12 STUDY OF SOUND

CHAPTER OUTLINE

12.1 Nature of sound
12.2 Production and propagation of sound
12.3 Velocity of sound
12.4 Audible, infrasound and ultrasound
12.5 Reflection of sound
12.6 Echo
12.7 Reverberation
12.8 SONAR
12.9 Sonography
12.10 Human ear

KEY CONCEPTS

- **Sound :** Sound is a form of energy which produces the sensation of hearing in our ears.
- **Production of sound :** Sound is produced due to vibrations of an object such as a stretched membrane or a string under tension.
- **Longitudinal waves :** Sound waves are created by a chain of compressions (place of higher density) and rarefactions (place of lower density) in the medium.
- **Transverse waves :** The particle oscillations are perpendicular to the direction of propagation of the wave, such waves are called transverse waves.

CAN YOU RECALL? (Textbook page 128)

(1) How does the velocity of sound depend on its frequency ?

(2) How is the direction of the oscillation of the particles of the medium related to the direction of propagation of the soundwave ?

Ans. (Can you recall?)

(1) The velocity of sound does not depend on its frequency.

(2) Sound is a form of energy that produces the sensation of hearing in our ears. This energy is in the form of waves. A medium is necessary for the propagation of sound waves. Sound waves are a chain of compressions (regions of higher density) and rarefactions (regions of lower density) in the medium. The particles of the medium oscillate about their central (mean) positions in a direction parallel to the propagation of the wave. Such waves are called longitudinal waves.

3 Waves

- A wave is a disturbance moving through a medium when the particles of the medium set neighbouring particles in motion.
- A wave transmits energy through the medium without transporting the medium itself.
- A wave in which the particles of the medium oscillate (vibrate) about their mean positions in a direction perpendicular to the direction of wave propagation is called a transverse wave.
- A wave in which the particles of the medium oscillate (vibrate) about their mean positions in a direction parallel to the direction of wave propagation is called a longitudinal wave.
- The particles do not move from one part to another part of the medium.

4 Propagation of Sound

- Sound requires a medium for propagation, i.e., it cannot travel through a vacuum.
- Sound propagates in the form of longitudinal waves.
- As sound propagates through a medium, there is a change in the density and pressure of the medium.
- Compressions are regions of highest pressure as well as highest density and rarefactions are regions of lowest pressure as well as lowest density.

5 Velocity of Sound

(1) Take your friend to a place where there are iron pipes e.g. the school verandah, a staircase or a fence.

Activity : Exploring Sound through a Pipe

(2) Stand near one end of the pipe and ask the friend to stand 20 feet to 25 feet away from you near the pipe.

(3) Ask the friend to gently tap the pipe with a stone. Press your ear to the pipe and listen to the sound coming through the pipe.

(4) The same sound coming through the air can also be heard. But which sound reaches you first?

Observation : The sound coming through the pipe reaches first. (This shows that the speed of sound in iron is greater than that in air.)

6. A Historical Note

The Italian physicists Borelli and Viviani, in the 1660s, first calculated the speed of sound. They measured the time between seeing the flash of a gun and hearing its sound from a long distance. Their value of 350 m/s is very close to the value of 346 m/s which is accepted today.

7. Characteristics of Sound Waves

The following are the important characteristics of sound waves :

(1) Wavelength (λ) : The distance between two successive compressions or two successive rarefactions is called the wavelength (λ).

(2) SI and CGS units : Its SI unit is the metre (m) and CGS unit is the centimetre (cm).

(3) Vibration : One oscillation (vibration) corresponds to a change of density of the medium from the maximum to the minimum value and again to the maximum value. The number of oscillations (vibrations) per unit time is called the frequency (ν) of the wave.

(4) Units of frequency and time period :

- SI unit of frequency : hertz (Hz).
- Time taken by consecutive compressions or rarefactions to cross a fixed point is called the time period (T) of the wave.
- SI unit of time period : second (s).
- CGS unit of time period : second.

(5) Relation between frequency and period : The relation between frequency and period is

$$\nu = \frac{1}{T}$$

(6) Amplitude (A) : The magnitude of the maximum disturbance in the medium on either side of the mean value is called the amplitude (A) of the wave.

(7) Unit of amplitude : In the case of a sound wave, the unit of amplitude is that of density or pressure.

(8) Intensity : The amount of sound energy passing per unit time through unit area is called the intensity of sound.

8. Speed of Sound

The distance which a point on a wave, such as a compression or a rarefaction, travels per unit time is called the speed (v) of sound.

$$v = \frac{\lambda}{T} = \nu\lambda$$

It is almost the same for all frequencies in a given medium under the same physical conditions. It depends on the medium and increases with temperature.

The higher the frequency of sound the higher is the pitch. It depends upon how the brain interprets the frequency of sound. Loudness of sound depends on the physiological perception of intensity of sound and increases with intensity. The quality or timber of sound is the characteristic of sound that enables us to distinguish one sound from another having the same pitch and loudness.

9. Range of Hearing in Humans

The range of hearing in humans is from 20 Hz to 20000 Hz.

10. Infrasound and Ultrasound

The sound of frequency less than 20 Hz is called infrasound and that of frequency more than 20000 Hz is called ultrasound. We cannot hear infrasound and ultrasound.

Ultrasounds are used : (1) to establish ship to ship communication (2) for welding plastic surfaces (3) to kill bacteria in liquids like milk to preserve them (4) in echocardiography (5) for imaging internal organs of the human body (sonography) (6) in industry to clean parts of a machine (7) to detect cracks and flaws in metal blocks.

11. Reflection of Sound

Sound waves follow the same laws of reflection as followed by light waves. The directions in which sound is incident and reflected make equal angles with the normal to the reflecting surface at the point of incidence and the three are in the same plane.

12. Echo and Reverberation

Repetition of original sound due to reflection from a surface is called echo. The sensation of sound persisting in our ears for a short time due to repeated reflections of sound is called reverberation.

? Question Bank

(1) How many oscillations are completed in 6 s by a vibrating body of frequency 3 Hz?

Ans. Number of oscillations $= n = \nu t = 3 \times 6 = 18$.

(2) What is the distance between two consecutive rarefactions of a sound wave of frequency 740 Hz traveling in air with a speed of 360 m/s?

Ans. The distance between two consecutive rarefactions is the wavelength (λ).

$$\lambda = \frac{v}{\nu} = \frac{360}{740} \approx 0.486 \text{ m} \approx 48.6 \text{ cm}.$$

12.1 Persistence of Sound (Echo)

A sound produced at a source remains in our brain for about 0.1 second. The speed of sound in air at 22 °C is 344 m/s. Hence, for hearing a distinct echo, the minimum distance of the reflecting surface from the source of sound must be 17.2 m at 22 °C. The persistence of sound due to repeated reflection of sound in a large hall or an auditorium is called reverberation.

12.12 SONAR

SONAR (Sound Navigation And Ranging) is the technique used to determine the distance and location of underwater objects by means of ultrasonic waves.

12.13 The Human Ear

The human ear converts changes in air pressure associated with an audible frequency into electrical signals that travel to the brain through the auditory nerve. Hence, we can hear sound.

