What is Sound?

Sound is a form of energy produced by vibrations that travels through a medium as a longitudinal mechanical wave.

Communication:
Voice box (larynx) vibrations.

Medicine:
Ultrasound mapping (frequencies > 20 kHz).

Navigation:
SONAR depth tracking in ships.

Production → Propagation → Characteristics → Reflection (SONAR)

Wave Motion & The Pendulum

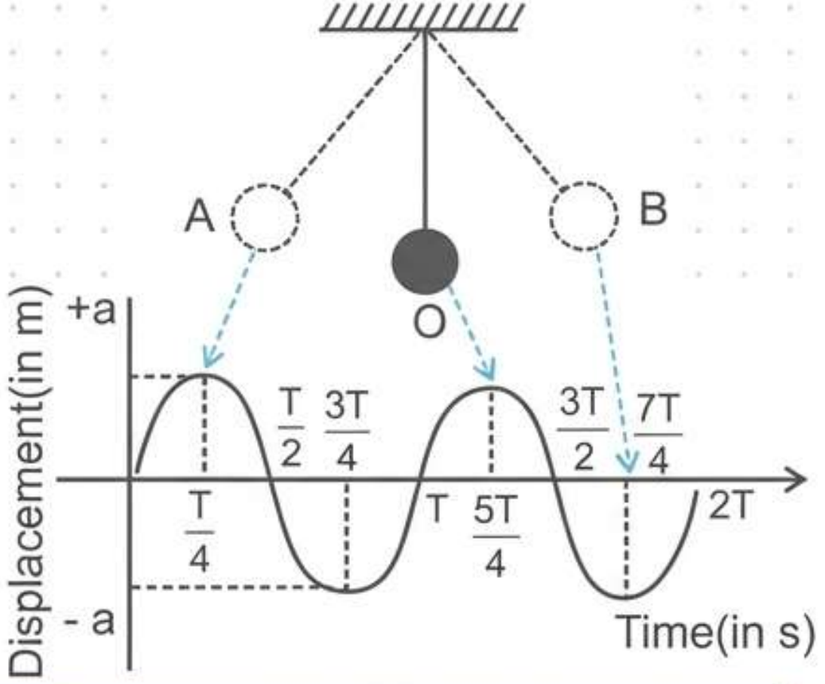
How Energy Travels Without Transporting Matter

Wave Propagation in Water

Particles do not travel with the wave. They only vibrate in place. The energy moves forward!

Oscillation = Vibration: The repetitive back-and-forth motion performed about a central point (Mean Position 'O').

Connecting the Pendulum to the Wave



Connecting the Pendulum to the Wave

- **Mean Position (O):** Displacement is zero.
- **Extreme Positions (A, B):** Maximum displacement (+a or -a). This is the **Amplitude.**
- **One Complete Oscillation:** Produces one full wave loop on a graph.

The Classification of Waves

WAVES

Branch 1: Based on Medium

Mechanical Waves

Require a **medium** to travel (e.g., solid, liquid, gas).

(SOUND IS HERE)

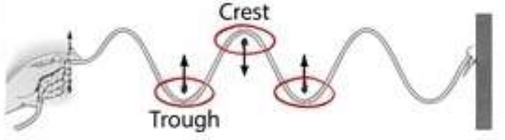
Non-Mechanical Waves

Can travel through a vacuum without a medium (e.g., Light, X-rays).

Energy transfer!

Branch 2: Based on Nature of Propagation

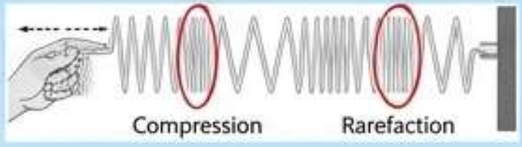
Transverse Waves



Particles vibrate perpendicular to the direction of wave travel.
Form **Crests** (highs) and **Troughs** (lows).
Example: Water waves, Light.

