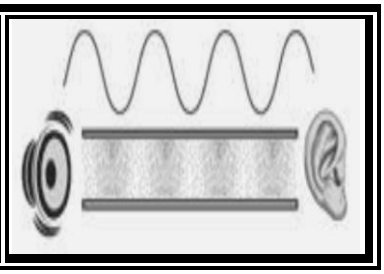
UNIT – 5
ACOUSTICS



I. Choose the correct answer

1. When a sound wave travels through air, the air particles **[SEP – 2021]**
   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 ms^{-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 **[PTA – 6]**
   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 ms^{-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}
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 ms^{-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

II. Fill up the blanks

1. Rapid back and forth motion of a particle about its mean position is called **vibration.**
2. If the energy in a longitudinal wave travels from south to north, the particles of the medium would be vibrating in **both south and north**.
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}) **500 Hz**.
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 **2067.8 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 and **cannot travel through 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 **directly proportional to the square root of temperature.*
4. The velocity of sound is high in gases than liquids. **[False]**
   ******The velocity of sound is **low** in gases than liquids.*

IV. Match the following

Column I	Column II	Answer
1) Infrasonic	a) Compressions	**1-c) 10 Hz**
2) Echo	b) 22 kHz	**2-d) Ultrasonography**
3) Ultrasonic	c) 10 Hz	**3-b) 22 kHz**
4) High pressure region	d) Ultrasonography	**4-a) Compressions**

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 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. ***Both assertion and reason are False.***

2. Assertion : Sound travels faster in solids than in gases.
Reason : Solid possess a greater density than that of gases.

Ans. (b) ***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?
It is the wave in which particles vibrate along the direction of propagation of wave.

2. What is the audible range of frequency? **[SEP – 2021]**
20 Hz and 20,000 Hz (Or) 20 kHz.

3. What is the minimum distance needed for an echo? **[SEP – 2021, MDL – 19]**
17.2 m.

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

$$n = \frac{V}{\lambda} = \frac{331}{0.20} = \frac{3310}{2} = 1655 \text{ Hz}$$

5. Name three animals, which can hear ultrasonic vibrations.
1) Mosquito 2) Dogs 3) Bats

VII. Answer briefly

1. Why does sound travel faster on a rainy day than on a dry day? (or) Why does sound propagate faster on a rainy season than on summer season? **[PTA – 6]**

- ❖ Presence of moisture in air decreases the density and increases velocity.
- ❖ Hence, with high moisture, sound travel faster on a rainy day than on a dry day.

2. Why does an empty vessel produce more sound than a filled one? [PTA – 2]

- ❖ Amplitude of vibration of air is greater than liquid.
- ❖ Also amplitude is more due to the free space in empty vessel.
- ❖ Intensity is also increased by multiple reflections in empty 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})

$V_0 = 331\ m\ s^{-1}$ $\quad T = 46°C$

$V_T = V_0 + 0.61\ T = 331 + 0.61 \times 46 = 359.06\ ms^{-1}$

4. Explain why, the ceilings of concert halls are curved. [MAY-2022, PTA-6]

- ❖ Ceilings of concert halls are curved because sound intensity is maximized after multiple reflections and reaches every corner. Audience can listen the sound clearly.

5. Mention two cases in which there is no Doppler effect in sound. [MDL – 19, SEP - 2020]

- ❖ When source (S) and listener (L) both are at rest.
- ❖ When source (S) and listener (L) move with constant distance between them.

IX. Answer in Detail

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

i) Effect of density :

Velocity of sound in a gas is inversely proportional to the square root of its density.

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

ii) Effect of temperature :

- ❖ Velocity of sound in a gas is directly proportional to the square root of its temperature.

$$V \propto \sqrt{T}$$

- ❖ ***Velocity of sound at a temperature T is,*** $V_T = (V_0 + 0.61T)\ ms^{-1}$

Where, V_0 →velocity of sound in the gas at 0° C.

iii) Effect of relative humidity :

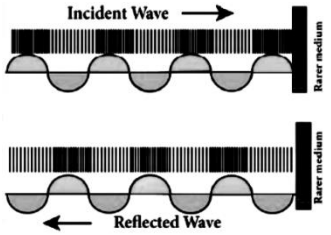
When humidity increases, the speed of sound increases. That is why we can hear sound from long distances clearly during rainy seasons.

2. What is mean 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: It is the bouncing of sound waves from the interface between two media.

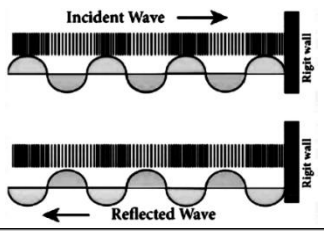
a) Reflection at boundary - rarer medium :

- ❖ A wave travelling in a solid medium strikes the interface between solid and air.
- ❖ Compression exerts a force F on the surface of air which is pushed backwards as air has smaller resistance.
- ❖ As particles are free to move, rarefaction is produced at the interface which travels from right to left.



b) Reflection at boundary - denser medium :

- ❖ Suppose a compression travelling in air from left to right, on reaching a rigid wall exerts a force F.
- ❖ In turn, the wall exerts an equal and opposite reaction R= – F. Thus, a compression travelling towards the rigid wall is reflected back as a compression.



c) Reflection at curved surfaces:

- ❖ Intensity of reflected waves is changed.
- ❖ If it is a convex surface, reflected waves are diverged and intensity is decreased.
- ❖ If it is a concave surface; reflected waves are converged and intensity is focused at a point.

