3.4 Sound

Name: _____ Class: _____ Date: _____ **Total: 25 marks**

0 Vocabulary

Word	Example
frequency /'fri:kwənsi/ 频率	A **frequency** of 50 Hz means 50 waves every second. **频率**为 50 Hz 表示每秒有 50 个波。
longitudinal wave 纵波 /ˌlɒŋgɪ'tju:dɪnl weɪv/	Sound is a **longitudinal wave**. 声音是**纵波**。
normal /'nɔ:ml/ 法线	The **normal** is a line at 90° to the surface. **法线**是一条与表面成 90° 的直线。
angle of refraction 折射角 /'æŋgl ɒv rɪ'frækʃn/	The **angle of refraction** is measured from the normal. **折射角**是从法线开始测量的。
refractive index 折射率 /rɪ'fræktɪv 'ɪndeks/	Glass has a **refractive index** of 1.5. 玻璃的**折射率**是 1.5。
critical angle /'krɪtɪkl 'æŋgl/ 临界角	The **critical angle** for glass is about 42°. 玻璃的**临界角**约为 42°。
enlarged /en'lɑ:dʒd/ 放大的	A magnifying glass gives an **enlarged** image. 放大镜成的是**放大的**像。
diminished /dɪ'mɪnɪʃt/ 缩小的	A camera gives a **diminished** image: smaller than the object. 照相机成的是**缩小的**像：比物体小。
inverted /ɪn'vɜ:tɪd/ 倒立	The real image from one lens is **inverted**: it is upside down. 一个透镜形成的实像是**倒立**的：它上下颠倒。
short-sightedness 近视 /ʃɔ:t 'saɪtɪdnəs/	People with **short-sightedness** cannot see far objects clearly. 有**近视**的人看不清远处的物体。
retina /'retɪnə/ 视网膜	The **retina** detects light. **视网膜**感受光线。

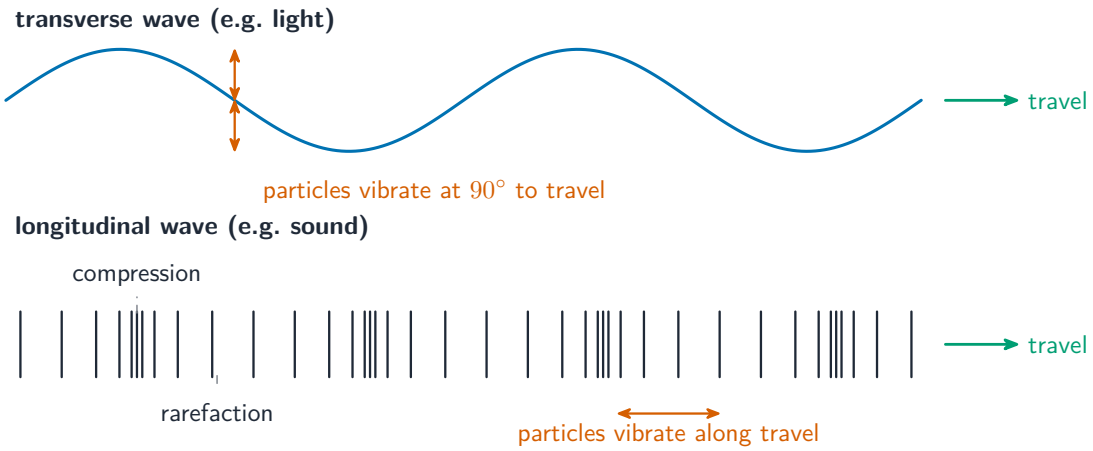
Word	Example
long-sightedness 远视 /lɒŋ ˈsaɪtɪdnəs/	People with **long-sightedness** cannot see near objects clearly. 有**远视**的人看不清近处的物体。
sound /saʊnd/ 声音	**Sound** cannot travel through a vacuum. **声音**不能在真空中传播。
compression /kəmˈpreʃn/ 压缩	**Compression** makes the file smaller. **压缩**使文件变小。
rarefaction /ˌreərɪˈfækʃn/ 稀疏	A **rarefaction** is where the air particles are far apart. **稀疏**区域的空气粒子相距较远。
medium /ˈmiːdɪəm/ 介质	Sound needs a **medium**, such as air, to travel. 声音传播需要**介质**，例如空气。
loudness /ˈlaʊdnəs/ 响度	A bigger amplitude gives more **loudness**. 振幅越大，**响度**越大。
pitch /pɪtʃ/ 音调	A higher frequency gives a higher **pitch**. 频率越高，**音调**越高。
echo /ˈekəʊ/ 回声	We heard an **echo** from the cliff. 我们听到了悬崖传来的**回声**。
Ultrasound /ˌʊltrəˈsaʊnd/ 超声波	**Ultrasound** scans show a baby in the womb. **超声波**扫描可以显示子宫里的胎儿。

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.

