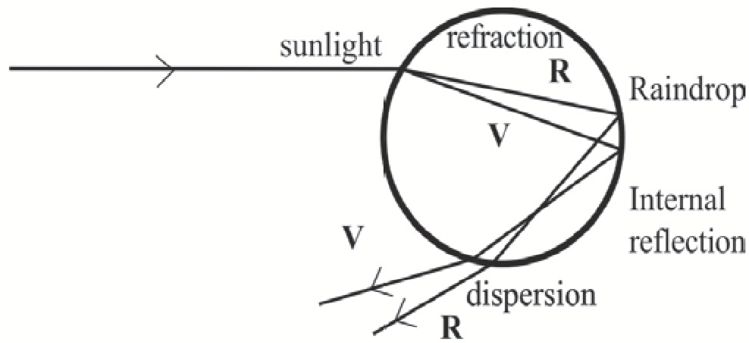



**Fig 2.37 The passage of light through a drop of water**

**Activity 2.9**
**To observe a made up rainbow.**

Fill a bucket with water. Dip a coir rope into the water. Take the rope out of water. Face a direction so that the sun is behind you. Shake the rope in the sunlight. You can see a rainbow forming in the flowing droplets of water.

**Activity 2.10**

Take some water into your mouth. Face a direction so that the sun is behind you. Blow out a spray of water from the mouth. Watch whether you could see a rainbow in the spray of water.

## 2.4 Use of lenses to design optical instruments

### Thin lenses

Lenses are made out of glass or transparent plastics. The lenses which are thick in the middle and thin at the edges are called **convex lenses.** Those which are thin in the middle and thick at the edges are called **concave lenses.**

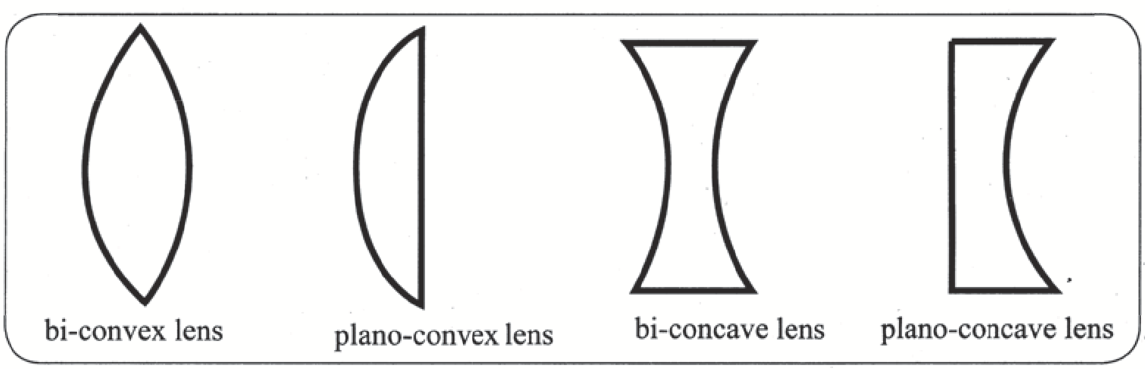



Fig 2.38

Convex lenses are converging lenses.Concave lenses are diverging. When rays parallel and close to the principal axis pass through a convex lens, they are bent inwards ,The point F where they converge and meet is called the **principal focus**. The real centre of the lens is named as **optical centre**. The distance between the optical centre and the principal focus is known as the **focal length**.

When rays of light parallel and close to the principal axis pass through a concave lens they bend outwards (diverge).The principal focus of a concave lens is the point from which the refracted rays appear to diverge. This is virtual.