12.14 Speed of Sound in a Gas

The speed of sound in a gas is

$$v = \sqrt{\frac{p}{\rho}} = \sqrt{\frac{RT}{M}}.$$

Research (Textbook page 128)

(1) How are the frequencies of notes *sa, re, ga, ma, pa, dha, ni* related to each other?

Ans. Standard tuning : *sa* (सा) 440 Hz, *re* (रे) about 494 Hz, *ga* (गा) about 554 Hz, *ma* (म) about 587 Hz, *pa* (प) about 659 Hz, *dha* (ध) about 740 Hz, *ni* (नी) about 831 Hz, *sa* (octave, तार सा) 880 Hz.

Frequency ratio : *re* : *sa* about 1.12, *ga* : *re* about 1.12, *sa* (octave) : *sa* = 2.

(2) What is the main difference between the frequencies of the voice of a man and that of a woman?

Ans. The voice of a man has higher pitch (higher frequency) than that of a woman.

Science in the Surroundings (Textbook page 132)

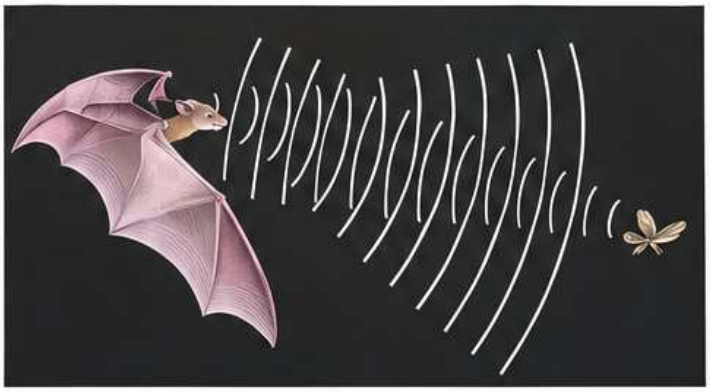
Echo can be heard multiple times due to continuous or multiple reflections. The Golghumat at Vijapur in Karnataka is an excellent example of this.



A Peep into the Past (Textbook page 130)

The Italian scientist Spallanzani was the first to discover a special mechanism present in bats. He covered various organs of bats like the eyes, ears, nose, etc. one by one and allowed them to fly in the dark, thereby discovering how they can fly easily in the dark. He found that the bats with their ears covered began to collide with whatever came in their path. Even though their eyes were open, they were of no use to the bats. He thus discovered that their ability to fly in the dark depends on their ears and not eyes.

The ultrasonic sound produced by bats gets reflected on hitting an obstacle. This reflected sound is received by their ears and they can locate the obstacle and estimate its distance even in the dark.



QUESTIONS & ANSWERS

Q. 1 Fill in the blanks with appropriate words and write the completed statements :

(1) Sound waves need ..... medium for propagation.

(2) Sound produced by vibrations of a simple pendulum is ..... sound.

(3) The pitch of a sound depends upon ..... of the wave.

(4) Technique of echocardiography is based on the reflecting property of ..... waves.

(5) For determination of the depth of the sea ..... technique is used.

(6) The SI unit of frequency is the ..... .

(7) Sound of frequency greater than 20 kHz is called ..... .

(8) In ..... waves, the particles of the medium vibrate perpendicular to the direction of wave propagation.

(9) Sound waves are ..... in nature.

Ans. (1) material (2) inaudible (3) frequency (4) ultrasonic (5) SONAR (6) hertz (7) ultrasound (8) transverse (9) longitudinal

Q. 2 Choose the correct alternative and write it along with its alloted alphabet :

(1) Which of the following is the requirement for regular reflection of sound ?

(a) Smooth surface (b) Rough surface
(c) Vacuum (d) Transparent rough surface

(2) What can you say about the planes in which the incident and reflected sound waves lie ?

(a) Planes perpendicular to each other
(b) The same plane
(c) Planes parallel to each other
(d) Two different planes

Ans. (1) (a) Smooth surface (2) (b) The same plane

Q. 4 State whether the following statements are True or False :

(1) Wave speed, $v = \lambda T$.

(2) If a sound has frequency greater than 20000 Hz, it is ultrasound.

(3) Ultrasound has frequency less than 20 Hz.

(4) SONAR technique can be used to locate a submarine.

(5) Ultrasonic waves are used to kill bacteria in fluids like milk.

(6) The speed of sound in water is less than that in air.

(7) The speed of sound in a solid is greater than that in a liquid.

Q. 3 Fill in the blanks and explain :

(1) Sound does not travel through ..... .

(2) The velocity of sound in steel is ..... than the velocity of sound in water.

(3) The incidence of ..... in daily life shows that the velocity of sound is less than the velocity of light.

(4) To discover a sunken ship or objects deep inside the sea ..... technology is used.

Ans. (1) vacuum (2) greater (3) thunder (4) SONAR

Explanation : (for explanation, see the answer to the question on how this technique is used [Q. 8 (2)]).

Note : Students should write whether the given statement is true or false. There is no need to correct a false statement and rewrite it.

Other Important Questions

(3) What is the measure of the angle made by the reflected sound with the reflecting surface when the angle of incidence is 30° ?

(a) 0° (b) 30° (c) 90° (d) 60°

Ans. (b) 30°

(5) A wave speed, $v = \lambda T$.

Ans. (1) True

(6) If a sound has frequency greater than 20000 Hz.

Ans. (2) True

(7) Ultrasound has frequency less than 20 Hz.

Ans. (3) False

(8) SONAR technique can be used to locate a submarine.

Ans. (4) True

(9) Ultrasonic waves are used to kill bacteria in fluids like milk.

Ans. (5) True

(10) The speed of sound in water is less than that in air.

Ans. (6) False

(11) The speed of sound in a solid is greater than that in a liquid.

Ans. (7) True

Key Concepts at a Glance

- Sound waves are longitudinal in nature.
- The SI unit of frequency is hertz (Hz).
- Frequency > 20 kHz → ultrasound.
- Ultrasound is used in medical imaging (e.g., echocardiography) and in SONAR.
- SONAR helps to determine the depth of the sea and to locate submerged objects.

Q. 7 Answer the following questions :

(1) What is sound?

Ans. Sound is a form of energy that produces sensation of hearing in our ears.

(2) What is vibration? Give one example.

Ans. Vibration is a rapid, to and fro motion of an object about its mean position.

Example : When a string is clamped between two supports and plucked at the centre, it performs to-and-fro motion. To what extent the motion is rapid depends upon a number of factors such as the length and mass of the string, and the tension in the string.

Key Concepts : Waves and Sound

(3) (i) What is a wave?

Ans. A wave is a disturbance moving through a medium when the particles of the medium set neighbouring particles in motion.

(ii) What is a wave motion?

Ans. A wave motion is a mode of transmission of energy. The particles of the medium vibrate about their mean position but do not move from one place to another part of the medium.

(4) How is sound produced? How does it propagate? Can it travel through a vacuum?

