Waves: measuring the speed of sound in air

Key stage 3

The scenario

The Mars Insight mission scientists will use their knowledge of the speed at which different waves travel through the ground to calculate the distance that an impactor is from the Insight lander. In this activity your students will work out the speed of one wave, sound, through a medium of air.

The activity

There are two methods that can be used to work out the speed of sound in air using the popping of a balloon or the clapping together of two pieces of wood. One is much more accurate than the other.

1. Single echo approach

In theory, as long as you know the distance to the wall, it is possible to work out the speed of sound in air.

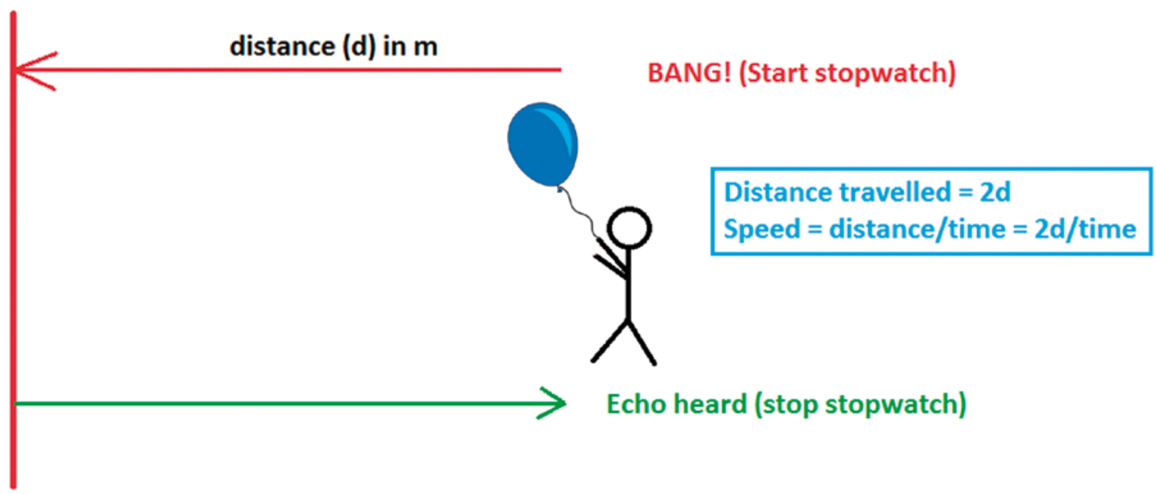
- Have one volunteer to be the 'banger' and three volunteers to be the timers. Position them together and measure the distance between them and the wall with a tape measure (at least 30 metres).
- Get the 'banger' to pop their balloon (you may want to pop one first so the students know what to expect). When the balloon is popped, the timers start their stopwatches.
- When the timers hear the echo, the stopwatches are stopped and an average time is taken.

Learning objectives

- errors and accuracy
- repeating measurements
- using the equation speed = distance/time

Equipment needed

- a wall (that you can stand 30–50 metres from)
- a pack of balloons
- two large pieces of wood to bang together to produce a sound
- several stopwatches
- tape measure



MarsQuake

Since the sound had to travel the whole distance to the wall, and the same distance back again, we know that in the time the students recorded, the sound travelled twice the distance to the wall, and so we can use the equation:

$$\text{Speed (m/s)} = \frac{\text{Distance (m)}}{\text{Time(s)}} = \frac{2 \times \text{distance to wall}}{\text{time taken to hear echo}}$$

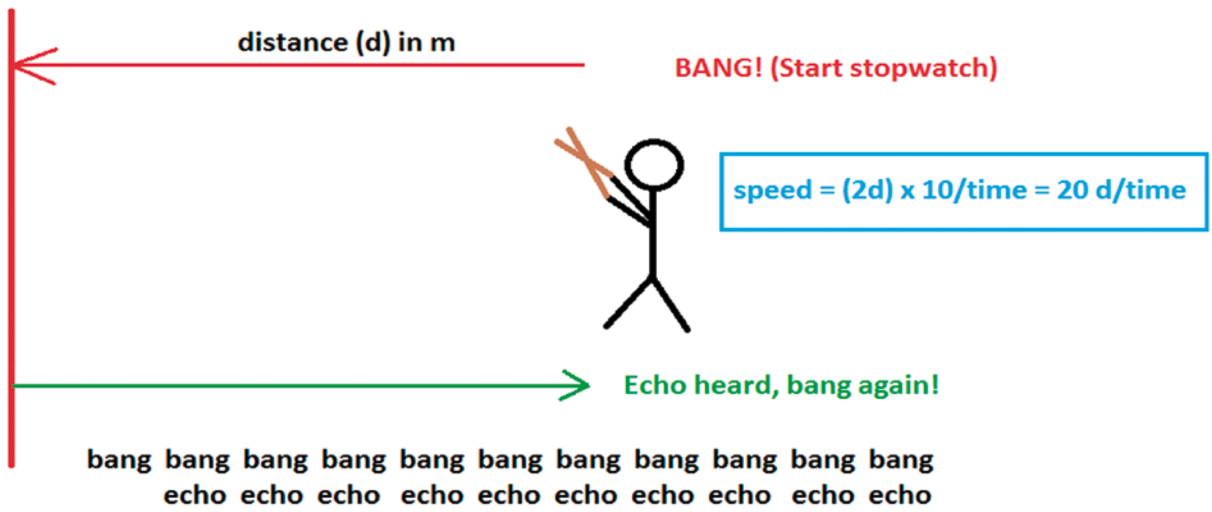
However, there is a problem with this method. Get your students to think about how much human error there is in the timing — far too much for the result to be accurate!

