

3.3 Sound

KEY IDEAS

- ✓ Sound waves are produced by vibrating objects
- ✓ The faster the vibrations, the higher the frequency and hence the higher the pitch of the vibrations
- ✓ The greater the amplitude of the vibrations, the louder the sound
- ✓ Sound waves are longitudinal, producing a series of compressions and rarefactions in the medium
- ✓ Sound waves cannot travel through a vacuum. They travel faster through denser media
- ✓ Oscillations in the ear allow us to hear sounds in a range from 20 Hz to 20 kHz

Vibrating objects such as this tuning fork vibrate the molecules in the air and form a series of **compressions** (higher pressure than normal where the air molecules are close together) and **rarefactions** (lower pressure than normal where the air molecules are far apart).

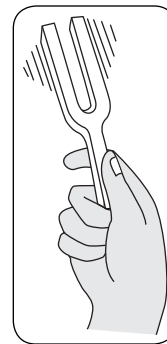
The faster the tuning fork vibrates, the higher the **frequency** of the sound wave and hence the higher the **pitch**. If the tuning fork vibrates with greater **amplitude**, the sound is **louder**.

Sound waves in air are **longitudinal**. We hear sound when sound waves cause our ear drums to vibrate. We can hear a range of frequencies from about 20 Hz to 20 kHz. As we get older, this upper limit of 20 kHz gets lower.

Sound waves cannot travel through a vacuum. They must be transmitted through the vibrations of particles in a medium. The closer together the particles in the medium, the faster the sound waves travel. So sound travels faster in solids than in the air.

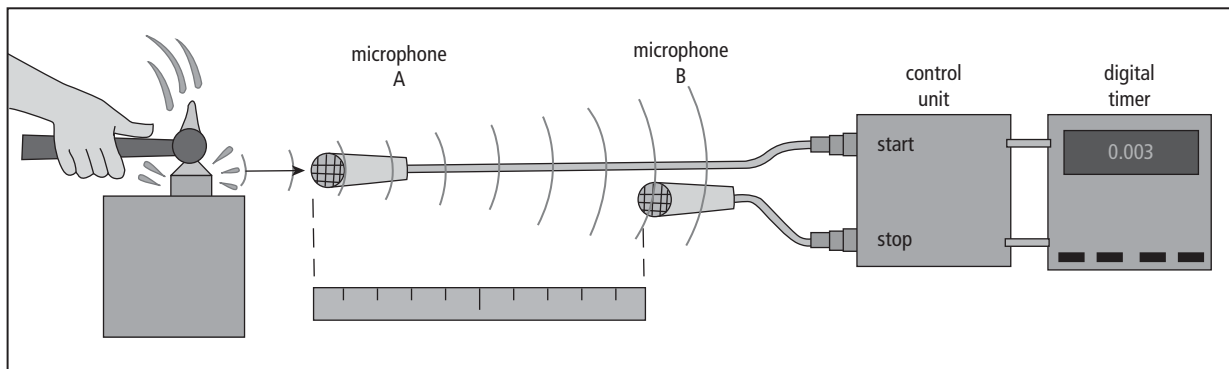
For example:

	air	water	metal
slowest	→ fastest		
	330 m/s	1500 m/s	5000 m/s



▲ Tuning fork

An experiment to find the speed of sound in air



When the hammer hits the metal plate, microphone A receives the sound wave almost instantaneously. The sound travels a distance of 1.0 m (measured with a ruler) before it reaches microphone B. The digital timer starts when the sound wave reaches microphone A and stops when the sound wave reaches microphone B. The experiment is repeated several times and an average time found. The speed can then be found:

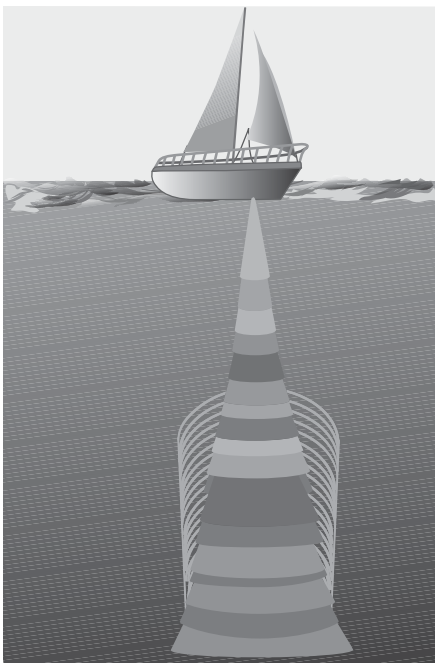
$$\begin{aligned} \text{speed} &= \frac{\text{distance}}{\text{average time}} \\ &= \frac{1.0}{0.003} \\ &= 330 \text{ m/s} \end{aligned}$$

Echoes

Sound waves obey the same laws of reflection as light waves. Sound waves reflect from any surface. A reflected sound wave is called an echo.

