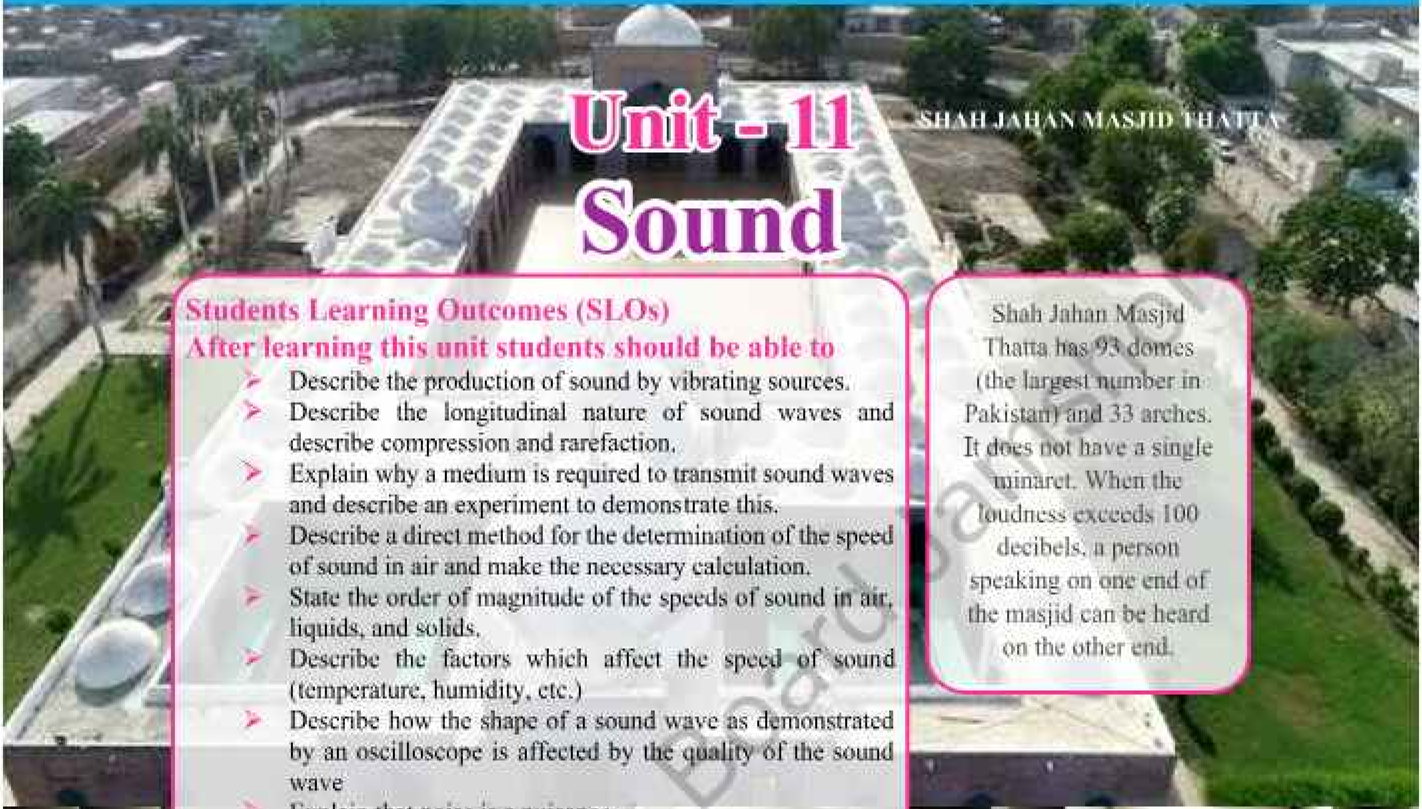
Unit - 11
Sound

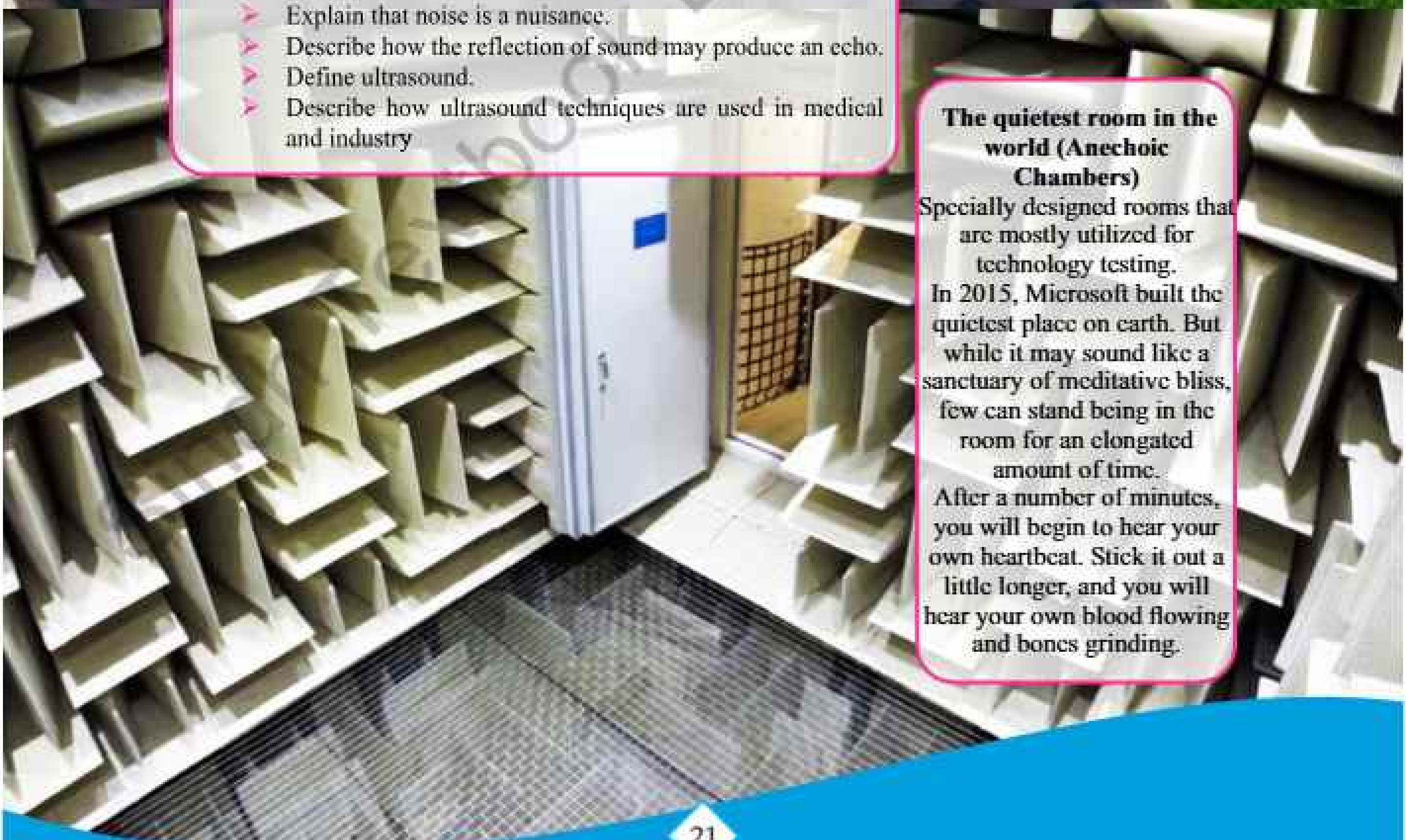


Students Learning Outcomes (SLOs)

After learning this unit students should be able to

- Describe the production of sound by vibrating sources.
- Describe the longitudinal nature of sound waves and describe compression and rarefaction.
- Explain why a medium is required to transmit sound waves and describe an experiment to demonstrate this.
- Describe a direct method for the determination of the speed of sound in air and make the necessary calculation.
- State the order of magnitude of the speeds of sound in air, liquids, and solids.
- Describe the factors which affect the speed of sound (temperature, humidity, etc.)
- Describe how the shape of a sound wave as demonstrated by an oscilloscope is affected by the quality of the sound wave
- Explain that noise is a nuisance.
- Describe how the reflection of sound may produce an echo.
- Define ultrasound.
- Describe how ultrasound techniques are used in medical and industry

Shah Jahan Masjid Thatta has 93 domes (the largest number in Pakistan) and 33 arches. It does not have a single minaret. When the loudness exceeds 100 decibels, a person speaking on one end of the masjid can be heard on the other end.



The quietest room in the world (Anechoic Chambers)

Specially designed rooms that are mostly utilized for technology testing.
In 2015, Microsoft built the quietest place on earth. But while it may sound like a sanctuary of meditative bliss, few can stand being in the room for an elongated amount of time.
After a number of minutes, you will begin to hear your own heartbeat. Stick it out a little longer, and you will hear your own blood flowing and bones grinding.

Do you know that elephants can hear a storm from a distance of 200 km away? Also, communicate over great distances using sound that we cannot hear. Some animals such as bats, use sound echoes to find their way and catch prey. Scientists use ultrasound (echoes) to detect objects underwater or even to produce images of the organs inside of the human body. How are they able to do this? The physics behind it will explain the phenomenon.

11.1 Sound waves

Sound waves are mechanical, longitudinal waves comprising compressions and rarefactions.

Production of sound by vibrating sources

