Experiment- 7

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Ruben's Tube

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1. Aim:

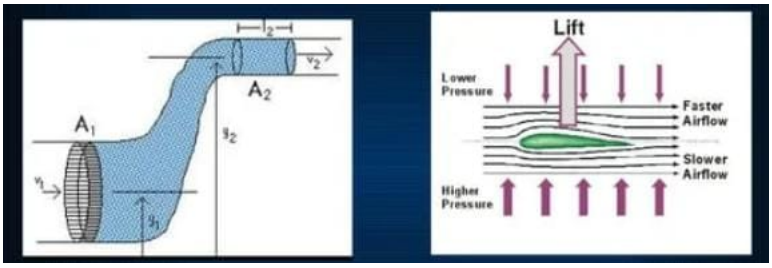
- To study the acoustic behaviour of combustion flame in a flame Ruben's Tube and also determine the speed of sound in propane.
- To demonstrate the correlation between sound waves and sound pressure.

2. Apparatus:

2.1 Ruben's Tube:

The Ruben's Tube, is a classic physics experiment that provides a spectacular visual demonstration of sound waves.To make a Ruben's Tube, a bunch of tiny holes are drilled in a line about 1 cm apart along one side of a steel pipe. A flexible membrane is stretched over one end of the pipe, while the other end is sealed off, except that a flammable gas (propane, C_3H_8) is pumped through the closed end. Finally, a speaker is set up next to the flexible membrane.

Figure 1: Diagram representing a Ruben's Tube



3. Theory:

3.1 Principle:

The atpparatus is based on Befrnoulli's Principle.
The time-averaged mass flow rate of the gas is proportional to the square root of the pressure difference between the inside and outside of the tube.

Let the speed with which the gas comes outside of the setup be v ,the interior pressure of the tube P_T and the atmospheric pressure or pressure outside the tube be P_0.We get the relation

$$\text{v} \propto \sqrt{P_0 - P_T}$$

3.2 Working:

1. Sound wave created by loudspeaker at the start.
2. Now there are two waves travelling in opposite directions since the first wave hit the end of the tube and is being reflected back.
3. The combination of the two waves creates a standing wave with the additional areas of oscillating pressure (antinodes) and constant pressure(nodes).
4. Short flames produced by areas of oscillating pressure and large flames produced by areas of constant pressure.

3.3 Sound Waves:

Sound is often a often portrayed as a sine waveform because it's easier to illustrate than the longitudinal compression wave that it actually is.
The first image shows the typical way a sound wave, or just about any wave, is portrayed visually.Because sound is basically a vibration created by changes in air pressure, the peaks on the waveform correspond to the highest pressure and the troughs correspond to the lowest pressure. The wavelength is measured by the distance between two peaks, or two troughs.

The second image is more accurate way to visualize compressional waves, including sound waves. Each dot could represent a molecule of the matter (such as air) that the wave is traveling through. At the points where the pressure is highest you can see that the density of the material is relatively higher than the areas with lower pressure. These are called condensation and rarefaction, respectively.

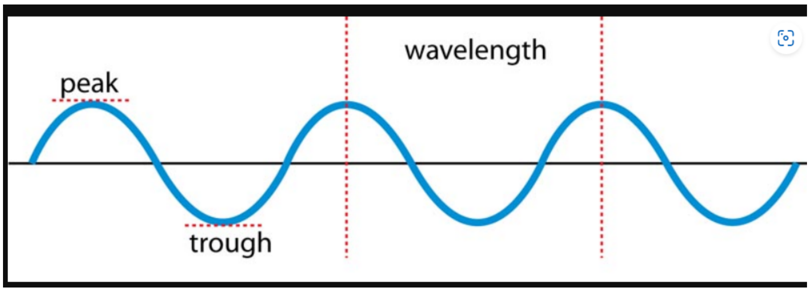


Figure 2: A sound wave

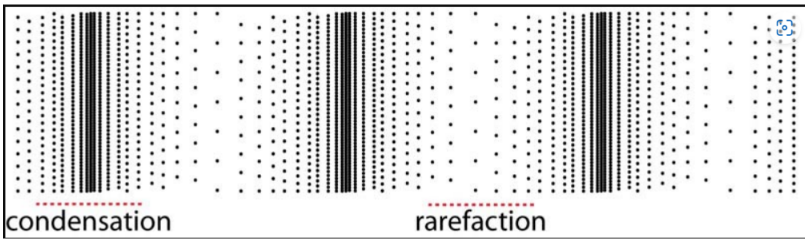


Figure 3: Visualization of compressional waves, including sound waves

The third image shows the previous two stacked, it's easy to see how the peaks of the wave correspond to condensation, and how the troughs correspond to rarefaction.

