

NCERT Class 9: Sound Waves: Characteristics and Applications - Ultimate Question Bank

This document contains a structured collection of questions covering the propagation of sound, longitudinal and transverse waves, characteristics of sound waves (amplitude, wavelength, frequency, time period, speed), speed of sound in different media, reflection of sound, echo, reverberation, range of hearing (infrasound, ultrasound), applications of ultrasound (sonar, medical imaging), and the basic working structure of the human ear. The materials strictly follow the Class 9 curriculum parameters while driving deeper analytical engagement.

1. Easy Level Segment

Multiple Choice Questions (20 Items)

1. Sound waves in air are characterized as: (a) Transverse waves, (b) Electromagnetic waves, (c) Longitudinal waves, (d) Torsional waves
2. The region of high density and high pressure in a longitudinal wave is called a: (a) Rarefaction, (b) Crest, (c) Trough, (d) Compression
3. The SI unit of frequency is: (a) Meter, (b) Second, (c) Hertz, (d) Newton
4. The distance between two consecutive compressions or two consecutive rarefactions is called: (a) Amplitude, (b) Wavelength, (c) Frequency, (d) Wave velocity
5. Sound cannot travel through: (a) Solids, (b) Liquids, (c) Gases, (d) Vacuum
6. The human range of hearing typically extends from: (a) 20 Hz to 20,000 Hz, (b) 2 Hz to 200 Hz, (c) 200 Hz to 2,000 Hz, (d) 20,000 Hz to 200,000 Hz
7. Sound waves with frequencies below 20 Hz are known as: (a) Ultrasonic, (b) Infrasonic, (c) Supersonic, (d) Audible
8. The pitch of a sound wave is primarily determined by its: (a) Amplitude, (b) Speed, (c) Frequency, (d) Loudness
9. Loudness of sound depends directly on the wave's: (a) Wavelength, (b) Frequency, (c) Amplitude, (d) Phase
10. To hear a distinct echo, the minimum distance of the reflecting surface from the sound source in air (at 22°C) must be roughly: (a) 17.2 m, (b) 34.4 m, (c) 11.2 m, (d) 5.1 m
11. The persistence of sound in a big hall due to repeated reflections is called: (a) Echo, (b) Reverberation, (c) Rarefaction, (d) Diffraction
12. SONAR stands for: (a) Sound Navigation and Ranging, (b) Sound Number and Ranging, (c) Sonic Navigation Radiation, (d) Sound Network and Resonance
13. In which of the following media does sound travel the fastest at room temperature? (a) Water, (b) Air, (c) Iron, (d) Hydrogen gas
14. The relationship between wave speed (v), frequency (ν), and wavelength (λ) is: (a) $v = \nu / \lambda$, (b) $v = \nu \times \lambda$, (c) $v = \lambda / \nu$, (d) $v = 1 / (\nu \times \lambda)$
15. The tiny bone that transmits vibrations to the inner ear is part of the: (a) Outer ear, (b)

Middle ear, (c) Inner ear, (d) Auditory nerve

16. The specialized structure in the inner ear that converts mechanical vibrations into electrical signals is the: (a) Tympanic membrane, (b) Pinna, (c) Cochlea, (d) Anvil
17. An object moving at a speed greater than the speed of sound is said to be traveling at: (a) Infrasonic speed, (b) Ultrasonic speed, (c) Supersonic speed, (d) Audible speed
18. The quality or timbre of a sound allows us to distinguish between: (a) Two sounds of different loudness, (b) Two sounds of different pitch, (c) Two sounds of the same pitch and loudness, (d) Audible and inaudible sounds
19. When a wave passes from a rarefied zone to a compressed zone, the particle density: (a) Decreases, (b) Increases, (c) Remains zero, (d) Stays constant
20. Bats navigate and catch prey in the dark by emitting and detecting: (a) Infrasonic waves, (b) Radio waves, (c) Ultrasonic waves, (d) Light waves

Answer Key (Easy MCQs): 1-(c), 2-(d), 3-(c), 4-(b), 5-(d), 6-(a), 7-(b), 8-(c), 9-(c), 10-(a), 11-(b), 12-(a), 13-(c), 14-(b), 15-(b), 16-(c), 17-(c), 18-(c), 19-(b), 20-(c)

Subjective Questions (20 Items)