When you hit the skin of a drum, it starts vibrating, and it moves back and forth very quickly. These vibrations squeeze and stretch the air in its front and disrupt the surrounding molecules. This series of squeezes and stretches accordingly produce compressions and rarefactions which travel through the air. It produces sound waves.

Weblinks

Encourage students to visit below link for Sound waves experiment

https://www.youtube.com/watch?v=2mlBh5d1IUY&ab_channel=FuseSchool-GlobalEducation

Sound is produced by vibrating sources placed in a medium.

A vibrating object in the medium causes of alternating compressions and rarefactions that carry the sound further away through the medium.

Sound is the form of energy related to the vibrating motion of molecules.

This energy travels from one point to another as a wave. For example, a guitar produces a musical note when the string vibrates.

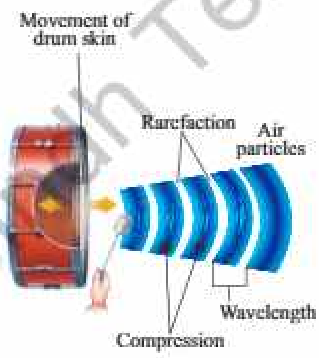


Fig: 11.1
Vibration of drum skin

Longitudinal nature of sound waves

A sound is a mechanical longitudinal wave. The direction of vibration of air molecules is parallel to wave motion, similar to the longitudinal waves produced when a slinky spring is vibrated parallel to its direction of motion, as we studied in the previous unit page no 4.

Let us consider the drum how can produce longitudinal sound waves by disturbing the molecules surrounding it; Fig. 11.1. Note the compressions (C) and rarefactions (R) produced by vibrating drum skin.

Now, we can consider that the compressions and rarefactions of sound waves are due to a slight change in the air pressure.

Compressions are regions where air pressure is slightly higher than surrounding air pressure and
Rarefactions are regions where air pressure is slightly lower than the surrounding air pressure.

This rising and falling of air pressure take place continuously as long as the drum produces the sound. Thus, we can illustrate the region where the sound travels through air as in figure 11.2.

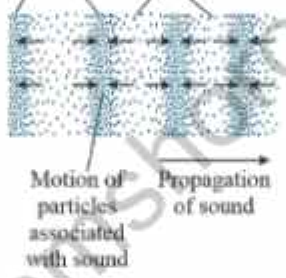


Fig: 11.2. The vibrating drum skin produce alternating regions with high density and low density of air molecules

Electric bell jar Experiment

Sound is a mechanical wave that needs a material medium such as gases, liquids, solids to propagate due to the vibratory motion of particles of the medium that transport sound waves in the form of energy from one point to another. Sound cannot travel through a vacuum, demonstrated by the following experiment.