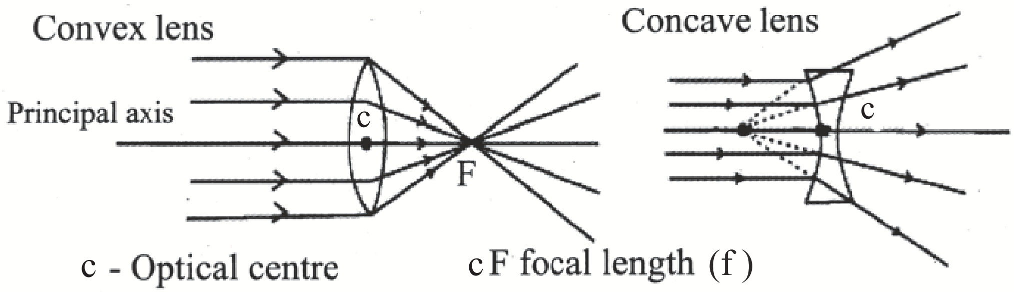



Fig 2.39- Main points of concave and convex lenses

**Activity 2.11**

**Observing refraction of light through lenses**

Take a convex lens, a concave lens and a sheet of paper to outside the class room when there is bright sunlight. Hold the convex lens parallel to the ground and keep a sheet of paper underneath.cc Adjust the position of lens till you geta very bright spot of light on the paper. The bright spot on the paper is at the focal length of the convex lens. Repeat the activity using the concave lens. You will see a wider circular colour patch around beyond the edges. This shows that concave lenses are diverging

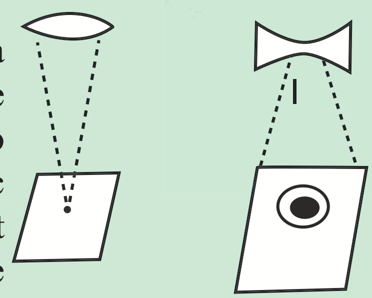


Fig 2.40

## Location of images formed by lenses

### (i) Convex lenses.

**Special rays that can be used to draw a ray diagram are ;**

1. A ray through the optical centre passes straight through the lens. This is true for concave lenses too. [ 2.41 (a) ]
2. A ray parallel and close to principal axis passes through F after passing through the lens. [ 2.41 (b) ]
3. A ray through F leaves the lens parallel to the principal axis. [ 2.41 (c) ]

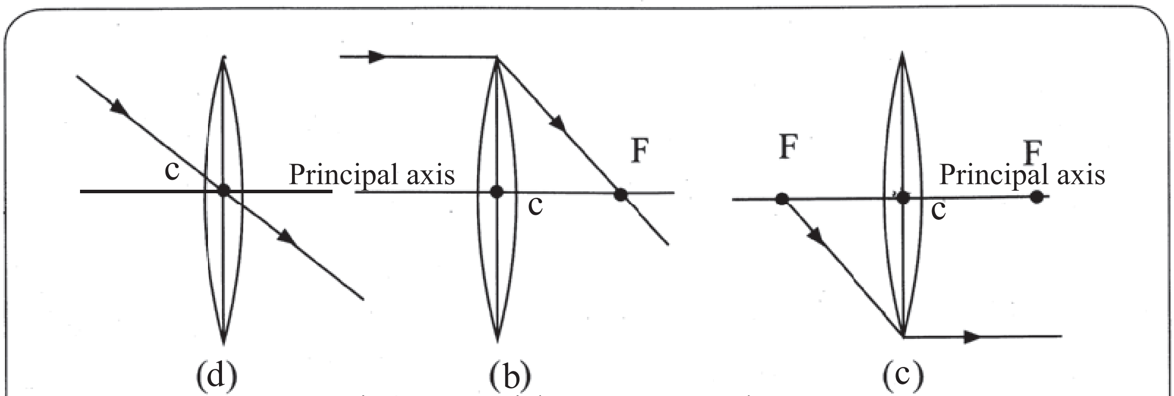


Fig. 2.41 special rays on convex lenses

In ray diagrams, any two of the above special rays are needed to fix the position of the image and its size.

**Worked example**

A ray diagram to locate position and size of an image formed by a convex lens is given below. Where: focal length of the convex lens = 4 cm

object distance = 6 cm

object height = 3 cm

Image formed is ;

- Real (can be taken on to a screen),
- Inverted,
- Magnifed

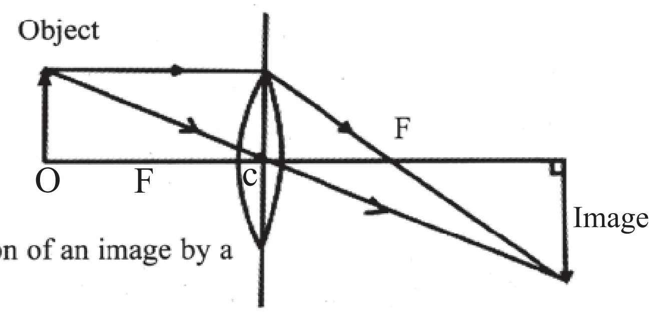


Fig 2.42 Formation of an image by a convex lens

**(ii). Special rays for concave lenses.**

1. A ray through the optical centre passes straight through the concave lens. (2.43 (a))
2. A ray parallel and close to principal axis diverge on as if it is coming from the focus. (2.43 (b))
3. A ray directed towards the focus after refraction goes parallel to the principle axis. (2.43 (c))

