# 5 Light and Shadows

We interact with our surroundings through the five senses of touch, hearing, sight, taste and smell. Among these, sight is probably the most useful. We can see the world around us because something, which we call light, exists in nature. When the light from an object enters our eyes, we see the object. You will learn about the exact nature of light in higher classes. Here, we will study only how light is produced and how it behaves.

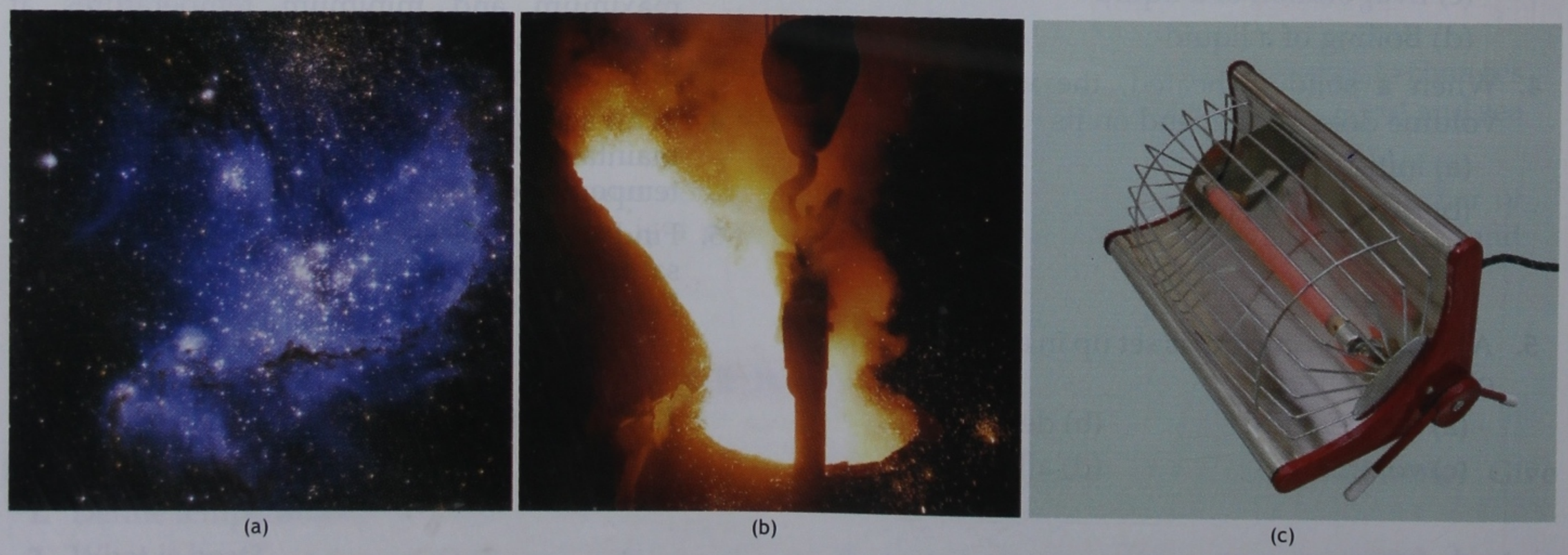
## SOURCES OF LIGHT

Anything that emits (gives out) light is called luminous, from the Latin word *lumen* for light. If it emits light on its own, without receiving any light from outside, it is called a source of light. During the day, the sun is our principal source of light. The flame of a candle, the filament of an electric bulb and a fluorescent tubelight are some other sources of light. All luminous bodies, however, are not sources of light. For example, the moon is a luminous body, but it does not emit light on its own. It reflects some of the light which reaches it from the sun. Thus, the moon is not a source of light.

Sources of light may be divided into three categories—high-temperature sources, fluorescent sources and bioluminous sources.

### High-Temperature Sources

When any material is at a high temperature, it emits light. The material may be a gas, liquid or solid.



(a) (b) (c)

**Fig. 5.1** Light is emitted by (a) the hot gases of stars, (b) molten iron and (c) the glowing coil of a heater.

In the chapter on heat we have discussed how a flame is produced by burning gases. We could also say that a flame is the light emitted by gases at a high temperature. The gases are raised to that temperature by the energy released in the chemical reaction of burning. However, burning, or combustion, is not the only reaction that can raise the temperature of gases to such a degree that they emit light. The sun and the stars, for example, are composed of very hot gases that emit enormous amounts of light, but the gases are not heated by combustion. The energy that raises them to very high temperatures comes from nuclear reactions.

The lava (molten rock) flowing out of a volcano glows a fiery red. So does molten iron in iron and steel mills. These are examples of hot liquids emitting light.