Take an electric bell and an airtight glass bell jar and then suspend the electric bell inside the jar. Connect the bell jar to a vacuum pump; Fig. 11.3. When you switch on the electric bell, you can hear the sound of the bell coming from inside air and glass material. Now start the vacuum pump. As the air in the jar is gradually pumped out, the sound becomes fainter, although the same current is passing through the bell and hammer that strikes the gong. After a while, you will hear the faintest sound, when there is less air. What happens when the air is completely removed? Will you still be able to hear the sound of the bell?
The electric bell still produces the sound, but now we cannot hear it. This is because sound waves always need a medium to propagate sound energy. In the bell jar, it was a vacuum hence sound waves cannot travel.
This experiment makes sure that the bell does not touch glass and that the connecting wires used are thin. This prevents the sound energy from being transmitted through the glass and wires to the outside of the jar as the hammer vibrates vigorously.

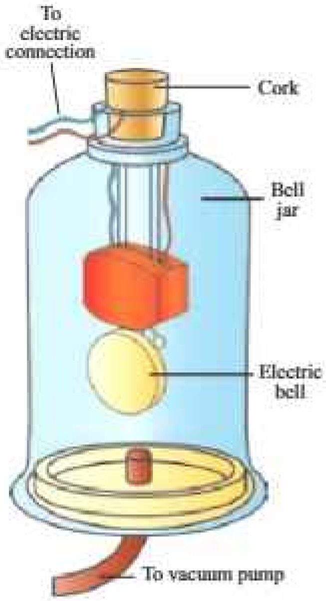


Fig: 11.3 Bell jar experiment showing sound cannot travel in a vacuum

SELF-ASSESSMENT QUESTIONS:

Q1: Why pressure is greater at compression region of longitudinal waves.

Q2: Why can we not hear the explosives sound produced in the Sun?

Q3: Can sound travel through solids and liquids?

11.2 Speed of sound

A direct method for the determination of the speed of sound in air

As we know, sound travels quite fast, but it is still possible to measure its speed in the air by direct methods. To do this, we have to measure the time it takes for sound to travel a measured distance. However, how do we measure the speed of sound? The following experiment demonstrates the direct method.

Do You Know!

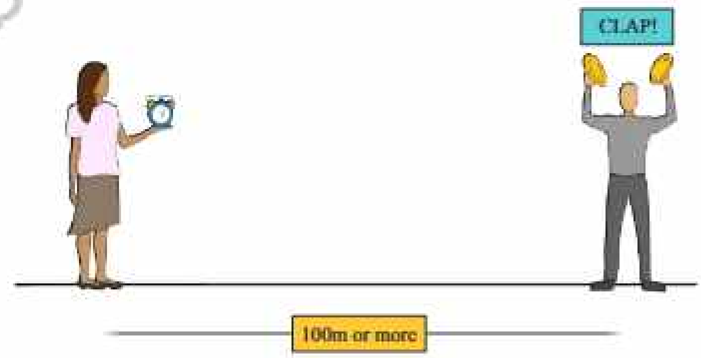
Trundle wheel is a mechanical device which is used to measure distance and it is also known as Surveyor wheel

Experiments to Determine the Speed of Sound

- There are several experiments that can be carried out to determine the speed of sound
- Two methods are described below
- The apparatus for each experiment is given in **bold**

Method 1: Measuring Sound Between Two Points

Measuring the speed of sound directly between two points



1. Two people stand a distance of around 100 m apart
2. The distance between them is measured using a **trundle wheel**
3. One person has **two wooden blocks**, which they bang together above their head

4. A second person with a stopwatch starts watch when he hears one of the claps and ends timing after 20 claps.
5. This is then repeated several times and an average value is taken for the time.
6. The speed of sound can then be calculated using the equation:

$$\text{Speed od sound} = \frac{\text{Distance traveled by sound}}{\text{Time taken}}$$

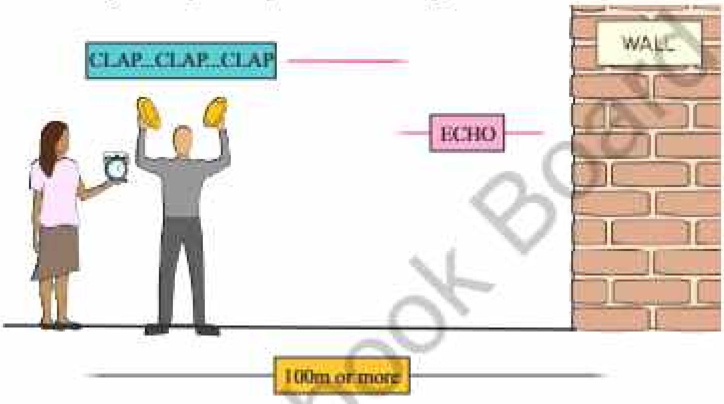
Weblinks

Encourage students to visit below link for measuring speed of sound by using echo

https://www.youtube.com/watch?v=1wrD4JLgb1c&ab_channel=VTPhysics

Method 2: Using Echoes

Measuring the speed of sound using echoes



1. A person stands about 50 m away from a wall (or cliff) using a **trundle wheel** to measure this distance
2. The person claps **two wooden blocks** together and listens for the echo
3. The person then starts to clap the blocks together repeatedly, in rhythm with the echoes
4. A second person has a **stopwatch** and starts timing when they hear one of the claps and stops timing 20 claps later
5. The process is then repeated and an average time calculated
6. The distance travelled by the sound between each clap and echo will be (2 × 50) m
7. The total distance travelled by sound during the 20 claps will be (20 × 2 × 50) m

Weblinks

Encourage students to visit below link for echo method determination of speed of sound

https://www.youtube.com/watch?v=Hb5z2d6G5jU&ab_channel=CBSE

8. The speed of sound can be calculated from this distance and the time using the equation:

$$\text{Speed od sound} = \frac{2\times \text{Distance to the wall}}{\text{Time taken}}$$

Speed of sound in solids, liquids, and gases.

