

Standing waves on strings and in pipes

Physics grades 11-12 (A Level · IB · Class 11-12) · Worksheet

Name: _____ Date: _____ Class: _____

These problems train you to draw and read stationary waves, to find wavelengths from nodes and antinodes and to calculate harmonics for strings and for open and closed pipes. They suit A Level, IB physics and Class 11-12 students and finish with multi-step data analysis.

Level: Physics grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** IB C.4

Problem 1 Progressive or stationary? (easy)

Wanjiru in Nairobi compares a wave travelling along a rope with a stationary wave on a guitar string.

1. State two differences in amplitude and energy transfer.
2. Define a node and an antinode.
3. State the distance between two adjacent nodes in terms of λ .

Problem 2 Loops on a rope (easy)

A rope 3.0 m long is fixed at both ends and shaken to form a stationary wave with 3 loops.

1. Calculate the wavelength.
2. State the distance between adjacent nodes.
3. State the total number of nodes, including the two ends.

Problem 3 Guitar string harmonics (easy)

A guitar string has vibrating length 0.65 m. Waves travel along it at 260 m/s.

1. Calculate the fundamental frequency.
2. Calculate the frequency of the second harmonic.
3. Calculate the frequency of the third harmonic.

Problem 4 Bamboo flute (easy)

Aarav in Pune plays a bamboo flute modelled as an open pipe 0.60 m long. Take $v = 343$ m/s.

1. State the pattern of nodes and antinodes at the ends.
2. Calculate the fundamental frequency.
3. Calculate the next two harmonics.

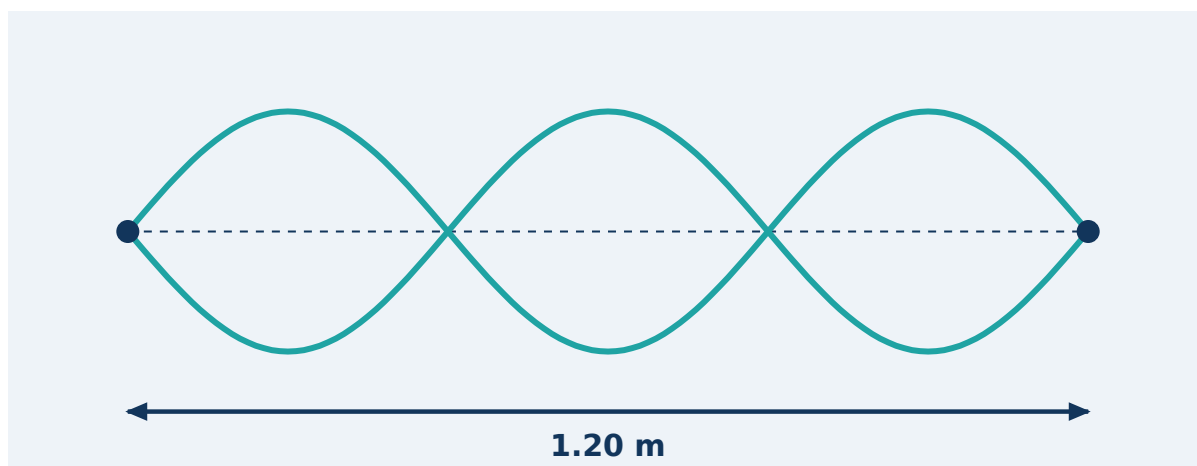
Problem 5 Closed organ pipe (easy)

A pipe closed at one end has length 0.25 m ($v = 343$ m/s).

1. Calculate the fundamental frequency.
2. Calculate the next two resonant frequencies.
3. Explain why $2f_1$ is not a resonance.

Problem 6 Reading a string diagram (easy)

A vibrator drives a string at 150 Hz and produces the pattern shown.



Stationary wave on a string of length 1.20 m.

1. State the number of antinodes and the harmonic number.
2. Calculate the wavelength.
3. Calculate the speed of waves on the string.

Problem 7 Chocolate in the microwave (easy)

A microwave oven with the turntable removed melts a bar of chocolate in spots 6.1 cm apart. The oven frequency is 2.45 GHz.

1. Explain why melting happens in spots.
2. Calculate the wavelength of the microwaves.
3. Calculate the speed of the waves from your result.

Problem 8 Sitar string (medium)

A sitar string of length 0.80 m has tension 80 N and mass per unit length 2.0 g/m.

