11

Light Energy

Can you read a book in the dark? If you try to do so, then you will realize, how much we are dependent on light. Light is very important part of our daily life. We require light for a number of activities. Even the plants on which we depend, need light for their food production. Without light we feel helpless. Truly speaking, life is not sustainable without light.

It is an experience from our early childhood that objects become visible in presence of light. You see the objects when the light after reflection from them falls on your eyes and thus makes their image at the retina of your eye. In fact, light is a form of energy and hence it is invisible, although the presence of light gives us the ability to see the things around us.

You may have seen in torches that there is a curved sheet of metal around the bulb. Can you think why is it so? We are very fond of looking at the image of our face in a looking glass. Do you know how the image is formed? You would also have noticed that when a rod is placed in a tumbler of water, it appears bent. What has caused the rod to bend ? We see that the stars twinkle on a clear night, that on a clear day the sky appears blue, at the time of sunset or sunrise the sky near horizon appears orange red. Have you ever tried to find out the reason for such natural events? In the present lesson you will find the answers to all such questions. You will also study about some man-made otpical instruments like microscope and telescope in this lesson.

OBJECTIVES

After completing this lesson, you will be able to:

- recognise the importance of light in day to day life;
- define the reflection of light and state the laws of reflection;
- describe the image formation by plane and curved mirrors with suitable ray diagrams;
- use mirror formula and define magnification;
- define refraction of light and state the laws of refraction;
- give some examples from nature showing refraction of light;
- explain the refraction of light through prism and rectangular glass slab;
- describe the types of lenses and explain the image formation by convex and concave lenses with the help of ray diagrams;
- use lens formula and define magnification;
- explain the power of lens and define dioptre;
- describe briefly the construction and working of the instruments, like simple microscope, compound microscope and astronomical telescope.

11.1 REFLECTION OF LIGHT

Can you think how does an object become visible to you. When we see an object, we do so because light from the object enters our eyes. Some objects such as sun, stars, candle, lamp etc. may emit their own light, called *luminous objects.* Some other objects may bounce back a part of the light falling on them from other luminous objects. This bouncing back of the light after falling on any surface is called *reflection of light*. The light bounced back from the surface is called **reflected light**.

Thus, when a beam of light travelling through a medium comes in contact with an object, a part of it gets bounced back (however, a part of it is absorbed and some part of it is able to penetrate through the object). This phenomenon is called **reflection of light**.

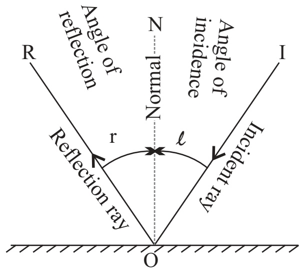

Fig. 11.1 Reflection of light from a plane mirror

Some objects having smooth and shiny surfaces reflect light better than others. A smooth shining surface, which reflects most of the light incident on it is *mirror.* The reflection of light from a plane mirror is shown in Fig 11.1

While studying the reflection of light, you will come across different **terms related to it.** They are given below :

- **Ray** can be defined as the direction of propagation of light.
- **Beam of light** consists of a number of rays.
- **Incident ray** is the ray of light that falls on the reflecting surface.
- **Normal** is the name given to a line drawn at 90^0 to the surface at the point where the incident ray strikes the surface.
- **Angle of incidence** is the angle between the normal and the incident ray.

11.1.1 Laws of reflection of light

Suppose, a ray of light (IO) falls on a reflecting surface AB at O, after reflection it goes along OR, as shown in Fig 11.1. The reflection of light from the surface takes place according to the following two laws:

(i) First law of reflection: The incident ray, the reflected ray and the normal at the point of incidence, all lie in the same plane.

(ii) Second law of reflection: The angle of incidence is equal to the angle of reflection i.e., $\angle i = \angle r$

11.1.2 Types of reflection

Depending on the nature of the surface the reflection of light can be of two types:

(i) Regular reflection: When the reflecting surface is very smooth and the rays of light falling on it are reflected straight off it, then it is called *regular reflection,* as shown in Fig. 11.2.

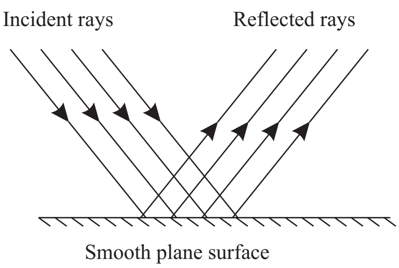

Fig. 11.2 Regular reflection

(ii) Diffused reflection : When the reflection of light takes place from rough surfaces, the *light is reflected off in all directions, as shown in Fig. 11.3*. It depends on the angle of the incidence on the part of the surface it hits. This is called **diffused reflection.**

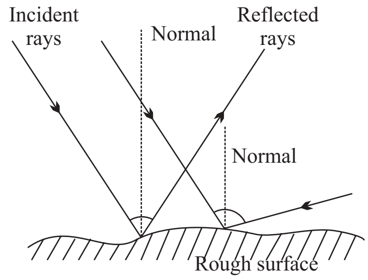

Fig. 11.3 Diffused reflection

Do you know ?

The rough surface diffuse or scatter the light falling on it and prevent the formation of image. Light is reflected from the paper of this book also but the surface of paper is much rougher than mirrors. That is why no image is formed by the paper.

You might have seen people putting frosted window glass pane? Have you ever thought why are frosted glass used? The frosted glass has a rough surface which does not allow the light to form clear images. Instead, the rough surface of glass diffuses the light and no clear image can be seen through it .

How do we see non-luminous objects?

Sunlight or light from a lamp incident over non-luminous objects undergo regular as well as diffuse reflection. When these reflected rays strike the retina of our eyes, an image of that object is formed in the eye, and thus we are able to see the objects.

11.1.3 Formation of images due to reflection

You know that a mirror is a good reflector of light rays. Daily at least once a day, you must be using a mirror to see your face. What do you actually see in the mirror? You see your image.

The images are of two types – real and virutal.

(i) Real image: The images which are obtained by the actual intersection of reflected rays, are called *real images*. The real images can be cast on a screen. In case of spherical mirrors real images are formed on the same side of the mirror as the object.

(ii) Virtual image: The image obtained when the rays appear to meet each other but actually do not intersect each other, are called *virtual images.* They cannot be cast on a screen. Virtual images are formed behind the mirror.

To understand the formation of image by a plane mirror, let us do an activity.

ACTIVITY 11.1

Aim : Image formation by a plane mirror

What is required?