The filament of an electric bulb emits light because it is heated to a very high temperature by the electric current flowing through it. An electric bulb is also called an incandescent lamp. 'Incandesce' means to glow with heat. Other solids also emit light when they are very hot. For example, iron glows red when it is heated by a blacksmith. The coil of a heater also glows red when it is hot.

### Fluorescent Sources

Tubelights, CFLs (compact fluorescent lamps), large vapour lamps used for lighting in public places, and halogen lamps (halogens: a group of similar elements) used in automobile headlights are called fluorescent sources. They use different processes through which electrical energy is converted to light without producing too much heat.

(a) (b)

**Fig. 5.2** (a) Incandescent lamp, (b) halogen lamp, CFL and tubelight

### Bioluminous Sources

Some living organisms are able to produce small amounts of light. The process by which they do so is called bioluminescence, combining the Greek *bios*, which means living, with *lumen*. In this process, chemical energy changes directly to light, almost without producing any heat. That is why bioluminescence is also called 'cold light'. Deep in the oceans, where sunlight does not reach, a large number of small creatures use bioluminescence for many of their activities. Fireflies and some bacteria are also capable of bioluminescence.

## HOW LIGHT TRAVELS

Unlike sound, light does not need a material medium to travel. It can travel through vacuum, the way thermal radiation does. That is how it reaches us from the sun.

## Transparent, Translucent and Opaque Substances

Everyday experience will tell you that light can pass or travel through some mediums (materials) and not through others. Light can pass through clear glass, water and colourless polythene sheets, for example, but it cannot pass through wood, bricks or metals. Materials that light can pass through are called transparent. We can see through such materials because light from objects on the other side can pass through them and enter our eyes. Materials that light cannot pass through are called opaque. We cannot see through opaque materials because they block the light from objects on the other side.

There are some materials through which light can pass only partially. Such materials, for example, tracing paper and ground glass, are called translucent. We can see things dimly through such materials.

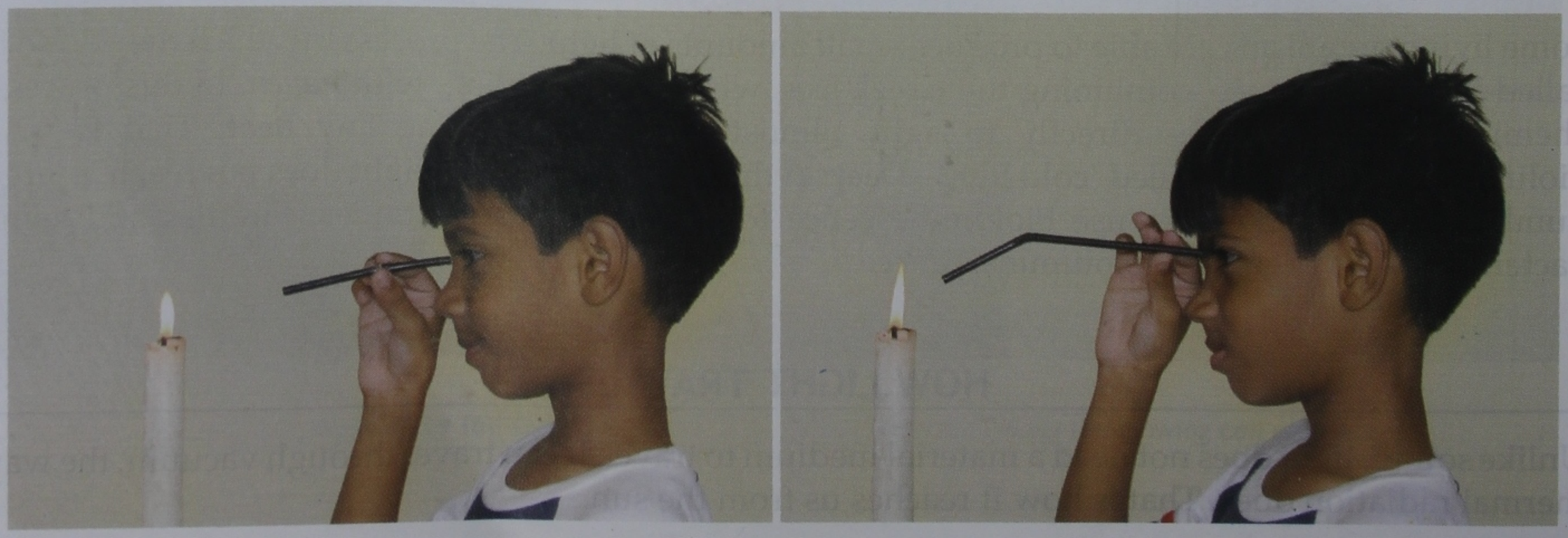
## Rectilinear Propagation of Light

On a misty night, you may have seen the beams of light from the headlamps of a car. Or you may have had fun watching the powerful beams of light rotated in the sky by circus companies or the organisers of a fair. You may even have seen beams of sunlight making their way through the clouds or through the leaves of trees. Perhaps you have noticed that all such beams of light are always straight. Light always travels in straight lines. This is called the rectilinear propagation of light.