Ans. Sound is produced when an object vibrates. It propagates in the form of waves. It requires a medium (substance in the form of solid/liquid/gas) for propagation, i.e., it cannot travel through a vacuum.

Nature and Types of Sound

(5) Loudness is a measure of the response of the ear to the sound.

(6) Infrasound is produced before earthquakes by vibrations of the earth's surface.

(7) A hard and flat surface is a good reflector of sound.

(8) Clothes, curtains are bad reflectors of sound.

(9) True **(10)** True **(11)** False **(12)** False

(13) False **(14)** True **(15)** True

Activity and Observation

(Board's specimen activity sheet)

Sound waves, Waves on the surface of water, Waves on a stretched string, Light waves.

Ans. (1) Metal Sheet, Paper, clothes and mat are bad reflectors of sound.

(2) Light waves do not need a medium for their propagation. In other cases, a medium is needed.

Q. 5 Find the odd one out and give the reason.

Paper, Clothes, Mat, Metal sheet.

Ans. Metal sheet.

Reason : Paper, clothes and mat are good absorbers of sound whereas a metal sheet is a good reflector of sound.

Q. 6 Match the following :

Column 'A'	Column 'B'
(a) Frequency less than 20 Hz	(d) 2000 Hz
(b) Frequency greater than 20000 Hz	(c) Frequency range : 20 Hz – 20000 Hz
(c) Frequency range : 20000 Hz	(b) Frequency greater than 20000 Hz
(d) Frequency range : 10 Hz – 2000 Hz	(a) Frequency less than 20 Hz

Ans. (1) Infrasound – Frequency less than 20 Hz

(2) Ultrasound – Frequency greater than 20000 Hz

Key terms and Definitions

Infrasound	Sound waves having frequency less than 20 Hz.
Ultrasound	Sound waves having frequency greater than 20000 Hz.

Q. 8 Answer the following questions :

(1) Mention a few sources of sound.

Ans. (i) A tuning fork, (ii) a musical instrument (e.g., flute, drum), (iii) human voice, (iv) loudspeaker, (v) moving vehicles, etc.

(2) Name the vibrations from which sound is produced.

Ans. The to-and-fro (back-and-forth) motions of the particles of the medium produce sound.

(3) Why do we not hear the sound of light waves?

Ans. Light waves do not create any disturbance in a medium. Hence, they do not produce sound.

(4) Why is a bad reflector of sound a good absorber of sound?

Ans. A surface that reflects sound poorly absorbs most of the incident sound energy. Thus, bad reflectors are good absorbers of sound.

(5) What is the frequency of infrasound?

Ans. The frequency of infrasound is less than 20 Hz.

(6) What is the frequency of ultrasound?

Ans. The frequency of ultrasound is greater than 20000 Hz.

(7) What is the range of audible sound (sound that can be heard by human ears)?

Ans. 20 Hz to 20000 Hz.

Numerical Information from the Text

- Frequency of infrasound : < 20 Hz
- Frequency of ultrasound : > 20000 Hz
- Range of audible sound : 20 Hz – 20000 Hz
- Low-frequency sound (given) : 10 Hz – 2000 Hz

Diagram : Changes in Pressure in a Sound Wave

Figure 12.1 shows the changes in density while a sound wave moves through a medium. The changes in density or pressure are shown in the form of a graph in Figure C.

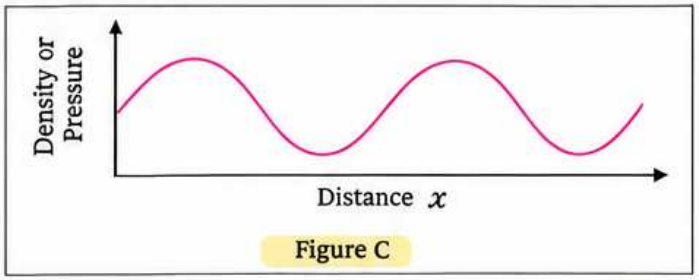


Figure C

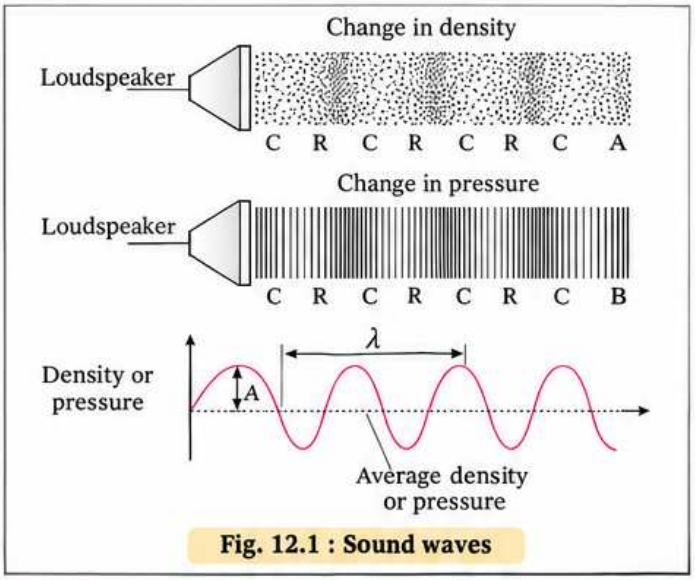


Fig. 12.1 : Sound waves

1. Wave Description and Basic Relations

Here, λ (wavelength), A (amplitude; maximum pressure or maximum density) and T (time period) are for one oscillation of pressure or density at a point in the medium. The frequency ν is the number of oscillations per unit time.

The loudness of sound determines the pitch, and A decides the loudness.

(5) Define the following (in brief):

(i) Compression **(ii)** Rarefaction **(iii)** Wavelength
(iv) Frequency **(v)** Time period **(vi)** Amplitude
(vii) Speed of sound **(viii)** Intensity of sound

Ans. **(i) Compression :** A region of higher density and higher pressure in a longitudinal wave is called a compression.

(ii) Rarefaction : A region of lower pressure and lower density in a medium is called a rarefaction.

(iii) Wavelength (λ) : The distance between two successive compressions or two successive rarefactions is the wavelength.

(iv) Frequency (ν) : The number of oscillations (vibrations) per unit time is the frequency.

(v) Time period (T) : The time taken for one complete oscillation (vibration) is the time period.

(vi) Amplitude of a wave (A) : The magnitude of the maximum disturbance (maximum change in pressure or density) from the mean value is the amplitude.

(vii) Speed of sound (v) : The distance covered by the wave on a wave, such as a compression (highest density) or a rarefaction (lowest density), per unit time is the speed of sound.

(viii) Intensity of sound : The amount of sound energy transferred per unit time through unit area is the intensity of sound.

2. Other Important Definitions

(iii) Wavelength (λ) : The distance between two consecutive compressions or rarefactions is called wavelength.

(iv) One oscillation : One complete compression or vibration corresponds to a change of density (or pressure) of the medium from its maximum value to the minimum value and again to the maximum value. ***OR*** One complete vibration of the medium is called one oscillation.

The period (T) is the time for one oscillation of pressure or density at a point in the medium.

OR

The time period of an oscillating (vibrating) particle is also called the time period of the wave.

