Sound

(a) describe the production of sound by vibrating sources

(b) describe the longitudinal nature of sound waves in terms of the processes of compression and rarefaction

(c) explain that a medium is required in order to transmit sound waves and that the speed of sound differs in air, liquids and solids

(d) describe a direct method for the determination of the speed of sound in air and make the necessary calculation

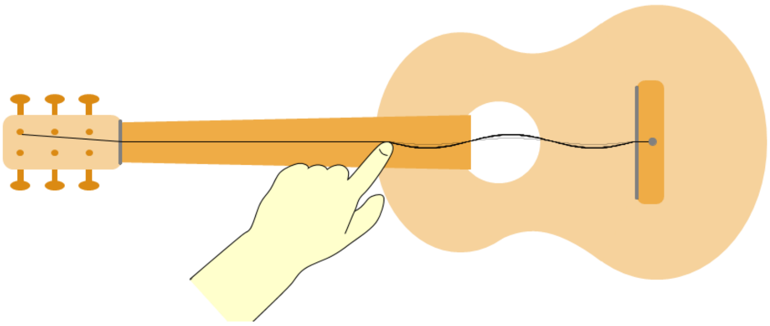
(e) relate loudness of a sound wave to its amplitude and pitch to its frequency

(f) describe how the reflection of sound may produce an echo, and how this may be used for measuring distances

(g) define *ultrasound* and describe one use of ultrasound, e.g. quality control and pre-natal scanning

Production and transmission of sound

- Sound is **produced** by **transverse vibrations of a source** (e.g. drum skin or guitar string)
- Sound energy is **transmitted** when mechanical vibrations are set up in the medium around the vibrating source (air, water, glass etc)
- The **direction of vibration** of the medium is **parallel** to the direction in which the sound energy travels

