Sound

Matthew Williams • Physics • May 20, 2026

Sound

Sound as a Longitudinal Wave

Sound is produced by a vibrating object (e.g. a tuning fork, vocal cord, loudspeaker). The vibrating object compresses and stretches the surrounding medium alternately, creating regions of **compression** (high pressure) and **rarefaction** (low pressure) that travel outward as a **longitudinal wave**.

Since sound requires a medium in which compressions can form, **sound cannot travel through a vacuum**. This is demonstrated by placing a ringing bell inside an evacuated jar, the sound fades as the air is pumped out.

Sound travels as longitudinal waves through solids, liquids, and gases. The speed of sound depends on the medium: it is fastest in solids (stiffest) and slowest in gases.

Speed of sound in air at room temperature: approximately 330 m s^{-1} to 340 m s^{-1}.

Pitch and Loudness

Property	What determines it	Measurement
Pitch	Frequency of the sound wave	Hz, higher frequency, higher pitch
Loudness	Amplitude of the sound wave	Decibels (dB), larger amplitude, louder sound

A high-pitched sound has a high frequency and a short wavelength. A deep (bass) sound has a low frequency and a long wavelength. The human ear detects frequencies from roughly 20 Hz to 20 000 Hz.

Echo Calculations

An echo is sound reflected from a surface (wall, cliff, building). Since the sound must travel to the reflector and back, the distance to the reflector is:

$$d = \frac{v \times t}{2}$$

where v is the speed of sound and t

is the time between making the sound and hearing the echo.

Echo distance calculation

A ship sends a sonar pulse and receives the echo 0.8 s later. The speed of sound in seawater is 1500 m s{. Find the depth of the seabed.

$$d = \frac{v \times t}{2}$$

$$d = \frac{1500 \times 0.8}{2}$$

$$d = \frac{1200}{2}$$

$$d = 600 \text{ m}$$

Reflection, Refraction, and Diffraction of Sound

Sound obeys the same wave behaviours as light.

Reflection: Sound reflects from hard, flat surfaces. Echoes are reflections. Concert halls use curved reflective surfaces to direct sound evenly to the audience.

Refraction: Sound refracts when it passes between media of different densities. Sound can be refracted downward toward the ground at night when the air is cooler near the ground (the cooler, denser air slows sound, bending it downward).

Diffraction: Sound diffracts (spreads around corners) readily because its wavelength (approximately 0.017 m to 17 m for audible sound) is comparable to everyday objects and openings. This is why you can hear someone talking around a corner even though you cannot see them.

Ultrasound

Ultrasound is sound with a frequency above the human hearing limit, greater than about 20 000 Hz (20 kHz).

Applications of ultrasound:

Application	How it works
Medical scanning	Pulses of ultrasound are directed into the body; reflections from tissue boundaries are detected and used to build an image (e.g. foetal scanning)
Sonar (depth sounding)	Timed echoes from the seabed give depth; used in submarines and fishing vessels
Cleaning of delicate instruments	High-frequency vibrations in a liquid dislodge dirt without mechanical contact
Crack detection in metals	Reflections from internal cracks reveal defects in structural components

Ultrasound is preferred to X-rays for foetal scanning because it does not involve ionising radiation.

📝 **Exam Tip**

In echo problems, always halve the total time, the sound travels to the reflector AND back. Forgetting to halve gives an answer twice too large.

When asked why sound cannot travel through a vacuum: state that sound requires a medium because compressions and rarefactions cannot form without particles.