UNIT

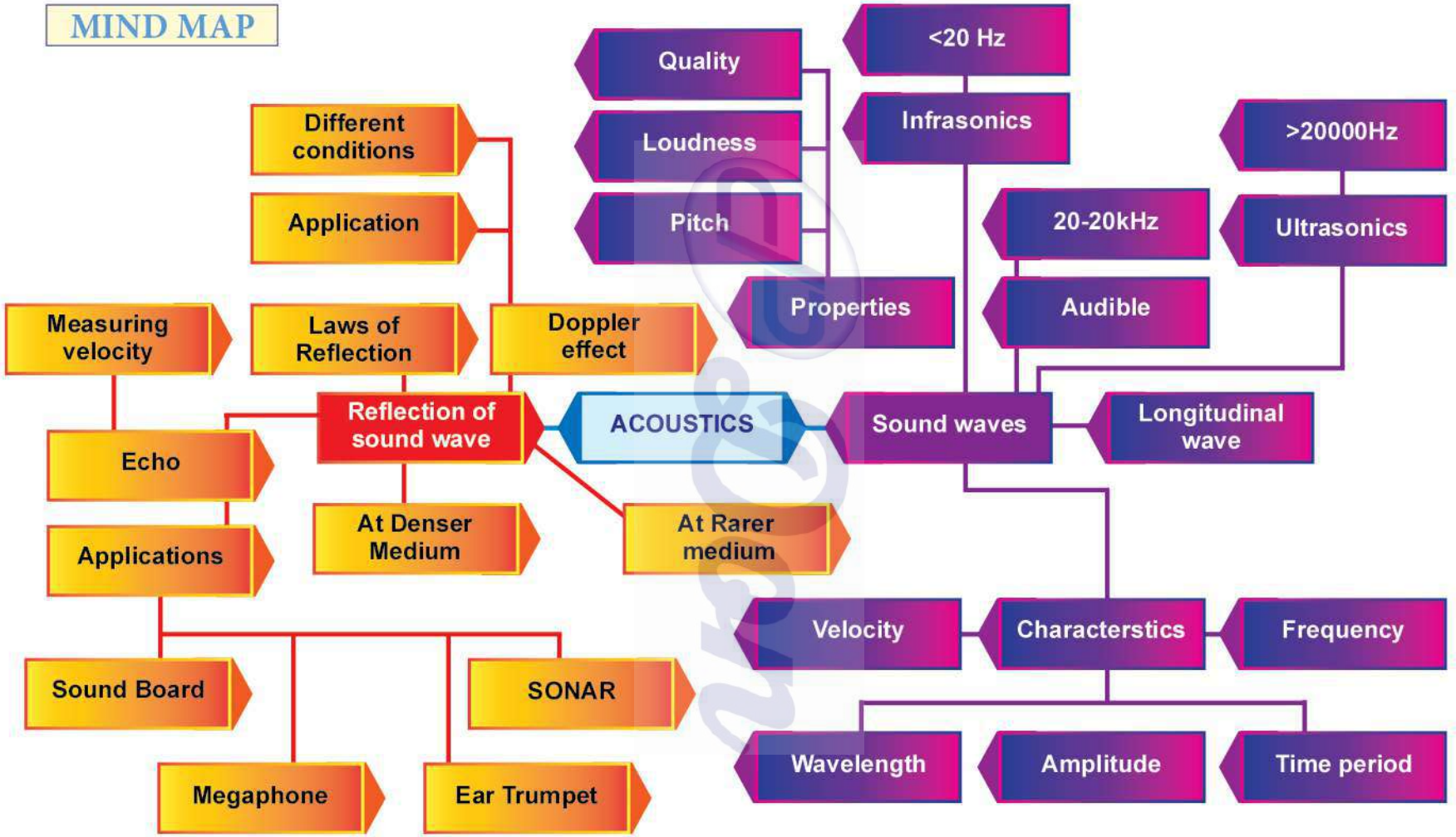
5

Acoustics

POINTS TO REMEMBER

- Time period is the time taken by a particle to complete one vibration in the medium.
- Frequency is the number of vibrations (waves) produced per second.
- Particle velocity is the velocity with which the particles of the medium vibrate in order to transfer energy in the form of a wave.
- Wave velocity is the velocity with which the wave travels through the medium.
- Pitch is the characteristic of a sound wave, which distinguishes a sharp sound from a dull sound. It depends upon the frequency of the wave.
- Loudness (L) is the sensation produced in the ear which enables us to distinguish between a loud and a soft sound.
- Quality is the sensation received by the ear by which, you are able to differentiate two sounds (even if they are of the same pitch and loudness).
- Doppler effect is defined as the frequency of the sound as received by a listener is different from the original frequency produced by the source whenever there is a relative motion between the source and the listener.
- Intensity of sound is defined as the power carried by sound waves per unit area in a direction perpendicular to that area. (or) Sound energy passing per second through an unit area held perpendicular.
- Any vibrating object behaves as a sound source.
- The human audible range of frequency is 20 Hz to 20000 Hz.
- The sound waves that have a frequency more than 20000 Hz are called ultrasonic and frequency less than 20 Hz is called infrasonic.
- A longitudinal wave can travel in all three media.
- The speed of sound increase with the increase in temperature.
- Sound waves reflect from any surface similar to light waves and follow the laws of reflection as well.
- The distinct reflected sound from any right surface is called an echo.
- The sensation of sound persists in our ears about 0.1 s and speed of sound in air is 340 m/s.
- The ships use the methods of SONAR to detect a rock, an iceberg or a submarine in their way.
- Water is rarer compared to air for sound.
- Air is denser compared to water for sound.
- The minimum distance required to hear an echo is 17.2 m.
- Echo is used to determine the velocity of sound waves in any medium.
- The apparent frequncy is the frequency of the sound as heard by the listener.

