3.1 General properties of waves

Name: _____ Class: _____ Date: _____ **Total: 27 marks**

0 Vocabulary

Word	Example
wave /weɪv/ 波	A **wave** moves across the water. 一道**波**在水面上传播。
ripple tank /ˈrɪpl tæŋk/ 波纹水槽	A **ripple tank** shows water waves. **波纹水槽**可以显示水波。
wavefront /ˈweɪvfrʌnt/ 波前	Each **wavefront** joins points on the same crest. 每个**波前**连接同一个波峰上的各点。
wavelength /ˈweɪvleŋθ/ 波长	The **wavelength** is the distance from one crest to the next. **波长**是相邻两个波峰之间的距离。
crest /krest/ 波峰	The **crest** is the top of the wave. **波峰**是波的最高点。
peak /piːk/ 峰	The wave's **peak** is its highest point. 波的**峰**是它的最高点。
trough /trɒf/ 波谷	The **trough** is the lowest point of the wave. **波谷**是波的最低点。
amplitude /ˈæmplɪtjuːd/ 振幅	Loud sounds have a large **amplitude**. 响亮的声音具有较大的**振幅**。
wave speed /weɪv spiːd/ 波速	The **wave speed** is 340 m/s. **波速**是 340 m/s。
transverse wave 横波 /træns'vɜːs weɪv/	Light is a **transverse wave**. 光是**横波**。
propagation /ˌprɒpəˈgeɪʃn/ 传播	Sound needs a material for its **propagation**. 声音的**传播**需要介质。
reflection /rɪˈflekʃn/ 反射	**Reflection** in a mirror lets you see yourself. 镜子的**反射**让你看到自己。
refraction /rɪˈfrækʃn/ 折射	**Refraction** makes a straw look bent in water. **折射**使水中的吸管看起来弯了。

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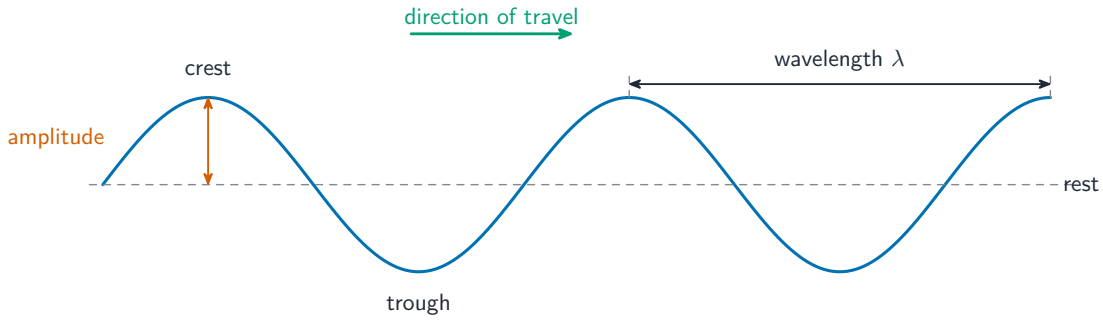
Word	Example
diffraction /dɪˈfrækʃn/ 衍射	**Diffraction** lets you hear sound around a corner. **衍射**使你能听到拐角另一侧的声音。
light /laɪt/ 光	A sensor measures the amount of **light** in a room. 传感器测量房间里的**光**的强度。
angle of incidence 入射角 /ˈæŋgl ɒv ˈɪnsɪdəns/	The **angle of incidence** is measured from the normal, not from the surface. **入射角**是从法线量起的，不是从表面量起的。
angle of reflection 反射角 /ˈæŋgl ɒv rɪˈflekʃn/	The **angle of reflection** equals the angle of incidence. **反射角**等于入射角。
plane mirror /pleɪn ˈmɪrə/ 平面镜	A flat **plane mirror** forms a virtual, upright image the same size as the object. 平坦的**平面镜**形成正立的虚像，像的大小与物体相同。
virtual image 虚像 /ˈvɜːtʃuːəl ˈɪmɪdʒ/	A **virtual image** cannot be shown on a screen. **虚像**不能呈现在屏幕上。
magnifying glass 放大镜 /ˈmægnɪfaɪɪŋ glæs/	Hold a **magnifying glass** close to the page to make the words look bigger. 把**放大镜**靠近书页，就能让文字看起来更大。
upright /ˈʌpraɪt/ 正立	A convex security mirror always gives an **upright** image. 凸面安防镜所成的像总是**正立**的。

1 Key knowledge and worked examples

Study these first. Each one shows the method for a question type used later: follow the steps and you can do the Practice and Exam-style questions yourself.

■ Describing a wave

term	meaning	unit
wavelength λ	distance from one crest to the next	m
amplitude	greatest displacement from the rest position	m
frequency f	number of complete waves passing a point each second	Hz
wave speed v	distance a crest moves each second; $v = f\lambda$	m/s



Wavelength = crest-to-crest distance; amplitude = rest-to-crest height; $v = f\lambda$

- Waves transfer **energy** without transferring matter.
- **Transverse:** vibrations at right angles to the direction of travel; light and all electromagnetic waves, water ripples, seismic **S-waves**.
- **Longitudinal:** vibrations along the direction of travel, in compressions and rarefactions; sound, seismic **P-waves**.

