Physics Department
Image and Sound Laboratory

STATIONARY SOUND WAVES IN TUBES

1. Objetives

To analyse the formation of stationary sound waves in tubes.
To determine the speed of sound propagation in tubes.

2. Theoretical concepts

When a longitudinal wave propagating in a fluid inside a tube reaches one end of the tube, it is reflected, in the same way that transverse waves are reflected in a rope. The reflected wave also travels through the tube with the same frequency as the incident wave, and gives rise to new reflections. These reflected waves are out of phase with each other and with respect to the incident wave. The superposition of the incident wave and the reflected waves produces a standing wave. For certain frequencies, the phase difference between the waves traveling through the tube is such that the amplitude of the resulting standing wave is very large, giving rise to a RESONANT STANDING WAVE.

A longitudinal wave consists of a series of compressions and rarefactions of the medium in which it propagates. In a standing wave there are points where the medium does not vibrate and are called displacement nodes, and points where the amplitude of the vibration of the medium is maximum, which are called displacement antinodes. In terms of pressure, displacement nodes correspond to pressure antinodes (points where the pressure is maximum) and displacement antinodes correspond to pressure nodes (points where the pressure is the equilibrium pressure).

The frequencies at which resonant standing waves are formed in a tube depend on whether it has both ends open or one of them is closed.

In a tube open at both ends, a resonant standing wave is formed if:

$$L = n\frac{\lambda}{2} \quad , \; n = 1,2,3... \qquad [1]$$

While if the tube is open at one end and closed at the other, it must be true that:

$$L = (2n+1)\frac{\lambda}{4} \quad , \; n = 0,1,2... \qquad [2]$$

where L is the length of the tube and λ to the wavelength of the waves in the tube.

Under resonance conditions, the closed end coincides with a displacement node (pressure antinode), and the open end(s) must coincide with a displacement antinode (pressure node).

Taking into account equation [3] we can obtain the relationship between the length of the tube, the speed of propagation of the longitudinal wave in the medium and the frequencies for which resonant standing waves are produced.

$$\lambda = \frac{v_{pro}}{v} \qquad [3]$$

Thus, in an open tube,

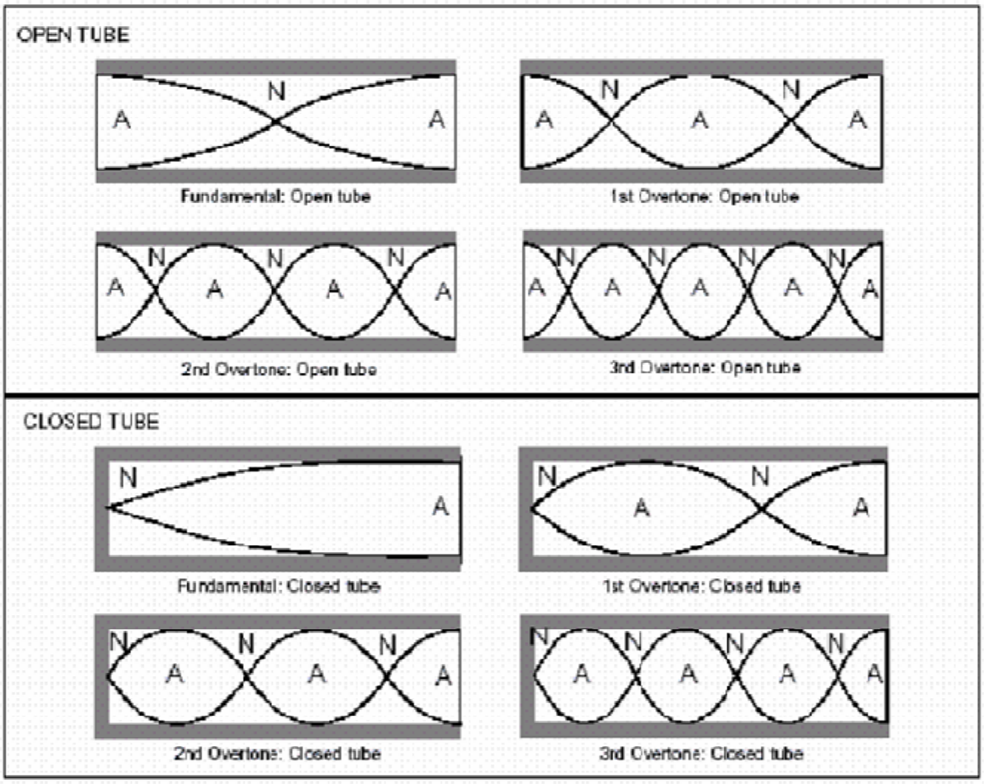
$$\nu = 2\frac{v_{pro}}{2L}\ con\ n=1,2,3... \qquad [4]$$

While in a close tube,

$$\nu = (2n+1)\frac{v_{pro}}{4L}\ con\ n=0,1,2,3... \qquad [5]$$

The lowest frequencies obtained according to the previous expressions are called fundamentals. Those obtained with successive values of n are called harmonics or overtones.

