CHAPTER 17

Reflection of Light

17.1 INTRODUCTION

Light has played an important part in the evolution of humans since the beginning of time. Light from the Sun has supplied the energy for plants to photosynthesise, thus producing plant growth and food for animals and humans. A by-product of this, if it can be called such, is the production of oxygen — a necessary ingredient for sustaining life on Earth.

Over the past two decades energy from sunlight has played an important part in the conservation of other forms of energy. The development of non-polluting forms of energy will add to our quality of life. Use of solar energy will play a major part in our energy needs in the future. Light energy from the Sun is used to provide energy to heat water in solar hot water systems, reducing the dependence on coal-burning electricity production. Light is used in the production of solar electricity — electricity used to provide energy for remote telephone boxes, to fuel cars that race experimentally, and for energy-conscious households of the future.

But light has a more important use — it allows us to see. It allows us to identify objects, see colours and in most cases to choose our partners.

Scientists have developed many devices that enhance our perception of the world around us, with the development of mirrors and lenses that allow us to see better — glasses; to see further — telescopes and binoculars; and to see finer detail — microscopes. This is the content of this chapter and the next three chapters: Optics — the study of light and devices that use light.

A study of mirrors and lenses will enable you to answer questions such as:

- Where is light energy being used today?
- How can we concentrate light energy to be able to use it?

17.2 THE PRODUCTION OF LIGHT

Light energy can be converted to other forms of energy and vice versa. Light energy from the Sun is converted into chemical energy stored in plants, as well as into heat energy, and electrical energy. Other forms of energy such as heat energy and electrical energy are converted into light energy, such as when a light is turned on. Objects that emit their own light energy such as light bulbs, light from a star, or even a hot flame are called **luminous** objects. But these are few, because we see most objects by the reflection of light. When a light source illuminates objects they reflect light to our eyes; these objects could not be seen in a dark room. These are **non-luminous** bodies.

Light travels at a speed of 3×10^8 m s^{-1} in a vacuum and, contrary to Newton's original proposal, at a slower speed in water, glass, or any other medium.

17.3 LIGHT RAYS

Contrary to the belief of small children and our early ancestors, we see objects because light from these objects travels to our eyes, and not the other way around. It is no use covering your eyes, the 'bogey man' will still be there and able to see you.

To determine the position of an object requires narrow beams of light, **light rays**, to reach your eye, preferably your two eyes. Your brain traces these rays back to where they appear to meet. This, your brain tells you, is where the light originates. The wider the base for triangulation the better the positioning of the object. We call this 'stereoscopic vision'.

EI Activity 17.1 DEPTH PERCEPTION

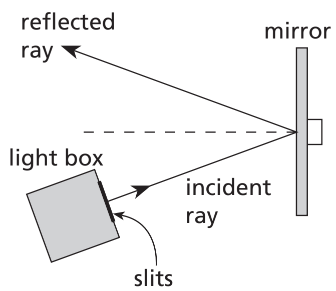
1. Ask a partner to hold up a finger within your reach.
2. Close one eye and try to touch your finger on the top of theirs.
3. How close did you get?
4. Try this again with both eyes open.
5. How close did you get this time?
6. Is one eye better than the other?

When only one eye is open, rays enter this eye at either side of the pupil, creating a narrow base and producing poor depth perception. With both eyes open, the base for triangulation is greater and so is the depth perception. Animals and fish that are hunters have eyes placed wide apart on the front of their heads so as to improve depth perception.

We use rays of light to determine where objects or images are. Rays of light travel in straight lines from objects. Importantly, rays from distant objects are close enough to be considered parallel.

Light boxes are common devices used to produce thin beams or rays of light for the investigation of optics in the laboratory (Figure 17.1).

Figure 17.1
Light boxes that produce thin beams of light (rays) are used in laboratory optical investigations.



A **laser** is another device used to produce thin beams of light. These also have the added convenience of emitting light of one wavelength. Laser stands for 'light amplification by stimulated emission of radiation'. Briefly, light is produced when the atoms of the laser medium are excited by electrical discharges or intense light flashes. When these atoms return to their unexcited state they give off energy in the form of light of a particular frequency and phase. Notice that you cannot see the light of a laser or even the light from a light box unless it strikes a wall or an object, as your eye and brain only respond to light when it strikes your eye. However, the following activity will allow you to see the laser beam without looking directly into it **as this is very dangerous and can damage your eye.**

EI Activity 17.2 LASER LIGHT

1. Place a laser at one end of the laboratory and turn it on so the beam strikes the wall at the other end of the room.
2. Hit a chalk-filled duster with a ruler around the area where the beam passes.
3. What do you notice?
4. Try to explain why this occurs.

PLANE MIRRORS 17.4

Plane mirrors normally consist of flat pieces of glass that have their backs coated with a thin layer of aluminium, and with lacquer to stop the aluminium from flaking. However, up until 1857 mirrors mainly consisted of highly polished pieces of steel. In that year Jean Foucault developed a method of silvering glass to make mirrors, thus producing a lighter and better-quality mirror than the common polished metals ones that tarnished. This brought about large advances in the development of astronomical telescopes.

producing a blurred focal point rather than a sharp point. This defect of curved mirrors is called spherical aberration. It occurs more often when the mirror is large. It can be overcome by using smaller aperture mirrors or by only using the central region of larger mirrors. Special larger parabolic mirrors whose geometry results in the sharp focusing of parallel light are also manufactured to overcome this defect (Figure 17.23).

