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LAKE FOREST COLLEGE

Department of Physics

Physics 115 Experiment 2:Speed of Sound Spring 2025

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Table number:

Preliminary Instructions
Create a folder for you and your lab partner on Teams. Save a copy of these instructions for each student to that folder. Include your name in the filename. As you edit this document put your text in a different color. Save one copy of the *Excel* template with both your and your partner’s name included in the filename.

Experimental purpose of today’s experiment
Find the speed of sound by measuring the wavelength of a sound wave with a known frequency. Show that the speed of sound is independent of the frequency.

Background
If a sound wave with a constant frequency enters a pipe that is open on one end and closed on the other, the sound can create a resonant standing wave in the pipe—but only for certain lengths of pipe. This effect is called *resonance.*

In this experiment, you will be studying the properties of sound waves using the resonance tube apparatus shown in Figure 1. You will create sound waves using a speaker driven by a function generator, which controls the amplitude and frequency of the sound. You will also have a pipe with a movable piston (plunger) that controls the effective length of the pipe. A microphone connected to a computer measures the increased intensity of the sound when the pipe has a proper length for resonance. The position of the piston is the location of an anti-node in the relative pressure standing wave. At this point the air pressure will vary the most, allowing the microphone to detect the sound wave. The open end of the tube is (almost) the location of a node in the relative pressure standing wave.

Here are some other things you need to know for this lab:

- $v = f\lambda$. This is the fundamental relationship between the speed v, the frequency f, and the wavelength λ of any sinusoidal traveling wave.

- For an open-closed tube, resonances occur when $L = \frac{\lambda}{4} m$, where L is the effective length of the tube, and $m = 1, 3, 5, \ldots$

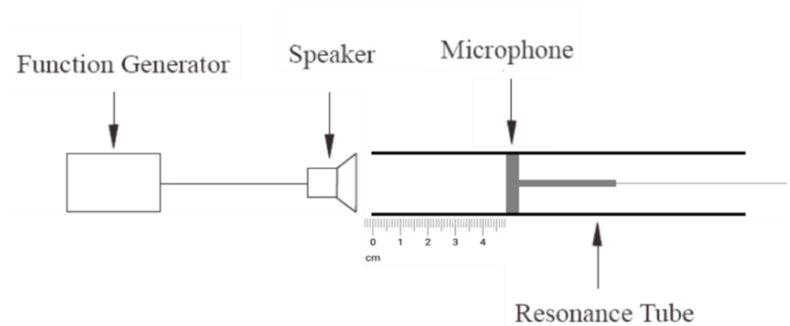

Figure 1

Procedure
To avoid unnecessary interference with the measurements of other lab students, leave your speaker on for only those times you are making measurements.

1. Turn on the function generator and set the amplitude to about 0.05V. Set the frequency to 2000 Hz. Since there are many speakers running simultaneously, try to keep your volume as low as possible so as not to interfere with your neighbor's work (but loud enough so that you can get good-quality data). Open the Exp 2 Logger Pro file from the computer's desktop.

2. Place the speaker about 3 cm away from the open end of the pipe. Starting with the piston near the speaker, move the piston away from the speaker and, using *LoggerPro*, observe the pressure detected by the microphone. Notice that the amplitude of the varying pressure changes as the length of the tube is changed. *Carefully* locate the positions of the piston, that is, the lengths of the tube, which give the largest amplitude of pressure as detected by the microphone. Find all of these positions of maximum amplitude <u>over the whole length of the tube</u>. Use the attached measuring tape to determine the positions of the piston that produce these resonances. Record these positions in the spreadsheet, labelled for 2000 Hz. **Paste a sketch of the apparatus that labels the tube length, *L*, here. Include a caption. Also paste a representative sample Logger Pro graphs with a caption here.**