(v) Frequency (ν) : The number of oscillations (vibrations) per unit time is the frequency of the wave.

(vi) Time period (T) : The time taken by consecutive compressions or rarefactions to cross a fixed point is called the time period of the wave.

2. Characteristics of Sound Waves

(6) Which type of waves are sound waves? State their characteristics.

Ans. Sound waves are longitudinal waves propagating through a medium (solid, liquid or gas).

The characteristics of sound waves are wavelength, frequency, time period, pitch, amplitude, intensity, loudness, quality (or timbre).

For reference, see the answer to Q. 7 (5).

3. Quality or Timbre of Sound

The quality or timbre of sound is the characteristic of sound that enables us to distinguish one sound from another having the same pitch and loudness.

4. Relations among Wave Quantities

If v = speed of sound, λ = wavelength and ν = frequency, then

$$v = \lambda\nu$$

Here, ν determines the pitch and A determines the loudness of sound.

Oscillation or vibration is a complete to-and-fro motion of the oscillating (vibrating) particle.

(v) Frequency (ν) : The number of oscillations (vibrations) per unit time is called the frequency of the oscillatory motion or the frequency of the wave.

(vi) Time period (T) : The time taken by consecutive compressions or rarefactions to cross a fixed point is called the time period of the wave.

The time period and frequency of sound are related by

$$T = \frac{1}{\nu} \quad \text{or} \quad \nu = \frac{1}{T}.$$

The quality of sound, the higher is its frequency, the higher is the pitch. It depends upon how the brain interprets the frequency of sound.

The loudness of sound depends on the perceived intensity of sound and increases with the amplitude of vibrations.

SI Units, Frequency and Vibration

(7) What are the SI units of wavelength and frequency?

Ans. The SI unit of wavelength is the metre (m) and that of frequency is the hertz (Hz).

(8) The frequency of vibration of a string is 100 Hz. What do you understand by this statement?

Ans. The string completes 100 vibrations per second.

Time Period and Frequency

(9) What is the relation between the frequency and the time period? If the frequency is 100 Hz, what is the time period?

Ans. The frequency (ν) and time period (T) are related by

$$\nu = \frac{1}{T}$$

If $\nu = 100$ Hz, time period,

$$T = \frac{1}{\nu} = \frac{1}{100\ \text{Hz}} = 0.01\ \text{s}$$

(10) How are the speed, frequency, time period and wavelength of sound related?

Ans. Speed of sound (v) = frequency (ν) × wavelength (λ)

$$v = \nu\lambda$$

Various Relations and Factors

(11) State how the velocity (or speed) of sound in a gas depends upon various factors.

Ans. The velocity (or speed) of sound in a gas is directly proportional to the square root of the absolute temperature of the gas ($v \propto \sqrt{T}$) and inversely proportional to the square root of the molecular mass of the gas $\left(v \propto \frac{1}{\sqrt{M}}\right)$.

Note : The expression for the speed of sound in a gas is:

$$v = \sqrt{\frac{\gamma RT}{M}} \quad \text{(at constant temperature, } P \propto \rho\text{)}$$

where γ = ratio of specific heats for the gas,
R = universal gas constant,
M = molecular mass of the gas.

(12) The molecular weight of oxygen gas (O_2) is 32 while that of hydrogen gas (H_2) is 2. Prove that under the same physical conditions, the velocity of sound in hydrogen is four times that in oxygen. (*Think :* Textbook page 130)

Ans. $v = \sqrt{\frac{\gamma RT}{M}} \Rightarrow v \propto \frac{1}{\sqrt{M}}$

$$\therefore \frac{v_{H_2}}{v_{O_2}} = \sqrt{\frac{M_{O_2}}{M_{H_2}}} = \sqrt{\frac{32}{2}} = \sqrt{16} = 4.$$

Variation of Speed of Sound

(13) What can you say about variation of the speed of sound in air, under given physical conditions, with frequency?

Ans. The speed of sound in air under given physical conditions is almost the same for all frequencies.

(14) What can you say about variation of the speed of sound in air with temperature?

Ans. The speed of sound in air increases with increase in temperature.

(15) Arrange the following materials in order of decreasing speed of sound at a given temperature (say, 25 °C) : oxygen, glass, sea water, aluminium.

Ans. The materials arranged in order of decreasing speed of sound at 25 °C are: aluminium, glass, sea water, oxygen.

(16) What is the audible range of sound for human beings?

Ans. The audible range of sound for human beings is 20 Hz to 20000 Hz.

Note : Children under the age of five years and some animals like dog can hear sound up to a frequency of about 25000 Hz, whereas the upper limit of hearing decreases with age in the case of human beings.

(17) What do infrasound and ultrasound refer to?

Ans. Infrasound refers to sound of frequency less than 20 Hz and ultrasound refers to sound of frequency greater than 20000 Hz.

(18) Read the following sequence of events and answer the questions based on the same.

(Board's specimen activity sheet)

Ranjit saw that the dog sitting by his side had suddenly become alert. In a short time, Ranjit heard footsteps of a man and the stranger approached Ranjit. Ranjit now understood why the dog had suddenly become alert.

Activity

Board's Specimen Activity Sheet

(a) What physical condition is suggested by the dog's early alertness?

Ans. The dog can hear sound up to a frequency of about 25000 Hz.

(b) What inference can you draw from this event?

Ans. The audible range of the dog is higher than that of human beings.

(1) What is the difference between the audible range of sound for Ranjit and the dog?

Ans. Human beings can hear sound in the frequency range of 20 Hz to 20 000 Hz, whereas a dog can hear sounds of frequencies beyond this range (i.e., some higher and lower frequencies) which are not audible to humans.

(2) Name some other animals that can hear sound of frequency not audible to human beings.

Ans. Rat, bat and dolphin can hear sounds of frequencies beyond the human audible range.

(19) State one similarity and one difference regarding reflection of sound and light.

Ans. Similarity : Both sound and light obey the laws of reflection.

Difference : The major difference is in the size of the obstacle. For reflection of sound, the obstacle should be large in size compared to that required for reflection of light.

Reflection of Sound

- **Laws :** Reflection of sound follows the same laws as reflection of light.
- **Requirement :** A large surface (in comparison with the wavelength) is needed for reflection of sound.

Activity: Observing Reflection of Sound

(20) ***Try this.*** *(Textbook pages 131 to 132)*

(i) Make two sufficiently long, identical tubes (e.g., cardboard tubes).
(ii) Place a table in front of a wall as shown in Fig. 12.2.
(iii) Put a clock near the end of one tube and keep the other tube at the opposite end.
(iv) Listen to the ticking of the clock at the other end through the tube.
(v) Adjust the angle of incidence θ_1 and the angle of reflection θ_2.
(vi) Observe the ticking sound clearly through the tubes.
(vii) Measure the angles θ_1 and θ_2 to see if they are equal.
(viii) Repeat for other angles of incidence.

Question : What happens if you lift one of the tubes to some height?

