

Chapter 8

Standing Waves and the Velocity of Sound

8.1 Purpose

In this experiment we will be using resonance points of a sound wave traveling through an open tube to measure the speed of sound in air. In order to understand how this can be done, we must discuss some properties of wave motion.

8.2 Introduction

The type of waves that we will be concerned with in this experiment are what are called standing waves. A standing wave is a stationary pattern produced by the interference of waves bouncing back and forth in a confined space. For example, in this experiment we shall use a plastic tube open on the top with water inside in order to constrain the waves and produce an interference pattern that results in a standing wave. We put water in the tube to create a bottom surface that can be raised and lowered, so that we can change the effective length of the tube in order to find the resonance points.

To get an idea of how the wave will travel through the resonance tube, refer to figure 8.1. If a sound source (a tuning fork in this experiment) is brought close to the top of the tube, a sound wave travels down the tube, reflects off of the water surface, and returns toward the top of the tube. The wave moving down and the wave moving up form an interference pattern that can be constructive or destructive. When the interference is constructive, we can hear a significant increase in sound volume. This increase in the amplitude of the sound is called resonance. The condition for the resonance in an open tube is that the reflected wave should be in phase with the original wave at the opening of the tube.

Let's say the length of a tube is l . When the wave bouncing off a dense obstruction (like the water) the wave changes phase by 180° . We can account for that by considering the reflection being as "long" as a half of wavelength. Finally, the path down and back up is

$$l + \lambda/2 + l = L,$$

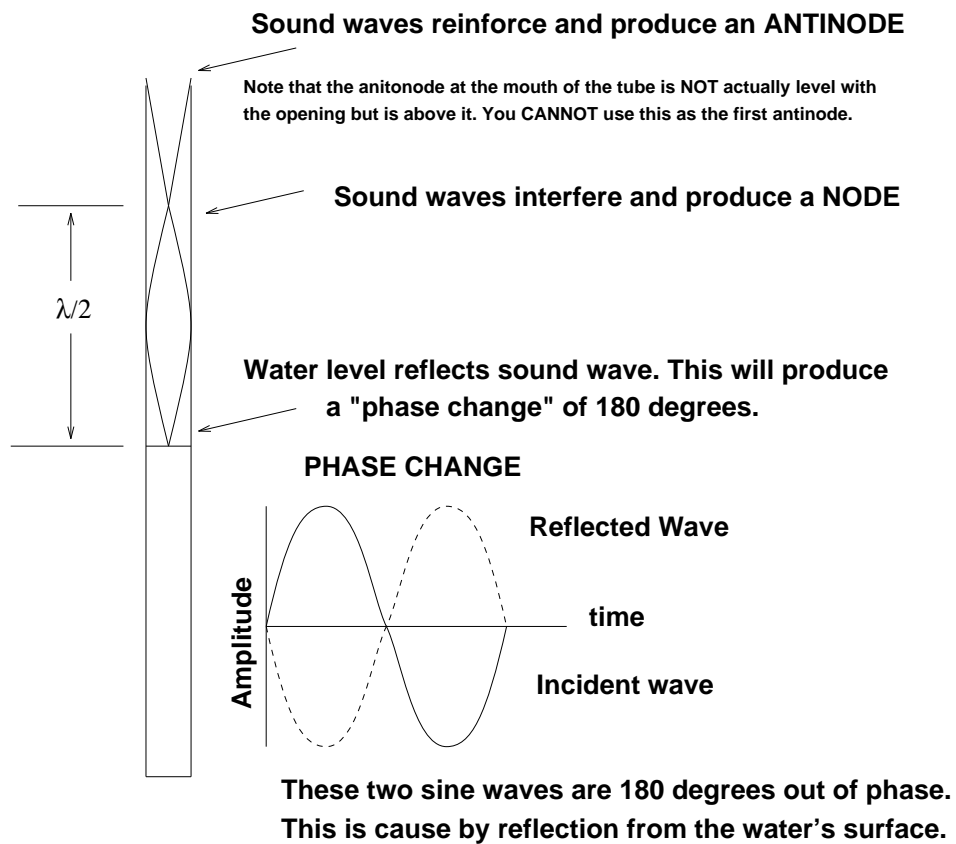


Figure 8.1: Standing sound waves in a tube.

where λ is a wavelength. The resonance condition is $L = n\lambda$, where n is an integer. Solving this equation for l one gets

$$l = \frac{2n - 1}{4}\lambda, \quad n = 1, 2, \dots$$

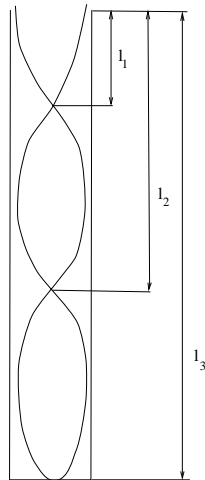


Figure 8.2: Resonance structure in an open tube

Once the wavelength is known one can easily find the speed of sound which is related to the wavelength and frequency by

$$V = f\lambda$$

where V is the velocity in meters per second, f is the frequency in Hz, and λ is the wavelength in meters.

8.3 Equipment

Standing wave tube. tuning fork, rubber hammer, meter stick.

8.4 Procedure

The apparatus is shown in figure 8.3. The cup is filled with water. When the cup is raised or lowered, the level of water in the tube changes. The tuning fork is held 3-6 cm from the open end of the tube. With the correct water height in the tube, a distinct increase in the sound (resonance) will be observed.

- Fill the cup (connected to the tube by a rubber hose) with water. Moving the cup up and down will change the level of water in the tube. Be careful, if you move the cup too low it may overflow. Watch the water level in the cup and pour out water when necessary.



Figure 8.3: The sound tube apparatus.

- Decide who in the group is going to do what: move the cup, hold the tuning fork, watch the level and listen to the resonance.
- Bring the level of water up to ≈ 10 cm from the top. Hit the tuning fork with a rubber hammer and hold it close to the tube's opening. Hit the fork from time to time keeping it vibrating.
- Move cup down bringing the water level down as well. Listen for the volume increase. When the water is ≈ 16 cm from the top of the tube, you should notice the resonance. Having found the approximate point of the resonance, carefully adjust the water lever to locate the resonance as precise as possible. Record the water level.
- Move the water level down until you find the approximate position of another resonance point. Slowly change the water level to get a precise value.
- Move down to the third resonance and measure its position. The structure of all resonances are shown on Figure 8.2.
- Repeat the measurements for all three points. You should make three sets of measurements and average the results as shown in the example data table.
- The first resonance point is not at $\lambda/4$ exactly (the effect of diameter of tube being finite). The actual anti-node of this resonance point is *above* the opening in the tube. But the $l_2 - l_1$ and $l_3 - l_2$ should be $\lambda/2$. Calculate λ from your data. Calculate the speed of sound. The frequency of the tuning fork is 512 Hz.

8.5 Questions

- If you double the frequency of the sound, how does the distance between nodes (or anti-node) change.

Resonance points	Trial #1	Trial #2	Trial #3	Average
l_1				
l_2				
l_3				

Table 8.1: The data for the measured resonant lengths of the tube in the open tube experiment

- The speed of sound increases with temperature. Would the distance between nodes increase or decrease if the temperature is increased.
- The speed of sound is 1482 m/s in water. For a 512 Hz wave, what is the wavelength?

