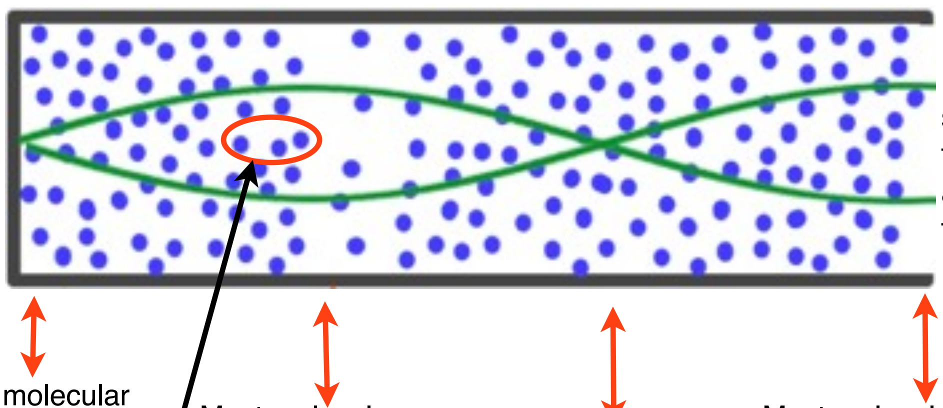
Standing waves in a tube

The Fizzics Organization
www.fizzics.org   www.fizzics.co.uk

A standing wave in a tube is produced by interference with the wave traveling down the tube and its reflection from the end.

The green line is a graphical indication of the amount of vibration of the air molecules along the tube, resulting in rapid pressure changes at the antinodes. The vibration is longitudinal, the molecules oscillate in a direction along the tube.

Node   Antinode   Node   Antinode



Energy input by a speaker, a tuning fork or by blowing across the end of the tube

No molecular motion here

Most molecular motion here with changes between compression and rarefaction

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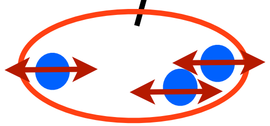
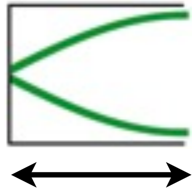


The individual molecules vibrate back and forth in a direction along the tube.

By blowing across a tube the fundamental note will be produced. The wavelength of the note will be 4 times the length of the tube.

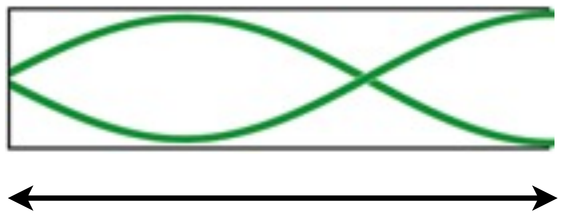


Fundamental note

$^{1}/_{4}\ \lambda$

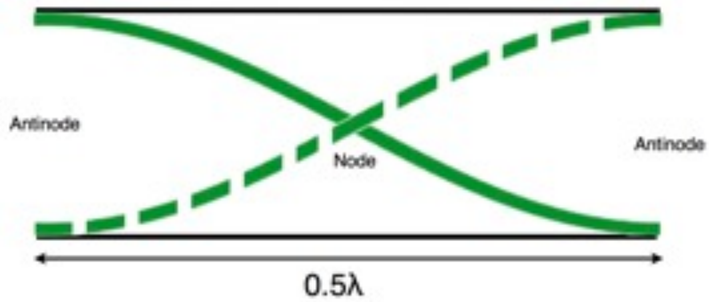
Second harmonic

Using a tuning fork or speaker we can induce harmonic notes.



$^{3}/_{4}\ \lambda$

A standing wave is possible in **an open tube**. There must be an antinode at each end. This is therefore a graphical representation of the fundamental note.



Calculating the speed of sound in air

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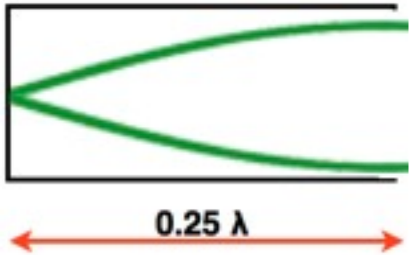
The simple method



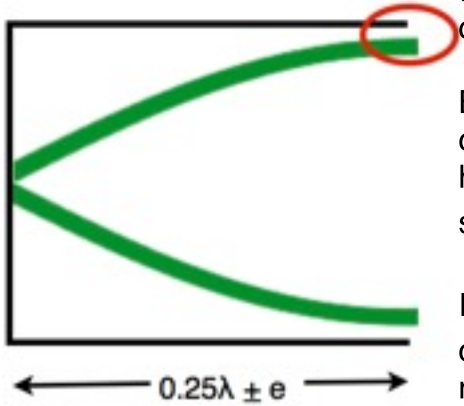
Resonance at 155mm with a note of 524Hz

Wavelength = 155 x 4 = 620mm or 0.62m

Since V = f λ then V = 524 x 0.62 = 325ms^{-1}

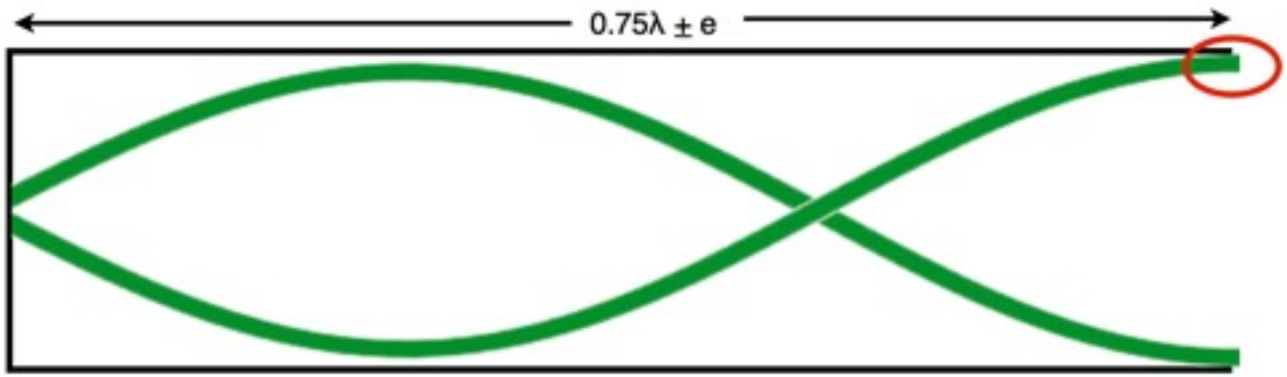
A more accurate method

The standing wave is not exactly the same length as the tube. There is an end correction. In the last calculation we did this was an intrinsic error in our measurement.



Because we use the same tube each time the end correction for the fundamental note and the second harmonic are the same. If we measure each one and then subtract the two, the difference is **0.5λ**.

If we use this value of 0.5 we have removed the end correction **but** we have also introduced an extra length measurement which is itself liable to a random error.



The calculation

Using the resonance points for the 440 Hz fork

The length measured at the fundamental was 0.188 m

At the second harmonic it was 0.582m

The difference between these two is 0.394m which is equal to a half wavelength. A full wavelength is therefore 0.788m

The speed of sound in air calculated from V= f λ

= 440 x 0.788 = 346.72 ms^{-1}

I estimate that the measurements were each made to an accuracy of about 3mm, so with a possible error of 6mm in 394, the possible error is + 1.5% or +5ms^{-1}. So our complete answer is 346.7 + 5ms^{-1}.

The speed of sound in air varies with temperature and humidity but is generally in the range 340 to 344ms^{-1}