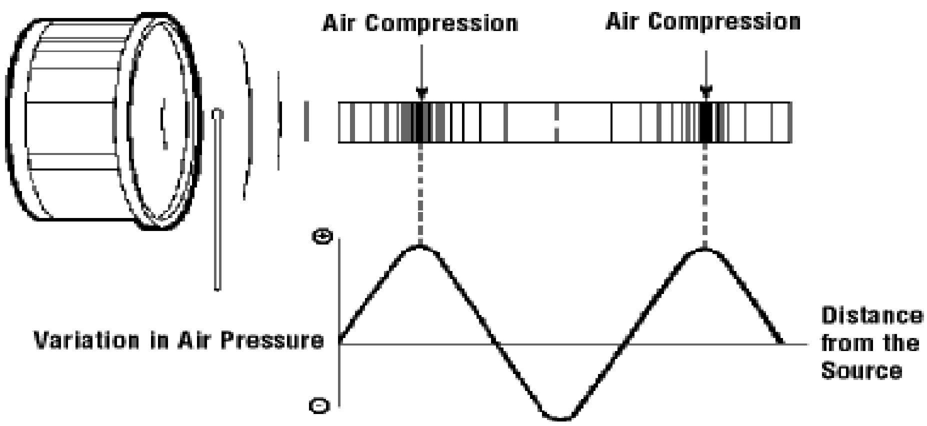


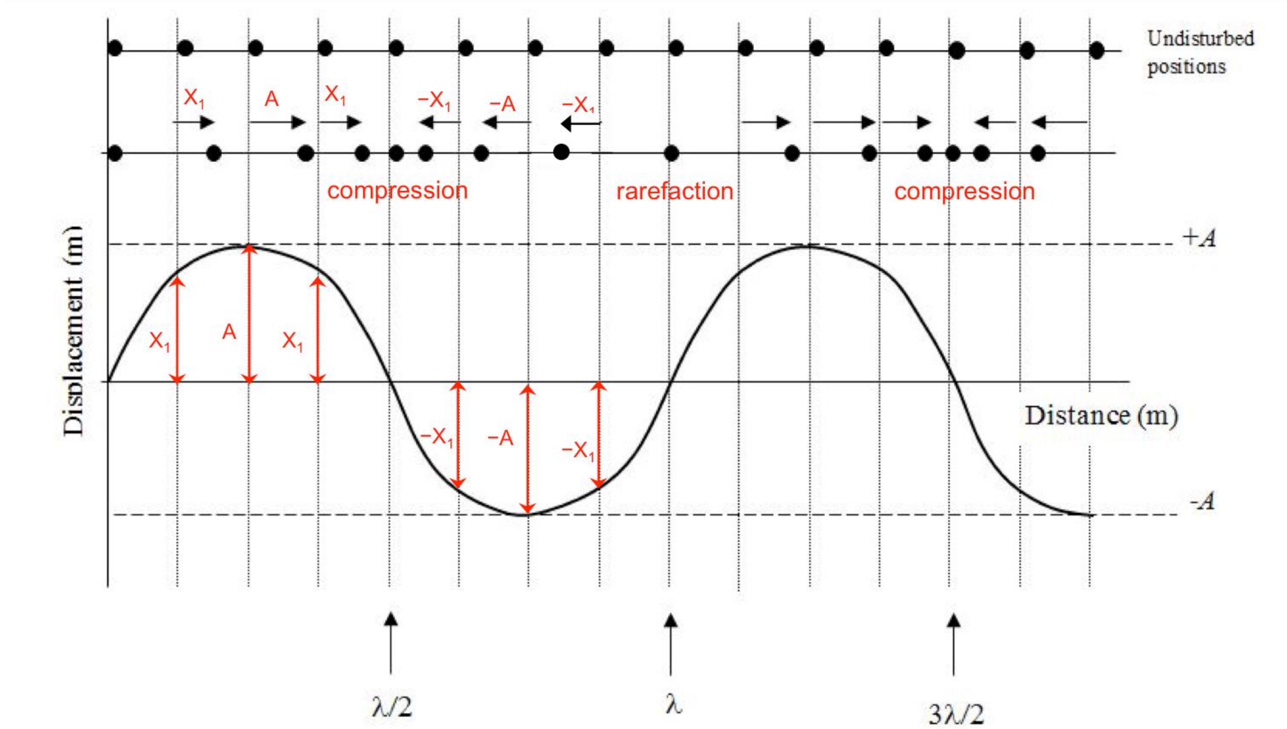
- The speed of the **wave** on the guitar string depends on the **tension** in the string, the **thickness and length** of the string. It is **NOT** the speed of sound in air.

- Typical speed of sound in air = 343 m/s at standard temperature and pressure

Longitudinal nature of sound (transmission of sound in air)

- When a source (like a drum skin or guitar string) vibrates, it causes air particles near it to vibrate
- Air particles move forward and backward repeatedly according to the frequency at which the source vibrates.
- Where air particles are pushed close together, a region of **compression** where **air pressure** is **higher is set up**
- **Where air particles are farther apart, a region** of **rarefaction,** where **air pressure** is **lower** than atmospheric pressure is set up.
- **The distance from one compression (or rarefaction) to the next compression (or rarefaction) is one wavelength λ**
- **The time taken for a complete wave to form is the period T**
- **Frequency f refers to the number of complete sound waves produced in 1 second.**
- **The wave equation $v = f\lambda$ applies**