Fig. 5.3 Light travels in straight lines.

ACTIVITY Look at a candle flame or an electric lamp through a drinking straw. Then bend the straw and try to look at

Fig. 5.4



the same object. You will not be able to see it because light will not be able to pass through the bent straw. You can try other variations, like looking at an object through a bent rubber tube. You will always come to the same conclusion—that light travels in straight lines.

## Pinhole camera

This simple camera works because light travels in straight lines. Make one yourself to see how it works.

**ACTIVITY** Take a toothpaste box. Use black chart paper to make a sleeve into which the box can slide. Fold in the flaps of the box and staple them to make a tube. Cut the tube into two unequal parts. Stick black chart paper and translucent sticky tape (or tracing paper) across the two parts, as shown in Figure 5.5. The sticky tape acts as the screen. Make a hole in the chart paper with a drawing pin. Stick the shorter tube to the sleeve. Then slide the other tube into the sleeve with its open end on the outside. Point the pinhole at bright objects, such as trees outside your window during the day, or an electric lamp at night. You will see inverted images of the objects on the screen.


Fig. 5.5

Look at Figure 5.6. You will see that rays of light coming from the top and bottom of an object cross the hole and continue to move in straight lines. Thus, rays from the top of the object fall at the bottom of the screen and those from the bottom of the object fall at the top of the screen. That is how the image formed is inverted.

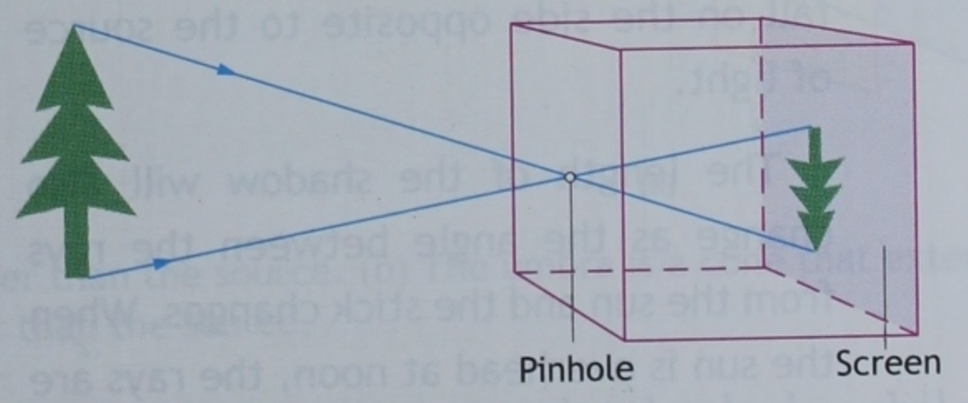



Fig. 5.6 The size of the image depends on the length of the camera.

You may try the following variations.

1. Point the camera at some object, and change the distance between the pinhole and the screen by sliding the movable part of the camera in or out. You will find that the size and brightness of the image changes with the distance between the pinhole and the screen.
2. You can check that the images of distant objects are smaller than those of objects nearby.
3. If you make the hole larger, you will find that the image becomes brighter but somewhat hazy.

## SHADOWS

A shadow is formed when an opaque object comes in the path of light. The opaque object does not allow light to pass through it, and light cannot bend around the object. Hence, the region behind the object is dark. This dark region behind an opaque object is the shadow of the object. Usually, we see a shadow when it falls on a surface, such as a wall or a floor.

Fig. 5.7 Usually, we see a shadow when it falls on a surface. Sometimes we can also see the shadow before it falls on a surface.

You may have noticed that the same object can form shadows of different shapes and sizes. The shadow formed by an object depends on many things, such as the relative sizes of the source of light and the object, the distance between them, and the nature of the source of light. Let us explore some things that determine the shape and size of a shadow.

**ACTIVITY** The shadow of a tree changes as the day progresses. To explore this, fix a stick upright in an open field. Observe the length of its shadow and the direction in which the shadow falls at different times of the day.

As the sun moves across the sky, the shadow will move from one side of the stick to the other. This should be obvious. The shadow will naturally fall on the side opposite to the source of light.

