum for violet and minimum for red, so option (a) is correct.

(iv) **(a) :** The red light has a single wavelength and when enters a prism, it will not split into other different colours.

(v) **(b) :** The boundaries of colours in the spectrum produced by prism are not sharp, so the spectrum is impure.

19. **(i)** **(b) :** Light is scattered by the air molecules present in atmosphere.

(ii) **(c) :** Scattering of a wave of light is only possible when the diameter of particle on which it is incident is bigger than its wavelength.

(iii) **(c) :** Due to the more scattering of blue colour by molecules of air.

(iv) **(a) :** Light with shortest wavelength scatter first as there are no particles in upper atmosphere which could scatter green, yellow, orange or red light.

(v) (c) : Scattering is least but velocity of red light is more.

20. (i) (a) : The angle between the two refracting surfaces of a prism is called angle of prism.

(ii) (b) : The angle between the incident ray and the emergent ray is called angle of deviation.

(iii) (d) : As the ray of light enters from rarer medium (air) to denser medium (glass), the angle of incidence is more than angle of refraction.

(iv) (c) : More be the refractive index, more be the angle of deviation and it also depends on the refractive index of prism.

(v) (c) : The refraction of light takes place through rectangular surfaces.

21. The ability of the eye lens to adjust its focal length is called power of accommodation.

The ciliary muscles modifies the curvature to some extent. The change in the curvature of the eye lens can thus change its focal length. When the ciliary muscles contract, the lens becomes thick and its focal length decreases, thus enables us to see nearby objects clearly.

OR

No, a person may have normal ability of accommodation and yet he may be myopic or hypermetropic.

In fact, myopia arises when length of eye ball (from front to back) gets elongated and hypermetropia arises when length of eye ball gets shortened.

However, when eye ball has normal length, but the eye-lens losses partially its power of accommodation, the defect is called presbyopia.

22. (a) Light suffers two total internal reflections in the formation of secondary rainbow. So more of light intensity is absorbed.

(b) The position of violet colour in the rainbow is at the bottom.

23. Here, distance of near point, $x' = 75$ cm, distance of book, $d = 25$ cm, $f = ?$

As $f = \dfrac{x'd}{x'-d} \Rightarrow \dfrac{75\times25}{75-25} = \dfrac{75\times25}{50} = 37.5$ cm

Thus, $P = \dfrac{100}{f} = \dfrac{100}{37.5} = 2.66$ D.

As f is positive, the corrective lens is convex.

OR

Scattering is the phenomenon of bouncing off of electromagnetic radiation by atom/molecules of the medium through which they are travelling.

According to Rayleigh, intensity of scattered light (I_s) varies inversely as the fourth power of wavelength (λ) of incident light, *i.e.*, $I_s \propto \dfrac{1}{\lambda^4}$.

The essential condition is that size of scatterer must be much smaller than the wavelength of light incident.

24. This defect is called Astigmatism. It arises because curvature of the cornea plus eye-lens refracting system is not the same in different planes. As vertical lines are seen distinctly the curvature in the vertical plane is enough, but in the horizontal plane, curvature is insufficient.

This defect is removed by using a cylindrical lens with its axis along the vertical.

25. For the person to see the object at near point (25 cm), the image should be formed at 50 cm by the corrective lens being used. The image will then act as an object and the final image will be formed at retina. We know that for near point defect, the corrective lens is convex lens.

