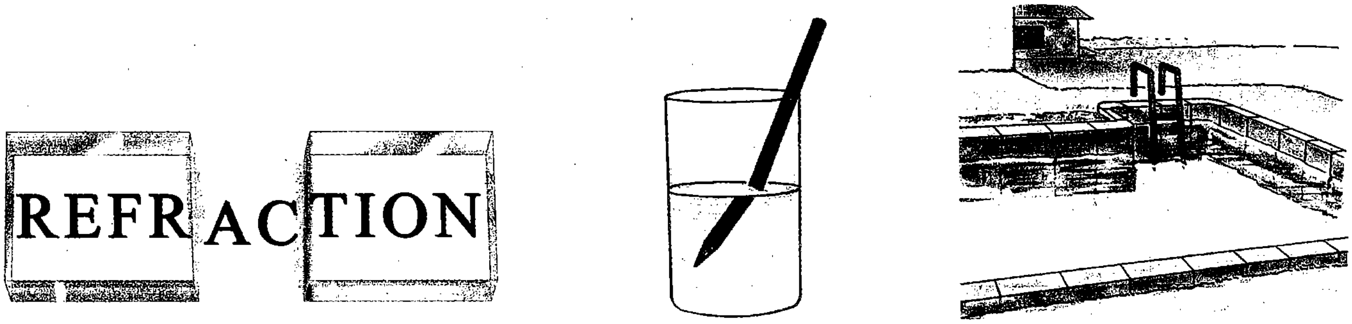
Light

2

LEARNING OUTCOMES

- Refraction of light: laws and refractive index
- Refraction through a glass slab and a glass prism
- Dispersion through a glass prism
- Lenses: convex and concave
- Optical instruments
- Defects of the eye

Look at the following figures. You might have observed such images in your day-to-day life.

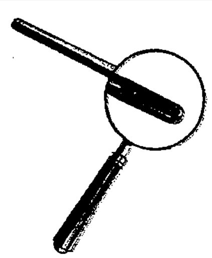


(a) (b) (c)

Can you tell what you notice in the above figures? In (a) you see that the letters below the glass slabs appear to be raised. In (b) you see that the part of the pencil that is dipped in water appears to be bent. Similarly, in (c) you see that the swimming pool appears shallower than its actual depth. Can you tell how all this happens?

This is because of a particular property of light rays known as *refraction*.

In this chapter you will study what refraction is, how it is caused, what are its effects, and many more things.



Is the pen that is seen through the lens actually broken or appears to be broken? You will get the answer when you read this chapter.

REFRACTION

You might have studied in earlier classes that light travels in straight lines. However, *when a ray of light travels from one transparent medium to another, such as from water to air, or air to glass (and vice versa), it undergoes a change in its direction at the boundary between the two mediums and bends. This phenomenon is called **refraction**.*

Before we learn what causes the light ray to bend, let us see how the speed of light is different in different mediums.

FACT FILE

Optical density vs. physical density!
The optical density that you study here is different from physical density. The physical density of a material refers to the mass/volume ratio of that material. But, optical density tells you how fast or slow a light ray can pass through the material.

Speed of light and optical density of a medium

You know that light travels with a speed of 3×10^8 m/s in air. However, its speed in water is 2.25×10^8 m/s and in glass is 1.8×10^8 m/s. Thus, we see that the speed of light is different in different mediums and depends on the properties of the medium. When light slows down in a medium, we say it is an *optically denser* medium. From the speed of light in different mediums, we can say that *water is optically denser than air*, and *glass is optically denser than water*. In other words, we say that water is optically rarer than glass, and air is optically rarer than water and glass.

The cause of bending of a light ray is due to the change in the speed of light in different materials/mediums. But the question that arises is why should a light ray bend at the boundary of the two mediums just because it cannot maintain the same speed? What happens if you roll your toy car gently from a smooth bitumen road to a grass lawn? At the boundary of the two surfaces, you will find that the wheel gets deflected from the path it follows (see Fig. 2.1). Thus, bending is a consequence of change in speed. Light rays also behave in the same way. By bending, light rays reach faster, obeying the *principle of least time*, which states that out of all the available paths, light takes the path that requires the shortest time.

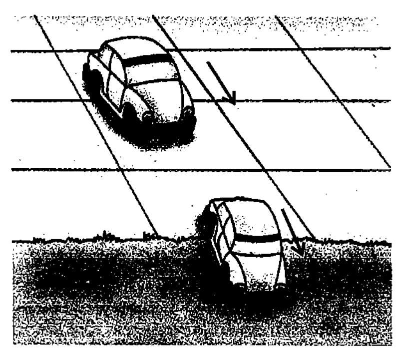


Fig. 2.1 *Toy car rolling from a road to a grass lawn*

Having understood this, let us understand why the pencil, when dipped in water, appears to be bent. Look at Figure 2.2. We have learnt in earlier classes that when light reflected from objects falls on our eyes, we see the objects. When a pencil is put in a beaker of water, light rays from the bottom of the pencil travel first through water (which is optically denser) and then through air to reach our eyes. When the light rays strike the boundary of the two mediums, they bend in such a way that they reach our eyes faster. As a result, the eyes feel as if the light rays are coming from X and not from Y. Hence, the pencil appears to be bent.

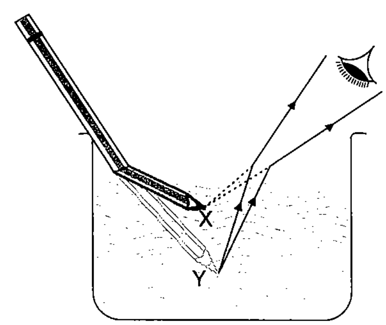


Fig. 2.2 *Pencil appears to be bent*

ACTIVITY

Aim: To prove that light rays bend as they travel from one medium to another.

Materials required: A beaker, water, and a coin.

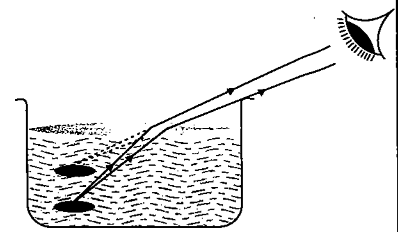
Procedure: 1. Take an empty beaker and put a coin in it.

2. Now step away from the beaker till the time the coin becomes invisible to you.

3. Stop at the place where you do not see the coin and ask your friend to slowly pour water into the beaker.

4. You will see that at some level of water the coin starts becoming visible to you.

Conclusion: When you pour water into the beaker, the light rays from the coin travel through water and then through air. Hence, due to change of the medium, the rays bend and reach your eyes. Thus, the coin seems to be raised.