■ Sound waves

- Sound is made by a **vibrating** source and travels as a **longitudinal wave**: the particles of the medium vibrate back and forth along the direction of travel.
- **Compressions** 压缩 are regions where the particles are closer (higher density and pressure); **rarefactions** 稀疏 are regions where they are further apart.
- Sound needs a **medium**: it cannot travel through a vacuum.



Sound is longitudinal: the air vibrates along the travel direction, making compressions and rarefactions

property	depends on	larger value gives
loudness	amplitude	a louder sound
pitch	frequency	a higher note
speed	the medium	air ≈ 340, water ≈ 1500, steel ≈ 5000 $\frac{\text{m}}{\text{s}}$

- Human hearing: about 20 Hz to 20 000 Hz. **Ultrasound** 超声波 is above 20 kHz; it is used to scan soft tissue and to measure depths.
- When sound enters a new medium its **frequency stays the same**, so faster sound has a longer wavelength ($\lambda = \frac{v}{f}$).

■ Worked example 1: speed of sound from an echo

A student claps 85 m from a wall and hears the echo 0.50 s later. Find the speed of sound.

1. The sound travels to the wall and back: $d = 2 \times 85 \text{ m} = 170 \text{ m}$.
2. Speed is distance over time, $v = \frac{d}{t}$:

$$v = \frac{d}{t} = \frac{170 \text{ m}}{0.50 \text{ s}} = \mathbf{340} \ \frac{\text{m}}{\text{s}}$$

■ Worked example 2: frequency from compressions and rarefactions

In a sound wave travelling at 330 $\frac{\text{m}}{\text{s}}$, the centre of a compression is 5.0 cm from the centre of the nearest rarefaction. Find the frequency.

1. A compression to the next compression is one wavelength, so compression to rarefaction is **half** a wavelength: $\lambda = 2 \times 5.0 \text{ cm} = 10 \text{ cm} = 0.10 \text{ m}$.

2. $v = f\lambda$, so $f = \dfrac{v}{\lambda}$:

$$f = \frac{v}{\lambda} = \frac{330\ \frac{\text{m}}{\text{s}}}{0.10\ \text{m}} = \mathbf{3300}\ \text{Hz}$$

■ **Worked example 3: the time delay of a sound**

A starting pistol is fired 170 m from a timekeeper. Light arrives almost instantly. Find how long after the flash the bang is heard, if sound travels at 340 $\frac{\text{m}}{\text{s}}$.

1. $v = \dfrac{d}{t}$, so $t = \dfrac{d}{v}$:

$$t = \frac{d}{v} = \frac{170\ \text{m}}{340\ \frac{\text{m}}{\text{s}}} = \mathbf{0.50}\ \text{s}$$

2 Practice

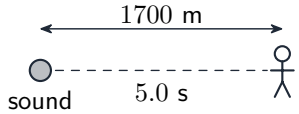
2.1 State why sound cannot travel through a vacuum. [1]

vacuum

2.2 State the approximate range of frequencies a human can hear. [1]

range of human hearing

2.3 A sound travels 1700 m through air in 5.0 s. Find the speed of sound. [2]



2.4 Name the regions of higher pressure and of lower pressure in a sound wave. [1]



2.5 State what is meant by ultrasound. [1]

ultrasound

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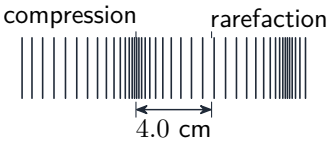
3 Exam-style questions

3.1 Sound is a: [1]

sound

- **A** transverse wave that needs no medium
- **B** longitudinal wave that needs a medium
- **C** transverse wave that needs a medium
- **D** longitudinal wave that needs no medium

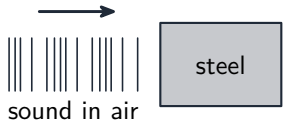
3.2 A sound wave travels at 340 $\frac{\text{m}}{\text{s}}$. The distance between the centre of a compression and the centre of the nearest rarefaction is 4.0 cm. What is the frequency of the sound? [1]



- **A** 43 Hz
- **B** 4300 Hz
- **C** 8500 Hz
- **D** 14 000 Hz

3.3 A sound wave in air strikes a block of steel. Some of the sound passes into the steel. How do the speed and the wavelength of the sound in the steel compare with those in the air? [1]

	speed in steel	wavelength in steel
A	less than in air	less than in air
B	less than in air	greater than in air
C	greater than in air	less than in air
D	greater than in air	greater than in air



