Chapter 10

Sound Waves

Can sound waves propagate to the bottom of the sea?

How do our ears respond to sound?

What is echo?

What is the limitation of a human's hearing?

Let's understand:

- Characteristics of sound waves
- Loudness and pitch of sound
- Phenomena and applications of reflection of sound waves

SCIENCE BLOG

Lightning and Thunder

Lightning is a phenomenon caused by huge discharge of static electricity in the sky. The static electricity passes through the air and causes the air particles to vibrate. The vibrations are heard as thunder. Have you noticed that we see the flash of lightning before hearing the rumble of thunder?

In reality, lightning and thunder occur at the same time but the different speeds of propagation of light and sound through the air cause the delay.

The light from the lightning travels to our eyes much quicker than the sound from the thunder. Therefore, the flash is seen before the rumble is heard.

Keywords

- Vibration
- Medium
- Wave
- Amplitude
- Frequency
- Echo
- Pitch
- Ultrasound
- Limit of hearing
- Sonar

10.1 Characteristics of Sound Waves

Our surroundings are filled with a variety of sounds. Sound is a form of energy caused by **vibration**. For example, the musical instruments in Photograph 10.1 produce sound through vibration. Touch the front of your throat with your fingertips while speaking. Can you feel the vibration of your vocal cords?

Photograph 10.1 *Musical instruments*

Let us carry out Activity 10.1 to study the characteristics of sound waves.

Activity 10.1

Aim: To study the characteristics of sound waves.

A Propagation

(i) Requires a medium to propagate

Apparatus: Bell jar, polystyrene sheet, alarm clock and vacuum pump

Instruction

1. Set up the apparatus as shown in Figure 10.1.
2. Activate the alarm clock and listen to the sound produced.
3. Then, turn on the vacuum pump to suck the air out.
4. Record your observation.

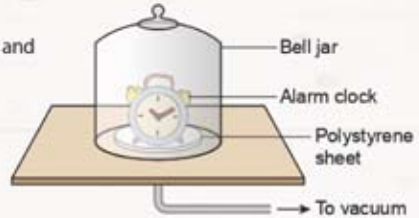


Figure 10.1

(ii) Propagate at different speeds in different medium

Materials: Water and flour

Apparatus: Plastic container and alarm clock

Safety Precaution

Ensure the water and flour are fully filled into the containers so that there is no trapped air.

Instruction

1. Prepare three plastic containers that are filled with air, water and flour respectively.
2. Place the empty plastic container (filled with air) tightly onto the table and place your ear onto the container (Figure 10.2).
3. Ask your friend to activate the alarm clock at the end of the table and listen to the sound produced.
4. Repeat steps 2 and 3 using the containers filled with water and flour. Compare the loudness of the sound produced.

Figure 10.2

Questions

1. What is observed when the vacuum pump is turned on? Give an inference for your observation.
2. Arrange the containers filled with air, water and flour in order of increasing loudness.

B Sound can be reflected and absorbed

Apparatus: Cardboard tube, analogue stopwatch, plasticine, wooden plank, metal sheet, softwood and towel

Instruction

1. Set up the apparatus as shown in Figure 10.3 and make sure there is a distance of about 5 cm between the wooden plank and the end of the cardboard tubes.
2. Move tube *Q* until you can hear the ticking stopwatch clearly.
3. Without moving tubes *P* and *Q*, replace the wooden plank with a metal sheet followed by a towel. Compare the loudness of the ticking of the stopwatch.
4. Record all your observations.

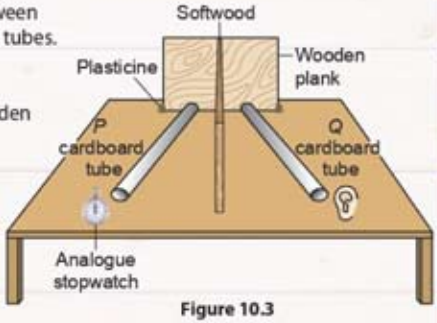


Figure 10.3

Questions

1. Based on your observation, which surface is a
   (a) good absorber of sound?
   (b) good reflector of sound?
2. Predict whether a glass sheet is a good absorber or reflector of sound.

Transfer of Sound

Sound **requires a medium to propagate.** Sound can propagate through a **liquid**, **solid** and **gas**, but not through vacuum. For example, when a bell is rung, the metal surface of the bell will vibrate. Air molecules near the surface will also vibrate and collide with the air molecules nearby. This vibration is transferred from one molecule to another molecule beside it in the form of **waves.** In this way, the bell produces sound that can be heard by the ears of the listener (Figure 10.4).

