Wave Characteristics

8.3

Some characteristics of waves, such as the large water wave in **Figure 1**, are based on geometric features, and some characteristics of waves are based on time. So waves can be described in terms of their size, their shape, and the speed at which they move.

Figure 1 The characteristics of this water wave can be described in terms of its height and its speed.

Geometric Wave Characteristics

Wave characteristics based on shape and size include amplitude, wavelength, phase, and phase shift.

Amplitude and Wavelength

In Section 8.1 you learned that vibrating particles in a medium create a wave, and that the equilibrium point in a vibration is halfway between the maximum distances that an object vibrates. The maximum displacement of a vibrating particle in a wave from its equilibrium point is called the **amplitude** (**Figure 2**). Since a vibrating particle passes the equilibrium point twice each cycle, the amplitude is half the distance between the maximum and minimum values. For transverse mechanical waves, the amplitude is measured in metres.

amplitude the maximum displacement of a wave from its equilibrium point

The **waveform**, or shape of a wave when graphed, in Figure 2 shows that the maximum point of a transverse wave is called a **crest**, and the minimum point of a transverse wave is called a **trough**. A continuous wave has many repeating crests and troughs. The amplitude of a longitudinal wave, such as a sound wave, is measured by the varying pressures it creates. So scientists define the amplitude of a longitudinal wave as the maximum pressure it creates compared to the pressure of the non-disturbed medium. For this reason, longitudinal waves are often referred to as pressure waves.

waveform the shape of a wave when graphed

crest the maximum point of a transverse wave

trough the minimum point of a transverse wave

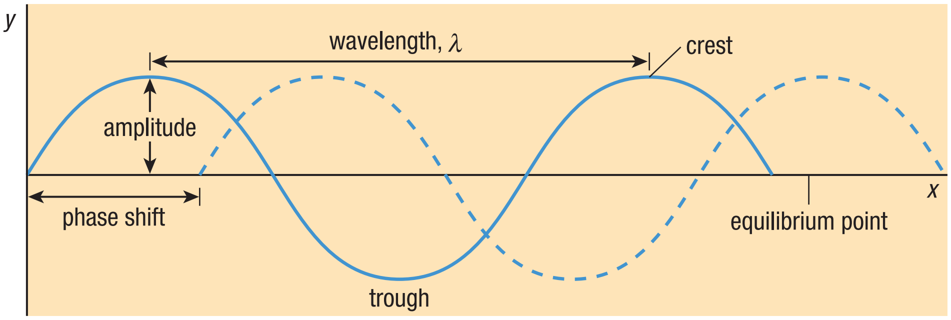

Figure 2 Geometric wave characteristics applied to both transverse and longitudinal waves. Sometimes, longitudinal waves are sketched as transverse waves to make them easier to observe.

Also shown in Figure 2 is wavelength. **Wavelength** is the distance between two similar points in successive identical cycles in a wave (such as from crest to crest or from trough to trough). The symbol for wavelength is the Greek letter lambda, λ (pronounced LAM-da).

wavelength (λ) the distance between two similar points in successive identical cycles in a wave, such as from crest to crest or trough to trough

Phase and Phase Shift

In both transverse and longitudinal waves, the x-coordinate of a unique point of a wave is called its **phase**. The units of phase are the same as the units of wavelength (metres). Phase can also be expressed as a decimal percentage. Thus, halfway through a single cycle is a phase of 0.5 (no units).

phase in a continuous transverse or longitudinal wave, the x-coordinate of a unique point of the wave

Two waves can be identical to each other but shifted along the x-axis with respect to each other. A **phase shift** is a shift of an entire wave with respect to an identical wave along the x-axis, usually by some fraction of a single wavelength (Figure 2).

phase shift a shift of an entire wave along the x-axis with respect to an otherwise identical wave

So a phase shift of $\frac{\lambda}{2}$ (or a phase shift of 0.5) means that the crest of one wave is opposite a trough in the other. This is a very important concept in electricity, electronics, the physics of sound (Chapter 9), and the study of the atom.

in phase the state of two identical waves that have the same phase shift

out of phase the state of two identical waves that have different phase shifts

Identical waves are **in phase** if their phase shifts are equal, and **out of phase** otherwise. The amount they are out of phase is equal to the phase shift. Often, if two waves are $\frac{\lambda}{2}$ out of phase, they are simply said to be "totally out of phase."

Time-Based Wave Characteristics

Time-based wave characteristics are related to the motion of the vibrating particle and the wave. These characteristics are frequency, period, and the speed at which a wave travels.

Frequency, Period, and Speed

frequency (*f*) the number of complete cycles that occur in unit time, usually 1 s; measured in hertz (Hz)

The number of complete cycles per unit time, usually 1 s, is called the **frequency (*f*)** (**Figure 3**). A wave has the same frequency as the vibrating particles that create and sustain it. The SI unit of frequency is the hertz (Hz) and is defined as one cycle per second.

period (*T*) the time for a vibrating particle to complete one cycle

The time it takes for any of the vibrating particles in a wave to complete one cycle is called the **period (*T*)**. When studying waves, the vibration of the particles is often difficult to observe, so the period can be found by measuring the length of time it takes for one wavelength to pass by a fixed point, or the time it takes for one complete vibration. Frequency and period are related mathematically:

$$\text{frequency} = \frac{\text{cycles}}{\text{unit time}} \qquad \text{period} = \frac{\text{time}}{\text{unit cycle}}$$

Consequently,

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

LEARNING TIP

Period
The term "period" is also used in other repeating motions, such as revolutions and rotations, to indicate the time for one cycle.