Rules regarding refraction

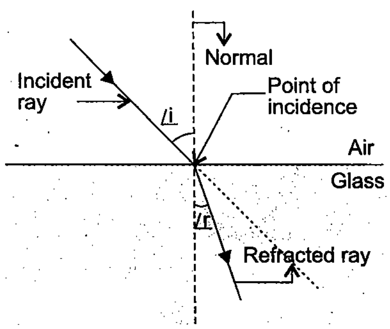
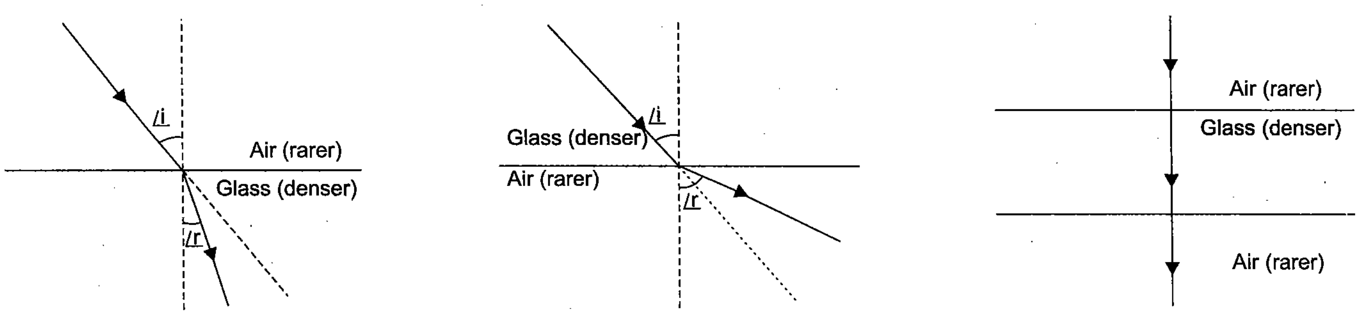


***Fig. 2.3** Refraction of a ray of light*

Figure 2.3 shows a single light ray travelling from air to glass, i.e, from a rarer to a denser medium. The point where the ray hits the boundary between the two mediums is called the *point of incidence*. A perpendicular drawn to the air–glass interface at the point of incidence is called the *normal*. The ray of light in the first medium is called the *incident ray*, and this ray of light after changing its direction (or after refraction) is called the *refracted ray*. The angle between the incident ray and the normal is called the *angle of incidence* ($\angle i$), and the angle between the refracted ray and the normal is called the *angle of refraction* ($\angle r$).

Now look at the following three figures. Do you notice any difference in the path of the light ray?



(a) (b) (c)

***Fig. 2.4** Rules regarding the refraction of light*

The three figures given above state the three rules regarding the refraction of light:

(i) When a ray of light travels obliquely from a rarer medium to a denser medium, it bends towards the normal [Fig. 2.4 (a)].

(ii) When a ray of light travels obliquely from a denser medium to a rarer medium, it bends away from the normal [Fig. 2.4 (b)].

(iii) When a ray of light travels perpendicular to the surface of separation of the two mediums, it goes without any deviation [Fig. 2.4 (c)].

We know that the speed of light is lesser in glass than in air because glass is optically denser than air. In (a) we see that the angle of refraction is smaller than the angle of incidence. Thus, we conclude that *when the angle of refraction is less, the speed of light in that medium is also less*. In (b) you can see that the angle of refraction is more, which tells you that the speed of light in that medium (air) is also more than that in the first medium (which is glass).

Laws of refraction

The laws of refraction state that

(i) the incident ray, the normal to the point of incidence, and the refracted ray all lie in the same plane; and

(ii) the ratio of the sine of angle of incidence to the sine of angle of refraction is a constant known as the *refractive index* of the medium. You will learn about this law, called Snell's law, in higher classes.

$$n = \frac{\sin i}{\sin r}$$

Refractive index

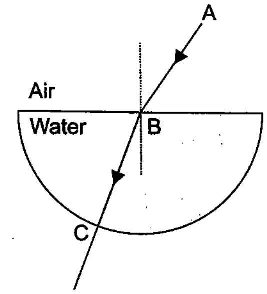
We know that refraction results from a change in speed when light passes from one medium to another.

*The ratio of the speed of light in vacuum to the speed of light in another medium is termed as the **refractive index** of that medium.* This tells you the amount by which the speed of light gets reduced, and the amount by which the light ray is refracted or bent for a given angle of incidence.

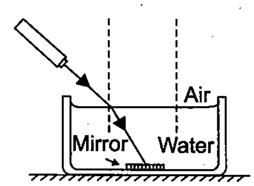
The refractive index is denoted by the letter ***n***. Also, since it is a ratio, it has no unit.

$$n = \frac{\text{Speed of light in vacuum } (c)}{\text{Speed of light in the medium } (v)}$$

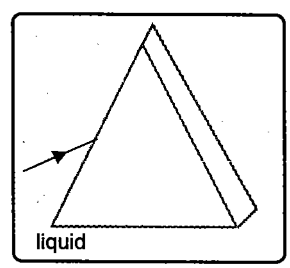
THINK QUEST



Can you tell why there is no refraction at C? *(Hint: 'Normal' at C is BC itself. Hence, ∠i=0.)*

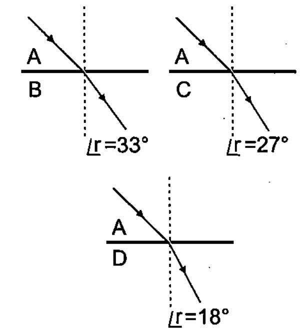


Draw reflected ray from the mirror and refracted ray into the air. *(Hint: apply laws of reflection and rules of refraction.)*



If a glass prism is kept in a liquid of the same refractive index as that of glass, will the ray of light bend? Complete the path of the ray of light. *(Hint: ray bends only if the refractive indices of the two mediums are different.)*

THINK QUEST



Looking at the angle of refraction in the figures given, which medium will have the maximum value of refractive index and in which medium will the speed of light be the least? (*Hint: when ∠r is more, speed of light is more, and refractive index is less.*)

***Table 2.1** Refractive indices of some materials*

Material	*Refractive index*
Air	1.0029
Ice	1.31
Water	1.33
Alcohol	1.36
Glass	1.50
Benzene	1.50
Diamond	2.42

Note that the speed of light in air and in vacuum is almost equal; therefore, for numerical purposes we take the speed of light in vacuum as that in air. Table 2.1 shows the refractive index of some materials.

SOLVED EXAMPLE

1. The speed of light in air is 3×10^8 m/s. Find its speed in diamond if the refractive index of diamond is 2.42.

We know that:

$$n = \frac{\text{Speed of light in air/vacuum } (c)}{\text{Speed of light in the medium } (v)}$$

Therefore, $2.42 = \frac{3 \times 10^8}{v}$, $v = \frac{3 \times 10^8}{2.42} = 1.24 \times 10^8$ m/s

Thus, speed of light in diamond has reduced considerably.

The refractive index tells you how much light has slowed down in that medium with respect to air. Table 2.1 shows the refractive indices of some materials. You will notice that *the speed of light in that medium is low whose refractive index is high*. Hence, the angle of refraction will also be less than the angle of incidence. If the angle of incidence is the same as the angle of refraction, the light ray travels straight without any bending.

REFRACTION THROUGH A GLASS SLAB

In a glass slab, there are two parallel interfaces through which a light ray passes. The first interface is the air–glass interface, and the second interface is the glass–air interface.

In order to understand refraction through a glass slab, let us first perform an activity.

ACTIVITY

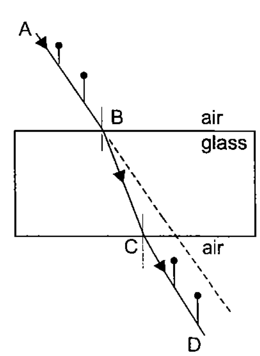
Aim: To trace a ray of light through a glass slab.