The following figures show the relative displacement configurations of the medium for the first four resonance states.



Resonance States: Open and Closed Tubes

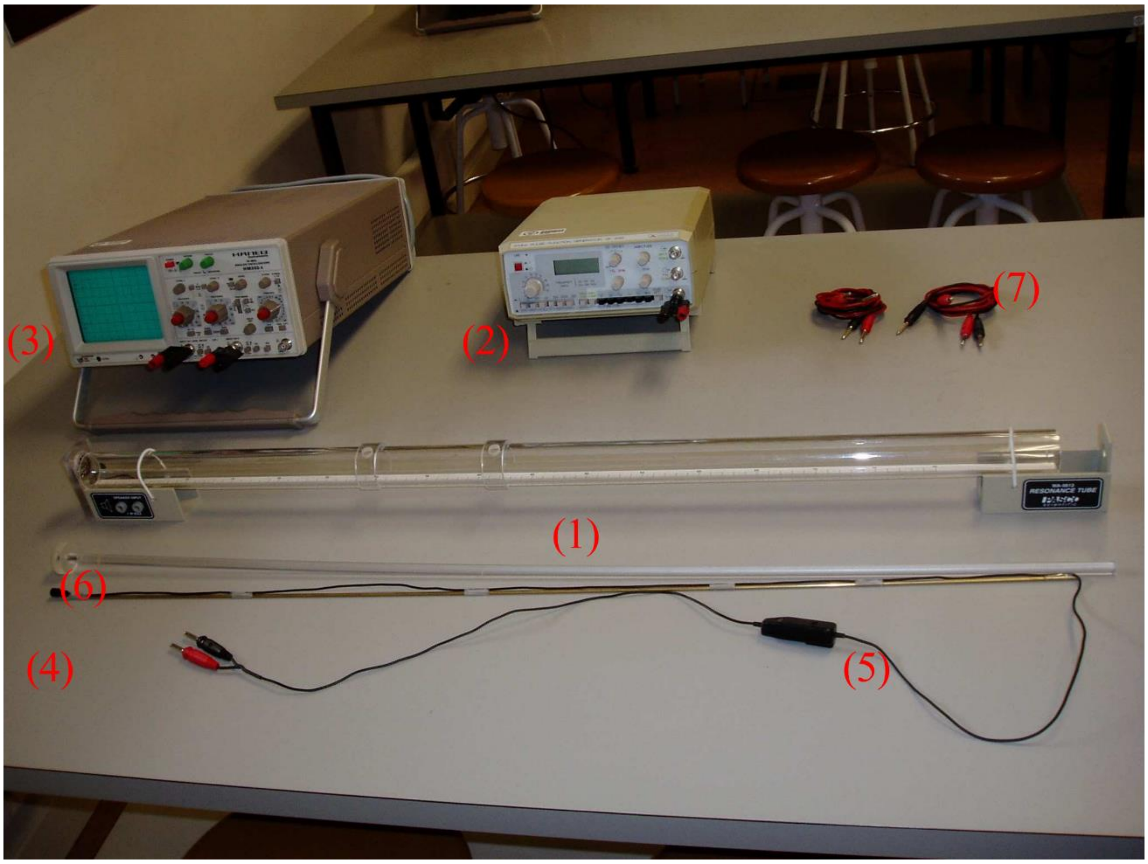
3. Experimental

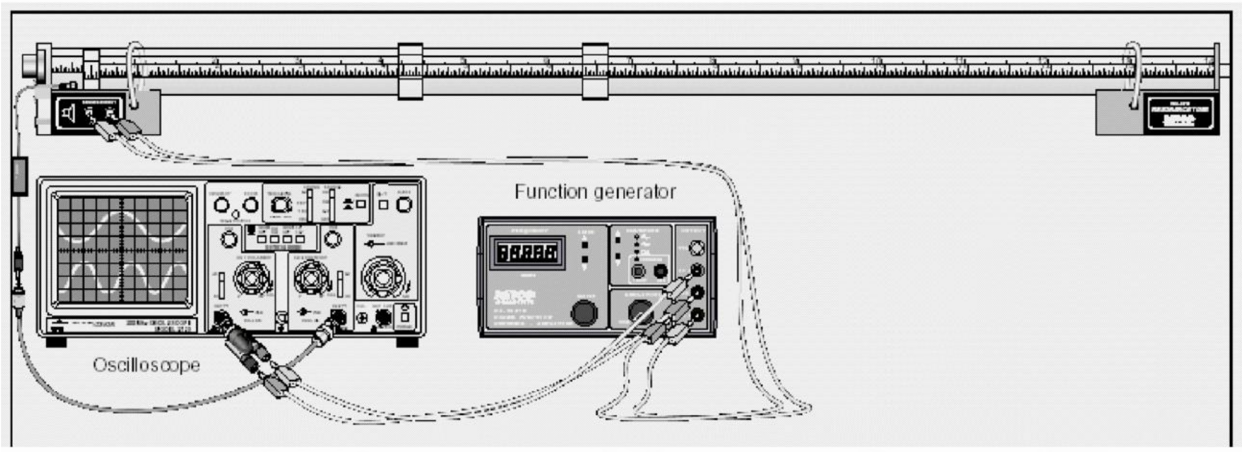
3.1 MATERIAL

1. Transparent tube with metric scale.
2. Function generator.
3. Oscilloscope.
4. Microphone.
5. Amplifier.
6. Movable piston.
7. Connection cables

3.2 EQUIPMENT AND SETTING

The graduated tube has a speaker housed at one end. The output of the function generator must be connected to the input of the speaker. Likewise, both the output of the function generator and the output of the microphone amplifier will be connected to each oscilloscope channel. The microphone amplifier switch should be turned to the ON position. At the end of the practice, said switch must be placed back in the OFF position.





Assembly diagram.

3.3 EXPERIMENTAL METHOD

Before beginning, measure the total length of the tube.
ATTENTION: the microphone detects pressure variations, not displacement.

3.3.1. Measurement of the frequencies of resonant standing waves in a tube.

A) TUBE OPEN AT BOTH ENDS

- Insert the microphone into the hole located under the speaker, and in line with it. (Be careful with the rod to which the microphone is attached).
- Select a sine-type function in the function generator.

- Select a frequency of 100 Hz. Adjust the signal intensity until the sound from the speaker is audible. ATTENTION: If you increase the intensity too much, the speaker may be damaged.

- View the signal coming from the microphone on the oscilloscope.

- Increase the frequency slowly and listen. In general, the sound will be louder as the frequency is increased because the speaker is more efficient at higher frequencies. However, for certain frequencies a maximum intensity will be heard, which corresponds to the resonant frequencies in the tube. At the same time, it is observed on the oscilloscope that the intensity of the microphone signal varies with frequency, and that for each resonant frequency a relative intensity maximum is recorded.

- Write down the values of the resonance frequencies.

