CLASS 9 SCIENCE

CHAPTER 10

SOUND WAVES: CHARACTERISTICS AND APPLICATIONS

Detailed • Colorful • Exam-Friendly Study Notes

Production • Propagation • Wave Characteristics • Speed • Human Hearing • Reflection • Echo • Reverberation • Ultrasound • SONAR

CHAPTER FOCUS	Sound is produced by vibrating objects and travels through a material medium as a longitudinal mechanical wave. The chapter explains compressions, rarefactions, wavelength, frequency, amplitude, intensity, speed, perception and applications such as echo, echolocation and SONAR.

1. Chapter Roadmap

Section	Key learning
10.1 Production of Sound	Vibration produces sound; sources include strings, membranes, air columns and vocal cords.
10.1.1 Tuning fork	A vibrating tuning fork demonstrates sound production.
10.2 Propagation	Sound travels through solids, liquids and gases.
Sound needs a medium	Sound cannot travel through vacuum.
10.3 Sound waves	Compressions and rarefactions form a longitudinal wave.
10.4 Energy	Sound transfers energy through the medium.
10.5 Graphical representation	Density varies periodically in space/time.
10.6 Characteristics	λ, frequency, time period, amplitude, intensity and speed.
Human perception	Pitch, loudness, audible range and timbre.
10.7 Reflection	Reflection, echo and reverberation.
10.8 Applications	Infrasound, ultrasound, echolocation and SONAR.

MEMORY MAP	Vibration → Medium → Compressions/Rarefactions → Sound Wave → Energy → λ, ν, T, amplitude → Speed → Pitch/Loudness → Reflection → Applications

2. Production of Sound

Sound is produced by vibrations. Vibration means periodic to-and-fro motion (oscillation) of an object.

Rubber-band activity

- Pluck a stretched rubber band: sound is heard while the band vibrates.
- When the vibration stops, the sound stops.
- Changing the tension changes the sound produced.
- The vibrating object producing sound is called the source of sound.

Examples

- Strings vibrate in stringed instruments.
- Membranes vibrate in drums.
- Air columns vibrate in instruments such as a bansuri.
- Human vocal cords vibrate during speech and singing.

HUMAN VOICE	Human sound is produced by vibration of vocal cords inside the larynx. The tongue, lips, mouth and nasal cavity help convert the sound into speech or music.

3. Tuning Fork

A tuning fork is a U-shaped metal bar with a stem. Its two sides are called prongs or tines. Striking a prong gently on a soft rubber pad makes it vibrate.

What the experiment shows

- A vibrating tuning fork produces an audible sound.
- A vibrating prong touching water produces visible waves on the water surface.
- These observations support the conclusion that sound is produced by vibrating objects.

Vibrating object $\rightarrow$ Sound

The vibration is the source of the sound.

EXAM POINT	If an object stops vibrating, it stops producing sound. This is a fundamental idea of the chapter.

4. Propagation of Sound

Sound travels from a source to a listener through a material medium. It can propagate through solids, liquids and gases.

Medium	Sound travels?	Evidence/idea
Solid	Yes	Sound can be heard through a desk or table.
Liquid	Yes	Sound from submerged spoons can reach the listener.
Gas	Yes	Ordinary sound travels through air.
Vacuum	No	Vacuum bell-jar experiment shows sound fades away.

Vacuum bell-jar experiment

- As air is pumped out, the bell is still seen vibrating but the sound becomes fainter.
- Near vacuum $\rightarrow$ almost no sound is heard.
- When air is allowed back in, the sound returns.
- Therefore sound requires a material medium: solid, liquid or gas.

Sound cannot propagate through vacuum.

Outer space is near-vacuum, so astronauts use communication devices in spacesuits.

5. Sound Waves: Compressions & Rarefactions

A sound wave is a disturbance consisting of alternating compressions and rarefactions propagating through a medium. The particles do not travel with the wave; they vibrate about their mean positions.

Term	Meaning
Compression (C)	High-density region where particles are closer together.
Rarefaction (R)	Low-density region where particles are more spread out.
Propagation	Direction in which the disturbance travels.
Particle motion	Back-and-forth oscillation about mean position.

C — R — C — R — C — R

Alternating high- and low-density regions travel through the medium.

VERY IMPORTANT

The disturbance and energy propagate through the medium. Individual particles only oscillate around their mean positions.

