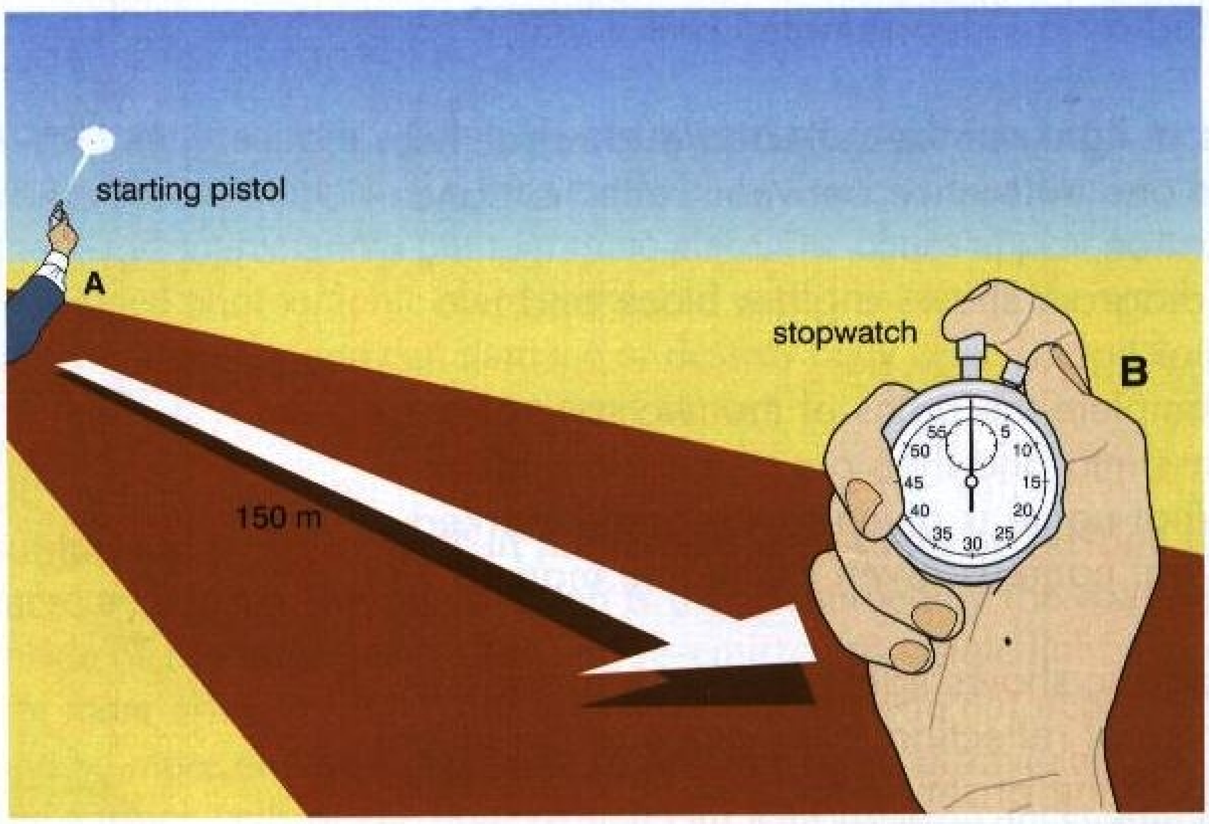
3 Sound

EXPERIMENT TO FIND THE SPEED OF SOUND

Sound travels much more slowly than light in the air. We can use this to measure how quickly the sound does travel.