Materials required: A glass slab, a thick sheet of paper, a pencil, and few thumb pins.

Procedure: 1. Keep the glass slab on a thick white sheet of paper and draw its outline. Now remove the glass slab. And draw a line AB on one side of the block.

2. Fix two thumb pins on the line, one behind the other (as shown in the figure). Now place the glass block over its outline again and look at the pins through the glass block from the opposite side.

3. By looking at the images of the two pins, place two pins on the other side such that all the four pins are in a straight line. Now remove the



glass slab again and draw a line CD passing through the two pins you placed at the images of the previous two pins. Join AB to CD.	**Conclusion:** You will find that the light ray has bent at the two interfaces, first at the air–glass interface and second at the glass–air interface.

Now let us study the diagram shown in the activity above to understand how the path of a light ray changes when it passes through a glass slab. Look at Figure 2.5.

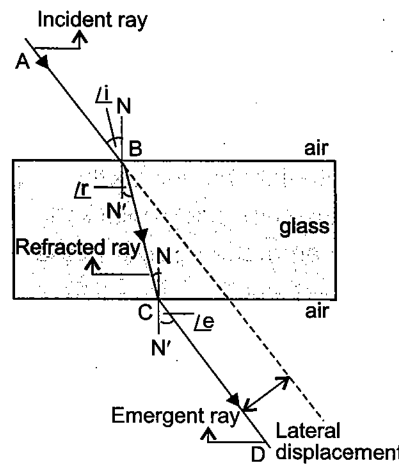


***Fig. 2.5** Refraction of a light ray through a glass slab*

The light ray AB (incident ray) on reaching the air–glass interface undergoes refraction and bends. Notice that since here the light ray is moving from a rarer to a denser medium, it bends towards the normal and follows the path BC inside the glass slab. Ray BC is the refracted ray. Here, you find that the angle of refraction ($\angle r$) is smaller than the angle of incidence ($\angle i$). The refracted ray BC on reaching the glass–air interface again undergoes refraction. This time it bends away from the normal as it moves from a denser to a rarer medium and emerges from the glass slab as CD. The ray CD is called the *emergent ray*, and the angle this ray makes with the normal is called the *angle of emergence* ($\angle e$).

When the incident ray is produced further (represented by the dotted line), it is found to be parallel to the emergent ray. The perpendicular distance between these two rays is called *lateral displacement*. Thus, any object placed at A will be displaced sideways to D as a result of refraction through a glass slab.

REFRACTION THROUGH A PRISM

A prism is a piece of glass or any other transparent material, which is bounded by two triangular surfaces and three rectangular surfaces. The rectangular surfaces are called the *refracting surfaces*. The angle between any two refracting surfaces is called the *angle of prism*. Figure 2.6 shows an equilateral prism.

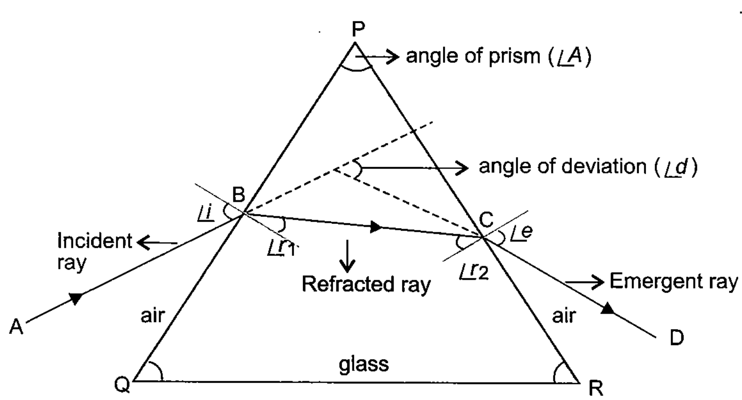


***Fig. 2.6** Refraction through a prism*

FACT FILE

Principle of reversibility
According to the principle of reversibility of light, the path of a light ray is reversible. Hence, if a ray of light travels from air to glass to air as AB, BC and then CD, the ray follows the path DC to CB to BA if it is reversed.

FACT FILE

Why does a parallel-sided glass slab not disperse light just like a glass prism? Actually, a parallel-sided glass slab also disperses white light but inside the glass slab, each coloured ray emerges parallel to the others and to the original ray. The lens in our eye focuses all the parallel-coloured light onto one spot on the retina of the eye; thus, we see only white light coming out of the slab.

Consider a ray AB incident on the face PQ of the prism. Since this ray undergoes refraction while passing from a rarer medium (air) to a denser medium (glass), it bends towards the normal and follows the path BC inside the prism. Here, $\angle r_1$ is the angle of refraction. The ray BC is called the *refracted ray*. This refracted ray again undergoes refraction at the glass–air interface, and this time it bends away from the normal (because now it moves from a denser medium to a rarer medium). The final ray that comes out of the prism moves along CD and is called the *emergent ray*. The angle between the emergent ray and the normal is called the *angle of emergence* ($\angle e$).

You can see in the figure that the incident ray, which was travelling along AB has been turned along CD such that the ray gets deviated through an angle $\angle d$. This angle d is called the *angle of deviation*. It is the angle between the incident ray and the emergent ray and is formed by extending the ray AB forward and CD backward.

If we measure the angle of incidence, angle of emergence, the angle of the prism, and the angle of deviation, it has been found that $\angle i + \angle e = \angle A + \angle d$, where $\angle A$ is the angle of the prism.

Dispersion of white light through a prism

What happens if, instead of a single light ray, a beam of white light is passed through a prism?

Isaac Newton found that when a beam of white light is passed through a glass prism, the white light breaks into its constituent colours, i.e., the colours of the rainbow (Fig. 2.7). *This phenomenon of splitting up of white light into its constituent colours is called **dispersion**.*

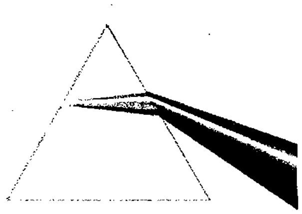


Fig. 2.7 Dispersion of white light through a prism

From this, Newton concluded that white light is a mixture of seven colours. The band of colours obtained on a screen on passing white light through a prism is called a *spectrum*. These bands together constitute the colours of the rainbow, violet, indigo, blue, green, yellow, orange, red (VIBGYOR).

Do you know why white light splits into seven colours when passing through a prism? Light of all colours travels at the same speed in vacuum. But in other transparent mediums, it travels with different speeds. We have already studied that change in the speed of light is the cause of refraction. When white light is incident on the prism, the different colours of light get refracted or deviated through different angles. In Figure 2.7, you can see that violet deviates the most, while red the least. Remember *blue bends better*.

What would happen if we put two prisms side by side and then make white light pass through them? Will the colours of the spectrum be split up more? No! If a combination of two prisms is made (one lying inverted with respect to the other), and white light is made to pass through both of them, we see that the first prism disperses white light into its seven constituent colours, and the second prism again combines those seven colours to form white light (Fig. 2.8).