Sonar is a method of measuring distances with sound. If a sound wave is sent from a boat and reflects off the sea-bed, it will be received a short time later. The depth of the sea-bed can then be calculated. Ultrasound images are built up in the same way.

For example:



time between sending the sound wave and receiving the echo = 0.20 s

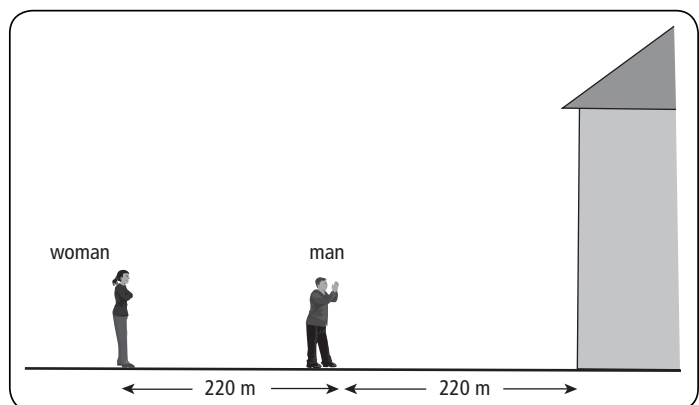
speed of sound in water = 1500 m/s

distance to the sea-bed = $\frac{0.20 \times 1500}{2} = 150 \text{ m}$

($\div 2$ since 0.20 s is the time to travel to the sea-bed **and back**)

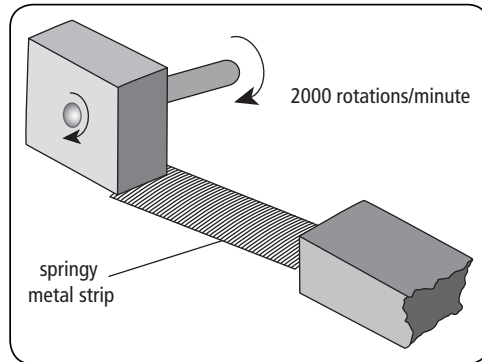
Examination style questions

1. The speed of sound in air is 330 m/s. A man stands 220 m from a flat wall as shown below and claps his hands once.
 - a. Calculate the time interval between the time when the man claps his hands and when he hears the echo.
 - b. A woman is standing 220 m further away from the wall than the man. She hears the clap twice, once directly and once after reflection from the wall. How long after the man claps does she hear these two sounds?



Adapted from CIE 0625 June '05 Paper 2 Q9

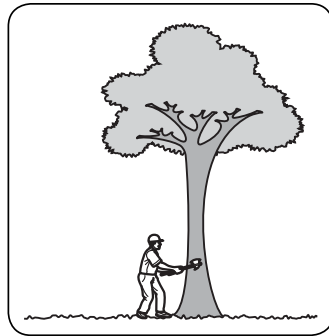
2. A square wooden block is made to rotate 2000 times per minute. A springy metal strip presses against the block, as shown in the diagram. A person nearby observes what is happening.



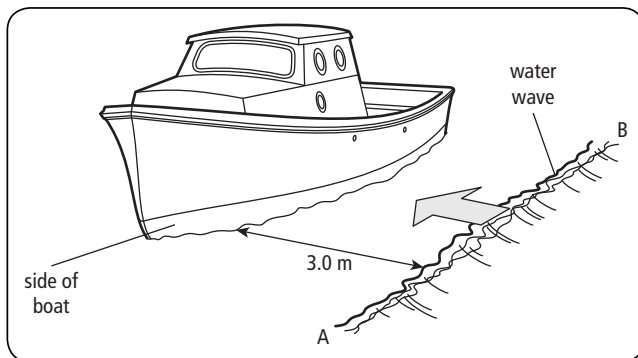
- Calculate how many times per second the block rotates.
- Calculate the frequency of the sound caused by this arrangement.
- State whether or not this sound could be heard by the person nearby, and give a reason for your answer.

