Chapter 5
Acoustics

I. Choose the correct Answer:

Question 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.
Answer:
(a) vibrate along the direction of the wave motion.

Question 2.
The 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 ms^{-1}
(b) 660 ms^{-1}
(c) 156 ms^{-1}
(d) 990 ms^{-1}.
Answer:
(a) 330 ms^{-1}
Hint: Pressure has no effect on the velocity of sound in the gas. So velocity of sound remains unchanged.

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

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

(c) $330 \times \sqrt{2}$ ms^{-1}
Hint: As there is no effect of change in pressure on the velocity of sound in air, and $v \propto \sqrt{T}$ therefore, when the temperature is doubled, so the velocity becomes $330\sqrt{2}$ m/s.

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

Question 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
Answer:
(d) none of these

Question 7.
The 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 hearing the echo should be _____.
(a) 17 m
(b) 20 m
(c) 25 m
(d) 50 m.
Answer:
(c) 25 m
Hint: The minimum distance of the source of the sound and hear the echo,
$d=\frac{vt}{2}$
$t = 0.1$ s, $d=\frac{500\times0.1}{2} = 25$ 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 ms^{-1}. The frequency heard by the observer is (speed of sound = 330 ms^{-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 …….

Answer:

1. Wave
2. South to north
3. 500 Hz
4. 2067-3 Hz

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

1. Sound can travel through solids, gases, liquids and even vacuum.
2. Waves created by Earthquake are Infrasonic.
3. The velocity of sound is independent of temperature.
4. The Velocity of sound is high in gases than liquids.

Answer:

1. False – Sound cannot travel through vacuum.
2. True
3. False – The velocity of sound depends on temperature.
4. True

IV. Match the following:

Column I		Column II	
A	Infrasonic	*(i)*	Compressions
B	Echo	*(ii)*	22 kHz
C	Ultrasonic	*(iii)*	10 Hz
D	High pressure region	*(iv)*	Ultrasonography

Answer:
A. (iii)
B. (iv)
C. (ii)
D. (i)

V. Assertion and Reason Questions.

Question 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.
(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) If the assertion is true, but the reason is false.
(d) If the assertion is false, but the reason is true.
Answer:
(d) If the assertion is false, but the reason is true.

Question 2.
Assertion : Sound travels faster in solids than in gases.
Reason : Solid posses a greater density than that of gases.
(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) If the assertion is true, but the reason is false.
(d) If the assertion is false, but the reason is true.
Answer:
(c) If the assertion is true, but the reason is false.

VI. Answer very briefly:

Question 1.
What is a longitudinal wave?
Answer:
In longitudinal wave, the particles of the medium vibrate along the direction of the wave.

Question 2.
What is the audible range of frequency?
Answer:
Audible waves: These are sound waves with a frequency ranging between 20 Hz and 20,000 Hz.

Question 3.
What is the minimum distance needed for an echo?
Answer:
The minimum distance needed for an echo is 17.2 metre.

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

Answer:

Frequency of sound $= \frac{\text{velocity of sound}}{\text{wavelength of sound}}$

$n=\frac{v}{\lambda}=3310.20$

$n = 1655$ Hz.

Question 5.

Name three animals, which can hear ultrasonic vibrations.

Answer:

The animals are dogs, bats and dolphins.

VII. Answer briefly:

Question 1.

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

Answer:

When humidity increases, the speed of sound increases. Hence, sound travels faster on a rainy day than a dry day.

Question 2.

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

Answer:

The intensity of sound is directly proportional to the square of the amplitude of vibration. $I \propto A^2$ since, the amplitude of vibration of air molecules (empty vessel) is greater than liquid molecules (filled vessel), therefore empty vessel produces a louder sound than the filled vessel.

Question 3.

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

Answer:

Velocity of sound at 0°C is $V_o = 331$ ms^{-1}

Let the sound at 46°C is be v_t

$$\frac{v_t}{v_o} = \sqrt{\frac{273+T}{273}}$$

where temperature is T = 46°C

$$= \frac{v_t}{331} = \sqrt{\frac{273+46}{273}}$$

$$= \sqrt{\frac{319}{273}} = \sqrt{1.168}$$

$= 1.080$

$v_t = 331 \times 1.080 = 357.48$ m/s.

∴ Velocity of sound in air at that temperature = 357.48 m/s.

Question 4.
Explain why the ceilings of concert halls are curved.
Answer:

1. These are basically curved surfaces (concave), which are used in auditoria and halls to improve the quality of sound. This board is placed such that the speaker is at the focus of the concave surface.
2. The sound of the speaker is reflected towards the audience thus improving the quality of sound heard by the audience.

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

1. When source (S) and listener (L) both are at rest.
2. When S and L move in such a way that distance between them remains constant.

VIII. Problem Corner:

Question 1.
A sound wave has a frequency of 200 Hz and a speed of 400 ms-1 in a medium. Find the wavelength of the sound wave.
Answer:
Speed of sound wave v = 400 m/s
Frequency of sound wave n = 200 Hz
∴ Wavelength sound wave $\lambda = \frac{v}{n}$
$= \frac{400}{200} = 2$ m
∴ Wavelength = 2 m

Question 2.
The thunder of the cloud is heard 9.8 seconds later than the flash of lightning. If the speed of sound in air is 330 ms^{-1}, what will be the height of the cloud?
Solution:
The height of the cloud (distance) = speed of sound × time
d = v × t = 330 × 9.8 = 3234 m
The height of the cloud is 3234 m.