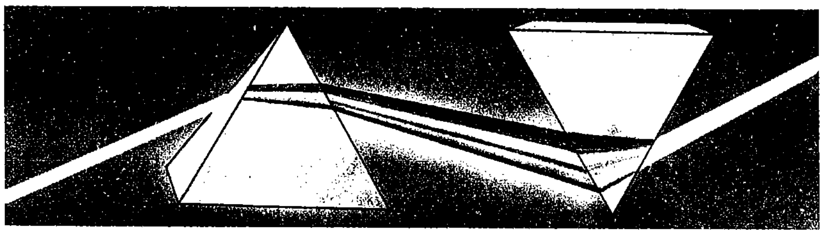


Fig. 2.8 *Recombination of rainbow colours into white light*

Note that when you join two prisms, as in Figure 2.8, you get parallel sides where the light enters and also where the light leaves. Hence, although the light disperses inside, when it finally emerges out it travels parallel to each other with the same speed, and our brain registers it as white light.

THINK QUEST

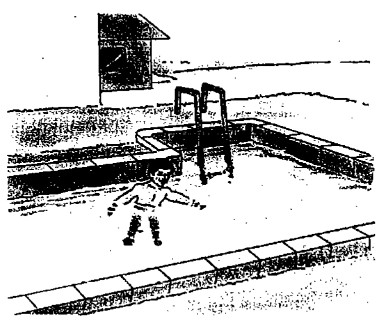
Suppose we have a prism which disperses white light into its seven colours. Now we place a slit screen in the path of the seven colours, so that only one colour, say red, is able to pass through the screen. This red beam is made to fall on another prism. Trace the path of the colour through the prism. What will happen to the colour of the beam when it emerges from the prism? (*Hint: red colour gets refracted and emerges as red colour.*)

Everyday effects of refraction

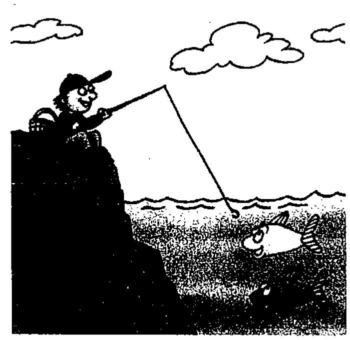
The figures below show some real-life examples of refraction of light.

Fruit appears to be bigger in a glass of water due to refraction.

Print appears to be raised when a glass block is placed over it.



A swimming pool appears shallower than its actual depth. A person's legs also appear shorter than the actual length when he is standing in a pool.



Due to refraction at the air–water interface, the path of the light is bent and the fish appears to be in a raised position where it actually is not. A visual distortion occurs and the hunter launches the spear at the location where the fish is thought to be and misses the fish.

FACT FILE

Have you ever marvelled at the colours of the rainbow?
A rainbow is the result of dispersion of sunlight by water droplets in the atmosphere. Sunlight which consists of VIBGYOR colours, on entering the water droplets gets refracted (or bent). In a large region of raindrops, the circular symmetry of the drops causes us to see the colours displayed in a circular band in the sky.

Twinkling of stars

Have you ever wondered how the stars in the sky twinkle?

The light from the stars reach our earth by travelling a great distance through space and then through the different layers of the atmosphere. We know that the density of the atmosphere decreases with increasing altitude.

Thus, when light from a star travels through different layers of the atmosphere, it bends constantly, and the star appears to change its position slightly and varies in brightness and colour.

Apparent position of the sun

Do you know that the sun is seen a few minutes before it actually rises above the horizon in the morning and a few minutes longer in the evening after it sets? The ray of light passing through different layers of the atmosphere undergoes refraction and bends, and the viewer views the sun at a higher position than it actually is. This is the reason why we see the sun a few minutes earlier than it actually rises (Fig. 2.9).

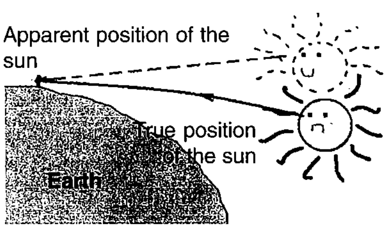


Fig. 2.9 *Apparent position of the sun at sunrise*

LENSES

We have seen how light behaves when it passes through plane interfaces, like a glass slab and a prism. Let us now study how light rays behave when they pass through curved interfaces like a lens.

*Any transparent medium which is bounded by atleast one curved surface is called a **lens**.* The common types of lenses are *convex lens* or *converging lens* and *concave lens* or *diverging lens*. See Figure 2.10.

In case of convex lens, the middle portion is thicker than the edges. However, in case of concave lens, the edges are thicker than the middle. These are called *plano-convex* or *plano-concave*, if they have only one curved surface. If both the surfaces are curved, they are called *bi-convex* or *bi-concave*.

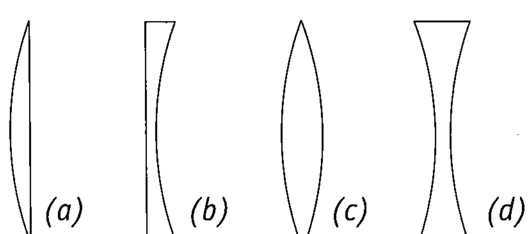
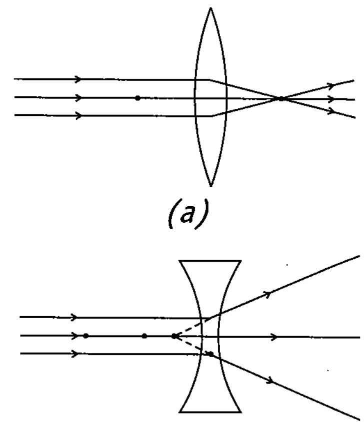


Fig. 2.10 *Types of lenses: (a) plano-convex; (b) plano-concave; (c) bi-convex; and (d) bi-concave*

A convex lens is called a *converging lens* because when parallel light rays fall on it, the light rays meet at one point after refraction through the lens. On the other hand, a concave lens is called a *diverging lens* because when parallel light rays pass through it, they diverge and seem to be coming from a single point in front of the lens. See Figure 2.11 (a) and (b).



(a) (b)

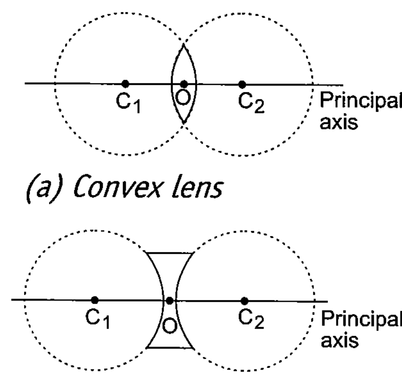
Fig. 2.11 *(a) Converging lens; and (b) Diverging lens*

Terms associated with lenses

Optic centre: is the geometric centre of the lens, where a line drawn through it horizontally meets the principal axis. See O in Figure 2.12 (a) and (b).

Centre of curvature: is the centre of the imaginary sphere of which the lens is a part. Since in bi-convex or bi-concave lens, there are two curved surfaces, they have two centres of curvature. In Figure 2.12, C_1 and C_2 are the centres of curvature.

Principal axis: is an imaginary line joining the centres of curvatures of the two spheres of which lens is a part. See Figure 2.12.



