FUTURISING EDUCATION WITH INNOVATION

Solutions of Sound Worksheets

Worksheet -1

Solutions for Section A (MCQs)

1. **(b) Energy.** Sound is a form of mechanical energy that travels as a wave.
2. **(c) A vibrating object.** The fundamental cause of sound is the vibration of an object.
3. **(c) Medium.** Sound waves are mechanical waves and require a material medium (solid, liquid, or gas) for their propagation.
4. **(d) Outer space.** Outer space is largely a vacuum, and sound cannot travel through a vacuum.
5. **(b) Strings.** Plucking the strings of a guitar causes them to vibrate, producing sound.
6. **(c) Vocal cords.** Air from the lungs passes through the vocal cords, causing them to vibrate and produce sound.
7. **(b) Mechanical wave.** A mechanical wave is a disturbance that transfers energy through a medium.
8. **(b) The entire metal body.** When struck, the metal body of the bell vibrates, creating sound waves.
9. **(c) Vibration.** Vibration is the specific term for this type of motion.
10. **(b) Vibrates.** The plucked rubber band vibrates, which in turn vibrates the surrounding air particles, creating sound.

Solutions for Section B (Very Short / Short Answer Questions)

1. **Sound** is a form of energy that creates the sensation of hearing. It is produced when an object undergoes **vibration** (a rapid back-and-forth motion).
2. Sound is called a **mechanical wave** because it needs a material medium (like a solid, liquid, or gas) for its propagation. It cannot travel through a vacuum as there are no particles to carry the vibrations.
3. Two examples are:

> **Ringing a bicycle bell:** The metal of the bell vibrates.
> **Speaking:** Our vocal cords vibrate.

4. There is no atmosphere (and therefore no medium) on the Moon. Since sound is a mechanical wave and requires a medium to travel, the sound waves produced by the friend cannot propagate to the astronaut's ear.

5. Activity: Take a tuning fork and strike its prong on a rubber pad. Bring it near your ear; you will hear a sound. Now, touch one of the vibrating prongs to the surface of water in a bowl. You will see the water splash. This shows that the tuning fork was vibrating, and these vibrations produce sound.

Solutions for Section C (Long Answer Questions)

1. Different musical instruments produce sound through the vibration of specific parts:

- **String Instrument (e.g., Guitar, Violin):**
  - **Vibrating Part:** The strings.
  - **Explanation:** When the strings are plucked, bowed, or struck, they vibrate. The frequency of this vibration depends on the tension, length, and thickness of the string. This vibration is transferred to the body of the instrument, which amplifies the sound.
- **Wind Instrument (e.g., Flute, Clarinet):**
  - **Vibrating Part:** The air column inside the instrument.
  - **Explanation:** The player blows air across an opening or through a reed, causing the column of air inside the instrument to vibrate. The length of the vibrating air column is changed by opening or closing holes, which in turn changes the pitch of the sound produced.
- **Percussion Instrument (e.g., Drum, Tabla):**
  - **Vibrating Part:** A stretched membrane (skin).
  - **Explanation:** When the membrane is struck with hands or sticks, it vibrates rapidly. This vibration creates pressure waves in the air, which we perceive as sound. The tightness and size of the membrane determine the pitch of the sound.

2. Propagation of Sound: The propagation of sound is the process by which a sound wave travels through a medium. When a sound source vibrates, it causes the adjacent particles of the medium to vibrate. These particles then transfer their energy to the next set of particles, and so on. This creates a chain reaction where the disturbance travels, but the particles themselves only oscillate about their mean positions. This disturbance, in the form of a wave, eventually reaches our ear, causing the eardrum to vibrate, which our brain interprets as sound. **Why sound can't travel in a vacuum (Bell Jar Experiment):**

Setup: An electric bell is suspended inside an airtight glass bell jar, which is connected to a vacuum pump.

Procedure:

1. Initially, with air inside the jar, the switch for the bell is turned on. We can clearly hear the bell ringing.
2. Now, the vacuum pump is started to slowly remove the air from the jar. As the air is pumped out, the sound of the bell becomes fainter, even though we can still see the hammer striking the gong.
3. When most of the air is removed (creating a near-vacuum), we can no longer hear any sound.