A plane mirror, a few pins and a sheet of paper.

What to do?

(i) Spread the sheet of paper over a soft, smooth wooden plank or a piece of card board.

(ii) Put the mirror M_1 M_2 in a vertical position over the sheet as shown in figure 11.4

(iii) Put two pins, one at 'A' little far from the mirror and the other one very near to the mirror at 'B' so that, the line AB makes an angle with the line M_1 M_2 showing the position of the mirror.

(iv) Look at the images A and B of the two pins through the mirror, put two other pins at C and D so that all four pins A, B, C and D are in the same straight line.

(v) Now, look at the images of all these pins closing one of your eyes and moving your face in side ways. If the image of the two earlier pins and the two pins you have put just now, appear to be moving together you can say your observation is free-from *parallax error.*

(vi) Join the positions of pins by straight lines.

(vii) Keeping the first pin as it is, take out other three pins and repeat the experiment described above by putting the pins in new positions. This way take a few more readings.

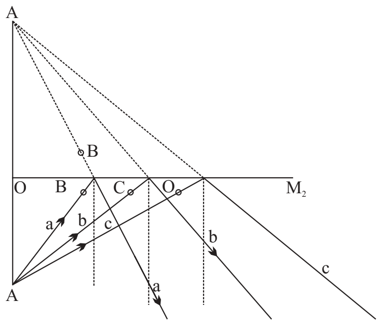

Fig. 11.4 Image formation by a plane mirror

What do you observe?

Besides the formation of image of the pins by the mirror, you are able to trace the directions of various incident and reflected rays.

To understand the formation of image, you may consider the light rays emerging out of the object A. We have drawn only three rays namely (a), (b) and (c). These rays after striking the mirror M_1 M_2 get reflected in the directions (d), (e) and (f), respectively, (as shown in the figure 11.4) obeying the laws of reflection.

It is clear that these reflected rays never meet with each other in reality. However, they appear to be coming (emerging) out from the point A´, inside the mirror i.e., if the reflected rays (d), (e) and (f) are extended in the backward direction, they will all meet with each other at A´. Thus, at A´ we get the image of object A.

From the above activity we find that the image formed by a plane mirror has the following **characteristics:**

This image is virtual (i.e., not real), erect and same in size as the object.

- The object distance and the image distance from the mirror are found to be equal i.e., OA = OA´.

Hence, the image of a point in a plane mirror lies behind the mirror along the normal from the object, and is as far behind the mirror as the object is in front. It is an erect and virtual image of equal size.

11.1.4 Few important facts about reflection

Put your left hand near a plane mirror. What do you see? You will find that on reflection, the image of the hand appears as right hand as shown in Fig. 11.5 (a). Similarly, the number 2 will appear in an inverted fashion on reflection as shown in Fig. 11.5 (b).

Hence, due to reflection in a plane mirror left handedness is changed into right handedness and vice-versa. This is known as *lateral inversion.*

For example a left handed screw will appear to be right handed screw on reflection as shown in Fig. 11.5(c).

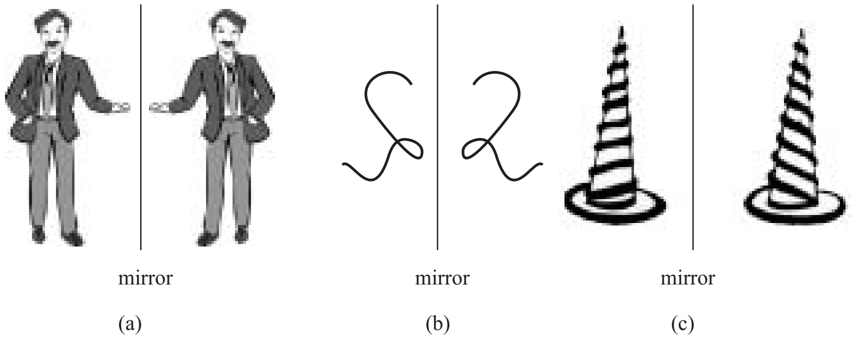

Fig. 11.5 Lateral inversion in image formed by a plane mirror

Do you know ?

(i) If you are approaching towards a plane mirror, even your image will also appear to be approaching towards you.

(ii) A woman can see her full image in a plane mirror whose height is half of her height. See the ray diagram in Fig. 11.6 and try to understand why this happens.

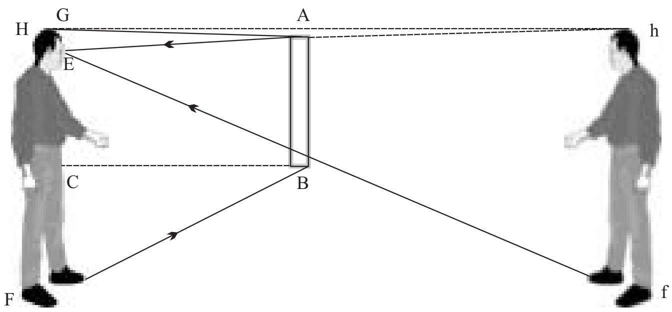

Fig. 11.6 Size of plane mirror to see full image

CHECK YOUR PROGRESS 11.1

1. Name four luminous objects.
2. Name the phenomenon of bouncing back of light from a rigid surface.
3. What is the relationship between the angle of incidence and the angle of reflection?
4. Although the light is reflected from the book you read, why is your image not visible in it?
5. Give two differences between diffused and regular reflection.

11.2 REFLECTION AT CURVED MIRRORS

A curved mirror is a section of a hollow sphere whose inner or outer surface has been polished. Thus, there are mainly two types of spherical mirrors-convex mirror and concave mirror.

(i) Convex mirror: It is a mirror in which the reflection takes place from the outer or the bulging side (i.e. the polishing is on the inner side) as shown in Fig 11.7 (a).

(ii) Concave mirror: It is a mirror in which the reflection takes place from the hollow side (i.e., the polishing is on the outer-side) as shown in Fig. 11.7 (b).

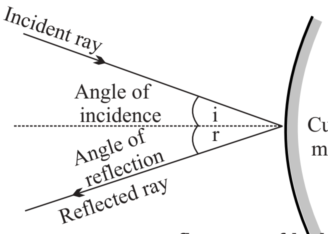

Fig. 11.7 Reflection of light by curved mirrors

For understanding the reflection at spherical mirrors, certain important terms are very useful. They are as shown in Fig 11.8 and defined below.

(i) **Pole (P):** It is the mid-point of the spherical mirror.