The length of the shadow will also change as the angle between the rays from the sun and the stick changes. When the sun is overhead at noon, the rays are almost parallel to the stick and the shadow is the smallest. When the rays slant the most, in the morning and evening, the shadow is the longest.

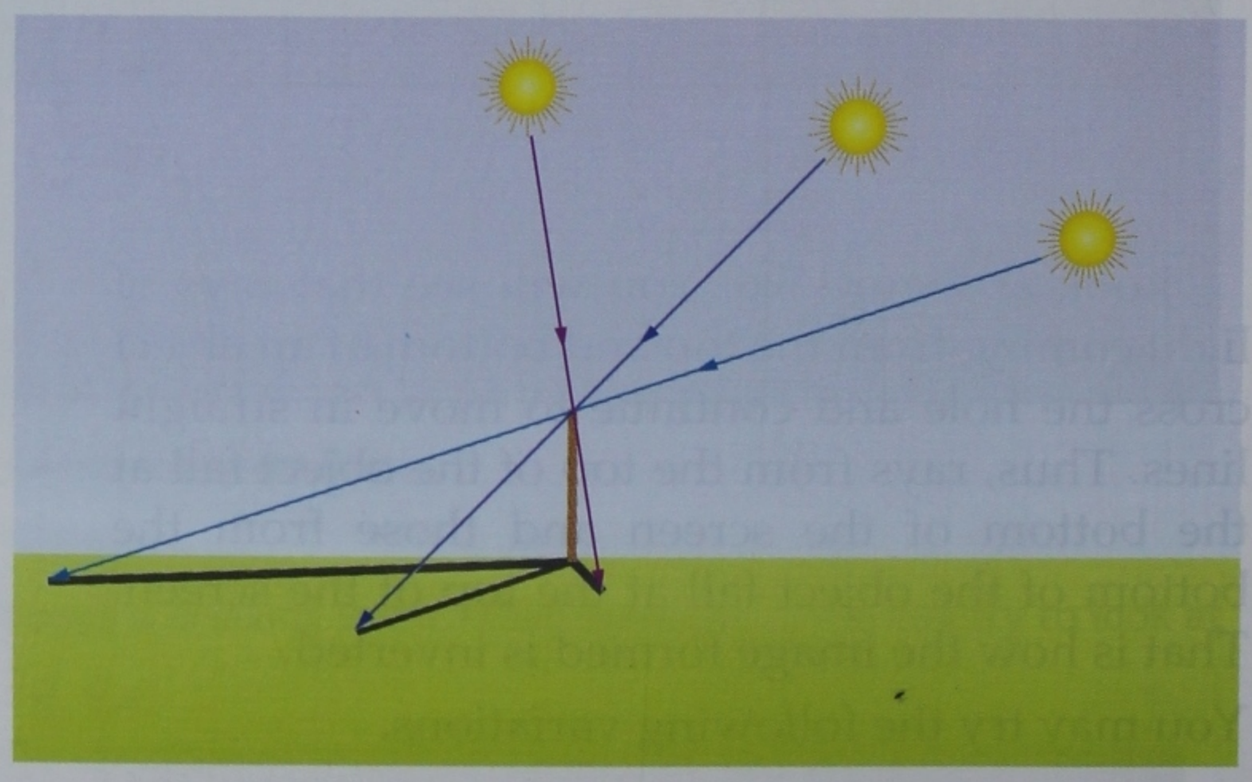


Fig. 5.8 The length of the shadow changes with the angle between the rays of the sun and the stick.

### Point Source

The kind of shadow an object forms also depends on the nature of the source. If the source is a point of light, called a point source, the shadow formed by an object that comes in the path of its light is completely dark. This is because the light spreading out from the point source is *completely* cut off from the region behind the object. This dark region is called the umbra or the umbral region.

If you place a screen (a surface) in the umbral region, you will see a completely dark shadow with sharp edges. The farther you move the screen from the object, the larger will be the shadow. The size

of the shadow will also change if you keep the screen fixed and move the object. The shadow will become larger as you move the object closer to the source.

The shape of the shadow also depends on the relative positions of the source, object and screen, or rather the angles between them. For example, if you hold a square sheet of cardboard in front of a point source, the shadow will be square only when the sheet and the screen are parallel. If you tilt the sheet or the screen a bit you will see a diamond-shaped shadow.