1. Convert μ to kg/m.
2. Calculate the wave speed.
3. Calculate the fundamental frequency.

Problem 9 Tuning the string (medium)

The sitar string in the previous problem is tuned from 125 Hz to 150 Hz by adjusting the tension, with the same length and mass per unit length.

1. Explain why $f \propto \sqrt{T}$.
2. Calculate the new tension.
3. State the percentage increase in tension.

Problem 10 Melde string (medium)

In a school lab in Lahore a vibrator of frequency 50 Hz drives a string 1.20 m long. The string passes over a pulley and carries a 0.50 kg mass. Four loops form between the vibrator and the pulley. Take $g = 9.81 \text{ m/s}^2$.

1. Calculate the wavelength.
2. Calculate the wave speed.
3. Calculate the tension and the mass per unit length.

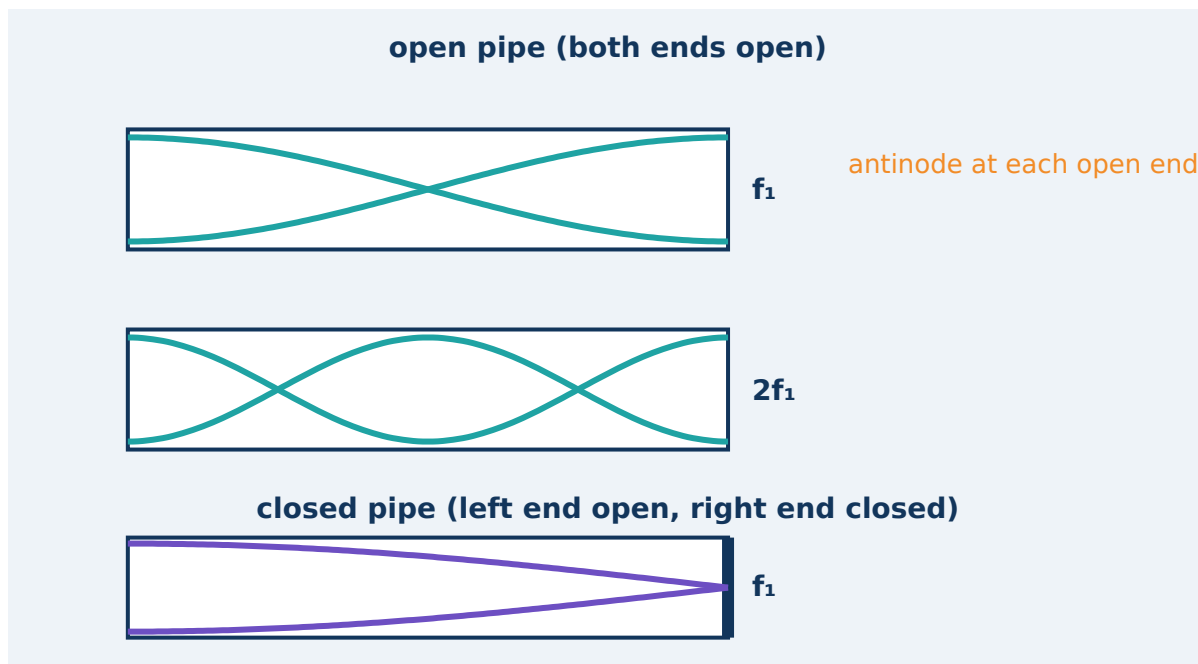
Problem 11 Vocal tract (medium)

Model the vocal tract of Emma in Leeds as a pipe 0.17 m long, closed at the glottis and open at the lips. Take $v = 343 \text{ m/s}$.

1. Calculate the first three resonant frequencies.
2. State why the vocal tract can be modelled as a closed pipe.
3. Explain which harmonics appear.

Problem 12 Which pipe? (medium)

Two pipes of the same length 0.50 m are shown. One is open at both ends; the other is closed at one end. Take $v = 343 \text{ m/s}$.



Displacement patterns in an open and a closed pipe.

1. Identify which pattern has a node at the right-hand end.
2. Calculate the fundamental frequency of each pipe.

3. Calculate the ratio of the two fundamentals.

Problem 13 End correction (medium)

A closed pipe of length 0.30 m and radius 2.0 cm is used with $v = 343$ m/s.

1. Calculate the fundamental frequency ignoring end correction.
2. Calculate the effective length using $L + 0.6r$.
3. Calculate the corrected fundamental frequency.