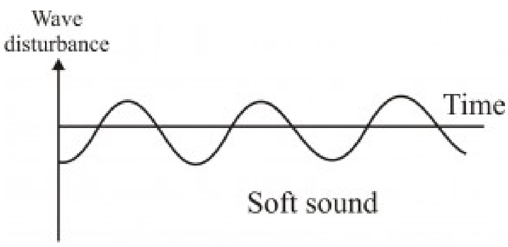


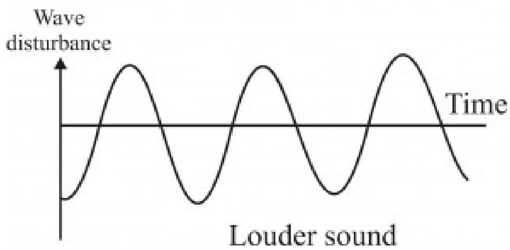


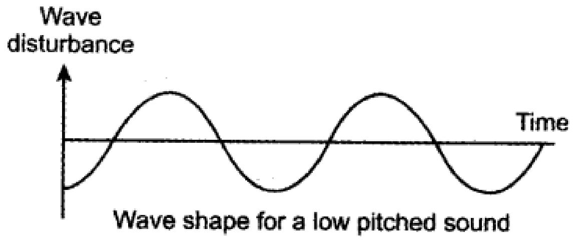
A = amplitude, the maximum distance each particle moves from the equilibrium distance

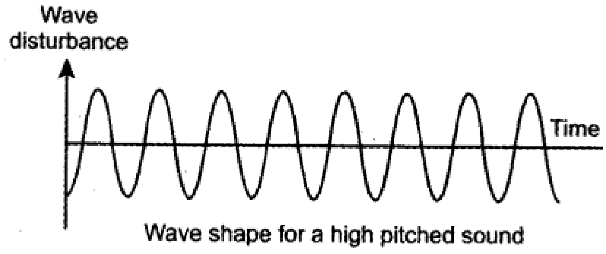
Loudness and pitch of sound

- Loudness of a sound is related to the amount of **energy** in a sound wave. The larger the **amplitude**, the larger the amount of **energy** being transmitted and the **louder** is the sound.
- The **pitch** is related to the **number of complete waves produced in 1 second** or the **frequency** of the sound.





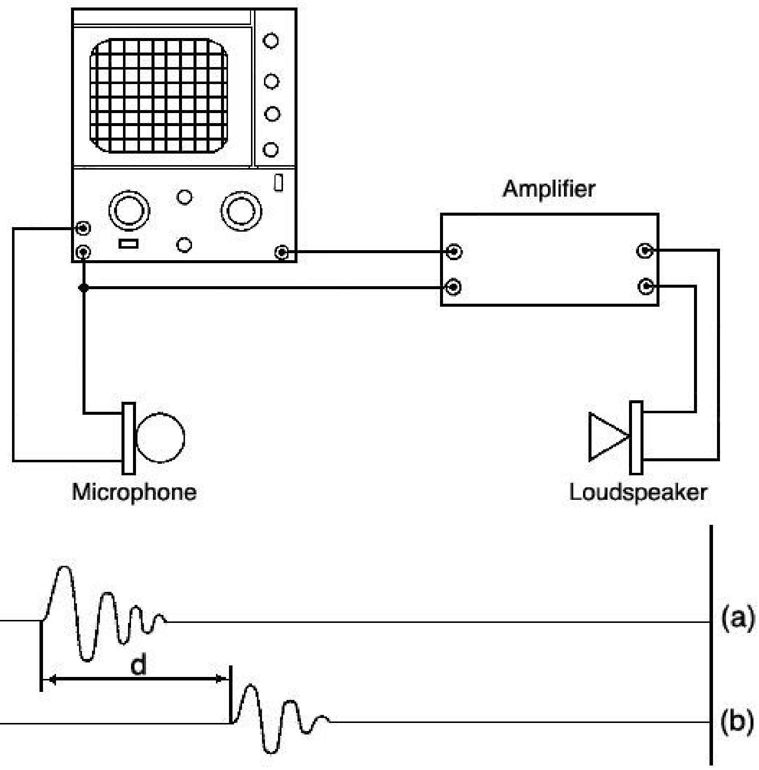




Speed of sound in solid, liquid and gas

- Sound travels fastest in solid, followed by liquid and gas.
- This is due to the spacing between particles.
- Particles in a **solid** are **closely packed** hence they **collide more frequently** compared to liquids and gases. Therefore **sound travels fastest** in solids.