Conclusion: This experiment demonstrates that sound requires a material medium (in this case, air) for its propagation. In the absence of a medium (a vacuum), the sound waves cannot travel from the bell to the wall of the jar and then to our ears.

Solutions Worksheet-2

Solutions for Section A (MCQs)

1. **(b) Parallel to the direction of wave propagation.** This is the definition of a longitudinal wave.
2. **(b) Compression.** Compressions are regions where particles are crowded together, resulting in higher pressure and density.
3. **(a) Rarefaction.** Rarefactions are regions where particles are spread apart, resulting in lower pressure and density.
4. **(c) Sound wave.** Sound waves in fluids (gases and liquids) are longitudinal.
5. **(b) Transverse wave.** Crests (high points) and troughs (low points) are characteristic features of transverse waves.
6. **(a) Density variations.** Compressions are regions of high density and rarefactions are regions of low density.
7. **(b) Vibrate about their mean position.** In a wave, energy is transferred, not the particles of the medium themselves.

8. (c) Both transverse and longitudinal waves. Pushing and pulling a slinky demonstrates a longitudinal wave; shaking it side-to-side demonstrates a transverse wave.

9. (c) Wavelength. The wavelength in a longitudinal wave is the distance between consecutive compressions or rarefactions.

10. (b) Longitudinal. The air particles vibrate back and forth in the same direction as the wave travels.

Solutions for Section B (Very Short / Short Answer Questions)

1. A **longitudinal wave** is a wave where the particles of the medium oscillate back and forth in the same direction as the wave is moving (parallel to the direction of energy transfer).

2. Compressions (C) are regions in a longitudinal wave where the particles of the medium are crowded together, resulting in high pressure and density. **Rarefactions (R)** are regions where the particles are spread apart, resulting in low pressure and density.

3. (The student should draw a diagram similar to the one provided in the notes section, showing alternating regions of closely packed lines (C) and spread-out lines (R)).

4. Longitudinal Wave Transverse Wave Particles vibrate parallel to the wave direction. Particles vibrate perpendicular to the wave direction. Consists of compressions and rarefactions. Consists of crests and troughs. Example: Sound waves in air. Example: Light waves, waves on a string.

5. Sound waves are longitudinal because the vibrations of the source cause the particles of the medium (e.g., air) to be pushed and pulled. This creates a series of pressure changes (compressions and rarefactions) that travel in the same direction as the particle movement. The energy is transferred through these parallel oscillations.

Solutions for Section C (Long Answer Questions)

1. Activity to Demonstrate a Longitudinal Wave with a Slinky:

- **Setup:** Place a long slinky spring on a smooth floor or tabletop. Fix one end of the slinky firmly (or have a friend hold it). Hold the other end in your hand.
- **Procedure:**

    1. Stretch the slinky.

2. Give the end in your hand a sharp push forward and then pull it back quickly.
3. Observation: You will see a "bunching" or compression of the coils travel down the slinky. After the compression passes, the coils spread out again. This moving compression is a longitudinal pulse. If you push and pull your hand rhythmically, you will create a series of compressions and rarefactions that travel along the slinky.

- **Diagram:** (A diagram showing a stretched slinky with a hand pushing it, creating a compressed region that moves along its length).
- **Relation to Sound Propagation:** This is a direct analogy for how sound travels.
    - Your hand represents the **vibrating sound source**.
    - The coils of the slinky represent the **particles of the air**.
    - The compressed region of coils is analogous to a **compression** in a sound wave (high pressure).
    - The stretched-out region of coils is analogous to a **rarefaction** (low pressure).
    - Just as the coils of the slinky only move back and forth while the wave travels along its length, air particles only oscillate while the sound wave travels from the source to the ear.

2. Production and Propagation of Sound from a Tuning Fork: When a tuning fork is struck, its prongs begin to vibrate rapidly back and forth. This vibration creates sound waves in the surrounding air through the following process:

1. Forward Movement (Creates Compression): As a prong of the tuning fork moves forward (outward), it pushes the layer of air **particles** directly in front of it. These particles are forced closer together, creating a region of high density and high pressure. This region is called a **compression**. This compression starts to move away from the prong as the high-pressure particles push on the next layer of particles.
2. Backward Movement (Creates Rarefaction): As the prong moves backward (inward) to its original position and beyond, it leaves a space with fewer air particles. This creates a region of low density and low pressure. This region is called a **rarefaction**.
3. Wave Propagation: The tuning fork continues its rapid **vibration**, producing a continuous series of compressions and rarefactions.

