Complete Physics for Cambridge IGCSE®
Third edition
Revision Guide

For the updated syllabus

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3.1 General wave properties

**KEY IDEAS**

✓ Waves transfer energy without transferring matter
✓ Every wave can be described in terms of its frequency, wavelength, velocity and amplitude
✓ In a longitudinal wave the vibrations of the particles are parallel to the direction of motion. In a transverse wave, the vibrations are perpendicular to the direction of motion
✓ All the particles along a wavefront are at the same point in their vibration
✓ Water waves, produced by a ripple tank, can be reflected, refracted and diffracted
✓ Velocity = frequency × wavelength

A wave transfers energy from one place to another without transferring the particles of the medium. Individual particles vibrate (oscillate) about fixed positions.

There are two types of wave:

<table>
<thead>
<tr>
<th>Longitudinal</th>
<th>Transverse</th>
</tr>
</thead>
<tbody>
<tr>
<td>direction of travel</td>
<td>wavelength</td>
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<tr>
<td>wavelength</td>
<td>displacement</td>
</tr>
<tr>
<td>compression</td>
<td>rarefaction</td>
</tr>
<tr>
<td>amplitude</td>
<td>direction of travel</td>
</tr>
</tbody>
</table>

In a **longitudinal** wave the particles vibrate **parallel** to the direction of the wave. This leads to a series of **compressions** and **rarefactions**. In compressions, the particles are **closer together** than normal. In rarefactions, the particles are **further apart** than normal.

An example of a longitudinal wave is sound in air.

In a **transverse** wave the particles vibrate **perpendicular** to the direction of the wave. This leads to a series of **peaks** and **troughs**. At peaks, the particles are displaced **higher** than normal, at troughs they are displaced **lower** than normal.

An example of a transverse wave is light.

As shown on the two diagrams, the **wavelength** is the distance between adjacent particles that are at the same point in their vibration e.g. the distance between a compression and the next compression or the distance between a peak and the next peak.

The **amplitude** cannot easily be shown for the longitudinal wave, but for the transverse wave it is the distance from the centre of a vibration to the peak, measured in metres (m).

The amplitude is the maximum displacement from the rest position.

**The velocity of a wave is the distance travelled per second**, measured in metres per second (m/s).

**The frequency of a wave is the number of complete waves passing a point every second**, measured in hertz (Hz).
Velocity = distance travelled by the wave in 1 second
Frequency = number of waves passing a point every second or the number of oscillations made by a particle on the wave every second.
The unit of frequency is hertz (Hz)

Formula: Velocity (m/s) = frequency (Hz) × wavelength (m)

\[ v = f \times \lambda \]

**Worked examples**

1. A sound wave has a frequency of 10 000 Hz and a wavelength of 0.033 m. What is the speed of the wave?

2. A radio wave of speed 300 million m/s has a frequency of 600 MHz. What is its wavelength?

3. What is the frequency of an ultrasound wave of speed 1500 m/s and wavelength 0.05 m?

**Answers**

1. \[ v = f \times \lambda \]
   \[ = 10 000 \times 0.033 \]
   \[ = 330 \text{ m/s} \]

2. \[ \lambda = \frac{v}{f} \]
   \[ = \frac{300 000 000}{600 000 000} \]
   \[ = 0.5 \text{ m} \]

3. \[ f = \frac{V}{\lambda} \]
   \[ = \frac{1500}{0.05} \]
   \[ = 30 000 \text{ Hz} \]
   \[ = 30 \text{ kHz} \]

**Note:** 1 MHz = 1 million Hz = 1 000 000 Hz

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Wavefronts can be represented as lines which are always perpendicular to the direction of wave travel. The distance between one wavefront and the next is one wavelength.
Ripple tank

The ripple tank has a vibrating bar attached to a motor, which can be used to set up waves of varying frequency in water.

Water waves reflect at solid surfaces. There is no change in frequency, speed or wavelength on reflection.

Wave theory suggests that each point on a wavefront can be considered to be a source of circular waves. These circular waves combine to make the wavefront and as they spread out, the wave travels forward.

Refraction

Water waves travel more slowly in shallow water.

As a wavefront AB approaches the boundary between the deep and shallow water, point A meets the shallower water first and this part of the wavefront slows down. Point B is still moving at the same speed as before. Wavefront AB turns clockwise which means that the new wavefront A’B’ is now moving in a different direction. This change in direction is called refraction.
**Diffraction**

Water waves spread out as they go through a gap in a barrier. Only part of the wavefront can go through the gap. The waves that come from the original wavefront form a new curved wavefront. Diffraction through the gap occurs when the gap is greater than or equal to the wavelength of the waves.

If the wavelength is approximately equal to the size of the gap, maximum diffraction occurs:

If the gap is much larger than the wavelength, little diffraction occurs:

Similarly, with diffraction at an edge, the closer the wavelength is in size to the diffracting object, the greater the diffraction.
Examination style questions

1. The diagram shows the waveform of the note from a bell. A grid is given to help you take measurements.

![Waveform diagram]

a. i) State what, if anything, is happening to the loudness of the note.
   ii) State how you deduced your answer to (a)(i).

b. i) State what, if anything, is happening to the frequency of the note.
   ii) State how you deduced your answer to (b)(i).

c. i) How many oscillations does it take for the amplitude of the wave to decrease to half its initial value?
   ii) The wave has a frequency of 300 Hz.
       1. What is meant by a frequency of 300 Hz?
       2. How long does 1 cycle of the wave take?
       3. How long does it take for the amplitude to decrease to half its initial value?

d. A student says that the sound waves, which travelled through the air from the bell, were longitudinal waves, and that the air molecules moved repeatedly closer together and then further apart.
   i) Is the student correct in saying that the sound waves are longitudinal?
   ii) Is the student correct about the movement of the air molecules?
   iii) The student gives light as another example of longitudinal waves. Is this correct?

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2. The diagram above shows how the pressure in air varies at one instant with distance along a sound wave.
   ![Pressure diagram]

   a. Mark with a letter C on the diagram a point where there is a compression. Mark with a letter R on the diagram a point where there is a rarefaction.
   b. Describe the motion of a group of air particles along the wave shown in the diagram.
   c. The sound wave has a speed of 330 m/s and a frequency of 500 Hz. Calculate the wavelength of the wave and find the distance PX.

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