STANDING WAVES IN AN AIR COLUMN

The objective of the experiment is:

- To study the harmonic structure of standing waves in an air column.

APPARATUS: Function generator, oscilloscope, speaker, tube with rod, meter stick.

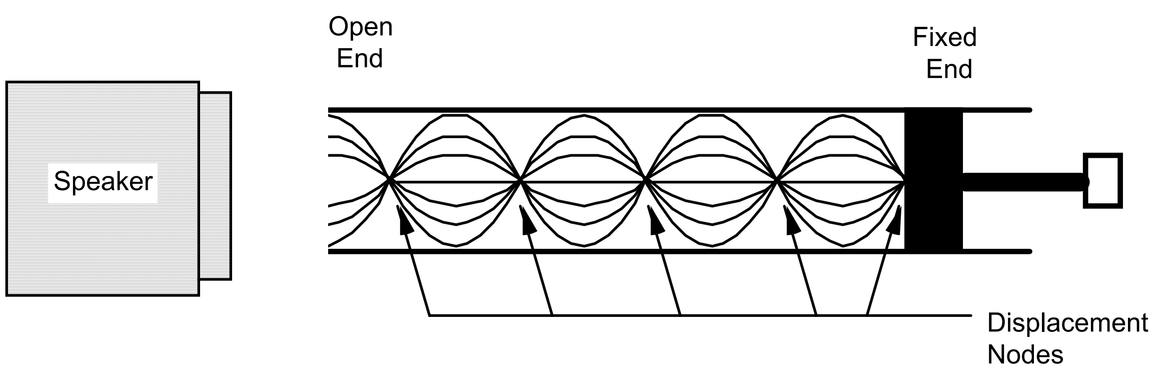
INTRODUCTION

A traveling wave of sinusoidal shape goes a distance λ (the wavelength) in one period interval, *T*. The wave velocity *c* is therefore equal to λ/T. Because *f* (the frequency) is defined as *1/T*, we can also write $c = f\lambda$.

Consider the diagram below. The speaker is driven by an electrical source that produces a single frequency sound wave that is directed towards the open end of a tube. At the other end is a plunger that can be slid back and forth to vary the effective length of the column of air in the tube. When the sound wave enters the tube it travels down to the plunger, it is reflected and returns to the open end of the tube. For most sound waves the incoming and reflected waves will have no particular phase relationship and will produce nothing noteworthy. But, if the phase relationship is correct, standing waves can be formed. This condition of constructive interference is when

$$L = n\frac{\lambda}{4} \qquad n = 1,3,5,\ldots$$

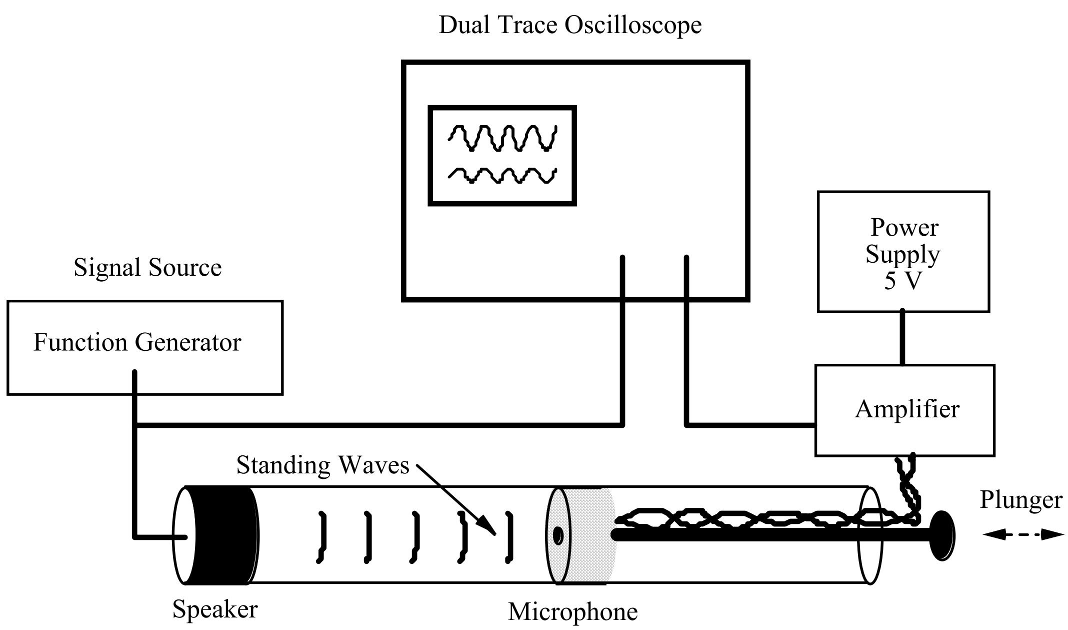
where λ is the wavelength of the sound wave and L is the effective length of the tube, that is the distance from the plunger wall to the open end.