Each compression is followed by a rarefaction, which is followed by another compression, and so on. This sequence of alternating pressure regions travels outward through the air.

4. Energy Transfer: It is crucial to understand that the air particles themselves do not travel from the tuning fork to the ear. They simply oscillate back and forth about their fixed positions. What travels is the disturbance—the wave of changing pressure. This wave carries the **energy** from the vibrating source. When this wave reaches our ear, it causes our eardrum to vibrate, and our brain interprets this as sound.

Solutions of Worksheet-3

Solutions for Section A (MCQs)

1. (b) Amplitude. Loudness is directly related to the square of the amplitude of the sound wave.

2. (a) Frequency. Pitch is our brain's interpretation of the frequency of a sound.

3. (c) Hertz. Hertz (Hz) means cycles or oscillations per second.

4. (c) 200 m/s. Speed (v) = Frequency (f) × Wavelength (λ) = 50 Hz × 4 m = 200 m/s.

5. (b) Time Period. This is the definition of the time period (T).

6. (c) Higher frequency. High pitch corresponds to a high frequency of vibration.

7. (b) 50 Hz. Frequency (f) = 1 / Time Period (T) = 1 / 0.02 s = 50 Hz.

8. (b) Wavelength. Wavelength is the distance between two consecutive compressions or rarefactions.

9. (c) Loudness. Loudness, determined by amplitude, is the characteristic that describes the intensity of the sound.

10. (a) 2 m. First, find the speed: v = distance/time = 10 m / 2 s = 5 m/s. Then, find the wavelength: λ = v / f = 5 m/s / 2.5 Hz = 2 m.

Solutions for Section B (Very Short / Short Answer Questions)

1. Amplitude is the maximum displacement of a particle of the medium from its mean position. The **loudness** of a sound is determined by its amplitude. A larger amplitude results in a louder sound.

2. Frequency (f) and time period (T) are inversely proportional to each other. The relationship is given by the formula: **$f = 1/T$**.

3. 20 compressions and 20 rarefactions mean there are 20 complete waves (or oscillations). Number of oscillations = 20. Time taken = 0.2 s. Frequency (f) = Number of oscillations / Time taken = 20 / 0.2 s = **100 Hz**.

4. Given: Speed (v) = 340 m/s, Frequency (f) = 200 Hz. We know, $v = f \times \lambda$. Therefore, Wavelength (λ) = v / f = 340 m/s / 200 Hz = **1.7 m**.

5. Loudness Pitch It is the characteristic that distinguishes a loud sound from a faint one. It is the characteristic that distinguishes a shrill sound from a flat one. It depends on the **amplitude** of the wave. It depends on the **frequency** of the wave.

Solutions for Section C (Long Answer Questions)

1. Definitions: Derivation of $v = \lambda f$: Numerical Problem:

- **Wavelength (λ):** The distance between two consecutive compressions or two consecutive rarefactions. Its SI unit is the meter (m).
- **Frequency (f):** The number of complete oscillations per second. Its SI unit is the Hertz (Hz).
- **Time Period (T):** The time taken for one complete oscillation. Its SI unit is the second (s).
- **Amplitude (A):** The maximum displacement of a particle from its mean position. It determines the loudness.
- By definition, speed is the distance traveled divided by the time taken.
- Let's consider one complete wave. The distance traveled by the wave in this time is one wavelength (λ).
- The time taken to complete one oscillation (and thus travel one wavelength) is the time period (T).
- So, Speed (v) = Distance / Time = Wavelength / Time Period = λ / T.
- We also know that frequency (f) is the reciprocal of the time period, i.e., $f = 1/T$.
- Substituting 1/T with f in the speed equation, we get: **$v = \lambda \times f$**.
- The time interval between successive compressions is equal to the time period (T) of the wave.
- Given: Frequency (f) = 500 Hz.
- We know, T = 1 / f.

- T = 1 / 500 Hz = **0.002 s**.
- (Note: The distance of 450 m and speed of sound are extra information not needed to find the time interval between compressions).