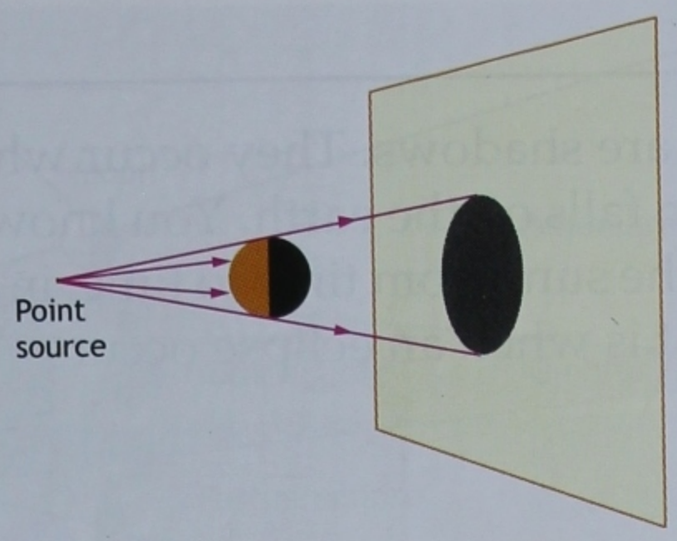
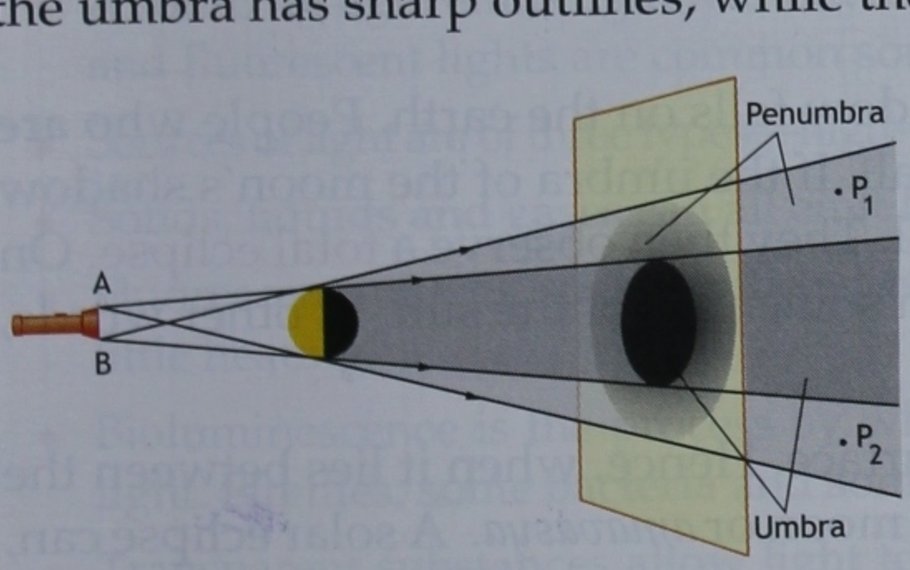



**Fig. 5.9** A shadow formed by light from a point source is completely dark. It becomes larger as you move the screen farther away.

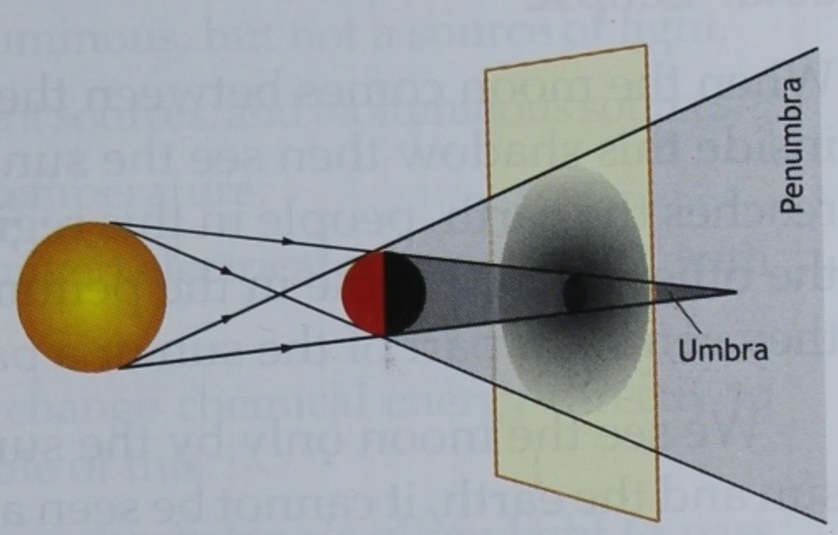
## Extended Source

Any source of light that is not a point source is called an extended source. In other words, an extended source has a finite size. The common sources of light around us are all extended sources.