Figure 10.4 *Transfer of sound from bell to the ears of the listener*

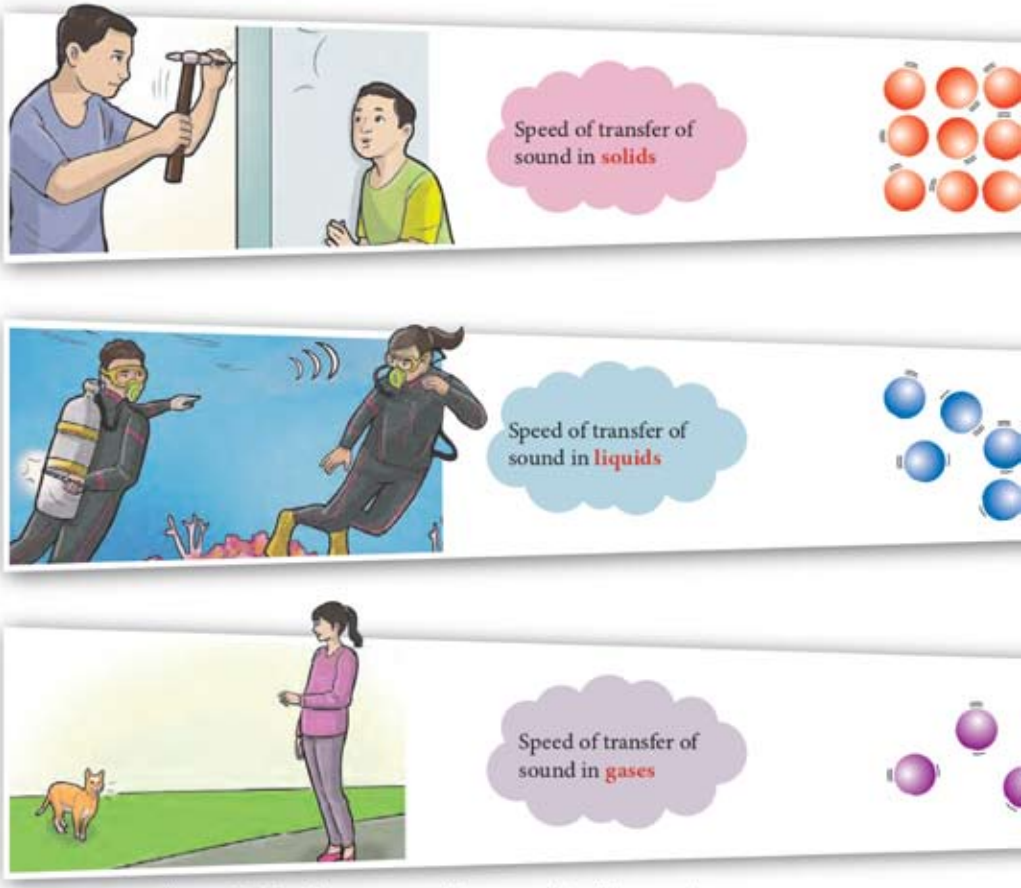
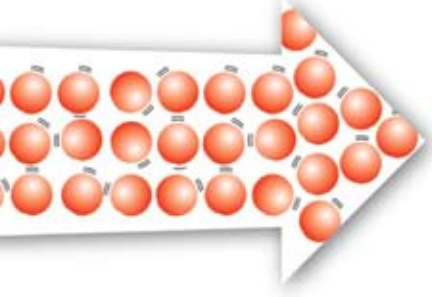
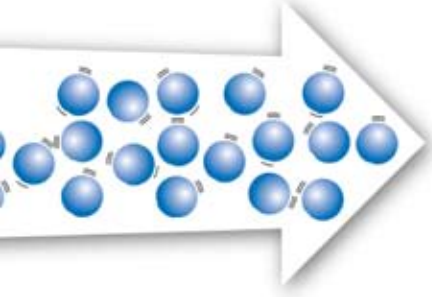


Figure 10.5 *Sound propagates at different speeds in different media*

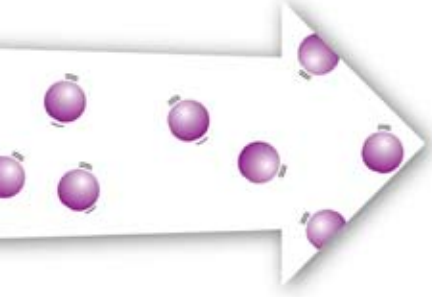
Photograph 10.2 *Sound of the aircraft engines can be heard because sound can propagate through air*



Sound is transferred **very rapidly** in solids. When the particles at one end of the solid start to vibrate, the vibration causes the nearby particles to also vibrate as the particles of solids are arranged very closely together.