MIND MAP



Formulae	
Effect of density	$V \propto \sqrt{\frac{1}{d}}$
Effect of temperature	$v_t = (v_0 + 0.61\ T)\ ms^{-1}$
Speed of sound	$\frac{\text{Distance travelled}}{\text{Time taken}} = \frac{2d}{t}$
Velocity = $\frac{2d}{t}$	$\frac{\text{Distance travelled by sound}}{\text{Time taken}}$
Source and listener move towards each other	$n' = \left(\frac{v + v_L}{v - v_s}\right) n$
Source and listener move away from each other	$n' = \left(\frac{v - v_L}{v + v_s}\right) n$
Listener move towards the stationary source	$n' = \left(\frac{v + v_L}{v}\right)$
Listener move away from the stationary source	$n' = \left(\frac{v - v_L}{v}\right) n$
Source move towards stationary listener	$n' = \left(\frac{v}{v - v_s}\right) n$
Source move away from stationary listener'	$n' = \left(\frac{v}{v + v_s}\right) n$
Frequency	$n = \frac{1}{\text{Time period (T)}}$
Wavelength	$\lambda = \frac{\text{Velocity of sound(V)}}{\text{frequency(n)}}$
Amplitude	$A = \frac{D(\text{Distance})}{F(\text{Frequency})}$
Time Period	$T = \frac{1}{\text{frequency(n)}}$
Velocity (of a wave) or wave velocity	$\text{Velocity (v)} = \frac{\text{Distance (D)}}{\text{Timetaken (T)}}$ $V = \lambda \times \frac{1}{T}$ Also, $V = \lambda n \quad [\Rightarrow v = \frac{1}{T}]$
Intensity of sound	$I = \frac{\text{Work(W)}}{\text{Area(A)} \times \text{time(t)}}$ Also, $I = \frac{\text{Power(P)}}{\text{Area(A)}}$

Textbook Evaluation

I. Choose the most suitable answer from the given four alternatives and write the option code and corresponding answer:

1. **When a sound wave travels through air, the air particles**
   a) vibrate along the direction of the wave motion
   b) vibrate but not in any fixed direction
   c) vibrate perpendicular to the direction of the wave motion
   d) do not vibrate

2. **Velocity of sound in a gaseous medium is 330 m s^{-1}. If the pressure is increased by 4 times without causing a change in the temperature, the velocity of sound in the gas is** ★★
   a) 330 m s^{-1} b) 660 m s^{-1} c) 156 m s^{-1} d) 990 m s^{-1}

3. **The frequency, which is audible to the human ear is**
   a) 50 kHz b) 20 kHz c) 15000 kHz d) 10000 kHz

4. **The velocity of sound in air at a particular temperature is 330 m s^{-1}. What will be its value when temperature is doubled and the pressure is halved?** ★
   a) 330 m s^{-1} b) 165 m s^{-1}
   c) $330 \times \sqrt{2}$ m s^{-1} d) $320 / \sqrt{2}$ m s^{-1}

5. **If a sound wave travels with a frequency of 1.25×10^4 Hz at 344 m s^{-1}, the wavelength will be**
   a) 27.52 m b) 275.2 m c) 0.02752 m d) 2.752 m

6. **The sound waves are reflected from an obstacle into the same medium from which they were incident. Which of the following changes?**
   a) Speed b) Frequency c) Wavelength d) None of these

7. **Velocity of sound in the atmosphere of a planet is 500 m s^{-1}. The minimum distance between the sources of sound and the obstacle to hear the echo, should be**
   a) 17 m b) 20 m c) 25 m d) 50 m

Ans:

1.	a)	Vibrate along the direction of the wave motion.			
2.	a)	330 ms^{-1}	5.	c)	0.02752 m
3.	b)	20 kHz	6.	d)	None of these
4.	c)	$330 \times \sqrt{2}$ ms^{-1}	7.	c)	25 m

II. Fill up the blanks

1. **Rapid back and forth motion of a particle about its mean position is called _____** ★★

2. **If the energy in a longitudinal wave travels from south to north, the particles of the medium would be vibrating in _____**

3. A whistle giving out a sound of frequency 450 Hz, approaches a stationary observer at a speed of 33 m s^{-1}. The frequency heard by the observer is (speed of sound = 330 m s^{-1}) _____.

4. A source of sound is travelling with a velocity 40 km/h towards an observer and emits a sound of frequency 2000 Hz. If the velocity of sound is 1220 km/h, then the apparent frequency heard by the observer is _____. ★★

Ans:

1.	Vibration	2.	South to north
3.	500 Hz	4.	2067 Hz

III. True or false:- (If false give the reason)

1. **Sound can travel through solids, gases, liquids and even vacuum.** **False**
   Sound can travel through solids, gases, liquids but not in vacuum.
2. **Waves created by Earth Quake are Infrasonic.** **True**
3. **The velocity of sound is independent of temperature.** **False**
   The velocity of sound is dependent of temperature.
4. **The velocity of sound is high in gases than liquids.** **False**
   The velocity of sound is high in liquids than gases.

IV. Match the following

1.	1) Infrasonic	- a) Compressions	(c)
	2) Echo	- b) 22 kHz	(d)
	3) Ultrasonic	- c) 10 Hz	(b)
	4) High pressure region	- d) Ultrasonography	(a)

V. Assertion and Reason Questions :

Mark the correct choice as

a) If both the assertion and the reason are true and the reason is the correct explanation of the assertion.
b) If both the assertion and the reason are true but the reason is not the correct explanation of the assertion.
c) Assertion is true, but the reason is false.
d) Assertion is false, but the reason is true.

