Advanced Higher Physics: Assignment Support

Astronomy & Physics Education Group

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Measuring speed of sound using resonance tube

Introduction

The aim of this experiment is to examine the resonance of sound in an open-ended tube and hence determine a value for the speed of sound in air at room temperature.

If a loudspeaker connected to a signal generator is placed above an open-ended tube, as shown in Figure 1, then the sound waves from the loudspeaker will travel down the tube and be reflected at the surface of the water. As a result, stationary sound waves are produced by the interference of the incident and reflected waves.

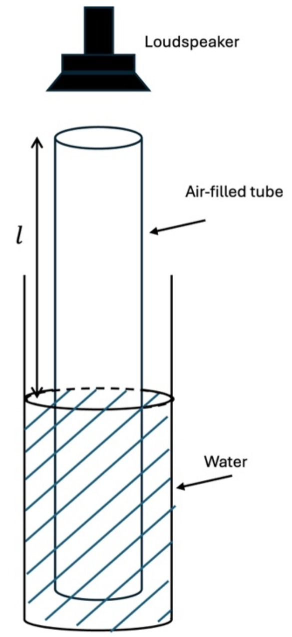

Figure 1: Tube partially immersed in water

The air is at rest at the water surface, i.e. there is a node at the water surface (a point of zero wave amplitude). For resonance there must be an antinode (a point of maximum wave amplitude) at the mouth of the tube.

In practice, the antinode occurs at a short distance beyond the mouth of the tube, i.e. the effective length, L, of the resonating air column is greater than the length, l, of the air column contained within the tube. This difference in length is known as the end correction, ε.

The first resonance for a particular frequency of sound occurs when the effective length, L, of the air column is exactly one-quarter the wavelength of the sound (Figure 2a) and the second resonance for the same frequency occurs when L of the air column is exactly three-quarters of a wavelength (Figure 2b).

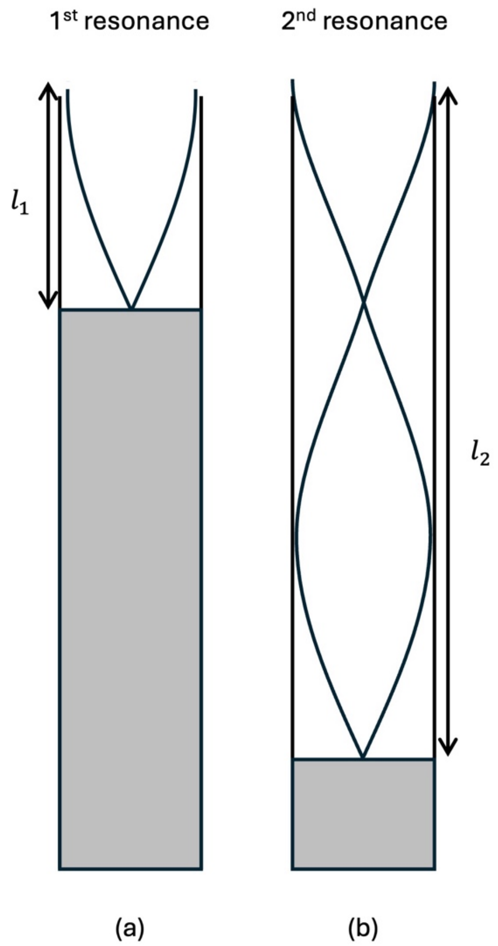

Figure 2: Resonances in tube

Hence,

$$L_1 = l_1 + \varepsilon = \frac{\lambda}{4}$$

[1]

and

$$L_2 = l_2 + \varepsilon = \frac{3\lambda}{4}$$

[2]

By subtraction of [1] from [2] we get

$$L_2 - L_1 = l_2 - l_1 = \frac{\lambda}{2}$$

[3]

So by measuring l_1 and l_2 we can calculate the wavelength of the sound from [3] above, and from there determine the speed of sound in air, v, using $v = f\lambda$.

Combining [1] and [3] we arrive at an expression for finding ε:

$$\varepsilon = \frac{1}{2}(l_2 - 3l_1)$$

[4]

Alternatively, if the lowest resonant frequency (also known as the 1st harmonic) f_1 is found for a range of air column lengths l then v and ε can be determined graphically. [1] can be rewritten:

$$l_1 + \varepsilon = \frac{v}{4f_1}$$

[6]

So if a plot of l against $\frac{1}{f_1}$ will yield v from the gradient of the graph and ε from the intercept.

Notes on equipment

Equipment list

The equipment provided for this Experiment are:

- Hollow plastic tube
- Water-filled glass cylinder
- Signal generator and loudspeaker
- Metre rule
- Water-resistant marker

Equipment guidance

Tube

- Use the pen and metre rule to add a scale to the plastic tube – 10 cm steps is best, starting at 30 cm from the top of the tube through to 90 cm.

Determining the value of ε

- Acoustic calculations[1] show that for a freely open-ended tube the end correction ε is related to the cross-sectional area, A of the tube by $\varepsilon = 0.34\sqrt{A}$
- and for a baffled tube, i.e. one where the open end faces a nearby obstruction the expression is $\varepsilon = 0.48\sqrt{A}$
- The values obtained in this experiment allow for the determination of which model best describes the experimental set up.

Original script: Peter Law

[1] End Corrections at a Flue Pipe Mouth by Johan Liljencrants

Updated script: Peter H Sneddon