3.4 Two sounds are played. Sound X is louder than sound Y and has a higher pitch. State how the waves of X differ from those of Y. [2]

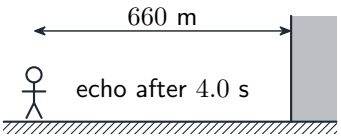
X: louder, higher pitch

Y

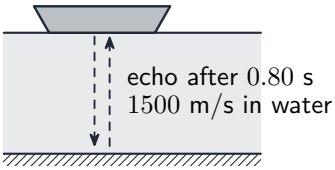
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3.5 A person stands 660 m from a cliff and shouts. The echo returns 4.0 s later.

Calculate the speed of sound. [3]

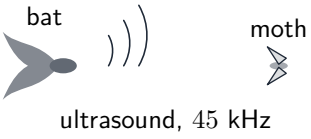


3.6 A ship sends a pulse of sound down to the seabed. The echo returns to the ship 0.80 s later. The speed of sound in water is 1500 $\frac{\text{m}}{\text{s}}$. Find the depth of the sea. [3]



3.7 A bat finds insects by emitting pulses of ultrasound of frequency 45 kHz and listening for the echoes. The speed of sound in air is 340 $\frac{\text{m}}{\text{s}}$.

(a) Explain why a person with normal hearing cannot hear these pulses. [2]



(b) Calculate the wavelength of the ultrasound. [2]

(c) The echo from a moth returns to the bat 0.012 s after the pulse is emitted. Calculate the distance from the bat to the moth. [2]

(d) Describe how the ultrasound travels through the air from the bat to the moth. [2]

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Solutions

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

2.1

- sound needs a medium (particles) to travel through, and a vacuum has none

2.2

- about 20 Hz to 20 000 Hz

2.3

- speed = distance ÷ time, $v = d/t$

$$v = \frac{d}{t} = \frac{1700\ \text{m}}{5.0\ \text{s}} = \mathbf{340}\ \frac{\text{m}}{\text{s}}$$

2.4

- compressions (higher pressure) and rarefactions (lower pressure)

2.5

- sound with a frequency above 20 kHz, too high for humans to hear

3.1 B

- sound is a longitudinal wave that needs a medium

3.2 B

- compression to rarefaction is half a wavelength: $\lambda = 2 \times 4.0\ \text{cm} = 0.080\ \text{m}$

$$f = \frac{v}{\lambda} = \frac{340\ \frac{\text{m}}{\text{s}}}{0.080\ \text{m}} = 4250\ \text{Hz} \approx 4300\ \text{Hz}$$

- C uses $\lambda = 4.0$ cm, forgetting the half

3.3 D

- sound travels faster in steel; the frequency is unchanged, so $\lambda = \frac{v}{f}$ is greater too

3.4

- louder: X has a larger **amplitude**
- higher pitch: X has a higher **frequency**

3.5

- distance there and back $= 2 \times 660\ \text{m} = 1320\ \text{m}$
- speed is distance over time, $v = \frac{d}{t}$

$$v = \frac{d}{t} = \frac{1320\ \text{m}}{4.0\ \text{s}} = \mathbf{330}\ \frac{\text{m}}{\text{s}}$$

3.6

- distance travelled $= vt$

$$d = vt = (1500\ \frac{\text{m}}{\text{s}})(0.80\ \text{s}) = 1200\ \text{m}$$

- the sound travels down and back up, so halve it

$$\text{depth} = \frac{1200\ \text{m}}{2} = \mathbf{600}\ \text{m}$$

3.7

(a)

- the pulses have a frequency of 45 kHz
- this is above the upper limit of human hearing, about 20 kHz

(b)

- $v = f\lambda$, so $\lambda = \frac{v}{f}$, with $f = 45\,000$ Hz

$$\lambda = \frac{v}{f} = \frac{340\ \frac{\text{m}}{\text{s}}}{45\,000\ \text{Hz}} = \mathbf{7.6 \times 10^{-3}}\ \text{m}$$

(c)

- the pulse travels to the moth and back, so the moth is half the total distance: $d = \frac{vt}{2}$

$$d = \frac{vt}{2} = \frac{(340\ \frac{\text{m}}{\text{s}})(0.012\ \text{s})}{2} = \mathbf{2.0}\ \text{m}$$

(d)

- the air particles vibrate back and forth along the direction the wave travels
- forming compressions and rarefactions that pass energy from particle to particle

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