For corrective lens, $u = -25$ cm, $v = -50$ cm, $f = ?$

Using $\dfrac{1}{v} - \dfrac{1}{u} = \dfrac{1}{f}$ we get $\dfrac{1}{-50} - \dfrac{1}{-25} = \dfrac{1}{f}$

$\therefore \quad \dfrac{1}{f} = -\dfrac{1}{50} + \dfrac{1}{25} = \dfrac{-1+2}{50} = \dfrac{1}{50} \Rightarrow f = 50$ cm

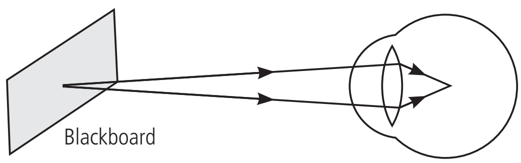
$\Rightarrow \quad P = \dfrac{1}{50}$ cm^{-1}

$\therefore \quad P = \dfrac{100}{50}$ D $= 2$ D

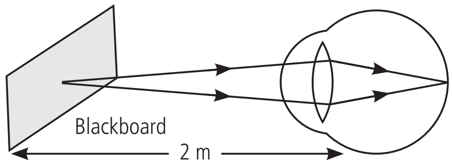
26. The part of the human eye that controls the amount of light entering into it is pupil. When a bright light enters the eye then most of the refraction for the light rays entering the eye occurs at the outer surface of the cornea. Then, the crystalline lens merely provides the finer adjustment of focal length required to focus object at different distances on the retina. The pupil regulates and controls the amount of light entering the eye. At retina, the light-sensitive cells get activated upon illumination and generate electric signals. These signals are sent to the brain via the optic nerves. The brain interprets these signals and finally, processes the information so that we perceive objects as they are.

27. The student can not see the far object clearly and is therefore, suffering from myopia.

Student sitting at the last desk cannot see the writing on the blackboard distinctly because the rays are converged before retina.

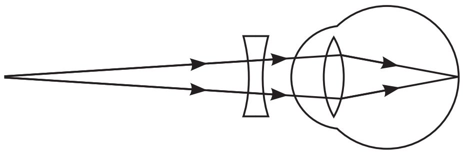


When he sits comparatively near the blackboard (at a distance of 2 m), he is able to see the writing because the rays are converging on retina. Due to myopia the far point of the student is 2 m.



OR

On using concave lens the defect is removed as shown in the diagram.



28. Three common defects of vision are

(i) Myopia

(ii) Hypermetropia

(iii) Presbyopia

Myopia can be caused due to following reasons.

(a) Elongation of eyeball.

(b) Excessive curvature of eye lens.

Hypermetropia can be caused due to following reasons.

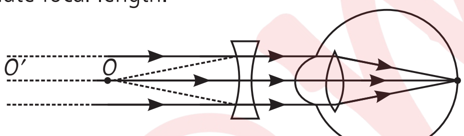
(a) Shortening of eyeball.

(b) Focal length of eye lens becomes too long.

Presbyopia is caused due to gradual weakening of ciliary muscles and diminishing flexibility of eye lens due to ageing.

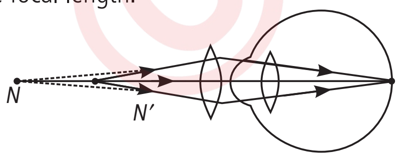
Correction of these defects:

(i) Myopia can be corrected by using concave lens of appropriate focal length.



Correction of myopia

(ii) Hypermetropia can be corrected by using convex lens of appropriate focal length.



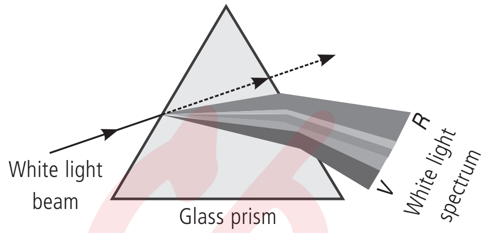
Correction for hypermetropic eye

(iii) Presbyopia can be corrected by using convex on bifocal lens.

29. Speed of colour in a medium depends upon its wavelength. All the colours have different wavelength. The red colour has the longest and violet colour has the least wavelength. Therefore, red colour has the highest speed in the glass prism and the violet colour has the lowest speed in the glass prism. Hence, all colours of white light are refracted by different amount while passing through the glass prism. Therefore, all the colours have different angles of deviations.

