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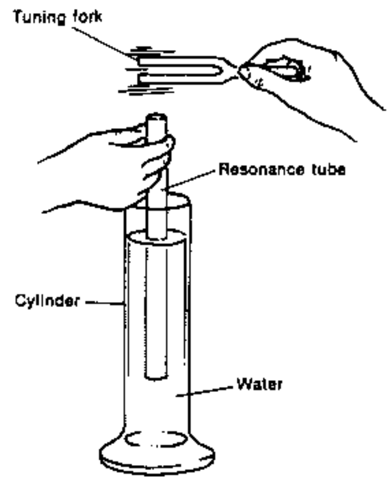
LAB. SPEED OF SOUND

AP PHYSICS I

Driving Question | Objective

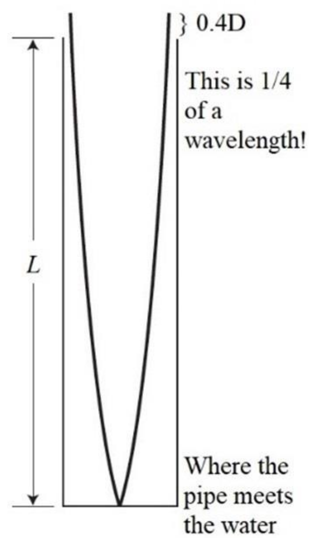


How does a wind-instrument create such a loud sound with relatively little input of energy? How can standing waves of sound help to determine the speed of sound? In this lab, we will try to answer these questions by resonating PVC tubes with a frequency generator or set of tuning forks.

Materials and Equipment

- Large Graduated Cylinder
- Meter Stick
- Frequency Generator or Tuning Forks
- PVC Pipe
- Source of Water
- Ruler

Part 1 – Fundamental Resonance



1. The fundamental frequency of any resonance tube is the smallest frequency that creates a standing sound wave. Since standing waves of sound will form nodes of displacement at closed ends and antinodes at open ends, it follows that the smallest frequency would also produce the longest standing wavelength.
2. However, true antinodes of displacement occur slightly above the entrance of an open end. Research shows that the actual location of maximum displacement of air lies about 40% of the inner diameter (ID) beyond the open end. Therefore, ¼ of the fundamental wavelength will be the addition of the length of the pipe plus 0.4*ID: $\frac{1}{4}\lambda = L + 0.4 * ID$. Please see the image to the right for reference. Measure the inner fdiameter of your PVC pipe in meters and calculate 40% of this value.

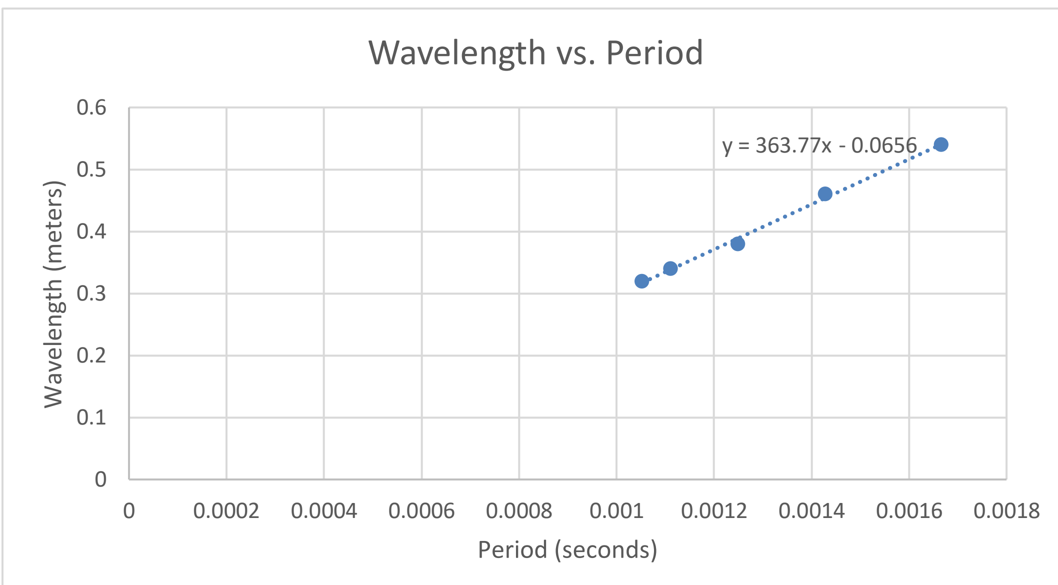
Inner Diameter (in meters)	0.4xDiameter
0.05	0.02