(a) Convex lens

(b) Concave lens

Fig. 2.12 *Optic centre, centre of curvature, and principal axis of convex and concave lens*

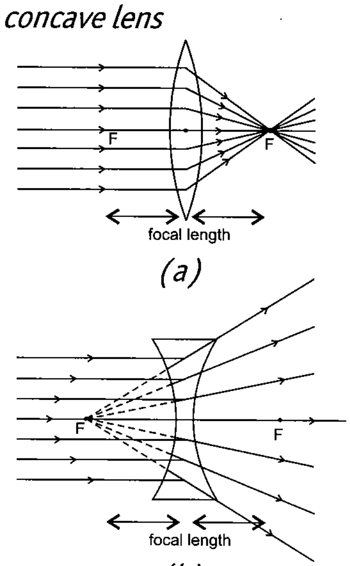
Principal focus of a convex lens (F): is a point on the principal axis where a parallel beam of light, travelling parallel to the principal axis, after refraction actually meet. See Figure 2.13 (a).

Principal focus of a concave lens (F): is a point on the principal axis of a concave lens where a parallel beam of light, travelling parallel to the principal axis, after refraction appears to meet. See Figure 2.13 (b).

Lenses have two focal points, one on each side. We can find the second focal point by reversing the direction of light, and the light then focuses at a point on the other side of the lens. It can be shown that the focal points are at the same distance from the centre of the lens if it is thin. A lens is considered to be thin if its thickness is very small in comparison to its focal length.

Focal length(f): is the distance between the principal focus and the optic centre of a lens.

Radius of curvature: is twice the focal length of any lens (2f).



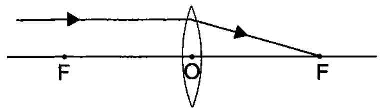
(a) (b)

Fig. 2.13 *Focus and focal length of convex and concave lens*

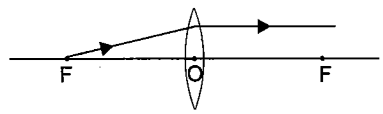
Ray diagrams using convex lens

The ray diagram technique that you used for curved mirrors in class 7 will help you to locate images formed by lenses.

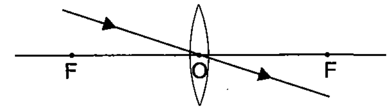
The rules that apply to a ray of light when it passes through a convex lens are:



Any ray of light travelling parallel to the principal axis, after refraction, passes through the principal focus.



Any ray of light passing through the principal focus, after refraction, travels parallel to the principal axis.



Any ray of light which passes through the optic centre of the lens remains undeviated and passes on without any change in the path.

Keeping the above rules in mind, let us see the different types of images produced in a convex lens, depending on the position of the object.

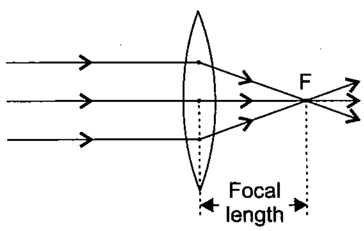


***Fig. 2.14** Object at infinity*

When object is at infinity

Here, infinity means a distance much greater than the focal length of the lens. Object (**O**) 'at infinity' means the object is very far from the lens. The rays from an object at infinity are always considered to be parallel. See Figure 2.14.

Image characteristics

- The image (**I**) is formed at the **principal focus (F)** of the lens.
- The image is **diminished** (very small).
- The image is **inverted**.
- It is a **real image**, i.e., if we place a screen at the focal point, an image of the object will be formed on it.

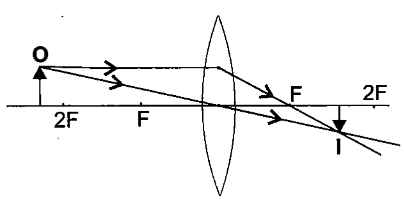


***Fig. 2.15** Object beyond 2F but not infinity*

When object is beyond 2F, but not infinity

2F means twice the focal length. See Figure 2.15.

Image characteristics

- The image is formed **between F and 2F** on the other side of the lens.
- The image is **diminished**.
- The image is **inverted**.
- It is a **real image**.

This arrangement is used in a *photographic camera*.

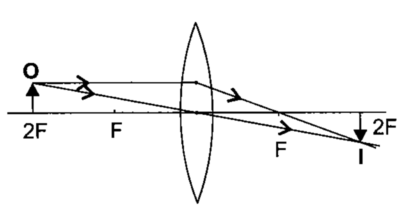


***Fig. 2.16** Object at 2F*

When object is at 2F

Image characteristics

- The image is formed **at 2F** (on the other side of the lens).
- The image is of the **same size** as the object (Fig. 2.16).

- The image is **inverted.**
- It is a **real image.**

This arrangement is used as *erecting lens in telescopes.*

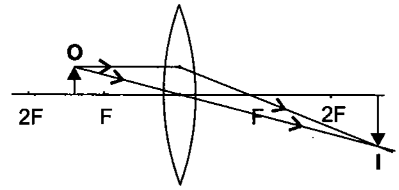


Fig. 2.17 Object anywhere between 2F and F

When object is anywhere between 2F and F

Image characteristics

- The image is formed **beyond 2F** on the other side of the lens.
- The image is **enlarged.**
- The image is **inverted.**
- It is a **real image** (Fig. 2.17).

This arrangement is used in *cinema projectors.*

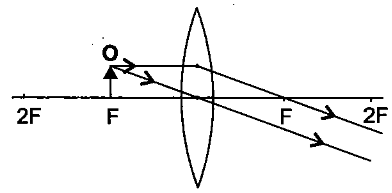


Fig. 2.18 Object at the principal focus

When object is at the principal focus (F)

Image characteristics

- The image is formed **at infinity** on the other side of the lens.
- The image is **enlarged.**
- The image is **inverted.**
- It is a **real image** (Fig. 2.18).

This arrangement is used in *search lights.*

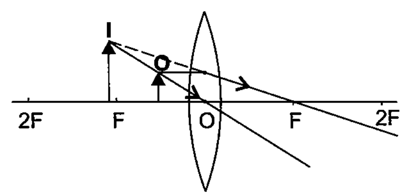


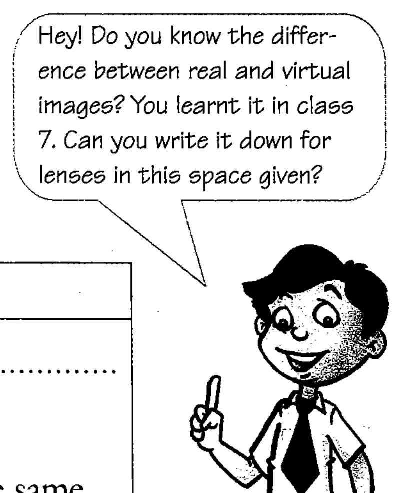
Fig. 2.19 Object anywhere between F and the optic centre

When object is anywhere between F and the optic centre

Image characteristics

- The image is formed **between F and 2F on the same side of the lens as the object.**
- The image is **highly enlarged.**
- The image is **erect.**
- It is a **virtual image,** i.e., this image cannot be formed on a screen. (Fig. 2.19).

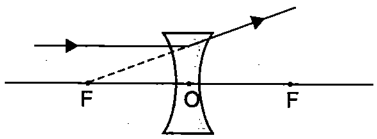
This arrangement is used in *simple microscopes.*



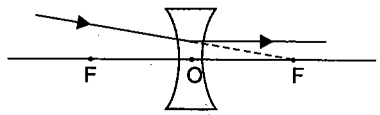
Real image	*Virtual image*
It can be obtained on a screen.	....
....	It is always erect.
....	The image is formed on the same
....	side of the lens as the object.
....	....

