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Measurement of Speed of Sound using Smartphones

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Abstract

The goal of this experiment is to determine the speed of sound in air. To measure the speed of sound, I used two smartphones and an app called “Phyphox”. This app uses the microphone of the smartphone to detect the time between two acoustic events. The “acoustic stopwatch” tool on the app is used to measure the time between two sound signals. These two signals are produced by hand clapping. In this experiment, the speed of sound is determined using the time-of-flight method. This method is based on measuring the time delay between the generation and the detection of a sound signal of finite duration. This method is used for many applications in science and technology. In medical ultrasound, the speed of sound is used to distinguish between different tissues in the body.

Introduction

Sound is a type of energy that is transmitted through matter in the form of periodic vibrations of density and pressure. These vibrations traveling through a medium are called sound or acoustic waves. The sound waves can exist in all states of matter such as gas, liquid and solid. When sound waves reach our ears, they cause the vibration of our eardrums. These vibrations are then turned into nerve signals which go to the brain. We distinguish the sound signals according to their volume, frequency, and direction of travel. Sound is produced by the collective back-and-forth motion of the molecules of the medium. We can use our hands to understand how sound is produced and travels. Try clapping your hands under water. As your hands move towards each other they gather water, creating a space behind them that the surrounding water particles rush to fill. Once your hands meet, the water particles between your hands are compressed. As a result, ripples move away from your clapped hands through the water. In my experiment, I measure the speed of sound in air. When you clap your hands, you displace the air molecules between and around your hands. This creates a compression wave that travels through the air.

The speed of sound depends on the type of medium it travels through. Sound waves are generally known to travel faster through solids than through gas because the molecules in gas are much further apart then in solids and are easily compressible. The other factor to consider apart from what type of medium sound is passing through, is the temperature of the medium.

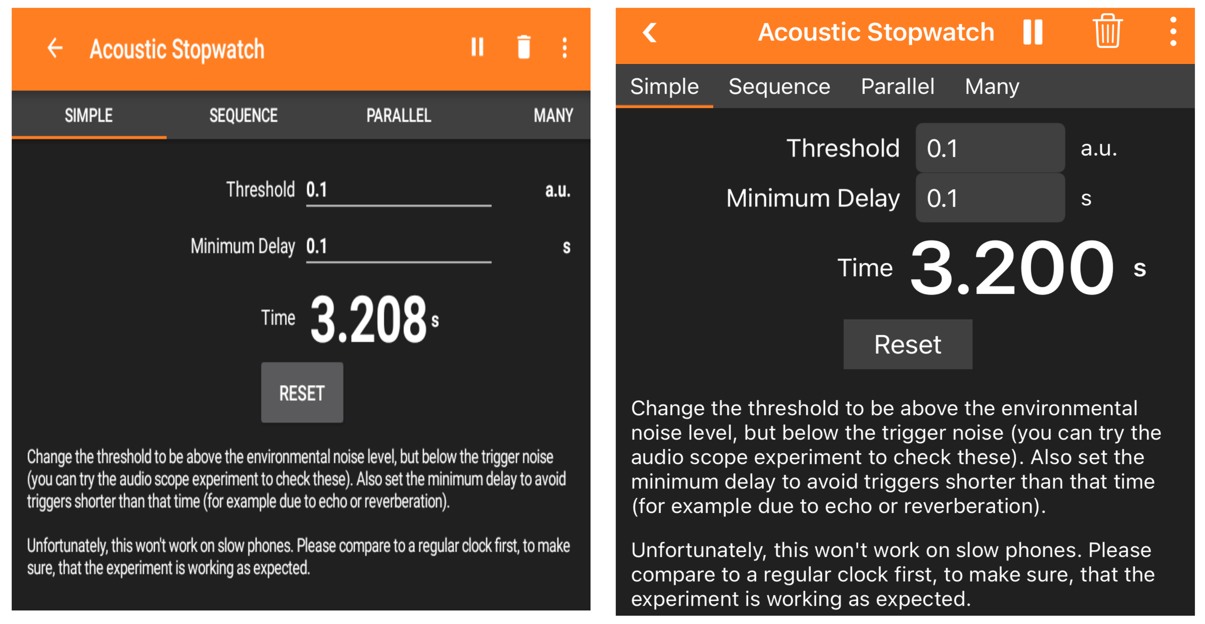
Sound waves are characterized by their wavelength and frequency. Wavelength is defined as the distance between two consecutive crests or troughs (measured in meters). Frequency of sound is the number of cycles per unit (measured in hertz). The faster an object vibrates the higher the frequency of the sound. Sound in air is a longitudinal wave because the disturbance is usually parallel to the direction of propagation.