Person A makes a loud sound and produces a visual signal at the same time – this could be by firing a starting pistol or by banging large cymbals together. Person B starts a stopwatch when they *see* the sound being made and stops the stopwatch when they *hear* the sound. They can work out the speed of sound using this formula:

$$\text{speed of sound} = \frac{\text{distance between the two people/m}}{\text{time measured/s}}$$

Properties of sound waves

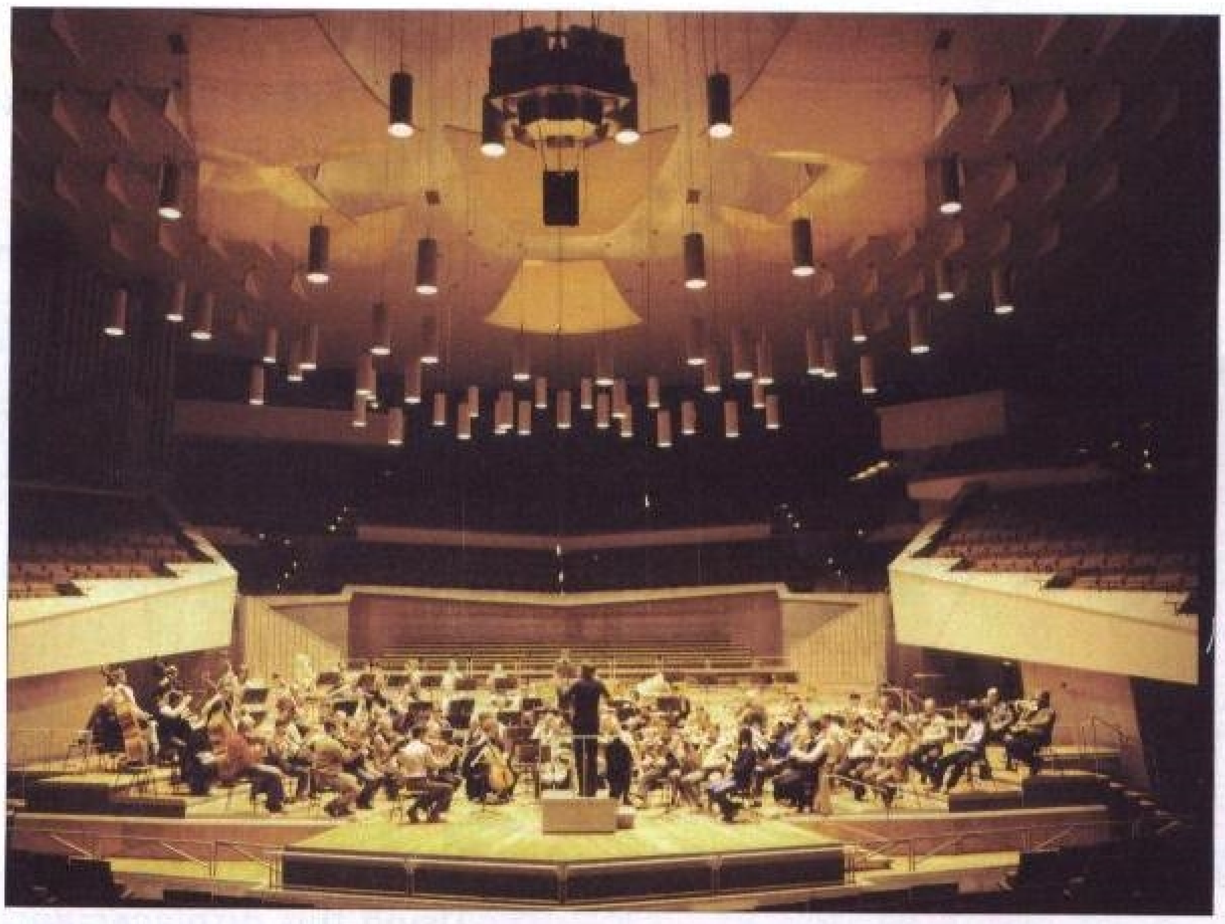
Sound waves travel at about 340 m/s in the air – much slower than the speed of light. This explains why you almost always see the flash of lightning before hearing the crash of the thunder.

Sound is caused by vibrations, of the front of a violin or a cello, or of the column of air inside a trumpet. In the case of a loudspeaker you can see that the cone of the loudspeaker moves in and out and changes the pressure in the air in front of it. The sound travels as **longitudinal** waves. The compressions and rarefactions of sound waves result in small differences in air pressure.