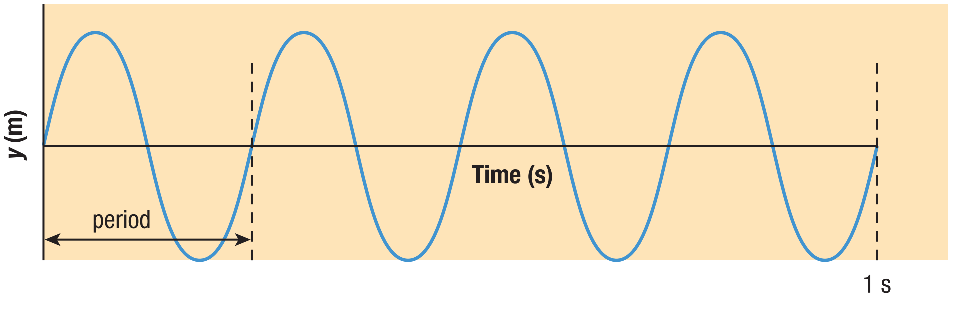

Figure 3 Wave characteristics based on time. Frequency is the number of complete cycles per second. Here, there are about $4\frac{1}{4}$ crests per second, so the frequency is $f \approx 4.25$ Hz. The period is $T \approx 0.235$ s.

wave speed (*v*) the rate at which a wave is travelling through a medium; also a measure of how fast the energy in the wave is moving

If you stay in one spot and measure how fast the wave crests are passing by, you will have a measure of the **wave speed (*v*)**. The speed of a wave is also a measure of how fast the energy in the wave is moving. If you know the wavelength and the period of a wave, you can calculate wave speed. As you learned in Chapter 1, speed is calculated by dividing the distance (wavelength, in this case) by time (period). Hence,

$$v = \frac{\lambda \text{ (m)}}{T \text{ (s)}} = \frac{\text{length of one cycle}}{\text{time for one cycle}}$$

The unit of wave speed is metres per second (m/s). As you will learn in Section 8.4, how fast a wave moves depends on the medium in which it is travelling as well as the temperature of the medium.

Simple Harmonic Motion

One common type of oscillation (vibration) is called simple harmonic motion (SHM). **Simple harmonic motion** is any motion that repeats itself at regular intervals about an equilibrium point. The amplitude, period, and frequency are the same for each oscillation. Examples of SHM are spring-mass systems (**Figure 4**), a simple pendulum oscillating with a small amplitude, a particle vibrating within a solid, and driven oscillators, such as wave machines.

Investigation 8.3.1

Investigating Vibrations (p. 402)
In this investigation, you will hypothesize the factors that affect transverse and longitudinal motion and then test your hypotheses.

simple harmonic motion any motion that repeats itself at regular intervals

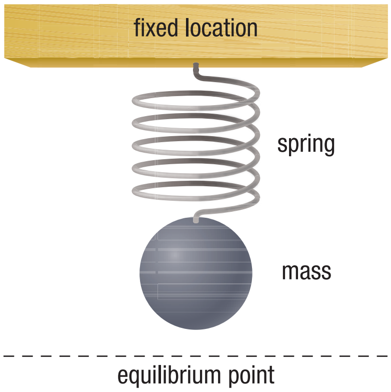

Figure 4 A spring-mass system

8.3 Summary

- Wave characteristics are based on both wave shape and the behaviour of a wave in time.
- Amplitude is the maximum distance a vibrating particle moves from its equilibrium point.
- Wavelength is the distance between two similar points in successive identical cycles in a wave, such as from crest to crest or trough to trough.
- The phase shift is the amount that one waveform is displaced along the x-axis from an otherwise identical waveform.
- Frequency is the number of complete cycles of a wave that occur per unit of time (usually 1 s). Period is the time it takes for a vibrating particle to complete one cycle.
- Wave speed is the rate at which a wave travels through a medium. It is also a measure of how fast the energy in the wave is moving.
- Simple harmonic motion (SHM) is any oscillating motion that repeats itself at regular intervals.

8.3 Questions

1. Copy **Figure 5** into your notebook. K/U

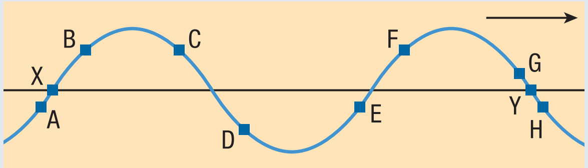

Figure 5

   (a) Label the amplitude, wavelength, and equilibrium point of the waveform.
   (b) List all pairs of points that are in phase.

2. Contrast wavelength and amplitude for (a) longitudinal waves and (b) transverse waves. K/U C
3. In your own words, distinguish between wave speed and frequency. K/U C
4. Make a sketch that shows two identical transverse waveforms, except one waveform is phase-shifted one-half a wavelength from the other. K/U C A
5. Make a sketch that shows two identical longitudinal waveforms, except one waveform is phase-shifted one-half a wavelength from the other. K/U C A
6. If you did the activity at the beginning of this chapter, you performed a simple demonstration of two types of wave motion using a Slinky. Do you think that these motions were examples of simple harmonic motion? Explain your answer. K/U T/I C