CIE 0625 June '07 Paper 2 Q8

3. A man is using an axe to chop down a tree, as shown below.



- A short time after the axe hits the tree, the man hears a clear echo. He estimates that the echo is heard 3 seconds after the axe hits the tree.
 - Suggest what type of obstacle might have caused such a clear echo.
 - The speed of sound in air is 320 m/s. Calculate the distance of the obstacle from the tree.
- A branch from the tree falls into some shallow water in a pond nearby. The branch sets up a wave. The wave moves to the left a distance of 3.0m before hitting the side of a moored boat and reflecting back again.



The wave takes 5.0 s to travel from AB to the boat and back to AB. Calculate the speed of the water-wave.

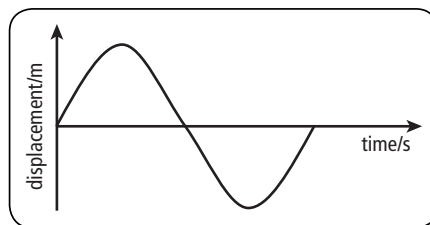
CIE 0625 November '06 Paper 2 Q7

Summary questions on unit 3

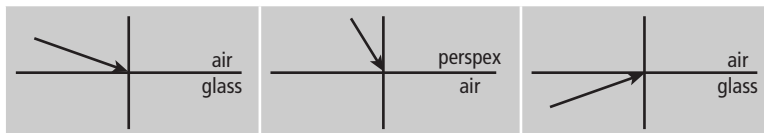
1. Fill in the blanks

There are two type of wave: _____ and _____. In a _____ wave the oscillations are perpendicular to the direction of travel of the _____. In a _____ wave the _____ are _____ to the direction of travel. The _____ of a wave is the distance between adjacent points on the wave that are at the same stage in their oscillation. The _____ of a wave is the time for one complete wave. The frequency is the number of _____ passing a point each _____. Velocity (or speed), frequency and wavelength are related by the equation _____. When waves meet a barrier, they bounce off. This is called _____. When waves speed up or slow down the change direction. This is called _____. When waves pass through a gap in a barrier, they spread out. This is called _____.

2. Mark amplitude and wavelength on the diagram below.



3. Complete the following diagrams to show the reflected and refracted rays.



4. In each of the following cases, draw a diagram to show the incident, refracted and reflected rays and the normal to the boundary. Calculate the angle of **refraction** and state the angle of **reflection** in each case. The refractive index for air to glass is 1.5. The refractive index for glass to air is 0.67.

- Light incident at an angle of 56° to the normal in air on a glass surface.
- Light incident in glass on an air/ glass boundary at an angle of 35° to the normal.
- Light incident in glass at an angle of 60° to the normal at an air/glass boundary.

What is different about part c?

