16 Transfer of Sound Energy through Vibrations

Content

Learning Outcomes

Candidate should be able to:

Knowledge, Understanding and Application

(a) explain that sounds are produced due to interactions between molecules of a medium caused by a vibrating source

(b) recognise that sound transfers energy and that it takes different lengths of time to travel from one point to another through different media

(c) *identify sounds of different pitch and relate the pitch to their frequencies

(d) outline how the ear detects sounds in terms of the vibrations of the eardrum and ear bones, and the subsequent interpretation of sound by the brain

Skills and Processes

(a) infer that the loudness of sounds can be changed by changing the size of vibrations and *pitch by the frequency

Ethics and Attitudes

(a) recognise the importance of sound in our society (e.g. for communication, music for pleasure, ultrasound in medicine) and the adverse effect of noise in our environment

(b) demonstrate precision and accuracy in making measurements (taking into consideration parallax errors)

16.1 Sound production by vibrating sources

Sound

- Sound is a **wave** and is normally associated with our sense of hearing.
- Sound is produced by **vibrating** sources in a medium, such as air, water or a piece of string.

Example

① A tuning fork, a violin string and a loudspeaker cone can produce sound as they are sources that are in the state of vibration.

- Sound is important to us as it allows us to be aware of the surrounding, such as a thunder indicates an approaching storm.
- Sound is used as means of communication. Animals communicate with each other using various sound pitches. Humans developed sophisticated communication of ideas and emotions using music.
- Sound is also used in navigation, industrial, medical and scientific applications.

Examples

① Bats emit ultrasonic sound as they fly. The sound waves bounce off obstacles in front of the bats, allowing them to fly around the obstacles.

② Ultrasound is used in airports to look into luggage for banned items. It is also used by industries for cleaning jewelleries.

③ Ultrasound with frequency above 20,000 Hz is used in hospitals to observe the foetus of a pregnant mother, or detect signs of tumour in the body.

④ Exploration ships transmit sound to the ocean bed using a sonar, and use the reflected sound waves to create a map of the ocean floor.

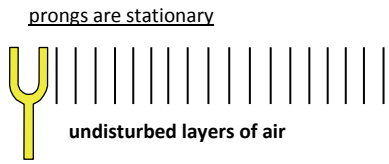
16.2 Sound travel in medium

How does Sound travel

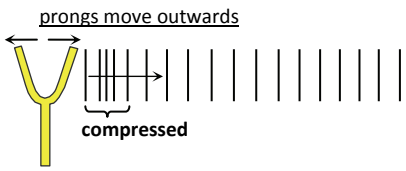
- Sound is caused by **vibration** of **matter**.
- Sound travels through a **medium**. The medium can be air, water, glass, etc. Sound **cannot** travel through vacuum.

Example

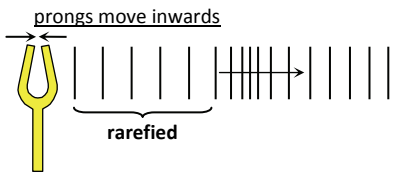
- Vibration in a tuning fork produces disturbances in the surrounding air. When the prongs' movement is outwards, the prongs push the surrounding air particles away, creating a local compression.



- This disturbance of air particles is then passed from particle to particle by collisions, causing the local compression to move outwardly.



- When the prongs' movement is inwards, it creates an area with few air particles.



- Pressure differences cause the air particles to rush back into the region again. This periodic to-and-fro movement of the prongs will create alternating regions of plentiful particles and few particles.

- The sound waves travel **outward parallel** to the direction of the vibrations.
- Sound is a form of **kinetic energy**, as it involves the movement of particles.
- Sound energy can be **transferred** from one point to another through different media.

Speed of sound

- The speed of sound varies in different medium:
  - Air – 343 m/s.
  - Water – 1440 m/s
  - Glass – 4500 m/s
- Hence, the speed of sound is **slowest** in gases, **faster** in liquids and **fastest** in solids.

Did you know?

You can estimate the distance of a lightning, by count the number of seconds that pass between a flash of lightning and the crack of thunder that follows it, then divide that number by three to get the distance in kilometre.

16.3 Loudness, pitch and frequency

Characteristics of Sound

- A sound can be characterized by its **loudness**, **pitch** and **frequency**.
- A sound is described as musical if the pitch and vibrations are **controlled**.
- Noises are sounds in which the vibrations and pitch are **non-periodic** and **uncontrolled**.