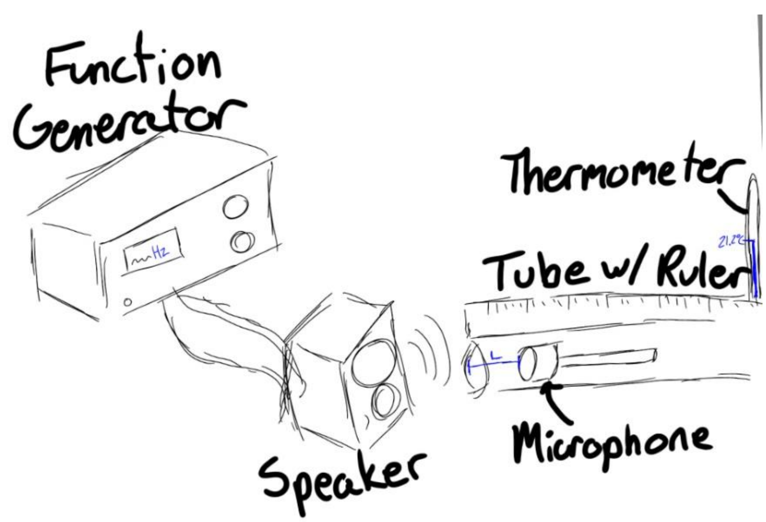

Figure 1. Sound Wave Apparatus. The Pasco Function Generator controlled the Hz (2000 or 3000) and the voltage (0.05V) use for each part of this experiment. The RCA speaker was approximately

3cm from the end of the acrylic tube. The microphone started at the end of the tube and was moved a length (L) till the sound pressure reach a peak. The thermometer was used to obtain the temperature of the room (°C) since temperature affects pressure.

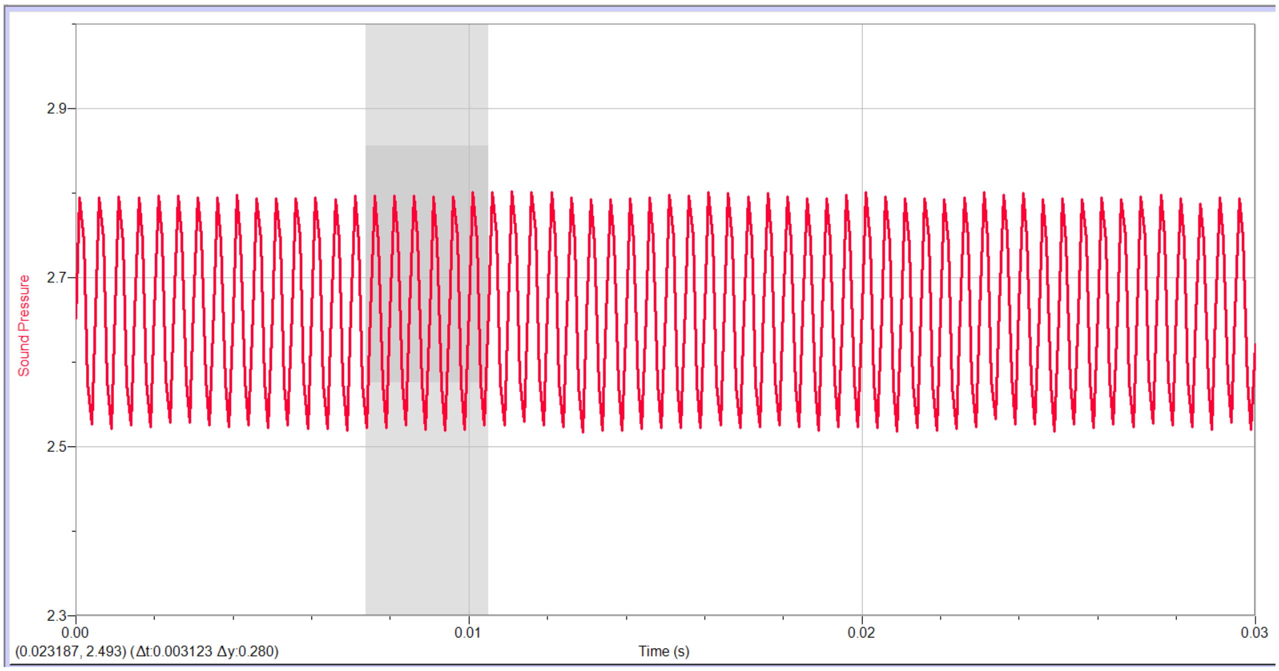

Figure 2. Sound Pressure over Time Logger Pro Graph. This graph represents an example of a sound pressure peak. In this case the function generator was outputting at 2000Hz and the microphone was 3.2cm from the end of the tube. Shifting the microphone in either direction reduced the size of the peaks. The sound pressure peaks occurred where the sound waves resonated with constructive interference.