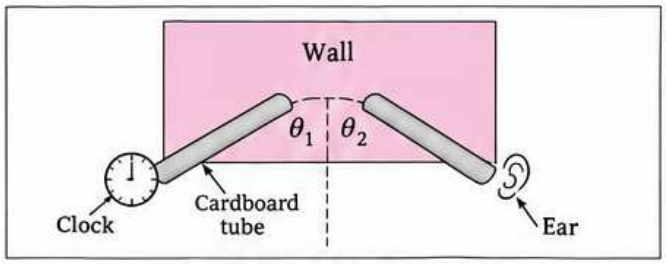


Fig. 12.2 : Reflection of sound

Echo

(21) Define echo.

Ans. Echo is the repetition of original sound due to reflection from some surface.

(22) Find the speed of sound in air at 22 °C, hearing distinct echo in terms of the distance between the source of sound and obstacle.

Ans. The sensation of sound lasts in our brain for about 0.1 s. The distance covered by sound in this time = speed of sound × time = 344 m/s × 0.1 s = 34.4 m.
Total distance (source to obstacle and back),
34.4 m = 2 × distance between the source and obstacle.
∴ Distance between the source and obstacle $= \frac{34.4\text{ m}}{2} = 17.2\text{ m}$.

(23) What is an echo? What factors are important to get a distinct echo?

Ans. An echo is a sound heard again due to its reflection from a distant obstacle.

For a distinct echo, the source and obstacle should be sufficiently far apart so that the reflected sound reaches the ear after 0.1 s or more.

(24) Study the construction of the Golghumat at Vijaypur and discuss the reasons for the multiple echoes produced there.

Ans. This question is essentially a project.

(25) What should be the dimensions and the shape of classrooms so that no echo can be produced there?

Ans. The distance between the opposite walls, and also the height of the ceiling, should be less than 17.2 m.

Numerical Example

(3) For sound of frequency 680 Hz, the wavelength at room temperature is about one metre. For red light of frequency 4.2×10^{14} Hz, its wavelength at room temperature is about 6.38×10^{-7} m. It is far less than one metre.

Derived Relation

(4) Make the derivation of the relation between the speed of sound (v), frequency (ν) and wavelength (λ) of sound.

Ans. The distance covered by a wave in one second is its speed (v). In the same time, the wave completes ν oscillations. In one oscillation, the wave travels a distance equal to its wavelength (λ).

Therefore, speed of sound = number of oscillations × wavelength

$$v = \nu\,\lambda$$

(5) Measure the angle of incidence θ_1 and the angle of reflection θ_2. Try to see if they are related in any way.

Ans. In the experiment, we find that $\theta_1 = \theta_2$.

(6) What is the minimum distance between the source and obstacle for hearing distinct echo in the present case?

Ans. This gives the minimum distance between the source and obstacle for hearing distinct echo in the present case.

Important Terms

- **Audible range :** For human beings, 20 Hz to 20 000 Hz.
- **Reflection of sound :** The bouncing back of sound from a surface.
- **Echo :** Repetition of the original sound due to reflection.
- **Distinct echo :** An echo heard separately, obtained when the reflected sound reaches the ear after 0.1 s or more.
- **Minimum distance (for distinct echo) :** 17.2 m (at 22 °C, with speed of sound 344 m/s).
- **Relation between speed, frequency and wavelength :**

$$v = \nu\,\lambda$$

(26) Where and why are sound absorbing materials used?

Ans. Sound absorbing materials are used in auditorium, cinema halls, etc. to avoid production of echo.

(27) To hear the echo distinctly, will the distance from the source of sound to the reflecting surface be same at all temperatures?

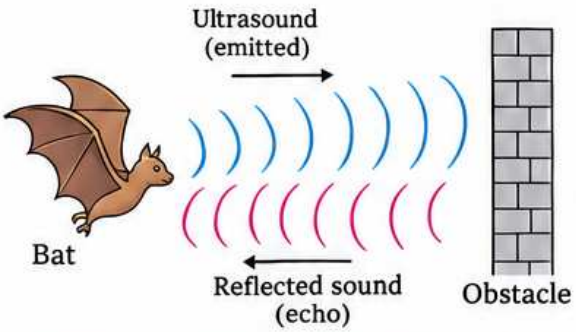
Ans. No. The speed of sound in air is directly proportional to the square root of the absolute temperature of air. Hence, the minimum distance between the source of sound and the reflecting surface, for echo to be heard clearly, will be more at higher temperature.

(28) When is the reflection of sound harmful?

Ans. When the loudness of sound is very high (Use your brain power! **Textbook page 132**)

(29) Explain how a bat can find its way in the dark.

Ans. While flying, a bat produces ultrasound (ultrasonic waves). These waves strike obstacles in their path and are reflected. The bat can use echoes to detect the obstacles and hence avoid collisions with them. Thus, a bat can find its way even in the dark.



(30) Why can we not hear echo produced in our classroom?

Ans. (i) To hear distinct echo, the minimum distance between the source of sound and obstacle should be 17.2 m (assuming room temperature 22 °C).

(ii) This condition is not satisfied in our classroom as the ceiling is not so high and the distance between the opposite walls is usually less than 17.2 m. Hence, we cannot hear echo produced in the classroom.

(31) Sometimes reflections of sound may be undesirable. Can you give some example?

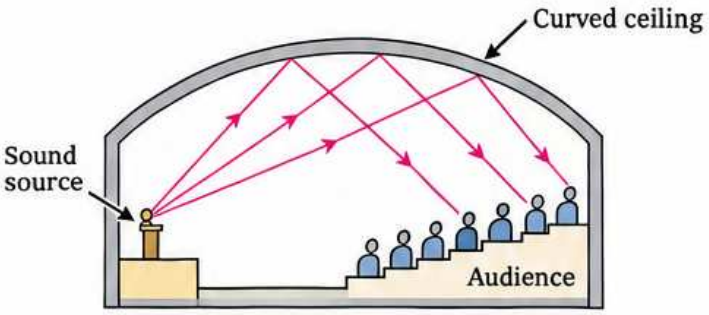
Ans. If an auditorium (or a big hall) is not designed properly, multiple reflections of sound may occur. Due to these the speech made by a speaker or music played by an orchestra cannot be heard clearly or may become unpleasant to hear. In such cases multiple reflections of sound are undesirable.

(32) What is reverberation?

Ans. The persistence of sound due to repeated reflection of sound in a big hall or an auditorium is called reverberation.

(33) Why are ceilings of concert halls and cinema halls curved?

Ans. Ceilings of concert halls and cinema halls are curved to avoid undesirable reverberation. Otherwise, pitch of music will not be heard distinctly.



(34) Close all doors and windows of a room. Play a radio or music system with maximum possible volume. What do you experience?

Ans. Under the conditions stated in the question, the sound produced by the radio or the music system becomes unbearable due to increased loudness and multiple reflections of sound within the room.

(35) Compare the two cases.

Ans. (i) Go to an empty, closed house with your friends. (ii) Once inside, chat with your friends. (iii) Repeat what you experience.