3. a) What do you understand by the term 'ultrasonic vibration'? [SEP – 2020]

These are vibrations with a frequency greater than 20 kHz. Human ear cannot detect this.
Ex: Waves produced by bats.

b) State three uses of ultrasonic vibrations.

- ❖ Used in Ultrasonic soldering and welding.
- ❖ Used to scan the growth of foetus.
- ❖ Used in Sonar.
- ❖ Used to forecast tsunami and earthquakes.

c) Name three animals, which can hear ultrasonic vibrations.

1. Mosquito, 2. Dogs, 3. Bats

4. What is an echo?

a) State two conditions necessary for hearing an echo. [PTA – 1]

b) What are the medical applications of echo? [PTA – 1, SEP - 2020]

c) How can you calculate the speed of sound using echo?

Echo: It is the sound reproduced due to reflection from rigid surfaces like walls, ceilings, etc.

a) Two conditions necessary for hearing an echo:

1. Minimum time gap between original sound and an echo must be 0.1 s.
2. Minimum distance required to hear an echo is 1/20 times the magnitude of velocity of sound.

b) The medical applications of echo:

Echo is used in obstetric ultrasonography. It capture images of fetus in mother's uterus.

c) Calculation of speed of sound :

$$\textbf{Speed of Sound} = \frac{\textbf{Distance travelled}}{\textbf{Time taken}} = \frac{2d}{t}$$

Where 2d → distance travelled by sound from source to wall and then back to receiver.

t → time taken for an echo to be observed

VIII. Problem Corner

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 m s^{-1},

$\lambda = ?$

Solution :

Velocity, $v = n\lambda$

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

$$\lambda = \mathbf{2\ m}$$

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 =?

Solution :

The time period between successive thecompressions = The time period of the wave(T).

$$T = \frac{1}{n} = \frac{1}{600} = 0.00166\ s$$

$$T = 1.7 \times 10^{-3}\ \text{seconds}$$

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?

Given : t = 9.8 s, v = 330 m s^{-1},
d = ?

Solution :

$$v = \frac{\text{height}}{\text{Time}}$$

$$\text{height} = v \times t$$

$$= 330 \times 9.8$$

$$\text{height} = \mathbf{3234\ m}$$

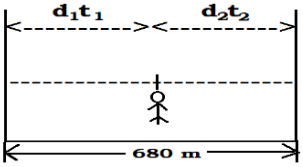
4. An ultrasonic wave is sent from a ship towards the bottom of the sea. It is found that the time interval between transmission and reception of the wave is 1.6 seconds. What is the depth of the sea, if the velocity of sound in the seawater is 1400 m s^{-1}?

Given : t = 1.6 s; v = 1400 m s^{-1}
Distance travelled = 2d; Sea Depth = ?

Solution : Velocity, $V = \frac{2d}{t}$

$$d = \frac{V\,t}{2} = \frac{1400 \times 1.6}{2} = \mathbf{1120\ m}$$

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?



Given: $t_1 = 0.9$s, $t_2 = 1.1$s, $d_1 + d_2 = 680$m

Solution: $V = \frac{2d}{t} \implies d = \frac{V\,t}{2}$

$$d_1 + d_2 = \frac{V \times t_1}{2} + \frac{V \times t_2}{2} = \frac{V}{2}(t_1 + t_2)$$

$$\frac{V}{2}(0.9 + 1.1) = 680\ \text{m}$$

$$\frac{V}{2} \times 2 = 680\ \text{m}$$

$$V = \mathbf{680\ m\ s^{-1}}$$

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

Solution : $V = \frac{d}{t} = \frac{4500}{3} = \mathbf{1500\ m\ s^{-1}}$

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

Given : V = 1450 m s^{-1}; t = 1 s

Solution: Velocity = $\frac{2 \times \text{depth}}{\text{time}}$

$$\text{Depth} = \frac{\text{Velocity} \times \text{time}}{2} = \frac{1450 \times 1}{2}$$

$$\text{Depth} = \mathbf{725\ m}$$

X. HOT Questions

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

$\lambda \propto V \therefore$ ***Light has longer wavelength.***

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.

- As temperature increases, speed of sound increases. ∴ Speed of sound is more on hotter day.
- The distance is same. Hence, time taken by the sound would be less on hotter day.
- Echo occurs when time difference is atleast 0.1 s.
- Thus, if the new time is less than 0.1 s, echo won't be heard. If it is greater than 0.1 s, echo can be heard even on a hotter day.