Topic 4 – Practical 1

Experimental determination of the speed of sound using stationary waves

Safety

Wear protective glasses and be careful not to break the glassware.

Apparatus and materials

- deep cylindrical container (e.g. 1 dm^3 measuring cylinder)
- glass resonance tube (diameter smaller than cylindrical container)
- stand and clamp
- set of tuning forks and rubber bung
- metre rule
- water
- thermometer

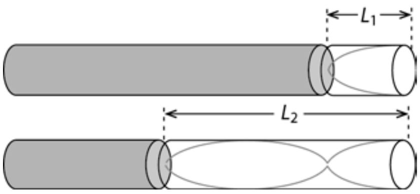
Introduction

In this practical, you will use the formation of stationary waves to experimentally determine the speed of sound.

Sound waves generated by the tuning fork travel down the tube and are reflected at the surface of the water. This leads to the formation of stationary waves when the length of the empty portion of the tube has specific values. At the surface of the water there is going to be a node and at the open end of the tube there is going to be an antinode. The figure below represents the first two resonance modes, for which the relationships between lengths of the empty part of the tube L_1 and L_2 and the wavelength of the sound wave λ are:

$L_1 = \frac{\lambda}{4}$ and $L_2 = 3\,\frac{\lambda}{4}$

Therefore $(L_2 - L_1) = \frac{\lambda}{2}$



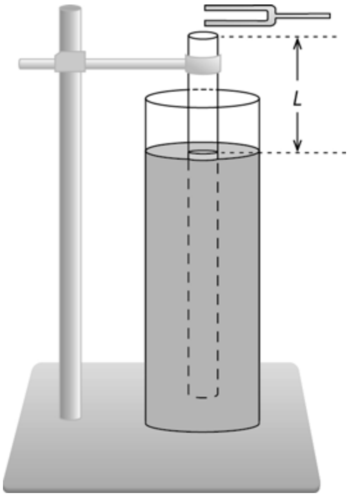
Using the wave equation, $c = f\lambda$, we get

$$(L_2 - L_1) = \frac{c}{2} \times \frac{1}{f}$$

where c is the speed of the sound wave and f its frequency.

Procedure

1 Fill in the cylindrical container with water up to about 5 cm from the top. Place the glass tube deep in the water and secure it to the stand with the clamp.



2 Measure the temperature of the air inside the tube.

3 Select the tuning fork of the higher natural frequency and hit it with the rubber bung. Hold the vibrating fork at the mouth of the tube and slowly raise the tube to find the resonance position (loudest volume). Measure the length L_1.

4 Continue raising the tube until the second resonance position is achieved and measure the length L_2.

5 Record your measurements in an appropriate table.

6 Repeat steps **2**–**5** four more times and calculate the average values of L_1 and L_2.

7 Repeat the process (steps **2**–**6**) with four more tuning forks of lower natural frequencies.

8 Plot a graph with suitable axes that will allow you to determine the speed of sound from its gradient.

9 Determine the gradient uncertainty and use it to calculate the uncertainty of the experimental value of c.

10 Comment on the value for the speed of sound determined experimentally compared with the theoretical one, which is given by:

$$c = 331\sqrt{1 + \frac{T}{273}}$$

where c is the speed of sound in $\mathrm{m\,s^{-1}}$ for air temperature of T °C.

Questions

1 In practice, the position of the antinode is not exactly at the rim of the tube but at a short distance e away from it, which is known as the end correction. Taking this into account, we now have:

$L_1 + e = \frac{\lambda}{4}$ and $L_2 + e = 3\,\frac{\lambda}{4}$

which can be combined to give:

$(L_2 + e) = 3\,(L_1 + e)$

and finally:

$$e = \frac{L_2 - 3L_1}{2}$$

Determine the value of the end correction e for one of the frequencies used in your experiment.

2 Why does the speed of sound depend on the temperature of the air?