The loose arrangement of particles in liquid causes sound vibrations to be transferred **less rapidly** compared to solids.



Sound waves propagate **very slowly** in gases because the arrangement of gas particles which are far apart from each other causes a delay in transfer of vibration.

Reflection and Absorption of Sound

Sound can be reflected and absorbed when it hits the surface of an object. These characteristics are the same as the characteristics of light that you have learned in Form One. The amount of sound reflected or absorbed depends on the surface of the object.

Marble tiles

Wall

Hard and **smooth** surfaces are good sound reflectors. (Photograph 10.3)

Photograph 10.3 *Examples of good sound reflectors*

Carpet

Softboard

Soft and **rough** surfaces are good sound absorbers (Photograph 10.4)

Photograph 10.4 *Examples of good sound absorbers*

Formative Practice 10.1

1. State four sources of vibration that produce sound.
2. Tick (✓) the correct statement regarding sound waves.
   (a) Sound waves can only be reflected. ☐
   (b) Astronauts can hear sounds more clearly in the space than on Earth. ☐
   (c) Sound waves require a medium to propagate. ☐
3. The walls of cinema halls are usually covered with layers of thin softboards. What is the purpose of these boards?

10.2 Loudness and Pitch of Sound

Our ears can differentiate the sounds that are heard because sounds have different strengths and pitches. **The strength or loudness of sound** produced depends on the amplitude of the sound wave (Photograph 10.5), whereas **pitch of sound** depends on the frequency of the sound produced (Photograph 10.6). Frequency is measured in the unit of **hertz (Hz)**.

The mooing of a cow is a low frequency sound.

The squeaking of a rat is a high frequency sound.

Photograph 10.6 *Animals produce sounds with different frequencies*

Photograph 10.5 *The way we press the piano keys determines the strength of the sound produced*

What is the effect of amplitude and frequency on the loudness and pitch of sound respectively? Let us carry out Activity 10.2 to investigate these effects.

Activity 10.2

Aim: To study the effect of amplitude on the loudness and the effect of frequency on the pitch of sound.

Apparatus: Cathode Ray Oscilloscope (C.R.O.), audio signal generator, loudspeaker and connecting wire

Instruction

1. Arrange the apparatus as shown in Figure 10.6.
2. Adjust the audio signal generator and C.R.O. until sound is produced and the waveform can be observed on the screen of the C.R.O.
3. Fix the frequency of the audio signal generator and gradually increase the output power.
4. Listen to the sound produced and observe the waveform on the screen of the C.R.O. Record your observation.
5. Then, fix the output power of the audio signal generator and gradually increase the frequency.
6. Listen to the sound produced and observe the waveform on the screen of the C.R.O. Record your observation.

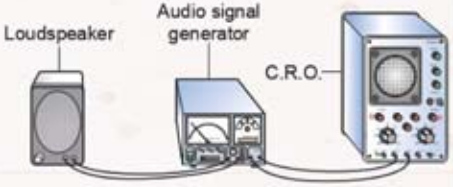


Figure 10.6

Observation

Adjustment done on audio signal generator		Change in the waveform on C.R.O.		Change in the sound produced by the loudspeaker
Output power	Frequency	Amplitude	Frequency	
Increased	Fixed			
Fixed	Increased			

Questions

1. What are the conclusions that can be made regarding the effect of
   (a) amplitude on loudness?
   (b) frequency on the pitch of sound?
2. Explain the relationship between the increase in amplitude and the changes in the sound produced with reference to vibration energy.
3. If an object produces vibration at a high amplitude and frequency, what will happen to the sound produced?

Based on Activity 10.2, we can summarise the relationship between, loudness and amplitude; pitch of a sound and frequency as shown in Figure 10.7.