1. Explain how sound is produced and propagated through a material medium.
2. Describe a simple conceptual experiment to demonstrate that sound waves require a material medium to propagate.
3. Distinguish between longitudinal waves and transverse waves with one example of each.
4. Define the terms: (i) Wavelength, (ii) Frequency, and (iii) Time Period of a sound wave.
5. Establish the mathematical relationship between the frequency and time period of a wave.
6. Why are sound waves called mechanical waves?
7. Explain the difference between the loudness and the pitch of a sound.
8. An object vibrates 400 times in 2 seconds. Calculate its frequency and time period.
9. Explain what an echo is and state the conditions required to hear a distinct echo.
10. What is reverberation? How can reverberation be reduced in a modern auditorium?
11. List two distinct practical applications of the reflection of sound waves.
12. What is ultrasound? State its frequency threshold.
13. Explain how bats use ultrasound to catch their prey at night.
14. Briefly describe how a SONAR system works to determine the depth of an ocean.
15. Why does sound travel faster on a hot, humid day compared to a cold, dry day?
16. State the functions of the following parts of the human ear: (i) Pinna, (ii) Eardrum.
17. A sound wave has a frequency of 2 kHz and a wavelength of 35 cm. How long will it take to travel 1.5 km?
18. What is a sonic boom? How is it caused?
19. Why is the roof of a concert hall generally curved? Explain the physical principle involved.
20. Explain why we cannot hear the massive thermonuclear explosions occurring continuously on the surface of the Sun.

2. Moderate Level Segment

Multiple Choice Questions (20 Items)

1. A sound source emits waves of wavelength 0.8 m in air. If the time period of the wave is 0.0025 seconds, the speed of sound is: (a) 320 m/s, (b) 340 m/s, (c) 200 m/s, (d) 400 m/s
2. A ship sends out an ultrasound signal that returns from the seabed after 3 seconds. If the speed of ultrasound in seawater is 1500 m/s, the depth of the sea is: (a) 4500 m, (b) 2250

- m, (c) 1500 m, (d) 750 m
3. When a sound wave travels from air into water, which of the following properties remains completely unchanged? (a) Wavelength, (b) Speed, (c) Frequency, (d) Amplitude
 4. The amplitude of a sound wave is doubled while its frequency is halved. The intensity/energy of the sound wave will: (a) Be doubled, (b) Be halved, (c) Remain unchanged, (d) Become four times
 5. A compression and its adjacent rarefaction together travel a distance equal to: (a) λ , (b) $\lambda/2$, (c) 2λ , (d) $\lambda/4$
 6. The speed of sound in hydrogen gas compared to that in oxygen gas at the same temperature is: (a) Faster because hydrogen is less dense, (b) Slower because oxygen has more nucleons, (c) Equal, (d) Zero
 7. A person claps their hands near a cliff and hears the echo after 2 seconds. If the speed of sound is 340 m/s, the distance to the cliff is: (a) 680 m, (b) 340 m, (c) 170 m, (d) 85 m
 8. An ultrasonic scanner operates at a frequency of 4 MHz. The time period of these waves is: (a) 2.5×10^{-7} s, (b) 2.5×10^{-6} s, (c) 4×10^{-6} s, (d) 0.25 s
 9. A tuning fork A produces a sound of higher pitch than tuning fork B. This means: (a) A vibrates with a larger amplitude, (b) A completes more cycles per second, (c) The sound from A travels faster, (d) B has a higher frequency
 10. The note produced by a musical instrument contains a mixture of several frequencies. The lowest frequency produced is called the: (a) Overtone, (b) Fundamental note, (c) Harmonics, (d) Timbre
 11. A wave completes 20 full cycles in 0.5 seconds. If the distance between a compression and the next rarefaction is 80 cm, the wave speed is: (a) 32 m/s, (b) 64 m/s, (c) 16 m/s, (d) 8 m/s
 12. The auditory canal in the human ear terminates at the: (a) Cochlea, (b) Oval window, (c) Tympanic membrane, (d) Eustachian tube
 13. Medical ultrasound equipment uses frequencies typically in the range of: (a) 20 kHz to 100 kHz, (b) 1 MHz to 15 MHz, (c) 20 Hz to 20 kHz, (d) Below 20 Hz
 14. Sound waves travel faster in solids than in gases primarily because solids have: (a) Higher density, (b) Much higher elasticity/rigidity, (c) Lower temperature profiles, (d) Atoms that are farther apart
 15. A sound wave has a time period of 0.01 s. Its frequency falls in which range? (a) Infrasonic, (b) Audible, (c) Ultrasonic, (d) Supersonic
 16. If the temperature of a gas is increased, the speed of sound in that gas: (a) Decreases, (b) Increases, (c) Stays identical, (d) First increases then decreases
 17. The three tiny bones in the middle ear are called the malleus, incus, and stapes. Their collective mechanical role is to: (a) Filter out unwanted noises, (b) Amplify the pressure variations of the sound wave, (c) Convert sound to electrical pulses, (d) Keep the eardrum dry
 18. A structure that protects the inner ear from sudden high-pressure shocks by leveling pressure via the throat is the: (a) Pinna, (b) Eustachian tube, (c) Auditory nerve, (d) Cochlea
 19. A radar uses radio waves, whereas a SONAR must use ultrasound because: (a) Ultrasound travels faster than radio waves in water, (b) Electromagnetic waves are highly attenuated/absorbed in water, (c) Sound waves do not reflect off metals, (d) Water conducts radio waves too well
 20. The graphical representation of a sound wave shows a displacement-time curve. The peaks of this curve represent: (a) Maximum rarefactions, (b) Maximum compressions, (c) Zero pressure states, (d) Speed changes