2. Echo rhythm approach

However, we can improve the accuracy by timing how long it takes for multiple echos. To do this, the banger now needs to produce a sound that they can then reproduce as soon as they hear the echo. This can be achieved by hitting two pieces of wood together very hard.

- Have one volunteer to be the 'banger' and three volunteers to be the timers. Position them together and measure the distance between them and the wall with a tape measure (at least 30 metres).
- Get the banger to smash the wood together and tell them to do this again as soon as they hear the echo. Ask the timers to listen to make sure that there is one single sound — an overlap of echo and bang.
- Once the banger is in rhythm, get the timers to start their stopwatches when they hear the next bang, and count until 11 bangs have been recorded at which point they should stop their stopwatches and take an average time.

Since 11 bangs cycles have been measured, 10 full travel time intervals have been measured. So the total distance travelled in the time for 11 bangs is twice the distance to the wall times 10 or 20 times the distance to the wall.



The speed of sound can now be calculated using:

$$\text{Speed (m/s)} = \frac{\text{Distance (m)}}{\text{Time (s)}} = \frac{2 \times \text{distance to wall}}{\text{time taken to hear 11 bangs}}$$

InSight BGS NATIONAL SPACE ACADEMY UK SPACE AGENCY

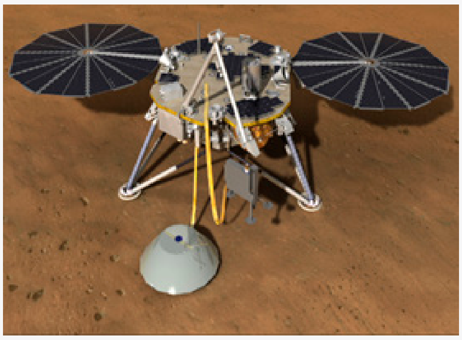
Worksheet

Waves: measuring the speed of sound in air

Key stage 3

Scenario

The Mars Insight scientists need to know how fast different waves travel in different materials in order to work out how far away an impact was from the lander. You are going to help them by working out the speed of sound in air.



Method — measuring the speed of sound using one echo

Four volunteers will stand together a good distance from the wall. Measure this distance using a tape measure.

One volunteer will pop a balloon to make a big noise. As soon as the balloon is popped the other three volunteers start their stopwatches.

When they hear the echo the volunteers stop their stopwatches and an average time is calculated.

Keywords

- speed
- echo
- distance
- time

Results and calculations

How far away were the volunteers from the wall? .... m

In the table below write the three times that the volunteers recorded for how long it took for the sound to travel to the wall, reflect off and the echo to be heard.

	Person 1	Person 2	Person 3	Average
Time taken (s)				

Calculating the speed of sound in air:

How far did the sound have to travel in total to get to the wall, reflect off and come back to the observers? .... m

Use the equation: $\textit{Speed (m/s)} = \dfrac{\textit{Distance (m)}}{\textit{Time (s)}}$ to calculate the speed of sound in air

Speed of sound in air = ... m/s

How reliable was your result? What is the main source of error?

MarsQuake

Method — measuring the speed of sound using multiple echos

To improve the accuracy of your results, you should measure the time taken for multiple journeys of sound to the wall and back.

One volunteer will be the 'banger' and three volunteers will be the timers. Position them together and measure the distance between them and the wall with a tape measure.

Get the banger to smash the wood together and tell them to do this again as soon as they hear the echo. The timers should listen to make sure that there is one single sound — an overlap of echo and bang.

Once the banger is in rhythm, the timers to start their stopwatches when they hear the next bang, and count until 11 bangs have been recorded at which point they should stop their stopwatches and record their results.

Work out the average time for 11 bangs to be heard.

Results and calculations

How far away were the volunteers from the wall? .... m

Fill in and complete the table below

	Person 1	Person 2	Person 3	Average
Time for 11 bangs (s)				

Use the equation: $\textit{Speed (m/s)} = \dfrac{\textit{Distance (m)}}{\textit{Time (s)}} = \dfrac{\textit{2} \times \textit{distance to wall}}{\textit{time taken to hear 11 bangs}}$ to calculate the speed of sound in air

Speed of sound in air = ... m/s

Improvements

How could you improve this investigation to further reduce error?