Methodology

I used an app called “Phyphox” to conduct this experiment. This experiment requires the use of two smartphones. After downloading, I made sure the app was running properly on the two devices. The experiment was conducted indoors at a temperature of 20°C. I conducted the experiment in a quiet location. I also adjusted the threshold on the app to minimize the background noise.

The two smartphones were placed at a distance of 1.5m from each other. The experimental procedure consists of generating two sound signals of short duration. I produced the first signal by clapping my hands near the first smartphone. I made sure that the sound was loud enough to start the timers on both smartphones. After some time delay, a second clap is made near the other phone. This second sound signal stops the timers on both smartphones.

Once this process was completed the time Δt_1 on the first smartphone and Δt_2 on the second smartphone were recorded (see the table below). This process is repeated for a distance of 2.1m.



Pictures showing the interface of the app “Phyphox”

Result/Calculations

After collecting the data, I used Excel to determine the velocity and time delay for each trial. The data analysis is shown below:

Measuring speed of sound with smartphones

First trial with a distance of 1.524m				
Δt_1, s	Δt_2, s	ΔT, s	D, m	V, m/s
3.208	3.200	0.008	1.5	381.0
2.410	2.401	0.009	1.5	338.7

Second trial with a distance of 2.134m				
Δt_1, s	Δt_2, s	ΔT, s	D, m	V, m/s
5.847	5.833	0.014	2.1	304.86

Average value for the velocities of both the first trial and second velocity = 381.00 m/s
338.67 m/s
304.86 m/s

Experimental Average value = 341.51 m/s (at 20 degrees)
Standard Deviation = 38.15
Standard value for speed of sound at 20 degrees = 342.9m/s

% Error between the standard value of speed of sound to the experimental value gotten from the experiment conducted
% Error = 0.41

Because the sources of the sound signals which start and stop the timers are located near the first and second smartphones, there is an overall time delay between the time intervals measured by the two smartphones. This time delay is given by the following formula:

$$\Delta t = \Delta t_1 - \Delta t_2$$

Using this time delay, we can calculate the speed of sound from the following equation:

$$v = \frac{d}{\Delta t_d} = \frac{2d}{\Delta t_1 - \Delta t_2}$$

Where d is the distance between the two smartphones.

Note that the distance is multiplied by 2 because the sound signal travelled the distance d when the first clap was made at the position of the first phone, and then the second signal traveled the same distance from the second phone to the first.

The percentage error was calculated by comparing the average value of the speed of sound from the three measurements and the standard value for the speed of sound at $20°C$. The standard value was calculated by using the following equation:

$$v = 331m/s\sqrt{1 + \frac{T_C}{273°C}}, \text{ Where } T_C = 20°C$$

Conclusion

In this experiment, I was able to measure the speed of sound in air using the time-of-flight method. I used the app “Phyphox” and two smartphones to accurately calculate the speed of sound made by clapping my hands. Smartphones are used every day in our lives, which is why I was able to properly conduct and set up this experiment with little to no cost.

The accuracy of my measurement is 0.41%. This experimental error is due to delay in the response of the timers in the two smartphones.

Reference

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