Answer Key (Moderate MCQs): 1-(a), 2-(b), 3-(c), 4-(c), 5-(b), 6-(a), 7-(b), 8-(a), 9-(b), 10-(b), 11-(b), 12-(c), 13-(b), 14-(b), 15-(b), 16-(b), 17-(b), 18-(b), 19-(b), 20-(b)

Subjective Questions (20 Items)

1. A stone is dropped into a well 44.1 m deep. The splash is heard 3.13 seconds later. Calculate the speed of sound in the well. (Take $g = 9.8 \text{ m/s}^2$)
2. Explain the mechanism of pressure and density changes that take place in air when a vibrating tuning fork moves forward and backward.
3. Derive the relationship between wave speed, frequency, and wavelength from fundamental definitions of speed and time period.
4. Why does an empty room appear to have more reverberation than a room filled with furniture, curtains, and carpets? Explain using sound absorption properties.
5. A body is producing sound waves of wavelength 17 mm in air. Check whether this sound is within the audible human range if the speed of sound is 340 m/s.
6. Describe how ultrasonic waves are utilized to detect cracks and flaws in massive metal blocks in heavy engineering industries.
7. Explain the operational steps of Echocardiography (ECG/ultrasound of the heart) based on wave principles.
8. A submarine equips a SONAR system. It flashes an ultrasonic pulse and receives its echo from another submarine hidden below at a distance of 3.75 km after 5 seconds. Find the speed of sound in that block of water.
9. How does the human ear amplify sound waves before converting them into nerve signals? Explain the anatomical advantage of the middle ear bones.
10. Explain why the flashes of lightning during a thunderstorm are seen much before the thunderous sound is heard. Support your answer with speed values.
11. What happens to the wavelength of a sound wave when it passes from a cooler layer of air into a warmer layer of air? Assume frequency remains constant.
12. A person standing between two vertical cliffs fires a gun. They hear the first echo after 1.5 seconds and the second echo after 2.5 seconds. If the speed of sound is 340 m/s, find the distance between the two cliffs.
13. Explain why sound waves cannot travel through a vacuum, whereas light waves can travel across vast empty space from stars.
14. Describe how ultrasound is used in medical science to break small stones formed in the kidneys of a patient.
15. What is the difference between a high-pitched sound and a low-pitched sound in terms of their graphical wave profiles? Draw a qualitative sketch.
16. Why do elephants communicate with each other using infrasonic sounds over miles? What property of low frequency allows this?
17. A wave pulse traveling along a string hits a fixed boundary and reflects. If a compression hit the boundary, explain what reflects back for a longitudinal string wave.
18. Define 'Intensity' of sound and explain how it differs from 'Loudness'.
19. Explain the basic path of an electrical signal generated in the ear as it travels to the human brain.
20. A tuning fork of frequency 512 Hz is vibrated. Find the total number of compressions that will pass a stationary observer in 15 seconds.

3. Difficult Level Segment

Multiple Choice Questions (20 Items)