Sound waves travel faster through liquids than through air. Sound travels fastest through solids. This is because particles are linked most strongly in solids. Note, however, that sound must have a medium through which to travel. Unlike electromagnetic waves, sound will not travel through a vacuum.

High-pitch sounds have a high frequency. Examples of high-pitch sounds include bird-song, and all the sounds that you hear from someone else's personal player when they have set the volume too high. Low-pitch sounds have a low frequency. Examples of low-pitch sounds include the horn of a large ship and the bass guitar.

The human ear can detect sounds with pitches ranging from 20 Hz to 20 000 Hz. Sound with frequencies above this range is known as **ultrasound**. Ultrasound is used by bats for navigation and by doctors for looking at unborn babies.



This orchestra is creating a single longitudinal wave of very complicated shape. In ways that we barely understand, our brains can pick out the sounds of all the individual instruments that are playing together.

The ear is far more easily damaged than most people realise, and care needs to be taken both with the volume of sound and the length of time that the ear is exposed to it. The damage is cumulative, and so you don't notice it at first. Many older rock stars have serious hearing problems, and younger ones often wear ear plugs.

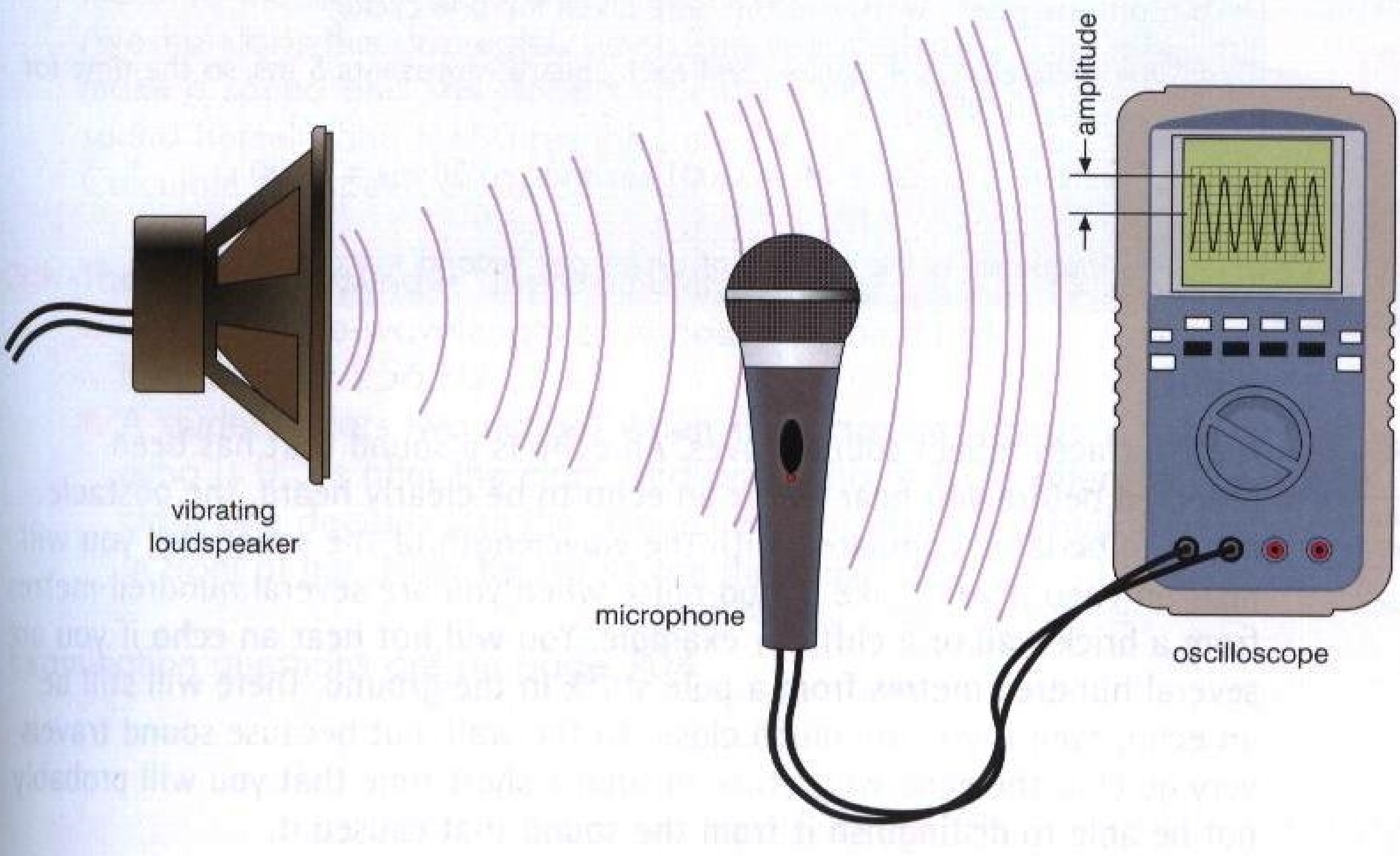
Loud sounds have high amplitude whereas quiet sounds have low amplitude. The unit in which we measure the loudness of sounds is the decibel (dB). Decibels are used to measure various electrical quantities as well, but when they are used for sound, 0 dB is defined to be the quietest sound that can be heard. This then makes a quiet room at night about 40 dB; a noisy classroom is 60 dB; the sound 1 m from a vacuum cleaner is 80 dB; a loud disco could be 100 dB, which would be illegal in many countries; sounds of 120 dB are extremely painful; and windows break at 160 dB.