5. Match the terms on the right with the correct definition from the left hand column.

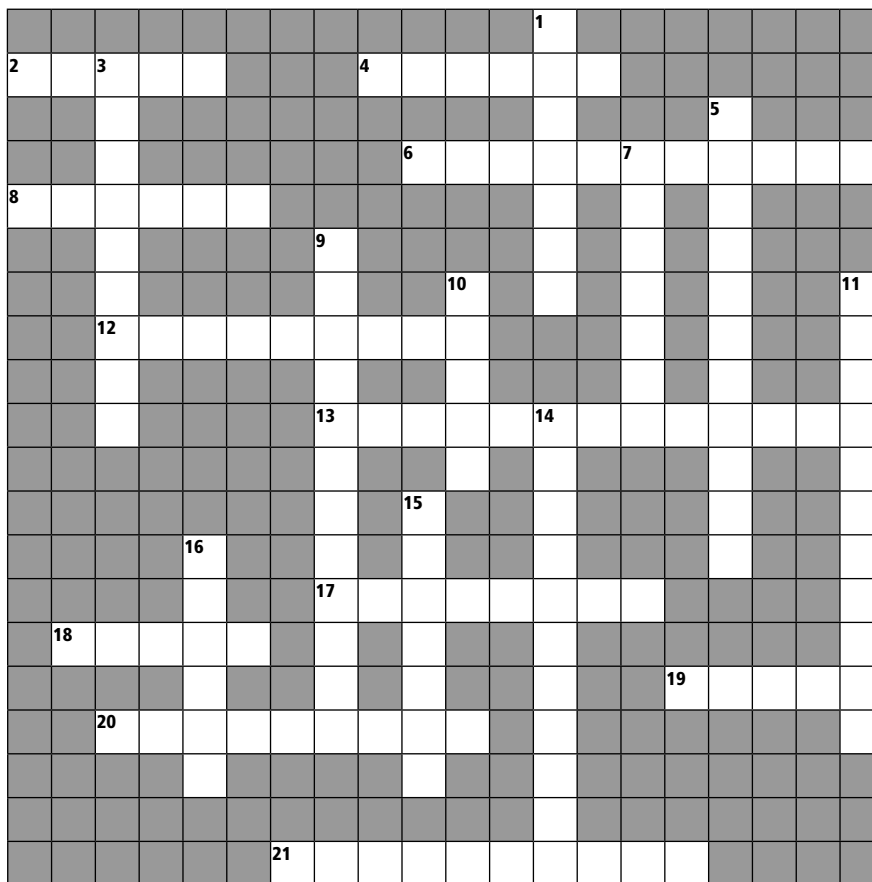
Ratio of speed of light in air to speed in material	Diffraction
Wave spreading out as it passes through a gap	Refractive index
Wave changing direction as its speed changes	Dispersion
Light bouncing off a smooth surface	Reflection
White light splitting into a spectrum as it is deviated by a prism.	Refraction

6. On graph paper, draw the following ray diagrams to scale:
- An object of height 2 cm at a distance of 5 cm from a convex lens of focal length 3 cm.
 - An object of height 3 cm at a distance of 5.5 cm from a convex lens of focal length 2.5 cm.
 - An object of height 2 cm at a distance of 2 cm from a convex lens of focal length 3 cm.

In each case, state a possible use for the arrangement.

7. a. What is the wavelength in air of electromagnetic radiation of frequency 1.0×10^{16} Hz? Which region of the spectrum does this belong to?
- b. What is the frequency of the electromagnetic radiation which has a wavelength of 0.1 m in air? Which region of the spectrum does this belong to?
- c. What is the wavelength in air of electromagnetic radiation of frequency 1.0×10^{20} Hz? Which region of the spectrum does this belong to?

8. Crossword

**Across:**

- 2 Region of the electromagnetic spectrum that has the highest energy (5)
 4 The colour in the visible spectrum that is deviated the most by a prism (6)
 6 Region between visible and X-rays in the electromagnetic spectrum (5-6)
 8 Perpendicular to a boundary between two media (6)
 12 The distance between the mid position of a particle on a wave and its maximum displacement. (9)
 13 Angle of incidence when the angle of refraction is 90° (8, 5)
 17 Region of the electromagnetic spectrum with longer wavelengths than visible light (5-3)
 18 This type of wave cannot travel in a vacuum (5)
 19 Region of the electromagnetic spectrum with the longest wavelength (5)
 20 20 to 20 000 is the _____ range that the human ear can hear. (9)
 21 Speed = frequency x _____ (10)

Down:

- 1 Water waves do this when they pass from deep to shallow water (7)
 3 Electromagnetic radiation used to cook food quickly (9)
 5 Distance between the centre of a lens and its principal focus (5,6)
 7 An image that cannot be focused on a screen (7)
 9 Carries information by total internal reflection of light (7, 5)
 10 The unit of frequency (5)
 11 Region of a sound wave where the pressure is lowest (11)
 14 Region of a sound wave where the pressure is highest (11)
 15 Sound waves do this when they hit a hard smooth surface (7)
 16 Lens that is thicker in the middle than the edges (6)

9. Explain what is meant by dispersion.

10. Draw a diagram to show what happens to water waves, produced by a straight vibrating rod, when they are incident on a gap in a barrier.

11. A sound wave travels at 330 m/s in air with a wavelength of 0.1 m. What is its frequency? The wave enters water and the wavelength changes to 0.45 m. What is the speed of the sound wave in water?

12. A sound wave travels through a 2 m long metal rod in 0.42 ms. What is the speed of the wave?