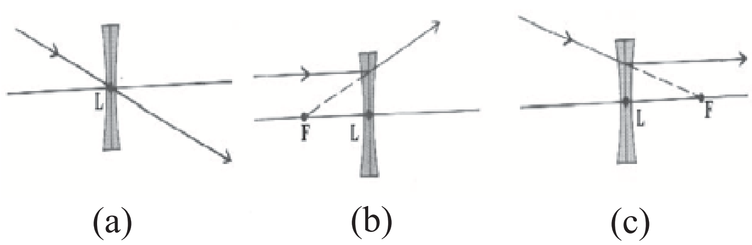


Fig 2.43 Standard rays for concave lenses

A ray diagram to locate position and size of image formed by a cancave lens is given in Fig. 2.43(d)

**Image is always;**

- Virtual (cannot be taken on to a screen)
- erect.
- diminished.

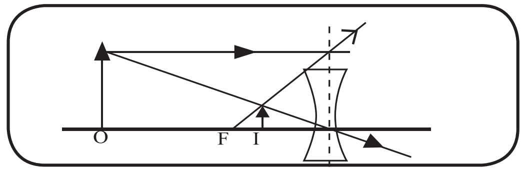
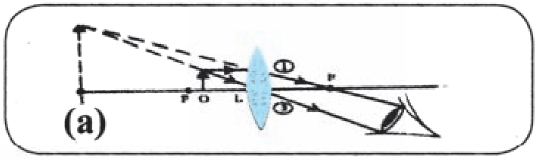
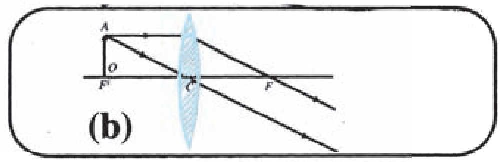



Fig 2.43 Image formed by a concave lens

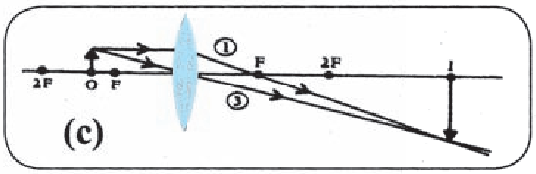
**Images formed by converging lenses**



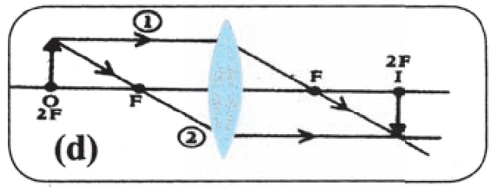

Object between F and C image; virtual, erect and magnified.Same side of the lens as object.



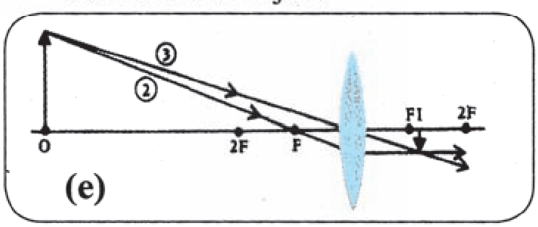

Object at F, image at infinity



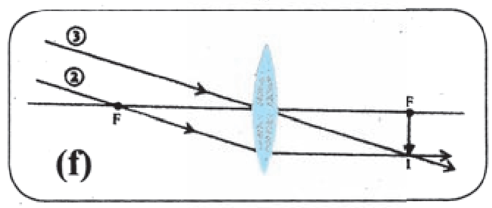

Object between F and 2F image: Real,inverted,magnified on opposite side of lens to object.




Object at 2F Image real, inverted same size as object opposite side of the lens to the object.




