

Sound, echoes, ultrasound and hearing

Physics grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · Lesson

Quick answer: Sound is a longitudinal wave of compressions and rarefactions that needs a medium to travel through. It moves at about 330 m/s in air, 1500 m/s in water and 5000 m/s in steel. Humans hear about 20 Hz to 20 kHz, and echoes give distance using $d = v t / 2$.

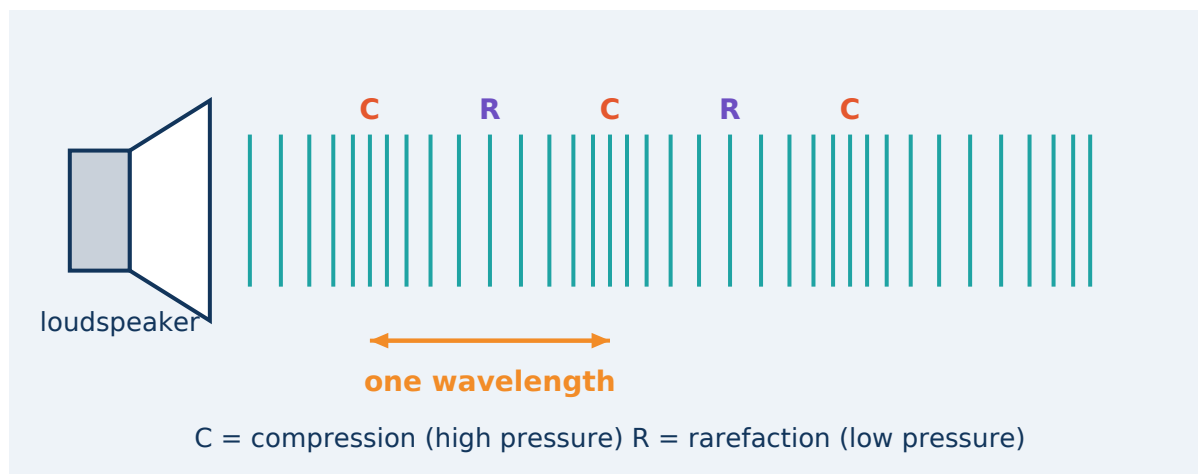
Level: Physics grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · **Curriculum:** IGCSE 3.4

What is sound and how does it travel?

Sound is produced by a vibrating object. When a guitar string or a loudspeaker cone vibrates, it pushes on neighbouring air particles, which push on their neighbours, and a pattern of squashed and stretched air travels outwards. That pattern is a sound wave.

Definition

A **sound wave** is a longitudinal wave of compressions (high pressure) and rarefactions (low pressure) that passes through a material medium. Sound cannot travel through a vacuum.



Sound is a longitudinal wave: air is squeezed and stretched as the pattern moves outwards.

The particles only vibrate to and fro about their positions; they do not travel from the speaker to your ear. The energy does. This is why sound needs particles to pass the vibrations along, and why there is silence in space.

How fast does sound travel?

The speed depends on the material. Particles in a solid are closer together and linked by stronger bonds, so they pass the vibration on faster than the particles of a gas.

Medium	Speed of sound (m/s)
Air (about 20 °C)	330
Water	1500
Steel	5000

Formula

speed = distance / time, or $v = d / t$

v = speed in m/s · d = distance in m · t = time in s. In air we use $v \approx 330$ m/s unless told otherwise.

Worked example 1

Bilal in Lahore sees a lightning flash and hears the thunder 5.0 s later. Light arrives almost instantly.

$$d = v t = 330 \times 5.0 = 1650 \text{ m.}$$

Answer: **1.65 km** (about 1.7 km) away.