(Textbook pages 132)

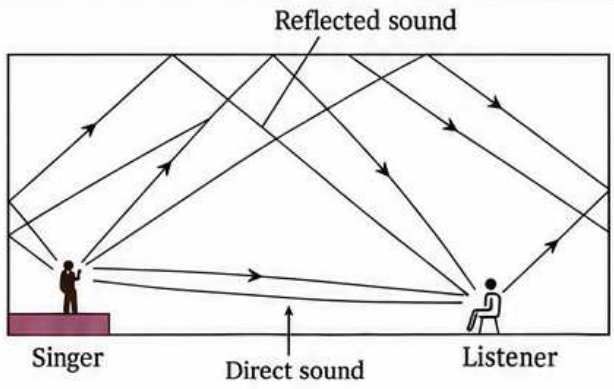
(Board's specimen activity sheet)

(1) Close the doors and windows of your house and switch on the music system.

OR

(2) Increase the loudness of the system as much as possible. (3) Note what you sense.

Fig. 12.3 : Reverberation



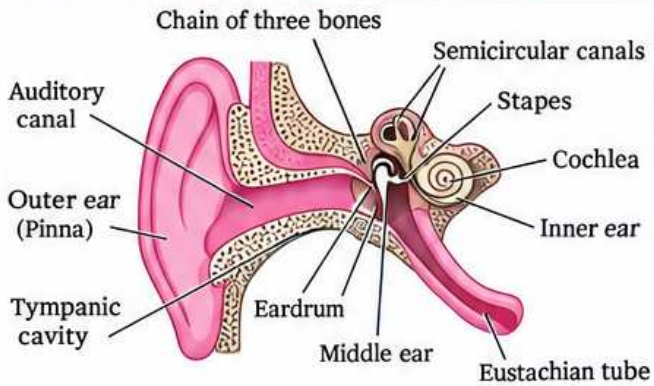
(36) How will you reduce reverberation in public halls or buildings?

(Use your brain power! Textbook page 133)

Ans. See the answer to *Q. 7* (25).

(37) With a neat labelled diagram, explain the structure and working of the human ear.

Fig. 12.4 : Structure of the human ear



Ans. **Outer ear or Pinna :** It collects the sound waves which then pass through a tube to a cavity in the middle ear.

Middle ear : There is a thin membrane called the eardrum in the cavity of the middle ear. When a compression reaches the eardrum, the pressure outside it increases and it gets pushed inwards. When a rarefaction reaches the eardrum the pressure outside decreases and the membrane gets pulled outwards. Thus, sound waves produce vibrations of the membrane.

Inner ear : The auditory nerve connects the inner ear to the brain. The inner ear has a structure called the cochlea resembling the shell of a snail. It receives the vibrations from the membrane and converts them into electrical signals. The signals are sent to the brain through the nerve. The brain analyses these signals and interprets them as sound. The loudness depends upon the intensity of the incident sound.

The ear is an important sensory organ. Sticks or other pointed objects should never be inserted into the ear for cleaning it. Also, one should not hear very loud music using earphones. It may cause grave injury to the eardrum.

(38) How is ultrasound used in medical science?

(Find out. Textbook page 134)

Ans. See the note on sonography *Q. 8* (4).

Q. 8 Write short notes on :

(1) Ultrasound.

Ans. Sound with frequency greater than 20000 Hz is called ultrasound. We cannot hear ultrasound. Ultrasound is produced by bats, rats, dolphins, etc. Ultrasounds are used (i) to establish ship to ship communication (ii) for welding plastic surfaces (iii) to kill bacteria in liquids like milk to preserve them (iv) in echocardiography (v) for imaging internal organs of the human body (vi) in industry to clean parts of a machine (vii) to detect cracks and flaws in metal blocks.

(2) SONAR.

Ans. **SONAR** (Sound navigation and ranging) : It is a technique used to determine the distance and location of underwater objects such as submarine, icebergs, etc., using ultrasonic waves. It can be used to determine the depth of the sea. For this a transmitter and a detector are installed in a ship (Fig. 12.5).

The transmitter produces and transmits ultrasonic waves which travel through water towards the bottom of the sea. On reflection at the sea bed, the waves are received by the detector which converts them into electrical signals. If t is the time recorded

$$\text{depth } d = \frac{vt}{2}$$

where, v = velocity of sound in water (m s^{-1}),
t = time taken (s).

(4) Sonography

Ans. In this case, ultrasounds (ultrasonic waves) are used to produce images of internal organs of the human body. A gel is applied to the skin outside the internal organ to be examined. The gel provides proper contact between the skin and the organ to transmit ultrasounds inside the body. The waves reflected from the internal organ are collected by a probe and fed to a computer. The computer produces the images of the organs. This method is painless. It is used in determining the cause of swelling, infection, pain, the condition of the heart, the growth of the foetus inside the womb of a pregnant woman, etc.

Fig. 12.6 : Sonography Machine and Images Obtained



Sonography machine | Examination procedure | Image obtained

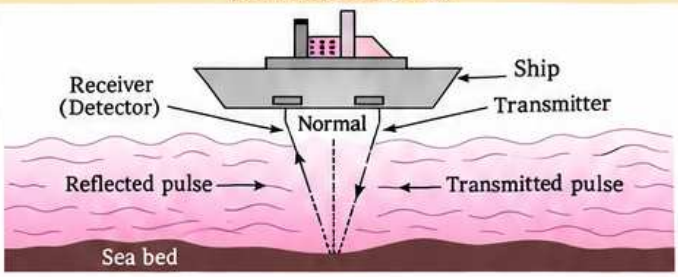
Developments and Applications

Developments in science have led to advances in technology which have helped us make much progress. However, every coin has two sides and the misuse of science has had serious consequences for human life. The sonography technique can help to follow the growth and well-being of an unborn baby. But the increasing incidence of female foeticide as a result of the discrimination between the girl and the boy child is an example of the grave misuse of this technique. Female foeticide is now a cognizable offence under the PNDT Act.

The SONAR Technology

The SONAR (Sound Navigation And Ranging) technology was first developed during World War I to detect enemy submarines. This technology can be used in air also. In fact, bats use this technique to detect obstacles in their path so that they can avoid them and fly freely even in the dark.

Fig. 12.5 : Determination of the Depth of the Sea (schematic diagram)



(3) Reverberation

Ans. The persistence of sound due to repeated reflection of sound in a big hall or an auditorium is called reverberation. In reverberation, the intensity of sound and the time interval between two successive arrivals of the same sound depend on the decreasing with time. Excessive reverberation is undesirable as the speech of a speaker or the pitch of music cannot be heard clearly due to the mixing of the reflected waves and direct waves produced after the production of earlier waves. To avoid this, reverberation should be reduced/controlled. For this, the roof and walls of the auditorium are covered with sound absorbent materials such as compressed fibreboards, rough plaster or curtains. Even the material of the seat is chosen such that it absorbs sound waves to the desired extent.

Facts to Remember

- Reverberation is the repeated reflection of sound in a large hall.
- It causes persistence of sound.
- It makes speech and music unclear if excessive.
- Control it using sound-absorbing materials (e.g. compressed fibreboards, rough plaster, curtains, absorbent seat material).

Question–Answer Bank

Q1 What is sonography? How is it useful?