1. A student stands at a distance x from a large wall. They fire a starter pistol and start a

- stopwatch. They hear the echo, but due to human reaction time error, they stop the watch 0.1 seconds late. If the recorded time is T seconds and the speed of sound is v , the calculated value of x will exceed the true value by: (a) $0.1 v$, (b) $0.05 v$, (c) $v / 2$, (d) $0.2 v$
2. Two sound waves, W_1 and W_2 , travel through the same homogeneous air column. W_1 has a frequency of 250 Hz and W_2 has a frequency of 500 Hz. The ratio of the speed of W_1 to that of W_2 is: (a) 1:2, (b) 2:1, (c) 1:1, (d) 1:4
 3. A person standing exactly midway between two parallel vertical cliffs fires a rifle. They hear a series of echoes at intervals of 1 second, 2 seconds, 3 seconds, etc. The distance between the two cliffs is (Speed of sound = 340 m/s): (a) 340 m, (b) 680 m, (c) 170 m, (d) 510 m
 4. An ultrasound signal of frequency 5 MHz is launched into a steel block. It encounters a flaw at a depth of 20 cm and reflects. If the elastic modulus and density of steel mean sound travels at 6000 m/s in it, the wavelength of the wave inside the steel block is: (a) 1.2 mm, (b) 1.2 cm, (c) 0.83 mm, (d) 3.0 mm
 5. A wave pattern is observed where the time interval between a compression peak and the immediate next rarefaction trough at a fixed point is 1.25 milliseconds. The frequency of this wave is: (a) 800 Hz, (b) 400 Hz, (c) 200 Hz, (d) 100 Hz
 6. A sound wave passes from medium X to medium Y. The speed of sound in Y is double that in X. To maintain the frequency constant, the wavelength of the sound wave in medium Y must change by a factor of: (a) 0.5, (b) 2, (c) 4, (d) Remains identical
 7. An acoustic alarm is set off underwater. An observer inside a boat hears the sound through the air, and an underwater hydrophone records it through the water. If the straight-line distance to the alarm is 1.5 km, the time lag between the two recorded signals is (Speed of sound in air = 340 m/s, in water = 1500 m/s): (a) 3.41 s, (b) 4.41 s, (c) 1.00 s, (d) 2.50 s
 8. The pressure variations in a sound wave are represented by a graph. If the maximum pressure change from the ambient value is P , the total range of pressure variation between a compression peak and a rarefaction trough is: (a) P , (b) $2P$, (c) $P/2$, (d) Zero
 9. A source of sound is moving towards a stationary wall. The echo reflected from the wall is heard by an observer standing behind the source. Within the Class 9 framework, the frequency of the wave striking the wall: (a) Increases because the source crowds the waves towards the wall, (b) Decreases, (c) Remains identical to the source frequency, (d) Becomes zero
 10. A boy stands in front of a wide staircase with steps of uniform depth 34 cm. If he claps his hands once, the reflected sound will consist of a train of pulses. The virtual frequency of this echo train is (Speed of sound = 340 m/s): (a) 500 Hz, (b) 1000 Hz, (c) 250 Hz, (d) 750 Hz
 11. A ship uses SONAR to map a trench. It fires a pulse vertically downwards. Due to a steep underwater slope, the pulse reflects at an angle of 30 degrees to the vertical and hits a receiver located on a second ship 500 m away. If the total travel time is 2 seconds and speed in water is 1500 m/s, the depth of the trench directly beneath the first ship is roughly: (a) 1500 m, (b) 1479 m, (c) 1350 m, (d) 750 m
 12. Two identical strings are plucked. String 1 vibrates at 300 Hz and String 2 vibrates at 900 Hz. If both sounds are heard by a person at a distance, the sound from String 2 will reach the person: (a) 3 times faster than String 1, (b) 3 times slower than String 1, (c) At the exact same time as String 1, (d) Delayed by the time period difference
 13. The eardrum or tympanic membrane behaves as an elastic membrane. If the area of the eardrum is A and a sound wave creates a peak pressure variation ΔP , the maximum force exerted on the eardrum is: (a) $\Delta P / A$, (b) $\Delta P \times A$, (c) $A / \Delta P$, (d) $0.5 \times \Delta P \times A$
 14. A special siren has a rotating disc with 60 holes around its circumference. A jet of air is blown against the holes. If the disc rotates at 1200 revolutions per minute, the frequency