3. Place the PVC Pipe inside of a large graduated cylinder and completely fill the cylinder with water. Very little of your PVC pipe should be sticking outside of the water.
4. Whether you are using a set of tuning forks or a frequency generator app on your phone to create resonance, the source of sound will need to be held just above the opening of the PVC pipe. Create a frequency between 1-1000Hz and hold the source directly over the opening (if using tuning forks, only strike it on the designated rubber wedge. DO NOT strike it against the table!).
5. Begin slowly lifting the PVC pipe upward, while always holding your sound source above the opening of the pipe.
6. As you continue to lift the pipe, you will reach a length in which a noticeable increase in volume will emanate from your PVC tube. Once you have reached this length, you have round your fundamental resonance length, as seen in the image to the right.
7. Hold the PVC pipe stationary at this location and have a table partner measure the "effective length" of the PVC tube.
    a. The **<u>Effective Length</u>** is the distance of the top of the PVC tube, to where the tube meets the water. Measure this length with a meter stick and record the length in meters.

8. Once you have obtained this length, you will need to calculate the "adjusted length".
    a. The **Adjusted Length** is the Effective Length of the tube plus 40% of your tube's inner diameter (ID). This method is called the 40% ID Rule.
9. Record these values in the table below and repeat the procedure with at least 4 other frequencies between 1-1000Hz of your choosing.
10. Convert your frequencies to period: $T = \frac{1}{f}$
11. Calculate your wavelength: $\lambda = 4 * Adjusted\ Length$

	x-variable			**y-variable**
***f*, Frequency (*Hz*)**	**T, Period (*s*)**	**EL, Eff Length (*m*)**	**AL, Adj. Length (*m*)**	**λ, Wavelength (m)**
600	0.001667	0.115	0.135	0.54
700	0.001429	0.095	0.115	0.46
800	0.00125	0.075	0.095	0.38
900	0.001111	0.065	0.085	0.34
950	0.001053	0.06	0.08	0.32

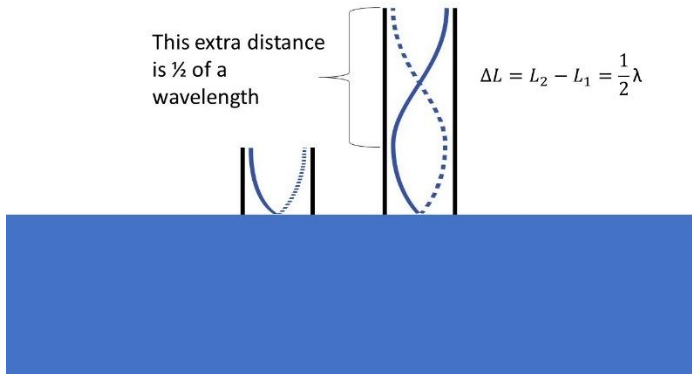
12. In the graph below, plot your data as Wavelength vs. Period.



13. In the table above, what is the value of your slope? What physical quantity does this value represent?

The value of the slope in the graph above is 363.77. In terms of physical quantity this represents the velocity.