The reason for this condition is easily seen. A displacement antinode forms at the open end of the tube. Displacement is the range of the vibrating air molecules, and an antinode is where it oscillates as a maximum. At the closed end the displacement variations are very small as the waves compress the air molecules and are reflected at the surface of the plunger (pressure, however, is high at this surface). So a displacement node forms on the surface of the plunger.

The distance between each node is the same as between each antinode, namely $\lambda/2$. Thus, the distance between a node and an antinode is $\lambda/4$. The fundamental or lowest frequency harmonic occurs for $L = \lambda/4$ which is when we have one antinode at the open end and one node at the closed end. As the sound frequency is increased, additional standing wave patterns occur whenever the wavelength has decreased enough that another half λ can fit into the tube so that the reflected waves travel an additional full wavelength. Thus, we see only odd harmonic standing waves develop in a column of air with one end closed end. From this argument we can also see that if the frequency is kept constant and the length of the tube is varied by moving the plunger, then standing waves will reoccur each time the plunger moves by $\lambda/2$.

Procedure:



The waves in this setup are made by a small loudspeaker attached to a sine wave (function) generator. The speaker sets the air molecules into <u>longitudinal</u> vibration (vibration in the direction of wave propagation). The speaker always acts as a displacement antinode because the surface of the vibrating diaphragm sets the air molecules into motion. Set the generator at a frequency near 1000 Hz. The sine-wave generator should not be set at the maximum-amplitude or the loudspeaker will be damaged.

Watch the oscilloscope screen. One signal trace on the screen is the original input signal, a sine wave. Move the plunger to vary the length of the air column. When you find an anti-node where the standing wave's amplitude reaches maximum amplitude and a powerful resonance grows. Determine all positions of the plunger for maximum sound intensity. The distance between two adjacent positions of maximum intensity is equal to

$\lambda/2$. Repeat for two other frequencies. From f and λ determine the speed of sound c for each pattern. Collect the data for three frequencies and calculate $\bar{c}$

Compare your average experimental value with the theoretical value

$$c = (331.4 + 0.6T)\,\text{m/s}, \quad (4)$$

where T is the temperature in degrees centigrade. If your instructor doesn't have a thermometer, assume $T = 22$ C.

QUESTION

From the air column data, what can you conclude about the dependence of the speed of sound on frequency ? Make sure you have the evidence to support your conclusion.

NOTES

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IN AN AIR COLUMN

Name:____Section:_________

Partner:____Date:___________

Try frequencies in the range 500 to 1500 Hz.

Standing Waves.

Frequency f_1 ______ Temperature:_________ Assume 22 C if there is no thermometer.

Record the locations of the nodes; the difference between these gives $\lambda/2$.

Positions of intensity maxima:						
Take the difference between intensity max. to get $=\lambda/2$						--
Average $\lambda/2$						
Average wavelength, λ						

Experimental wave velocity $f\lambda$: ______

Theoretical wave velocity $331.4 + 0.6T_c$: _______

Ratio $R = c_{exp}/c_{th}$ = _______

Frequency f_2 ______ Temperature:_________

Positions of intensity maxima:						
Take the difference between intensity max. to get $=\lambda/2$						--
Average $\lambda/2$						
Average wavelength, λ						

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Experimental wave velocity $f\lambda$: ______

Theoretical c: _______ **Ratio $R = c_{exp}/c_{th}$ =** _______

Frequency f_3 ______ Temperature:_________

Positions of intensity maxima:						
Take the difference between intensity max. to get $=\lambda/2$						--
Average $\lambda/2$						
Average wavelength, λ						

Experimental wave velocity $f\lambda$: ______

Theoretical wave velocity $331.4 + 0.6T_c$: _______

Ratio $R = c_{exp}/c_{th}$ = _______

Based upon your data, explain whether the velocity of sound, c, depend on frequency, f, for the air column? Show evidence for your conclusion.