Longitudinal Waves

(SOUND IS HERE)

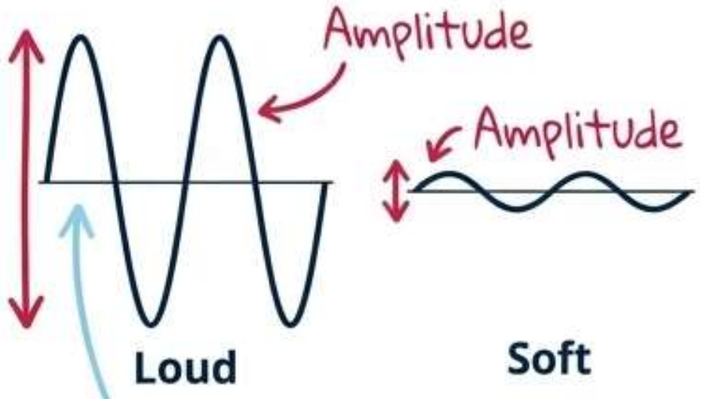


Particles vibrate parallel to the direction of wave travel.
Form **Compressions** (crowded) and **Rarefactions** (spread out).

Vibration is key!

The Three Characteristics of Sound

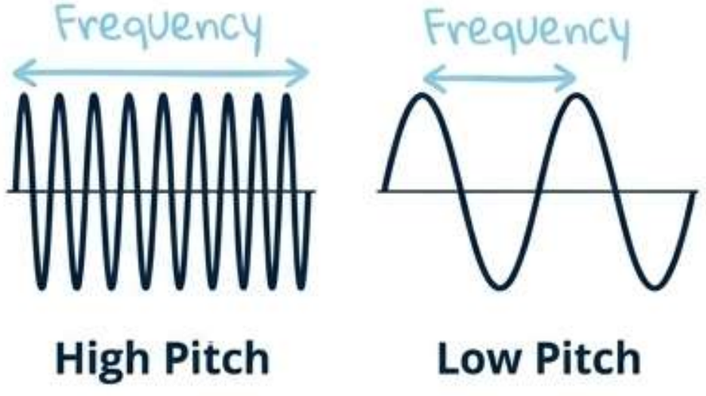
Loudness



Depends on: Amplitude (Mainly), Area of vibrating body, and distance from source.

Key Fact: The greater the amplitude, the louder the sound.

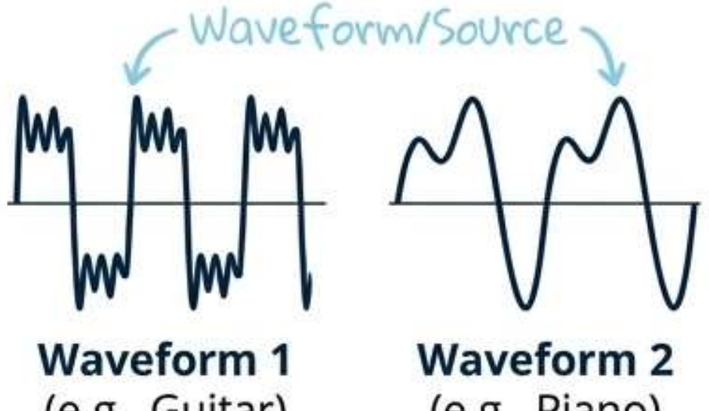
Pitch



Depends on: Frequency.

Key Fact: Pitch determines the shrillness of a sound. (Subjective property based on frequency).

Quality (Timber)



Depends on: The waveform/source.

Key Fact: Allows us to distinguish between two sounds (like a guitar vs. a piano) even if they have the exact same pitch and loudness.

Infrasonic: < 20 Hz
(Elephants, earthquakes)

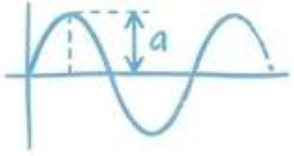
Audible: 20 Hz to 20,000 Hz
(Humans)

Ultrasonic: > 20,000 Hz
(Dogs, bats, medical ultrasound)

Key Formulas & Definitions

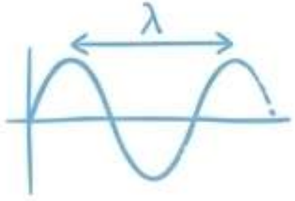
Amplitude (a)

Maximum displacement of particles from the mean position (upwards or downwards).



Wavelength (λ)

The distance between two successive crests or two successive compressions.



Time Period (T)

The time required to complete exactly one oscillation.

$$T = 1 / f$$
(measured in seconds)

Crucial Formula!

Frequency (f or η)

The number of oscillations or vibrations made by a particle in exactly one second.