The ears start to be damaged at 85 dB, a level that some personal players can reach without difficulty.

Sound waves can be displayed on an oscilloscope by using a microphone. This produces a voltage-time graph on the oscilloscope.

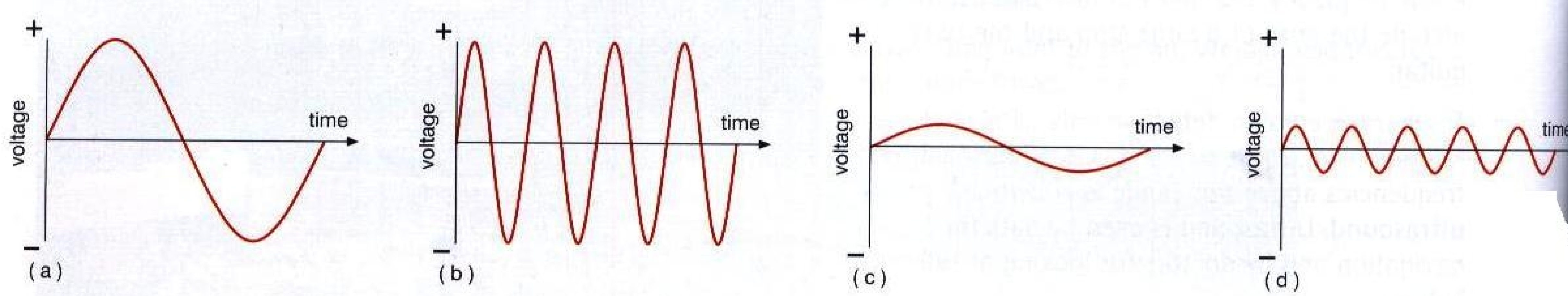
A* EXTRA

- The speed of sound in water is about 1500 m/s, and in hard metals and wood it is about 5000 m/s.



Typical results are shown on the graphs below.