2. Loudness: Loudness is the attribute of a sound that determines its intensity, i.e., whether it is loud or soft. It depends primarily on the **amplitude** of the sound wave. A wave with a larger amplitude carries more energy and is perceived as a louder sound. **Pitch:** Pitch is the quality of a sound that makes it seem "high" or "low." It is determined by the **frequency** of the sound wave. A wave with a higher frequency is perceived as a high-pitched (shrill) sound, while a wave with a lower frequency is perceived as a low-pitched (grave or deep) sound. **Graphical Representations:** Graph 1: Pitch Comparison i) Pitch Comparison (Same Loudness) Low Pitch
Low Pitch (Low Frequency) High Pitch
High Pitch (High Frequency)
Graph 2: Loudness Comparison ii) Loudness Comparison (Same Pitch) Soft Sound
Soft Sound (Small Amplitude) Loud Sound
Loud Sound (Large Amplitude)

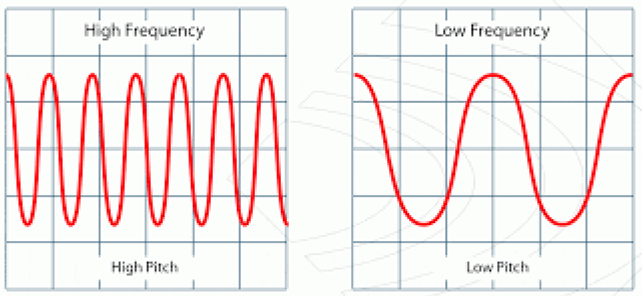

Fig: Graphical representation of sound waves with different pitch and loudness.

Solutions of Worksheer-4

Solutions for Section A (MCQs)

1. (c) Steel. Sound travels fastest in solids, followed by liquids, and then gases.
2. (c) Properties of the medium. The speed of sound is determined by the elasticity and density of the medium.

3. **(b) Increases.** At higher temperatures, particles have more kinetic energy and transmit vibrations more quickly.
4. **(b) Particles in solids are closer together.** This allows for a much faster transfer of vibrational energy.
5. **(a) v(gas) < v(liquid) < v(solid).** This is the correct ascending order of the speed of sound.
6. **(b) 331 m/s.** The speed of sound in air at 0°C is approx. 331 m/s, which increases to 343 m/s at 20°C.
7. **(a) Sound travels slower than light.** The speed of light (approx. 3×10^8 m/s) is vastly greater than the speed of sound (approx. 343 m/s).
8. **(c) Pressure (in gases).** For an ideal gas, changes in pressure at a constant temperature do not significantly affect the speed of sound because density changes proportionally.
9. **(c) Frequency.** When a wave passes from one medium to another, its frequency remains constant as it is determined by the source. Speed and wavelength change.
10. **(c) Have a much higher ratio of elasticity to density.** Although solids are much denser than gases, their elasticity is vastly greater, leading to a much higher speed of sound.

Solutions for Section B (Very Short / Short Answer Questions)

1. The decreasing order of the speed of sound is: **Solids > Liquids > Gases**.
2. The speed of sound **increases** with an increase in temperature. This is because a higher temperature means particles have more kinetic energy, vibrate faster, and can transmit the sound wave more quickly.
3. We see the flash first because the speed of light (approx. 3×10^8 m/s) is extremely high compared to the speed of sound in air (approx. 343 m/s). The light reaches our eyes almost instantaneously, while the sound takes a noticeable amount of time to travel the same distance.
4. Sound travels much faster through solids than through gases. The railway track is made of steel (a solid). Therefore, the sound from the train travels faster through the track and reaches the boy's ear before the sound traveling through the air.
5. Let t_air be the time in air and t_glass be the time in glass. Time = Distance / Speed. t_air = d / v_air = d / 340 t_glass = d / v_glass = d / 4500 Ratio (t_air / t_glass) = (d / 340) / (d / 4500) = 4500 / 340 ≈ 13.24. The ratio of time taken is **4500:340 or approximately 13.24:1**.

Solutions for Section C (Long Answer Questions)

1. The speed of sound is fundamentally determined by how quickly vibrations can be transferred from one particle to another in a medium. This depends on two main properties of the medium: **elasticity** and **density**. The speed of sound is generally given by v = √(Elasticity/Density).