6. Mechanical & Longitudinal Nature

Sound is a mechanical wave because it needs a material medium. It is longitudinal because particles vibrate parallel to the direction of propagation.

Wave	Particle vibration	Medium
Sound wave	Parallel to propagation	Required
Longitudinal wave	Parallel to propagation	Mechanical examples require a medium
Transverse wave	Perpendicular to propagation	Light can travel through vacuum

Sound = Mechanical + Longitudinal

A high-priority definition for examinations.

Sound can spread in all directions from a point-like source, producing spherical wavefronts in the surrounding medium.

7. Sound Carries Energy

A loud sound can make a stretched sheet vibrate and cause grains placed on it to jump. This demonstrates that sound carries energy.

- The vibrating source transfers energy to the surrounding medium.
- Particles vibrate and collide with neighbouring particles.
- These interactions transfer energy through the medium.
- The particles themselves do not flow from the source to the listener.

MICROPHONE & SPEAKER	A microphone converts sound energy into electrical energy. A speaker converts an electrical signal into vibration and then sound.

Energy, not matter, is transferred by the propagating sound wave.

8. Graphical Representation

At a fixed instant, the density of the medium varies periodically with distance from the source.

- Compression corresponds to density above the average.
- Rarefaction corresponds to density below the average.
- The highest point on a density graph is the crest.
- The lowest point is the trough.
- Corresponding repeating points give the wavelength.

One complete oscillation = maximum → minimum → maximum

The reverse sequence also represents one complete oscillation.

GRAPH TIP	For a density–distance graph, mark C at high-density regions and R at low-density regions. The C-to-C or R-to-R distance is one wavelength.

9. Wavelength, Frequency & Time Period

Quantity	Symbol	Meaning	SI unit
Wavelength	λ	Distance between consecutive crests or troughs.	m
Frequency	ν	Number of density oscillations per second.	Hz
Time period	T	Time for one complete density oscillation.	s

$$\nu = 1/T \text{ and } T = 1/\nu$$

Frequency and time period are inversely related.

Solved example

10 oscillations in 2 s → ν = 5 Hz; T = 0.2 s

Frequency = oscillations/time; time period = 1/frequency.

Remember

- Higher frequency → shorter time period.
- Lower frequency → longer time period.

10. Amplitude & Intensity

Amplitude is the maximum change in air density in a compression or rarefaction compared with average density.

Larger amplitude	Smaller amplitude
Larger density variation	Smaller density variation
More energy carried	Less energy carried
Generally perceived as louder	Generally perceived as softer

Intensity = sound energy passing through unit area per unit time

Intensity is a measurable physical quantity.

Why intensity decreases with distance

- Sound spreads over a larger area as it moves away from the source.
- The same energy is distributed over a larger area.
- Therefore intensity decreases with distance.

11. Speed of Sound

$$v = \lambda/T = \lambda\nu$$

Speed = wavelength × frequency.

Dependence on medium

- Fastest in solids, slower in liquids and slowest in gases.
- The chapter notes sound is about 4–5 times faster in water and typically 15–20 times faster in solids than in air.
- Temperature and humidity also affect the speed in air.

Medium at about 15 °C	Approx. speed
Steel	5000 m s^{-1}
Water	1500 m s^{-1}
Air	340 m s^{-1}

AIR VALUES

Dry air: about 331 m s^{-1} at 0 °C and nearly 344 m s^{-1} at 22 °C. In ordinary media, changing frequency changes wavelength while speed remains determined mainly by the medium.

12. Important Numericals

Example 1 — Wavelength

$$v = 344 \text{ m s}^{-1},\ \nu = 20 \text{ Hz} \rightarrow \lambda = v/\nu = 17.2 \text{ m}$$

At 20 kHz, $\lambda = 0.0172$ m = 1.72 cm.

Example 2 — Lightning and thunder

$$v = 340 \text{ m s}^{-1},\ t = 5 \text{ s} \rightarrow d = vt = 1700 \text{ m} = 1.7 \text{ km}$$

Light reaches us much faster than sound.

Example 3 — Steel

$$v = 5000 \text{ m s}^{-1},\ \lambda = 50 \text{ m} \rightarrow \nu = 100 \text{ Hz};\ T = 0.01 \text{ s}$$

Use $v = \lambda\nu$ and $T = 1/\nu$.