(ii) **Centre of curvature (C):** It is the centre of the hollow sphere of which the spherical mirror is a part.

(iii) **Radius of curvature (R):** It is the distance between the pole and the centre of curvature of a spherical mirror.

(iv) **Principal axis:** It is the imaginary line joining the pole with the centre of curvature.

(v) **Principal focus (F):** The rays of light parallel and close to the principal axis of the mirror after reflection, either pass through a point ***(in concave mirror)*** or appear to be coming from a point ***(in convex mirror)*** on the principal axis; this point is called principal focus of the mirror.

(vi) **Focal Length (f):** It is the distance between the pole and the principal focus of the mirror.

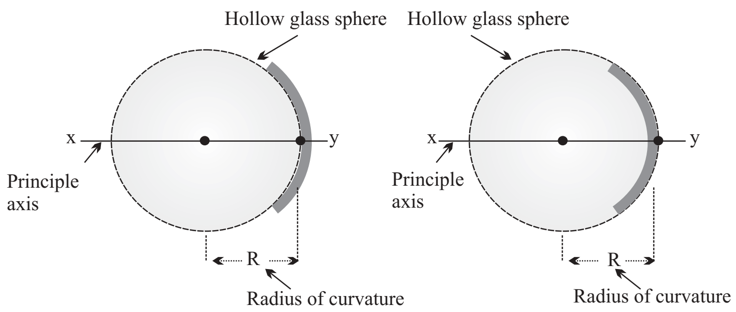

Fig. 11.8 Some terms in image formation by spherical mirrors

Relationship between focal length and radius of curavture

Focal length (F) of a spherical mirror is equal to half of the radius of curvature (R) of that mirror. In mathematical terms it can be written as,

$$f = \frac{R}{2}$$

11.2.1 Rules of image formation by spherical mirrors

The ray diagram for image formation by mirrors can be drawn by taking any two of the following rays :

(i) Central ray: The ray of light striking the pole of the mirror is reflected back at the same angle on the other side of the principal axis (Ray no. 1 in Fig. 11.9).

(ii) Parallel ray: For a concave mirror the ray parallel to the principle axis is reflected in such a way that after reflection it passes through the principal focus. But for a convex mirror the parallel ray is so reflected that it appears to come from principal focus (Ray no.2 in Fig 11.9).

(iii) Ray through centre of curvature: A ray passing through the centre of curvature hits the mirror along the direction of the normal to the mirror at that point and retraces its path after reflection (Ray no.3 in Fig 11.9).

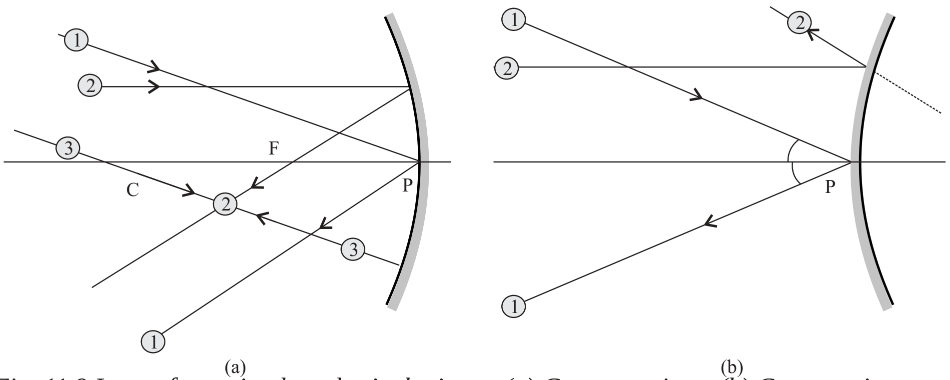

Fig. 11.9 Image formation by spherical mirrors (a) Concave mirror (b) Convex mirror

Now, let us see how images are formed by concave and convex mirrors when the object is placed in different positions.

(a) Formation of image by concave mirror

Using the above said rules of image formation, the ray diagram for the image formed for different positions of object are given below:

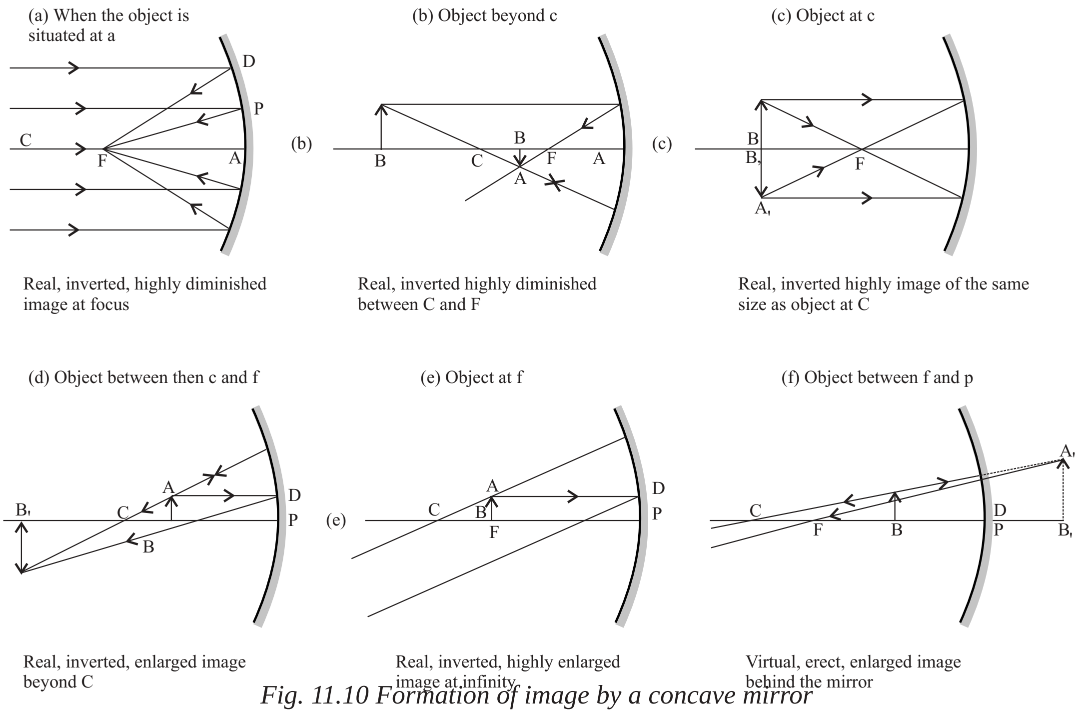

Fig. 11.10 Formation of image by a concave mirror

In all these diagrams we have considered two rays starting from a point at the top of the object. The image is formed where these rays intersect after reflection.