Comparison of Media:

- **Elasticity:** This is the ability of a material to return to its original shape after being deformed. A more elastic medium allows particles to return to their equilibrium positions faster, thus transmitting the wave more quickly.
- **Density:** This is the mass per unit volume. A denser medium has more massive particles, which are harder to move (more inertia), and this tends to slow down the wave.
- **Solids:** Particles in solids are packed very tightly and are held by strong intermolecular forces. This makes solids very elastic. Although they are also very dense, their elasticity is overwhelmingly greater than their density, resulting in a very high speed of sound (e.g., steel ~5960 m/s).
- **Liquids:** Particles in liquids are less tightly packed than in solids and can slide past one another. They are less elastic than solids but more elastic than gases. This intermediate state results in a speed of sound that is slower than in solids but faster than in gases (e.g., water ~1500 m/s).
- **Gases:** Particles in gases are very far apart with negligible intermolecular forces. They are highly compressible but not very elastic in the sense of returning to a shape. Vibrations are transferred through random collisions, which is a much slower process. This results in the lowest speed of sound (e.g., air ~343 m/s).

2. (a) Two factors on which the speed of sound depends are: (b) Numerical Problem: (c) Sound clarity at night: During the day, the ground is warmer than the air above it. This makes the air near the ground warmer and less dense. Sound travels faster in warmer air. As sound waves travel from the source, they bend away from the ground (refract upwards). At night, the ground cools faster than the air above it. This creates a temperature inversion, where the air near the ground is cooler (and denser) than the air higher up. Sound travels slower in the cooler air near the ground. This causes the sound waves to bend towards the ground (refract downwards). This downward refraction allows the sound to travel farther along the ground, making distant sounds seem clearer and louder at night.

1. **The nature of the medium:** Its elasticity and density (i.e., whether it is a solid, liquid, or gas).
2. **The temperature of the medium:** Speed increases with temperature.

- Given: Speed (v) = 339 m/s.
- Wavelength (λ) = 1.5 cm = 0.015 m (It is important to convert to SI units).
- Using the wave equation, v = f × λ.
- Frequency (f) = v / λ = 339 m/s / 0.015 m = **22600 Hz**.
- **Audibility:** The audible range for humans is from 20 Hz to 20,000 Hz. Since 22,600 Hz is greater than 20,000 Hz, this sound is in the ultrasonic range and **will not be audible** to humans.

Solutions of worksheet-5

Solutions for Section A (MCQs)

1. (b) Echo. An echo is a single, distinct reflection of sound.
2. (c) 0.1 s. The brain retains the impression of a sound for about 1/10th of a second.
3. (b) Sound-absorbent materials. Materials like fiberboard, heavy curtains, and carpets absorb sound energy, preventing multiple reflections.
4. (b) 680 m. Distance (d) = (v × t) / 2 = (340 m/s × 4 s) / 2 = 1360 / 2 = 680 m.
5. (c) Both sound and light. Both wave phenomena obey the laws of reflection.
6. (b) 17.2 m. d = (344 m/s × 0.1 s) / 2 = 17.2 m.
7. (d) Reverberation. This is the definition of reverberation.
8. (a) Multiple reflection of sound. The sound of the heartbeat is guided through the tube to the doctor's ears by multiple reflections.
9. (b) Large and hard. A large, hard surface (like a cliff or wall) is required to reflect most of the sound energy without absorbing or scattering it.
10. (c) 30°. According to the law of reflection, the angle of incidence is equal to the angle of reflection.

Conceptual Learning

Solutions for Section B (Very Short / Short Answer Questions)

1. An **echo** is the repetition of sound due to its reflection from a distant, hard surface. **Conditions:** 1. The time interval between the original sound and the reflected sound must be at least 0.1 s. 2. The distance to the reflecting surface must be at least 17.2 m (in air at room temperature).
2. **Reverberation** is the persistence of sound caused by repeated or multiple reflections in an enclosed space. It can be reduced by using sound-absorbent materials like carpets, heavy curtains, and covering walls with rough plaster or fiberboard.
3. **Laws of reflection of sound:** 1. The angle of incidence is equal to the angle of reflection. 2. The incident wave, the reflected wave, and the normal at the point of incidence all lie in the same plane.
4. Given: Time (t) = 2 s, Speed (v) = 346 m/s. The distance traveled by sound is 2d (to the cliff and back). 2d = v × t d = (v × t) / 2 = (346 m/s × 2 s) / 2 = **346 m**.
5. The ceilings of concert halls are often curved so that sound, after reflecting from the ceiling, reaches all corners of the hall uniformly. This ensures that the sound is distributed evenly throughout the audience.