3. Start an additional copy of *Logger Pro* using the link of the desktop. Use it to plot the length of the resonant tube on the vertical axis and the corresponding number ($m = 1, 3, 5, \cdots$) of the resonance on the horizontal axis. Fit the data to a straight line. Right-click on the dialog box to display the uncertainties of the slope and the intercept of the best-fit straight line. Record these in the spreadsheet. **Place the graph for 2000 Hz here. Include a caption.**

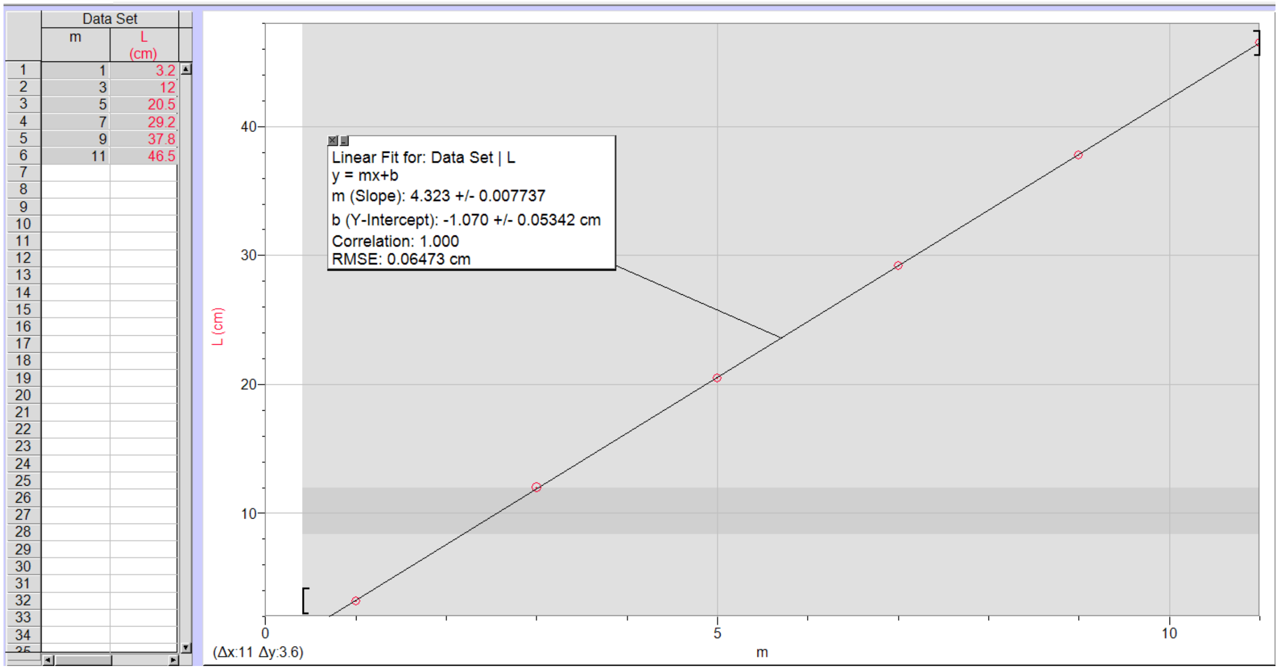

Figure 3. 2000Hz Linear Fit Logger Pro Graph. The length of the resonance tube, controlled by moving the microphone, is on the y-axis. The node number, at odd intervals, is on the x-axis. The fitted line connects the measured points where pressure peaked at 2000Hz. The y-intercept is the distance (in cm) from the front of the tube to the first node (node 0) which is why it is negative.

4. **Explain why the wavelength is four times the slope of the fitted line**.

The ideal wavelength is four times the slope of the fitted line because the length is the node divided by four multiples times the wavelength. Since the slope of the line is the length divided by the node to solve for the wavelength just multiply by four.

5. The speed of the wave is the wavelength times the frequency. Calculate the speed of the wave and its uncertainty in the spreadsheet. Also calculate the relative uncertainty in the speed.

6. The predicted speed of sound in dry air at Celsius temperature T is $v = (331\text{ m/s})\sqrt{1+\dfrac{T}{273\text{ °C}}}$.

   Use the ratio test to compare the predicted speed (assuming no uncertainty) with the speed determined from the slope of the best-fit line.

7. The open end of the tube near the speaker is not exactly where the pressure node is located: the node is located a short distance beyond the tube. The intercept corresponds to the position of the node and it is negative because it is measuring the distance from the end of the tube to a point outside the tube.