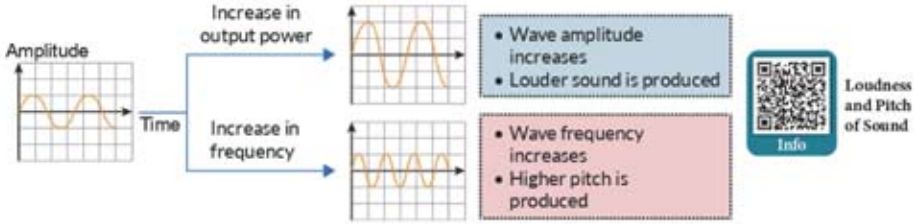


Figure 10.7 *Display on screen of C.R.O. when output power and frequency are changed*

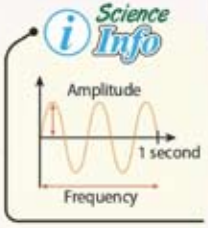
Activity 10.3

21st Century

Aim: To search for information regarding the strength and pitch of musical instruments.

Instruction

1. Work in groups.
2. Gather information regarding the following musical instruments:
   (i) piano (iii) guitar
   (ii) recorder (iv) drum
3. Gather the following information:
   (a) audio recordings
   (b) waveform of every sound produced by the musical instruments
   (c) comparison between the waveforms of each musical instrument
4. Present your discussion in the form of a multimedia presentation.



Doppler Effect

The **Doppler effect** is the **apparent change in frequency** caused by the relative movement of sound source, the relative movement of the observer or both. Figure 10.8 explains the Doppler effect.

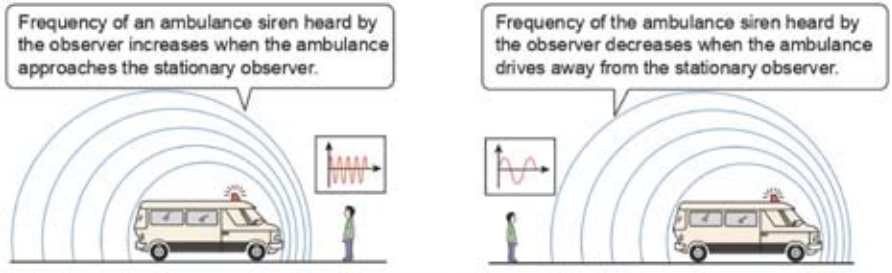


Figure 10.8 *The Doppler effect*

Activity 10.4

21st century

Aim: To study the Doppler effect of sound using an air horn.

Apparatus: Air horn

Instruction

1. You are required to stand in the middle of the assembly area.
2. Ask your friend to sound an air horn while running past you.
3. Record the pitch of the sound of the air horn during and after your friend has run past you.

Questions

1. What happens to the pitch of the sound when the air horn is sounded while passing by the observer?
2. State the relationship between the frequency of sound and the distance of the sound source from the observer.
3. Does the person who carries the sound source also feel the change in the pitch of the sound? Give a reason.

Formative Practice 10.2

1. State one difference in the characteristics of the vibration of the voice box of men and women.
2. If a musician plays a soft note, what is the characteristic that has been changed?

   (a) Loudness ☐

   (b) Pitch of sound ☐

3. Figure 1 shows several waveforms formed in one second. Which waveform has the lowest frequency?

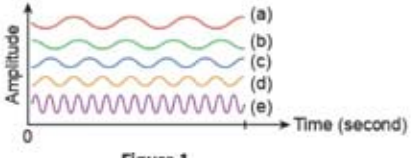


Figure 1

10.3 Phenomenon and Application of Reflection of Sound Waves

Reflection of sound waves is one of the characteristics of sound waves that you have learned in 10.1. This characteristic produces a phenomenon known as echo. Apart from that, reflection of sound waves is also used in various devices and sectors.

Phenomenon of Reflection of Sound Waves

An echo is produced when sound waves are **reflected** from a hard surface to the listener. The reflected echo sounds the same as the original sound but takes some time to reach the listener's ears. An echo can be heard in places like enclosed halls, empty rooms, caves, tunnels and gorges. Observe Figure 10.9 to understand the phenomenon of echo.

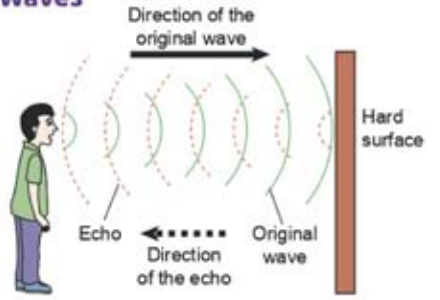


Figure 10.9 *Echo formed in an empty room*

Application of Reflection of Sound Waves

The reflection of different sound waves can be produced when sound waves hit different surfaces. The recorded reflections will provide a variety of information and images that can be used in different sectors.