- of the sound produced is: (a) 1200 Hz, (b) 72000 Hz, (c) 60 Hz, (d) 20 Hz
15. A sound wave travels through a metal bar. The distance between a compression center and the nearest zero-displacement point of the particles is 15 cm. The wavelength of this wave is: (a) 30 cm, (b) 60 cm, (c) 15 cm, (d) 45 cm
 16. A sound wave has an amplitude of 2 mm at a distance of 1 m from a point source. Neglecting any dissipation into heat, the amplitude of the wave at a distance of 2 m from the source will be approximately: (a) 2 mm, (b) 1 mm, (c) 0.5 mm, (d) 4 mm
 17. An infrasonic wave traveling through the earth's crust during an earthquake has a wavelength of 50 m and a speed of 4000 m/s. How many full cycles does a rock particle undergo in 10 seconds? (a) 80, (b) 800, (c) 40, (d) 400
 18. A sophisticated sound-absorbing tile reduces the amplitude of a reflected sound wave to one-third of its initial incident amplitude. The percentage of sound wave energy absorbed by the tile is: (a) 66.7%, (b) 33.3%, (c) 88.9%, (d) 11.1%
 19. A person stands at a distance D from a flat cliff wall. He fires a gun and simultaneously starts running away from the cliff at a speed of 10 m/s. He hears the echo after 3 seconds. If the speed of sound is 340 m/s, the value of D is: (a) 510 m, (b) 495 m, (c) 525 m, (d) 480 m
 20. The velocity of sound in a gas is v . If the pressure of the gas is doubled at a constant temperature, the new velocity of sound will be: (a) $2v$, (b) $v/2$, (c) v , (d) $4v$
- Answer Key (Difficult MCQs):** 1-(b), 2-(c), 3-(a), 4-(a), 5-(b), 6-(b), 7-(a), 8-(b), 9-(a), 10-(a), 11-(b), 12-(c), 13-(b), 14-(a), 15-(b), 16-(b), 17-(b), 18-(c), 19-(b), 20-(c)

Subjective Questions (20 Items)

1. A person standing in front of a vertical mountain cliff fires a rocket signal vertically upwards. The rocket explodes at a height of 82.25 m above the ground. The person hears the echo of the explosion from the cliff 4 seconds after the explosion takes place. Find the horizontal distance of the person from the cliff. (Speed of sound = 340 m/s, neglect the height of the person)
2. Explain why the speed of sound waves in a gas depends explicitly on temperature but is completely independent of changes in gas pressure at a constant temperature.
3. A train of sound waves is moving through a metal pipe filled with air. The equation of the wave indicates that the distance between a point of maximum density and a point of minimum density is 45 cm. If the speed of sound in air is 340 m/s, calculate the time it takes for one full wave cycle to pass any cross-sectional marker.
4. A multi-layered geological boundary contains two mediums: Rock X (speed of sound = 5000 m/s) and Soil Y (speed of sound = 1500 m/s). A seismic sound pulse is generated at the surface. Explain using refraction trends why the wavelength must compress when entering Soil Y, and calculate the ratio of the wavelengths.
5. A person standing between two parallel walls claps his hands continuously at a steady rate of 2 claps per second. He finds that each clap coincides perfectly with the echo of the previous clap reflecting from the closer wall. If the speed of sound is 340 m/s, calculate the distance of the person from the closer wall.
6. Explain the acoustic phenomenon that creates a 'dead spot' or areas of poor audibility in a badly designed theater hall. Address how reflections cause this.
7. An ultrasonic probe is used to measure the thickness of a steel plate. The pulse is sent into the plate, reflects from the back surface, and returns to the probe in 8 microseconds. If the speed of sound in this grade of steel is 5900 m/s, calculate the thickness of the plate in millimeters.
8. A driver inside a car moving at a speed of 20 m/s towards a large factory wall blows the horn. He hears the echo after 2 seconds. Calculate the distance of the car from the wall at

- the moment the horn was blown. (Speed of sound = 340 m/s)
9. Provide a detailed step-by-step account of how the human brain processes different frequencies of sound using the variable mechanical stiffness along the cochlear fluid channel. Keep the description within Class 9 conceptual terms.
 10. A sound wave of frequency 600 Hz travels a distance of 1200 m through a gas line in 4 seconds. Find: (i) the speed of the wave, (ii) its wavelength, and (iii) the total number of wavelengths contained in that 1200 m length.
 11. Explain why a long iron railing can convey two distinct sounds to a far-away observer when struck once with a hammer at the other end. Calculate the theoretical time difference if the rail length is 680 m. ($v_{\text{air}} = 340 \text{ m/s}$, $v_{\text{iron}} = 5100 \text{ m/s}$)
 12. How does the presence of high water vapor content (humidity) in the atmosphere physically reduce the density of air and thereby increase the speed of sound waves? Detail the molecular weight substitution logic.
 13. A compression wave meets an open end of a pipe (a boundary where air can move completely freely). Explain qualitatively why the compression reflects back as a rarefaction wave.
 14. A directional acoustic device sends a sound beam toward a target. If the beam consists of a fundamental frequency of 1000 Hz and an overtone of 3000 Hz, calculate the ratio of their wavelengths in air.
 15. Why do sound professionals use heavy foam sheets with complex open-pore structures to line the walls of a recording studio instead of using smooth hardwood panels? Detail the wave dissipation mechanism.
 16. A boy stands at a distance of 170 m from a high wall. He claps his hands at a regular rate such that the echo of a clap blends with the next clap. If he counts 20 claps in 20 seconds, calculate the speed of sound from his experiment.
 17. An object is traveling at Mach 2.5 (2.5 times the speed of sound in air). Explain visually what the shape of the wavefront envelope looks like, and why a shock wave is formed behind the object.
 18. A sound wave has an intensity level that scales with the square of the pressure amplitude. If the pressure amplitude increases by 40% due to a voice amplifier, calculate the percentage increase in the sound wave's intensity.
 19. Explain why low-frequency sound waves can easily bend around large obstacles like corners and buildings (diffraction), whereas high-frequency ultrasound waves travel along highly directional straight paths.
 20. A group of marine scientists maps an underwater cave using a SONAR transducer arrays. The array emits a pulse that splits along two columns, one reflecting from the ceiling of the cave in 0.4 seconds and the other from the floor in 1.2 seconds. Find the total vertical height of the cave entrance if $v_{\text{water}} = 1500 \text{ m/s}$.

