Unit 9 · Acoustic Phenomena

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

1. pressure amplitude
2. intensity
3. loudness
4. pitch
5. ultrasonic
6. quality
7. Doppler's effect
8. Mach number

Each carries 0.5 mark. **K · 4**

2 Label the diagram

1. y_1
2. Δx
3. $\Delta x + \Delta y$
4. y_2

Each carries 0.5 mark. **K · 2**

3 Multiple choice

i. **b.** 60 dB **A · 1**

$\beta = 10 \log_{10}(10^{-6}/10^{-12}) = 10 \times 6 = 60$ dB.

ii. **c.** 9.5 dB **A · 1**

The intensity falls to 1/9 (inverse square law): $10 \log_{10} 9 = 9.5$ dB.

iii. **b.** four times as large **U · 1**

$I \propto a^2$, so doubling a makes I four times as large (6 dB more).

iv. **b.** 42° **A · 1**

$\sin\theta = v/v_s = 1/1.5 = 0.667$, so $\theta = 41.8°$.

v. **a.** the same wavelength, but pass her more often **U · 1**

The source isn't moving, so the waves in the air keep their wavelength; she meets them faster, at $v + v_l$ relative to her, so she hears a higher frequency.

4 Short answers

a. **MARKING SCHEME** **K · 2**

- ✓ Any one, e.g. intensity is a physical quantity measured with an instrument (in W/m^2); loudness is a sensation of the listener.
- ✓ Any second, e.g. intensity doesn't depend on the listener; loudness depends on the listener's ear and on the frequency (loudness grows as the logarithm of the intensity).

b. **MARKING SCHEME** **U · 2**

- ✓ Approaching: waves crowded, higher frequency.
- ✓ Moving away: waves stretched, lower frequency, so the note drops as it passes.

c. **MARKING SCHEME** **A · 3**

- ✓ $f' = v/(v - v_s) \times f$ for approaching.
- ✓ 756 Hz.
- ✓ 652 Hz going away.

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5 Long answer

ANSWER U · 4

In one second the source sends out f waves. The first travels a distance v towards the listener, but the source follows it by v_s, so the f waves are packed into a length $v - v_s$.

The wavelength is then $\lambda' = \frac{v - v_s}{f}$.

The waves still travel at v through the air, so the listener receives $f' = \frac{v}{\lambda'} = \frac{v}{v - v_s} f$, higher than f.

Moving away, the f waves are spread over $v + v_s$: $f' = \frac{v}{v + v_s} f$, lower than f.

MARKING SCHEME

- ✓ f waves in a length $v - v_s$.
- ✓ $\lambda' = (v - v_s)/f$.
- ✓ $f' = v\,f/(v - v_s)$, higher.
- ✓ Moving away: $f' = v\,f/(v + v_s)$, lower.

6 Numerical problems

a. **ANSWER** A · 4

i. $I = \frac{(\Delta P)_{\max}{}^2}{2\rho v} = \frac{0.20^2}{2 \times 1.2 \times 340} = \mathbf{4.9 \times 10^{-5}\ W/m^2}$.

ii. $\beta = 10 \log_{10}(4.9 \times 10^{-5}/10^{-12}) = \mathbf{77\ dB}$.

iii. $a = \frac{(\Delta P)_{\max}}{\rho v \omega} = \frac{0.20}{1.2 \times 340 \times 2\pi \times 1000} = \mathbf{7.8 \times 10^{-8}\ m}$.

iv. Four times as far, I is 1/16: the level falls by $10 \log_{10} 16 = 12$ dB, to **65 dB**.

MARKING SCHEME

- ✓ $I = 4.9 \times 10^{-5}$ W/m^2.
- ✓ $\beta = 77$ dB.
- ✓ $a = 7.8 \times 10^{-8}$ m.
- ✓ 65 dB at four times the distance.

b. **ANSWER** A · 4

i. Source towards a still listener: $\frac{340}{325} \times 450 = \mathbf{471\ Hz}$.

ii. The wall sends back 471 Hz, and the driver moves towards it: $\frac{340 + 15}{340} \times 470.8 = \mathbf{492\ Hz}$ (in one step, $\frac{v + u}{v - u} f = \frac{355}{325} \times 450$).

iii. Away: $\frac{v - u}{v + u} f = \frac{325}{355} \times 450 = \mathbf{412\ Hz}$.

MARKING SCHEME

- ✓ 471 Hz at the wall.
- ✓ The echo: the wall's frequency, received by the moving driver.
- ✓ 492 Hz.
- ✓ 412 Hz moving away.

7 Think

ANSWER HA · 3

The Doppler shift depends only on the part of the source's velocity along the line joining it to the listener. At the closest point the car moves at right angles to that line: it is neither coming nearer nor going away, so there is no shift for that instant. Before it, the car approaches (higher); after it, it recedes (lower).

MARKING SCHEME

- ✓ Only the velocity along the line to the listener matters.
- ✓ At the closest point the car moves at right angles to that line.
- ✓ So there is no shift then; higher before, lower after.

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8 Activity: Measure the inverse square law

(not marked)

WHAT STUDENTS SHOULD FIND

The level should fall by about 6 dB each time the distance doubles: the intensity falls to a quarter, and $10 \log_{10} 4 = 6$ dB. Walls, the ground or wind nearby make it less exact.

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 Inverse Square Law** (exhibit): Light obeys the same inverse square law as sound: at twice the distance the light covers four times the squares, each a quarter as bright.
- **Whisper Dishes — Send a Whisper Across the Garden** (exhibit): Whisper at one dish's ring: the dishes send the sound across as a narrow beam instead of in all directions, so it fades far more slowly than $1/d^2$.
- **The Chime Instrument** (exhibit): Play the rods from shortest to longest: the pitch falls, because each longer rod vibrates at a lower frequency.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	8	8	14	3	**33**