CBSE CLASS 9 SCIENCE

Chapter 11: Sound

Complete Concept & Question Bank

EXAM BOOSTER EDITION

SECTION 1: Chapter Overview

What is Sound?

Sound is a distinct form of energy that produces the dynamic sensation of hearing in our ears. It is generated via mechanical vibrations in objects and propagates through an elastic material medium as a series of mechanical waves.

How Sound is Produced and Managed

Vibrating bodies create localized kinetic disturbances in the surrounding medium. This energetic disturbance travels outward from the source, while the individual particles of the medium oscillate locally about their equilibrium positions.

Learning Outcomes

By the end of this chapter, you will be able to:

- Explain the micro-mechanisms behind sound production and wave propagation.
- Differentiate thoroughly between longitudinal and transverse mechanical waves.
- Define and calculate core wave characteristics: frequency, wavelength, time period, and amplitude.
- Analyze the physics of reflection: echoes, reverberation fields, and marine applications.
- Solve core mathematical applications using the fundamental wave equation.

SECTION 2: Important Concepts

1. Sound Propagation & Media Requirements

Sound waves are fundamentally classified as **mechanical waves** because they cannot travel through a vacuum; they strictly require a material medium (solid, liquid, or gas) containing physical particles to transmit energy.

> **Core Speed Invariance Rule**
>
> Sound travels fastest in dense solids, propagates slower in liquids, and moves slowest across loose gaseous media due to molecular proximity differences.

2. Longitudinal Waves vs Transverse Waves

Sound in air propagates purely as a **longitudinal wave**, meaning the individual particles of the medium oscillate back and forth parallel to the vector trajectory of wave energy movement.

- **Compression (High Pressure, High Density):** A region where medium particles are compressed closer together by the forward-moving vibration front.
- **Rarefaction (Low Pressure, Low Density):** A region where medium particles spread apart as the vibration front moves backward.

[Image of sound wave propagation showing compressions and rarefactions]

Figure 11.1: Longitudinal propagation layout detailing the matching cycles of particle compressions and rarefactions with pressure peaks.

3. Mathematical Wave Properties

- **Wavelength (λ):** The physical linear distance between two successive compressions or consecutive rarefactions. (Unit: metre).
- **Frequency (f):** The net number of complete acoustic oscillations or cycles executed per single second. Measured in Hertz (Hz), where $1\ Hz = 1\ cycle/s$. Frequency dictates the **pitch** of the sound.
- **Time Period (T):** The absolute time required to complete one full particle oscillation cycle. Derived simply as $T = 1 / f$.
- **Amplitude (A):** The maximum spatial displacement of an oscillating particle away from its central mean equilibrium line. Amplitude dictates the perceived **loudness**.

4. Reflection, Echoes, and Reverberations

Echo: The distinct repetition of a sound resulting from acoustic reflection off a hard, distant boundary surface. To perceive a clear echo, the reflected sound wave must reach the human ear after an absolute minimum time delay of $0.1\ s$ (the duration of human auditory persistence). At standard temperature conditions (22°C), this requires a minimum boundary path distance of exactly **17.2 metres**.

Reverberation: The undesirable prolongation or blurring of sound in closed spaces caused by rapid, repeated internal reflection cycles. It is minimized by covering walls with sound-absorbing materials like coarse acoustic plaster, heavy curtains, or compressed fibreboards.

5. Human Auditory Range & Sonics

- **Infrasonic Range:** Frequencies below $20\ Hz$ (produced during earthquakes or by elephants).
- **Audible Spectrum:** The natural human hearing window spanning $20\ Hz\ to\ 20{,}000\ Hz$.

- **Ultrasonic Range:** High-frequency sound waves exceeding $20{,}000\ Hz$ (utilized extensively by bats for echolocation, marine sonar rigs, and diagnostic medical imaging).

6. Marine SONAR Functionality

SONAR (Sound Navigation And Ranging) devices calculate underwater depth coordinates by transmitting ultrasonic bursts downwards. The pulse strikes the seafloor and reflects back up. By tracking the total round-trip time loop (t), distance is accurately calculated:

$$d = (v \times t) / 2$$

7. Anatomy of the Human Ear

[Image of the structure of the human ear]

Figure 11.2: Anatomical layout of the Outer Ear (Pinna), Middle Ear (Ossicles), and Inner Ear (Cochlea).