Solutions for Section C (Long Answer Questions)

1. **(a) Difference between Echo and Reverberation:** Echo Reverberation It is a single, clear, and distinct repetition of sound. It is the persistence of sound due to multiple, overlapping reflections. Caused by reflection from a single, distant surface. Caused by multiple reflections from various surfaces in an enclosed space. The distance to the reflector must be large (> 17.2 m). Occurs in large enclosed spaces like halls, even if distances are less than 17.2 m. Example: Shouting towards a distant cliff or mountain. Example: Sound in an empty, large auditorium or a cave. **(b) Calculation of Minimum Distance for Echo: (c) Two devices based on the reflection of sound:**

- The human ear can distinguish between two sounds only if they reach the ear with a time gap of at least 0.1 seconds. This is the persistence of hearing.
- For an echo, the sound must travel from the source to the reflector and back to the listener's ear. Let this distance be 'd'.
- Total distance traveled by sound = d + d = 2d.
- Minimum time interval (t) = 0.1 s.

- Speed of sound (v) = 340 m/s (given).
- Using the formula: Speed = Total Distance / Time Taken
- v = 2d / t
- d = (v × t) / 2
- d = (340 m/s × 0.1 s) / 2 = 34 m / 2 = **17 m**.

1. Stethoscope: Guides sound from the patient's chest to the doctor's ears through multiple reflections inside its tube.

2. Megaphone/Horn: Confines sound and directs it in a particular direction using reflection, preventing it from spreading out.

2. (a) Reflection of Sound: When a sound wave strikes a hard surface, it bounces back into the same medium. This phenomenon is called the reflection of sound. The sound wave obeys the laws of reflection, similar to light waves. The angle at which the sound wave strikes the surface (angle of incidence) is equal to the angle at which it bounces off (angle of reflection). A large, rigid, and smooth surface is an effective reflector. Reflection of Sound

Reflecting Surface

Normal

Incident Wave

Reflected Wave

i

r *Fig: Reflection of a sound wave, where angle of incidence (i) = angle of reflection (r).* **(b) SONAR Problem:** This is an application of echo, used in SONAR (Sound Navigation and Ranging). Therefore, the distance of the seabed from the ship is 2618.01 meters.

- Given: Time for the ultrasound to travel to the seabed and back (t) = 3.42 s.
- Speed of ultrasound in seawater (v) = 1531 m/s.
- Let 'd' be the distance of the seabed from the ship.
- The total distance traveled by the ultrasound is 2d.
- Using the formula, Total Distance = Speed × Time.
- 2d = v × t
- 2d = 1531 m/s × 3.42 s = 5236.02 m
- d = 5236.02 m / 2 = **2618.01 m**.

solutions of Worksheet-6

Solutions for Section A (MCQs)

1. (c) 20 Hz to 20,000 Hz. This is the standard audible range for humans.
2. (b) Infrasound. Frequencies below 20 Hz are classified as infrasound.
3. (c) Dolphin. Dolphins, bats, and porpoises are well-known producers of ultrasound.
4. (c) Ultrasonic. 25 kHz is 25,000 Hz, which is above the human hearing limit of 20,000 Hz.
5. (a) Infrasound. Elephants and whales use low-frequency infrasound to communicate over long distances.
6. (c) Ultrasound. Echolocation is the process of using high-frequency sound (ultrasound) and its echoes to navigate and find objects.
7. (b) Shrinks from the high-frequency end. Age-related hearing loss typically affects the ability to hear higher frequencies first.
8. (c) Infrasonic. Earthquakes produce low-frequency infrasonic waves that some animals can detect.
9. (c) 1000 Hz. The prefix 'kilo' (k) means 1000.
10. (c) 18 Hz. 18 Hz is below the lower limit of human hearing (20 Hz), so it is infrasonic.