Loudness

- It is easy to distinguish between loud and soft sounds.
- The loudness of the sound depends on how big is the **vibration** of the matter in the medium. The bigger the vibration, the louder is the sound.

  Example

  ① The chime of a bell in a clock tower can be heard from hundreds of metres away, while the ringing of an alarm clock can only be heard tens of metres away.

- The loudness of sound is measured in decibels (dB).
- Prolonged exposure to sound level higher than 100 dB can lead to hearing loss.

Pitch

- Pitch of a sound can be described as **high** (sharp), like the sound of a violin, or **low**, like the sound of a bass drum. The physical quantity that determines pitch is the **frequency**.
- The higher the frequency, the higher is the pitch.
- Pitch is usually used to describe the general frequency of a sound, e.g. in music, or a bird's chirp.

Frequency

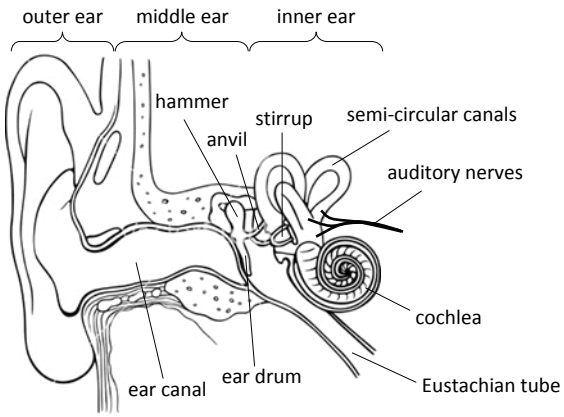
- The frequency of a sound is the **number of vibrations** the matter in a medium makes per second.
- The frequency of a sound is measured in **Hertz** (Hz). One Hertz represents one vibration per second.
- The frequency of a sound determines its pitch.

- Human ears generally can hear sound frequencies of between 20 Hz and 20,000 Hz.

Did you know?

Dogs have a hearing range of 40 Hz ~ 60,000 Hz. Hence we cannot hear a dog whistle, which gives out sounds at 23,000 to 54,000 kHz.

How the ear detects Sound



- Sound waves enter the ear canal and make the ear drum vibrate.
- This moves the tiny chain of bones – hammer, anvil and stirrup in the middle ear, and also amplifies the vibrations.
- The stirrup in this chain transfers the vibrations to the cochlea and makes the fluid in the cochlea move.
- The fluid movement then triggers a response in the auditory nerves which send the signal to the brain.
- The signal is then interpreted by the brain.

16.4 Worked examples

Example 1

A tuning fork, a violin string and a loudspeaker cone are producing sounds. This is because they are all in a state of

(A) Compression

(B) Expansion

(C) Rotation

(D) Vibration

Solution:

(D) The vibrating sources are all in the state of vibration

Example 2

Vibrating prongs of a tuning fork produces sound that we can hear. Why we don't hear anything from vibration of our hands?

Solution:

The lowest audible frequency range for human ear is from 20 Hz. In order to hear a sound, we must vibrate our hand at least 20 times within a second. A tuning fork can vibrate 250 times in a second (i.e., 250 Hz). That's why the tuning fork is heard but not the waving hand. (ans)

Example 3

Four different whistles, when blown, emit pure notes with the frequencies shown below:

0.1 kHz 1 kHz 10 kHz 100 kHz

How many of the frequencies are above the normal audible range for humans?

Solution:

Audible range for human ear is from 0.02 kHz to 20 kHz. Hence, only the sound emitted by the whistle of frequency 100 kHz cannot be heard.

Example 4

Which of the following is a source of sound?