(b) Formation of image by convex mirror

In case of convex mirror, the formation of the image is shown in Fig 11.11. The incident ray AQ parallel to principal axis is reflected such that it appears to come from focus F. The incident ray AN towards the centre of curvature being normal to the mirror is reflected back along the same path. These two reflected rays appear to be coming from the common point A´, which is the image of point A.

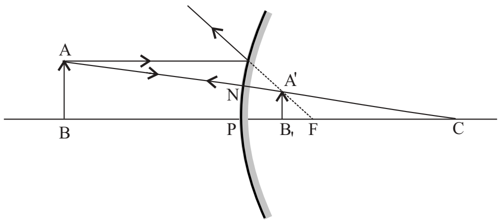

Fig. 11.11 Formation of image by convex mirror

The image formed by convex mirror is between pole P and focus F, virtual, diminished, and erect.

In convex mirror, whatever may be the position of the object infront of the mirror, the image formed is always virtual, erect, diminished, (i.e, smaller than the pize of the object) and is situated between the pole and the focus.

11.2.2 Uses of mirrors

The different types of mirrors have different uses in our daily life. Let us study them one by one.

(i) Plane mirror is used
- in looking glasses,
- in construction of kaleidoscope, telescope, sextent, and periscope etc.,
- for seeing round corners,
- as deflector of light.

(ii) Concave mirror is used
- as shaving and makeup mirrors,
- as a reflector in search light, head light of motor cars and projectors etc,
- for converging solar radiation in solar cookers,
- as mirror for the dentists,
- in flood lights to obtain a divergent beam of light to illuminate buildings,
- in reflecting telescopes large concave mirrors are used.

(iii) Convex mirror is used
- as a rear view mirror in motor cars, buses and scooters, etc,
- as safety viewers at dangerous corners and on upper deck buses

11.2.3 Sign convention and mirror formula

To measure distances with respect to a curved mirror, following convention is followed:

(i) All distances are measured from the pole of the mirror.
(ii) The distances measured in the same direction as incident light, are taken as positive.
(iii) The distances measured against the direction of incident light, are taken as negative.
(iv) The distances above the principal axis are taken positive, whereas, below it are taken negative.

Using the sign convention, the relationship between object distance (u), image distance (v) and the focal length for a curved mirror is given by,

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

You can use this formula to find out any of the quantities, provided the other two are given.

11.2.4 Magnification in spherical mirrors

Often we find that a spherical mirror can produce an enlarged or magnified image of any object. The ratio of the size of the image to the size of the object is called **linear magnification**.

$$\text{i.e., linear magnification (M)} = \frac{\text{size of image (I)}}{\text{size of object (O)}} = -\frac{v}{u}$$

Where, v = image distance from mirror, and u = object distance from mirror
Positive value of M tells that image formed is erect while negative value of M indicates that an inverted image is formed.

CHECK YOUR PROGRESS 11.2

1. What is the focal length of a plane mirror?
2. Write the position and nature of image formed by a concave mirror when the object is placed between the focus and centre of curvature.
3. List any two differences between real and virtual images.
4. What type of mirror is used to view the rear objects by an autodriver?
5. If an object of 5cm size is placed infront of a concave mirror, the size of the image formed by it is 7.5 cm, what is the linear magnification of the mirror?

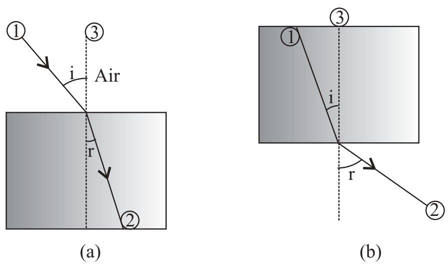

Fig. 11.12 Refraction of light

11.3 REFRACTION OF LIGHT

When a light ray passes from a less dense medium to a more dense medium (e.g., from air to glass), it bends towards the normal (Fig. 11.12) and when it passes from a denser medium to a less dense medium (e.g., from glass to air) it bends away from the normal (Fig. 11.12). This phenomenon of deviation of light rays from their original path, when they pass from one medium to another, is called refraction of light.

ACTIVITY 11.2

Aim : To study the refraction through a glass slab

What is required ?

A glass slab, drawing sheet, pencil, drawing board, alpins, protector, and a scale.

What to do?

(i) Place glass slab on a drawing sheet fixed on a wooden drawing board, sketch a pencil boundary. Draw a line OC meeting the boundary line obliquely.

(ii) Fix the pins A and B on that line. Now look for these pins through the other side of the glass slab.

(iii) Take a pin and fix it on the sheet such that A, B and E are in a straight line.

(iv) Now fix another pin F such that it is in a straight line with pins A, B and E. Remove the slab and the pins.

(v) Draw a line joining the points F to E to meet the boundary at D.

(vi) Join point C to D by a dotted line.

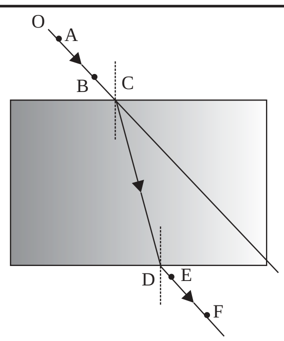

Fig. 11.13 Refraction through a glass slab

What do we observe?

As shown in Fig. 11.13, the line ABC gives the direction of incident ray on the glass slab while the line DEF gives the direction of emergent ray. The line CD gives the direction of refracted ray. Draw normals N_1CN_2 at C and N_3DN_4 at D to the boundaries. Now check the indication of these rays. Do you find that the refracted ray D has slightly bent towards the normal to the boundary at C?

What do you conclude?

The ray of light when goes from a rarer (air) to a denser (glass) medium, it bends towards the normal. Also, the ray of light when goes from denser (glass) to rarer (air) mediums it bends away from the normal.

11.3.1 Refractive index of the medium

When the light travels from one medium to another medium, the speed of light changes.*A ray of light from a rarer medium to a denser medium slows down and bends towards the normal. On the other hand the ray of light going from a denser medium to a rarer medium, is speeded up and bends away from the normal.* It shows that the speed of light in different substances varies. Therefore, different substances have different abilities to bend or refract light. We call this bending ability of a material as the index of refraction or refractive *index* of that material.

The refractive index (μ) of a material is defined as the ratio of the speed of light in vacuume to that in the material medium.

