2.1 Light

Why can you hear your friends if they are standing round a corner but you cannot see them? What form of energy enables you to read this page? Light enables us to see but you cannot see something unless light is shining on it.

> Light from the Sun takes 8 minutes to reach the Earth. If you travelled in a car at over 160 km/hr it would take you more than a hundred years to cover the same distance.

> Lightning flashes can be 30 km long.

Light

Light is the form of energy which enables us to see objects, as our eyes are sensitive to it. It is part of the **electromagnetic spectrum** and travels at a speed of 300 000 000 m/s (see Section 4, chapter 1 for a definition of speed).

Sound is very slow compared with light. It travels at only 330 m/s. If you are watching a race you can see the smoke from the starting pistol before you hear the sound. Thunder and lightning happen at the same time. You see the lightning before you hear the thunder. This is because sound travels so much slower than light. You can roughly estimate how far away a thunderstorm is by counting the number of seconds between the lightning flash and the thunder. The larger the number you count the further away the storm is. The storm will be 1 km away for every three seconds that you count.

Light is an energy wave. This type of wave is called a **transverse wave** and all the forms of energy in the electromagnetic spectrum travel this way.

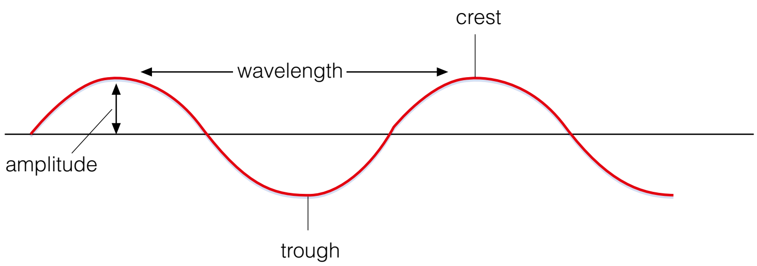

Figure 1.1 *A transverse wave.*

Luminous and illuminated

Imagine being in a very dark cave. It is impossible to see anything unless you strike a match or turn on a torch. The match and the torch give off their own light: they are called **luminous** objects. Your computer screen or a burning candle are also luminous objects. The light from these will hit other things around you and bounce into your eyes. This light will illuminate these things and you will be able to see them. Some source of light is illuminating the page you are reading.

The stars are luminous but the planets and the moon are **illuminated** by light from our star, the sun. Moonlight is really light reflected from the Sun. Jupiter and Venus can be seen at night because they are illuminated by the Sun and reflect the light.

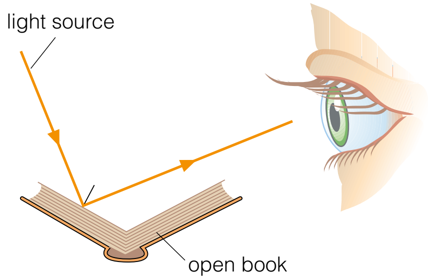

Figure 1.2 *The light is hitting the object and reflecting into the eye.*

Rectilinear propagation

A car headlight will not light the road round a corner. This is because light travels in straight lines. We call this **rectilinear propagation**. In Figure 1.3 you can see the light travelling out from behind the trees. Can you think of any other way to show that light travels in straight lines?

Figure 1.3 *Light travels in straight lines.*

Shadows

You cannot see through a brick wall. This is because the brick will not allow light to go through it. It is **opaque** to light. Windows will allow light to go through them: they are **transparent**. A frosted bathroom window will let some light through. It is **translucent**.

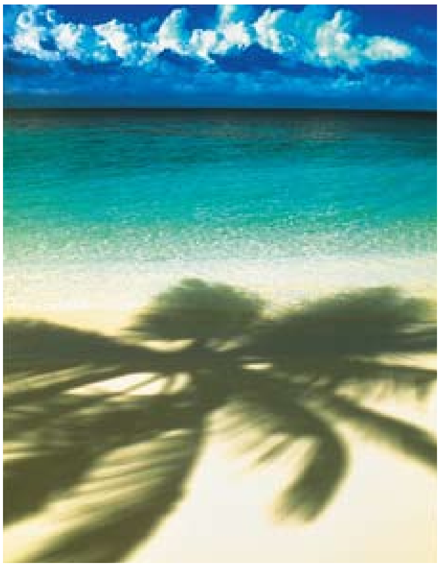

Figure 1.4 *The tree is blocking the light and casting a shadow onto the sand.*

The shadow of the palm tree on this beach is fuzzy, because the top of the tree is several metres above the sand. If you were to hold your hand out just above the sand, the shadow of your hand would be clear and sharp.