30. Splitting of white light into its seven constituent colours due to refraction is known as dispersion of white light.

Cause of dispersion : When a beam of white light enters a prism, it gets refracted and splits into seven constituent colours. The splitting of the light ray occurs due to the different bending angle of each colour having different wavelength. Thus, each colour of light when passing through the prism bends at different angles with respect to the incident beam, which gives rise to a colour spectrum.



Dispersion of white light by the glass prism

31. (a) For a normal eye, the near point is at 25 cm and the far point is at infinity from the eye. The given person cannot see object clearly either closer to the eye or far away from the eye. So, he is suffering from both myopia and hypermetropia.

(b) A bi-focal lens consisting of a concave lens and convex lens of suitable focal lengths will be required to correct the defects and to increase his range or vision from 25 cm to infinity. In a bi-focal lens, upper portion is concave which corrects distant vision and lower portion is convex which corrects near vision.

32. (a) As here far point is 5 m while for normal eye it is ∞,

$u = -\infty$ and $v = -5$ m

So, $\frac{1}{-5} - \frac{1}{-\infty} = \frac{1}{f} = P$ *i.e.*, $P = -0.2$ D

(b) If the object is at a distance of 2 m

$$\frac{1}{v} + \frac{1}{2} = \frac{1}{-5} \quad i.e., \ \frac{1}{v} = \frac{1}{-5} - \frac{1}{2}$$

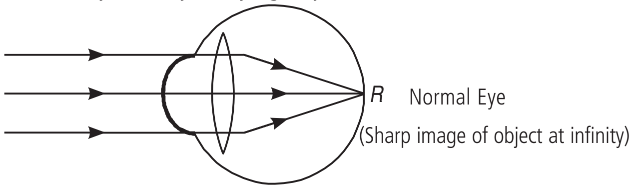
$$i.e., \ \frac{1}{v} = -\frac{7}{10} \quad \text{or} \ v = -\frac{10}{7} = -1.43 \text{ m}$$

i.e., the virtual image of object which is at 2 m will be formed at a distance of 1.43 m from the lens on the same side.

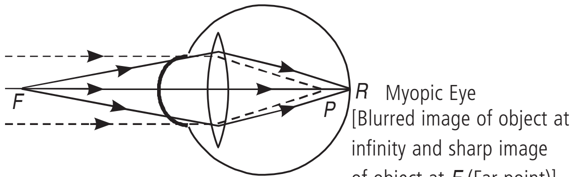
33. Myopia or short sightedness is that defect of human eye by virtue of which a person can see clearly the objects lying at short distances from it. But the far off objects can not be seen clearly by the myopic eye.

Myopic person can not see distinctly the objects lying beyond a particular distance. This is as if the far point of a myopic person has shifted from infinity at some particular distance from the eye.

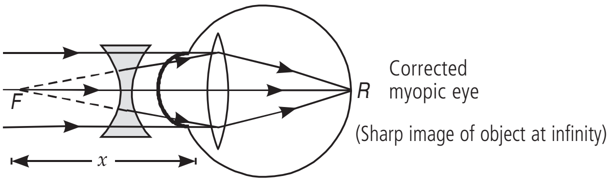
In figure (a), we have shown a normal eye, in which parallel rays from infinity are focussed on the retina. Figure (b), shows a myopic eye, in which parallel rays from infinity are focussed at a point *P* in front of the retina. That is why distant objects are not seen clearly, by the myopic eye. In the same figure, we have shown that the rays from a point *F* are focussed on the retina of the myopic eye. It means that far point of myopic eye has shifted from infinity to *F*, and the myopic person can not see clearly the objects lying beyond *F*.