Question 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?
Answer:
Distance of the observer = 400 m
Frequency of sound n = 600 Hz

Let velocity of sound be v = 330 $\frac{m}{s}$

Wavelength $\lambda = \frac{v}{n} = \frac{330}{600}$

$= 55 \times 10^{-2} = 0.55$ m

Distance between two successive compressions is $\frac{\lambda}{2}$

Time period successive compressions is = $\frac{1}{\frac{\lambda}{2}}$

$= \frac{2}{\lambda} = \frac{2}{0.55}$

T = $\frac{2}{0.55}$ = 3.6363 second

Time period = 3.6363 second.

Question 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 ms^{-1}?

Answer:

Time interval t = 1.6 s

Velocity of sound in water = 1400 m/s.

Depth of the sea = $\frac{v \times t}{2}$

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

= 1120 m

Depth of the sea = 1120 m

Question 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?

Answer:

∴ Frequencies $n_1 = \frac{1}{T_1} = \frac{1}{0.9} = \frac{10}{9}$

= 1.11 Hz

$n_2 = \frac{1}{T_2}$

$= \frac{1}{1.1} = \frac{10}{11}$

= 0.9090 Hz.

Difference $x_1 - x_2$ = 1.11 – 0.9090

= 0.201 Hz

Speed of sound = $(n_1 - n_2)\lambda$

$= 0.201 \times 680 = 136.68$

Question 6.
Two observers are stationed in two boats 4.5 km apart. A sound signal sent by one, underwater, reaches the other after 3 seconds. What is the speed of sound in the water?
Solution:
Distance between the two boats, d = 4.5 km
d = 4500 m
Time, t = 3 seconds
Speed of sound in the water = $\frac{\text{Distance travelled by sound}}{\text{Time taken}} = \frac{4500}{3}$
v = 1500 ms^{-1}.

Question 7.
A strong sound signal is sent from a ship towards the bottom of the sea. It is received back after Is.What is the depth of sea given that the speed of sound in water 1450 ms^{-1}?
Answer:
Speed of sound in water v = 1450 m/s
Time taken t = 1 + 1 = 2 s.
Depth of the sea d = $\frac{v}{t}$
$= \frac{1450}{2}$
= 725 m
Depth of the sea = 725 m.

IX. Answer in Detail.

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

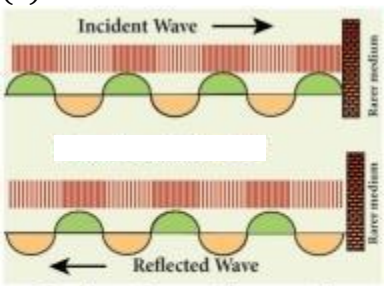
$$v \propto \sqrt{\frac{1}{d}}$$

Effect of temperature:
(i) The velocity of sound in a gas is directly proportional to the square root of its temperature.
(ii) The velocity of sound in gas increases with the increase in temperature,
$v \propto \sqrt{T}$ Velocity at temperature T is given by the following equation:
$v_T = (v_0 + 0.61\ T)\ ms^{-1}$
Here, v_0 is the velocity of sound in the gas at 0° C. For air, $v_0 = 331\ ms^{-1}$.

Hence, the velocity of sound changes by 0.61 ms^{-1} when the temperature changes by one – degree celsius.

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.

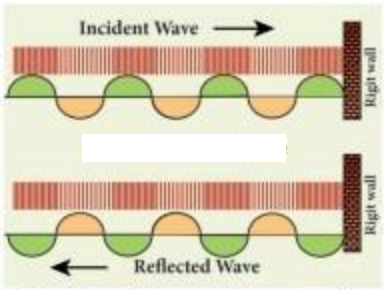
Question 2.
What is mean by reflection of sound? Explain:
(a) Reflection at the boundary of a rarer medium.
(b) Reflection at the boundary of a denser medium.
(c) Reflection at curved surfaces.
Answer:
When sound waves travel in a given medium and strike the surface of another medium, they can be bounced back into the first medium. This phenomenon is known as reflection.
(a) Reflection at the boundary of a rarer medium :



Reflection of sound at 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 defonnation, 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 :



Reflection of sound at 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. That is the direction of compression is reversed.

(c) Reflection at 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.

Question 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.
Answer:
(a) Ultrasonic Vibration: The vibrations whose frequencies are greater than 20000 Hz are called ultrasonic vibrations.

(b) (i) They are used in SONAR to measure the depth of the sea (or ocean) and to locate underwater objects.
(ii) It is used for scanning and imaging the position and growth of a foetus and presence of stones in the gall bladder and kidney.
(iii) It is used for homogenising milk in milk plants where fresh milk is agitated with the desired quantity of fat and powdered milk to obtain toned milk.

(c) Mosquito, Dogs and Bats are the three animals that can hear ultrasonic vibrations.

Question 4.
What is an echo?
Answer:
An echo is the sound reproduced due to the reflection of the original sound wave.

(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?
Answer:
(a) (i) 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 at least 0.1 s. Thus, the minimum time gap between the original sound and an echo must be 0.1 s.

(ii) 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

$$d = \frac{v \times 0.1}{2} = \frac{v}{20}$$

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

(c) 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:

Speed of sound

$$= \frac{\text{distance travelled}}{\text{time taken}}$$

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

X. HOT Questions

Question 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

Answer:

(b) Light: Since the velocity of light ($C = 3 \times 10^8$ m/s) is greater than the velocity of sound, light wave has a longer wavelength.

Question 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.

Answer:

An echo can only be heard if it reaches the ear after 0.1 secs.

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

As on a hotter day, the velocity of sound is more. So if the time taken by the echo is less than 0.1 sec than it won't be heard.