- **Outer Ear:** The *Pinna* collects ambient waves, focusing them down the auditory canal to vibrate the tympanic membrane (eardrum).
- **Middle Ear:** Three tiny interconnected bones—the *hammer, anvil, and stirrup*—mechanically amplify the eardrum's physical vibrations.
- **Inner Ear:** The fluid-filled, spiral-shaped *Cochlea* translates these amplified mechanical pressures into precise electrical nerve impulses, which are sent via the auditory nerve to the brain.

SECTION 3: Important Formula Sheet

Formula	Physical Description	Standard SI Unit
$v = f \times \lambda$	The Fundamental Wave Equation	m/s
$f = 1 / T$	Frequency vs Time Period relationship	Hertz (Hz)
$d = (v \times t) / 2$	Echo Path & SONAR Mapping Equation	metre (m)

SECTION 4: Top 30 Frequently Repeated Questions

Very Short Answer Type (1 Mark)

Q1. Why are sound waves characterized specifically as mechanical waves?

Ans: Because they absolutely require a physical material medium (solid, liquid, or gas) to facilitate propagation via particle-to-particle kinetic collisions.

Q2. What fundamental wave property governs acoustic pitch?

Ans: Frequency. Higher oscillation frequencies correspond directly to higher perceived pitch levels.

Q3. State the total auditory range of a healthy human ear.

Ans: $20\ Hz$ to $20{,}000\ Hz$.

Short Answer Type (2-3 Marks)

Q13. Differentiate clearly between longitudinal and transverse mechanical waves.

Ans: In a longitudinal wave, the particles of the medium vibrate back and forth parallel to the direction of wave travel (e.g., sound waves in air). In a transverse wave, particles vibrate perpendicularly to the direction of wave propagation (e.g., waves on a plucked string or light waves).

SECTION 5: Top 20 Most Expected Questions

Q4. Explain the operational mechanics of SONAR systems in mapping marine depth coordinates.

Ans: A transmitter installed on a ship sends a burst of high-frequency ultrasonic waves downward through the water. These waves travel in straight lines until they hit the seabed or an underwater target, reflecting back as an echo. A receiver catches the reflected signal and logs the time delay (t). Knowing the speed of sound in seawater (v), technicians map depth using: $d = (v \times t) / 2$.

Q8. An acoustic wave maintains an operating frequency of 2 kHz with a tracking wavelength of 35 cm. Compute how long it requires to clear a linear distance of 1.5 km.

Ans: Convert to standard SI units: $f = 2\ kHz = 2000\ Hz$; $\lambda = 35\ cm = 0.35\ m$.

Calculate wave velocity first: $v = f \times \lambda = 2000 \times 0.35 = 700\ m/s$.

Target distance to clear: $s = 1.5\ km = 1500\ m$.

Time equation: $t = s / v = 1500 / 700 = 2.14\ seconds$.

SECTION 7: Most Important Numericals

Q3. A wave profile travels at a measured velocity of 339 m/s with a recorded wavelength scale of 1.5 cm. Compute its operational frequency. Is this signal audible to humans?

Ans: Given: $v = 339\ m/s$; $\lambda = 1.5\ cm = 0.015\ m$.

Using the wave equation: $f = v / \lambda = 339 / 0.015 = 22{,}600\ Hz$ (or $22.6\ kHz$).

Because this frequency exceeds the maximum human audibility threshold of $20{,}000\ Hz$, it is classified as ultrasonic and is completely inaudible to human ears.

Q4. A person claps near a steep rocky cliff face and registers a clear echo exactly 2 seconds later. If the local speed of sound in air is 346 m/s, calculate the distance to the cliff.

Ans: The sound wave travels to the cliff face and back, covering the distance twice ($2d$) in $t = 2\ s$.

Using the echo equation: $d = (v \times t) / 2 = (346 \times 2) / 2 = 346\ metres$.

SECTION 12: One-Day Before Exam Quick Sheet

Top 3 Mistakes to Avoid on the Exam

1. **Echo Equation Trap:** Remember to divide by 2 ($d = vt / 2$) when a question asks for the distance to a cliff or the seabed. Do not use $d = vt$ unless you are calculating the total distance traveled by the sound wave itself.
2. **Wavelength Conversions:** Double-check that wavelengths given in centimetres are converted into standard metres ($\div 100$) before pairing them with velocity parameters.
3. **Anatomy Mapping:** Ensure you label the three bones of the middle ear (hammer, anvil, stirrup) in their correct functional order. Their primary role is mechanical amplification, not signal conversion.