Ray diagrams using concave lens

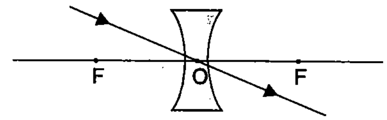
The following rules apply to a ray of light when it passes through a concave lens:



Any ray of light travelling parallel to the principal axis, of concave lens, after refraction, diverges out, but if produced backwards, it appears to meet at the principal focus.



Any ray of light appearing to meet the principal focus of a concave lens, after refraction, emerges parallel to the principal axis.



Any ray of light passing through the optic centre of a concave lens passes on undeviated.

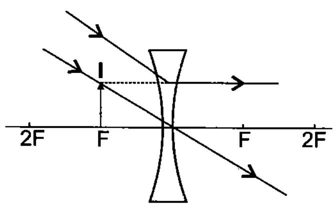


Fig. 2.20 *Object at infinity*

Let us now see the different types of images formed in a concave lens, depending on the position of the object.

When object is at infinity

Image characteristics

- The image is formed **at F on the same side of the lens** (as the object).
- The image is **highly diminished** and **erect.**
- It is a **virtual image** (Fig. 2.20).

This arrangement is used as *eye lens in Galileo telescopes.*

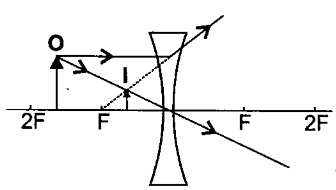


Fig. 2.21 *Object between the optic centre and infinity*

When the object is between the optic centre and infinity

Image characteristics

- The image is formed between **the optic centre and F** on the same side of the lens as the object.
- The image is **diminished** and **erect.**
- It is a **virtual image** (Fig. 2.21).

This arrangement is used to correct *short sightedness.*

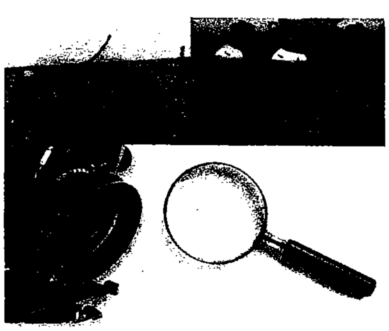


Fig. 2.22 *Some uses of lenses*

USES OF LENSES—OPTICAL INSTRUMENTS

Have you ever tried to look at very small things like a bacterium or distant objects like stars and planets? Can you see them with the naked eye? No! Because our eye cannot see such things. To view such things, we use *optical instruments* fitted with lenses, like a microscope and a telescope. Let us study them in detail.

Magnifying glass—simple microscope

A magnifying glass or a simple microscope is an optical device used to make things look bigger (Fig 2.23). It is used to examine very small objects, which cannot be clearly seen with the naked eye. It consists of a convex lens of small focal length and is fitted with a holder for our convenience. A highly enlarged image of the object is formed when the object is placed close to the lens (between F and the optic centre).

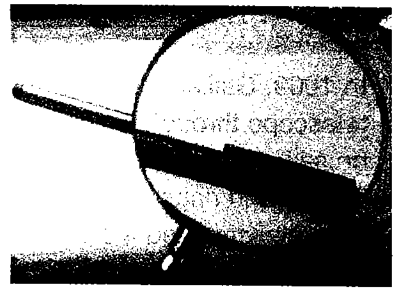


***Fig. 2.23** A magnifying glass*

Compound microscope

The simple microscope that we have just studied cannot be used to see very small objects, such as bacteria or viruses. For such very minute things, we use a compound microscope (Fig. 2.24). A compound microscope basically consists of two convex lenses: a *short-focus objective lens* (which is closer to the object) and a *long-focus eyepiece lens* (which is closer to our eye). Light is projected up through the specimen and the objective lens makes an enlarged image of the object. This image produced by the objective lens serves as an object for the eyepiece lens, which is adjusted manually to form a sharp enlarged image of this object. Here in Figure 2.25, AB is the object, A′B′ is the image formed by the objective lens, and A″B″ is the final image formed by the eyepiece lens.

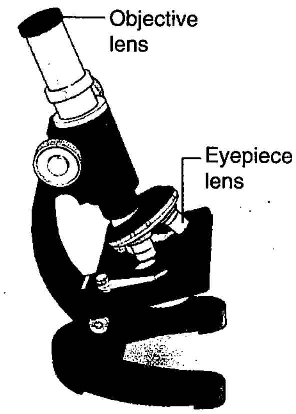
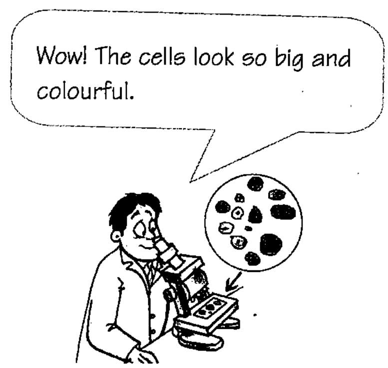


***Fig. 2.24** A compound microscope*



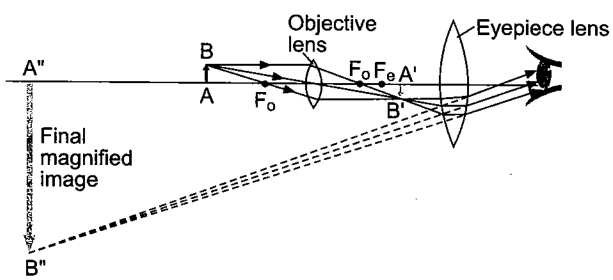


***Fig. 2.25** Image formed in a compound microscope*

Telescope

Do you know how heavenly bodies like the moon and the planets are viewed from the earth? Optical instruments used to view distant objects are called *telescopes.* Telescopes used to see heavenly bodies are called *astronomical telescopes,* and the ones used to see distant objects at ground level are called *terrestrial telescopes.*

An astronomical telescope consists of two convex lenses, a *long-focus objective lens* and a *short-focus eyepiece lens*. See Figure 2.27.

Rays from a point on a distant object such as a star, are nearly parallel on reaching the telescope. The objective lens forms a real,

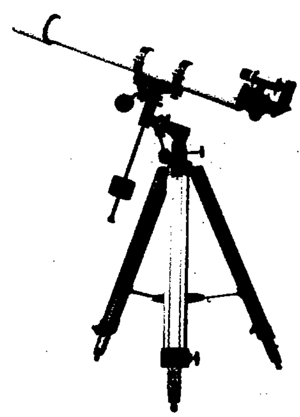


***Fig. 2.26** A telescope*

FACT FILE

In 1609, Galileo made a telescope through which he saw the satellites of Jupiter and rings of Saturn. The telescope led the way for great astronomical discoveries.

