Unit 9 · Acoustic Phenomena

HARDER PRACTICE QUESTIONS · ANSWER KEY

Full marks 28

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

By the inverse square law, four times the distance makes the intensity **1/16**, not 1/4. The level falls by $10 \log_{10} 16 = 20 \log_{10} 4 =$ **12 dB**, to **72 dB**.

MARKING SCHEME

- ✓ The mistake: the intensity falls as the square of the distance.
- ✓ I falls to 1/16: a fall of 12 dB.
- ✓ 72 dB.

2 Show that

ANSWER A · 2

$I \propto 1/d^2$, so $\frac{I_1}{I_2} = \frac{d_2^{\,2}}{d_1^{\,2}} = 4$ for $d_2 = 2d_1$. Then $\beta_1 - \beta_2 = 10\log_{10}4 = 20\log_{10}2 =$ **6.0 dB**, which doesn't depend on d_1.

MARKING SCHEME

- ✓ Doubling d makes I a quarter.
- ✓ $\Delta\beta = 10 \log_{10} 4 = 6.0$ dB, whatever the distance.

3 Predict, then explain

ANSWER HA · 3

Prediction: **no**, she hears 500 Hz.

The wind carries the sound faster towards her, at 340 + 10 = 350 m/s, but the siren and the listener are at rest relative to each other (and to the ground), so the waves are not crowded or stretched by any motion of theirs: each wave the siren sends reaches her, and in the steady state as many waves arrive each second as are sent, 500. The wind changes the speed (and the wavelength, 350/500 = 0.70 m), not the frequency.

MARKING SCHEME

- ✓ She hears 500 Hz.
- ✓ Source and listener don't move relative to each other.
- ✓ The wind changes the speed and wavelength, not the frequency.

4 Read the data

ANSWER A · 4

i. Each doubling of the distance lowers the level by 6 dB: the intensity falls to a quarter, as the inverse square law says.

ii. $I = I_0 \times 10^{\beta/10} = 10^{-12} \times 10^{8.6} =$ **4.0×10^{-4} W/m²**.

iii. $P = I \times 4\pi d^2 = 4.0 \times 10^{-4} \times 4\pi \times 2^2 =$ **0.020 W**.

MARKING SCHEME

- ✓ 6 dB less for each doubling: inverse square.
- ✓ $I = 10^{-12} \times 10^{8.6}$.
- ✓ 4.0×10^{-4} W/m².
- ✓ P = 0.020 W.

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5 A real setting

ANSWER A · 3

The blood receives and sends back the wave as a moving reflector: $f'' = \frac{v+u}{v-u} f = \frac{1540.3}{1539.7} \times 2.0 \times 10^6$ Hz.

Shift = f″ − f = **780 Hz** (about 2fu/v), so the echo is about **2 000 780 Hz**: a shift we can hear, which is how the machine lets the doctor listen to the flow.

MARKING SCHEME

- ✓ f″ = (v + u)/(v − u) × f.
- ✓ Shift about 780 Hz.
- ✓ Echo about 2 000 780 Hz.

6 Estimate it

ANSWER HA · 3

The Mach cone's half-angle: sin $\theta = 1/1.5$, $\theta = 41.8°$. The boom reaches you when the cone's edge passes you, while the jet is ahead by a distance x with tan $\theta = 3000/x$: x = 3000/tan 41.8° ≈ **3.4 km**. It has already passed overhead before you hear anything.

MARKING SCHEME

- ✓ $\theta = 41.8°$ from sin $\theta = 1/M$.
- ✓ x = h/tan θ.
- ✓ About 3.4 km ahead.

7 Check the claim

ANSWER A · 2

60 dB more means $10^{60/10} = 10^6$: the road's intensity is **a million times** the whisper's, not four times. (Our sense of loudness grows only as the logarithm of the intensity.)

MARKING SCHEME

- ✓ Difference 60 dB.
- ✓ 10^6 times the intensity, not 4.

8 Correct the misconceptions

ANSWER U · 3

1. For sound the two are not the same: a moving source changes the wavelength, a moving listener changes how fast the waves pass; the source moving gives the larger shift.
2. The pressure change is greatest where the displacement is zero: they are 90° out of phase.
3. A 3 dB rise means the intensity has about **doubled** ($10 \log_{10} 2 = 3$); tripling is about 4.8 dB.

MARKING SCHEME

- ✓ Source moving and listener moving give different shifts for sound.
- ✓ Greatest pressure change where the displacement is zero.
- ✓ 3 dB is about double the intensity.

9 Work backwards

ANSWER A · 3

$\frac{380}{320} = \frac{v+v_s}{v-v_s}$, so 380(340 − v_s) = 320(340 + v_s), 700v_s = 20 400, **v_s = 29 m/s**.

Then $f = 380 \times \frac{340 - 29.1}{340} =$ **347 Hz**.

MARKING SCHEME

- ✓ The ratio 380/320 = (v + v_s)/(v − v_s).
- ✓ v_s = 29 m/s.
- ✓ f = 347 Hz.

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10 Make your own

HA · 2

ANSWER

90 dB is $I = 10^{-12} \times 10^{9} = 10^{-3}\ \text{W/m}^2$. $P = I \times 4\pi d^2 = 10^{-3} \times 4\pi \times 10^{2} = \mathbf{1.3\ W}$.

MARKING SCHEME

✓ $I = 10^{-3}\ \text{W/m}^2$.

✓ $P = 4\pi d^2 I = 1.3$ W.

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	0	6	14	8	**28**

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