(A) Satellite moving in space

(B) A sonar on a ship

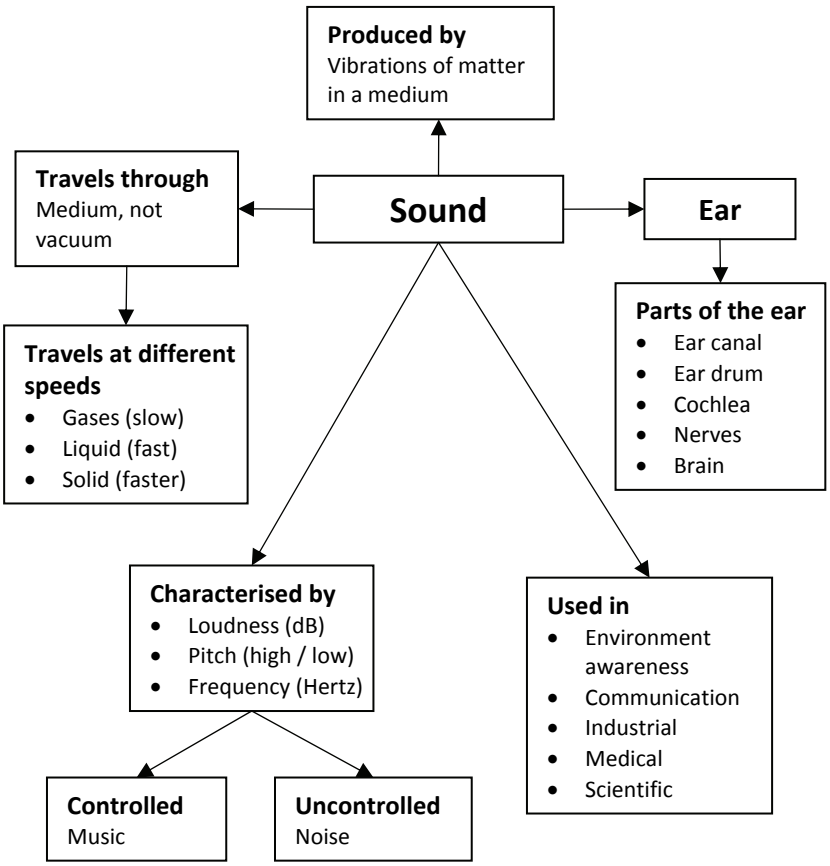
(C) A lighted bulb

(D) Ear muffler

Solution:

(B) The sonar transmits sound waves to the sea bed, and uses the reflected sound waves to detect objects on the sea bed.

16.5 Concept map



16.6 Practice questions

Multiple-choice questions

1. When sound travels through a medium, what has been transferred?

   (A) Particles in the medium

   (B) Particles of the source

   (C) Energy from the source

   (D) Energy from the medium

   ( )

2. When sound travels through a medium, what happen to the particles in the medium?

   (A) Vibrate randomly

   (B) Vibrate along the direction of travel of the sound wave

   (C) Vibrate perpendicular to the direction of travel of the sound wave

   (D) Do not vibrate

   ( )

3. What is the factor affecting the speed of sound in a medium?

   (A) Frequency

   (B) Pitch

   (C) Loudness

   (D) Properties of the medium

   ( )

4. A vibrator strikes a surface 10 times in one second. What is the frequency of the sound produced?

   (A) 0.1 Hz

   (B) 1 Hz

   (C) 10 Hz

   (D) 100 Hz

   ( )

5. Vibrations inside the ear are amplified by the three bones namely the _____ in the middle ear

   (A) hammer, anvil and stirrup

   (B) hammer, cochlea and stirrup

   (C) anvil, stirrup and cochlea

   (D) hammer, anvil and cochlea

   ( )

Structured questions

1. Describe how a piano produce music.

   _____

   _____

2. Why is sound unable to travel through a vacuum?

   _____

   _____

3. What is the difference between music and noise?

   _____

   _____

4. A boy listens to music at about 100 decibels for half an hour. Is this likely to cause damage to his hearing?

   _____

   _____

Answers

Multiple-choice questions

1. Answer: (C)

   Explanation: Sound is a form of kinetic energy, as it involves the movement of particles. Hence energy is transferred from the source.

2. Answer: (B)

   Explanation: The particles in the medium is being pushed and pulled by the vibrating source, hence the sound waves travel outward parallel to the direction of the vibrations

3. Answer: (D)

   Explanation: The speed of sound in a medium is dependent on the properties of the medium, such as density. Speed of sound is in the order $\rightarrow$ gas $<$ liquid $<$ solid.

4. Answer: (C)

   Explanation: The frequency of a sound is measured in Hertz (Hz). One Hertz represents one vibration per second.

5. Answer: (A)

   Explanation: The chain of bones – hammer, anvil and stirrup in the middle ear amplify and transmit vibrations from the ear drum to the cochlea.

Structured questions

1. A small hammer strikes a string when you push the key down. This causes the string to vibrate, giving off sound. Depending on the length of the string, sound of a specific frequency is produced. The shorter the string, the higher is the frequency.

2. Sound is a wave that travels in matter, and there is no matter in a vacuum.

3. Music is a controlled sound production at selected loudness, pitch and rhythm. Noise is uncontrolled sound production with random loudness, pitch and rhythm.

4. Yes. Sound at loudness level of 100 dB can cause permanent loss of hearing, even for just a short duration.