When an object comes in the path of light from an extended source, the shadow formed by it has two distinct parts. There is a completely dark region called the umbra, surrounded by a comparatively lighter region called the penumbra. When such a shadow falls on a screen or a surface, the umbra has sharp outlines, while the penumbra looks fuzzy.




(a)




(b)

**Fig. 5.10** (a) The umbra extends indefinitely when the object is larger than the source. (b) The umbra is a cone that extends only up to a particular distance when the object is smaller than the source.

If you look at Figure 5.10(a), you will understand why the umbra is completely dark, while the penumbra is lighter. Light is completely blocked from the central region (umbra) of the shadow by the object. The outer region (penumbra) of the shadow, on the other hand, gets some light from the source. For example, the point $P_1$ in the outer region gets light from points like A in the upper portion of the source, but not from points like B in the lower portion of the source. The point $P_2$, on the other hand, gets light from points like B, but not from points like A. The region of the screen outside the penumbra gets light from the entire source.

Figure 5.10(b) shows what happens when the object is smaller than the source. The umbra is like a cone that extends only up to a particular (finite) distance. If you place a screen beyond this distance, you will not see a dark shadow. This is in contrast to Figure 5.10(a), where the object is larger than the source, and the umbra extends indefinitely into space. When birds and aeroplanes fly above the earth, the situation is as in Figure 5.10(b). The umbra is too small to reach the earth and we do not see a shadow.

# ECLIPSES

Eclipses are shadows. They occur when the shadow of the earth falls on the moon or the shadow of the moon falls on the earth. You know that the moon revolves around the earth, and together they go around the sun. From time to time, in the course of these travels, all three happen to be in one straight line. That is when an eclipse occurs.

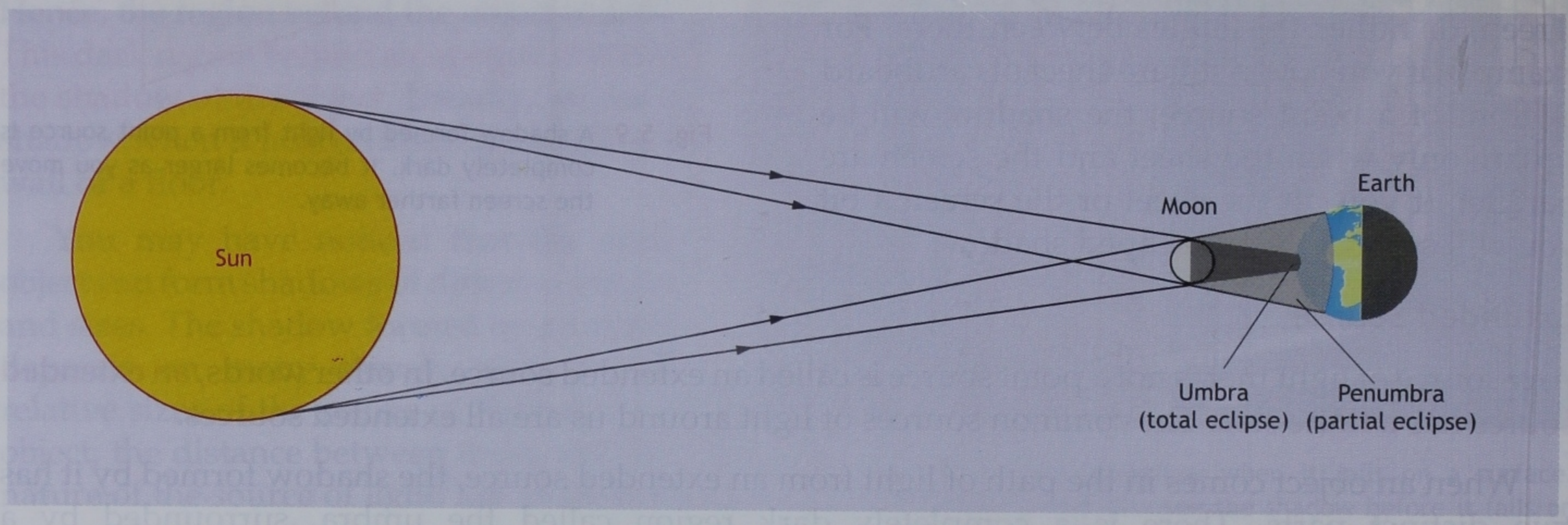



**Fig. 5.11** A solar eclipse can occur only on the day of a new moon.

## Solar Eclipse

When the moon comes between the sun and the earth, its shadow falls on the earth. People who are inside this shadow then see the sun either partially, or not at all. If the umbra of the moon's shadow reaches the earth, people in this region do not see the sun at all. They then observe a total eclipse. On the other hand, people in the penumbral region get light from some part of the sun. In other words, they can see a part of the sun or a partial eclipse.