1) **Assertion:** The change in air pressure affects the speed of sound.
Reason: The speed of sound in a gas is proportional to the square of the pressure
Ans: (c) Assertion is true, but the reason is false.

2) **Assertion:** Sound travels faster in solids than in gases.
Reason: Solid posses a greater density than that of gases.
Ans: (b) If both the assertion and the reason are true but the reason is not the correct explanation of the assertion.

VI. Answer very briefly

1. What is a longitudinal wave?

If the particles of the medium vibrate along the direction of propagation of the wave, then the waves are said to be longitudinal.

2. What is the audible range of frequency? ✱ ✱

- The audible range of frequency is **20 Hz to 20000 Hz.**
- These are generated by vibrating bodies such as vocal cords, stretched strings, etc.

3. What is the minimum distance needed for an echo? ✱ ✱

The minimum distance required to hear an echo is $1/20^{th}$ part of of the magnitude of the velocity of sound in air.

i.e $\frac{1}{20} \times 344 = \mathbf{17.2m}$

4. What will be the frequency sound having 0.20 m as its wavelength, when it travels with a speed of 331 m s^{-1}?

Formula used:

$V = n\lambda$

$\boxed{V = n\lambda}$

$331 = n(0.20)$

$n = \frac{331}{0.20} = \mathbf{1655\ Hz}$

5. Name three animals, which can hear ultrasonic vibrations.

Dolphins, dogs, cats can hear the ultrasonic vibrations.

VII. Answer briefly

1. Why does sound travel faster on a rainy day than on a dry day?

- During rainy days, the moisture content is more in the atmosphere and speed of sound increases with **increase in humidity.**
- Hence the **sound travels faster** on rainy days.

2. Why does an empty vessel produce more sound than a filled one?

- When an empty vessel is struck, the air molecules are set in vibration and when filled vessel is struck the liquid molecules are set in vibration.
- Since the amplitude of vibration of air molecules is greater than liquid molecules, empty vessel produces louder sound than the filled vessel.

3. Air temperature in the Rajasthan desert can reach 46°C. What is the velocity of sound in air at that temperature? (V_0 = 331 m s^{-1})

Given

Formula used:

$V_T = [V_0 + 0.61\ T]\ ms^{-1}$

$t = 46°\ C$

$V_0 = 331\ ms^{-1}$

$V_T = ?$

$\mathbf{V_T = [V_0 + 0.61\ T]\ ms^{-1}}$

$= 331 + [0.61 \times 46]\ ms^{-1}$

$= 331 + [28.06]$

$= 359.06\ ms^{-1}$

The velocity of sound in air at 46° C is **359.06 ms^{-1}**

4. Explain why, the ceilings of concert halls are curved? ★ ★

- When sound is reflected from a concave surface, the reflected waves are converged at a point.
- So the ceilings of the concrete wall is curved.

5. Mention two cases in which there is no Doppler effect in sound?

In the cases given below there will be **no Doppler effect.**

- When source (s) and listener (L) both are at **rest**.
- When source S and L are moving in mutually **perpendicular directions.**
- When source and listener move in such a way that distance between them remains **constant**.
- If the source is situated at the center of the **circle** along which the listener is moving.

VIII. Numerical Problems:

1. A sound wave has a frequency of 200 Hz and a speed of 400 m s^{-1} in a medium. Find the wavelength of the sound wave. ★ ★ ★

Given:

$n = 200$ Hz

$V = 400\ ms^{-1}$

$\lambda = ?$

$V = n\lambda$

$$\lambda = \frac{V}{n} = \frac{400}{200}$$

$\lambda = 2$ m

Formula used:

$V = n\lambda$

2. The thunder of cloud is heard 9.8 seconds later than the flash of lightning. If the speed of sound in air is 330 m s^{-1}, what will be the height of the cloud?

The speed of light is so phenomenal that it will render its contribution to the time taken negligible so

Distance = Velocity × time

$= 330 \times 9.8$

Distance = 3234 m

Formula used:

$D = V \times t$

3. A person who is sitting at a distance of 400 m from a source of sound is listening to a sound of 600 Hz. Find the time period between successive compressions from the source? ★

Given:

$n = 600$ Hz

$T = ?$

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

$$= \frac{1}{600} = 0.0016 \text{ s}$$

(or)

T = 1.6 ms

Formula used:

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

4. **An ultrasonic wave is sent from a ship towards the bottom of the sea. It is found that the time interval between the transmission and reception of the wave is 1.6 seconds. What is the depth of the sea, if the velocity of sound in the seawater is 1400 m s^{-1}?**

Given:

$t = 1.6$ s

$v = 1400$ ms^{-1}, $\mathbf{V = d \times t}$

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

$$d = \frac{1400 \times 1.6}{2}$$

d = 1120 m

Formula used:

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

5. **A man is standing between two vertical walls 680 m apart. He claps his hands and hears two distinct echoes after 0.9 seconds and 1.1 second respectively. What is the speed of sound in the air?**

$d = 680$ m

$t = 1.1 + 0.9 = 2$

$$\mathbf{d = \frac{ct}{2}}$$

$$c = \frac{2d}{t}$$

$$c = \frac{2 \times 680}{2}$$

c = 340 ms^{-1} which is the speed of sound in air

Formula used:

$$c = \frac{2d}{t}$$

6. **Two observers are stationed in two boats 4.5 km apart. A sound signal sent by one, under water, reaches the other after 3 seconds. What is the speed of sound in the water?**

Given:

$d = 4.5$ km $= 4500$ m

$t = 3$ s

$v = ?$

$$\mathbf{v = \frac{d}{t} = \frac{4500}{3}}$$

v = 1500 m/s

Formula used:

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

7. **A strong sound signal is sent from a ship towards the bottom of the sea. It is received back after 1s.What is the depth of sea given that the speed of sound in water 1450 m s^{-1}?**

Given:

$t = 1$s

$v = 1450$ ms^{-1}

$$d = \frac{v \times t}{2} = \frac{1450 \times 1}{2}$$

d = 725 m

Formula used:

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

IX. Answer in Detail :

1. What are the factors that affect the speed of sound in gases? ★ ★

Factors affecting velocity of sound:

- The following factors affect the velocity of sound waves.