Sound waves are mechanical waves. Any medium that contains particles can transmit sound. The speed of sound is not the same in all mediums. Sound waves travel at different speeds in different mediums. Remember that the speed of sound depends on the properties such as temperature, pressure and density of the medium through which it travels. Sound moves faster in solid because the molecules/ particles of solid are very close to each other, as compare to liquid and gases.

The speed at which a sound wave travels depends upon the medium and state of the medium (steel, water, air). The rate of sound wave travel decreases when we go from solid to the gaseous state. The speeds of sound at $25^{o}C$ in various media are listed in Table 11.1.

The speed of sound is defined as the distance which a point on a wave, such as a compression or a rarefaction, travels per unit of time.

We know,

$$\text{Speed } v = \text{distance / time}$$

$$v = \frac{\lambda}{T}$$

Where λ is the wavelength of the sound wave. It is the distance traveled by the sound wave in one time period (T) of the wave. Thus,

$$v = \lambda f \,(\therefore 1/T = f)$$

or $$v = \lambda f$$

The speed of sound remains almost the same for all frequencies in a given medium under the same physical conditions.

Weblinks

Encourage students to visit below link for speed of sound through solid, liquid and gases

https://www.youtube.com/watch?v=bSA4gfiahNw&ab_channel=Clapp

Weblinks

Encourage students to visit below link for the speed, distance and time rules and how to apply them to real life

https://www.youtube.com/watch?v=7fz-4BUDyqg&ab_channel=XcelerateMath

Table 11.1 Speed of sound in different mediums at 25 °C

Speed of sound in different media at 25 °C		
State	**Substance**	**Speed in m/s**
Solids	Aluminum	6420
	Nickel	6040
	Stainless Steel	5960
	Brass	4700
	Copper	2270
	Glass (Pyrex)	3980
Liquids	Water (Sea)	1531
	Water (distilled)	1498
	Ethanol	1207
	Methanol	1103
Gases	Hydrogen	1284
	Helium	965
	Air	340
	Oxygen	316
	Sulfur dioxide	213

Weblinks

Encourage students to visit below link for how sound travels across different medium

https://www.youtube.com/watch?v=AxNdr0Bcx20&ab_channel=KnowledgePlatform

Factors that affect the speed of sound

The speed of sound is affected by a variety of factors. Two of the factors affecting the speed of sound in the air are given in detail below.

Effect of Temperature

Temperature is also a condition that affects the speed of sound. Heat is a form of energy that depends upon the kinetic energy of molecules. Molecules of the medium at higher temperatures have more energy. Thus, they can vibrate at a higher rate. As the molecules vibrate faster, sound waves can travel more quickly. The speed of sound at room temperature (25^0C) in the air is 346 meters per second. It is faster than 331 meters per second, which is the speed of sound in air at (0^0C).

The formula to find the speed of sound at temperature T in the air is given as follows:

$$v = 331 \times \sqrt{\frac{T}{273K}}$$

Here v is the speed of sound, and T is the absolute temperature of the air. This formula shows that the speed of sound in air is directly proportional to the square root of the

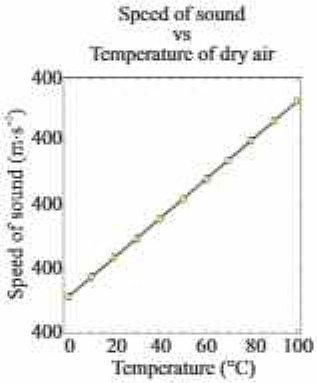


Fig: 11.4 Graphical representations for speed of sound against temperature absolute temperature; Fig. 11.4. Thus, the temperature of the air increases, so the speed will also increase.

Effect of humidity:

Humidity also affects the speed of sound in the air. The effect of water vapor on the speed of sound is minimum than that of dry air. The presence of moisture in air replaces oxygen and nitrogen gases that reduce the density of air because the molecular mass of water vapors (Molecular Mass =18) is less than that of oxygen (Molecular Mass = 32) and nitrogen (Molecular Mass = 28) gases since the speed of sound in gases are inversely related to the square root of its density $\left(V \propto \frac{1}{\sqrt{\rho}}\right)$.

Thus, humidity increases, the density of the air decreases and sound travels faster.

Weblinks

Encourage students to visit below link for why moist air is less dense than dry air

https://www.youtube.com/watch?v=-75kAiV6y-s&ab_channel=How-ToWeather

Worked Example 1

A sound wave has a frequency of 6 kHz and wave length 25 cm. How long will it take to travel1.5 km?

Solution:

Step 1: Write down the known quantities and quantities to be found.

f = 6 kHz = 6000 Hz

λ = 25 cm = 0.25 m

d= 1.5 km = 1500 m

t=?

Step 2: Write down the formula and rearrange if necessary.

$v = \lambda f$, and

$d = v \times t$

$t = d/v$

Step 3: Put the values and calculate.

$v = (0.25\ m) \times (6000\ Hz)$

$v = 1500\ m/s$, and

$t = d/v$

$t = 1500\ m / 1500 ms^{-1}$

$t = 1\ s$.

Result: Time = t = 1.0 second

Worked Example 2

Calculate the speed of sound in air at 30^0C? Given that speed of sound at 0^0C is 331 m/s.

Solution:

Step 1: Write down the known quantities and quantities to be found.

$T = 30\,^0C = 30 + 273K$

$T = 303\ K$

Step 2: Write down the formula and rearrange if necessary.

$v = 331 \times \sqrt{T/273}$

Step 3: Put the values and calculate.

$v = 331 \times \sqrt{303K/273K}$

$v = 331 \times \sqrt{1.1099}$

$v = 331 \times 1.05352$

$v = 348.7\ m/s.$

Result: Speed of sound V = 348.7m/s

SELF-ASSESSMENT QUESTIONS:

Q1: Can any object produce a sound without any vibrations in it?