Therefore, **refractive index** of a medium (μ) $= \dfrac{\text{speed of light in vacuum}}{\text{speed of light in medium}}$

The refractive index of a rarer medium is less as compare to that of a denser medium.

11.3.2. Laws of refraction

The extent to which a ray bends, depends not only on the refractive index of medium, but also on the angle of incidence. The laws of refraction are :

(i) **First law of refraction:** The incident ray, the refracted ray and the normal at the point of incidence all lie in the same plane.(see fig. 11.13)

(ii) **Second law of refraction:** The ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant and it is equal to the refractive index of the medium. This law is also called as the **Snell's law** of refraction.

$$\text{Refractive index } (\mu) = \frac{\text{sine of angle of incidence}}{\text{sine of angle of reflection}} = \frac{\sin i}{\sin r}$$

11.3.3 Application of refraction of light

(i) If you look at a coin placed at the bottom of a container full of water, you will notice that it appears to be raised as shown in Fig. 11.14. You know that an object is visible only when the rays of light from the object reach your eyes. In the first case, when there is no water in the container, the coin will not be visible to you from the side of the container as shown in Fig. 11.14(a), because the rays of light traveling in a straight line do not reach your eyes. But on pouring the water into the container, the rays of light from the coin change their direction as they travel from water (denser medium) into air (rarer medium) and thus, reach your eyes. Thus, the coin becomes visible to your eyes. The rays now appear to be coming from C^1 instead of C. In this way, the coin appears to be raised.

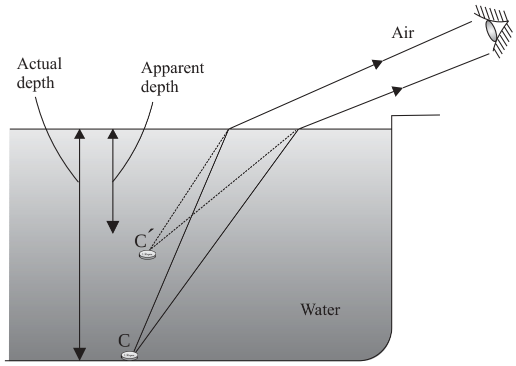

Fig. 11.14 (a) Apparent depth of a coin in water

The ratio of the actual depth of the coin to the apperent depth of the coin is equal to the refractive index of the liquid of the container.

$$\text{Refractive index } (\mu) = \frac{\text{actual depth}}{\text{apparent depth}}$$

(ii) Another example of refraction observed in our daily life is the twinkling of stars. Visibility of the sun before actual sunrise or after actual sunset can also be explained on the basis of refraction of light.

(ii) You would have observed that a pencil half kept in water in a glass appears to be bent. When the part of a pencil is kept inside the water in a glass, it appears to be broken or bent with respect to the part outside the water as shown in Fig 11.14 (b). This is also due to the bending of light rays when they pass from water to air.

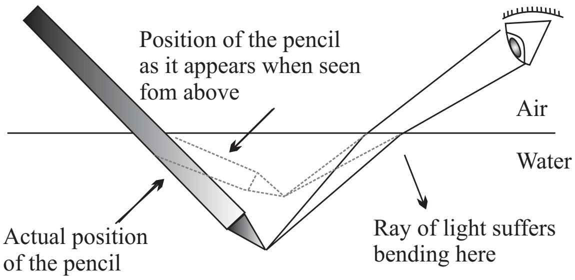

Fig. 11.14 (b) The pencil inside water appears bent

Try to explain these events and discuss your answer with your teacher or fellow students.

CHECK YOUR PROGRESS 11.3

1. What happens when a ray of light passes from one medium to another of different density?

2. Why do the stars twinkle at night?
3. What happens to a ray of light, if it enters a glass block along its normal?

11.4 REFRACTION THROUGH CURVED SURFACE

In the present discussion under this section, we will confine ourselves to the refraction of light through lenses only. Do you know what is a lens? *A lens is a portion of a transparent refracting medium bounded by two spherical surfaces. Because* the lenses are made from spheres, they are called as spherical lenses. They are mainly of two types :

- Convex lens
- Concave lens

(i) **Convex lens:** A convex lens is thick in middle and thin at the rim. It makes the parallel rays of light to converge and come to a point. Hence, it is also called a **converging lens**. The conveging property of a convex lens is shown in Fig. 11.15(a).

(ii) **Concave lens :** A concave lens is thin in the middle and thick at rim. It makes the parallel rays of light to spread from a point. Hence it is also called a diverging lens. The diverging property of concave lens is shown in Fig. 11.15(b).

(a) Convex lens *(b) Concave lens*

Fig. 11.15 Types of lenses

The point at which the incident rays parallel to principal axis will converge upon after refraction in a convex lens is called its principal focus. Where as in a concave lens the point from where incident rays parallel to the principal axis of the lens appear to be coming, is called as its *principal focus (F)*.

11.4.1 Rules of image formation by lenses

In order to draw the image formed by any lens only two rays are required. These two rays are:

(i) A ray parallel to the principal axis of the lens after refraction, converges upon (appears to diverge off) the principal focus of a convex *(concave)* lens.

(ii) A ray towards the optical center falls on the lens symmetrically and after refraction passes through it undeviated.

Let us now see the image formation in cases of convex and concave lens in different situations of the objects.

(a) Image formation by convex lens

According to the above said rules of image formation, the position and nature of the image formed for different positions of object is shown by the following ray diagrams: (see Fig. 11.16).

(i) If the object is placed between the optical centre O and first focus F_1, the image is formed on the same side of lens and it is virtual, upright and magnified.

(ii) If the object is at first focus F_1 ,the image is at infinity and it is real, inverted and very much magnified.

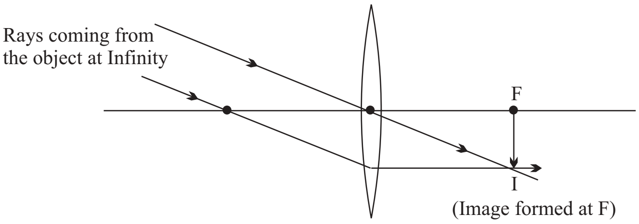

Fig. 11.16 (a) Object placed between optical centre and first focus

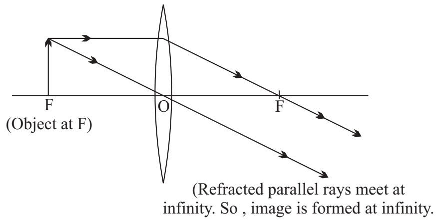

Fig. 11.16 (b) Object at the first focus

(iii) If the object is between F_1 and $2F_1$, the image is beyond $2F_2$ on the other side of the lens and it is real, inverted and larger in size.