We see the moon only by the sunlight reflected from its surface. Hence, when it lies between the sun and the earth, it cannot be seen at all. This is called the new moon or *amavasya*. A solar eclipse can, thus, occur only on the day of a new moon.

**ACTIVITY** You can see how a solar eclipse occurs. Shine a torch (sun) on a globe (the earth). Then hold a ball (the moon) between the torch and the globe. Move the ball back and forth to see how the shadow changes.

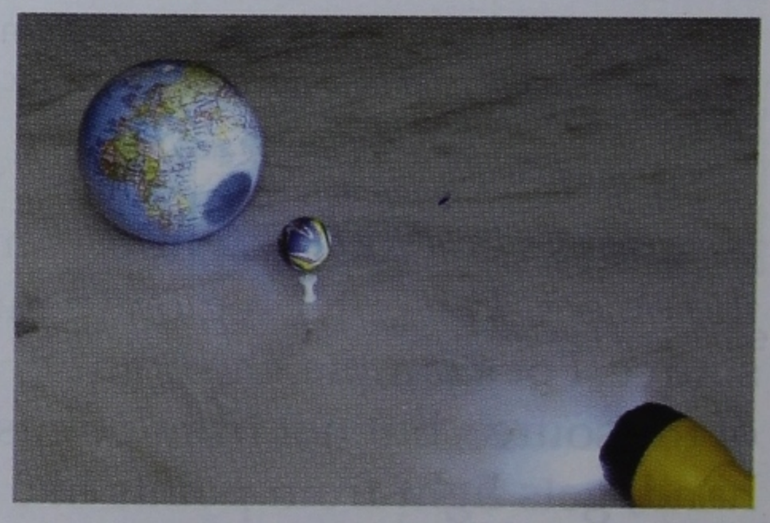


**Fig. 5.12**

## Lunar Eclipse

When the earth comes between the sun and the moon, the moon may pass through the umbra of the earth's shadow. When this happens, the moon becomes dark and there is a total lunar eclipse. If only a part of the moon passes through the umbra, there is a partial eclipse. And if the moon passes through the penumbra, it looks a little dull, but hardly dull enough for us to make out. You know that when

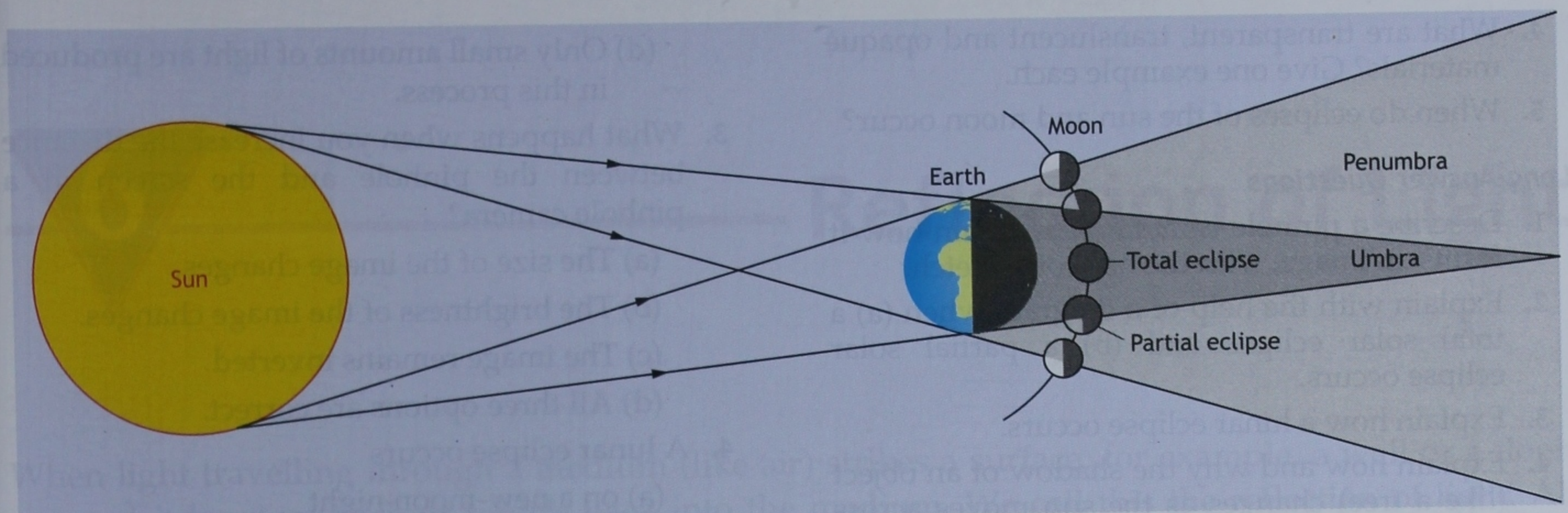



Fig. 5.13 A total lunar eclipse occurs when the moon passes through the umbra of the earth's shadow.

the moon lies opposite the sun we see its full face or there is a full moon. A lunar eclipse can, thus, occur only when the moon is full.

