Unit 7 · Mechanical Waves

ANSWER KEY · FOR TEACHERS

Full marks 33

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

1 Key words

K · 4

1. mechanical wave
2. elastic property
3. inertial property
4. Young's modulus
5. bulk modulus
6. isothermal
7. adiabatic
8. humidity

Each carries 0.5 mark.

2 Label the diagram

U · 2

1. v^2 (10^3 m^2/s^2)
2. 331 m/s
3. 387 m/s
4. T (K)

Each carries 0.5 mark.

3 Multiple choice

i. **b.** 60 m/s — A · 1

$v = \sqrt{T/\mu} = \sqrt{90/0.025} = \sqrt{3600} = 60$ m/s.

ii. **b.** rises 1.1 times — A · 1

$v \propto \sqrt{T}$: $\sqrt{363/300} = \sqrt{1.21} = 1.1$.

iii. **b.** γP — K · 1

The changes are adiabatic, PV^{γ} = constant, which gives K = γP.

iv. **b.** has a much smaller molar mass, so is less dense — U · 1

$v = \sqrt{\gamma RT/M}$: both are diatomic (the same γ), and hydrogen's M is 16 times smaller, so the speed is 4 times larger.

v. **a.** the frequency stays the same, the wavelength increases — U · 1

The source sets the frequency. Sound is faster in water, so λ = v/f is larger.

4 Short answers

a. MARKING SCHEME — U · 2

- ✓ v depends on modulus ÷ density.
- ✓ Steel's modulus is very much larger, which outweighs its density.

b. MARKING SCHEME — K · 2

- ✓ Newton assumed isothermal changes (K = P).
- ✓ They are really adiabatic: too fast for heat to flow.

c. MARKING SCHEME — A · 3

- ✓ $v = \sqrt{(K/\rho)}$.
- ✓ v = 1070 m/s.
- ✓ λ = 0.53 m.

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5 Long answer

ANSWER U · 4

For one mole of an ideal gas PV = RT, and V = M/ρ, so $\frac{P}{\rho} = \frac{RT}{M}$.

So $v = \sqrt{\frac{\gamma RT}{M}}$: for a given gas γ, R and M are fixed, so $\mathbf{v} \propto \sqrt{\mathbf{T}}$.

Then $\frac{dv}{dT} = \frac{v}{2T}$. At 0 °C, v = 331 m/s and T = 273 K: $\frac{331}{2 \times 273} = 0.61$ m/s for each kelvin (each °C).

MARKING SCHEME

- ✓ P/ρ = RT/M from PV = RT and V = M/ρ.
- ✓ v = $\sqrt{(\gamma RT/M)}$.
- ✓ So v $\propto \sqrt{T}$.
- ✓ dv/dT = v/(2T) $\approx$ 0.6 m/s per degree.

6 Numerical problems

a. **ANSWER** A · 4

i. $v_N = \sqrt{\frac{P}{\rho}} = \sqrt{\frac{1.013 \times 10^5}{0.090}} = \mathbf{1061\ m/s}$.

ii. $v_L = \sqrt{\gamma}\, v_N = \sqrt{1.41} \times 1061 = \mathbf{1260\ m/s}$.

iii. λ = v/f = 1260/500 = **2.5 m**.

MARKING SCHEME

- ✓ Newton: v = $\sqrt{(P/\rho)}$.
- ✓ 1061 m/s.
- ✓ Laplace: 1260 m/s.
- ✓ λ = 2.5 m.

b. **ANSWER** A · 4

i. $\mu = \rho \times \pi r^2 = 8900 \times \pi \times (0.50 \times 10^{-3})^2 = \mathbf{7.0 \times 10^{-3}\ kg/m}$.

ii. $v = \sqrt{T/\mu} = \sqrt{60/0.0070} = \mathbf{93\ m/s}$.

iii. $v = \sqrt{Y/\rho} = \sqrt{1.2 \times 10^{11}/8900} = \mathbf{3670\ m/s}$, about **40 times** faster.

MARKING SCHEME

- ✓ $\mu = \rho\pi r^2 = 7.0 \times 10^{-3}$ kg/m.
- ✓ Transverse: 93 m/s.
- ✓ Longitudinal: 3670 m/s.
- ✓ About 40 times faster.

7 Think

ANSWER HA · 3

The pressure alone changes nothing: at a fixed temperature the density changes in the same proportion as the pressure, so P/ρ stays the same. The speed is faster inside, but because the air is hotter: $\sqrt{393/300} = \mathbf{1.14\ times}$.

MARKING SCHEME

- ✓ Pressure alone doesn't change the speed (P/ρ stays the same).
- ✓ The speed rises because of the temperature.
- ✓ $\sqrt{(393/300)} = 1.14$ times.

8 Activity: Clap for an echo

(not marked)

WHAT STUDENTS SHOULD FIND

Between two claps the sound goes to the wall and back, 2d, so the speed is 2d × 20 ÷ (time for 20 claps). The results should come out near 340–350 m/s on a warm day, close to 331 + 0.6t. The farther wall gives a longer time but the same speed.

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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	7	10	13	3	**33**

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