Part 2 – Consecutive Resonances

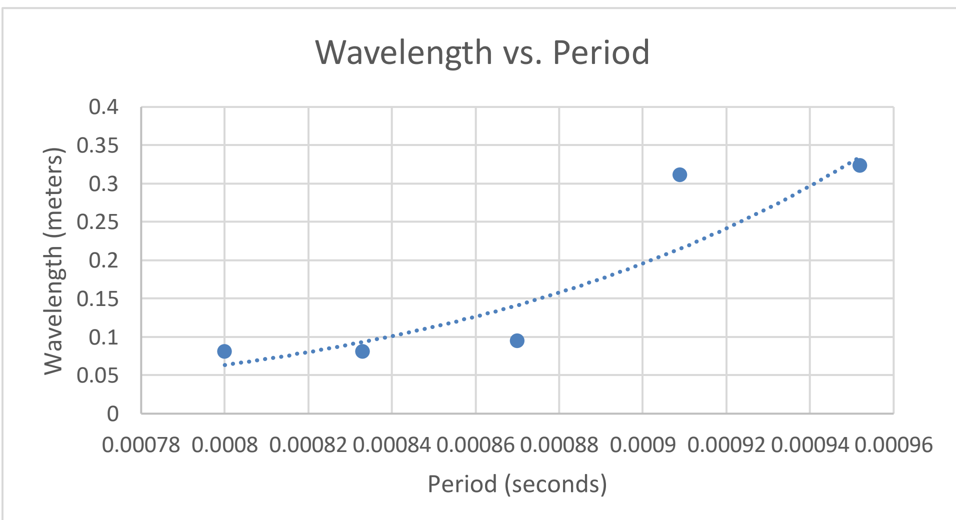


1. Adding 40% of the inner diameter (ID) of the PVC pipe can produce quite accurate results with longer wavelengths, but often causes problems with shorter ones. This is because as wavelength of the sound approaches the same length as the diameter of the pipe, the correction becomes inaccurate. In this section we will be using higher frequencies (shorter wavelengths) to also estimate the speed of sound. However, we will also eliminate the 40% ID rule altogether. This method could not be used with the lower frequencies because the PVC tube would not be long enough to reach the 2nd harmonic before fully leaving the water.
2. To achieve this, we can find two consecutive resonance lengths. The difference of these lengths will always be equal to $\frac{1}{2}\lambda$. Please view the diagram on the right for reference.
   a. Please note that this rule works for **any two** consecutive resonance lengths. It does **not** just apply to the difference between the 1st and 2nd harmonic, which is what the diagram depicts. This means that you could, in theory, accidentally skip the 1st harmonic and run this calculation on the 2nd and 3rd harmonic lengths.
3. To begin, set your frequency generator to any frequency above 1000 Hz (if using tuning forks, please find the tuning forks with such frequencies). Find any two consecutive resonance lengths and calculate the wavelength: $\lambda = 2 * \Delta L$. Repeat this procedure for a total of 5 different frequencies.

x-variable   **y-variable**

***f*, Frequency (*Hz*)**	**T, Period (*s*)**	**1st Resonance Length (*m*)**	**2nd Resonance Length (*m*)**	**λ, Wavelength (m)**
1050	0.000952	0.0525	0.214	0.323
1100	0.000909	0.0475	0.203	0.311
1150	0.00087	0.043	0.09	0.094
1200	0.000833	0.038	0.078	0.08
1250	0.0008	0.033	0.073	0.08

4. In the graph below, plot your data as Wavelength vs. Period.



5. What does this graph suggest the speed of sound is?

The graph suggests that the speed of the sound is increasing as the frequency increased.

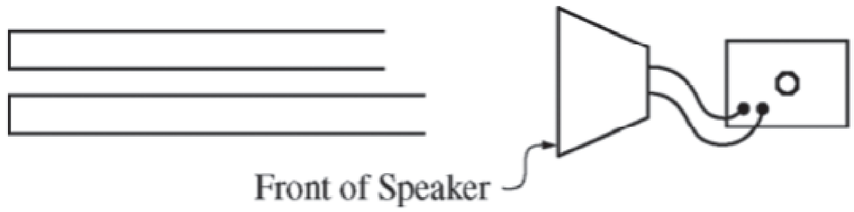
6. Considering that the accepted speed of sound is 343 m/s, which set of data produced a more accurate estimation?

The first set of data appears to be more accurate

7. Your teacher will now provide your group an unknown frequency from their own frequency generator. Please use whichever technique you deem most appropriate to estimate what this mysterious frequency is.
8. What is your estimated frequency vs the true value of the mysterious frequency? (True value not provided, not done)

Estimated Frequency	True Frequency

Real AP Exam Question Free Response – Resonating Tubes



(7 of 45 points, suggested time 13 minutes)

The figure above shows two tubes that are identical except for their slightly different lengths. Both tubes have one open end and one closed end. A speaker connected to a variable frequency generator is placed in front of the tubes, as shown. The speaker is set to produce a note of very low frequency and then turned on. The frequency is then slowly increased to produce resonance in the tubes. Students observe that at first only one of the tubes resonates at a time. Later, as the frequency gets very high, there are occasions when both tubes resonate at the same time.

In a clear, coherent, paragraph-length answer, explain why there are some high frequencies, but no low frequencies, at which both tubes resonate. You may include diagrams and/or equations as part of your explanation.

At lower frequencies, the shorter tube has a lower chance of having resonance. However, as the frequency increases, the wavelength decreases and the possibility that there is a node is at the closed end and an antinode at the open end in the smaller tube increases as well. The greater possibility that a harmonic exists in the smaller tube at the same time as the larger tube. Partial explanation in the picture below.

Attach an image below of a diagram that shows an example of both tubes resonating at the *same frequency*.