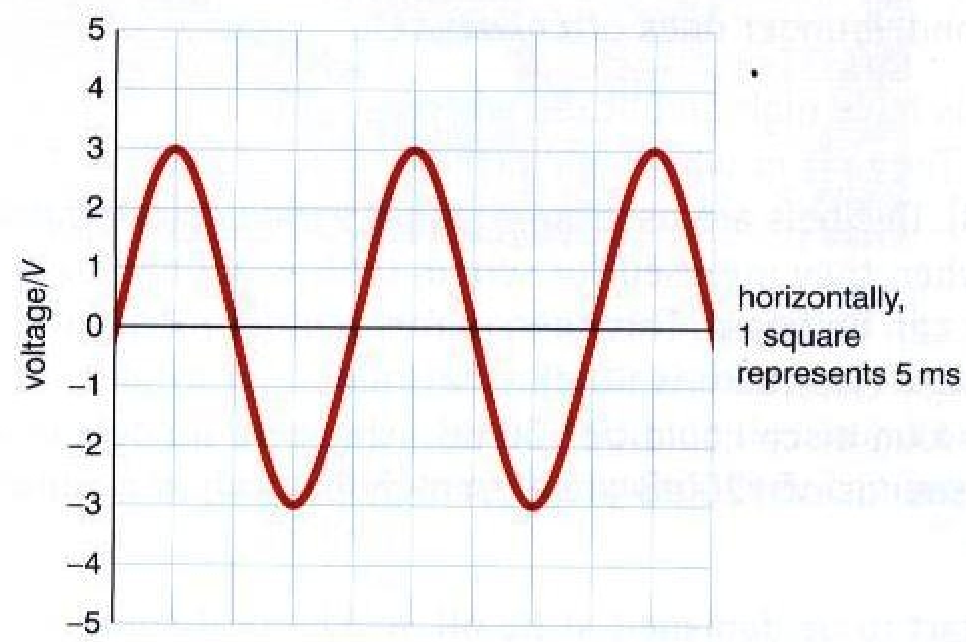
(a) A loud sound of low frequency
(b) A loud sound of high frequency
(c) A quiet sound of low frequency
(d) A quiet sound of high frequency.



WORKED EXAMPLE

Using this displacement–time graph for a sound wave, calculate:

a the amplitude of the sound
b the frequency of the sound.



a The amplitude is the maximum displacement from the mean position, so can be read straight from the graph.

Amplitude = 3 mm.

b From the graph, work out the time taken for one cycle:

One cycle covers 4 squares and each square represents 5 ms, so the time for one cycle is 20 ms.

Convert to seconds: 1 ms = 0.001 seconds, so 20 ms = 0.020 s

The frequency is the number of cycles per second $= \frac{1}{0.020} = 50$ Hz.

ECHOES

Hard surfaces reflect sound waves. An echo is a sound that has been reflected before you hear it. For an echo to be clearly heard, the obstacle needs to be large compared with the wavelength of the sound. So, you will hear an echo if you make a loud noise when you are several hundred metres from a brick wall or a cliff, for example. You will not hear an echo if you are several hundred metres from a pole stuck in the ground. There will still be an echo, even if you are much closer to the wall, but because sound travels very quickly, the echo will return in such a short time that you will probably not be able to distinguish it from the sound that caused it.

Measuring the speed of sound by an echo method

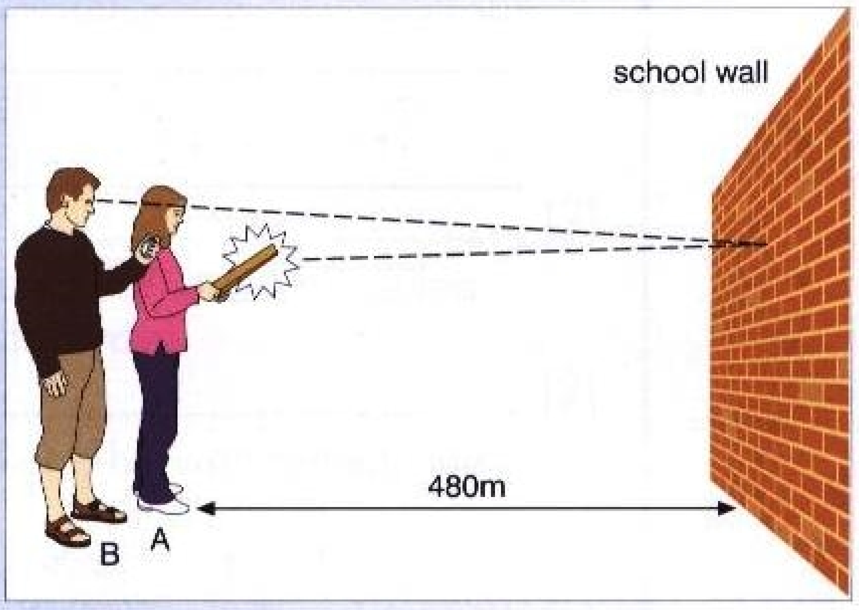
The following worked example illustrates how echoes may be used to measure the speed of sound.