Effect of density:

- The velocity of sound in a gas is inversely proportional to the square root of the density of the gas.
- Hence, the velocity decreases as the density of the gas increases.

$$V \propto \frac{1}{\sqrt{d}}$$

Effect of temperature:

- The velocity of sound in a gas is directly proportional to the square root of its temperature.
- The velocity of sound in a gas increases with the increase in temperature. $v \propto \sqrt{T}$.
- Velocity at temperature T is given by the following equation:

$$v_T = (v_0 + 0.61\ T)\ m\ s^{-1}$$

- Here, v_0 is the velocity of sound in the gas at 0° C.
- For air, $v_0 = 331\ m\ s^{-1}$.
- Hence, the velocity of sound changes by 0.61 $m\ s^{-1}$ when the temperature changes by one degree celsius.

Effect of relative humidity:

- When humidity increases, the speed of sound increases.
- That is why you can hear sound from long distances clearly during rainy seasons.

2. What is meant by reflection of sound? Explain: a) reflection at the boundary of a rarer medium b) reflection at the boundary of a denser medium c)Reflection at curved surfaces.

Reflection of sound waves:

- When sound waves travel in a given medium, and strikes the surface of another medium, they can **bounce back** into the first medium.
- This phenomenon is known as reflection.

a) Reflection at the boundary of a rarer medium

- Consider a wave travelling in a solid medium striking on the **interface** between the **solid** and the **air**.
- The **compression** exerts a force F on the surface of the **rarer medium**.
- As a rarer medium has **smaller resistance** for any deformation, the surface of separation is **pushed backwards.**
- As the particles of the rarer medium are free to move, a rarefaction is produced at the interface.
- Thus, a **compression** is reflected as a rarefaction and a rarefaction travels from **right** to **left**.

b) Reflection at the boundary of a denser medium

- A longitudinal wave travels in a medium in the form of compressions and rarefactions.
- Suppose a compression travelling in air from **left** to **right** reaches a rigid wall, the compression exerts a **force F** on the rigid wall.
- In turn, the wall exerts an **equal** and **opposite** reaction R = – F on the air molecules
- This results in a compression near the rigid wall.
- Thus, a compression travelling towards the rigid wall is **reflected** back as a compression. i.e: the direction of compression is **reversed.**

c) Reflection of sound in plane and curved surfaces

- When the sound waves are reflected from the **curved surfaces**, the **intensity** of the reflected waves is **changed**.
- When reflected from a **convex** surface, the reflected waves are **diverged** out and the intensity is **decreased**.
- When sound is reflected from a **concave** surface, the reflected waves are **converged** and **focused** at a point.
- So the intensity of reflected waves is concentrated at a point.
- **Parabolic** surfaces are used when it is required to focus the sound at a particular **point.**
- Hence, many halls are designed with parabolic reflecting surfaces.
- In **elliptical** surfaces, sound from one focus will always be **reflected** to the **other focus**, no matter where it strikes the wall.

3. a)What do you understand by the term 'ultrasonic vibration'? b)State three uses of ultrasonic vibrations. c) Name three animals which can hear ultrasonic vibrations.

a) Ultrasonic Vibrations:

- The Vibrations produced by sound waves with a frequency **greater than 20 KHz** are called ultrasonic vibrations.
- Human ear cannot detect these waves.

b) Uses of Ultrasonic vibration:

- Ultrasonic devices are used to **detect objects** and measure distances.
- Ultrasound imaging or sonography is often used in **medicine.**
- In the non destructive testing of products and structures. Ultra sound is used to detect **invisible flaws.**

c) Certain creatures like mosquitoes, dogs, bats and dolphins can detect these waves.

4. What is an echo? a) State two conditions necessary for hearing an echo. b) What are the medical applications of echo? c) How can you calculate the speed of sound using echo? ★

Echo:

- An echo is the sound reproduced due to the **reflection** of the **original sound** from various rigid surfaces such as walls, ceilings, surfaces of mountains, etc.

a) Conditions necessary for hearing echo:

- The persistence of hearing for human ears is 0.1 second.
- This means that you can hear two sound waves clearly, if the time interval between the two sounds is atleast 0.1 s.

- Thus, the minimum time gap between the original sound and an echo must be 0.1 s.
- The above criterion can be satisfied only when the distance between the source of sound and the reflecting surface would satisfy the following equation:

$$\text{Velocity} = \frac{\text{distance travelled by sound}}{\text{time taken}}$$

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

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

since, t = 0.1 second, then $d = \frac{331}{0.20} = \frac{v}{20}$

- Thus the minimum distance required to hear an echo is $1/20^{th}$ part of the magnitude of the velocity of sound in air.
- If you consider the velocity of sound as 344 $ms^{-1,}$ the minimum distance required to hear an echo is 17.2 m.

b) Applications of echo:

- The principle of echo is used in obstetric **ultrasonography**, which is used to create real-time visual images of the developing embryo or fetus in the mother's uterus.
- This is a safe testing tool, as it does not use any harmful radiations.

c) Calculation of speed of sound:

- The sound pulse emitted by the source travels a total distance of 2d while travelling from the source to the wall and then back to the receiver.
- The time taken for this has been observed to be 't'. Hence, the speed of sound wave is given by

$$\text{Velocity} = \frac{\text{distance travelled}}{\text{time taken}} = \frac{2d}{t}$$

X. Higher Order Thinking Skills (HOTS)

1. Suppose that a sound wave and a light wave have the same frequency, then which one has a longer wavelength?

a) Sound **b) Light**
c) both a and b **d) data not sufficient**

Ans: a) Sound

Sound waves travel a million times slower than light waves. They have wavelengths between 1cm and 10 m and will easily diffract around the corners.

