CHAPTER 13

Wave Motion in One Dimension

13.1 INTRODUCTION

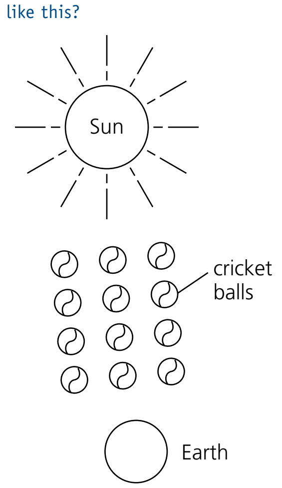
When a prize fighter trains by hitting a punching bag, energy travels from the closed fist to the bag, and if someone is holding the bag, to that person.

When a baseball is hit, energy travels with the ball to the person who catches it. The amount of energy it carries can be felt by the stinging of the hands.

But how does light energy travel from the Sun to be used by solar cells on Earth? Is the energy carried by moving cricket balls, perhaps?

There seems to be no particle like a fist or a ball to carry the energy — at least no visible particle. Where the answer lies may be seen by observing a surfboard rider in the ocean. As the unbroken wave passes the rider, he or she goes up and down but does not move forward. However, this water wave carries energy — very much energy. Consider the energy carried by a 'tidal wave'. (A poor or misleading term. A giant wave produced in the ocean often by volcanic activity or earthquakes is called a 'tsunami', and has nothing to do with the normal tide movements.) One of the largest tsunamis recorded was caused by a volcanic explosion on the island of Krakatoa on 27 August 1883. The resulting 40 m high tsunami lashed the coast of Indonesia killing some 36 000 people. This tsunami was even registered by the tide gauges in the English Channel. Tsunamis created this way often cause more deaths than the disturbance that created them. As tsunamis often cause havoc in Japan, Hawaii, and other Pacific Islands, great efforts are made to detect the epicentre of the earthquakes by measuring wave velocities. This allows determination of the expected time of arrival of the tsunami so people in low-lying areas can be warned and evacuated.

Figure 13.1
Does the energy from the Sun come like this?



The above is one example of wave motion in nature. There are many more examples. Can you think of some?

The understanding of waves is also important in modern-day conveniences. Water beds have baffles in them to stop waves when a person rolls over. Wave generators are being used to create waves in theme parks for the entertainment of patrons. The motion of the waves in oceans is one of the latest methods of generating electricity.

So waves can carry energy, but how do they do this?

13.2 WAVES

Waves are classified according to the method of transfer of energy. If a medium is required for the transfer of energy, then the waves are called **mechanical** waves. If no medium is required and the waves are able to travel through a vacuum, then the waves are called **electromagnetic**. In this chapter we will discuss only mechanical waves, while in Chapter 15 forms of electromagnetic waves such as radio waves, light and X-rays will be discussed.

A good working example of a mechanical wave can be created by dropping a stone in a pool of water. A circular wave is seen to radiate outward from the point the stone enters the water. In this case water is the 'medium'.

Photo 13.1
Circular waves produced when a stone is dropped into a pool.

Notice that, to create the wave, you have to create a **disturbance** in an undisturbed medium. The wave continues to go outward until it runs out of energy. How is this loss of energy seen? The height of the wave is called the **amplitude** of the wave. It is the maximum displacement of the wave from its equilibrium position shown as '*A*' in Figure 13.2.

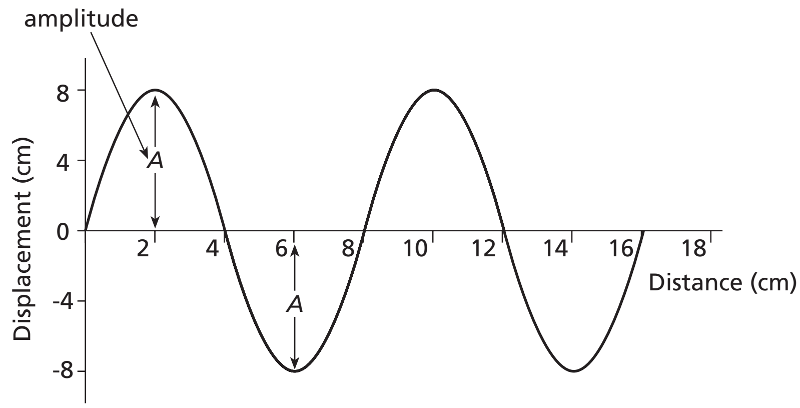


Figure 13.2
The amplitude of a wave is the maximum distance from the equilibrium position.

NOVEL CHALLENGE

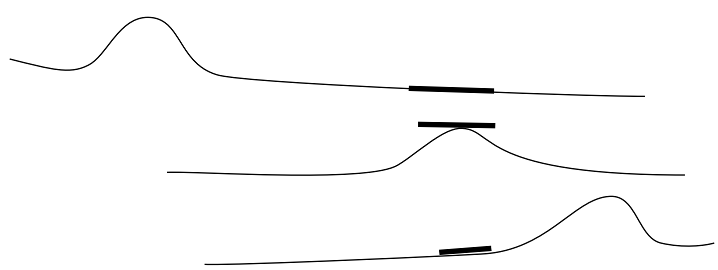
Put a lit candle in a room and open a door quickly. How long will the breeze take to get to the candle? Measure the distance and the time. Do you think the breeze would travel at the speed of sound in air?

What other quantity is determined by the amplitude of a wave?