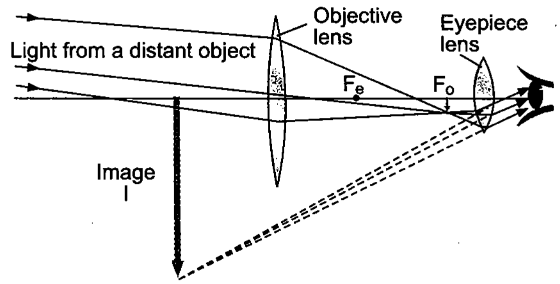
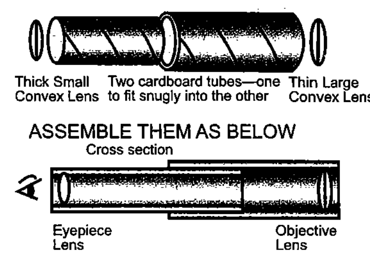


Fig. 2.27 Image formed in a telescope

inverted, and diminished image of the object at its principal focus F_o. The eyepiece lens acts as a magnifying glass treating this image as an object and forms its magnified, virtual image. The final image **I** is formed behind the objective lens.

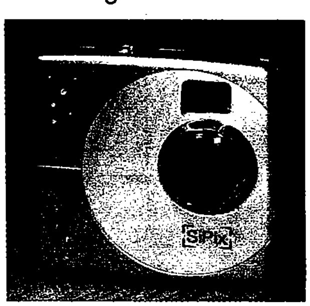
ACTIVITY

Aim: To make your own telescope.
Materials required: A cardboard tube, two convex lenses of different focal lengths, and tape to stick the lens.
Procedure: 1. Take the cardboard tube and fit a convex lens into its one end. This tube should be wide enough for another tube to fit in.
2. Take the narrower tube and insert a small convex lens into one end of the tube. This is the end that you will look through.
3. Push the narrow tube inside the wider tube, making sure that it slides smoothly in and out. Your telescope is now ready to use.
4. Hold it up and point to a distant object. Adjust the inner tube to get a clear image of the distant object.



TECH FILE

You might have heard of **digital cameras,** which are now being used very commonly. All digital cameras have a built-in computer, which stores images digitally or electronically rather than recording them on films.



Photographic camera

You might have used a camera to click photographs. Do you know how it works? It is based on the principle that when an object is placed between infinity and 2F of a convex lens then an inverted, diminished, and real image of the object is formed between F and 2F on the other side (see Fig. 2.15). In a camera the convex lens forms a real image on a film. The film contains chemicals that change on exposure to light. The film is then developed to give a negative from which a photograph is made by printing.

In simple cameras the lens is fixed and all distant objects, which are beyond 2 m are in reasonable focus. In other cameras, an object is brought into focus by altering the lens position. When a photograph is taken, the shutter opens for a certain time and exposes the film to light entering the camera. The brightness of the image on the film depends on the amount of light passing through the lens when the shutter is opened and this is controlled by the size of the hole (aperture). In some cameras this is fixed, but in others it can be varied. When the object is bright, the aperture is made smaller but for a dull object, it is made large.

DEFECTS OF VISION

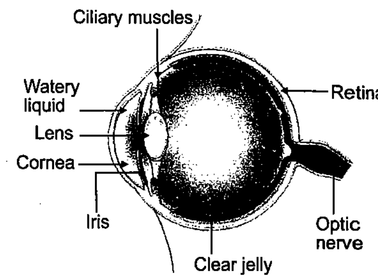


Fig. 2.30 *A human eye*

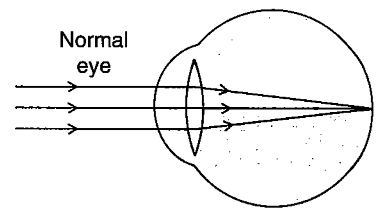
You must have studied about the human eye in your biology class. It has a convex lens, which forms an image of the object on a screen called the *retina* at the back of the eye. The human eye focuses the image for different objects at different distances by changing the focal length of the lens by stretching and relaxing the muscles.

Sometimes the human eye loses the ability to focus the images of objects, kept at different distances, properly on the retina. Thus, such a person cannot see things properly and his vision becomes defective.

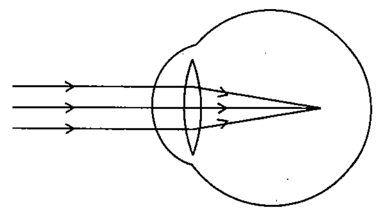
Myopia or short-sightedness

A short-sighted person is one who sees objects very close to the eye clearly, usually upto a metre. He can only focus light from near objects onto the retina. The parallel light from a distant object is focused in front of the retina as his eyeball is too long. So, the retina receives a blurred image (Fig. 2.31).

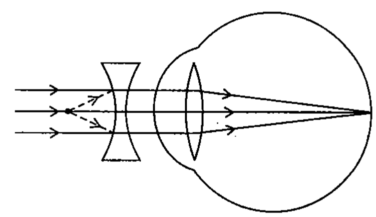
By selecting a diverging lens of suitable focal length, and placing it close to the eye, it refracts and spreads rays from distant objects as though coming from nearer objects that the eye can focus on.



(a) Normal vision



(b) Myopic eye



(c) Corrected myopic eye

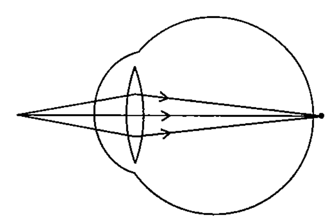
Fig. 2.31

Hypermetropia or long-sightedness

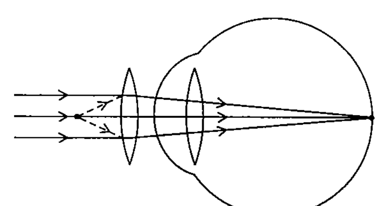
A long-sighted person sees distant objects clearly as light from them can be focused on the retina. The image of a near point is focused behind the retina because the eyeball is too short. This defect is corrected by using a convex spectacle lens.

By selecting a converging lens of suitable focal length, and placing this close to the eye, it refracts and spreads rays from nearer objects as though coming from distant object that the eye can focus on (Fig. 2.32).

However, in tomorrow's world, wearing eyeglasses and contact lenses may be a thing of the past due to laser technology. Laser technology allows eye surgeons to shape the cornea of the eye to allow normal vision.



(a) Hypermetropic eye



(b) Corrected hypermetropic eye

Fig. 2.32

KEYWORDS

Refraction Bending of a ray of light as it passes from one medium to the other

Refractive index Determines the amount by which the speed of light gets reduced in a medium

Dispersion Splitting up of white light into its constituent colours (VIBGYOR)

Lens Transparent medium bounded by atleast one curved surface

Microscope Optical device used to make things look bigger

Telescope Optical device used to provide an enlarged image of a distant object

Myopia Eye defect where a person sees near objects clearly but not distant objects

Hypermetropia Eye defect where a person sees distant objects clearly but not near objects

SUMMARY

- The bending of a ray of light as it passes from one optical medium to another is called refraction.
- The cause of refraction is the change in the speed of light in different mediums.
- The medium in which the speed of light is less is called optically denser medium and the medium in which its speed is more is optically rarer medium.
- The refractive index of a material can be calculated using the formula, speed of light in air/speed of light in that material.
- The splitting of white light into its constituent colours is called dispersion.
- The two types of lenses are convex lens and concave lens.
- Any ray of light travelling parallel to the principal axis, after refraction passes through the principal focus in the case of a convex lens or appears to diverge out from the principal focus in the case of a concave lens.
- Any ray of light passing through the focus in the case of a convex lens, after refraction, passes parallel to the principal axis.
- Any ray of light appearing to pass through the focus, in case of a concave lens, after refraction, passes parallel to the principal axis.
- Any ray of light passing through the optic centre of a lens passes on undeviated.