2. When sound is reflected from a distant object, an echo is produced. Let the distance between the reflecting surface and the source of sound remain the same. Do you hear an echo sound on a hotter day? Justify your answer.

An echo is heard when the time for the reflected sound is heard after 0.1 s.

Time taken = Total distance/Velocity

On a hotter day, the velocity of sound is more. If the time taken by echo is less than 0.1 s, it will not be heard.

Additional Questions

I. Choose the most suitable answer from the given four alternatives and write the option code and corresponding answer:

1. **Sound can propagate**
   a) Only through solids
   b) Only through liquids
   c) Only through gases
   d) Through any medium[solid,liquid,gases]

2. **Sound waves are**
   a) longitudinal
   b) tansverse
   c) both longitudinal and transverse
   d) Neither longitudinal nor transverse

3. **The speed of the sound waves**
   a) depends on the properties of the medium
   b) doesnot depends on the properties of the medium
   c) may or may not depends on the properties of the medium
   d) None of the above

4. **Audible range of frequency is**
   a) 20 Hz to 20000 Hz
   b) below 20 Hz
   c) greater than 20000 Hz
   d) None of the above

5. **Sound waves with frequencies below 20 Hz are called as**
   a) Audible waves
   b) Infrasonic waves
   c) Ultrasonic waves
   d) None of the above

6. **Sound waves with frequencies greater than 20 kHz are called as** ★
   a) Audible waves
   b) Infrasonic waves
   c) Ultrasonic waves
   d) None of the above

7. **Waves Produced by bats are**
   a) Audible waves
   b) Infrasonic waves
   c) Ultrasonic waves
   d) None of the above

8. **Which of these statements are true about sound waves?**
   a) Medium is not required for the propagation
   b) Sound waves are longitudinal
   c) Wavelength ranges from 4×10^{-7} m to 7×10^{-7} m.
   d) The speed of sound waves is 3×10^{8} m/s

9. **The relation between V, λ and n is given by**
   a) $V = n\lambda$
   b) $n = V\lambda$
   c) $\lambda = nV$
   d) $V = \frac{n}{\lambda}$

10. **Velocity of sound is**
    a) maximum in solids
    b) maximum in liquids
    c) maximum in gases
    d) equal in all the three media

11. **If V_S, V_L and V_G represent velocity of sound in solids, liquids and gases respectively, then which of the following is correct?** ★★
    a) $V_S > V_L > V_G$
    b) $V_S < V_L < V_G$
    c) $V_S = V_L = V_G$
    d) $V_S < V_L > V_G$

12. **Velocity of sound in gas is**
    a) inversely proportional to the density of the gas
    b) inversely proportional to the square root of the density of gas
    c) directly proportional to the density of the gases
    d) directly proportional to the square root of the density of the gas

13. **Velocity of sound in a gas**
    a) increase with increase in temperature
    b) increase with decrease in temperature
    c) does not depends on temperature
    d) None of the above

14. **The persistance of hearing for human ear is**
    a) 1 s
    b) 10 s
    c) 0.1 s
    d) 0.01 s

15. **The minimum distance required to hear an echo is** ✶
    a) 17.2 m
    b) 16.2 m
    c) 172 m
    c) 1.72 m

16. **To improve the quality of sound heard by the audience in a auditorium which of the following is used?**
    a) ear trumpet
    b) megaphone
    c) sound board
    d) wall hangings

17. **According to Doppler effect, when the source and the listener are moving towards each other, the apparent frequency is**
    a) more than the actual frequency
    b) less than the actual frequency
    c) equal to the actual frequency
    d) more or less than the actual frequency

18. **A radar sends a signal to an aeroplane at a distance 45 km away with a speed of 3×10^8 ms^{-1}. The time taken to receive the signal back from the aeroplane is**
    a) 3×10^{-4} s
    b) 3×10^4 s
    c) 6×10^{-4} s
    d) 6×10^4 s

Ans:

1.	d)	Through any medium (Solid, Liquid, Gas)	2.	a)	Longitudinal
3.	a)	depends on the properties of the medium	4.	a)	20 Hz to 20000 Hz
5.	b)	Infrasonic waves	6.	c)	Ultrasonic waves
7.	c)	Ultrasonic waves	8.	b)	Sound waves are longitudinal
9.	a)	$V = n\lambda$	10.	a)	maximum in solids
11.	a)	$V_S > V_L > V_G$			
12.	b)	inversely proportional to the square root of the density of gas			
13.	a)	increase with the increase in temperature	14.	c)	0.1 s
15.	a)	17.2 m	16.	c)	Sound board
17.	a)	more than the actual frequency	18.	a)	3×10^{-4} s

II. Fill up the blanks

1. The human audible range of frequency is _____.
2. The sound waves that have the frequency more than 20,000 Hz are called as ____
3. A distinct reflected sound from any rigid surface is called as _____
4. The speed of a longitudinal wave depends on _____ and _____ of the medium
5. The minimum distance of a reflector should be _____.
6. A_____ is necessary for propagation of sound
7. Velocity of sound waves is maximum in _____ ★
8. Sound waves obey laws of _____
9. When a compression hits the boundary of a _____medium, it is reflected as rarefaction.
10. The principle of _____is used in obstetric ultra sonography
11. The apparent change in frequency was first observed and explained by_____
12. For 1°C rise in temperature the speed of sound in air increases nearly by _____ ms^{-1} ★
13. To detect the obstacles in their path, bats produce _____
14. The distance travelled by the wave in one second is called the _____
15. _____ is the frequency of the sound as heard by the listener

Ans:

1.	20 Hz to 20 kHz	2.	Ultrasonics
3.	Echo	4.	Elasticity, density
5.	17.2 m	6.	medium
7.	Solids	8.	reflection
9.	Rarer	10.	Echo
11.	Christian Doppler	12.	0.61
13.	Ultrasonic waves	14.	Wave velocity
15.	The apparent frequency.		