NUMERICAL METHOD	Known values → formula → substitution → calculation → final answer with unit.

13. Human Perception of Sound

Pitch is how frequency is perceived. High-frequency sounds generally have high pitch; low-frequency sounds have low pitch.

Human audible range ≈ 20 Hz to 20 kHz

The range varies between people and tends to decrease with age.

Range	Name	Examples/notes
Below 20 Hz	Infrasonic	Elephants can detect infrasound.
20 Hz–20 kHz	Audible	Human hearing range.
Above 20 kHz	Ultrasonic	Dogs, cats, bats and dolphins can detect ultrasound.

Loudness

- Humans perceive amplitude as loudness.
- Larger amplitude is generally heard as louder.
- Loudness decreases as we move farther from the source.
- Loudness is commonly expressed in decibels (dB).

14. Timbre, Tone & Musical Sound

- **Tone:** sound of a single frequency, such as from a tuning fork or whistling.
- **Musical note:** may contain a fundamental frequency plus higher-frequency overtones.
- **Timbre:** quality that makes different instruments sound different even at the same note and loudness.
- **Octave:** interval between two notes whose fundamental frequencies have a 2:1 ratio, e.g. 200 Hz and 400 Hz.

INDIAN MUSIC CONNECTION	The chapter notes that instruments such as the sarangi, sitar and veena can enrich sound through combinations of frequencies. Tabla and mridangam use a central black patch (syaahi) that alters vibration and contributes to tonal control.

C. V. Raman

The chapter highlights Sir C. V. Raman's contributions to acoustics, including studies of Indian percussion instruments such as tabla and mridangam.

15. Reflection of Sound

Sound waves can bounce off obstacles such as solids or liquids. This is reflection of sound.

Angle of incidence = Angle of reflection

The incident direction, reflected direction and normal lie in the same plane.

Surface	Effect
Hard and smooth	Strong reflection; echoes clearer
Soft	Absorbs more sound
Rough	Scatters sound in different directions

Echo

An echo is reflected sound heard again after the original sound, such as near a mountain, cliff or long corridor.

For a clear echo: time gap ≥ 0.1 s; minimum reflector distance ≈ 17 m at 340 m s^{-1}

Total round-trip distance in 0.1 s = 34 m; one-way distance = 17 m.

16. Echo Numericals & Reverberation

Echo numerical

Echo after 0.5 s; $v = 340\ m\ s^{-1} \rightarrow d = vt/2 = 85\ m$

Divide by 2 because sound travels to the wall and back.

Reverberation

Multiple reflections in a hall or auditorium can make sound persist after the source stops. This is reverberation.

Reverberation: successive reflections arrive with time differences < 0.05 s

Controlled reverberation can improve speech and music; excessive reverberation can make sound garbled.

- Sound-absorbing panels reduce unwanted reflections.
- Upholstered chairs, curtains and soft porous surfaces reduce reverberation.
- Auditoriums are designed to provide desirable acoustic conditions.

INDIAN EXAMPLE	The chapter mentions the Whispering Gallery of Gol Gumbaz, Bijapur, where the dome's architecture allows faint whispers to be heard multiple times.

17. Infrasonic & Ultrasonic Applications

Type	Frequency	Applications
Infrasonic	< 20 Hz	Earthquakes, volcanic eruptions and severe storms
Audible	20 Hz–20 kHz	Human hearing
Ultrasonic	> 20 kHz	Ultrasonography, kidney-stone treatment, cleaning, welding, defect detection and object location

Ultrasound applications

- Ultrasonography images internal organs without surgery.
- Ultrasound can break kidney stones into smaller pieces.
- Ultrasonic welding is used in industry.
- Ultrasonic cleaning can clean delicate machine parts.
- Ultrasonic testing can detect defects inside metal blocks.

18. Echolocation & SONAR

Echolocation means locating objects using reflected sound waves. Bats emit short ultrasonic bursts and sense echoes from objects and prey.

Echolocation = sending sound + receiving reflection + interpreting the echo

Bats, dolphins, whales and some birds use echolocation for navigation or hunting.

SONAR — Sound Navigation and Ranging

- SONAR sends ultrasonic waves into water.
- Reflected waves are received and analysed.
- The distance, direction and speed of underwater objects can be determined.
- Uses include locating submarines, shipwrecks and measuring underwater depth.