8. Repeat steps 1-7 for a frequency of 3000 Hz. A new sketch is not needed. **Place the graph for 3000 Hz here. Include a caption.**

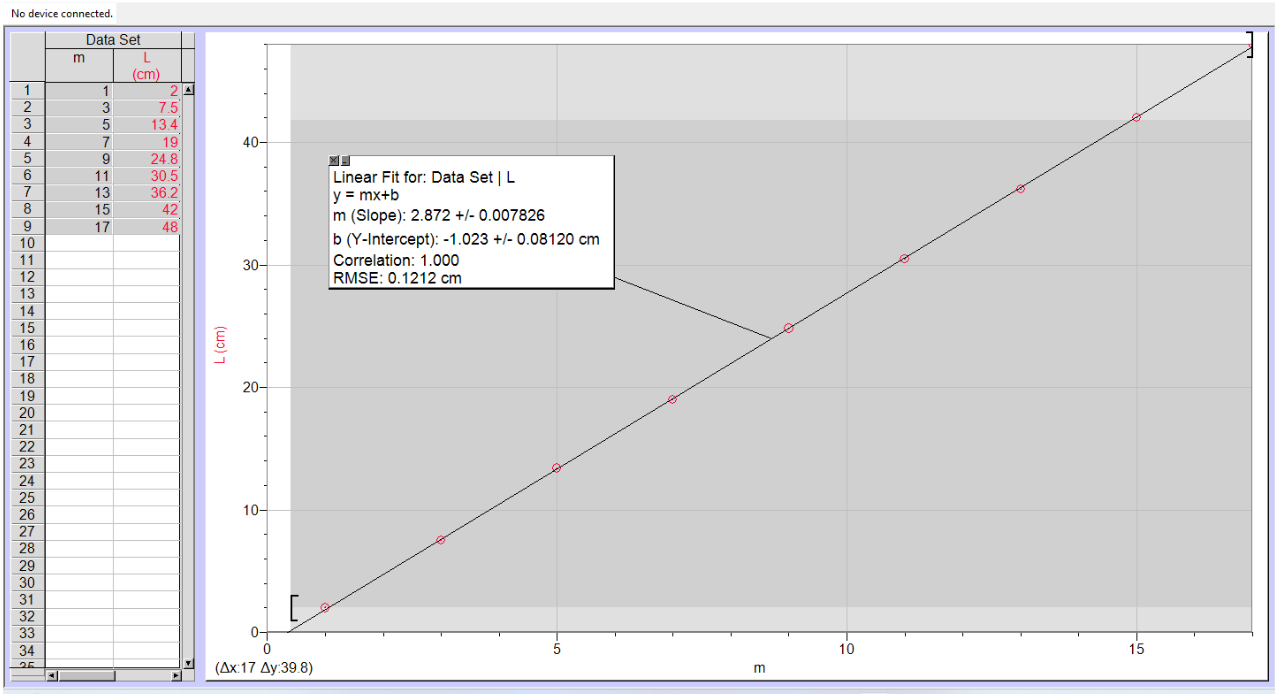

Figure 4. 3000Hz Linear Fit Logger Pro Graph. **The length of the resonance tube, controlled by moving the microphone, is on the y-axis. The node number, at odd intervals, is on the x-axis. The fitted line connects the measured points where pressure peaked at 3000Hz. The y-intercept is the distance (in cm) from the front of the tube to the first node (node 0) which is why it is negative.**

Comparisons

Include captions for the tables.

9. Paste a copy of the table for measurements at 2000 Hz here.

Frequency (Hz)	
2000	
m	**Mic Location (cm)**
1	3.2
3	12
5	20.5
7	29.2
9	37.8
11	46.5

Table 1. 2000Hz Measurements Table. The number of nodes (m) are counted in odd intervals. The microphone started at the front of the tube and was slowly pulled back as the sound pressure was observed. The mic location is the distance (cm) from the front of the tube that the mic was pulled when peaks were observed when the sound had a frequency of 2000Hz. The peaks were an average of 8.7cm apart.

10. Paste a copy of the table of the speeds, uncertainties, and comparisons for 2000 Hz here.

Slope (cm)	Slope unc (cm)	Temp (°C)	Intercept (cm)
4.32	0.008	21.2	-1.07
λ (cm)	**λ unc (cm)**	**pred v (m/s)**	**Node Location (cm)**
17.28	0.03	343.6	1.07
v (m/s)	**v unc (m/s)**	**ratio test of v to pred v**	
345.6	0.6	3.11	
	v rel unc (%)		
	0.19%		

Table 2. 2000Hz Statistics Table. The slope and its uncertainty were calculated by Logger Pro. The wavelength(ƛ) and its uncertainty were calculated by multiplying the slope and its uncertainty by 4. V was calculated by dividing ƛ by 100 and multiplying it by the frequency (2000Hz). The predicted v was calculated using the formula v = 331m/s $\sqrt{1+\frac{T}{273°C}}$ where T was the room temperature taken from a thermometer. The uncertainty of the slope was extremely small, so even though the predicted and calculated v are close together, they do not agree according to the ratio test.