4. Olympiad Level Segment

Multiple Choice Questions (20 Items)

1. A plane sound wave propagates along the x-axis through a gas cylinder. The displacement of a gas particle from its equilibrium position is plotted against x. At a point where the displacement curve crosses the x-axis with a steep negative slope, the local gas pressure is at its: (a) Absolute minimum (maximum rarefaction), (b) Absolute maximum (maximum compression), (c) Ambient atmospheric value, (d) Zero absolute value

2. A sound source moves at a constant speed u along a straight line past a stationary microphone. The frequency recorded by the microphone at the exact instant the source passes closest to it is: (a) Higher than the source frequency, (b) Lower than the source frequency, (c) Exactly equal to the source frequency, (d) Double the source frequency
3. An acoustic interferometer uses two paths to combine sound from a single source at a receiver. Path 1 is 2.0 m long and Path 2 can be varied. If the source frequency is 1700 Hz and the speed of sound is 340 m/s, the minimum non-zero path difference that causes complete destructive cancellation (silence) at the receiver is: (a) 10 cm, (b) 20 cm, (c) 5 cm, (d) 40 cm
4. A uniform string of length L and total mass M hangs vertically from a rigid ceiling. A wave pulse is generated at the bottom free end. As the pulse travels upwards, its speed: (a) Decreases because gravity pulls it down, (b) Increases because the tension increases towards the top, (c) Remains constant, (d) Drops to zero at the midpoint
5. A sound wave source of frequency f is moving at a speed equal to half the speed of sound ($v/2$) away from a stationary cliff. The frequency of the echo reflected from the cliff as heard by the source operator is: (a) $f/3$, (b) $2f/3$, (c) $f/2$, (d) $3f/2$
6. A sound wave travels through a gas mixture consisting of 1 mole of Helium and 1 mole of Neon. Within the Class 9 gas speed trends, if the temperature is kept constant, the speed of sound in this mixture compared to pure Helium gas at the same temperature is: (a) Slower because the average molecular mass of the mixture is higher, (b) Faster, (c) Exactly the same, (d) Zero
7. A localized pressure pulse is created in a long steel rod. The pulse takes time t_1 to travel the length of the rod. If the rod is heated uniformly, causing a small thermal expansion in length and a slight reduction in its structural elastic modulus, the new travel time t_2 will: (a) Be less than t_1 , (b) Be greater than t_1 , (c) Remain identical, (d) Depend on atmospheric pressure
8. A marine SONAR system emits a brief pulse containing two distinct frequencies, 50 kHz and 100 kHz. Due to microscopic bubbles and suspended particulate matter in seawater, the higher frequency wave suffers greater energy absorption. At a long distance, the returning echo profile will show: (a) A change in the pitch mix toward a lower virtual tone, (b) An increase in the speed of the 100 kHz wave, (c) A complete loss of both waves, (d) No change
9. A closed tube of length L contains an air column. A tuning fork is held at the open end. The air column is set into resonant vibration. If the wave pattern has a displacement node at the closed end and an antinode at the open end, the maximum possible wavelength of the sound wave that can cause this fundamental resonance is: (a) L , (b) $2L$, (c) $4L$, (d) $L/2$
10. A person stands at a distance of 15 m from a point source of sound. The sound intensity they experience is I . If they move to a new position 45 m away from the source, the new intensity will be: (a) $I/3$, (b) $I/9$, (c) $I/6$, (d) $3I$
11. A sound wave passes from a region of calm air into a region where a strong wind is blowing in the exact same direction as the wave propagation. The frequency observed by a stationary observer in the windy zone: (a) Increases, (b) Decreases, (c) Remains unchanged, (d) Becomes zero
12. The eardrum of a deep-sea diver has a surface area of 0.5 cm^2 . If the diver descends to a depth where the static water pressure is 2 atmospheres ($2 \times 10^5 \text{ Pa}$) and the Eustachian tube fails to open, the net static force pushing inward on the eardrum is: (a) 100 N, (b) 10 N, (c) 5 N, (d) 50 N
13. An explosion occurs on the surface of a deep lake. A sensor placed at the bottom of the lake records the arrival of the sound wave through the water. Another sensor placed at the same distance along the shore records the sound through the air. If the water path time is T , the air path time is closest to: (a) $4.4 T$, (b) $0.23 T$, (c) $2.2 T$, (d) T

