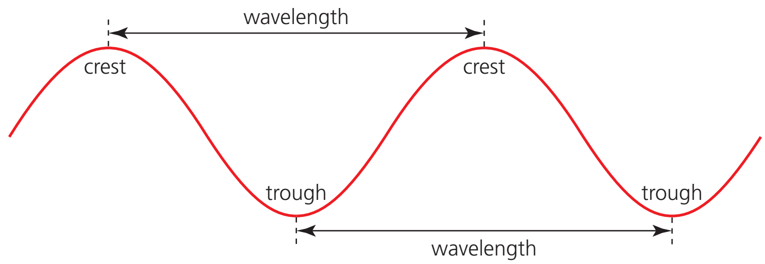
The concept of wavelength, λ, is central to the study of waves. See Figure C2.7.



■ **Figure C2.7** One wavelength of a transverse wave

◆ **Wavelength, λ** The distance between two adjacent crests of a wave. More precisely: the shortest distance between two points moving in phase.

◆ **Time period, T** The time taken for one complete wave to pass a point.

◆ **Wave speed, v** The speed at which energy is transferred by a wave.

One **wavelength**, λ, is the shortest distant between two crests, or two troughs. Or the shortest distance between two compressions or rarefactions in a longitudinal wave. More generally, it is defined as the shortest distance between two points moving in phase (SI unit: m).

Displacement, amplitude, time period and frequency have all been discussed before (Topics A.2 and C.1) and are defined in a similar way in the study of waves:

The *amplitude* of a wave is the maximum displacement of the medium from its equilibrium position.

We saw in Topic C.1 that the energy of an oscillation was proportional to its amplitude squared. So, speaking generally, waves with greater amplitude transfer more energy. (We will see in Topic C.3 that the *intensity* of a wave is proportional to its amplitude squared.)

The **time period** of a wave, T, is the time for one oscillation of a particle within the medium, or the time it takes for one complete wave to pass a particular point (unit: second).

The frequency of a wave, f, is the number of oscillations per second of a particle within the medium, or the number of waves to pass a particular point in one second (SI unit: hertz). The following equation is repeated from Topic C.1:

DB

$$f = \frac{1}{T}$$

A wave travels forward one wavelength, λ, every time period, T.

Therefore:

wave speed, $v = \dfrac{\lambda}{T}$

Since $T = 1/f$, we can write:

DB

$$\text{wave speed, } v = f\lambda \left(\text{or } v = \frac{\lambda}{T}\right)$$

WORKED EXAMPLE C2.1

Water waves are passing into a harbour. Five crests are separated by a distance of 9.6 m. An observer notes that 12 waves pass during a time of one minute. Determine:

a the wavelength
b the period
c the frequency
d the speed of the waves.

Answer

a $\lambda = \dfrac{9.6}{4} = 2.4\,\text{m}$

b $T = \dfrac{60}{12} = 5.0\,\text{s}$

c $f = \dfrac{1}{5.0} = 0.20\,\text{Hz}$

d $v = f\lambda = 0.20 \times 2.4 = 0.48\,\text{m}\,\text{s}^{-1}$

1 Consider Figure C2.1. Explain why the amplitude of the waves decreases as they spread away from the central point.

2 Consider Figure C2.2.
   a State the type of wave which is travelling along the rope.
   b If the wave speed is $1.7\,m\,s^{-1}$, calculate the wavelength produced by shaking the end seven times every 10 seconds.
   c If the rope was replaced by a thinner one, would you predict that the wave speed would increase, or decrease (under the same conditions)? Explain your answer.

3 Describe how the point P on the slinky spring shown in Figure C2.6 moves as the wave passes through it.

4 If you watch waves coming into a beach, you will notice that they get closer to each other.
   a State and explain how their wavelength is changing.
   b Suggest what has caused the waves to change speed.

5 After an earthquake, the first wave to reach a detector 925 km away arrived 149 s later. This type of wave is called a P wave (pressure wave).
   a Suggest whether this is a longitudinal or transverse wave.
   b Calculate the average speed of the wave ($m\,s^{-1}$).
   c Suggest why your calculation produces an 'average' speed.
   d If the wave had a period of 11.21 s, what was its wavelength?

LINKING QUESTION

- How can the length of a wave be determined using concepts from kinematics?

This question links to understandings in Topic A.1.

Tool 2: Technology

Generate data from models and simulations

Some time after a Primary (longitudinal) wave is received from an earthquake, a different kind of wave will be detected. This is called a Secondary (transverse) wave. If the delay between the detection of the two waves is measured and the speeds of both waves are known, the distance to the original earthquake can be determined.

Set up a spreadsheet that will calculate the distance to the source of an earthquake (dependant variable) for various time delays (independent variable). Assume speeds of waves are $5500\,m\,s^{-1}$ and $3200\,m\,s^{-1}$.

Representing waves graphically

Waves can be represented by displacement–position or displacement–time graphs. They both have similar sinusoidal shapes.

Figure C2.8 shows how the displacements of particles (from their mean positions) vary with *distance* from a fixed point (position). x_0 is the amplitude of their oscillations. It may be considered as a 'snapshot' of the wave at one particular moment.

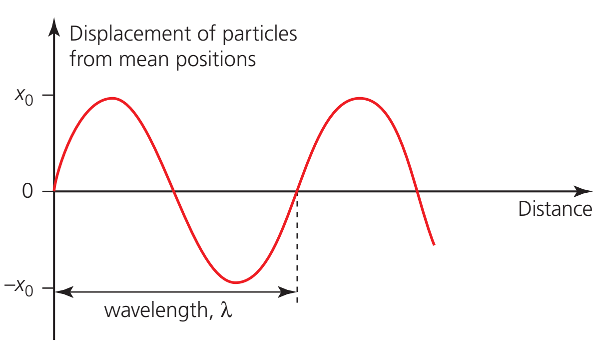


Figure C2.8 Displacement–distance graph for a wave

Figure C2.9 shows how the displacement of a certain particle (from its mean position) varies with time at one precise location. It could be considered as a video of that part of the medium.