



EXPANDED STUDY MATERIAL

CHAPTER 10

Sound Waves: Characteristics and Applications

Production, propagation, wave properties, hearing and applications

INSIDE THIS BOOKLET

Detailed theory notes • Key definitions • Formula and concept boxes • Worked examples • One full page of practice questions • Answer key at the end

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Learn clearly. Practise consistently. Improve every rank.

Use these notes alongside your prescribed textbook and classroom teaching. Scientific terms and examples are explained in student-friendly language for revision and practice.

THEORY NOTES

1. How sound is produced and travels

Sound is produced when an object vibrates. A vibrating tuning fork, vocal cord, drum skin or loudspeaker makes nearby particles of a medium vibrate. Those particles pass the disturbance to neighbouring particles, allowing sound energy to travel through the medium.

Sound is a mechanical wave, so it requires a material medium such as air, water or a solid. It cannot travel through a perfect vacuum because there are no particles to transmit the vibration. Astronauts outside a spacecraft cannot hear ordinary sound directly through space; they communicate using radio systems.

In air, sound usually travels as a longitudinal wave. Air particles oscillate back and forth parallel to the direction in which the wave travels. Compressions are regions where particles are closer together and pressure is higher; rarefactions are regions where particles are farther apart and pressure is lower. The particles do not travel all the way from the source to the listener; the disturbance and energy propagate.

2. Wave quantities

Amplitude is the maximum displacement of a vibrating particle from its mean position. For a given source and medium, greater amplitude is generally perceived as a louder sound. Loudness is also affected by frequency, distance and the sensitivity of the ear, so it is not determined by amplitude alone.

Frequency (f) is the number of complete vibrations or cycles per second. Its SI unit is hertz (Hz). A high-frequency sound is generally perceived as high-pitched; a low-frequency sound is low-pitched. Pitch and loudness are different: a sound can be loud and low-pitched or quiet and high-pitched.

Time period (T) is the time taken for one complete vibration. Frequency and time period are related by $f = 1/T$ and $T = 1/f$. If a source makes 100 vibrations in one second, its frequency is 100 Hz and its time period is 0.01 s.

Wavelength (λ) is the distance between two successive points in the same phase, such as compression to compression.

Wave speed (v) is the distance travelled by the disturbance per second. The relationship is $v = f\lambda$. For a given medium and condition, sound speed is approximately fixed, so higher frequency corresponds to shorter wavelength.

Wave relation

$v = f\lambda$ and $f = 1/T$. Check that units are consistent before substituting values.

3. Speed of sound and factors affecting it

Sound travels at different speeds in different media. It generally travels fastest in solids, slower in liquids and slowest in gases because the particles and elastic properties of each medium differ. The exact speed depends on the material and conditions.

In air at ordinary room temperature, sound speed is approximately 343 m/s; school problems may use 340 m/s. Sound speed in air increases as temperature rises. Wind can change the effective speed relative to the ground because the moving air carries the sound disturbance.

To calculate distance, use distance = speed $\times$ time. For echoes, the sound travels to the reflecting surface and back, so the total path is twice the one-way distance. If an echo returns after time t , distance to the wall = $vt/2$.

4. Audible sound, ultrasound and infrasound

The usual human audible range is approximately 20 Hz to 20,000 Hz (20 kHz), though the range varies with age and individual hearing. Frequencies below 20 Hz are called **infrasound**; frequencies above 20 kHz are called **ultrasound**.

Some animals detect sounds outside the human range. Bats use ultrasonic echoes to navigate and locate prey. Elephants and some whales can communicate using low-frequency sounds that travel long distances. Such examples show that hearing ability depends on the species and the environment.

Ultrasound has practical uses because high-frequency waves can reflect from boundaries and small structures. Medical ultrasound imaging helps examine organs and developing babies without using ionising radiation. Industrial ultrasound can detect cracks in materials, and ultrasonic cleaners can remove dirt from small objects.

5. Reflection of sound, echoes and reverberation

Sound can be reflected when it strikes a surface. A clearly heard **echo** occurs when reflected sound arrives sufficiently later than the original sound; in many ordinary conditions, the time gap must be about 0.1 s or more for the ear to distinguish it clearly. Hard, large surfaces reflect sound well; soft, porous materials absorb more sound.

For a distinct echo in air, using sound speed 340 m/s and a 0.1 s time gap, the sound travels about 34 m in total. The reflecting surface is therefore roughly 17 m away because the sound travels to the surface and back. The exact minimum

distance depends on conditions and the listener.

Reverberation is the persistence of sound caused by multiple reflections in a room or hall. Too much reverberation makes speech unclear. Curtains, acoustic panels, carpets and cushioned seats absorb sound and can improve clarity. Concert halls are designed to balance useful reflection with absorption.