- Repeat the measurements 3 times.

B) TUBE CLOSED AT ONE END

- Slide the piston until the effective length of the tube is 70 cm.

- Repeat all the measurements in section A), in this configuration.

3.3.2. Measurement tube lengths causing the condition of resonant standing waves.

- Insert the piston into the right end of the tube.

- Select a frequency of 800 Hz on the generator.

- Place the microphone in the hole located under the speaker, and in line with it.

- Adjust the signal strength until the sound from the speaker is audible.

- Slowly slide the piston until maximum intensity is heard. That piston position will match a maximum microphone signal strength on the oscilloscope.

- Write down the value of the effective length of the tube.

- Continue sliding the piston until you find all the lengths for which resonance occurs.

- Write down the value of the effective length of the tube.

- Continue sliding the piston until you find all the lengths for which resonance occurs.

- Repeat the entire series of measurements 3 times.

3.3.3. Characterization of a standing wave in a tube.

A) TUBE OPEN AT BOTH ENDS.

- From the results found in section 3.2.1, select a resonance frequency. In any case, use a frequency higher than 700 Hz.

- Adjust the signal strength until the sound from the speaker is audible.

- Place the microphone in the hole located under the speaker.

- Slide the microphone slowly along the tube. Observe the signal on the oscilloscope.

- Find the points on the tube (distances from the origin) where the intensity is minimum and the points where the intensity is maximum. The points where the intensity is minimum correspond to the nodes of the standing wave, and the points where the intensity is maximum correspond to the antinodes. Take the values.

- Repeat the measurements 3 times.

B) TUBE CLOSED AT ONE END.

- Slide the piston until the effective length of the tube is 70 cm.

- Repeat all the measurements from section A), in this configuration.

IMPORTANT: TURN OFF ALL EQUIPMENT, INCLUDING THE MICROPHONE

5. Bibliography

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In internet:

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