EXERCISES

I. Review questions

A. Choose the correct answer

1. The unit of refractive index is ....
   (a) m/s (b) no unit (c) kg/m^3 (d) none of these
2. When a ray of light travels perpendicular to the surface of separation of two mediums, it ....
   (a) bends towards the normal (b) bends away from the normal
   (c) goes without any deviation (d) none of these
3. The angle between the incident and the emergent ray from a glass slab is ....
   (a) 90° (b) 0° (c) less than 90° (d) more than 90°

4. When the object is kept at 2F of the convex lens, the image formed will be at .... on the other side of the lens.
   (a) F (b) 2F (c) at infinity (d) beyond 2 F
5. For a person suffering from hypermetropia, the image of a near object is focused .... the retina.
   (a) behind (b) in front of (c) on (d) none of these

B. Fill in the blanks

1. When a ray of light passes from a denser medium to a rarer medium, it bends .... (towards/away from) the normal.
2. Even though light travels a longer route in refraction, it takes the path in which it requires ....(less time/more time).
3. In an optically denser medium, the speed of light is .... (more/less) than the speed of light in air.
4. .... (Refractive density/Refractive index) tells you the amount by which the speed of light gets reduced in a material and is constant for that material.
5. The refracted ray bends more in diamond than in water as the speed of light in diamond is much .... (more/less) than that in water.
6. The phenomenon of splitting up of white light into its constituent colours is called .... (dispersion/refraction).
7. A swimming pool appears shallower than its actual depth due to .... (reflection/ refraction).
8. The angle between the incident ray and the emergent ray in a glass prism is called .... (angle of incidence/angle of deviation).
9. A concave lens is always .... (thicker/thinner) in the middle.
10. Myopia can be corrected using a .... (convex/concave) lens.

C. Match the following

1. Concave lens	(a) High refractive index
2. Convex lens	(b) Inverted
3. Virtual image	(c) Long sight
4. Diamond	(d) Always virtual image
5. Real image	(e) Erect

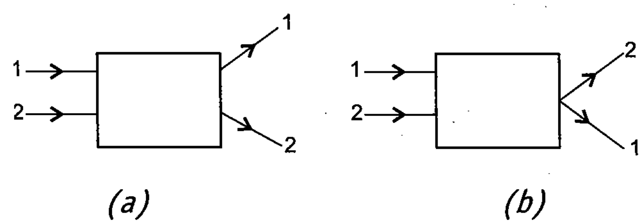
D. Answer the following questions

1. Define refraction of light.
2. What do you mean by optically denser medium? Explain giving examples.
3. Draw and show how a coin appears to be raised.
4. What are the three rules light obeys when it passes from one optical medium to the other?
5. Draw a diagram to show the refraction of a light ray as it passes through a glass slab and mark its angle of incidence and angle of refraction at the air–glass boundary and also the incident ray, the refracted ray, and the emergent ray.
6. Draw a diagram to show refraction by a prism and mark, i, r_1, r_2, d, and e. Also mark the angle of prism.
7. Briefly explain the cause for dispersion.
8. Why does a swimming pool appear to be shallower than its actual depth?
9. Why do stars twinkle?

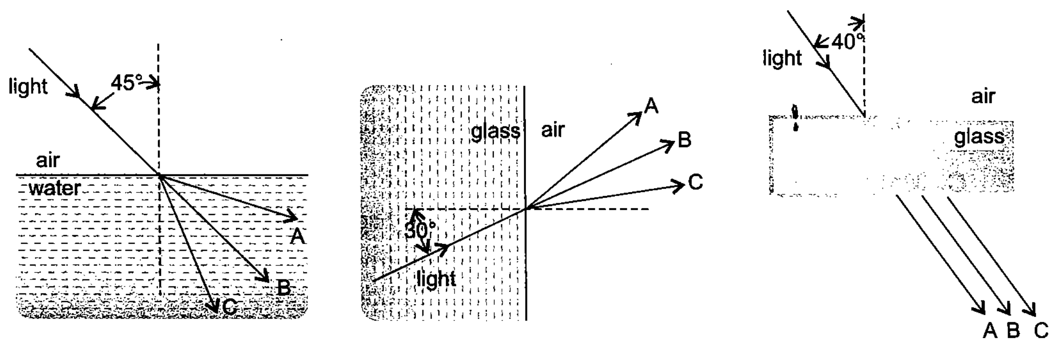
10. What are the rules for the construction of ray diagrams for convex lens? Explain with diagrams.
11. Construct images formed in a convex lens, when the object is kept at (a) infinity (b) beyond 2F (c) between F and 2F (d) at 2F (e) between optic centre and focus.
12. Construct an image for the concave lens when an object is kept anywhere between the optic centre and infinity.
13. What is myopia and how can it be corrected? Explain with diagrams.
14. What is hypermetropia and how can it be corrected? Explain with diagrams.

II. Skill-based questions

E. The figures below show the incident and the refracted rays through a lens kept in a box. Draw the lens and complete the path of rays

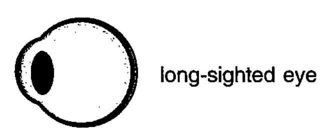


F. In the following figures, mark the correct light ray as it travels through different mediums



G. Complete the following sentences based on your understanding of the chapter

1. A long-sighted person cannot see .... objects.
   Show here what happens to rays from such objects.



2. We correct this problem using a .... lens.
3. On the other hand, a .... -sighted person cannot see .... objects. A .... lens can correct this problem.

III. Fun time

The word maze given here contains nine words related to this chapter. You can go up, down, sideways, backwards, etc. to locate the hidden words. The list alongside has the words that are hidden in the maze.

T	R	U	I	C	A	M	E	R	A
Q	E	M	E	R	G	E	N	T	X
W	F	X	S	F	K	I	O	R	E
K	R	E	Y	N	O	E	F	U	G
O	A	V	M	T	E	D	U	M	U
P	C	N	S	H	T	L	V	Y	H
B	T	O	I	F	S	U	C	O	F
M	I	C	R	O	S	C	O	P	E
C	O	D	P	T	U	R	W	I	D
Y	N	A	L	X	I	P	Q	A	Z

Refraction
Emergent
Microscope
Lens
Myopia
Focus
Prism
Convex
Camera

PROJECT IDEA

- **Aim:** Make your own spectrum without using a prism.
  Materials required: A shallow bowl, a handbag mirror, and water.
  Procedure: (Note that you will need to do this activity on a day when the sun is shining brightly through the window.)
  1. Put some water in the shallow bowl.
  2. Lean a mirror against the inside edge of the bowl. Place this arrangement in a room close to a window from where bright sunlight easily falls on the mirror.
  3. Gently move the mirror until you get a band of colours on the nearby wall or ceiling.

  You have produced a spectrum without using a prism! How many colours can you see in your spectrum? What are these colours? What happens if you gently disturb the surface of the water with your finger or with a pencil? Record your observations.

TEACHER'S NOTES

- Students get confused with mirrors and lenses. Showing concave lenses, convex lenses, and mirrors will help in clarifying their doubts.
- You could show the images formed by convex lens with the help of a candle and could demonstrate the differences between real and virtual images.