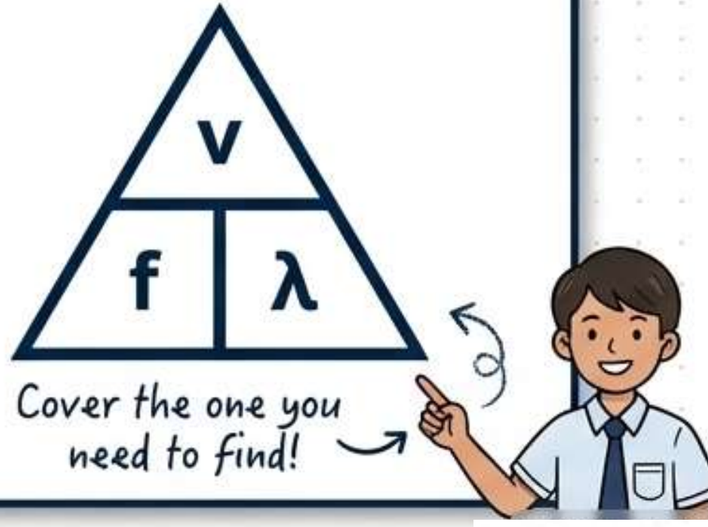
Reciprocal!

$$f = \frac{1}{T}$$ **(measured in Hertz, Hz)**

Wave Velocity (v)

The speed with which the wave propagates through a medium.

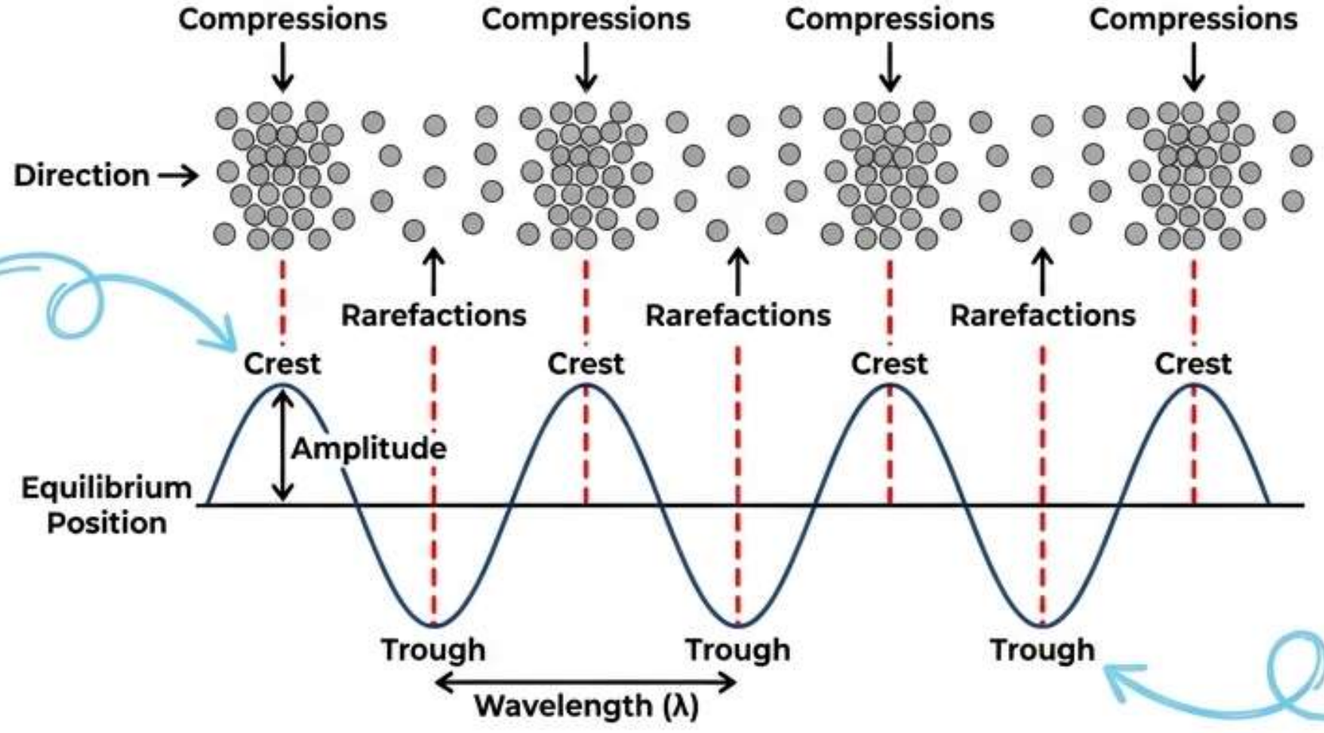
$$v = f \times \lambda$$



The Invisible Made Visible: Graphing Sound

Translating Air Pressure to a Graph

Compressions -> Crests:
Compressions are high-pressure, high-density regions where particles are closest together. On a graph, these are plotted as Crests (upward maximum displacement).