Solved example

Return time = 0.90 s; seawater speed = 1530 m s^{-1} → d = 1530×0.90/2 = 688.5 m

The measured time is the complete out-and-back journey.

19. Formula & Unit Sheet

Quantity / situation	Formula / unit
Frequency	ν = oscillations/time; unit Hz
Time period	$T = 1/\nu$; unit s
Wavelength	$\lambda = v/\nu$; unit m
Wave speed	$v = \lambda\nu$; unit m s■^{1}
Echo distance	$d = vt/2$
SONAR distance	$d = vt/2$
Intensity	Sound energy / (area × time)
Audible range	20 Hz–20 kHz
Infrasound	$\nu < 20$ Hz
Ultrasound	$\nu > 20$ kHz

GOLDEN RULE FOR ECHO/SONAR	The measured time is normally for the sound to travel to the reflecting object and return. Therefore divide vt by 2 to obtain the one-way distance.

20. Common Exam Mistakes

Incorrect idea	Correct idea
Sound travels through vacuum.	Sound requires a material medium.
Air particles travel from source to ear.	Particles oscillate; disturbance and energy propagate.
Sound is transverse.	Sound is longitudinal and mechanical.
Amplitude determines pitch.	Frequency determines pitch; amplitude is linked to loudness.
Higher frequency means higher speed in the same medium.	For ordinary media, speed is determined mainly by the medium.
Echo distance = vt.	Echo distance = vt/2 for round-trip time.
Infrasound is above 20 kHz.	Infrasound is below 20 Hz.
Intensity and loudness are identical.	Intensity is measurable; loudness is a perception.
Reverberation is just one reflection.	Reverberation results from multiple reflections.

MCQ CLUE

If asked why sound is a mechanical wave, the key statement is: **sound needs a medium to propagate.**

21. NCERT-Style Exam Practice

1. What observation supports the mechanical nature of sound?

Sound needs a medium to propagate.

2. If 20 compressions pass a point in 4 s, find frequency.

$$\nu = 20/4 = 5 \text{ Hz}$$

3. A sound wave has $\lambda = 3.44$ m and $v = 344$ m s^{-1}. Find T.

$$\nu = 344/3.44 = 100 \text{ Hz}; \; T = 0.01 \text{ s}$$

4. A sonar echo returns after 5 s in seawater at 1525 m s^{-1}. Find depth.

$$d = 1525 \times 5/2 = 3812.5 \text{ m}$$

5. A reflected sound reaches the ear 0.05 s after emission. Echo or reverberation?

It is not a distinct echo because the time gap is below 0.1 s; such persistence is associated with reverberation.

22. Final Chapter-at-a-Glance

Concept	One-line revision
Production	Sound is produced by vibrating objects.
Medium	Sound needs a material medium.
Nature	Sound is a longitudinal mechanical wave.
Propagation	Compressions and rarefactions travel through the medium.
Particles	Particles oscillate around mean positions.
Energy	Sound transfers energy through the medium.
Wavelength	Distance between consecutive corresponding wave points.
Frequency	Oscillations per second.
Time period	Time for one oscillation.
Amplitude	Maximum density variation from average.
Intensity	Sound energy through unit area per unit time.
Speed	$v = \lambda\nu$; fastest in solids, slowest in gases.
Pitch	Generally increases with frequency.
Loudness	Generally increases with amplitude.
Reflection	Sound can bounce from surfaces.
Echo	Distinct reflected sound; clear separation needs ≥ 0.1 s.
Reverberation	Persistence due to multiple reflections.
Infrasound	Below 20 Hz.
Ultrasound	Above 20 kHz.
Echolocation	Object location using reflected sound.
SONAR	Uses reflected ultrasound for underwater ranging.

FINAL MEMORY MAP	VIBRATION → SOURCE → MEDIUM → C/R → LONGITUDINAL WAVE → ENERGY → λ, ν, T, AMPLITUDE → SPEED → PITCH/LOUDNESS → REFLECTION → ECHO/REVERBERATION → ULTRASOUND/SONAR

Source basis: NCERT/CBSE Class 9 Science *Exploration*, Chapter 10 “Sound Waves: Characteristics and Applications”. The notes follow the chapter's terminology, definitions, examples and revision points. ■filecite■turn38file0■L257-L280■ ■filecite■turn39file0■L33-L71■