Unit 7 · Mechanical Waves

HARDER PRACTICE QUESTIONS · ANSWER KEY

Full marks 29

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Spot the error

ANSWER U · 3

v ∝ √T needs the **absolute** temperature: 17 °C = 290 K and 47 °C = 320 K. So $v = 342\sqrt{\frac{320}{290}} = \mathbf{359}$ **m/s**. (569 m/s would be faster than heating by hundreds of degrees could give.)

MARKING SCHEME

- ✓ The mistake: °C used in place of kelvin.
- ✓ v = 342 √(320/290).
- ✓ v = 359 m/s.

2 Show that

ANSWER A · 3

$\frac{v}{c_{\text{rms}}} = \sqrt{\frac{\gamma RT/M}{3RT/M}} = \sqrt{\frac{\gamma}{3}}$. For air, $\sqrt{1.4/3} = \mathbf{0.68}$.
Sound is passed on by the molecules themselves, colliding with one another, so it can't outrun them: it travels at a little less than their typical speed.

MARKING SCHEME

- ✓ $v/c_{\text{rms}} = \sqrt{\gamma/3}$.
- ✓ 0.68 for air.
- ✓ Sound is carried by the molecules' own motion, so it is a little slower.

3 Predict, then explain

ANSWER HA · 3

Prediction: in **helium**.
$\frac{v_{\text{He}}}{v_{\text{air}}} = \sqrt{\frac{\gamma_{\text{He}}}{\gamma_{\text{air}}} \times \frac{M_{\text{air}}}{M_{\text{He}}}} = \sqrt{\frac{1.67}{1.4} \times \frac{29}{4}} = \mathbf{2.9\ times}$. Mostly because helium's molar mass is much smaller; its larger γ adds a little.

MARKING SCHEME

- ✓ Faster in helium.
- ✓ v ∝ √(γ/M).
- ✓ About 2.9 times.

4 Read the data

ANSWER A · 4

i. v^2/T: 100 489/250 = 402, 120 409/300 = 401, 140 625/350 = 402, 160 801/400 = 402: the same each time, so $v^2 \propto T$.
ii. Slope = $v^2/T \approx$ **402 m²/(s² K)**.
iii. Slope = γR/M, so M = 1.4 × 8.31 ÷ 402 = **0.029 kg/mol**, 29 g/mol: **air**.

MARKING SCHEME

- ✓ v^2/T is the same for every reading.
- ✓ Slope ≈ 402.
- ✓ M = γR/slope.
- ✓ 29 g/mol: air.

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5 A real setting

ANSWER A · 3

Base Camp, 263 K: $v = 331\sqrt{263/273} = \mathbf{325\ m/s}$. Kathmandu, 293 K: $v = 331\sqrt{293/273} = \mathbf{343\ m/s}$. The low pressure **doesn't matter**: the density is lower in the same proportion, so P/ρ is unchanged. Only the colder air makes sound slower there.

MARKING SCHEME

- ✓ 325 m/s at Base Camp.
- ✓ 343 m/s in Kathmandu.
- ✓ Pressure doesn't matter; only temperature does.

6 What if?

ANSWER A · 3

$M = 0.96 \times 29 + 0.04 \times 18 = \mathbf{28.56\ g/mol}$.
$v \propto 1/\sqrt{M}$, so the speed rises by $\sqrt{29/28.56} = 1.0077$: about **0.8% faster**.

MARKING SCHEME

- ✓ Average M = 28.56 g/mol.
- ✓ $v \propto 1/\sqrt{M}$.
- ✓ About 0.8% faster.

7 Check the claim

ANSWER A · 2

$\sqrt{313/273} = 1.071$: sound is only about **7% faster**. The claim is wrong; the speed grows with the square root of the absolute temperature, which rises only 15%.

MARKING SCHEME

- ✓ Ratio $\sqrt{(313/273)} = 1.07$.
- ✓ About 7%, not 20%: the claim is wrong.

8 Correct the misconceptions

ANSWER U · 3

1. All notes travel at the same speed in a medium: the medium sets the speed; a higher frequency only gives a shorter wavelength.
2. Sound is slowest in gases; it is fastest in solids, which are far stiffer.
3. Density alone slows sound ($v = \sqrt{(\text{modulus}/\rho)}$); steel is faster because its modulus is much larger, not because it is denser.

MARKING SCHEME

- ✓ The speed doesn't depend on frequency.
- ✓ Sound is slowest in gases, fastest in solids.
- ✓ Greater density alone slows sound; stiffness makes solids fast.

9 Design it

ANSWER HA · 3

Put one phone at each end of the pipe (a known length, a few meters), make a click at one end, and find from the two recordings the time the click takes to travel the pipe: v = length ÷ time. Repeat with the air in the pipe at different temperatures (for example on a cold morning and a hot afternoon, or with the pipe warmed in the sun), measuring the air's temperature with a thermometer each time. Several readings at each temperature give an average. Plot v^2 against the absolute temperature T: a straight line through the origin shows $v \propto \sqrt{T}$.

MARKING SCHEME

- ✓ Measure the time over a known length: v = length ÷ time.
- ✓ Change the temperature and measure it each time, with repeats.
- ✓ v^2 against T (in kelvin) a straight line through the origin.

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10 Make your own

ANSWER HA · 2

$v^2 = T/\mu = 40\,000$, so any pair with $T = 40\,000\ \mu$, for example μ **= 0.0050 kg/m and T = 200 N**.

MARKING SCHEME

✓ $T/\mu = 40\,000$.

✓ A suitable pair, e.g. 0.0050 kg/m and 200 N.

See it at Science Playground

Exhibits and plants at the center, Bhaktapur, that go with this unit. Book a class visit at science-playground.com/booking.

- **The Echo Tube** (exhibit): Clap into the 38 m tube: sound covers the 76 m there and back in about 0.22 s, near the 343 m/s Laplace's formula gives at 20 °C.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	6	15	8	**29**

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