III. True or false:- (If false give the reason)

1. **Longitudinal displacements results in a series of high and low pressure called compressions and rarefactions** — **True**
2. **Infrasonic waves are sound waves with a frequency ranging between 20 Hz and 20000 Hz.** — **False**
   Audible waves are sound waves with a frequency ranging between 20Hz and 20000Hz.
3. **Sound waves do not require medium for propagation.** ★ — **False**
   Sound waves require medium for propagation.

4. **Sound waves are transverse in nature.** **False**
Sound waves are longitudinal in nature

5. **Dogs can detect ultrasonic waves.** **True**

6. **The velocity with which the wave travels through the medium is called particle velocity.** **False**
The velocity with which the wave travels through the medium is called wave velocity.

7. **Velocity of a sound wave is minimum in solids.** **False**
Velocity of a sound wave is maximum in solids.

8. **The velocity of sound in a gas is directly proportional to the square root of its pressure.** **False**
The velocity of sound in a gas is directly proportional to the square root of its temperature.

9. **When humidity increases, the speed of sound also increases.** **True**

10. **Speed of sound is same in all the media.** **False**
Speed of sound is different in different media.

11. **In a denser medium, the compression travelling towards rigid wall is reflected back as rarefaction.** **False**
In a denser medium, the compression travelling towards rigid wall is reflected back as compression.

12. **The principle of echo is used in obstetric ultrasonography.** **True**

13. **When source and listener are moving in mutually perpendicular directions there will be Doppler effect.** ★ **False**
When source and listener are moving in mutually perpendicular directions there will not be Doppler effect.

14. **The apparent frequency is the frequency of the sound as heard by the listener.** **True**

15. **The velocity of sound decreases as the density of the gas decreases.** **False**
The velocity of sound decreases as the density of the gas increases.

IV. Match the following

1.

1)	Compression	- a) light waves	(d)
2)	Rarefaction	- b) sound waves	(c)
3)	Longitudinal	- c) low pressure	(b)
4)	Transverse	- d) high pressure	(a)

2.

1)	Speed of sound	- a) 0.1 s ★	(d)
2)	Speed of light	- b) 17 m	(c)
3)	Persistence of human hearing	- c) 3×10^8 m/s	(a)
4)	Minimum distance to hear an echo	- d) 330 ms^{-1}	(b)

3.

1)	Sound Board	- a) Echo location	(d)
2)	Whispering gallery	- b) Doppler effect	(c)
3)	RADAR	- c) Multiple reflection	(b)
4)	Bats	- d) Reflection of sound	(a)

V. Assertion and Reason Questions :

Mark the correct choice as

a) If both the assertion and the reason are true and the reason is the correct explanation of the assertion.
b) If both the assertion and the reason are true but the reason is not the correct explanation of the assertion.
c) Assertion is true, but the reason is false.
d) Assertion is false, but the reason is true.

1. **Assertion:** One does not experience any echo sound in a small room.
   Reason: The minimum distance required to hear an echo is 17.2m.
   Ans: (a) Both the assertion and the reason are correct and the reason is the correct explanation of the assertion.

2. **Assertion:** Sound waves are longitudinal. ✶
   Reason: The speed of sound is directly proportional to the square root of elastic modulus.
   Ans: (b) Both the assertion and the reason are true, but the reason is not the correct explanation of the assertion.

3. **Assertion:** When temperature increases, the velocity of sound waves also increase.
   Reason: Velocity of sound in gas is inversely proportional to the square root of its temperature.
   Ans: (c) Assertion is true but the reason is false

4. **Assertion:** Air is rarer compared to water for sound.
   Reason: The medium in which the velocity of sound decreases compared to the other medium is called denser medium.
   Ans: (d) Assertion is false but the reason is true

VI. Answer briefly

1. What are sound waves?

The vibrating bodies **produce energy in the form of waves,** which are nothing but sound waves.

2. Suppose you and your friend are on the moon .Will you be able to hear any sound produced by your friend?

As the **moon does not have air,** I will not be able to hear any sound produced by my friend.

3. What are longitudinal waves?

- The waves in which the particles of the medium vibrate **along the direction of propagation** of the waves are called longitudinal waves.
- Eg: Sound waves

4. What are compressions and rarefactions? ✶ ✶

- Longitudinal waves are characterized by compression and rarefactions.
- A series of **high pressure** regions are called as **compression** and **low pressure** regions are called as **rarefactions**.

5. Distinguish between Infrasonic waves and Ultrasonic waves. ★★

S.No	Infrasonic waves	Ultrasonic waves
1	These are sound waves with frequency **below 20 Hz** that cannot be heard by human ear.	These are sound waves with frequency **greater than 20 kHz.** Human ear cannot detect these waves.
2.	e.g.: Waves produced during **earthquake, ocean waves, sound produced by whales, etc**	Waves produced by **bats.**

6. Define particle velocity.

The velocity with which the particles of the medium **vibrate in order to transfer energy** in the form of wave is called particle velocity.