Q2: How can the pressure affect the speed of the sound in the air?

Q3: A sound wave traveling in a solid pass into the air. What will happen to the speed of a sound wave when it enters the air? Explain.

Do You Know!

Timbre is what makes one instrument or voice sound different from other

11.3 Seeing sounds

When we listen to a musical song on a radio, we can distinguish between the notes of various instruments such as a recorder and a violin being played in the song. It is due to the varying quality of these notes. Figure 11.5 shows the waveform of the sound produced by a violin, oboe, and French horn. If the loudness and the pitch of these three sounds are the same, then how their waveforms are different. How do their qualities differ? How can they be distinguished from one another? To understand this, let us consider figure 11.5. Most of the sounds like our voice, chirping of birds, and notes from different musical instruments produce

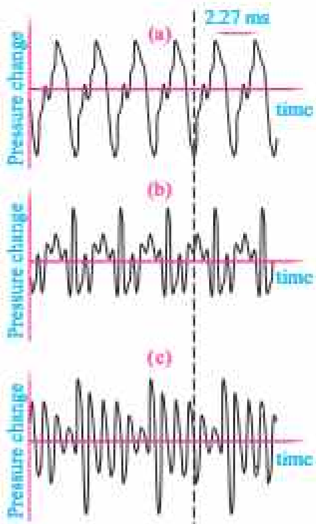


Fig: 11.5
wavefronts produced by
(a) violin
(b) oboe and
(c) French horn

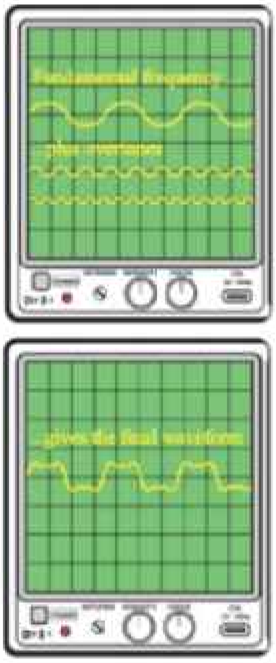


Fig: 11.6
Formation of a note on the oscilloscope

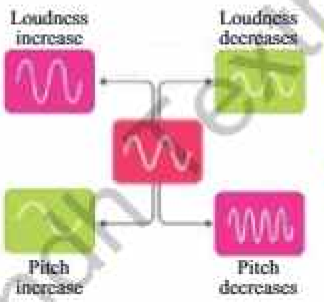


Fig: 11.7
Pitch and loudness
Loudness of the sound is dependent on the amplitude of sound.
Pitch the pitch of the sound is dependent on the frequency of sound.

varying waveforms. These waveforms are produced by blending different frequencies.

Quality: It is defined as the characteristic of sound by which we can distinguish between two sounds of the same loudness and pitch.

To understand this, let us consider a fundamental frequency and other two frequencies; if we combine these waves on an oscilloscope, we will get a single waveform with two overtones in it; Fig. 11.6.

loudness: It refers to the ability to distinguish between a loud and a quiet sound.

Pitch: It is the quality of sound that distinguishes between a shrill and a flat sound.

Loudness and pitch depends upon amplitude and frequency respevtively as shown in figure 11.7.

Sound intensity or acoustic intensity: It is defined as the power carried by sound waves per unit area in a direction perpendicular to that area.

The SI unit of intensity, which includes sound intensity, is the watt per square meter (W/m^2).

SELF-ASSESSMENT QUESTIONS:

Q1: What characteristic determines the quality of the sound?

Q2: If two sounds from different sources have the same frequency and loudness. Can you distinguish the sounds?

11.4 Noise pollution

In our daily life, we enjoy hearing sounds of different qualities. We hear the sound produced by musical instruments such as the recorder, guitar, violin, drum. The sound of these instruments has a tone with characteristics such as controlled pitch and quality that have a pleasant effect on our hearing sensation.

The sounds that are pleasant to our ears are called musical sounds.

However, some sounds have unpleasant effects on our ears, such as the sound of motor vehicles, the slamming of a door, and the sounds of machinery.

Sound which has an unpleasant effect on our ears is called noise.

Noise corresponds to irregular and sudden vibrations generated by some sources. Noise is pollution, has become a significant issue of concern all over the world. *Noise* is an unpleasant sound that is harmful not only to human health but also to other species. Transportation equipment and heavy machinery are the primary sources. For example, the noise of the machinery in industrial areas, loud vehicle horns, hooters, and alarms. The excessive noise level has harmful effects on human health as they can cause conditions such as stress and disturb concentration. Over time, hearing loss, sleeping disorder, aggression, hypertension, high-stress levels can occur.

A safe level of noise depends on two factors: the noise level; and the duration of exposure to the noise. The noise level recommended in most countries is usually 85-90 dB over an eight-hour workday. Noise pollution can be reduced to an acceptable level by replacing the noisy machinery with environment-friendly machinery and equipment, placing sound-reducing barriers, or using hearing protection devices.

Do You Know!

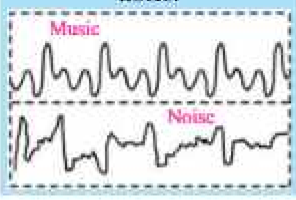
The decibel (dB) unit is usually used for measuring the relative loudness of sounds detectable by human hearing. The term *bel* is derived from the name of Alexander Graham Bell, Inventor of the telephone. Decibel is the smaller unit of bell.

Table 11.2 Noise levels in decibels

Noise	Noise levels in decibels (dB)
Personnel stereo, very loud	150
Damage to hearing	140
Rock concert	110
Sound of drill machine, 3 meters away	90
Busy road	70
Normal conversation	60
Whispering	30
Threshold of hearing	0

Do You Know!

Irregular repeating sound waves create noise, while **regular** repeating waves produce musical notes.



SELF ASSESSMENT QUESTIONS:

Q1: What types of sounds have pleasant effects on our hearing sensations?

Q2: How can we reduce noise pollution?