Object beyond 2F image:real, inverted, diminished, Opposite side of the lens to object




Object at infinity, image:real, inverted, diminished, opposite side of the lens to object

Fig 2.44

**Activity 2.12**

**Images formed by convex lenses**

Draw ray diagrams using the following data and describe size,position and nature of the images obtained in each case. For all ray diagrams take focal length of convex lens as 2 cm and height of the object as 2 cm.

1. The object distance 5cm (greater than 2f)
2. The object distance 4cm (equal to 2 f)
3. The object distance 3cm (between f and 2f)
4. The object distance2cm (equal to f)
5. The object distance 1cm(less than f)

Measure the distance and heights of the images in each case, record them and compare the results.

## Observing the images formed by convex lenses

**Activity 2.13**

Place a convex lens in front of a white wall. Keep a lighted candle in front of the lens, away from the wall. You would be able to get an image on the wall. Adjust the position of candle and the lens till you get a very clear image. Measure distance to the image and the object from the lens. Repeat the activity varying the object distance. Compare the results with Fig.2.45. Draw ray diagrams.

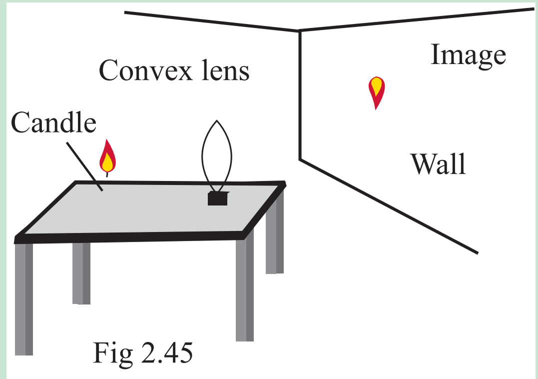



Fig 2.45

## Optical Instruments

### (1). Simple microscope

A convex lens fitted on to a handle is used to magnify small things. It is also called a hand lens or magnifying glass or a simple microscope.

**Activity 2.14**

**Using a convex lens as a simple microscope.**

Keep a convex lens on a support made by using thick wire as shown in fig 2.46. The paper with the letters to be seen magnified,can be placed between the support and the lens. If you look from above the lens, you can see the letters magnified. To get a very clear image of the letters,the placing of the paper can be adjusted.

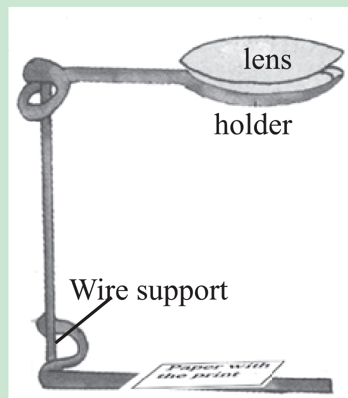



Fig 2.46

**Ray diagram to show how the magnified image is formed by the convex lens**

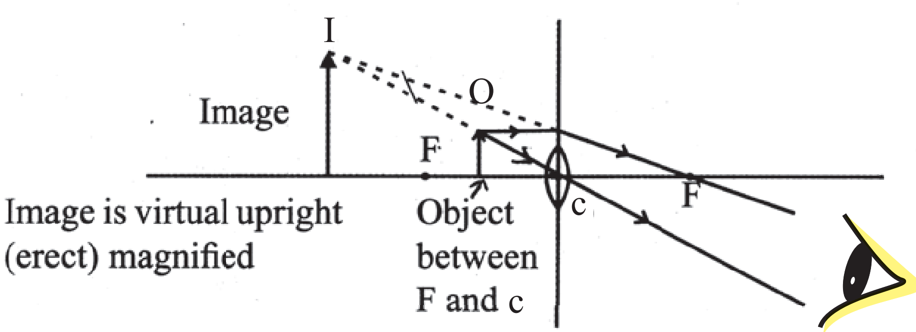



Fig 2.47
A magnified erect, upright image from a convex lens

## 2. Compound microscope

To increase the magnification, two lenses are used in a compound microscope. The first lens near the object (O) is called the objective lens. The second lens nearer to the eye is called the eyepiece lens .The objective lens is used to produce a real, inverted, magnified image $I_1$. Thus the object must be placed between $F_0$ and $2F_0$ of the objective lens. The eye piece lens is used to magnify the first image $I_1$. It acts as a magnifying glass. Thus the first image $I_1$ is the object for the eye piece lens and must be positioned between the lens and $F_e$. The final image formed by the eye piece $I_2$ is a virtual, inverted,magnified image of $I_1$. The combination of the two lenses produces a final image $I_2$ which is inverted compared with the object and (in normal adjustment)will be at a point near the object.