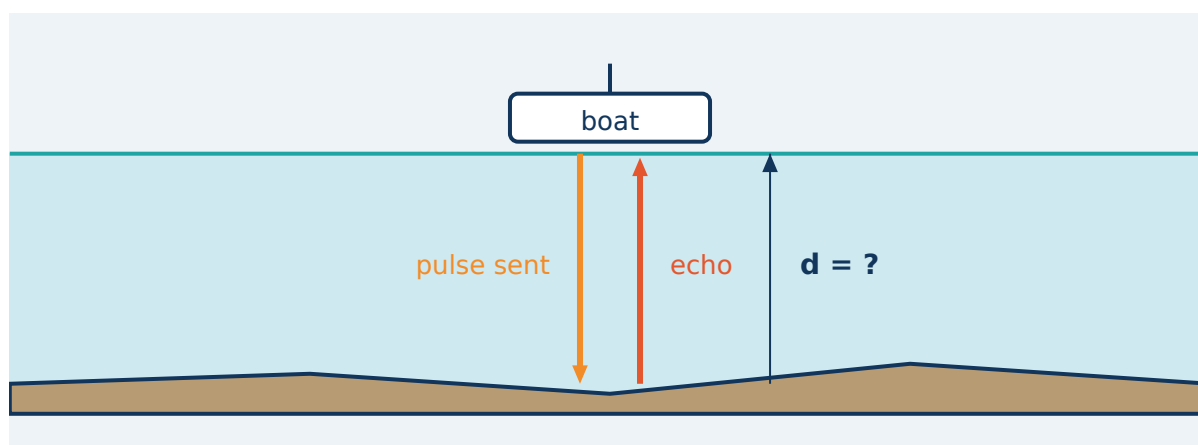
What are echoes and how does sonar work?

An echo is sound reflected from a hard surface. Because the sound has to travel to the surface and back, the distance covered is twice the distance to the surface.

Formula

$$d = v t / 2$$

d = distance to the reflector in m · v = speed of sound in m/s · t = time between sending and hearing the echo in s.



Sonar: depth = speed $\times$ time / 2, because the pulse goes down and back.

Worked example 2

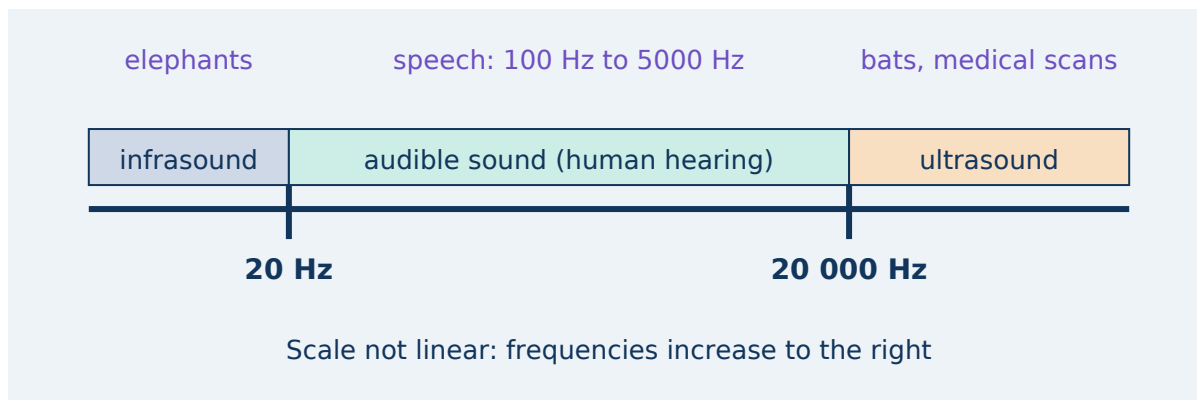
Mei's fishing boat in Singapore sends a sonar pulse and the echo from the seabed returns after 0.080 s. The speed of sound in water is 1500 m/s.

$$d = v t / 2 = 1500 \times 0.080 / 2 = 60 \text{ m.}$$

Answer: **60 m.**

What frequencies can we hear?

The frequency of a sound is the number of vibrations per second. The ear of a healthy young person detects frequencies from about 20 Hz to 20 000 Hz (20 kHz). Sound above this range is **ultrasound**; below it is **infrasound**.