Reflection of sound or an echo.

If we stand in front of a suitable reflecting object such as a tall building or a mountain and shout or clap our hands once, we will hear the exact sound repeat after a short moment; Fig.11.8.

The repetition of the sound after reflection is known as an echo.

If we take the speed of sound 340 m/s at a temperature of 20 ºC in air, the sound travels to the obstruction and reaches back to the listener on reflection after 0.1s. Hence, the total distance covered by the sound from the point of production to the reflecting surface and back should be at least

$$\text{distance} = \text{speed} \times \text{time}$$
$$d = 340\ \text{m/s} \times 0.1\ \text{s}$$
$$d = 34\ \text{m.}$$

Thus, for hearing clear echoes, the minimum distance of the obstruction from the source of sound should be half of this distance, that is, 17 m.

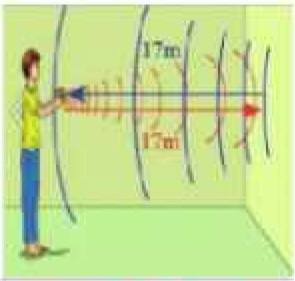


Fig: 11.8. A boy standing in front of a wall produces an echo

Do You Know!

The sound sensitivity persists in our brain for about 0.1 s. To hear a clear echo, the time interval between the produced original sounds and the reflected one must be at least 0.1s

Do You Know!

Echolocation is a technique to determine the location of objects using echo sound. Some incredibly blind people have also developed the ability to echolocate by actively creating sounds: for example, by lightly stomping their feet, tapping their canes, snapping their fingers. People trained to orient by echolocation can interpret the sound waves reflected by nearby objects, accurately identifying their location.

Worked Example 3

A boy clapped his hands near a wall and heard the echo after 1.6 s. What is the distance of the wall from the boy if the speed of the sound, v is taken as 340 ms^{-1}?

Solution:

Step 1: Write down the known quantities and quantities to be found.

$t = 1.6$ s

$v = 340\ \text{m s}^{-1}$

$d = ?$

Step 2: Write down the formula and rearrange if necessary.

$d = v \times t$

Step 3: Put the values and calculate.

$d = (340\ \text{m s}^{-1}) \times (1.6\ \text{s})$

$d = 544$ m

In 1.6s sound has to travel twice the distance, towards the wall and then back to the boy.

Result: the distance between the wall and the boy will be

$d = 544$ m/2

$d = 272$ m.

11.5 Ultrasound

We know that a vibrating body produces sound in a medium. The normal human ear is not able to detect sounds of all frequencies. If we could hear infrasound, we would hear the vibrations of a pendulum. Likewise, we hear the vibrations of the wings of a mosquito. Not only infrasonic of very low frequencies, but our ears also cannot hear very high frequency sounds known as ultrasound.

The sound with frequencies above the upper limit of the human range of audibility is known as **Ultrasound**.

Generally, we classify ultrasound as those having frequencies above 20,000 Hz.

The range of frequencies of sound that a person can hear is called the range of audibility or the **audible frequency range**.

Sound with frequencies below the lower limit of the human range of audibility is known as **infrasonic.**

Different animals can hear different ranges of frequencies as shown in figure no. 11.9 and as well as in table 11.3.

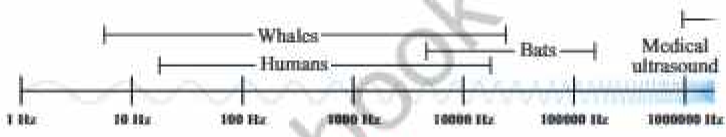


Fig: 11.9
The spectrum of sound frequencies for humans and other animals

Table 11.3 The audible frequency ranges of living organisms

Species	Frequency (hertz)	
	The lower limit of the audible frequency	The upper limit of the audible frequency
Elephants	16	12000
Human	20	20000
Horses	31	40000
Dogs	40	40000
Whales and dolphins	70	15000
Cats	100	32000
Locust	100	50000
Seals and sea lions	200	55000
Bats	1000	150000

Do You Know!

Different people have a different range of audibility. It also decreases with age as people grow older. Their hearing senses become less sensitive to higher frequencies. For the average human ear, the lower limit of audible frequency is 20 Hz, and the upper limit is 20000 Hz. In other words, our ears only respond to frequencies above20 Hz and below 20000 Hz.

Fig: 11.10.
Ultrasound cleaning

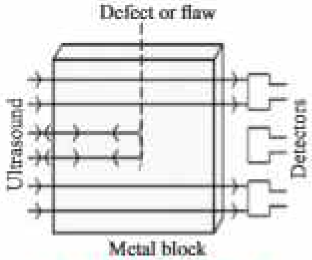


Fig: 11.11. A defect is detected by the ultrasound in metallic block

Fig: 11.12. Measuring the depth of seabed in the ocean by using ultrasound

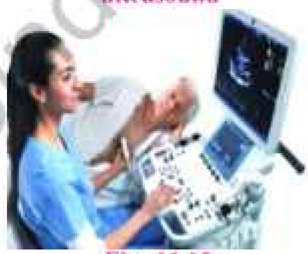


Fig: 11.13. Echocardiography to see the heart functions

Applications of ultrasound techniques in industry and medicine

Ultrasounds, high-frequency sound waves can propagate along well-defined straight paths, Ultrasounds are used extensively in industries and for medical diagnostic (imaging) purposes.

Cleansing

Ultrasound is commonly used to clean many objects even in hard-to-reach places, including jewelry, dental and surgical instruments, musical instruments. In this process, objects to be cleaned are placed in a cleaning solution, and ultrasonic waves are sent into the solution. Due to its high frequency, dust, grease, and contamination particles detached and dropped. The objects thus get thoroughly cleansed.

Quality control

Ultrasound has higher penetrating power due to its very high frequency. Thus, ultrasounds are also used to detect cracks, cavities, and flaws in metal and concrete blocks. These invisible cracks or cavities inside the blocks reduce the strength of the structure. Ultrasonic waves pass through the metal block, and detectors are used to detect the transmitted waves. If there is any defect, the ultrasound will be reflected, indicating the presence of the defect; Fig. 11.11.