Rarefactions -> Troughs:
Rarefactions are low-pressure, low-density regions where particles are spread apart.
On a graph, these are plotted as Troughs (downward maximum displacement).

Even though sound is a longitudinal wave in reality, we graph it as a transverse wave to easily measure amplitude and wavelength!

Most Asked Board Questions

Q1: Calculate the frequency and wavelength of a wave whose time period is 0.001 sec and speed is 200 m/s.

Step 1: **$f = 1/T$** = 1/0.001 = 1000 Hz.

Step 2: **$v = f \times \lambda \rightarrow \lambda = v/f$** = 200/1000 = 0.2 m.

Examiner's Eye:
Always write the units (Hz and m) at the end!

Q2: Why can we easily hear an approaching train by putting our ear to the railway track, long before we hear it through the air?

Answer: Sound travels fastest in solids and slowest in gases. The speed of sound in steel (≈ 5100 m/s) is vastly greater than in air (≈ 330 m/s).

Examiner's Eye:
Keyword required: "Speed in Solid > Liquid > Gas".

Q3: Differentiate between Pitch and Loudness.

Pitch: Depends on frequency and determines shrillness.

Loudness: Depends on amplitude and determines the physical intensity of the sound.

Common Mistakes & Exam Traps

Danger/Warning

Trap 1: The Traveling Particle Illusion

Mistake: Thinking that when ~~sound travels across a room,~~ the ~~air particles~~ travel across the room with it.

Focus on this!

Truth: ✅
Particles NEVER travel with the wave. They only vibrate back and forth in their mean position. **Only the energy travels!**

Danger/Warning

Trap 2: SONAR / Echo Math Errors

Mistake: Using the formula Distance = Speed × Time directly for reflection problems.

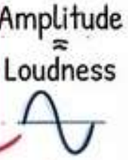
Truth: ✅
In an echo or SONAR, sound travels to the object and back. **You must divide by 2!**
Use **Distance = (v × t) / 2.**

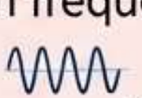
Danger/Warning

Trap 3: Pitch vs. Loudness Confusion

Mistake: Assuming a ~~loud~~ sound is a ~~high-pitched~~ sound.

Truth: ✅ They are **completely independent**. A lion's **roar** is very **loud** (high amplitude) but **low pitch** (low frequency). A **mosquito**'s buzz is **quiet** (low amplitude) but **high pitch** (high frequency).





Frequency ≈ Pitch

Rapid Revision Sheet

Zone 1 Speed of Sound

Solid > Liquid > Gas

Steel (5100 m/s) > Water (1450 m/s) > Air (330 m/s at 0°C)

Note: Speed is independent of amplitude/frequency. Needs a medium! No vacuum!

Zone 2 The Formula Hub

$f = \frac{1}{T}$ → $v = f \times \lambda$

SONAR Depth: $d = \frac{v \times t}{2}$

Zone 3 The Big Three Pairs

Loudness	⟺	Amplitude
Pitch	⟺	Frequency
Quality	⟺	Waveform shape

Zone 4 Audible Range

< 20 Hz (Infrasonic)	20 Hz - 20,000 Hz (Audible)	> 20 kHz (Ultrasonic)

Human Range

Answer Writing Framework

The 2-Mark Structure (The Quick Hit)

- **Format:** Definition + Formula (or Unit).

Example: Define frequency.
-> The number of oscillations per second.
Formula: f = 1/T.
S.I. Unit: Hertz (Hz).