2 Which of the following are luminous:

a) cat
b) torch (switched on)
c) Halley's comet
d) stained glass window? *[4]*

Figure 1.5a) shows a clear dark shadow is being cast on the screen. This is because the object is stopping all the light and only light round the edge is hitting the screen. This type of shadow is an **umbra**.

If the light source is large in comparison with the object, some of the light around the edges is getting through and the shadow is no longer clear and sharp. The grey fuzzy shadow is called the **penumbra**.

3 How does an umbra shadow show that light travels in straight lines? *[2]*

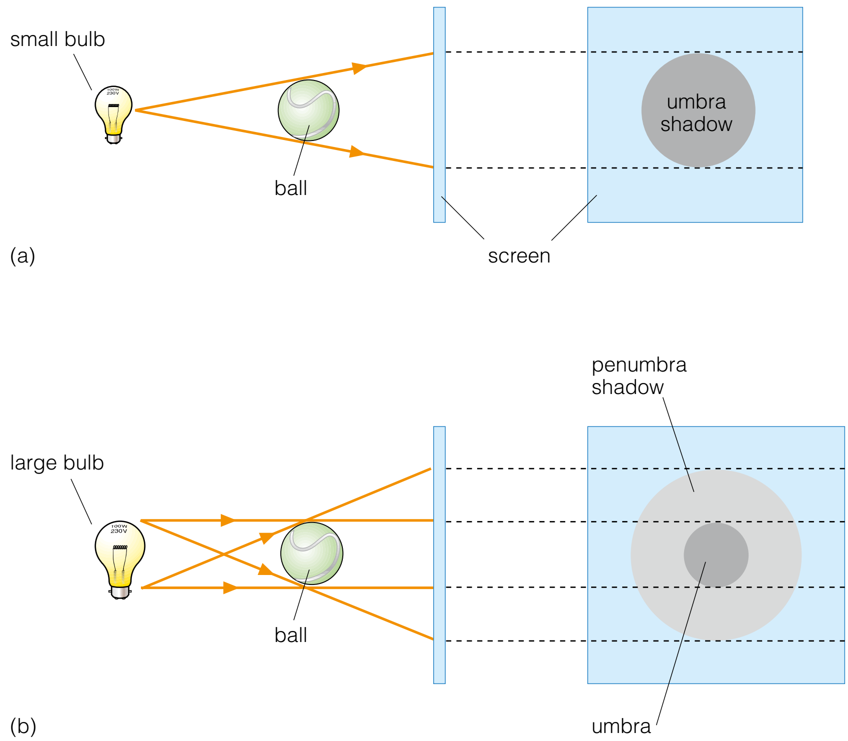

Figure 1.5 *The formation of an a) umbra and b) penumbra.*

Summary

- Light is part of the electromagnetic spectrum.
- A luminous object gives off its own light.
- An object that reflects light is visible when illuminated.
- Light travels in straight lines.
- Light travels very much faster (300 000 000 m/s) than sound (330 m/s).
- Light is reflected off objects into our eyes.
- Opaque objects can block light and cast shadows.

2 Different types of telescope

Figure 1 *A photo of Saturn from the Hubble Space Telescope.*

! When it was first launched, in 1990, the Hubble Space Telescope primary mirror was incorrectly manufactured. A space shuttle repair mission was sent up in 1993, and added a sequence of correcting mirrors to overcome the problem.

Looking at the sky

The telescope was probably invented in Holland late in the sixteenth century but it was Galileo Galilei (1564-1642) who turned it into a useful instrument. He ground the lenses of his telescope with care and positioned them in a long tube. He found that when he looked into the sky he could see things that nobody had seen before. He observed that the Moon has mountains, that Jupiter has its own moons and that the Sun has spots. Other people copied Galileo's designs and their astronomical discoveries helped to convince most people that the Earth and the planets orbit the Sun.