Determining speed of sound (direct method)
Method 1



- Connect the loudspeaker to the display
- Move the microphone about 2.0 m from the loudspeaker and connect it to the display.
- Trace (a) corresponds to the signal from the loudspeaker.
- Trace (b) corresponds to the signal picked up by the microphone.
- The time interval between the 2 signals is **d**
- The speed of sound is calculated using **speed = 2.0 m/time d**

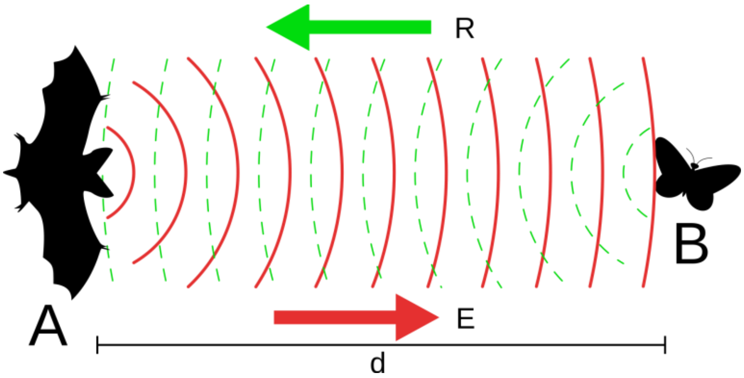
Method 2

- Person A and B stand 200 m apart.
- Person A fires a starting pistol.
- Person B starts a stopwatch when he sees the smoke from the pistol and stops the pistol when he hears the sound.
- **Speed of sound = 200 m/ time taken**

- Assumption = time taken by light to travel from starting pistol to B is negligible compared to the time taken by sound to travel the same distance (or time taken by light to travel from starting pistol to recorder is negligible as speed of light is much higher than speed of sound)
- To **eliminate the effect of wind**, repeat the procedure with person B firing the starting pistol now and use the **average of the time recorded to calculate the speed**

Echo

- Sound is able to reflect off surfaces and this is used by bats in **echolocation** to determine the exact location of prey or the submarines to detect underwater targets
- When the bat gets nearer to its prey, it increases the frequency at which pulses are sent. This allows the bat to determine the location of its prey with greater accuracy.
- **Sonar** (Sound Navigation and Ranging) – passive (receive only) and active (send and receive)
- Radio waves can be used for the same purpose (**Radar** – Radio detection and Ranging)



Ultrasound and Uses of ultrasound

- Human audible range = 20 Hz to 20 000 Hz
- Below 20 Hz = infrasound
- Ultrasound is sound with frequency above the human audible range of 20000 Hz
- Advantages
    - travel **slower than light** – signals can be **displayed**
    - Able to penetrate opaque objects

Ultrasonic imaging	Monitor growth of foetus. High frequency sound wave that bounces off the surface of a denser object Ultrasound gel is used to ensure a tight bond between the transducer and the skin so that the waves transmit directly to the tissues under the skin
Ultrasonic cleaning	Cavitation bubbles produced by high frequency sound waves in a cleaning liquid produce a high force on surfaces when they burst. The force is used to remove contaminants from hard to reach surfaces
Detect flaws in materials	A high frequency ultrasonic wave, which propagates through a medium, and when there is a crack in the path of a wave, part of the energy will be reflected from the flaw surface.

6 A technician uses pulses of ultrasound to detect imperfections in a sample of steel.

The speed of ultrasound in steel is 5 200 m/s.

Fig. 6.1 shows the pulses of ultrasound transmitted into steel when the ultrasound transmitter and receiver is placed at position X, Y and Z.