(a)



(b)



(c)

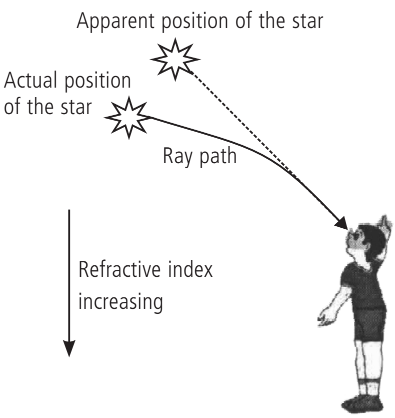
The two possible causes of this defect are :

(i) Excessive curvature of eye lens

(ii) Elongation of eye ball.

To correct a myopic eye, the person has to wear spectacles with a concave lens of suitable focal length or power.

34. Due to atmospheric refraction, position of star visible from sun is slightly different from its actual position. This apparent position of the star is not stationary, but keeps on changing with change in physical condition on earth's atmosphere. Since the stars are very distant, they are approximately point-sized sources of light. As the path of rays 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 the star sometimes appears brighter, and at some other time, fainter, which is the twinkling effect.



OR

(a) It is the defect of eye in which an old person can not see nearby objects comfortably and distinctly due to the loss of power of accommodation.

(b) The near point of an elderly person = 150 cm from the eye.

Hence, $v = -150$ cm, $u = -25$ cm

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{-1}{150} + \frac{1}{25} = \frac{-1+6}{150} = \frac{5}{150} = \frac{1}{30}$$

$\therefore$ $f = 30$ cm or 0.30 m

(c) Power of the lens $= \frac{1}{f} = \frac{1}{0.30\text{ m}} = +\,3.3\text{ D}$

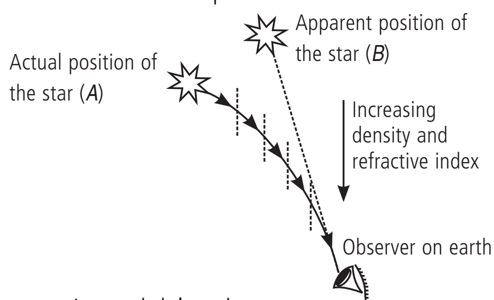
35. Atmospheric refraction is the phenomenon of bending of light on passing through earth's atmosphere.

As we move above the surface of earth, density of air goes on decreasing. Therefore, upper layers of earth's atmosphere are rarer compared to the lower layers of earth's atmosphere. Further, local conditions like temperature, etc. also affect the optical density of earth's atmosphere. Light coming from stars and entering earth's atmosphere passes from rarer to denser layers. Therefore, it suffers multiple refractions before reaching the surface of the earth. This is called atmospheric refraction.

Some of the phenomena based on atmospheric refraction and total internal reflection of light are discussed here briefly.

Stars seem higher than they actually are :

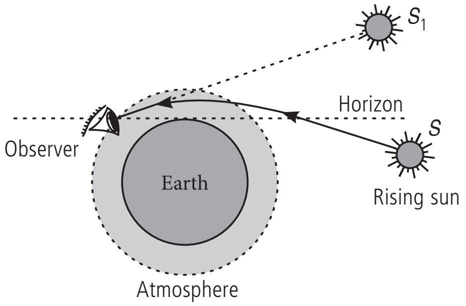
Stars are independent source of light, situated very far away from earth. Light from a star travels first in vacuum and then enters into earth's atmosphere. As optical density of air increases towards the surface of earth, therefore, light from the star travels from rarer to denser layers, bending every time towards normal. On producing the final refracted ray backwards as shown in figure, the apparent star position *B* is higher than the actual star position *A*.



Advance sunrise and delayed sunset :

The sun appears to rise above horizon, two minutes before it actually is above horizon. This is called advanced sunrise and can be explained in terms of atmospheric refraction.

As we move above the surface of earth, density of air goes on decreasing. Light from sun on entering earth's atmosphere passes from rarer to denser layers, bending towards normal everytime. The sun *S*, which is still below horizon appears to rise to S_1 just above the horizon, as shown in figure. The difference in time involved is 2 minutes, ***i.e.***, the sun appears to rise 2 minutes earlier.