More powerful telescopes need bigger lenses, but big lenses can produce distorted images. Isaac Newton (1642-1727) designed a telescope that used curved mirrors – a reflecting telescope. This kind of telescope could be made very large without distorting the image and could be used to see very distant objects in space. All the major astronomical telescopes today, including the Hubble Space Telescope, are based on Newton's design. The Hubble Space Telescope was put into orbit by the space shuttle in 1990 and orbits the Earth at a height of 610 km. Since its launch it has taken many pictures of stars, many of which had never been seen before.

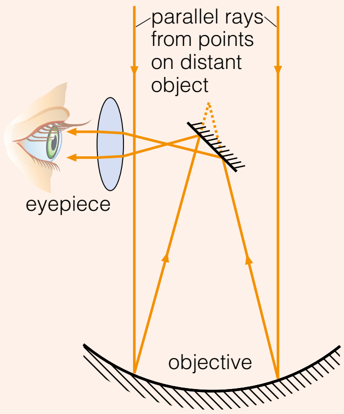

Figure 2 *How a reflecting telescope works.*

Astronomy across the spectrum

Stars give out energy in the form of electromagnetic (EM) waves. This means that we can see the visible light that comes from them but that they actually emit waves right across the EM spectrum. People have designed devices to detect each type of electromagnetic wave, and so it is now possible for astronomers to look at stars and galaxies in every part of the EM spectrum. Indeed, the Hubble Space Telescope can actually detect infra-red, visible light and ultra violet radiation.

? **1** Why did Newton design his telescope using mirrors instead of lenses? *[3]*

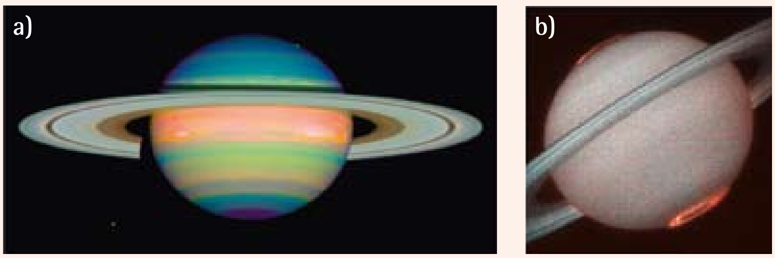

Figure 3 *The Hubble Space Telescope can take pictures in UV, IR or visible light (Figure 1). Here Saturn is viewed in a) UV b) IR.*

Radio Astronomy

As a very rough rule of thumb, a detector of electromagnetic radiation needs to be about the size of the wavelength of the wave to be effective. The light sensitive cells in your retina are similar to the size of the wavelengths of light that they can detect. So to detect the radio or microwave emissions from stars, we need to use much bigger detectors, as these wavelengths can range from one millimetre to several metres. This is why radio telescopes are such large dish shapes. Indeed, some radio telescopes work together so that the size of the detector is as long as the distance between them, which may be many kilometres.

Figure 4 *The Very Large Array (VLA) radio telescope in New Mexico has twenty-seven, 230 ton, 25 metre diameter radio dishes that work together.*

! Radio wavelengths over ten metres cannot penetrate our atmosphere.

? **2** Why are radio telescopes much larger than visible light telescopes? *[1]*

X-ray and gamma ray astronomy

X-rays and gamma rays are also emitted by stars, but very few penetrate our atmosphere. This means that these areas of astronomy have only developed in the last 50 years since we could put detectors onto high altitude balloons, or satellites in orbit around Earth. The detectors used are very similar to those for detecting radio emissions.

! Black holes and neutron stars do not emit visible light so cannot be detected using light telescopes. We therefore have to detect them using their emissions in other parts of the EM spectrum, such as the X-rays given off from material as it accelerates into a black hole.

Questions

1 Why have X-ray and gamma ray astronomy only developed in the last 50 years, whilst visible light telescopes have been in use for centuries? *[Total 2]*

2 Pick one part of the electromagnetic spectrum and describe how astronomy can be carried out using that part. *[Total 3]*

3 a) Suggest what problems there are with telescopes on the ground, that are not present for telescopes mounted on satellites? *[2]*

b) Suggest what difficulties there are with telescopes on satellites, that are not present for telescopes on the ground? *[2]*

[Total 4]