The 3-Mark Structure (The Matrix)

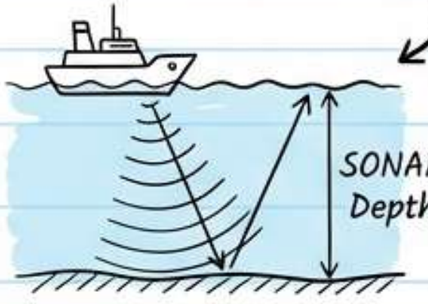
Format: 3 distinct bullet points **OR** a T-chart with 3 points of comparison.

Transverse	Longitudinal
Direction of Vibration (Perpendicular vs Parallel)	Parallel
Formation (Crests & Troughs	Compressions & Rarefactions)
Example (Light/Water	Example (Sound/Seismic-P)

The 5-Mark Structure (The Masterpiece)

Format: Intro -> Step-by-Step Mechanism -> Formula/Diagram.

Example: Explain how SONAR works.
-> Define SONAR.
-> List steps (Transmitter sends ultrasonic wave -> hits bottom -> echoes back to receiver).
-> State the formula d = (v × t)/2.
-> Draw a quick labeled diagram...



SOUND

Propagation & Range

Speed: Solid > Liquid > Gas

Infrasonic (<20 Hz) / **Audible** / **Ultrasonic** (>20,000 Hz)

Characteristics

- **Loudness** (Amplitude)

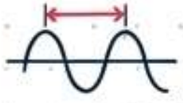
- **Pitch** (Frequency)

- **Quality/Timber** (Wave shape)

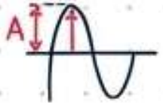
Waves (Terminology)

- **Time Period** (time for 1 osc.)

- **Frequency** (vib. per sec)



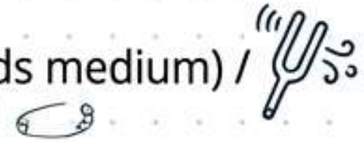
- **Wavelength** (dist. between crests)



- **Amplitude** (max displacement)

Classification

- **Mechanical** (needs medium) / **Non-Mechanical**



- **Transverse** (crests/troughs) / **Longitudinal** (compressions/rarefactions)

Memory Tricks & Mnemonics

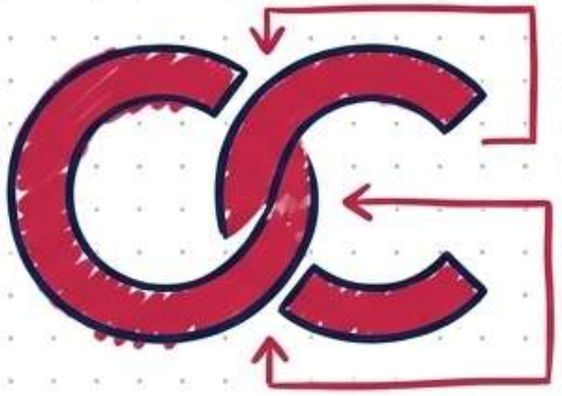
Trick 1: L.A.P. (The Runner)

Mnemonic: Run a L.A.P.

Loudness = Amplitude |
Pitch = Frequency.

Trick 2: C.C. (The Translators)

Mnemonic: **The Double C**



Compressions = Crests.
(Which means Rarefactions must equal Troughs!)

Trick 3: S.L.G. (The Speed Hierarchy)

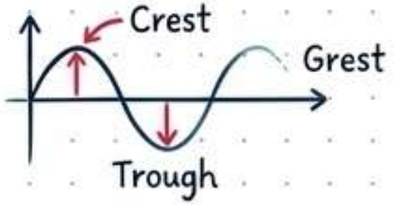
Mnemonic: Sound Loves Going fast... but only in solids.

Solid > Liquid > Gas.

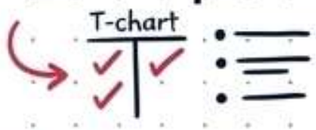
Final Exam Checklist

Are you ready? Check these off:

- [ ] **Concepts Understood:** I can explain how energy moves without particles moving.
- [ ] **Formulas Memorized:** I know $v = f \times \lambda$ and the SONAR division-by-two rule.
- [ ] **Visuals Mastered:** I can draw and label a transverse wave (Crest, Trough, Amplitude, Wavelength).



- [ ] **Answers Structured:** I know how to use bullet points and T-charts for maximum board marks.



You've put in the hard work. Take a deep breath.
You are ready for the exam!