14. A sound wave profile is non-sinusoidal, having sharp, abrupt pressure transitions (a saw-tooth wave form). This means the sound will be perceived by the human ear as having: (a) A very pure single pitch, (b) A harsh, rich, or noisy quality (timbre) due to many overtones, (c) No pitch at all, (d) Supersonic speed
15. A spherical sound wave spreads out uniformly from a point source in an ideal gas. The ratio of the particle displacement amplitude at a distance of 3 m to that at a distance of 9 m from the source is: (a) 1:3, (b) 3:1, (c) 9:1, (d) 1:9
16. A tuning fork of frequency f is sounded near the open top of a vertical glass tube filled with water. The water level is slowly lowered. The first loud resonance is heard when the air column length is 15 cm, and the second loud resonance is heard when the length is 47 cm. The wavelength of the sound wave in the air column is: (a) 32 cm, (b) 64 cm, (c) 16 cm, (d) 48 cm
17. A sound wave is traveling along a narrowing acoustic horn. As the cross-sectional area of the horn decreases, the energy density of the sound wave must increase. This causes the amplitude of the particle vibrations to: (a) Decrease, (b) Increase, (c) Stays constant, (d) Alternates to zero
18. An acoustic shield is made by sandwiching a layer of vacuum between two thin plates of glass. When a sound wave strikes the outer glass plate: (a) It passes through completely via radiation, (b) It is entirely blocked from passing through the vacuum layer via mechanical propagation, (c) The vacuum conducts the wave at a lower speed, (d) The wave turns into an electromagnetic wave
19. A sound source is moving at supersonic speed ($v_{\text{source}} = 2v_{\text{sound}}$) along a straight path. An observer stands at a perpendicular distance D from the line of motion. The observer will hear the sound of the source: (a) Continuously as it approaches, (b) Only after the source has already passed its closest point of approach, (c) Before the source reaches its closest point, (d) Never
20. A sound wave has a frequency of 1000 Hz and a speed of 340 m/s. The phase difference between the vibrations of two gas particles separated by a distance of 17 cm along the line of propagation is equal to: (a) A full cycle (360°), (b) A half cycle (180°), (c) A quarter cycle (90°), (d) Zero

Answer Key (Olympiad MCQs): 1-(b), 2-(c), 3-(a), 4-(b), 5-(b), 6-(a), 7-(b), 8-(a), 9-(c), 10-(b), 11-(c), 12-(b), 13-(a), 14-(b), 15-(b), 16-(b), 17-(b), 18-(b), 19-(b), 20-(b)

Subjective Questions (20 Items)

1. A uniform steel bar of length 10 m is struck axially at one end with a rapid pulse generator. The longitudinal wave pulse travels down the bar, reflects from the free far end, and returns to the input sensor. If the sensor records a round-trip time of 4 milliseconds, deduce the speed of the wave in the steel bar. Explain qualitatively how the free end reflection affects the particle displacement boundary condition.
2. An ambulance siren emits a sound of frequency f . The ambulance is driving at a constant speed towards a tall, rigid skyscraper wall. A stationary observer stands on the sidewalk between the ambulance and the wall. Analyze the complex sound profile heard by the observer, noting how the direct wave frequency compares to the frequency of the wave reflecting from the skyscraper wall.
3. Derive a generalized expression for the pressure variation within a longitudinal sound wave as a function of particle crowding (density variations). Explain why pressure peaks (compressions) correspond mathematically to points where the net particle displacement changes sign from positive to negative.
4. A deep-sea research vessel drops a heavy acoustic transceiver array into an oceanic trench. The speed of sound in seawater increases with depth due to changes in

hydrostatic pressure and temperature gradients. If the average speed of sound along the vertical column is given by a model, explain why the total travel time calculation of a SONAR pulse must integrate these variations, and show how a simple average speed can introduce mapping errors.

