TOPIC 15 Sound

Objectives

Candidates should be able to:

(a) describe the production of sound by vibrating sources
(b) describe the longitudinal nature of sound waves in terms of the processes of compression and rarefaction
(c) explain that a medium is required in order to transmit sound waves and the speed of sound differs in air, liquids and solids
(d) describe a direct method for the determination of the speed of sound in air and make the necessary calculation
(e) relate loudness of a sound wave to its amplitude and pitch to its frequency
(f) describe how the reflection of sound may produce an echo, and how this may be used for measuring distances
(g) define ultrasound and describe one use of ultrasound, e.g. quality control and pre-natal scanning

NOTES

15.1 Production of Sound Waves

1. Sound waves are produced when objects vibrate in a medium.

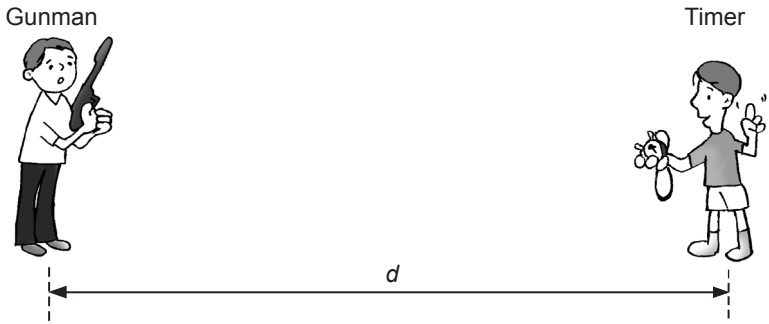
2. Sound waves are longitudinal waves which require a medium for propagation.

15.2 Medium of Propagation for Sound

1. When sound waves travel in different media, the speed differs.
   Speed of sound in solids > speed of sound in liquids > speed of sound in air.

2. In solids, the atoms are more closely packed together, as compared to liquids and gases. Hence, sound travels the fastest in solids.

15.3 Determining the Speed of Sound



1. To determine the speed of sound, a gunman and a timer can stand apart from each other in an open field at a known distance d.

2. The gunman will fire a pistol into the air. The timer will start his stopwatch upon seeing the flash of the pistol and stop the stopwatch when he hears the sound of the pistol. The time interval is recorded as Δt.

3. The speed of sound is calculated as:

$$v = \frac{d}{\Delta t}$$

4. The speed of sound in air is about 330 m/s. Since the human reaction time is about $\frac{2}{3}$ of a second, d has to be sufficiently large for the experiment to be accurate.

Example 15.1

In a storm, an observer saw a lightning flash, followed by the sound of thunder 4.0 seconds later. Given that the speed of sound in air is approximately 330 m/s, find the observer's distance from where the lightning occurred.

Solution

The lightning flash, which the observer sees, is assumed to reach him immediately after the lightning occurs (speed of light = 3.0×10^8 m/s).
Let the distance of the observer from the lightning be d.

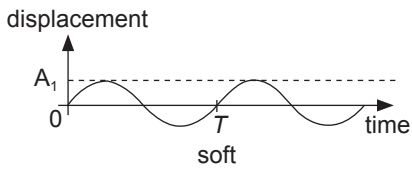
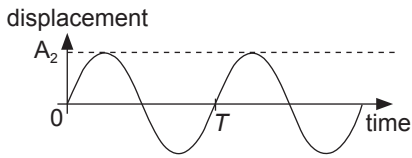
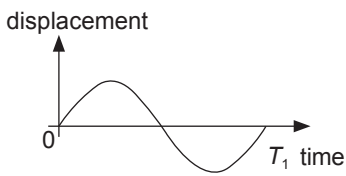
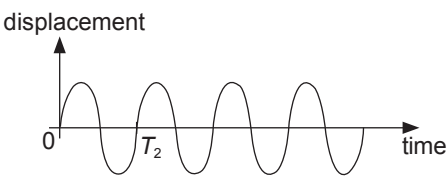
$\Delta t = 4.0$ s

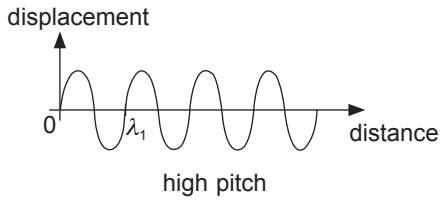
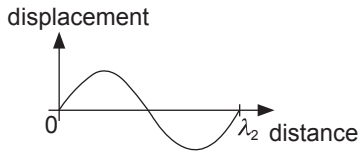
$$330 = \frac{d}{\Delta t} = \frac{d}{4}$$

$d = 1320$ m

15.4 Characteristics of Sound

1. The following table shows the main characteristics of sound and the factors affecting these characteristics:

Characteristics	Factors
Loudness	Amplitude of a sound wave (a higher amplitude leads to a louder sound)  soft  loud Note: amplitude $A_1 < A_2$
Pitch	Wavelength of a sound wave (a shorter wavelength leads to a higher pitch) Frequency of a sound wave (a higher frequency leads to a higher pitch) From the equation, $v = f\lambda$, since v is constant, we observe that when the wavelength, λ, decreases, the frequency, f, increases. As such, a shorter wavelength leads to a higher frequency which leads to a higher pitch.  low pitch  high pitch

Characteristics	Factors
	Note: $T_1 > T_2$ From the equation, $T = \frac{1}{f}$, we observe that when the period, T, increases, the frequency, f, decreases. As such, a longer period leads to a lower frequency which leads to a lower pitch.  high pitch  low pitch Note: $\lambda_1 < \lambda_2$

15.5 Echoes

1. Echoes are produced when a sound wave is reflected from a surface.
2. The reflected sound (echo) can be heard separately from the original sound if the source of the sound is much closer to the observer than to the reflecting surface.
3. To reduce the effect of echoes in buildings, walls are roughened up with padding and the floors are covered with rugs or carpets. This is to scatter the incident sound wave so that the reflected sound is reduced.
4. Using echo to measure distance.

Example 15.2

A man stood in front of a tall cliff. He fired a pistol into the air and started his stopwatch simultaneously. After 3.0 s, he heard the echo of the pistol shot. Given that the speed of sound is 330 m/s, find his distance from the cliff.

Solution

Let distance of man from cliff be d.

$2d = 330 \times 3.0$

$d = 495$ m

(We used $2d$ because 3.0 s is the time taken for the sound to hit the cliff and be reflected back to the man.)

15.6 Ultrasound

1. Ultrasound is the sound with frequencies that are greater than 20 000 Hz.
2. The audible range of sound for humans is between 20 Hz and 20 000 Hz. Hence humans cannot hear ultrasound.
3. Some applications of ultrasound:
   (a) Pre-natal scan to check the development of babies in womb.
   (b) Used by ships to find depth of seabed.
   (c) Check for cracks in metal pipes that are too small for the naked eye to see.