$F_o$-Focus of objective lens

$F_e$-Focus of eye piece lens

$I_1$-Inverted,magnified,real image formed by objective

$I_2$-Final image formed by eye piece

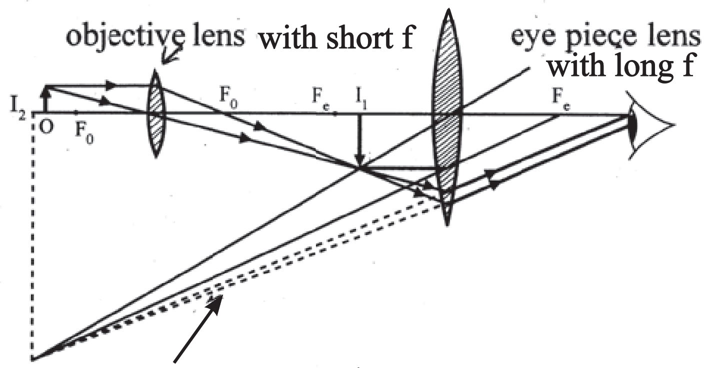



Fig 2.48

Ray diagram for laboratary compound microscope

### Different parts of the compound microscope

1. Microscope stage (platform)
2. The ray of light
3. Nose piece
4. Objective lens
5. Microscope tube (Optical tube)
6. Mirror
7. Coarse adjustment screw
8. Clip
9. Eye piece lens
10. Fine adjustment screw head

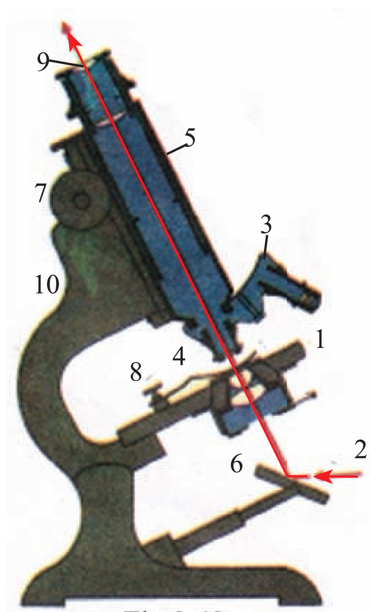



Fig 2.49
Compound microscope

### 3. Astronomical telescope

This is a refracting telescope which uses two converging lenses to produce an inverted virtual image at infinity (Fig 2.50 and 2.51)

**For your further knowledge**

**Objective** lens is a wide aperture, converging lens of long focal length. The large aperture enables to collect as much light as possible from weak distant sources. Acting like a camera taking a picture of a distant object, objective forms a real inverted image I, at its principal focus $F_0$. This image is diminished.

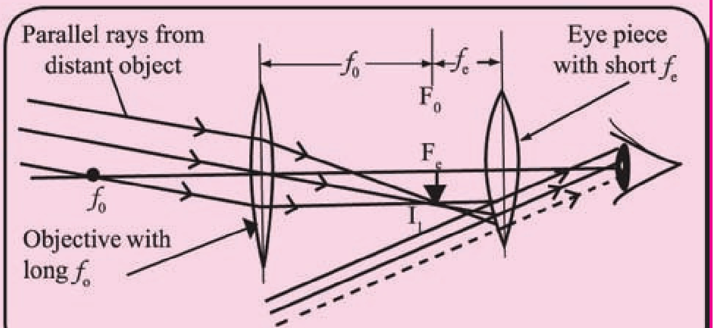


Fig 2.50 - Ray diagram for astronomical telescope

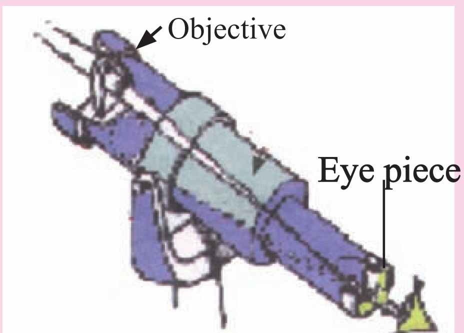


Fig.2.51 - Astronomical Telescope

**Eye piece** is a short focal lenghted converging lens, which acts as a magnifying glass. It is of usual practice to adjust the telescope so that the final image, like the object is at infinity. This is achieved by positioning the first real image I, to form a real object at the principal focus of the eye piece. The rays reaching the eye are parallel apparently coming from a virtual inverted final image at infinity.

