S7b: Measuring Sound Speed by Air Column Resonance

Introduction:

The velocity with which a sound wave travels in a substance may be determined if the frequency of the vibration and the length of the wave are known. This is expressed by the formula $v = f\lambda$. In this experiment, you will be using different frequencies produced by a frequency generator to determine the velocity of sound in air. Since the frequencies used will be known, to calculate the velocity of sound you need to find the wavelength corresponding to that sound. By holding the speaker connected to the frequency generator over a variable length tube, the sound waves will travel down the air column in the tube, and once reaching the bottom, they will be reflected back up. If the length of the air column is such that the returning waves are in phase with those being produced by the frequency generator, they will reinforce each other and produce a noticeable increase in the sound level known as resonance.

By manipulating the water level in the tube, you can change the length of the air column (L). Resonance occurs if this length of the air column is an odd number of a quarter wavelengths (λ) of the frequency being used (when L= $\frac{1}{4}\lambda$, $\frac{3}{4}\lambda$, $\frac{5}{4}\lambda$, etc).

Apparatus:

- function generator
- speaker
- resonance tube with a water reservoir
- Temperature and air pressure computer monitoring program

Figure 1

Discussion:

Sound waves are differences in pressure that result in displacement of the surrounding medium (air in most cases). The changes in the displacement of the air can be modeled as a sine function, with the node producing the least displacement and the antinode producing the greatest. At the closed end of the air column (at the water level), the air molecules cannot move freely, but at the open end they are free to do so. Resonance will take place when the sound's wavelength fits into the air column such that there is a node at the closed end and an antinode at the open end. However, there is a small adjustment to make, because the antinode is not exactly at the open end of the tube but rather slightly above it. This distance is mainly dependent on the diameter of the tube and is called the End Correction Factor. It is equal to approximately 0.6 of the radius of the tube. Keep in mind that this adjustment becomes unnecessary when dealing with the *difference* between two consecutive resonance positions, because the open end of the tube is not involved.

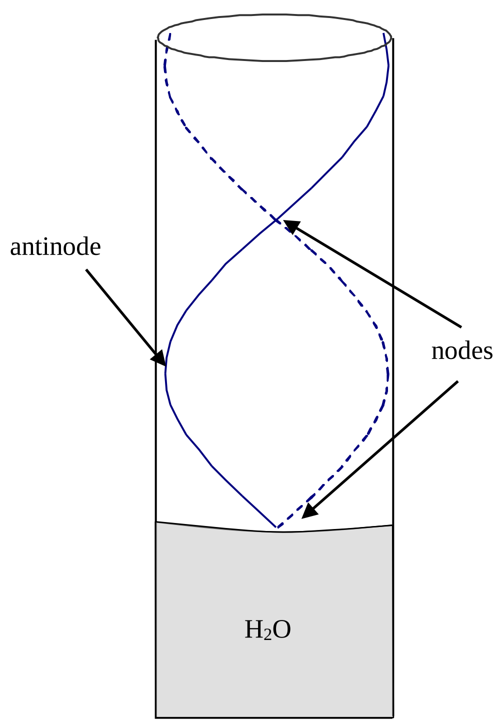

Figure 2

Procedures:

Part I:

1. Turn on the computer, log-in, then connect the USB cable from the 750 interface which is being used as a function generator. Open the physics experiment folder and run the S7b routine. Have one of the lab instructors demonstrate using the computer-based function generator.
2. The air column length is adjusted by raising or lowering the water reservoir. Begin each trial initially with the air column at a length of 15 cm (the position of the water).
3. Position the speaker, fixed on the lab stand, over the resonance tube. It should be approximately 2 cm above the resonance tube.
4. Adjust the function generator to a frequency of 400 Hz and amplitude of 0.2 Volt. Volume may be decreased or increased as needed, between a range of 0.1 and 0.5 Volts.
5. Increase the air column length (by lowering the water level) until you hear a sharp increase in volume. When you hear the increased volume, stop the water from continuing to lower (by raising the water reservoir). Continue adjusting the water in the air column until it remains stationary on the exact location that produces the loudest sound. Note that the increased volume will stop if the speaker is moved away from the tube. Record the exact water position that creates the greatest volume. This is the first resonance position and corresponds to ¼ of the wavelength.
6. Lower the water level in the tube, below the first resonance position, until the volume increases again. Once again continue adjusting the water, up or down, until it remains stationary on the exact position that produces the loudest sound. This will be the second resonance position and corresponds to ¾ of the wavelength.
7. Repeat these steps for 800 Hz and 1200 Hz frequencies, finding the $\frac{3}{4}\lambda$ and $\frac{5}{4}\lambda$ resonance positions for each.
8. Calculate the wavelength for each resonance position; don't forget to include the ECF before calculating the wavelength. Also calculate the wavelength for the difference between sequential positions. Next calculate the experimental velocity for each resonance position and the difference between positions for all frequencies.

Part II:

9. Adjust the air column height to 35.0 cm. Keep this air column length constant. Using the function generator find the three frequencies between 100 Hz and 1300 Hz that produce resonance. Note, adjust the frequencies slowly.
10. The fist resonance frequency you will hear occurs at its $\frac{1}{4}\lambda$ position, the second frequency will correspond to $\frac{3}{4}\lambda$ position, and the third will correspond to $\frac{5}{4}\lambda$ position.
11. Calculate the wavelength and experimental velocity for each resonance frequency.

Experiment S7b: Measuring Sound Speed by Air Column Resonance

Student Name____

*Lab Partner Name*____

*Lab Partner Name*____

Physics Course____

Physics Professor____

Experiment Start Date____

Lab Assistant Name	*Date*	*Time In*	*Time Out*

Experiment Stamped Completed

Data Sheets: S7b: Measuring the Speed of Sound Using Air Column Resonance

NAME: ______________________________ **DATE:** __________________

Room Temperature : ___________ °C

Theoretical Velocity V_T = __________________meters/seconds (velocity of sound at temperature T)

Diameter (inside) of Resonance Tube:___________________meters

Radius of Resonance Tube : __________________ meters

End-Correction Factor (radius*0.6) :__________________ meters (ECF)

↓ frequency		$^1/_4\lambda$	$^3/_4\lambda$	$^5/_4\lambda$	$^1/_2\lambda$	
400 Hz	position			NA		*difference in position* ($^3/_4\lambda$ - $^1/_4\lambda$)
	position + ECF			NA	NA	
	λ			NA		
	v			NA		
800 Hz	Position	NA				*difference in position* ($^5/_4\lambda$ - $^3/_4\lambda$)
	position + ECF	NA			NA	
	λ	NA				
	v	NA				
1200 Hz	position	NA				*difference in position* ($^5/_4\lambda$ - $^3/_4\lambda$)
	position + ECF	NA			NA	
	λ	NA				
	v	NA				

Air column height:____________meters + ECF = _________________(resonance length)

resonance position →	$^1/_4\lambda$	$^3/_4\lambda$	$^5/_4\lambda$
f			
λ			
v			