(iv) If the object is at $2F_1$, the image is at $2F_2$ on the other side of the lens and it is real, inverted and is of same size as object.

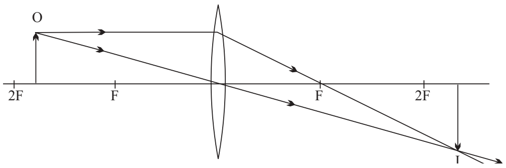

Fig. 11.16 (c) Object is between F_1 and $2F_1$

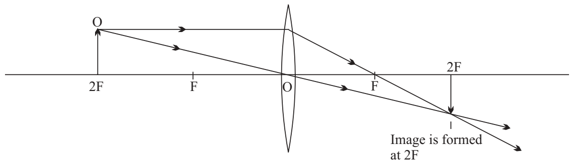

Fig. 11.16 (d) Object is at $2F_1$

(v) If the Object is beyond $2F_1$, the image is inbetween F_2 and $2F_2$ on the other side of the lens and is real, inverted and diminished.

(vi) If the object is at infinity, the image is at F_2 on the other side of the lens and is real, inverted and very much diminished.

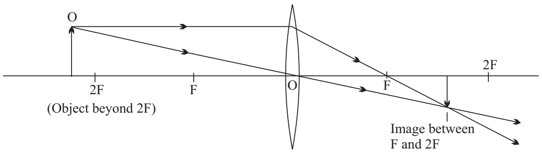

Fig. 11.16 (e) Object is beyond $2F_1$

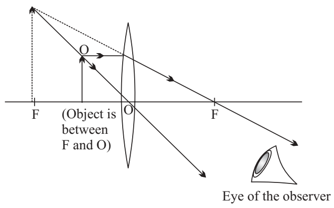

Fig. 11.16 (f) Object is at infinity

(b) Image formation by concave lens

The image formed by a concave lens is always smaller than the object, erect and virtual and is formed between focus and optical centre on the same side as the object whatever be the position of object as shown in Fig. 11.17.

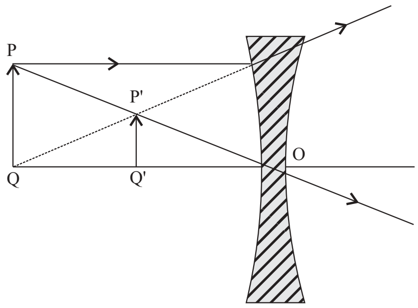

Fig. 11.17 Image by concave lens

11.4.2 Sign convention and lens formula

In case of the spherical lenses,

(i) all distances in a lens are to be measured from optical centre of the lens,

(ii) distances measured in the direction of incident ray are taken to be positive,

(iii) distances opposite to the direction of incident ray are taken to be negative.

(iv) the height of the object or image measured above the principal axis are taken positive whereas below it, are taken negative.

Using the above mentioned sign convention, in Fig. 11.18 let us assume, distance of object PQ from the optical center O = OQ = (-u), distance of iamge P´Q´ from the optical center O = OQ´ = (+V), and focal length of lens = OF´$_2$ = (+f).

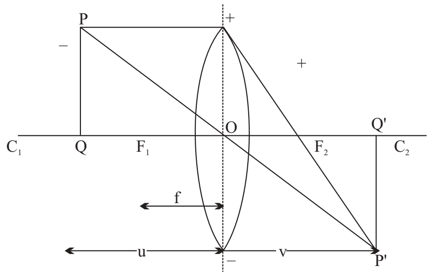

Fig 11.18 Sign convention in lenses

The relationship between u,v and f for a lens is as shown below:

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

This is called **lens formula.**

Focal length for convex lens is positive, whereas, for concave lens it is taken negative.

11.4.3 Magnification

You would have noticed that in case of some lenses, the size of the image of an object is enlarged whereas in some other cases it is diminished. If we take the ratio of the size of the image to the size of the object for a particular lens it remains constant for that lens. This ratio of the size of the image to that of the object is called as the magnification of the lens.

i.e., magnification (m) = $\dfrac{\text{size of image}}{\text{size of object}} = \dfrac{I}{O}$

also, m = $\dfrac{I}{O} = \dfrac{v}{u}$

A positive value of m tells that the image is erect and negative value of m tells that the image is inverted.

CHECK YOUR PROGRESS 11.4

1. If an object is placed at the focus of a convex lens, what will be the position and nature of the image?
2. Draw the ray diagram to show the image formed by a concave lens.

11.5 DISPERSION OF WHITE LIGHT

We are sure, you must have observed seven brillient colours of light in your surrounding. The separation of white light into its constituent seven colours is called *dispersion of light.*

11.5.1 Dispersion of light through glass prism

When the white light passes through a glass prism, it gets splitted into seven different colour rays.

In fact, the white light is supposed to be made up of seven colours. Different coloured light have different wavelengths. The refractive media like glass have different values of refractive indices for different colours. You should know that as we go from violet to red wavelength of light increases . The violet part of incident white light get refracted of the surface PQ at angle $<r_0$ which is different than angles of refraction for other colour-rays.

As a result of which different coloured light rays are seperated from each other. Thus, on emergence through the face PS, they get further separated resulting in the dispersion and forming a spectrum.

ACTIVITY 11.3

Aim : To produce a spectrum using a prism and sunlight.

What is required ?

A shoe box, knife, a transparent white paper.

What to do ?

(i) Take an empty shoe box. Make a rectangular opening on its cover with a knife and close it with a transparent white paper to see the spectrum.

(ii) Make a thin slit with knife on the opposite side cardboard of the shoe box.

(iii) Place the prism on a block inside the box as shown in the figure 11.19.

(iv) Turn the slit-side face of the box towards sunlight.

(v) Do you see coloured strips on the transparent paper?

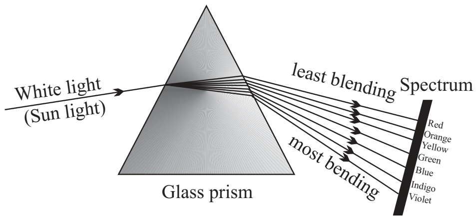

Fig. 11.19 Formation of spectrum by a prism

What do we conclude ?