5. A closed organ pipe of length L and an open organ pipe of length L' are filled with the same gas. If both pipes are excited into their lowest fundamental resonant modes, find the ratio of their resonant wavelengths, and determine the relation between L and L' if they produce the same fundamental frequency.
6. Explain the mechanism of acoustic impedance matching inside the human ear. Specifically, address why sound waves traveling through the air would mostly reflect away upon hitting the dense fluid of the cochlea if the middle ear bones and the mechanical area advantage of the eardrum did not act as a transformer.
7. A specialized ultrasound transducer array used for industrial non-destructive testing operates at a frequency of 10 MHz. The probe scans a composite aerospace wing section. The wave speed in the composite layer is 3000 m/s. Calculate the smallest internal delamination flaw size (gap width) that can be resolved if the resolution limit requires the flaw to be at least half a wavelength wide.
8. A person stands at a distance D from a massive mountain wall. He fires a gun and hears the first echo after t_1 seconds. He walks a distance d directly toward the wall and fires the gun again, hearing the echo after t_2 seconds. Derive an algebraic expression for the speed of sound v solely in terms of d , t_1 , and t_2 .
9. An acoustic barrier is constructed using two parallel panels separated by an air gap. When a sound wave hits the first panel, part of it is reflected and part is transmitted into the air gap. The wave in the air gap then strikes the second panel. Explain how this double-boundary setup causes multiple internal reflections that suppress the total wave transmission into the quiet zone behind the barrier.
10. A high-precision tuning fork of frequency 440 Hz is sounded just above a vertical glass tube filled with water. The water level can be adjusted using a drainage tap. The first resonance is caught when the air column is 18.5 cm long, and the second occurs at 57.5 cm. Calculate the speed of sound from these observations and determine the end-correction value of the tube mouth.
11. Explain why the velocity of sound in a gas mixture depends on the ratio of the specific heats (γ) and the average molecular mass of the constituent gases. Use this trend to analyze why sound travels faster in methane gas (CH_4) than in oxygen gas (O_2) at the exact same temperature.
12. A sound source is placed at the focus of a parabolic acoustic reflector. The reflector directs the sound into a highly collated parallel beam that travels across a stadium. Explain why the intensity of this sound beam decreases much more slowly with distance compared to the intensity of an open, unshielded spherical sound wave.
13. A longitudinal wave travels along a horizontal spring. A marker at a specific point on the spring undergoes simple harmonic motion with a time period T . Sketch a series of snapshots showing the positions of the spring coils at intervals of $T/4$, and label the moving positions of the compression centers.
14. An industrial engine produces a loud noise with a total sound power output of W watts. Assuming the sound radiates uniformly in all directions as a spherical wave, derive an algebraic expression for the sound energy passing through a unit area per second (intensity) at a radial distance R from the engine core.
15. Why does the sound of a distant train whistle seem to fluctuate or change in intensity when a strong, gusty wind is blowing across the landscape? Discuss how wind speed profiles at different heights bend the sound paths (acoustic refraction).
16. A student uses a computer software program to generate two pure audio tones, Tone 1 at

1000 Hz and Tone 2 at 1004 Hz. When played simultaneously through a single loudspeaker, an observer hears a single pitch that rises and falls in loudness at a regular rate. Explain the physical mechanism behind this phenomenon (acoustic beats) within the Class 9 wave superimposition concept.

17. An aerospace jet flies at a supersonic speed along a horizontal path at a high altitude H . An observer on the ground hears the sonic boom exactly T seconds after the jet has passed directly overhead. Draw a neat geometric diagram showing the Mach cone angle, and set up the trigonometric relation linking H , T , the jet speed U , and the sound speed V .
18. A sound wave traveling through a liquid line strikes a block of rubber. The rubber block acts as an acoustic attenuator because its internal macromolecular structure undergoes cyclic viscoelastic deformation under the wave's pressure variations. Explain how this converts wave mechanical energy into thermal energy (heat).
19. A delicate scientific experiment requires a completely vibration-free environment. The laboratory room is isolated by mounting the entire floor assembly on heavy steel springs. Explain how this mechanical filter blocks high-frequency ground acoustic waves from entering the lab space by treating the floor as a heavy inertial mass.
20. A SONAR transducer array on a surface ship simultaneously tracks two targets moving along the seabed. Target A is at a horizontal distance X and sends an echo back in 2.0 seconds. Target B is at a horizontal distance $2X$ and sends an echo back in 3.5 seconds. If the sea floor is perfectly flat, calculate the deep water depth of the floor using coordinate geometry trends under a constant sound speed of 1500 m/s.