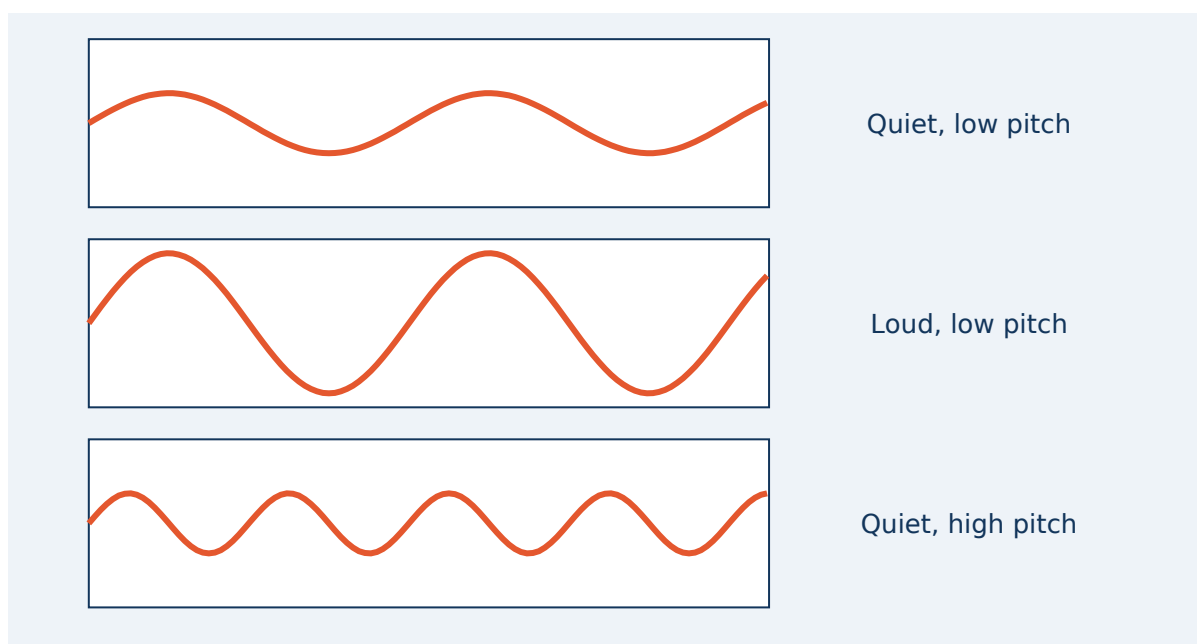


The human ear detects frequencies from about 20 Hz to 20 kHz; young people hear the most.

Ultrasound has very short wavelengths, so it reflects from small objects and travels in narrow beams. Doctors use it to scan unborn babies, engineers use it to find cracks inside metal, and bats use it to hunt insects in darkness.

What makes a sound loud or high-pitched?

A louder sound has a larger amplitude, so the wave trace is taller. A higher pitch means a higher frequency, so the waves are closer together on the trace. Loudness is measured in decibels, and pitch in hertz.



Taller waves are louder (larger amplitude); closer-packed waves have a higher pitch (higher frequency).

Common mistake

In an echo calculation, do not forget to halve the distance. The sound travels there and back, so $v \times t$ is the total distance and the wall is half as far away.

Lina's tip

To find a distance from an echo, picture the sound making a round trip. Work out the total distance $v \times t$ first, then divide by two to get the one-way distance.

Key points to remember

- Sound is a longitudinal wave and cannot travel through a vacuum
- Speed of sound: about 330 m/s in air, 1500 m/s in water, 5000 m/s in steel
- Echo distance $d = v t / 2$ (the sound goes there and back)
- Human hearing range: about 20 Hz to 20 000 Hz; ultrasound is above 20 kHz
- Greater amplitude means louder; higher frequency means higher pitch

Sound, echoes, ultrasound and hearing: frequently asked questions

Why can sound not travel through space?

Sound needs particles to pass the vibrations from one to the next. Space is a near-perfect vacuum with almost no particles, so a sound wave has nothing to travel through.

Why does sound travel faster in solids than in gases?

The particles of a solid are much closer together and held by strong bonds, so each vibration is passed to the next particle very quickly. In a gas the particles are far apart.

What is the frequency range of human hearing?

A young, healthy person hears from about 20 Hz to 20 000 Hz. The upper limit falls with age, and sounds above it are called ultrasound.

How do you calculate distance from an echo?

Multiply the speed of sound by the time between the sound and the echo, then divide by two. The division is needed because the sound travels to the surface and back.

How is ultrasound used?

Ultrasound scans produce images of unborn babies and organs, sonar finds the depth of the sea, engineers detect cracks in metal, and ultrasonic baths clean delicate objects. These uses rely on reflection of short-wavelength waves.