

Standing waves on strings and in pipes

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

Model answers use the sample table. Your own readings will differ slightly, but L plotted against $1/f$ should be a straight line with a small negative intercept equal to minus the end correction.

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

Question 1 Resonance condition

At the water surface there is a node (air cannot move) and near the open end there is an antinode, a distance e above the tube. The shortest pattern joining a node to an antinode is a quarter of a wavelength. $L + e = \lambda/4$.

Question 2 Line equation

Since $\lambda = v/f$, $L + e = v/(4f)$. So $L = (v/4)(1/f) - e$, a straight line when L (y-axis) is plotted against $1/f$ (x-axis), with gradient $v/4$ and intercept $-e$.

Question 3 Slope of the line

$1/f$ for 256 Hz = 3.906×10^{-3} s; for 512 Hz = 1.953×10^{-3} s. Gradient = $(0.158 - 0.326) \div (0.001953 - 0.003906) = \mathbf{86.02 \text{ m/s}}$ (metres per second, since L is in m and $1/f$ in s).

Question 4 Speed of sound

$v = 4 \times \text{gradient} = 4 \times 86.02 = \mathbf{344 \text{ m/s}}$.

Question 5 End correction

Intercept = $L - \text{gradient} \times (1/f)$ using the 256 Hz point = $0.326 - 86.02 \times 0.003906 = -0.01$ m, so $e = \mathbf{1 \text{ cm}}$. The tube radius is 2.0 cm, so $0.6r = 1.2$ cm is of the same order.

Question 6 Percentage difference

$|344 - 343| \div 343 \times 100 = \mathbf{0.31 \%}$.

Question 7 Second resonance

$L_2 - L_1 = \lambda/2$, so $\lambda = 2 \times (0.493 - 0.158) = 0.67$ m. $v = f\lambda = 512 \times 0.67 = \mathbf{343 \text{ m/s}}$. The end correction cancels in the difference.

Question 8 Uncertainty and improvement

$3 \text{ mm} \div 158 \text{ mm} \times 100 = \mathbf{1.9 \%}$. To improve, find the quietest positions either side of the maximum and take the midpoint, or use a loudspeaker and signal generator to give a steady tone.