Sound navigation and ranging (SONAR)

SONAR is extensively used in marine applications. Due to their high frequencies, ultrasound waves can travel greater distances. In this method, the transmitter sends out ultrasound pulses and measures the time it takes for the pulses to reflect off a distant object and return to the source or transducer. The position of that object can be identified, and its movement can be tracked. This technique is used to measure the depth of sea beds, locate and track submarines at sea, and locate explosive mines below the surface of the water; Fig. 11.12.

Echocardiography

Echocardiography is a painless and non-invasive medical imaging procedure. A transmitter sends out pulses of very high frequency. The transducer is positioned on the chest at specific locations and angles, the pulses move across the skin and other body tissues to the heart tissues, where the pulses bounce or echo of the heart structures; Fig. 11.13. These pulses are then transmitted to a computer to create moving images of the heart walls and valves. The image produced is called an echocardiogram.

Ultrasonography

It is a technique that uses an instrument ultrasound scanner. This scanner uses high-frequency sound waves to obtain images of the internal organs of the human body and to examine the fetus during pregnancy. A sonologist visualize the organs of the patient, such as the liver, gall bladder, uterus, kidney, etc. It helps the doctor to identify abnormalities, such as stones in the gall bladder and kidney or tumors and abnormalities in different organs. In this technique, the sound waves penetrate the body and hit a boundary between tissues, e.g., between fluid and soft tissue, bone and soft tissue, and get reflected from an area where their tissue density changes; Fig. 11.14. The instrument calculates the distance from the probe to the tissue or organ boundaries using the speed of sound in tissue and the time of the return of each echo. These pulses are then converted into electrical signals used to create two-dimensional images of the organ.

Fig: 11.14. The schematic diagram of the ultrasound scan machine

SELF-ASSESSMENT QUESTIONS:

Q1: Which one has a higher speed sound or light?

Q2: Is it possible to produce an echo in a room of length 10m?

Do You Know!

RADAR is used in Air traffic control and vehicle speed detection'

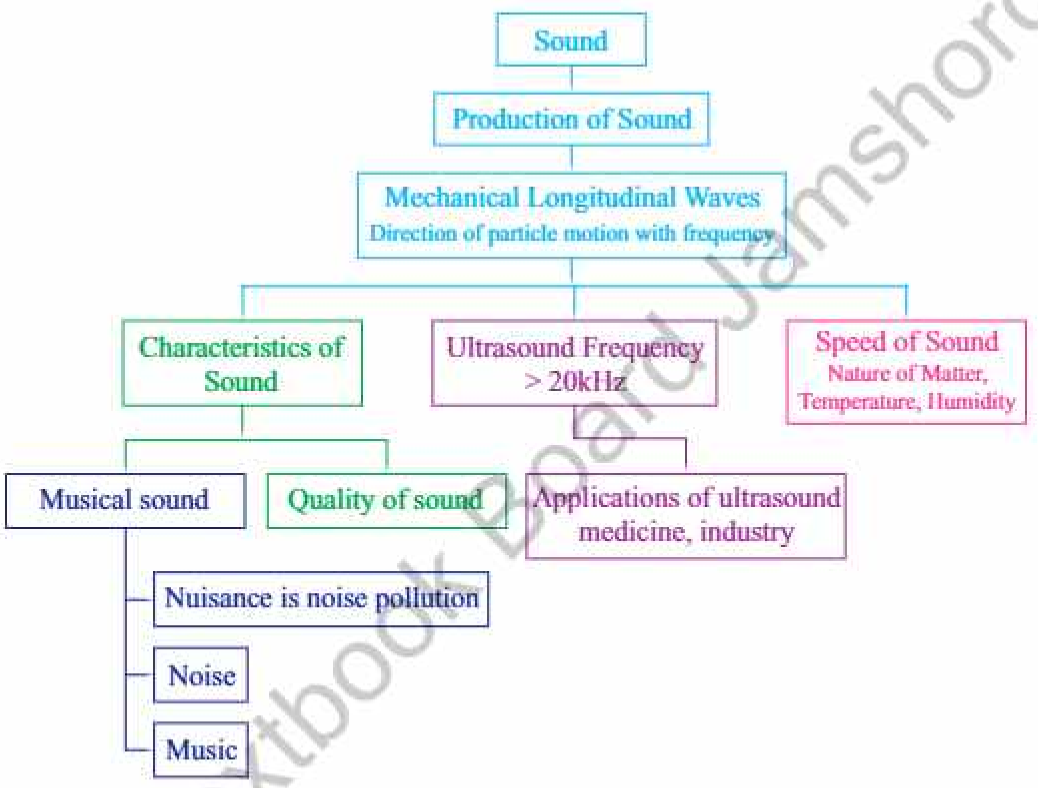
SONAR is used to measure ocean floor and locate submarines.

LiDAR is used in autonomous driving forestry, canopy heights, biomass measurement and LiDAR speed guns.

SUMMARY

- Sound is the form of energy related to the motion of vibrating molecules.
- Sound is a longitudinal wave; the direction of vibration of molecules is parallel to the direction of wave motion.
- Sound wave is comprised of successive compressions and rarefactions in the medium.
- Compressions are regions where air pressure is slightly higher than surrounding air pressure.
- Rarefactions are regions where air pressure is slightly lower than the surrounding air pressure.
- Sound needs a material medium to pass through energy.
- Sound cannot travel through a vacuum.
- Sound waves travel at different speeds in different mediums depending on their properties.
- The speed of sound is faster in solid materials and slower in liquids or gases.
- Temperature affects the speed of sound in air sound travels faster when the temperature of the medium rises.
- Humidity slightly affects the speed of sound in air, and sound travels faster when the humidity of the air rises.
- Quality is the characteristic of sound by which we can distinguish between two sounds of the same loudness and pitch.
- Sounds that are pleasant to our hearing sensations are called musical sounds.
- Sounds that are unpleasant to our hearing sensations are called noises.
- The high noise level has harmful effects on human health.
- The range of audibility is the range of sound frequencies that a person can hear.
- The normal human ear, the lower limit of audible frequency is 20 Hz, and the upper limit is 20K Hz.
- Ultrasound is the sound with frequencies above the upper limit of the human range of audibility.
- The echo is the reflection of the sound after reflection from an obstacle.
- In industry, ultrasounds can be used to detect cracks, cavities, and flaws in metal and concrete blocks.
- Sound navigation and ranging (SONAR) is used to measure the depth of sea beds, locate and track submarines at sea, and locate explosive mines below the surface of the water.
- Echocardiography uses ultrasound to produce the motional images of the heart and its valves.
- Ultrasonography uses ultrasound to scan soft organs and tissues.

