Speed of sound: two stopwatches

FizziQ activity · High school · 30 min

Scan to open in FizziQ

Two smartphones running FizziQ's acoustic stopwatch are triggered by the same claps; the delay over a known distance gives students the speed of sound directly.

Learning objectives

- Measure the speed of sound using two acoustic stopwatches separated by a known distance
- Understand the principle of differential timing to eliminate systematic errors
- Compare the measured speed with the accepted value and evaluate sources of error
- Investigate the effect of temperature on the speed of sound
- Connect the experiment to the historical measurements of the speed of sound

Instruments and sensors

Acoustic stopwatch · Microphone

Materials

- Two smartphones with the FizziQ application
- A clear space of at least 5 meters
- A tape measure to measure distance
- FizziQ experience notebook
- Note: the protocol remains adaptable to any comparable acoustic timing tool.

Protocol

1. Open FizziQ on both smartphones and set up the acoustic stopwatch (sound-triggered timer) on each.
2. Calibrate the sound threshold on both phones so they trigger reliably on a hand clap but not on background noise.
3. Place the two smartphones on the same table, side by side. Perform a test: clap once to start both, then clap again to stop both. The recorded times should be nearly identical (within a few milliseconds).
4. Now separate the smartphones by a measured distance. Start with 5 meters between them, measured precisely with a tape measure.
5. Stand at one end (near Phone A). Clap once to start both stopwatches. Both phones should start simultaneously (sound reaches both within ~15 ms at 5 m).
6. Wait 3-5 seconds, then clap again near Phone A to stop both. Phone A stops instantly; Phone B stops after a slight delay (the time for the second clap to travel 5 meters).
7. Record the time displayed on each phone: T_A and T_B. The difference $\Delta T = T_B - T_A$ is the sound travel time over the 5-meter distance.
8. Calculate the speed of sound: $v = \text{distance} / \Delta T$.
9. Repeat the measurement 5 times and calculate the average and standard deviation.
10. Increase the distance to 10 meters and repeat. A longer distance gives a larger ΔT, reducing relative error.
11. Try distances of 15 and 20 meters if the space permits. Plot speed versus distance to check consistency.
12. Compare your result with the theoretical speed at the current air temperature: $v = 331.3 + 0.606 \times T(°C)$ m/s.

Expected results

The measured speed of sound should fall between 330 and 360 m/s, depending on temperature (the accepted value is 343 m/s at 20°C, increasing by about 0.6 m/s per degree Celsius). At 5 meters, the time difference ΔT is only about 14.6 ms, which requires precise acoustic triggering to measure. At 10-20 meters, the time difference increases to 29-58 ms, giving more reliable results. The standard deviation across repeated measurements is typically 5-15% at 5 meters but improves to 3-8% at 10+ meters. Wind can introduce systematic errors if it consistently blows along or against the direction of sound propagation. The main source of random error is the acoustic trigger precision (±1-2 ms).

Questions

- Why does the differential timing method (using two phones) eliminate the reaction time error?
- How does temperature affect the speed of sound? Why?
- Why does a longer measurement distance generally give a more precise result?
- How did Marin Mersenne measure the speed of sound in 1635, and how accurate was his result?
- What is the speed of sound in water? In steel? Why are these so different from air?
- How is the speed of sound related to the properties of the medium (density, elasticity)?

Going further

- Measure the speed of sound at different outdoor temperatures and verify the temperature dependence
- Compare measurements on a windy day (with and against the wind) to detect the wind speed effect
- Use an echo from a building wall as a natural reflector: measure the time for sound to travel to the wall and back
- Compare the speed of sound in air with the speed in a solid (e.g., tap the end of a metal rail and measure the arrival time at the other end)
- Investigate whether the frequency of the sound affects its speed (it should not, for audible frequencies in air)