Worked example 1: frequency from a count of waves

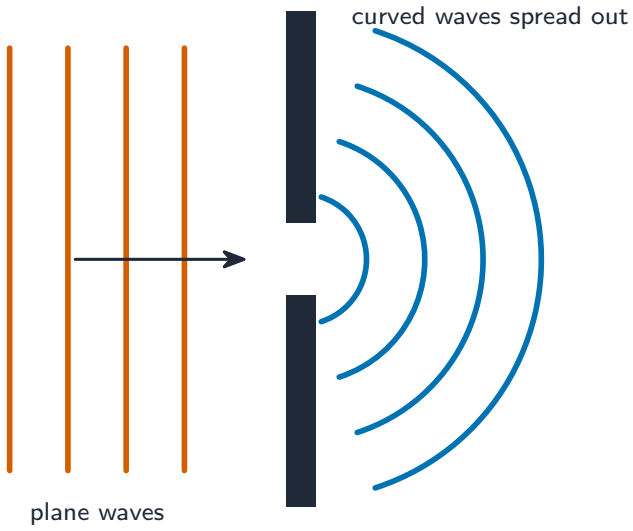
A monitoring station records 16 complete waves of an earthquake wave in 20 s. The wave travels at 6.0 km/s. Find its wavelength.

1. Frequency is the number of waves per second: $f = \dfrac{16}{20\ \text{s}} = 0.80\ \text{Hz}$.
2. Speed in SI units: $v = 6.0\ \text{km/s} = 6000\ \dfrac{\text{m}}{\text{s}}$.
3. $v = f\lambda$, so $\lambda = \dfrac{v}{f}$:

$$\lambda = \frac{v}{f} = \frac{6000\ \dfrac{\text{m}}{\text{s}}}{0.80\ \text{Hz}} = \mathbf{7500}\ \text{m}$$

Reflection, refraction, diffraction

- **Reflection** at a barrier: the angle of incidence equals the angle of reflection.
- **Refraction:** a wave changes speed when it enters a new medium (water waves slow down in shallow water). The **frequency stays the same**, so the wavelength changes, and a wave meeting the boundary at an angle changes direction.
- **Diffraction:** waves spread out through a gap or round an edge. The spreading is greatest when the gap is about one wavelength wide. A wider gap or a shorter wavelength gives less curved waves.



Diffraction is strongest when the gap is about one wavelength wide

Sound (wavelength about 1 m) diffracts through a doorway, so you hear round the corner. Light (wavelength about 5×10^{-7} m) hardly diffracts there, so you cannot see round it.

■ Worked example 2: waves entering shallow water

Water waves of frequency 10 Hz travel at 0.25 $\frac{\text{m}}{\text{s}}$ in deep water and 0.15 $\frac{\text{m}}{\text{s}}$ in shallow water. Find the wavelength in each.

1. The source sets the frequency, so $f = 10$ Hz in both depths; $\lambda = \frac{v}{f}$.
2. Deep:
$$\lambda = \frac{v}{f} = \frac{0.25\ \frac{\text{m}}{\text{s}}}{10\ \text{Hz}} = \mathbf{0.025}\ \text{m}$$
3. Shallow:
$$\lambda = \frac{v}{f} = \frac{0.15\ \frac{\text{m}}{\text{s}}}{10\ \text{Hz}} = \mathbf{0.015}\ \text{m}$$

2 Practice

2.1 A wave has frequency 50 Hz and wavelength 0.40 m. Find its speed. [2]



2.2 State the difference between a transverse and a longitudinal wave. [1]

transverse longitudinal

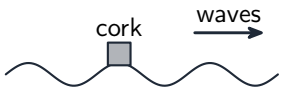
2.3 State what is meant by the amplitude of a wave. [1]



2.4 State whether each of these waves is transverse or longitudinal: light, sound. [1]

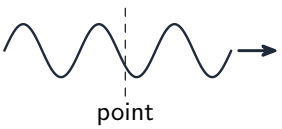
light sound

2.5 A cork floats on a pond as water waves pass. State what the waves transfer across the pond, and what they do not. [1]



3 Exam-style questions

3.1 The number of complete waves passing a point each second is the: [1]

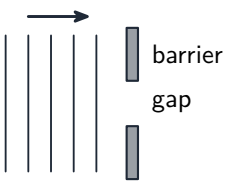


- ☐ **A** wavelength
- **B** amplitude
- **C** frequency
- **D** wave speed

3.2 Parallel waves in a ripple tank are diffracted as they pass through a gap in a barrier. Three changes are suggested.

1. Make the gap wider.
2. Increase the frequency of the waves.
3. Decrease the amplitude of the waves.

Which changes make the diffracted waves less curved? [1]



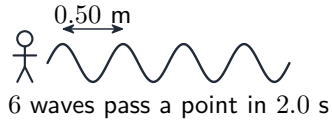
- ☐ **A** 1, 2 and 3
- **B** 1 and 2 only
- **C** 2 only
- **D** 2 and 3 only

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3.3 A student moves one end of a rope up and down. Six complete waves pass a point in 2.0 s. The wavelength is 0.50 m.