Ultrasound is a type of sound wave with a frequency of more than 20 000 Hz. An ultrasound cannot be heard by humans but can be heard by animals such as bats that use it for navigation (Figure 10.10). A sound reflection technology known as **sonar** is used in the shipping industry to detect underwater objects. This technology is also used in other sectors such as medical and fisheries. Scan the QR code below to learn more about sonar and its uses in the medical sector.

Figure 10.10

Video

Sonogram Video
http://bukutekskssm.my/Science/Video4.mp4

Activity 10.5

21st Century

Aim: To gather information regarding different applications of the reflection of ultrasound.

Instruction

1. Work in groups.
2. Gather information regarding different applications of the reflection of ultrasound in
   (a) shipping sector
   (b) fishery sector
   (c) medical sector
   (d) estimation of distance by bats
3. Present your discussion in the form of a multimedia presentation.

Limitations of Hearing

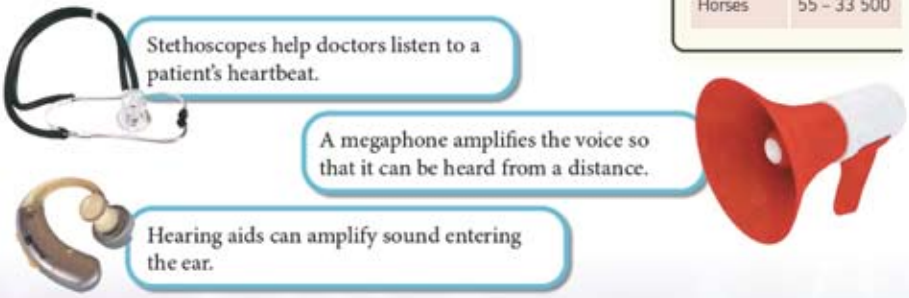
The frequency of sound that can be detected by humans is within the range of 20 Hz to 20 000 Hz. This range becomes narrower as we age because our ears lose their sensitivity to sound frequencies.

On the other hand, animals have their own limit of hearing. Bats, dolphins and dogs are examples of animals that have a higher range of hearing than humans.

The limited sense of hearing in humans makes us unable to hear soft sounds and sounds from a distance. Therefore, we need to use special devices to overcome these limitations (Photograph 10.7).

Science Info

Animal	Hearing range (Hz)
Bats	2 000 – 110 000
Dogs	67 – 45 000
Dolphins	40 – 100 000
Elephants	16 – 12 000
Horses	55 – 33 500



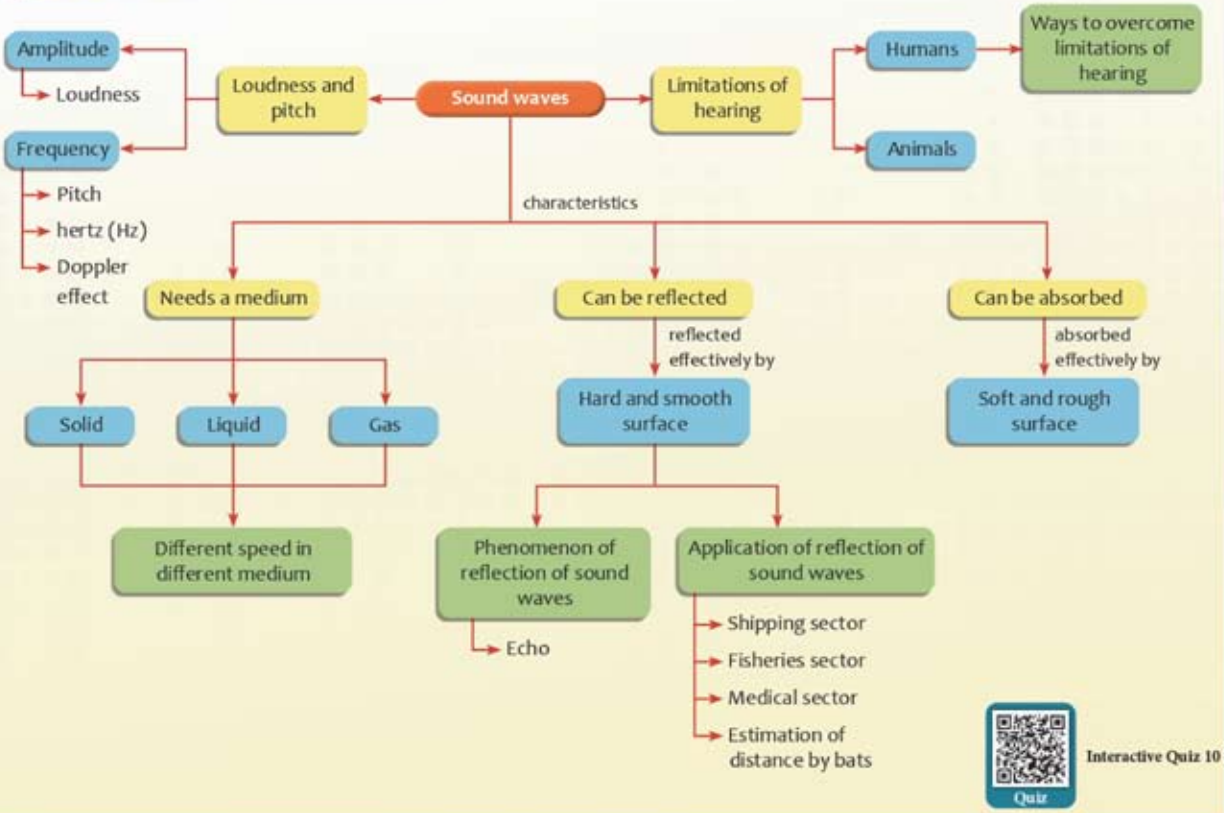
Photograph 10.7 *Devices to overcome human limitations of hearing*