The amplitude of a large water wave might be 10 m. This suggests that the wave would have large amounts of energy. The larger the amplitude the more energy the wave possesses. The energy of the wave comes from the disturbance. Some of the energy of the stone is transferred to the water wave. As you go further from the source of the wave the amplitude of the wave becomes less as the energy dissipates. Waves similar to these water waves can be created in many objects. Children can often be seen holding the ends of a piece of skipping rope or a hose and flicking it. A wave or **pulse** moves from the flicked end to the other end. The energy put into the wave can easily be felt by the child at the other end. The energy can be so great that it may cause the rope to flick out of the hands of the receiver. Notice that the energy and the pulse moves along the rope without the particles that make up the rope moving toward the receiver.

If there is a small branch floating in a pond what happens to it as a wave passes? The branch goes up and down as the wave passes but returns to its original rest position once the wave has passed. The same thing happens to you and your small fishing dinghy as the wash from a large boat passes under you. The rest position is also called the 'equilibrium' position.

Figure 13.3
A branch in a pond moves out and back as a wave passes.



Wave types

Water waves or rope waves are particular types of waves. As seen in the water wave, the water (and branch) move upward as the wave passes. The particles that make up the water move at right angles to the direction the wave is travelling. This is the same for the rope wave. The rope moves upward as the pulse passes and then back to its original position.

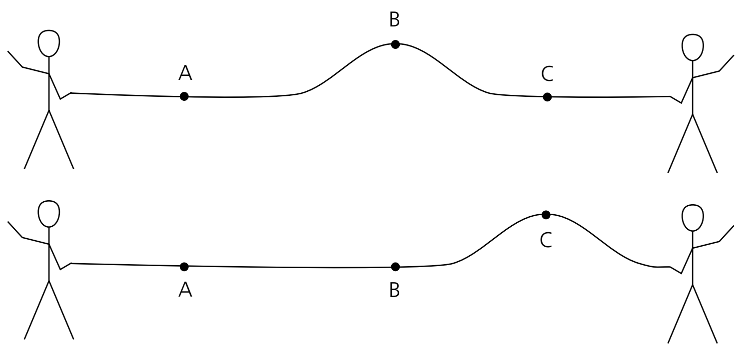


Figure 13.4
The parts of a rope move outward as waves pass.

Waves that do this are called **transverse waves**. (The word transverse comes from the Latin *transvertere* meaning 'to turn across'). Each point of the wave vibrates perpendicularly to the direction the wave is travelling — perpendicular to the direction of **propagation** of the wave (Latin *propago* = 'layer of a plant'; adds layers as it grows outwards). Examples of waves that are transverse in nature are waves in water; waves in ropes, hoses, and springs; and electromagnetic radiation, examples of which are light, radio waves, and television waves.

Notice the direction of the motion of the particles of a spring as a transverse wave passes as shown in Figure 13.5.

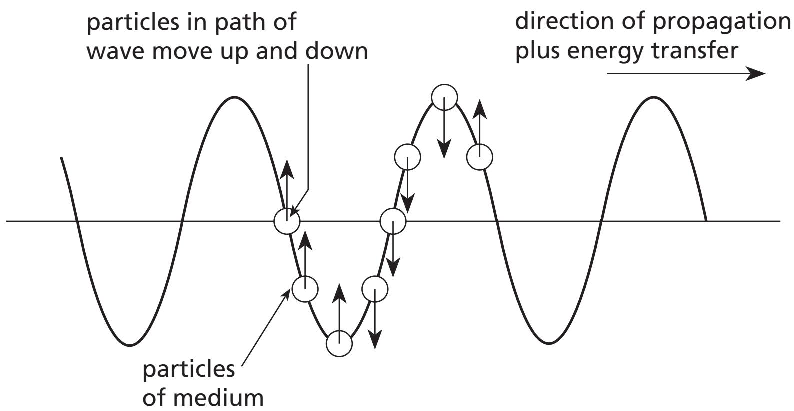


Figure 13.5
In a transverse wave the particles move at right angles to the motion of the wave. The direction of individual particles is given by the arrows.

Another type of wave is a **compressional** or **longitudinal** wave. Examples of these can be created in springs by compressing a part of a spring and then letting it go so the compression travels down the spring.

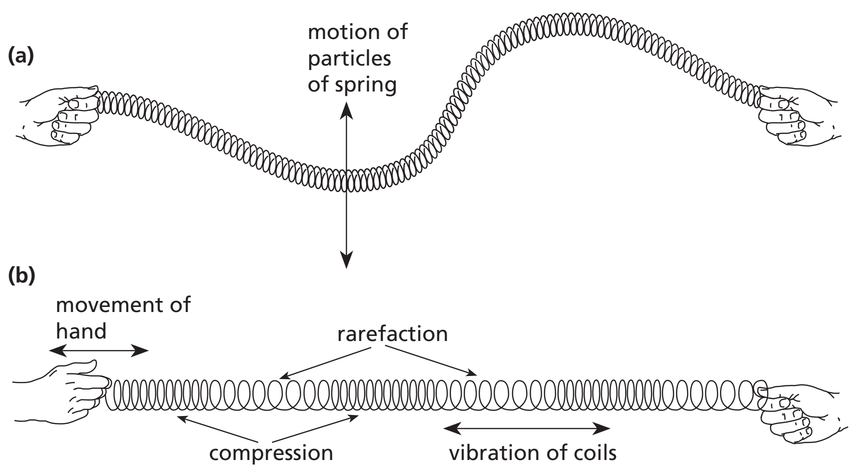


Figure 13.6
(a) Transverse waves.
(b) Longitudinal waves.