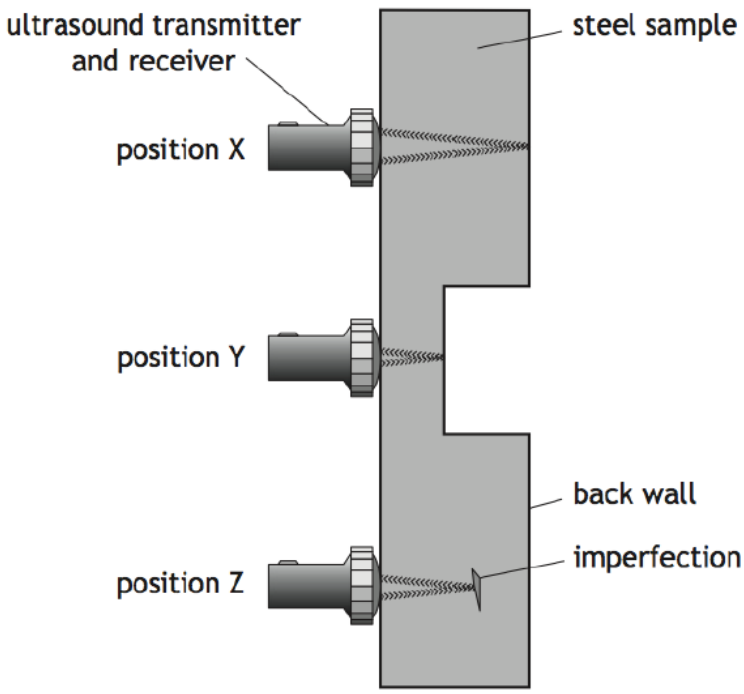


Fig. 6.1

(a) Explain how sound energy is transferred through the steel sample without transferring matter.

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.... [2]

(b) Fig. 6.2 shows the time between the pulses being transmitted and received.
The pulse being transmitted at t = 0 s is **not** drawn on Fig. 6.2.
The pulse being received when at position X and at position Y are both drawn on the same graph on Fig. 6.2.

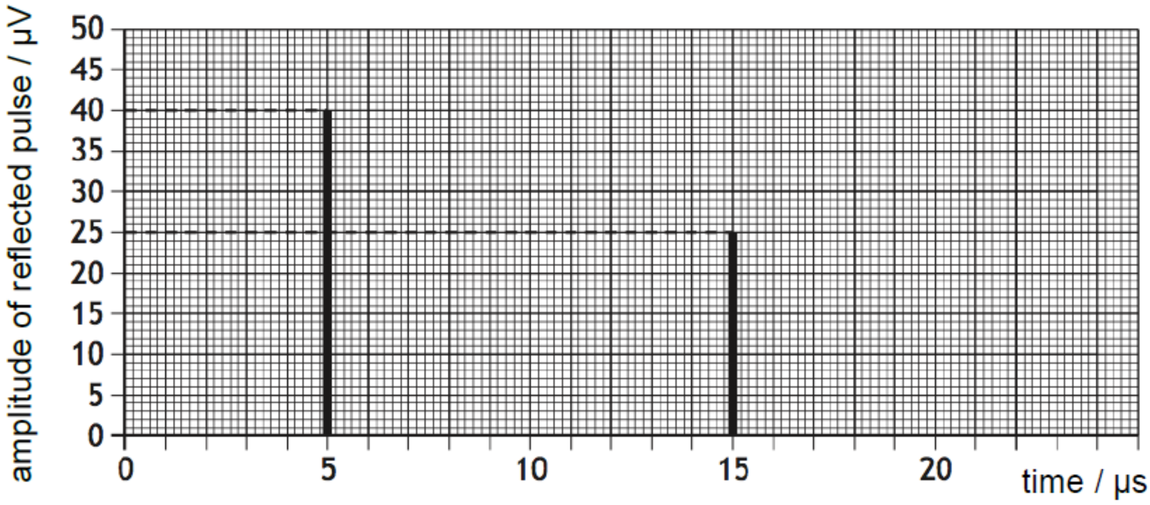

Fig. 6.2

(i) State the time taken between the pulse being transmitted and received at position X.

.... [1]

(ii) Calculate the thickness of the steel sample at position X.

thickness = ... [2]

(c) On Fig. 6.2, draw a line to show the reflected pulse at position Z. [1]

(d) Another application of ultrasound is to determine the depth of the sea.

Explain the difference in the speed of sound in steel and that in seawater.

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.... [1]