Unit 8 · Waves in Pipes and Strings

HARDER PRACTICE QUESTIONS · ANSWER KEY

Full marks 27

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/4l is the closed pipe's formula. An open pipe has an antinode at both ends, so its fundamental is half a wavelength: $l = \lambda/2$ and $f_1 = \frac{v}{2l} = \frac{340}{1.0} =$ **340 Hz**, twice his answer.

MARKING SCHEME

- ✓ The mistake: the closed pipe's formula used for an open pipe.
- ✓ Open pipe: $l = \lambda/2$, so $f_1 = v/2l$.
- ✓ $f_1 = 340$ Hz.

2 Read the data

ANSWER HA · 3

If it were **open**, neighboring resonances differ by f_1, so $f_1 = 150$ Hz; but $375/150 = 2.5$ is not a whole number, so it can't be open.

If it is **closed**, neighboring resonances (odd harmonics) differ by $2f_1$, so $f_1 = 75$ Hz; $375 = 5 \times 75$ and $525 = 7 \times 75$, both odd harmonics. It is a **closed pipe** with fundamental **75 Hz**.

MARKING SCHEME

- ✓ Open would need $f_1 = 150$ Hz, which 375 Hz doesn't fit.
- ✓ Closed: neighbors differ by $2f_1$, so $f_1 = 75$ Hz.
- ✓ 375 and 525 Hz are the 5th and 7th harmonics: closed.

3 Predict, then explain

ANSWER HA · 3

It goes **up**. $f = v/2l$, and $v \propto \sqrt{T}$: $\sqrt{308/288} = 1.034$, about **3.4% higher**.

A string's frequency, $\frac{1}{2l}\sqrt{T/\mu}$, depends on its tension, mass per length and length, not on the speed of sound in the air, so the warmer air doesn't change it this way.

MARKING SCHEME

- ✓ The flute's note goes up.
- ✓ About 3.4% ($\sqrt{(308/288)}$).
- ✓ A string's frequency doesn't depend on the speed of sound in air.

4 A real setting

ANSWER A · 4

i. $v = 2lf = 2 \times 0.86 \times 240 =$ **413 m/s**.

ii. $T = v^2\mu = 413^2 \times 0.40 \times 10^{-3} =$ **68 N**.

iii. $f \propto 1/l$: $240 \times 3/2 =$ **360 Hz**.

MARKING SCHEME

- ✓ $v = 2lf = 413$ m/s.
- ✓ $T = v^2\mu$.
- ✓ $T = 68$ N.
- ✓ 360 Hz with the fret.

Science Playground, Katunje, Bhaktapur
Book a class visit: https://science-playground.com/booking

5 Show that

ANSWER A · 3

$\mu = (\text{area}) \times \rho = \frac{\pi d^2}{4}\rho$. So $f = \frac{1}{2l}\sqrt{\frac{4T}{\pi d^2 \rho}} = \frac{1}{2l} \times \frac{2}{d}\sqrt{\frac{T}{\pi\rho}} = \frac{1}{ld}\sqrt{\frac{T}{\pi\rho}}$.

For the same f with d doubled, $\sqrt{T}$ must double: **four times** the tension.

MARKING SCHEME

- ✓ $\mu = \pi d^2\rho/4$.
- ✓ Substituted to give $f = (1/ld)\sqrt{(T/\pi\rho)}$.
- ✓ Twice the diameter needs four times the tension.

6 What if?

ANSWER A · 3

Before (closed): overtones are the odd harmonics, **480 Hz and 800 Hz**.
Opened, the same length gives $f_1 = v/2l$, twice v/4l: **320 Hz**. All harmonics now appear: overtones **640 Hz and 960 Hz**.

MARKING SCHEME

- ✓ Closed overtones 480 and 800 Hz.
- ✓ Open fundamental 320 Hz.
- ✓ Open overtones 640 and 960 Hz.

7 Check the readings

ANSWER A · 3

By the law of length f × l is the same for every fork: 256 × 0.60 = 153.6, 320 × 0.48 = 153.6, 384 × 0.40 = 153.6, but 512 × 0.32 = 163.8. The **512 Hz** reading is wrong; it should be 153.6 ÷ 512 = **0.30 m**.

MARKING SCHEME

- ✓ f × l should be constant.
- ✓ The 512 Hz reading doesn't fit.
- ✓ Its length should be 0.30 m.

8 Correct the misconceptions

ANSWER U · 3

1. An open end is an antinode: the air there is free to move. The closed end is a node.
2. A closed pipe has only odd harmonics, so its first overtone is the **third** harmonic.
3. Tightening a string makes its waves **faster** ($v = \sqrt{(T/\mu)}$), which raises the frequency for the same wavelength.

MARKING SCHEME

- ✓ An open end is an antinode.
- ✓ A closed pipe's first overtone is the third harmonic.
- ✓ More tension makes the waves faster, which raises the note.

9 Make your own

ANSWER HA · 2

l = v/4f = 340/(4 × 425) = **0.20 m**. The next note is its third harmonic, 3 × 425 = **1275 Hz**.

MARKING SCHEME

- ✓ l = 0.20 m.
- ✓ Next note 1275 Hz.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	6	13	8	**27**

Science Playground, Katunje, Bhaktapur
Book a class visit: https://science-playground.com/booking