Experiment 7 — Standing waves in water

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1 Purpose

The purpose of this experiment is to figure out the speed of sound by examining the resonances of an open-ended resonance tube.

2 Theory

A standing wave consists two traveling waves interfering with each other in a particular manner that makes it appear stationary as a whole. As such, they consist of both nodes and antinodes. Nodes are positions where the particles in the air are stationary and not moving, whereas antinodes are the opposite of nodes, where the air particles moves back and forth at its greatest amplitude possible. One such example of a standing wave is resonance.

When resonance (i.e. standing waves) occurs, there will be a series of antinodes and nodes set in fixed locations along the air column. This happens when the length of the air column L and the wavelength of the sound λ satisfies the equation:

$$L = N\,\frac{\lambda}{4}, \qquad N = \{1, 3, 5, \ldots\} \tag{2.1}$$

where L = length of air column,
N = resonance order (odd integer values only, e.g. 1, 3, 5, …),
λ = wavelength of sound.

Note that the length of the air column L does not equal to the length of the air chamber D in the tube, as the final antinode is located a distance x away from the open end of the tube. In terms of D, this means that

$$L = D + x \tag{2.2}$$

where L = length of air column
D = length of the air chamber,
x = end correction.

The end correction x is constant. This value depends on the diameter of the tube and the particular sound frequency that is made by the source, and cannot be dependent on the resonance order N.

3 Procedure

Before starting the experiment, we first moved the apparatus to the floor of the laboratory. This was done to minimise the chance of breaking the apparatus due to human error. After that, we added a relatively small amount of water to the resevoir in order to increase the range of measurement.

First, we lower the water level in the tube as fast as possible by lowering the resevoir by hand (as in removed from the stand it was placed in). While doing so, gently strike a tuning fork with a rubber mallet and place it just above the resonance tube, taking great care to make sure that the fork do not make contact with the tube. This allows us to locate roughly the values of D of which resonance happens (in which it will give out a greatly amplified tone of the struck tuning fork).

4 Data

Experiment no.	Note value	Frequency (f)/Hz
1	F_4	349.2
2	$\sim G_4$	392
3	$\sim A_4$	486.7
4	C_5	523.2

Table 1: Description of each experiment

Variable	Value	Description
T_C	$24 \pm 1\,°\mathrm{C}$	Room temperature in Celsius
d	$3.366 \pm 0.002\,\mathrm{cm}$	Inner diameter of the resonance tube

Table 2: List of measured constant variables in the experiment

N	$D_1/\pm 1$ cm	$D_2/\pm 1$ cm	$D_3 \pm 1$ cm	$D_4 \pm 1$ cm
1	24	21	19	15
2	73	65	59	48
3	–	–	–	81

Table 3: Experimental data for all four experiments

5 Analysis

Combine equations (2.1) and (2.2) and solve for D.

$$\begin{aligned} \frac{N\lambda}{4} &= D + x \\ D &= -\left(\frac{N\lambda}{4}\right) + x \\ D &= N\left(\frac{\lambda}{4}\right) - x \end{aligned} \tag{5.1}$$

As the wavelength λ is constant for each tuning fork, we can safely assume that Equation (5.1) is linear. As such, $\frac{\lambda}{4}$ is the gradient of the linear function, and the error correction x is the y-intercept of the function.

With the data from 3 (and after converting D_4 measurements to metres) and Equation (5.1), we were able to draw Graph 1 of D_4 as a function of N.

6 Discussion