

Name _____ Date _____

Partners _____

Air Column, Speed of Sound: Lab #2
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Objectives: to measure the speed of sound in air by several methods

Equipment: resonance tube apparatus, beaker with water, paper towels, tuning forks (f = 512, 480, 384 Hz), rubber mallet, long cardboard tube, computer with Vernier LoggerPro, Universal Lab Interface, microphone, thermometer

Sketch:

Definitions, in words and equations:

Sound wave =

Frequency =

Wavelength =

Speed =

Resonance =

Background:

A speed can be measured directly as time-of-flight, that is speed = distance/time, but for very fast speeds this is often very difficult to do accurately.

Persistent standing waves offer another method to measure the speed of sound because they can interfere with themselves if they reflect back in the direction they were coming. This interference can be noticed if it is constructive, and the sound gets louder. A sound wave in air reflecting from water at the bottom of a tube, then leaving the tube will have "resonance" if the air column is a certain specific length. We can change the length of the air column, listen hard, and experimentally find this "certain length" and then use it to calculate the speed of the sound wave.

The first resonance will happen at a distance L_1 where the reflected wave (180 degrees flipped) meets the incoming wave "in phase." This means a quarter wavelength down, a quarter wavelength back up, and 180 degrees flip equals a full wave difference, so the waves will be "in phase" thus intensifying the sound of the wave, when L_1 is a quarter of the wavelength.

Procedure:

A. Wave Interference Method:

1. Set up the resonance tube apparatus
2. Raise the reservoir to its highest position.
3. For the tuning fork with the highest frequency ($f=512$ Hz), calculate roughly the length of the air column for the first resonance by

$$\text{Estimated } L1 = (343 \text{ m/s}) / (4 f) =$$

4. Move the water reservoir until the water level in the tube is a few centimeters higher (less) than this length. Hit the tuning fork with the rubber mallet (NEVER a hard surface).

Hold the tuning fork about a centimeter above the tube with its tines vibrating in a vertical plane. NEVER let the tuning fork hit the tube as it might break the tube.

5. Move the water reservoir down about ten centimeters and listen intently at the mouth of the tube as the water level glides past your estimated length $L1$. Notice and record the length when the sound was loudest. Record this value in the data table. Repeat two more times, then average the lengths.

6. The second resonance will happen at a distance about three times $L1$. Calculate

$$\text{Estimated } L2 = 3 (\text{measured average } L1) =$$

7. Experimentally find the level for this new resonance, and record the length in the data table. Do this three times and average the lengths.

8. Calculate your experimental speed of sound in air by

$$\text{speed} = (\text{frequency}) (\text{wavelength})$$

$$\text{WavelengthA} = 4 (L1) = \quad \text{Speed A} = \text{frequency} * (4 * L1) =$$

$$\text{WavelengthB} = 4 (L2)/3 = \quad \text{Speed B} = \text{frequency} * (1.33 * L2) =$$

$$\text{WavelengthC} = 2 (L2 - L1) = \quad \text{Speed C} = \text{frequency} * 2 * (L2 - L1) =$$

9. The accepted value for the speed of sound in air is given by
 $\text{speed of sound} = (331 \text{ m/s}) + (.6 \text{ m/s}) \text{ per degree C above } 0 \text{ degrees C.}$

Use the thermometer to measure how much hotter room temperature is than 0 degrees C.

$$T = \underline{\hspace{2cm}}$$

Calculate the accepted value for the speed of sound at our room temperature.

$$\text{Accepted speed of sound in this room} =$$

Calculate your experimental errors by

$$\text{percent error} = 100 (\text{experimental} - \text{accepted}) / \text{accepted}$$

10. Repeat the procedure (steps 3 – 9) to find experimentally the two resonances for the tuning fork with the frequency of 480 Hz. Calculate the three new values of the speed of sound and their percent errors.

B. Direct time-of-flight method:

11. Check to see that the microphone is plugged into DIN 1 on the Universal Lab Interface (ULI) box. Turn on the ULI box.

12. Turn on the computer, and go to Start, Programs, Vernier Software, LoggerPro. Click OK, OK. Select File, Open, Probes & Sensors, Microphone, Sound with triggering.

13. Select Setup, Data Collection, Sampling, and set the experiment length to .03 seconds, and the samples/second to 11000. Set Averaging to Off. Set Triggering to greater than 3.0

14. On the graph itself set the ends of the vertical sound level axis to 0 and 5. (Click on the number, type the new number, hit Enter.)

15. Test the system by clicking on the "Collect" button, waiting a while, then snapping your fingers near the microphone's round input spot. The software should respond.

16. Lay your cardboard tube on the table so that the microphone looks into it from 2 centimeters away from the open end. Measure the length from the microphone to the reflecting far end of the tube. Double this length to get the total path length of the sound pulse from source to returning echo.

17. Click the Collect button, wait, then snap your fingers. Measure the time from snap to echo by using Analyze, Examine, and putting the cursor on the two large amplitudes in sound intensity on the graph.

18. Calculate the speed of sound by dividing the total path length by the time difference. Calculate your percent error.

19. If there is time, repeat the wave procedure for the tuning fork of lowest frequency (384 Hz).

Discussion of Errors:

Which of these methods gives the most accurate results?

Why?

How does this topic apply to your life?

Data Table:

Wave interference method, frequency = 512 Hz

L1	L1	L1	L1, average	Speed A	% error
L2	L2	L2	L2, average	Speed B	% error
				Speed C	% error

Wave interference method, frequency = 480 Hz

L1	L1	L1	L1, average	Speed A	% error
L2	L2	L2	L2, average	Speed B	% error
				Speed C	% error

Wave interference method, frequency = 384 Hz

L1	L1	L1	L1, average	Speed A	% error
L2	L2	L2	L2, average	Speed B	% error
				Speed C	% error

Direct time-of-flight method

Total Path length	Time	Speed	% error