11. Paste a copy of the table for measurements at 3000 Hz here.

Frequency (Hz)	
3000	
m	**Mic Location (cm)**
1	2.0
3	7.5
5	13.4
7	19.0
9	24.8
11	30.5
13	36.2
15	42.0
17	48.0

Table 3. 3000Hz Measurement Table. The number of nodes (m) are counted in odd intervals. The microphone started at the front of the tube and was slowly pulled back as the sound pressure was observed. The mic location is the distance (cm) from the front of the tube that

the mic was pulled when peaks were observed when the sound had a frequency of 3000Hz. The peaks were an average of 5.8cm apart.

12. Paste a copy of the table for the speeds, uncertainties, and comparisons for 3000 Hz here.

Slope (cm)	Slope unc (cm)	Temp (°C)	intercept (cm)
2.872	0.008	21.2	-1.02
λ (cm)	**λ unc (cm)**	**pred v (m/s)**	**node location (cm)**
11.488	0.03	343.6	1.02
v (m/s)	**v unc (m/s)**	**ratio test of v to pred v**	
344.6	1.0	1.1	
	v rel unc (%)		
	0.28%		

Table 4. 3000Hz Statistics Table Table 2. 2000Hz Statistics Table. The slope and its uncertainty were calculated by Logger Pro. The wavelength(ƛ) and its uncertainty were calculated by multiplying the slope and its uncertainty by 4. V was calculated by dividing ƛ by 100 and multiplying it by the frequency (3000Hz). The predicted v was calculated using the formula v = 331m/s $\sqrt{1+\frac{T}{273°C}}$ where T was the room temperature taken from a thermometer. The ratio test agrees that the predicted and calculated v values are similar.

13. Write an analysis for this experiment here. Make sure to include the following:

- **Do your measured speeds of sound agree with the values predicted from the temperature?**
- **Which of the two measurements of the speed of sound gives the smaller uncertainty or are they similar?**
- **How precisely are you able to find the resonant lengths? In other words, estimate the uncertainty of the resonant lengths that you measured. Were these length uncertainties the same for the two different frequencies?**

The measured speeds agreed with the prediction for 3000Hz but not for 2000Hz according to the ratio test. For both frequencies, the uncertainties were very small so even though the calculated and predicted values looked similar for 2000Hz, they did not agree according to the ratio test value of 3.1. For 3000Hz the values were so close that even with the small uncertainty the ratio agreed with a value of 1.1.

The 2000Hz measurement had a smaller uncertainty because the frequency was used in the speed uncertainty calculation. Since the wavelength is multiplied by the frequency to calculate speed, so is its uncertainty. If we had an uncertainty for frequency then it would be calculated differently, using relative uncertainties, but since the uncertainty for frequency would be so small, we do not use it.

We were able to measure resonant length to a tenth of a centimeter since you should estimate one decimal past the marks shown on the ruler. It was the ot a very accurate way of

measuring since it was by eye but the sound pressure shifted to quickly to get an accurate calculation of the size of the peaks. The length uncertainty were the same for both 2000 and 3000Hz. The actual uncertainty was likely much higher than the values given by Logger Pro.

Write a brief conclusion here. This should briefly restate your measured speeds, their uncertainties and state whether they agree with the prediction or not.

With a frequency of 2000Hz the waves had a speed of 345.6±0.6 m/s and with a frequency of 3000Hz the waves had a speed of 345±1m/s. The speed calculated at 200Hz disagrees with the predicted speed of 343.5m/s but the speed calculated at 3000Hz agrees. Increasing the temperature in the room decreased the predicted speed.

Final remarks

Adjust the formatting (pagination, margins, size of figures, etc.) of this report to make it easy to read. Save this report as a PDF document. Upload it to the course Moodle page. Double check that your Excel sheet, graphs, and Logger Pro files are saved in your folder on the Team.

Clean up your lab station. Put the equipment back where you found it. Remove any temporary files from the computer desktop. Make sure that you logout of Moodle and your email, then log out of the computer. Ensure that the laptop is plugged in. Check with the lab instructor to make sure that they received your submission before you leave.