Ans. Sonography uses ultrasonic waves to produce images of internal body organs. It is useful to determine the cause of swelling, infection, pain, check the condition of the heart, and to observe the growth of the foetus in the womb of a pregnant woman.

Q2 What is reverberation? How can it be reduced?

Ans. Reverberation is the continued (persistent) sound due to repeated reflection in a big hall or auditorium. It can be reduced by covering the roof and walls with sound absorbent materials such as compressed fibreboards, rough plaster or curtains and by using absorbent seats.

Q3 What is the SONAR technology? State its use.

Ans. The SONAR (Sound Navigation And Ranging) technology was first developed in World War I to detect enemy submarines. It can also be used in air. Bats use this technique to detect obstacles in their path in the dark.

Q4 Write a short note on the misuse of sonography.

Ans. The sonography technique helps to follow the growth and well-being of an unborn baby. However, it is misused in female foeticide due to discrimination between the girl and the boy child. Female foeticide is a cognizable offence under the PNDT Act.



Q. 9 Give scientific reasons :

*** (1) The roof of a movie theatre and a conference hall is curved.**

Ans. *See the answer to Q. 7 (39).*

*** (2) The intensity of reverberation is higher in a closed and empty house.**

Ans. In a closed and empty house, there is absorption of sound only by the floor, walls and the ceiling. Hence, the intensity of reverberation is higher.

*** (3) We cannot hear the echo produced in a classroom.**

Ans. *See the answer to Q. 7 (30).*

Q. 10 Solve the following examples (Numerical problems) :

(1) A sound wave passes over a fixed point in space. Ten compressions and ten rarefactions pass the point in 1 second. Find the frequency and time period of the wave.

Solution : Ten compressions and ten rarefactions pass the point in 0.1 second. It follows that in 1 second 100 compressions and 100 rarefactions will pass the point.

$\therefore$ The frequency of the wave, $\nu = 100$ Hz

$\nu = \frac{1}{T} \quad \therefore \quad T = \frac{1}{100}\ s = 0.01$ s

The time period of the wave, $T = 0.01$ s

---

(2) If the time period of a wave is 0.004 s, find the frequency of the wave.

Solution : **Data :** $T = 0.004$ s, $\nu = ?$

The frequency of the wave,

$\nu = \frac{1}{T} = \frac{1}{0.004\ s} = \frac{1000}{4}$ Hz $= 250$ Hz

---

(3) A sound wave having certain frequency travels with a speed of 336 m/s and wavelength 3 cm. Calculate the frequency. Will it be audible?

Solution : **Data :** $\nu = 336$ m/s, $\lambda = 3$ cm $= 0.03$ m, $\nu = ?$

The frequency of the wave,

frequency $= \frac{\text{speed}}{\text{wavelength}} = 336\ \text{m/s} \div 0.03\ \text{m} = 11200$ Hz

---

(4) A sound wave has frequency 320 Hz and wavelength 0.25 m. How much distance will it travel in 10 seconds?

Solution : **Data :** $\nu = 320$ Hz, $\lambda = 0.25$ m, $t = 10$ s, $s = ?$

$\nu = \nu\lambda \quad (\because \nu = \nu\lambda)$

$= 320\ \text{Hz} \times 0.25\ \text{m} \times 10\ \text{s}$

$= 800$ m

The wave will travel 800 m in 10 seconds.

---

(5) A source of sound has frequency 1000 Hz. If the speed of sound in air under certain conditions is 340 m/s, find the distance covered by sound when the source completes 100 vibrations.

[6) In the frequency of a sound wave is 340 Hz.

Solution : **Data :** $\nu = 1000$ Hz, $\nu = 340$ m/s, s (during 100 vibrations) $= ?$

The frequency of the source is 1000 Hz, i.e. the source completes 1000 vibrations in 1 s. Hence, the time (t) required to complete 100 vibrations $= \frac{100}{1000}$ s

$= 0.1$ s

$s = \nu t = 340\ \text{m/s} \times 0.1\ \text{s} = 34$ m

The distance covered by sound when the source completes 100 vibrations is 34 m.

---

(7) A gun is fired. The sound of the gunshot is not heard on a hill 0.8 km away. Find the minimum speed of sound in air for this.

Solution : **Data :** $s = 0.8$ km $= 800$ m, $t = 10$ s, $\nu = ?$

The minimum speed of sound in air,

$\nu = \frac{s}{t} = \frac{800\ \text{m}}{10\ \text{s}} = 80$ m/s

---

(8) A gun is fired. The time difference between the sound and the echo is 10 s. Find the distance between the gun and the cliff.

Solution : **Data :** $t = 10$ s, $\nu = 340$ m/s, d (gun–cliff) $= ?$

Time taken for the sound to travel from the gun to the cliff

$= \frac{t}{2} = \frac{10\ \text{s}}{2} = 5$ s

$s = \nu t$

$= 340\ \text{m/s} \times 5\ \text{s}$

$= 1700$ m

The distance between the gun and the cliff is 1700 m.

Q. 11 Formulae and Applications

(A) Use : $\nu = \nu\lambda$

For a given wave,

(i) $\nu = \frac{\nu}{\lambda} = \frac{336\ \text{m/s}}{0.03\ \text{m}} = 11200$ Hz

(ii) $\nu = \nu\lambda = 11200\ \text{Hz} \times 0.03\ \text{m}$

$= 336$ m/s

(B) Other useful relations :

- $\nu = \frac{1}{T}$
- $s = \nu t$

(6) Frequency from wavelength and speed

The frequency of sound = 400 Hz. The frequency of sound depends on the source, not on the medium.

Given: $\nu_{gas} = 400$ Hz, $\lambda = 0.9$ m

Find: The speed of sound in the gas.

Solution: The speed of sound in the gas,

$$v = \nu_{gas} = f\lambda = 400 \text{ Hz} \times 0.9 \text{ m}$$

$$v = 360 \text{ m/s}$$

(7) Wavelength of a sound wave in a gas

A sound wave has wavelength 0.86 m and speed 344 m/s in air. If its wavelength in a gas is 0.8 m, find the speed of sound in the gas.

Solution: **Data:** λ_1 (in air) = 0.86 m, v_1 (in air) = 344 m/s, λ_2 (in gas) = 0.8 m, v_2 (in the gas) = ?