### 4. Binoculars

The length of an astronomical telescope and the fact that its final image is inverted make it unsuitable for some applications. Two prisms are used in binoculars to overcome these problems. As shown in Fig 2.52, two prisms are placed between the objective and eyepiece lenses. They both shorten the length of the instrument by passing the light along the tube three times and also produce an erect final image. Total internal reflection through prisms is used here.

**The advantages of using a pair of prism binoculars over an astronomical telescope**

(i) Obtaining an erect image

(ii) The instrument is short and could be easily handled

(iii) A three dimensional view of the object is seen as both eyes are used

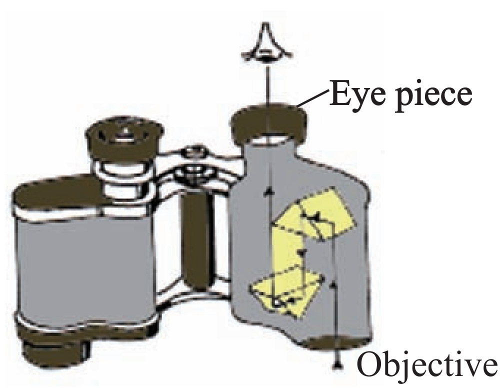


Fig.2.52 - Prism binocular

## 5. Slide projector

The slide projector contains a lamp and a concave mirror to make the object brighter. The lamp is placed at the centre of curvature of the concave mirror so that the rays of light are reflected back along their initial path. To give a brighter picture, a condenser is included. It is usually made of two plano- convex lenses as shown in Fig.2.53. As the light is converging towards the screen the film or the slide is illuminated brightly and evenly. The light is then scattered by the film or the slide and focussed by a convex (converging) projection lens on to the screen.

The film or the slide is placed between f and 2f of the projection lens so that the image is real, inverted and magnified. The film or the slide is put into the up-side down projector so that the picture is seen the right way up.

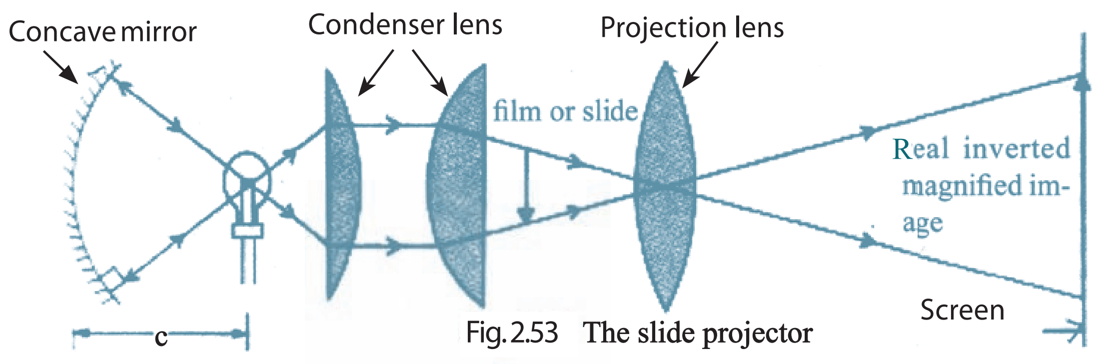



Fig. 2.53 The slide projector

## 6. Camera

The camera uses a converging lens(sometimes with combination of several lenses) to produce a real, inverted, diminished image on a light sensitive film at the back of the camera.Some important parts of a camera are shown in fig. 2.54 (a) and (b).