SONAR uses sound pulses and their echoes to detect underwater objects or measure depth. If sound speed in water is known and the round-trip time is measured, the distance is calculated by $d = vt/2$.

6. Noise pollution and hearing safety

Noise is unwanted or disturbing sound. Long exposure to loud sound can damage sensitive structures in the inner ear and cause temporary or permanent hearing loss. Noise pollution can also disturb sleep, concentration and communication, and may increase stress.

Noise can be reduced at the source, along its path or at the listener. Examples include maintaining machines, using silencers, limiting unnecessary honking, planting vegetation where suitable, fitting sound-absorbing materials and wearing appropriate hearing protection in noisy workplaces. Turning down headphone volume and taking listening breaks are useful habits.

Sound intensity decreases with distance from a source, but moving away is not always sufficient if the sound is very loud or exposure is prolonged. Hearing protection should be selected for the noise level and used correctly.

7. Solved examples

Example 1 — Frequency: A source makes 240 vibrations in 2 s. $f = 240/2 = \mathbf{120\text{ Hz}}$.

Example 2 — Time period: If $f = 50\text{ Hz}$, $T = 1/f = 1/50 = \mathbf{0.02\text{ s}}$.

Example 3 — Wavelength: Sound travels at 340 m/s and has frequency 170 Hz. $\lambda = v/f = 340/170 = \mathbf{2\text{ m}}$.

Example 4 — Echo: An echo returns after 0.8 s in air at 340 m/s. Distance = $vt/2 = 340 \times 0.8 / 2 = \mathbf{136\text{ m}}$.

QUICK REVISION SUMMARY

Key ideas to retain

Sound is a mechanical wave and needs a medium. $f = 1/T$; $v = f\lambda$. Pitch relates mainly to frequency; loudness relates to amplitude/intensity. Echoes and SONAR use reflection; noise exposure can damage hearing.

PRACTICE QUESTIONS

Attempt all questions before checking the answer key. Show working for numerical questions and write full sentences for explanation questions.

1. Explain why sound cannot travel through a vacuum.
2. Define amplitude, frequency, time period and wavelength.
3. A tuning fork makes 500 vibrations in 5 seconds. Calculate its frequency and time period.
4. A sound wave has frequency 250 Hz and speed 340 m/s. Find its wavelength.
5. Why is sound generally faster in solids than in gases?
6. What is the difference between pitch and loudness?
7. Distinguish between infrasound, audible sound and ultrasound.
8. An echo is heard 1.2 s after a shout. If sound speed is 340 m/s, how far away is the reflecting surface?
9. Explain the difference between an echo and reverberation.
10. Describe two applications of ultrasound.
11. How does SONAR determine the distance to an underwater object?
12. Why are curtains and acoustic panels used in halls?
13. State three measures to reduce noise pollution.
14. Can astronauts hear a metal tool clanking directly through the vacuum of space? Explain.
15. A wave has wavelength 0.5 m and frequency 680 Hz. Calculate its speed.

Before you submit

Check calculations, include units where appropriate, define important terms clearly and support explanations with examples.

ANSWER KEY

Use the answers to check your understanding. For explanation questions, equivalent scientifically correct wording is acceptable.

1. Sound is a mechanical wave and needs particles to transmit vibrations; a vacuum has no material particles.
2. Amplitude: maximum displacement; frequency: cycles per second; time period: time per cycle; wavelength: distance between successive points in the same phase.
3. $f = 500/5 = 100 \text{ Hz}$; $T = 1/100 = 0.01 \text{ s}$.
4. $\lambda = v/f = 340/250 = 1.36 \text{ m}$.
5. Particles in solids are strongly coupled and transmit mechanical disturbances rapidly; actual speed depends on material properties.
6. Pitch is mainly related to frequency; loudness is related to amplitude/intensity and hearing conditions.
7. Infrasound: below 20 Hz; audible: about 20 Hz–20 kHz; ultrasound: above 20 kHz.
8. $d = vt/2 = 340 \times 1.2 / 2 = 204 \text{ m}$.
9. Echo is a distinct reflected sound heard separately; reverberation is persistence caused by many closely spaced reflections.
10. Medical imaging; detecting cracks; ultrasonic cleaning; depth or object detection are acceptable.
11. It sends a pulse and measures round-trip echo time; distance = speed in water $\times$ time / 2.
12. They absorb some sound, reducing excessive reflections and improving speech clarity.
13. Maintain machinery, use silencers, avoid unnecessary honking, limit loudspeaker volume, use sound barriers or hearing protection.
14. No, not directly through vacuum; they need radio communication or a solid/air path for sound.
15. $v = f\lambda = 680 \times 0.5 = 340 \text{ m/s}$.

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Revise the theory, practise without looking at the answers, and revisit any question you could not explain in your own words.

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