CONCEPT MAP


Sound
Production of Sound
Mechanical Longitudinal Waves
Direction of particle motion with frequency
Characteristics of Sound
Ultrasound Frequency > 20kHz
Speed of Sound
Nature of Matter, Temperature, Humidity
Musical sound
Quality of sound
Applications of ultrasound medicine, industry
Nuisance is noise pollution
Noise
Music

Section (A) Multiple Choice Questions (MCQs)

Choose the correct answer from the following choices:

1. Sound is a form of:
   a) Electrical energy b) Mechanical energy
   c) Thermal energy d) Chemical energy
2. Audible frequencies range that a normal human ear can detect is:
   a) 10 Hz and 10 kHz b) 20 Hz and 20 kHz
   c) 25 Hz and 25 kHz d) 30 Hz and 30 kHz
3. The approximate value of the speed of sound in air at $0^{\circ}C$ temperature is:
   a) 332 m / s b) 34 m / s
   c) 17 m / s d) 680 m / s
4. Sound travel faster in solid as compare to gases because of:
   a) Gas molecules are packed loosely.
   b) Sound does not travel faster through a solid than a gas.
   c) Solid molecules are packed tightly.
   d) Gas molecules move faster.
5. The two factors that affect the speed of sound in air are:
   a) Humidity and volume of the air
   b) Temperature and mass of the air
   c) Volume and mass of the air
   d) Temperature and humidity of the air
6. The separation between two consecutive compressions of the sound wave is called:
   a) Time period b) Amplitude
   c) Frequency d) Wavelength
7. The order of speed of the sound in different mediums from faster to slowest is
   a) Gas → Liquid → Solid b) Liquid → Solid → Gas
   c) Solid → Liquid→ Gas d) Gas → Solid → Liquid
8. Ultrasound has several uses in medicine and industry. Which one has use of ultrasound?
   a) Absorption b) Pre-natal scanning
   c) Dispersion d) Measuring humidity of air
9. The causes of the echo is:
   a) Absorption b) Dispersion
   c) Reflection d) Refraction

10. Which type of wave cannot travel through a vacuum?

    a) Sound waves   b) Infra-red radiation
    c) Microwaves   d) X-rays

Section (B) Structured Questions

1. a) How is the sound produced?
   b) With the help of a diagram, describe how compressions and rarefactions are produced in the air near a source of the sound.

2. a) Why are sound waves referred to as mechanical waves?
   b) Sound requires a material medium for its propagation. Cite an experiment to prove this statement.

3. a) Distinguish between musical sound and noise.
   b) Explain how noise is harmful to humans?

4. a) Define the quality or timbre of the sound.
   b) Is it possible that two or more waves from different musical instruments combine to form a single wave?

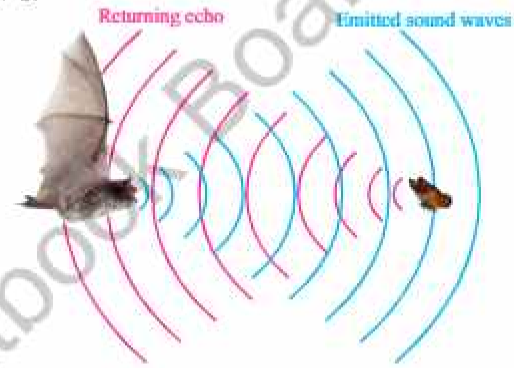
5. a) Why is the speed of the sound greater in solids than in liquids or gases?
   b) Explain the effect of the following factors on the speed of sound in the air.
      i. Temperature
      ii. Humidity

6. a) Define echo.
   b) Explain the working and application of a sonar.
   c) How can defects in a metal block be detected using ultrasound? Explain with the help of a diagram.

7. a) Define the following terms
      i. Infrasonic
      ii. The audible frequency range of hearing
      iii. Ultrasound
   b) How is ultrasound used for cleaning?
   c) Explain two applications of ultrasound that are used in hospitals for medical imaging.

Section (C) Numericals

1. Calculate the speed of sound in air at 50^0C? Given that speed of sound at 0^0C is 331m/s. **($360.0\ ms^{-1}$)**
2. A person has an audible range from 20 Hz to 20 kHz. What are the distinguishing wavelengths of sound waves in air corresponding to these two frequencies? Take the speed of sound in air as $340\ m\ s^{-1}$. **(58.8mm and 58.82m)**
3. A ship uses ultrasonic pulses to measure the depth of the submarine beneath the ship. A sound pulsing is transmitted into the sea, and the echo from the sea-bed is received after 40 ms. The speed of sound in seawater is 1480 m / s. Calculate the deepness of the submarine. **(29.6 = 30m)**
4. At night, bats emit pulses of sound to detect their prey. The speed of sound in air is 340 m / s.



(i) A bat emits a pulse of the sound of wavelength 0.0080 m. Calculate the frequency of the sound. **(42.5Hz)**
(ii) The pulse of sound hits its prey and is reflected in the bat. The bat receives the pulse 0.10 s after it is emitted. Calculate the distance traveled by the pulse of sound during this time. **(17m)**
(iii) Calculate the distance of prey from the bat. **(8.5m)**