Fig. 2.54 (a) Camera

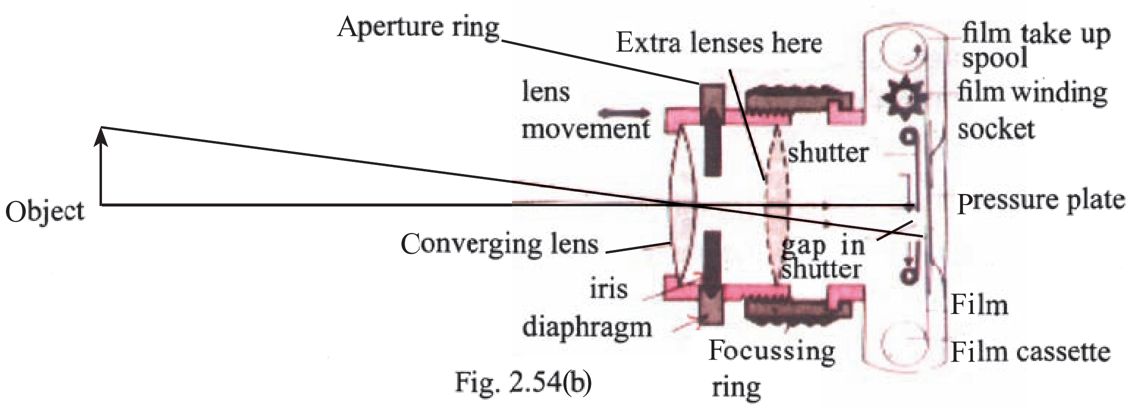



Fig. 2.54(b)

**The film**: A long thin strip wound from a cassette by a wheel on to a take -up spool and held flat by a pressure plate from behind. The light sensitive surface of the film which faces forwards can have different sensitivities for different intensities of light.

**Shutter**: When a photograph is taken, the shutter is opened for a certain time and exposes the film to light entering the camera. Sometimes exposure times can be varied and are given in fractions of a second. e.g.1/1000s, 1/60s etc. Fast moving objects require short exposure.

**Aperture**: The brightness of the image on the film depends on the amount of light passing through the lens,when the shutter is opened and controlled by the size of the hole(aperture). In some cameras this is fixed but others it can be made larger for a dull scene and smaller for a bright one. The aperture may be marked in f numbers .The diameter of an aperture with f number 8 is one eighth of focal length of the lens. Larger the f number,smaller the focal length.

### 7. Overhead projector (OHP)

An overhead projector (OHP) is a display system that is used to display images to an audience.

An overhead projector typically consists of a large box containing a very bright lamp and a fan to cool it off,on top of which is a large lens that refracts light. Above the box,on a long arm is a mirror that redirects the light forward instead of upwards.

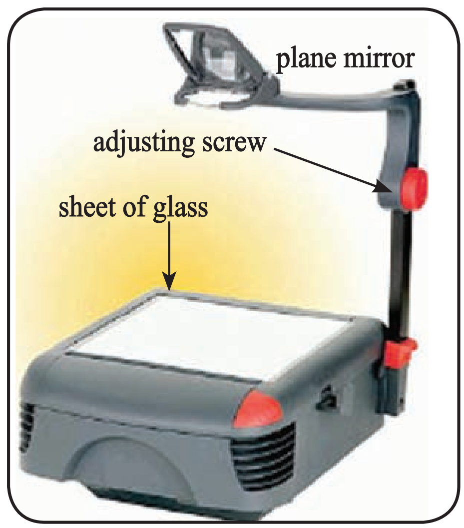



Fig. 2.55 - Overhead projector

Transparencies are placed on top of the glass stage for display. The light from the lamp travels through the transparency and into the mirror by which it is thrown forward onto a screen for display. While the presenter is looking down at the transparency and writing, the audience can observe the information by looking forward at the screen.

## Exercises

1. A man stands 10 m in front of a large plane mirror. How far must he walk before he is 5 m away from his image?

2. Mention the five (5) features of images formed in a plane mirror?

3. Make up two lists under "concave mirrors" and "convex mirrors" and list the following accordingly: shaving mirror, car head light mirror, search light mirror,driving mirror,dentists inspection mirror, torch mirror,projector lamp mirror,stair case mirror on a double decker bus,make up mirror, reflecting telescope mirror,solar shop security mirror.

4 (a) Draw a ray diagram to get the position of the image on a concave mirror of focal length 4 cm; object distance 5cm with an object of height 3 cm.
(b) Describe the (i) image distance(ii) size of the image and (iii) nature of the image.