The sun appears oval (or flattened) at sunrise and sunset, but appears circular at noon. This too can be explained in terms of atmospheric refraction.

At sunrise and sunset, the sun is near the horizon. The rays of light from the upper part and lower part of the periphery of the sun bend unequally on travelling through earth's atmosphere. That is why the sun appears oval of flattened at the time of sunrise and sunset.

At noon, the sun is overheat. The rays of light from the sun enter earth's atmosphere normally. Therefore, they suffer no refraction or bending on passing through earth's atmosphere. Hence the sun appears circular at noon.

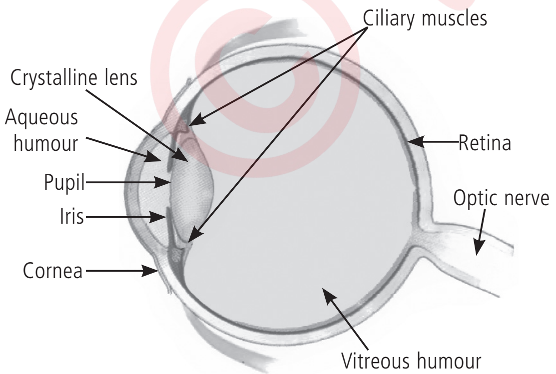
OR

Construction :

Human eye is almost spherical in shape having a diameter of approximately 2.3 cm.

The front portion which sharply bulges out is covered with a transparent and tough membrane called cornea.

Behind the cornea is a region which contains a liquid called aqueous humour. Next to it is present a circular coloured diaphragm called iris with a hole in its centre called pupil.



Behind iris is a crystalline convex lens held in its place by ciliary muscles. After the lens, the eye is composed of vitreous humour. The image is formed on a delicate innermost light-sensitive membrane of the eye called retina. Retina contains a large number of sensitive cells called rods and cones. The retina has two important region, yellow spot and blind spot. A blind spot where the optic nerve enters the eye. It is called blind spot because, it is totally insensitive to light.

Working of the eye :

The light rays entering the eye are focussed on the retina by the eye lens. A real and inverted image of the object is produced on the retina. It is important to note that most of the refraction of light entering the eye is done by the cornea. Only the final focussing is done by the eye lens. The retina converts light energy into electrical energy. The electrical signals produced by the retina reaches the brain by optic nerves. The brain interprets the electrical signals and produces sensation of vision.

36. **(a)** When the object is at infinity, the image forms at the focus of the lens ($v = f$). Hence, the focal length in this case is 2.5 cm. Thus the power is

$$P_1 = \frac{1}{f} = \frac{1}{2.5 \times 10^{-2}\,\text{m}} = 40\text{ D}$$

(b) In this case, the object is at 25 cm from the eye lens, and the image is formed at 2.5 cm from the eye lens.

So, $u = -25$ cm, $v = 2.5$ cm. Then,

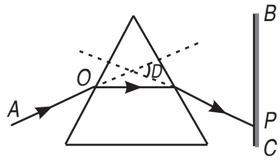
$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{1}{2.5\text{cm}} + \frac{1}{25\text{cm}}$$

$$\therefore \quad P_2 = \frac{100}{2.5\,\text{m}} + \frac{100}{25\text{m}} = 44\text{ m}^{-1} = 44\text{ D}$$

The maximum variation in the power is, 44 D – 40 D = 4 D

OR

(a) Here, in the figure, $\angle D$ is the angle of deviation of the given monochromatic light by the glass prism.



(b) If *AO* were a ray of white light, then

(i) On screen *BC*, a spectrum will be observe consisting of seven colours arranged from bottom to top as follows :

Violet, Indigo, Blue, Green, Yellow, Orange, Red (VIBGYOR).

(ii) This phenomenon is known as dispersion of light.

(iii) The cause of dispersion is that different colours of white light having different wavelength deviate through different angles on passing through a glass prism.

(iv) It proves that a white light consists of seven colours and lower the wavelength higher will be the deviation of light.