Since the frequency of sound does not depend on the medium,

$$\frac{v_1}{\lambda_1} = \frac{v_2}{\lambda_2} \quad \therefore v_2 = \frac{v_1\lambda_2}{\lambda_1}$$

$$v_2 = \frac{344 \text{ m/s} \times 0.8 \text{ m}}{0.86 \text{ m}}$$

$$v_2 = 320 \text{ m/s}$$

(8) Distance from echo (cliff)

A person standing before a cliff shouts and hears the echo after 1.6 s. Find the distance between the person and the cliff. (Speed of sound in air = 340 m/s)

Solution: **Data:** Total time = 1.6 s

Time for sound to reach the cliff (t)

$$t = \frac{1.6 \text{ s}}{2} = 0.8 \text{ s}$$

$$s = vt = 340 \text{ m/s} \times 0.8 \text{ s} = 272 \text{ m}$$

(9) Distance between person and cliff from echo time

A person standing between two hills fired a gun and heard the first echo after 0.5 s and the second echo after 0.9 s. Find the distance between the two hills. (Speed of sound in air = 340 m/s)

Solution: The distance between the person and the first hill,

$$s_1 = vt_1 = 340 \text{ m/s} \times 0.5 \text{ s} = 170 \text{ m}$$

The distance between the person and the second hill,

$$s_2 = vt_2 = 340 \text{ m/s} \times 0.9 \text{ s} = 306 \text{ m}$$

Distance between the two hills $= s_1 + s_2$

$$= 170 \text{ m} + 306 \text{ m} = \mathbf{476 \text{ m}}$$

(10) Distance from lightning and thunder

Nita heard the sound of lightning after 4 seconds of seeing it. What was the distance of the lightning from her? (The velocity of sound in air is 340 m/s.)

Solution: **Data:** $t = 4$ s, v (sound) = 340 m/s

The speed of light in air is about 3×10^8 m/s.

This is far greater than v (sound) in air.

Hence, the required distance,

$$s = vt = 340 \text{ m/s} \times 4 \text{ s} = 1360 \text{ m}$$

(11) Distance between two walls from echoes

Sunil is standing between two walls. The wall closest to him is at a distance of 660 m. If he hears the first echo after 4 s and another after 2 seconds,

(1) What is the velocity of sound in air?

(2) What is the distance between the two walls?

Solution:

(1) Velocity of sound in air,

$$v = \frac{s}{t} = \frac{660 \text{ m}}{\left(\frac{4 \text{ s}}{2}\right)} = \frac{660 \text{ m}}{2 \text{ s}}$$

$$v = 330 \text{ m/s}$$

(2) Distance between the two walls,

$$s = vt = 330 \text{ m/s} \times 2 \text{ s} = 660 \text{ m}$$

Conclusion: *For reference, see the solved Ex. (8).*

(12) Hydrogen gas in identical bottles

Hydrogen gas is filled in two identical bottles, A and B, at the same temperature. The mass of hydrogen in the two bottles is 12 g and 48 g respectively. In which bottle will sound travel faster? How many times as fast as the other?

Solution: As the bottles are identical and have the same temperature, the speed of sound in a gas depends only on the mass of the gas (ρ). Thus,

$$v \propto \frac{1}{\sqrt{\rho}}$$

Given: $m_A = 12$ g, $m_B = 48$ g

For identical bottles, volume (V) is the same.

$$\rho_A = \frac{m_A}{V} = \frac{12}{V}, \qquad \rho_B = \frac{m_B}{V} = \frac{48}{V}$$

$$\frac{v_A}{v_B} = \sqrt{\frac{\rho_B}{\rho_A}} = \sqrt{\frac{48}{12}} = \sqrt{4} \qquad \frac{v_A}{v_B} = 2$$

Thus, sound will travel faster in bottle *A*, and it will be 2 times as fast as in bottle B.

Practice Numerical

(1) If sound has a frequency of 1000 Hz, its period is ___ s.

(2) The speed of sound in water is 11200 Hz and in air is 320 Hz. Hence, the ratio of their wavelengths will be ___.

(3) If the distance covered by sound in 0.85 s is 340 m, find its speed.

(4) When the speed of sound is 272 m/s, its wavelength is 0.85 m. Find its frequency.

(5) The time required for sound to reach a cliff is 2 s. If the speed of sound is 340 m/s, find the distance of the cliff.

Answers: (1) 0.001 s (2) 1 : 35 (3) 400 m/s (4) 320 Hz (5) 680 m

FORMULA & BASIC RESULT

$$v = \sqrt{\frac{\gamma RT}{M}}$$

v = Speed of sound in a gas
T = Absolute temperature (K)
γ = Ratio of specific heats of the gas
R = Universal gas constant
M = Molar mass of the gas

Solution: 'The speed of sound in a gas,

$v = \sqrt{\frac{\gamma RT}{M}}$ (in the usual notation)

Here, the temperature T is the same in the two cases. Hence, v will be the same.

---

(13) Helium gas is filled in two identical bottles A and B. The mass of the gas in the two bottles is 10 g and 40 g respectively. If the speed of sound is the same in both bottles, what conclusion will you draw?

Solution: *For reference, see the solved Ex. (12) above.*

$\therefore$ Same T will be the same.

---

(14) The speed of sound in air at 0 °C is 332 m/s. If it increases at the rate of 0.6 m/s per degree, what will be the temperature when the velocity has increased to 344 m/s?

Solution: The speed of sound at t °C =

$v = 332 + 0.6\,t$ [in m/s]

Hence, by the data,

$344 = 332 + 0.6\,t$

$\therefore\ t = \frac{344 - 332}{0.6} = \frac{12}{0.6} = 20$ °C

This gives the required temperature.

EXAMPLES (NUMERICAL PROBLEMS) FOR PRACTICE

1. A wave passes over a fixed point in space. If 20 compressions and 20 rarefactions pass the point in 0.1 s, find the frequency and time period of the wave. **(Ans.** 200 Hz, 5×10^{-3} s)

2. If the period of a sound wave is 2×10^{-3} s, find the frequency of the wave. **(Ans.** 500 Hz)

3. A sound wave of wavelength 4 cm travels with a speed of 360 m/s. Find its frequency. **(Ans.** 9000 Hz)

4. A sound wave of frequency 8000 Hz travels with a speed of 340 m/s in air. Find its wavelength. **(Ans.** 4.25×10^{-2} m)

5. A sound wave has frequency 400 Hz and wavelength 0.9 m. How much distance will it cover in 1.5 s? **(Ans.** 540 m)

6. A source of sound has frequency 2000 Hz. If the speed of sound in air is 340 m/s, find the distance covered by sound when the source completes 400 vibrations. **(Ans.** 68 m)

7. A sound wave has wavelength 0.87 m in air and 0.88 m in a gas. The speed of sound in air is 338 m/s. Find the frequency of sound and the speed of sound in the gas. **(Ans.** 400 Hz, 352 m/s)

8. A sound wave has wavelength 0.86 m and speed 344 m/s in air. If its wavelength in a gas is 0.82 m, find the speed of sound in the gas. **(Ans.** 328 m/s)

9. A person standing before a cliff shouts and hears the first echo after 1.9 s. Find the distance between the person and the cliff. (Speed of sound in air = 340 m/s) **(Ans.** 323 m)

10. A person standing between two hills fired a gun and heard the first echo after 0.6 s and the second echo after 1 s. Find the distance between the two hills. (Speed of sound in air = 340 m/s) **(Ans.** 272 m)

11. A soldier standing between two hills hears two echoes after firing the gun. The first echo is heard after 1.2 s and the second echo after 2.4 s. Find the separation between the two hills. (Speed of sound in air = 340 m/s) **(Ans.** 612 m)

12. The speed of sound in air at 0 °C is 332 m/s. Find the speed of sound in air at 10 °C. **(Ans.** 338 m/s)