17.8 USES OF CURVED MIRRORS

Concave mirrors

- Concave mirrors are also used to produce magnified images so as to observe more detail in objects. Recall that if an object is inside the focal length then it produces an upright magnified image. Larger focal length concave mirrors are therefore used as shaving and make-up mirrors. Small concave mirrors are used by dentists.
- Concave mirrors are used as the reflectors in a number of applications where parallel or almost parallel light is required. If the light source is placed at the focal point of the mirror almost parallel light will be produced; for example, reflectors in headlights of cars, torches, and searchlights.
- Concave mirrors, because they bring together (or focus) light rays, are used to collect light energy as well as other forms of energy. Solar furnaces or ovens use large concave mirrors to concentrate light energy from the Sun onto pots and kettles placed at the focus. The biggest solar furnace in the world is located in the Pyrenees mountains in southern France. An array of computer-controlled plane mirrors (heliostats) on a nearby hill track the Sun and reflect the light onto an eight-storey-high converging mirror. The converging mirror focuses the sunlight onto a small building housing the solar furnace. Temperatures in excess of 3000°C have been reached in this experimental furnace.

  Concave mirrors are also used to concentrate other electromagnetic radiations such as radio and TV waves. Satellite dishes concentrate TV waves to be used by TV sets. Radio waves from stars can be focused onto the antennae placed at the focus of the receiving dish, which conducts the signal to an amplifier. (See Photo 17.2.)
- The same principle applies to astronomical telescopes. Larger optical reflecting telescopes concentrate visible light energy to the focus, where the eye piece or photographic equipment is placed. (Refer to Chapter 20, Optical Instruments.)
- Interestingly enough, because sound is so important to bats, bats' ears are concave in shape to collect and concentrate sound energy.

Photo 17.1
Torches use concave mirrors to produce a nearly parallel beam of light.

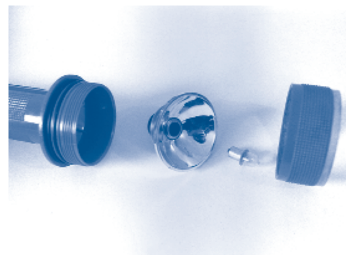


Photo 17.2
Satellite dishes enable TV sets to pick up TV waves that are reflected from satellites by concentrating TV waves on to an aerial.

Convex mirrors

Convex mirrors, because they have a wider field of view than plane mirrors and produce upright images, are used as rear-vision mirrors in cars; however, they have a disadvantage in that distances can be misjudged. They are also used on intersections of streets where vision is obscured. This allows drivers to see around 'blind' corners.

Because of their wide field of view they are also used in shops for security purposes.

Photo 17.3
Bats' ears are concave to collect reflected ultrasound waves.

Practice questions

The relative difficulty of these questions is indicated by the number of stars beside each question number: * = low; ** = medium; *** = high.

Review — applying principles and problem solving

***14** White paper or the desk top does not produce an image of an object. Does this mean the laws of reflection are not true for these surfaces? Explain!

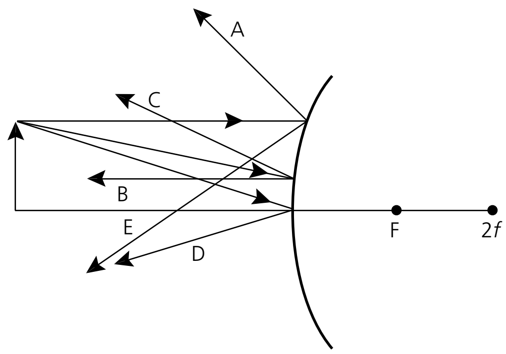


Figure 17.30
For question 35.

Extension — complex, challenging and novel

***38 A plane mirror and a convex mirror are placed facing each other and 50 cm apart. A candle is placed on the principal axis 20 cm from the plane mirror, as shown in Figure 17.31. If the distance between the two images in the plane mirror is 40 cm, calculate the focal length of the convex mirror.

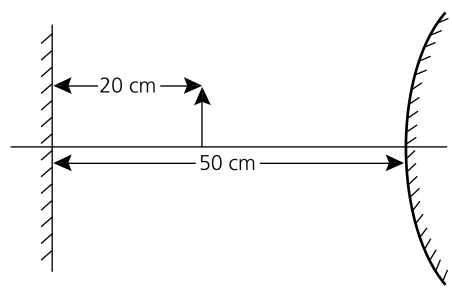


Figure 17.31
For question 38.

***39 An object is placed 20 cm in front of a convex mirror of focal length 30 cm. A plane mirror is placed between the object and the mirror so that the image of the top half of the object in the convex mirror and the bottom half of the object in the plane mirror coincide. What distance is the plane mirror from the convex mirror?

***40 A candle is placed in front of a concave mirror whose focal length is 20 cm. Find the position of the object and the image if **(a)** a virtual image of twice the size of the object is produced; **(b)** a real image of twice the size of the object is produced.

***41 Students determining the focal length of a concave mirror obtained the measurements listed in Table 17.2 for the distances of the object and the image formed on the screen. Plot the graph of image distance against object distance to determine the focal length of the mirror.

Table 17.2

Object distance (cm)	60	50	40	30	25	20	15	10
Image distance (cm)	9.2	9.5	10	10.9	11.8	13.3	17.1	40