## POINTS TO REMEMBER

- A source of light emits light without receiving any from outside. The sun, burning objects, electric bulbs and fluorescent lights are common sources of light. The moon is luminous, but not a source of light.
- Sources of light are of three types—high-temperature sources, fluorescent sources, and bioluminous sources.
- Solids, liquids and gases can all emit light when heated to a high temperature.
- Fluorescent sources, such as tubelights, CFLs and halogen lamps, convert electrical energy to light, with little heating.
- Bioluminescence is the process by which some living organisms change chemical energy directly to light. Fireflies, some bacteria and some marine creatures are capable of this.
- Transparent substances allow light to pass through them. Translucent substances allow light to pass through them only partially. Opaque substances do not allow light to pass through them.
- The pinhole camera is based on the rectilinear propagation of light (the fact that light travels in straight lines). In such a camera, the size of the image changes with the distance between the pinhole and the screen.
- A shadow is formed when some opaque object comes in the path of light.
- The dark region of a shadow, where no light reaches, is the umbra. The lighter region that receives light from some part of the source is called the penumbra.
- Eclipses of the sun and the moon can occur only when the moon, the earth and the sun lie in one straight line.
- A solar eclipse occurs when the shadow of the moon falls on the earth, on a new-moon day.
- A lunar eclipse occurs when the earth comes between the sun and the moon, on a full-moon night.

## EXERCISE

*Short-Answer Questions*

1. Distinguish between a luminous object and a source of light.
2. Name the three types of light sources, with one example each.
3. What is bioluminescence?

4. What are transparent, translucent and opaque materials? Give one example each.
5. When do eclipses of the sun and moon occur?

### Long-Answer Questions

1. Describe a pinhole camera and explain how it forms an image, with the help of a sketch.
2. Explain with the help of a diagram when (a) a total solar eclipse and (b) a partial solar eclipse occurs.
3. Explain how a lunar eclipse occurs.
4. Explain how and why the shadow of an object (like a tree) changes as the sun moves across the sky.

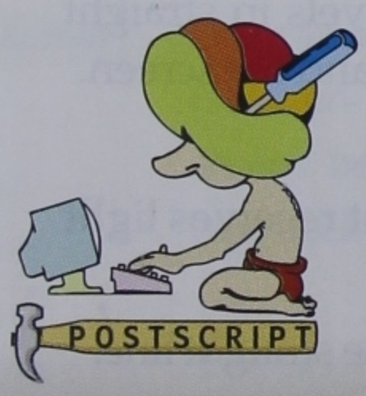
### Objective Questions

*Choose the correct option.*

1. A pinhole camera works because
   (a) light travels in straight lines
   (b) transparent materials allow light to pass through
   (c) opaque objects do not allow light to pass through
   (d) translucent materials form images
2. Which of the following is not true of bioluminescence?
   (a) It is a process by which some organisms emit light.
   (b) It can be called 'cold light'.
   (c) Heat is converted almost completely into light in this process.
   (d) Only small amounts of light are produced in this process.
3. What happens when you increase the distance between the pinhole and the screen in a pinhole camera?
   (a) The size of the image changes.
   (b) The brightness of the image changes.
   (c) The image remains inverted.
   (d) All three options are correct.
4. A lunar eclipse occurs
   (a) on a new-moon night
   (b) on a full-moon night
   (c) when the moon is waxing
   (d) on any night

*Fill in the blanks.*

1. The umbra extends indefinitely into space when the object is ..... than the source of light.
2. The part of a shadow that receives light from some part of the source is called ..... .
3. When you increase the size of the hole in a pinhole camera, the image becomes ..... .
4. The dark region behind an opaque object is called the ..... of the object.
5. When the object is smaller than the source, the umbra is like a ..... that extends to a finite distance.
6. CFLs convert electrical energy into light without producing much ..... .




You can actually 'see' that light travels in straight lines. Take some water in a glass and add a drop of milk. Let a beam of light from a laser pointer or a powerful torch pass through the water. You will see the path taken by the beam of light. Alternatively, trap some smoke from a joss stick (*agarbatti*) in a bottle or glass, and let the beam pass through it.