WORKED EXAMPLE

Two students stand side by side at a distance of 480 m from the school wall. Student A has two flat pieces of wood, which make a loud sound when clapped together. Student B has a stopwatch.

As student A claps the boards together, student B starts the stopwatch. When student B hears the echo, he stops the stopwatch. The time recorded on the stopwatch is 2.9 s.

Calculate the speed of sound.



Write down the formula: $\text{speed of sound} = \dfrac{\text{distance travelled}}{\text{time taken}}$

Work out the distance: distance to wall and back $= 2 \times 480$

$= 960$ m

Record the time the sound took to travel there and back: time $= 2.9$ s

Substitute in the formula: speed of sound $= \dfrac{960}{2.9}$

$= 331$ m/s

See if you can think of some things which might be done to improve the accuracy of this experiment.

REVIEW QUESTIONS

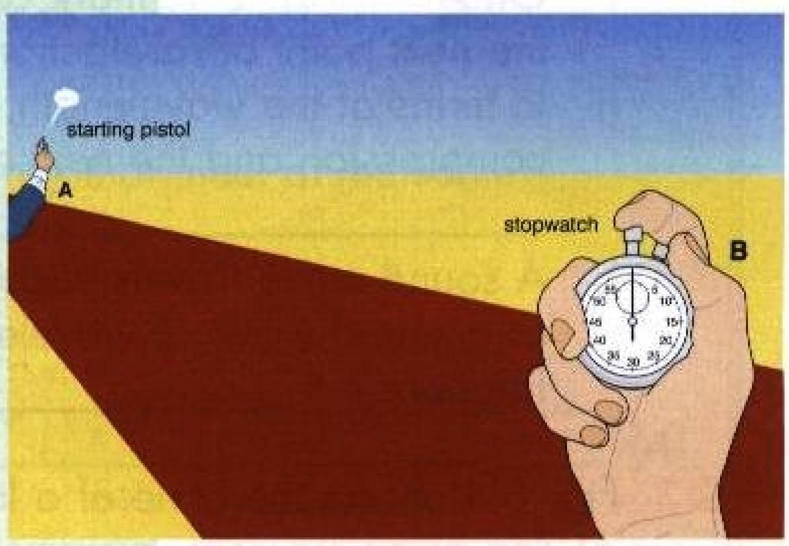
Q1 **a** i What causes a sound?

ii Explain how sound travels through the air.

b Astronauts in space cannot talk directly to each other. They have to speak to each other by radio. Explain why this is so.

c If a marching band is approaching you, explain why you can hear the bass drum long before you can hear the piccolo playing the highest notes.

Q2 Ayesha and Salma are doing an experiment to measure the speed of sound. They stand 150 m apart. Ayesha starts the stopwatch when she sees Salma make a sound and she stops it when she hears the sound herself. She measures the time as 0.44 seconds. Calculate the speed of sound in air from this data.



Q3 The speed of sound is approximately 340 m/s.

a Calculate the wavelength of middle C, which has a frequency of 256 Hz.

b A student hears two echoes when she claps her hands. One echo is 0.5 s after the clap, and one echo is 1.0 s after the clap. She decides that the two echoes are from two buildings in front of her. How far apart are the buildings?

More questions on the CD ROM

Examination questions are on page 104.