7. Define wave velocity.

The velocity with which the **wave travels through the medium** is called wave velocity.

VII. Numerical Problems:

1. A man shouts and hears an echo of sound from a distant hill after 1.4 s. What is the distance of hill from man? (velocity of sound in air = 340 ms^{-1})

Given:

$t = 1.4$ s

v = 340 m/s

Distance = Velocity × time

$(2d) = 340 \times 1.4 = 476$ m

Formula used:

$d = v \times t$

$$\text{Distance of hill (d)} = \frac{476}{2}$$

d = 238 m

2. A stone is dropped in a well of depth 19.6 m. After how many seconds the sound of splash will be heard to the observer (Velocity of sound in air = 340 ms^{-1}] ★

Given:

$s = 19.6$ m $V = 340\ ms^{-1}$

Using second equation of motion

$s = ut + \frac{1}{2}at^2$

$u = 0, \quad a = g$

$$s = \frac{1}{2}gt^2$$

Formula used:

Second equation of motion

$s = ut + \frac{1}{2}at^2$

Time taken to reach the depth

$$t_1 = \sqrt{\frac{2s}{g}} = \sqrt{\frac{2 \times 19.6}{9.8}} = 2 \text{ s}$$

Time taken to the sound to reach observer at the top.

$$t_2 = \frac{\text{distance}}{\text{Velocity}} = \frac{19.6}{340} = 0.05 \text{ s}$$

Total time = 2+ 0.05 = **2.05 s**

3. **The human ear can detect sound in the frequency range of 20 Hz to 20000 Hz. Find the corresponding wavelength (If the Speed of sound is 330 ms^{-1}]**

Given:

$V = 330\ ms^{-1}$, $n_{min} = 20$ Hz, $n_{max} = 20$ kHz

Formula used:

$V = n\lambda$

$\mathbf{V = n\lambda}$

$$\lambda = \frac{V}{n}$$

i) for $n_1 = 20$ Hz;

$$\lambda = \frac{330}{20} = \mathbf{16.5\ m}$$

ii) For $n_2 = 20000$ Hz

$$\lambda = \frac{330}{20000}$$

$\mathbf{\lambda = 16.5\ mm}$

4. **In a SONAR, Ultra sonic waves are sent into the sea water and the reflected waves from a sunken ship are received after 2 s. If the velocity of waves in sea water is 1450 ms^{-1}. Find the depth of the sunken ship.**

Given:

$v = 1450\ ms^{-1}$, $t = 2$ s

Formula used:

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

$$\mathbf{d = \frac{vt}{2} = \frac{1450 \times 2}{2}}$$

$d = 1450$ m

5. **A boy standing in front of a wall at a distance of 85 m produces 2 claps/second. He notices that the sound of his clapping coincides with the echo. The echo is heard only once when clapping is stopped. Calculate the speed of sound.** ✶

Given:

$d = 85$ m

To hear an echo, sound has to travel a total distance $2d = 2 \times 85 = 170$ m

Since 2 claps are made per second each clap is produced after $\frac{1}{2}$ s.

$t = 0.5$ s

Now the speed = $\frac{170}{0.5} = \mathbf{340\ ms^{-1}}$

VIII. Answer in Detail :

1. **Explain three different categories of sound waves based on their frequencies.**

Categories of sound waves based on their frequencies:

(i) Audible waves:

- These are sound waves with a frequency ranging between **20 Hz and 20,000 Hz.**
- These are generated by vibrating bodies such as vocal cords, stretched strings, etc.

(ii) Infrasonic waves:

- These are sound waves with a frequency **below 20 Hz** that cannot be heard by the human ear.
- e.g., waves produced during earthquake, ocean waves, sound produced by whales, etc.

(iii) Ultrasonic waves:

- These are sound waves with a frequency **greater than 20 kHz.**
- Human ear cannot detect these waves, but certain creatures like mosquito, dogs, bats, dolphins can detect these waves.
- e.g., waves produced by bats.

2. Write the difference between the sound waves and light waves. ★★

S.No	Sound	Light
1.	Medium is **required** for the propagation.	Medium is **not required** for the propagation.
2.	Sound waves are **longitudinal.**	Light waves are **transverse**.
3.	Wavelength ranges from **1.65 cm to 1.65 m**	Wavelength ranges from **4×10^{-7} m to 7×10^{-7} m.**
4.	Sound waves travel in air with a speed of about **340 ms^{-1}** at NTP.	Light waves travel in air with a speed of **3×10^{8} ms^{-1}.**

3. Derive the relation between, velocity, wavelength and frequency of a wave.

Wave velocity:

- The velocity with which the wave travels through the medium is called wave velocity.
- In other words, the distance travelled by a sound wave in unit time is called the velocity of a sound wave.

$$\text{Velocity} = \frac{\text{Distance}}{\text{Time taken}}$$

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

- If the distance travelled by one wave is taken as one wavelength (λ) and, the time taken for this propagation is one time period (T), then, the expression for velocity can be written as

$$\text{Velocity} = \frac{\text{Wave length}}{\text{Time taken}}$$

$$\boxed{v = \frac{\lambda}{t}}$$

- Therefore, velocity can be defined as the distance travelled per second by a sound wave.
- Hence, Frequency (n) =1/T, equation can be written as

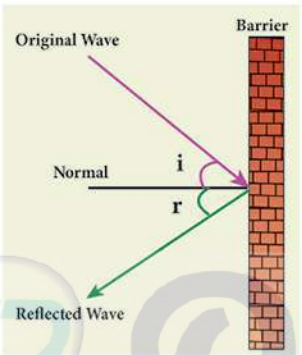
Velocity = Frequency × Wavelength

$$\boxed{V = n\lambda}$$

4. State and Explain law of reflection.

Laws of reflection:

- Like light waves, sound waves also obey some fundamental laws of reflection.
- The following two laws of reflection are applicable to sound waves as well.
- The incident wave, the normal to the reflecting surface and the reflected wave at the point of incidence lie in the **same plane.**
- The angle of incidence ∠**i** is **equal** to the angle of reflection ∠**r**



Laws of reflection

- In the above Figure the sound waves that travel towards the reflecting surface are called the incident waves.
- The sound waves **bouncing back** from the reflecting surface are called reflected waves
- For all practical purposes, the point of incidence and the point of reflection is the same point on the reflecting surface.
- A perpendicular line drawn at the **point of incidence** is called the normal.
- The angle which the incident sound wave makes with the normal is called the angle of incidence, 'i'.
- The angle which the reflected wave makes with the normal is called the angle of reflection, 'r'.

5. How will you measure the velocity of sound by echo method?

Measuring velocity of sound by echo method:

Apparatus required:

A source of sound pulses, a measuring tape, a sound receiver, and a stop watch.

Procedure:

- Measure the distance 'd' between the source of sound pulse and the reflecting surface using the measuring tape.
- The receiver is also placed adjacent to the source. A sound pulse is emitted by the source.
- The stopwatch is used to note the time interval between the instant at which the sound pulse is sent and the instant at which the echo is received by the receiver. Note the time interval as 't'.
- Repeat the experiment for three or four times. The average time taken for the given number of pulses is calculated.

Calculation of speed of sound:

- The sound pulse emitted by the source travels a total distance of 2d while travelling from the source to the wall and then back to the receiver.
- The time taken for this has been observed to be 't'. Hence, the speed of sound wave is given by

$$\text{Speed of sound} = \frac{\text{distance travelled}}{\text{time taken}} = \frac{2d}{t}$$

6. a) Define Doppler effect b) Write the expression for apparent frequency when i) Both source and listener move towards each other ii) Both source and the listener move away from each other iii) Both source and the listener move one behind the other

a) Definition:

Whenever there is a relative motion between a source and a listener, the frequency of the sound heard by the listener is different from the original frequency of sound emitted by the source. This is known as "Doppler effect"

b)

Case No	Position of source and listener	Note	Expression for apparent frequency
1	➢ Both source and listener move ➢ They move towards each other	Distance between source and listener decreases Apparent frequency is more than actual frequency	$n' = \left(\frac{v + v_L}{v - v_s}\right) n$
2	➢ Both source and listener move ➢ They move away from each other	Distance between source and listener increases Apparent frequency is less than actual frequency v_S and v_L become opposite to that in case-1	$n' = \left(\frac{v - v_L}{v + v_s}\right) n$
3	➢ Both source and listener move ➢ They move one behind the other ➢ Source follows the listener	Apparent frequency depends on the velocities of the source and the listener v_S becomes opposite to that in case-2	$n' = \left(\frac{v - v_L}{v - v_s}\right) n$

IX. Higher Order Thinking Skills (HOTS)

1. Why is the speed of longitudinal wave greatest in steel?

- The speed of longitudinal wave is greatest in steel due to its elasticity.
- Hence speed is also greatest in steel.

2. A man is standing at a distance of 12 m from a cliff. Will he be able to hear a clear echo of his sound?

No he will not be able to hear a clear echo, because the minimum distance between the source and the reflector is approximately 17 m.

Unit Test - 5

Acoustics

Time : 1 hr **Marks : 30**

I. Choose the most suitable answer and write the code with the corresponding answer. 5 × 1 = 5

1. When a sound wave travels through air, the air particles
   a) vibrate along the direction of the wave motion
   b) vibrate but not in any fixed direction
   c) vibrate perpendicular to the direction of the wave motion
   d) do not vibrate
2. The velocity of sound in air at a particular temperature is 330 m s^{-1}. What will be its value when temperature is doubled and the pressure is halved?
   a) 330 m s^{-1} b) 165 m s^{-1} c) 330 × $\sqrt{2}$ m s^{-1} d) 320 / $\sqrt{2}$ m s^{-1}
3. Velocity of sound in the atmosphere of a planet is 500 m s^{-1}. The minimum distance between the sources of sound and the obstacle to hear the echo, should be
   a) 17 m b) 20 m c) 25 m d) 50 m
4. The minimum distance required to hear an echo is
   a) 17.2 m b) 16.2 m c) 172 m c) 1.72 m
5. **Assertion:** The change in air pressure affects the speed of sound.
   Reason: The speed of sound in a gas is proportional to the square of the pressure
   a) If both the assertion and the reason are true and the reason is the correct explanation of the assertion.
   b) If both the assertion and the reason are true but the reason is not the correct explanation of the assertion.
   c) Assertion is true, but the reason is false.
   d) Assertion is false, but the reason is true.

II. Answer the following questions in one or two lines. 5 × 2 = 10

1. What is a longitudinal wave?
2. Air temperature in the Rajasthan desert can reach 46°C. What is the velocity of sound in air at that temperature? (V_0 = 331 m s^{-1})
3. Define acoustics.
4. Write any two uses of echo.
5. What is Doppler Effect?

III. Answer the fllowing questions in brief: 2 × 4 = 8

1. Write the difference between the sound waves and light waves.
2. i) What is Doppler Effect?
   ii) What is the minium distance needed for an echo?

IV. Answer the fllowing questions in detail: 1 × 7 = 7

1. i) A man shouts and hears an echo of sound from a distant hill after 1.4s. What is the distance off hil from man ? (velocity of sound in air = 340 ms^{-1})
   ii) State and Explain law of reflection.