Problem 14 Warm air in a pipe (medium)

The speed of sound in air is $v = 331 + 0.6\theta$ m/s, where θ is the temperature in °C. An open organ pipe is 0.50 m long.

1. Calculate the fundamental at 20 °C.
2. Calculate the fundamental at 35 °C.
3. Calculate the percentage change.

Problem 15 Sound against a wall (medium)

A loudspeaker produces a 1715 Hz tone facing a wall in a quiet room. A stationary wave forms between speaker and wall. Take $v = 343$ m/s.

1. Calculate the wavelength.
2. Calculate the distance between adjacent nodes.
3. The air at a hard wall cannot move. Calculate the distance from the wall to the nearest antinode.

Problem 16 Consecutive resonances (hard)

A string 1.50 m long, fixed at both ends, resonates at 240 Hz and 300 Hz with no resonance between these frequencies.

1. Show that the fundamental is 60 Hz.
2. State the harmonic numbers of 240 Hz and 300 Hz.
3. Calculate the wave speed on the string.

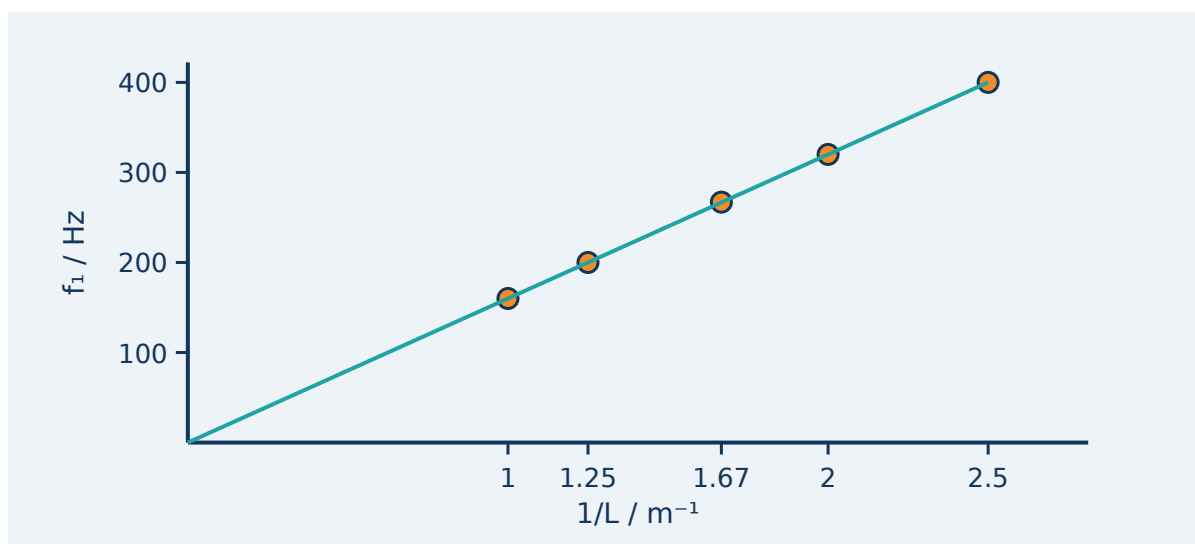
Problem 17 Which type of pipe? (hard)

A pipe resonates at 255 Hz and 425 Hz with no resonance between them. Take $v = 343$ m/s.

1. Show that the ratio of the frequencies suggests a pipe closed at one end.
2. Calculate the fundamental frequency.
3. Calculate the length of the pipe.

Problem 18 Frequency against $1/L$ (hard)

A student plucks a wire at different vibrating lengths L by moving a bridge and measures the fundamental frequency f_1 . The wire has mass per unit length 1.0 g/m.



f_1 against $1/L$ for a wire.

1. Explain why a graph of f_1 against $1/L$ is a straight line through the origin.
2. Calculate the gradient using the first and last points.
3. Calculate the wave speed and the tension.

Problem 19 Spot the error (hard)

A student states that a pipe 0.80 m long, closed at one end, has a fundamental of $343 \div (2 \times 0.80) = 214$ Hz and that its next resonance is at 428 Hz.

1. Identify the two errors.
2. Calculate the correct fundamental.
3. Calculate the correct next resonance.

Problem 20 A pipe filled with helium (hard)

A pipe closed at one end is 0.34 m long. In air the speed of sound is 343 m/s; in helium it is 970 m/s.

1. Calculate the fundamental frequency in air.
2. Calculate the fundamental frequency in helium.
3. Explain why a person who inhales helium sounds higher pitched.