We can see that a brilliant pattern of the colours is formed in the sequence of Violet, Indigo, Blue, Green, Yellow, Orange and Red which can be written as **VIBGYOR**.

If you repeat the same activity with a glass slab, you will find that a glass prism shows dispersion of white light but a glass slab does not? Can you think of Why? The emergent beam refracted through the other face of glass slab is a parallel beam and therefore, does not get separated. To produce dispersion, the emergent beam should be divergent.

CHECK YOUR PROGRESS 11.5

1. What is the sequence of colour in a spectrum of white light formed by prism?
2. Which colour has minimum wavelength? Violet, yellow or green.
3. For which colour the value of refrative index is more – orange or blue?
4. The emergent beam in a prism producing spectrum is convergent or divergent?
5. Why does a glass slab not produce a spectrum of white light?

11.6 OPTICAL INSTRUMENTS

You are advised to wash your hands before taking any food. Do you know why? Because, there may be harmful germs on your hands, which are not visible to you with your naked eyes. Then how do we see such minute germs, bacteria or other things. For this purpose we use microscope. Do you know or have you ever seen it? A *microscope is an optical instrument used to see very-very small objects by forming their magnified image at the least distance of distinct vision from the eye.*

There are a number of instruments and devices that make use of the light. For example, lens camera, pin hole camera, microscope, telescope and projector etc. are the optical instruments. Here, we will study about the microscope and telescope only.

Least distance of distinct vision

The minimum distance of an object from a normal eye up to which it is clearly visible, is called least distance of distinct vision.

11.6.1 Microscope

There are two types of microscopes-simple microscope and compound microscope. Let us study about them one by one.

(a) Simple Microscope

A simple microscope consists of just a convex lens of small focal length. We know that a convex lens produces an erect and magnified image when the object is placed at a distance less than its focal length. This property is made use of in a simple microscope. In other words, a simple microscope is nothing but a magnifying glass.

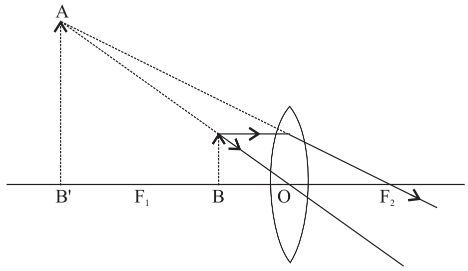

Fig. 11.20 Image formation by simple microscope

The magnification in the case of convex lens Fig. 11.20 is given by

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

Where, v is the image distance and is the focal length of the lens.

Now, taking the image distance to be equal to 25 cm, i.e. the least distance of distinct vision, the magnification *m* turns to be.

$$m = 1 - \frac{-25}{f} = 1 + \frac{25}{f}$$

Thus, we see that the magnification increases with the decrease in the focal length of the lens, even if the focal length of a convex lens is very small, say 1 cm. But the magnifying power of a simple microscope cannot exceed beyond a certain limit. To get higher magnification a compound microscope, therefore, has to be used.

Example 11.1: Find the magnifying power of a simple microscope having the focal length equal to 2.5 cm.

Solution : We know that for a simple microscope,

$$m = 1 + \frac{25}{f}$$

Given, f = 2.5 cm Therefore, substituting value of f, we get

$$m = 1 + \frac{25}{2.5} = 1 + 10 = 11$$

(b) Compound microscope

In order to see very minute objects, we use compound microscope.

In a compound microscope, unlike the simple microscope, the magnification takes place in two stages.

(i) Construction

It consists of two convex lenses. The lens towards the object is known as objective, whereas, the other lens towards eye of the viewers is called eyepiece. Both the eyepiece and objective are of short focal lengths. But the focal length of the objective is shorter as compared to that of the eyepiece as shown in Fig 11.21.

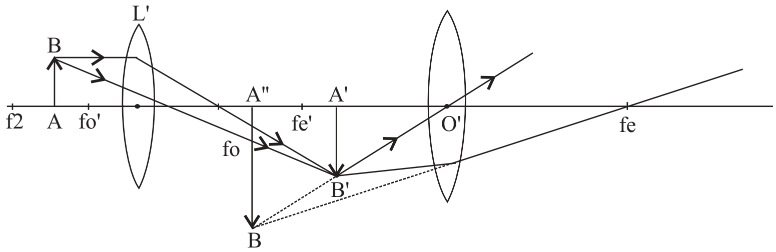

Fig. 11.21 Image formation by a compound microscope

(ii) Working

Consider figure 11.21. Let the object is placed at a distance slightly greater than the focal length of the objective. A real inverted and magnified image is formed by the lens on its other side. The eyepiece is so adjusted that this image is within its focal length. The image acts like an object for the eyepiece which produces a virtual, erect and enlarged final image. It is inverted image of the object.

(iii) Magnifying power of the microscope

Let u_1 = distance of the object AB; v_1 = distance of the image from the objective lens L_1 : u_2 = distance of A_1 B_1 from the eyepiece L_2; v_2 or D = the distance of its image A_2B_2 from L_2.

Now, with the eye placed very close to the eyepiece, the magnifying power (m) of the compound microscope is given as:

$$m = m_o \times m_e$$

Where, m_e is the magnification of eye piece and m_o is the magnification of the objective. Since the eyepiece acts like a simple microscope, so its magnifying power is,

$m_e = 1 + \frac{25}{f_e}$ where, f_e = focal length of the eye piece.

$m = m_e\left[1 + \frac{25}{f_e}\right]$ Hence, $m = \frac{v_1}{u_1}\left[1 + \frac{25}{f_e}\right]$

Thus, it is clear that the magnifying power of the compound microscope is greater than that of a simple microscope. From this equation it is clear that the magnifying power of the compound microscope can be increased if,

- u is small, that is the object AB is placed very near to the objective. It is possible only when the focal length of the objective is very small, since the object is to be placed beyond the focus to give real, inverted and magnified image.
- v_1 is greater, that is, the distance between the image and the objective is large. Again the object has to be placed near the focus of the objective. So the length of the microscope should be large.
- f_e, the focal length of the eyepiece is very small.

11.6.2 Telescope

A telescope is an optical instrument used to view the distant objects. There are mainly two types of telescopes:

- Refracting telescope
- Reflecting telescope

(i) The refracting telescope

The refracting telescope is normally used to observe the astronomical or heavenly bodies, therefore, it is known as *astronomical telescope* also. It consists of two convex lenses arranged in a tube. The lens towards the object is called objective and it is of larger focal length. The other lens towards the eye is called the eye lens or eye piece and it has a short focal length. Fig. 11.22.