5 A swimming pool appears to be 3 m deep. If the refractive index of water is 4/3 , what is the real depth?

6. An object of 4cm high is placed 15 cm from a convex lens of focal length 5cm. Draw a ray diagram on graph paper (full size or 1/2scale) to find the position, size and nature of the image.

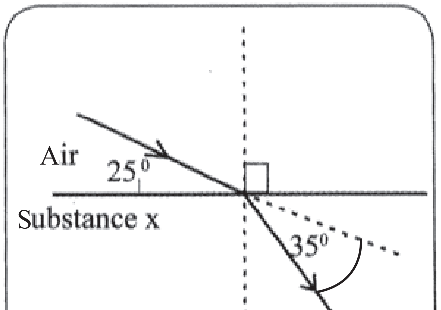


Fig. 2.56

7 (a) Using the diagram (Fig 2.56) calculate
(i) the angle of incidenc
(ii) the angle of refraction
(b) What is the refractive index of substance X?

8. State where an object should be placed if the image formed by a convex lens is to be
(a) large, up right and virtual
(b) real and smaller than the object
(c) real and larger than the object
(d) real and same size as the object

9 In an astronomical telescope
a) Where does the objective form an image?
b) What is the function of the eyepiece ?

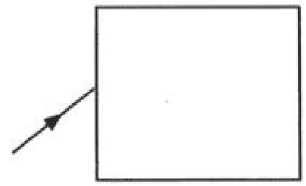
10 Write three advantages of a pair of binoculars have over an astronomical telescope.

11 How could you show that the colours of the spectrum combine to give white light?

12. The diagram (Fig 2.57) shows a ray of light entering a rectangular block of glass.

(a) Copy the diagram and draw the normal at the point of entry.
(b) Sketch the approximate path of the ray through the block and out of the other side.

Fig. 2.57



13. In Fig 2.58 two rays of light are shown entering a semi-circular glass block.

a) Why are they not bent at points P and Q ?
b) Copy the diagram and draw approximate paths to show what happens to each ray after it reaches (Critical angle of glass = $43^0$).

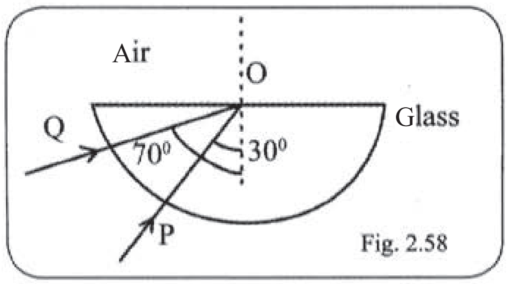


Fig. 2.58

14. Copy the diagrams given in Fig. 2.59 and fig. 2.60 and complete the paths of rays.

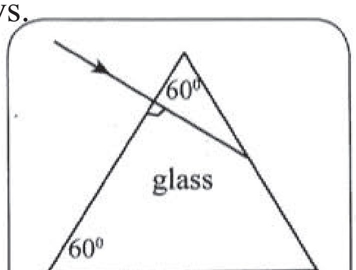


Fig. 2.59

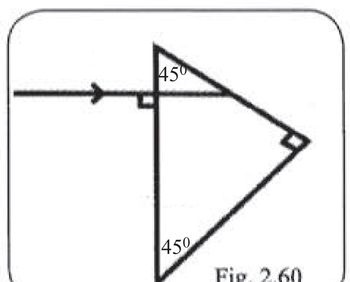


Fig. 2.60

15. Copy the diagram shown in Fig 2.61( a),(b) and (c) and complete the path of each light ray after it passes through the convex lens.

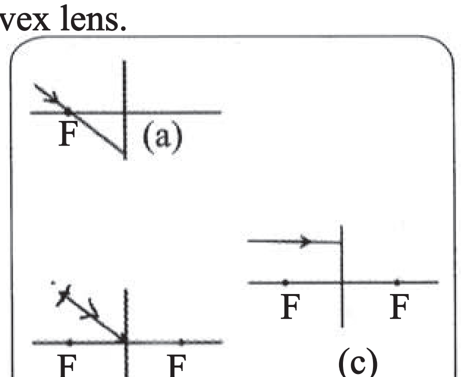


fig. 2.6.1