Formative Practice 10.3

1. Does the distance of a sound source from the reflecting surface have any effect on the echo produced? Give your opinion.
2. Why is echo heard repeatedly in a cave?
3. State two uses of ultrasound.

10.3.3
10.3.4

Summary



Quiz

Interactive Quiz 10

SELF-REFLECTION

After learning this chapter, you are able to:

10.1 Characteristics of Sound Waves

- ☐ Communicate the basic characteristics of sound waves.

10.2 Loudness and Pitch of Sound

- ☐ Explain frequency and its unit, and amplitude of vibration.
- ☐ Relate frequency to pitch.
- ☐ Relate amplitude to loudness.
- ☐ Explain with examples loudness and pitch using musical instruments.
- ☐ Doppler effect.

10.3 Phenomena and Application of Reflection of Sound Waves

- ☐ Explain with example the phenomena related to reflection of sound waves such as echo.
- ☐ Explain with example the applications of reflection of sound waves.
- ☐ Elaborate and communicate the limitations of hearing for humans and animals.
- ☐ Explain with examples ways to overcome human limitations of hearing.

Summative Practice 10

1. Figure 1 shows Aiman trying to communicate with Sam at a distance of 10 metres.

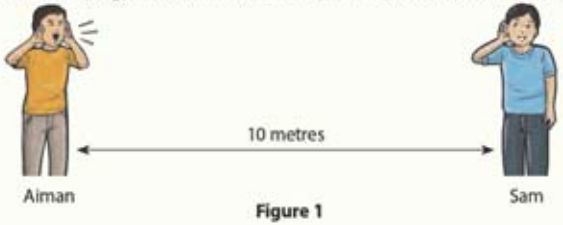


Figure 1

Suggest a method so that Sam can hear Aiman's voice more clearly.

2. Figure 2 shows the original waveform of a sound signal on a C.R.O. screen. Draw the resulting waveform when the following adjustments are made to the sound signal.

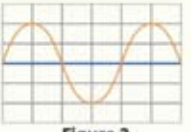


Figure 2

(a) Output power is reduced

(b) Frequency is increased

3. The speed of sound waves will change when travelling through different media. State the relationship between the speed of sound and temperature of air. Explain your answer.

4. Mr. Azli moved into a new house that has no furniture. He found that echo is produced when he speaks. The effect of echo becomes lesser when furniture is brought into the house.

(a) How is echo produced?

(b) Why does the effect of echo reduce when there is furniture in the house?

5. Figure 3 shows ultrasound waves being used to scan the condition of a foetus in the womb.

(a) Explain how ultrasound can be used to produce the image of the foetus in the womb.

(b) Give two advantages of using ultrasound compared to X-ray.

(c) Give two other uses of ultrasound waves.

Figure 3

6. What are the changes that can be observed if

(a) a guitar string is tightened?

(b) a guitar string is plucked harder?

HOTS Mastery 10

7. You have been assigned to design a recording studio. Explain the modifications to the studio that should be done so that sound recordings of good quality are produced.

8. Astronauts communicate with each other in space using radio frequency communication equipment. Suggest and explain another way for astronauts to communicate with each other.