Solutions for Section B (Very Short / Short Answer Questions)

1. The **audible range** for humans is the range of sound frequencies that can be perceived by the human ear. It is approximately from **20 Hz to 20,000 Hz**.
2. Infrasound refers to sound waves with frequencies below the lower limit of human audibility, i.e., **below 20 Hz**. An example of an animal that uses it is the **rhinoceros** or **elephant**.
3. Ultrasound refers to sound waves with frequencies above the upper limit of human audibility, i.e., **above 20,000 Hz**. An example of an animal that uses it is a **bat** or **dolphin**.
4. Since humans cannot hear the whistle but dogs can, we can conclude that the whistle produces sound at a frequency **above 20,000 Hz (20 kHz)**. This is in the ultrasonic range, which is audible to dogs but not to humans.
5. Two natural phenomena that produce infrasound are **earthquakes** and **volcanic eruptions**.

Solutions for Section C (Long Answer Questions)

1. Sound waves are classified into three categories based on their frequency: Category Frequency Range Definition & Examples **Infrasound** Below 20 Hz **Definition:** Sound with a frequency less than 20 Hz, inaudible to humans.
Examples:
1. Communication by elephants and whales.
2. Waves produced by earthquakes and volcanoes. **Audible Sound** 20 Hz to 20,000 Hz **Definition:** Sound that is within the range of human hearing.
Examples:
1. Human speech.
2. Music from instruments. **Ultrasound** Above 20,000 Hz (20 kHz) **Definition:** Sound with a frequency greater than 20 kHz, inaudible to humans.
Examples:
1. Echolocation by bats and dolphins.
2. Medical ultrasonography (scans).

2. Echolocation in Bats: Echolocation is a biological sonar used by animals like bats to navigate and find food in the dark. The process involves emitting sound waves and listening to the echoes that return from various objects.

- **Type of Sound Used:** Bats use **ultrasound**, which are high-frequency sound waves (typically 20 kHz to 100 kHz).
- **Why Ultrasound is Suitable:**

  1. High Directionality: Due to their short wavelength, ultrasonic waves can be confined to a narrow beam. This allows the bat to pinpoint the exact location of an object.
  2. High Energy: They carry high energy and can travel significant distances without losing much strength.
  3. Reflection from Small Objects: The short wavelength allows the sound to reflect off very small objects, such as insects, which would not be possible with lower-frequency (longer wavelength) sound.

- **How it Works:**

  1. Emission: The bat emits a series of short, high-frequency clicks or squeaks.

2. Reflection: These sound waves travel outward, hit objects in the environment (like trees, walls, or insects), and reflect back as echoes.
3. Detection: The bat's large, sensitive ears detect the returning echoes.
4. Interpretation: The bat's brain processes the information from the echoes with incredible speed and accuracy. By analyzing the **time delay** between emitting the sound and receiving the echo, the bat determines the **distance** to the object. By analyzing the differences in the sound reaching its two ears and the **nature of the echo** (its intensity and frequency), the bat can determine the object's **size, shape, texture, and direction of movement**. This allows it to create a detailed "sound map" of its surroundings, enabling it to fly and hunt with precision even in complete darkness.

Solutions of worksheet -7

Solutions for Section A (MCQs)

1. (c) Ultrasonic waves. SONAR uses high-frequency ultrasonic waves.
2. (b) High-frequency vibrations. These vibrations dislodge dirt and grease particles from surfaces.
3. (d) Ultrasonography. This is the specific term for imaging with ultrasound.
4. (c) Heart. 'Cardio' refers to the heart.
5. (b) Measuring distances underwater. This is the primary function of SONAR.
6. (a) Lithotripsy. This is the medical term for the non-invasive procedure.
7. (c) Distance. The time delay is directly proportional to the distance to the object.
8. (b) Gets reflected by flaws. A crack or void acts as a surface that reflects the ultrasound waves, which are then detected.
9. (b) 1875 m. Depth (d) = (v × t) / 2 = (1500 m/s × 2.5 s) / 2 = 3750 / 2 = 1875 m.
10. (c) Listening to music. Music falls within the audible range of frequencies, not the ultrasonic range.