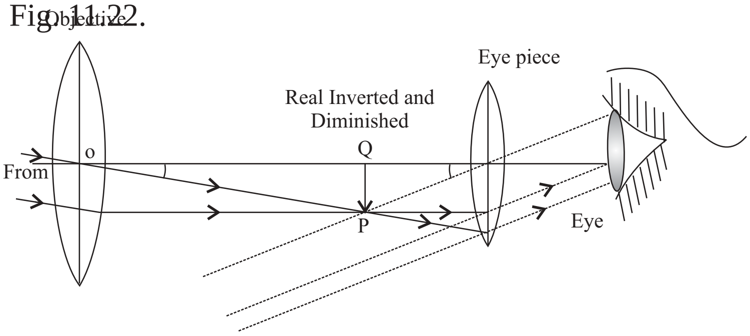

Fig. 11.22 Astronomical telescope

The objective forms an inverted upside down and real image of a distant object. The eye lens acts like a magnifying glass taking the image formed by the objective as its object.

ii) The reflecting telescope

The objective of this type of telescope is a spherical concave mirror of large focal length. Fig. 11.23 shows a reflecting telescope. The parallel rays from a distant object fall on the concave mirror. Before being focused at the focus, the rays are intercepted by a small convex mirror, M_1M_2 inclined at 45^o with the axis of the objective mirror. Thus, the image is shifted towards the eyepiece. The eyepiece magnifies the image as usual. The mirror M_1M_2 is so small that it does not obstruct much of the incident light. Hence, the brightness of the image is not affected. The mirror M_1M_2 can be replaced by a totally reflecting right angled isoscles prism.

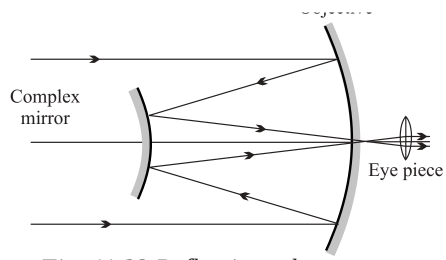

Fig. 11.23 Reflecting telescope

Most of the telescopes used for serious astronomical observations are reflecting telescopes.

CHECK YOUR PROGRESS 11.6

1. Write down the uses of a microscope and a telescope.
2. What type of lens is used in a simple microscope?
3. What is the difference between reflecting and refracting telescopes?
4. What do you mean by an objective and an eyelens?

LET US REVISE

- Light is a form of energy which itself is not visible but makes other things visible.
- When the light ray (called incident ray) strikes a polished surface, it is bounced back in the same medium (forming reflecting ray), and the phenomenon is said to be reflection of light.
- The reflection of light always takes place according to the two laws of reflection.
- The reflected light forms images. Images are of two kinds real image and virtual image.
- The image formed by a plane mirror lies along the normal from the object, is as far behind as the object is in front and it is erect, virtual and of equal size.
- Plane mirror gives an image in which left handedness turns into right handedness and vice-versa, i.e. it causes lateral inversion.
- The image formed by a concave or convex mirror depends on the position of the object in front of the mirror.
- When a ray of light passes from one medium to another medium of different density, it bends and this phenomenon is called refraction of light.
- Refraction of light is caused by the change in the speed of light as it passes from one medium to another of different density.
- The ability of any medium to bend light ray is called the refractive index of the medium. It is defined as the ratio of the speed of light in vacuum to that in the medium.
- A lens is bounded by two surfaces which may be spherical. There are two categories of spherical lenses convex lens and concave lens.
- Convex lens makes a parallel beam of light rays to converge and come to a point. Where as concave lens makes the light rays to diverge.
- Magnification is the ratio of the size of the image to the size of the object.
- A microscope is an instrument used to see very small objects by forming their enlarged images.
- A telescope is an instrument used for observing distant objects like the stars.

TERMINAL EXERCISES

1. What is reflection of light? Explain it with the help of a ray diagram.
2. State and explain the laws of reflection.
3. What is an optical image and how is it formed?
4. Name two types of images and distinguish between them.
5. Explain the formation of images with the help of ray diagrams for the following cases:
   (i) a plane mirror
   (ii) a convex mirror
   (iii) a concave mirror, for an object lying between focus and center of curvature.

6. Define the focus of convex and concave mirrors. Give relationship between focal length and radius of curvature.
7. What is refraction of light? State laws of refraction of light.
8. Define refractive index of a medium.
9. Explain why do the start twinkle?
10. Why is a convex lens is also called converging lens?
11. With the help of ray diagram show the image formed by a convex lens when the object is placed between F and C.
12. An object is placed at a distance of 30 cm from a convex lens of focal length 20 cm. Find the nature and position of the image formed.
13. What is a microscope? Explain briefly the principle of simple microscope with a suitable diagram.
14. What is a telescope? Explain briefly the principle of refracting telescope.
15. What is the difference between objective lens and eye lens in a telescope?

ANSWERS TO CHECK YOUR PROGRESS

11.1

1. The sun, candle flame, fire, lighted electric bulb
2. Reflection of light
3. Angle of incidence = angle of reflection
4. Because of diffuse reflection
5. Regular reflection:
   i) It takes place at smooth and shiny surfaces.
   ii) Reflected rays are in a particular direction.

   Diffused reflection :
   i) It takes place at rough surfaces.
   ii) Reflected rays are in different directions.

11.2

1. infinity
2. image is beyond C, real, inverted and magnified
3. Real image
   i) They are formed by actual intersection of reflected rays
   ii) They can be casted on the screen

   Virtual image
   i) They are formed by the reflected rays which appears to be coming from a point they do not intersect actually.
   ii) Cannot be casted on screen
4. Convex mirror
5. Magnification (m) $= \frac{I}{O} = \frac{7.5}{5} = 1.5$

11.3

1. It deviates from its original path
2. Because of multiple refraction of the light coming from the stars
3. It is refracted without deviation

11.4

1.The image will be at infinity, real, invested and magnified.

2. Ray diagram

11.5

1. Violet, indigo, blue, green, yellow, orange, red
2. Violet
3. Blue
4. Divergent
5. Because the emergent beam is parallel

11.6

1. Microscope is used to see very small objects by making an enlarged image.
   Telescope is used to see for distant objects by making their image nearer to the eye.
2. Convex lens
3. Reflecting telescope consists of a concave mirror as objective whereas refracting telescope consists of a convex lens on objective.
4. The lens towards the object is objective lens and the lens towards the eye is eye-lens.