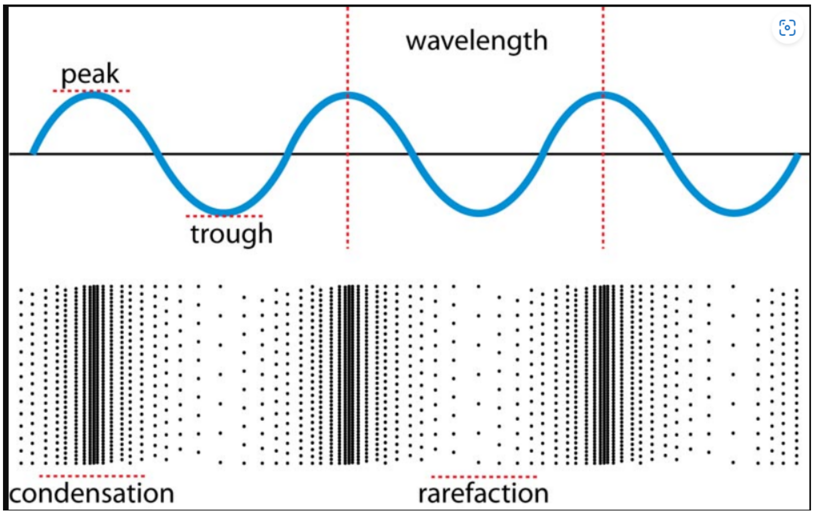


Figure 4: peaks of the wave correspond to condensation

3.3.1 Speed of Sound:

If we denote the frequency of sound as f,its speed as the medium as v and wavelength as λ,then these three are linked together by the equation:

$$v = f\lambda$$

Knowing the values of f and λ,the velocity of sound in the gas can be determined.

3.3.2 Loudness of Sound:

Loudness is the subjective perception of sound pressure,i.e. how loud or soft a sound seems to a listener.The loudness of sound is determined by the intensity or amount of energy in sound

waves.
Loundness of sound is measured in units of decibel(dB).

$$Loudness = 20\log(\frac{P_{rms}}{P_{ref}})$$

where,
P_{rms}=The root Mean Squared value of the Pressure of the sound wave.
P_{ref}=The Reference Pressure or Hearing limit for humans,usually take as 2×10^{-5} Pa.

4. Procedure:

- The system is checked in case of any leak of gas which might be dangerous for the experiment.
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- The gas is turned on and after 15 seconds, top of the tube which is perforated is lighted. The reason of waiting for 15 seconds is to let the gas fill and spread out evenly in the tube.
- After lighting the tube every opening gets flame as the gas escapes through the openings. The openings are lighted again, flames don't appear.
- The loudspeaker is placed close to the end of the tube with the membrane. It is connected to a frequency generator.
- Measure the wavelength of the standing waves produced for several frequencies and calculate the speed of sound in propane in the tube.

5. Results:

- Length of the Ruben's Tube, L = 183 cm.
- Frequency of operation, f = 650 Hz.
- The two crests are separated by a distance = 40.59 cm=0.4059 m .

The speed of sound in propane = v =fλ=650$\times$0.4059=263.84ms^{-1}
Thus, Speed of sound in propane is found to be 263.84ms^{1}

6. Sources of Error:

- Instrumental error.
- Setup may not be air tight, leading to leakage of gas. This is not only a source of error, but also a safe hazard.
- The tube may mixture of gas and air in the tube instead of pure Propane which may lead to inaccurate results.
- Human error while performing the experiment.

7. Conclusion

The velocity of gas that is attempting to leave through the small holes is related to the pressure,gas is to travel through the hole at a fast speed and that leads to the high flames.In areas of lower pressure that flames are much shorter since the velocity of the escaping flames is reduced.The sound waves are creating pattern of differing flame heights because of the varying high and low pressures.

8. Precautions:

- As propane is flammable,we have to make sure that we are in a well ventilated area or outside. In addition to the potential fire hazard, there is also a very real danger of carbon monoxide exposure from propane being less than completely burned. Carbon monoxide is deadly.
- Even after the propane is shut off, the tube and hosing will still contain fuel. After turning off the fuel,we can see the flames slowly start to lower. However, even after they're no longer visible,it's possible that they're still burning within the pipe itself. After shutting off the gas,we should remove the propane tank from the hose and allow plenty of time for the remaining fuel to burn off.
- The apparatus is supposed to be checked for gas leaks annualy.