Conceptual Learning

Solutions for Section B (Very Short / Short Answer Questions)

1. SONAR stands for **So**und **Na**vigation **a**nd **R**anging.
2. Two medical applications are: 1. **Ultrasonography:** To create images of internal organs and monitor fetal growth. 2. **Echocardiography:** To get images of the heart.
3. Objects to be cleaned are placed in a solution, and ultrasonic waves are passed through it. The high-frequency vibrations create tiny bubbles and agitate the liquid, effectively scrubbing and dislodging dirt and grease from the object's surface, even in hard-to-reach areas.
4. Ultrasonic waves are passed through the metal block. If the block is free of flaws, the waves pass through uninterrupted. If there is an internal crack or flaw, the waves are reflected back from it. Detectors placed on the surface pick up these reflections, indicating the location of the flaw.
5. Given: Time (t) = 1.02 s, Speed (v) = 1531 m/s. Distance to cliff (d) = (v × t) / 2 d = (1531 m/s × 1.02 s) / 2 = 1561.62 m / 2 = **780.81 m**.

Solutions for Section C (Long Answer Questions)

1. **Ultrasound** is sound with a frequency higher than the upper limit of human hearing, i.e., above 20,000 Hz (20 kHz). **Three important properties of ultrasound: Applications of Ultrasound:**

1. **High Energy:** They carry a large amount of energy.
2. **High Directionality:** They can be directed in a narrow, well-defined beam and do not bend easily around obstacles.
3. **Good Reflection:** They reflect well off surfaces, including small objects and boundaries between different media.

- **Medical Application (Ultrasonography):** This technique is used to create real-time images of the body's internal organs. A handheld device called a transducer is placed on the skin. It emits pulses of ultrasound into the body. These waves travel through the tissues and are reflected back when they hit a boundary between different types of tissue (e.g., between fluid and soft tissue, or soft tissue and bone). The transducer detects these returning echoes. A computer analyzes the time and intensity of the echoes to construct a two-dimensional image on a screen. It is a safe, non-invasive procedure commonly used to examine the heart, liver, kidneys, and to monitor the health and development of a fetus during pregnancy.

- **Industrial Application (Detecting Flaws in Metal):** Ultrasound provides a non-destructive way to test the integrity of metal components used in construction, aerospace, etc. An ultrasonic transmitter sends a pulse of ultrasound into the metal block. In a flawless block, the wave travels to the other side and is picked up by a detector. However, if there is an internal crack, void, or impurity, it acts as a surface from which the ultrasound will reflect. This reflected echo is picked up by a detector. By analyzing the time it takes for the echo to return, engineers can pinpoint the exact location of the flaw without damaging the block.

2. **Working Principle of SONAR:** SONAR (Sound Navigation and Ranging) is a system that uses sound propagation (usually underwater) to navigate, communicate with, or detect objects on or under the surface of the water. It is based on the principle of echo. The formula used is: **$2d = v \times t$**, which gives **$d = (v \times t) / 2$**. SONAR Application

Ship
SONAR
Seabed
Transmitted Pulse
Reflected Pulse *Fig: SONAR used to measure sea depth.* **Numerical Problem:** The depth of the sea is 3750 meters or 3.75 kilometers.

1. **Transmission:** A transmitter in the SONAR device, typically mounted on the hull of a ship, generates a powerful pulse of ultrasonic waves and sends it down into the water.
2. **Propagation and Reflection:** The ultrasonic pulse travels through the water. When it strikes an object with a different density, such as the ocean floor, a submarine, or a large school of fish, it is reflected back towards the ship.
3. **Detection:** A detector (or receiver) on the ship picks up the reflected echo.
4. **Calculation:** The SONAR system measures the time interval (t) between the moment the pulse was sent and the moment the echo was received. Knowing the speed of sound in water (v), the system can calculate the distance (d) to the object. Since the sound travels to the object and back, the total distance covered is 2d.

- Given: Time (t) = 5 s.

- Speed of sound in water (v) = 1500 m/s.
- We need to find the depth of the sea (d).
- Using the formula: d = (v × t) / 2
- d = (1500 m/s × 5 s) / 2
- d = 7500 m / 2
- d = **3750 m**