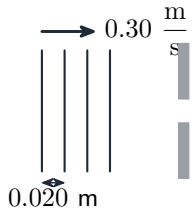
(a) Calculate the frequency of the waves. [1]

(b) Calculate the speed of the waves. [2]



3.4 Water waves of wavelength 0.020 m travel at 0.30 $\frac{\text{m}}{\text{s}}$.

(a) Calculate their frequency. [2]



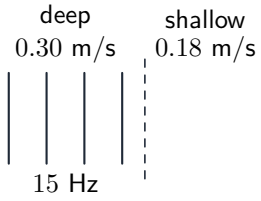
(b) State and explain what happens to the waves as they pass through a gap about 0.02 m wide. [2]

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3.5 Water waves of frequency 15 Hz travel at 0.30 $\frac{\text{m}}{\text{s}}$ in deep water. They pass into shallow water, where their speed is 0.18 $\frac{\text{m}}{\text{s}}$.

(a) State what happens to the frequency of the waves. [1]

(b) Calculate the wavelength in the shallow water. [2]



(c) Name the effect that changes the direction of the waves when they cross the boundary at an angle. [1]

3.6 An earthquake produces seismic waves. The diagram represents one seismic wave travelling through the ground from J towards K.

(a) Describe how a longitudinal wave differs from a transverse wave. [2]



(b) State whether this seismic wave is a P-wave or an S-wave. Give a reason. [2]

(c) The wavelength of the wave is 8.0×10^3 m. Calculate the distance from J to K. [2]

(d) The wave travels at 4000 $\frac{\text{m}}{\text{s}}$. As it passes a point, the ground there completes 6 oscillations. Calculate the time the wave takes to pass. [2]

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Solutions

Each answer shows the steps, then the **result**.

2.1

- $v = f\lambda$

$$v = f\lambda = (50\text{ Hz})(0.40\text{ m}) = \mathbf{20}\ \frac{\text{m}}{\text{s}}$$

2.2

- in a transverse wave the particles vibrate at right angles to the travel direction; in a longitudinal wave they vibrate along it

2.3

- the greatest displacement of a point on the wave from its rest position

2.4

- light: transverse; sound: longitudinal

2.5

- energy is transferred; the water (and the cork) is not carried along, it only moves up and down

3.1 C

- frequency is the number of waves per second

3.2 B

- a wider gap (1) and a shorter wavelength (2: higher frequency at the same speed) both reduce the spreading; amplitude (3) has no effect

3.3

(a)

- frequency is waves per second: $f = \dfrac{6}{2.0\text{ s}} = \mathbf{3.0}\text{ Hz}$

(b)

- $v = f\lambda$

$$v = f\lambda = (3.0\text{ Hz})(0.50\text{ m}) = \mathbf{1.5}\ \frac{\text{m}}{\text{s}}$$

3.4

(a)

- $v = f\lambda$, so $f = \dfrac{v}{\lambda}$

$$f = \frac{v}{\lambda} = \frac{0.30\ \frac{\text{m}}{\text{s}}}{0.020\text{ m}} = \mathbf{15}\text{ Hz}$$

(b)

- the waves spread out (diffract) into curved waves
- because the gap is about the same size as the wavelength

3.5

(a)

- it stays the same, 15 Hz

(b)

- $v = f\lambda$, so $\lambda = \dfrac{v}{f}$

$$\lambda = \frac{v}{f} = \frac{0.18\ \frac{\text{m}}{\text{s}}}{15\ \text{Hz}} = \mathbf{0.012}\ \text{m}$$

(c)

- refraction

3.6

(a)

- in a longitudinal wave the vibrations are along (parallel to) the direction the wave travels
- in a transverse wave they are at right angles to it; a longitudinal wave has compressions and rarefactions

(b)

- S-wave
- the diagram shows a transverse wave, and S-waves are transverse (P-waves are longitudinal)

(c)

- J to K is 2.5 wavelengths

$$d = 2.5\lambda = 2.5 \times (8.0 \times 10^3\ \text{m}) = \mathbf{2.0 \times 10^4}\ \text{m}$$

(d)

- frequency from $v = f\lambda$: $f = \dfrac{v}{\lambda} = \dfrac{4000\ \frac{\text{m}}{\text{s}}}{8.0 \times 10^3\ \text{m}} = 0.50$ Hz, so one oscillation takes $\dfrac{1}{f} = 2.0$ s
- 6 oscillations: $t = 6 \times 2.0\ \text{s} = \mathbf{12}\ \text{s}$

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