Sound

OSCILLATION AND WAVES

By Sir. Allan

Introduction

In this topic we will discuss the following:

- Definition of sound.
- Production of sound.
- Discussing loudness and pitch of sound.
- Free and forced vibrations.
- Resonance.
- Propagation of sound.
- Factors affecting the speed of sound.
- Quiz.

Definition & Production of sound

- Sound is a **form of energy** that travels through a medium as a wave.
- Sound can travel in air, water, or solids.
- Sound is produced by the **vibration of an object**, which causes the particles in the surrounding medium to vibrate.
- Examples of objects that produce sound are **loudspeakers**, **tuning forks**, **bells**, and **drums**.
- The vibration caused creates a **longitudinal wave** with **compressions** and **rarefactions** that propagate (move) away from the source.
- **Note**:
  - Compressions are areas in the medium with high pressure.
  - Rarefactions are areas in the medium with low pressure.

Loudness of Sound

- **Figure 1** shows a tuning folk that is vibrating to produce a sound wave

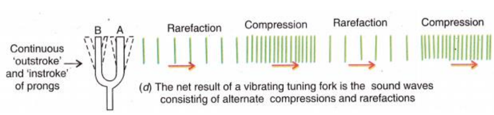


Figure 1

Loudness of sound

- Loudness is the **perception of the power** of sound.
- It is how we **perceive the volume** of sound and it is measured in decibels (dB).
- A louder sound has a **high amplitude**.
- The amplitude of a sound wave is the **maximum distance** the vibrating system moves **backward** and **forward** from its **resting** position.
- **Thus:** the loudness of sound depends on the amplitude of the wave producing it.

Pitch of Sound

- **Figure 2** shows the relationship between loudness and amplitude in sound.

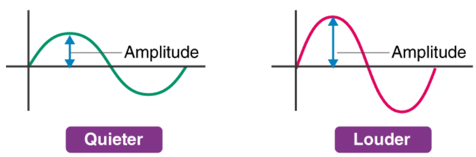


Figure 2

Pitch of sound

- Pitch is the perception of the frequency of a sound.
- It determines how high-pitched or low-pitched a sound is perceived.
- Frequency is defined as the number of complete vibrations per unit time
- A sound wave with a high frequency has a higher pitch, and that with a low frequency has a lower pitch.
- Since the pitch of a sound wave is related to frequency, it is measured in Hertz (Hz)

Pitch of Sound

- **Figure 3** shows the relationship between pitch and frequency in sound.

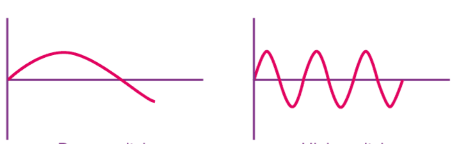


Figure 3

A simple experiment to demonstrate that a vibrating system produces energy

a. Strike one prong of a turning folk on a rubber pad.
b. Bring the vibrating prong in contact with a small pith ball supported by a string.

- The pith ball will be jerked to one side showing that the vibrating prong produces energy which is in the form of sound.

Free & Forced Vibrations

- A **free vibration** is a vibration that occurs **naturally** after an initial disturbance, **without** any continuous external force acting on it.
- This free vibration vibrates at a **natural frequency**.
- An **example** of a natural frequency vibrating system is an **oscillating simple pendulum** and a **vibrating tuning fork**.
- A **forced vibration** occurs when an external force **periodically** oscillates a vibrating system.
- An example of a forced vibration is **plucking the string** of a guitar **continuously**.
- This forced vibration vibrates at a **forced frequency**.
- When the external force being applied to a vibrating system increases, the amplitude of the sound wave produced also increases. This makes the sound a bit louder.

Resonance

- This is a happening that occurs when a vibrating system is driven to oscillate at its natural frequency by an eternal force resulting in an increase in the amplitude of the vibrations.
- Resonance occurs when a body is made to vibrate at its natural frequency by vibrations received from another vibrating source of the same frequency.
- For resonance to occur it requires two vibrations:
  - Natural vibration
  - Force vibration
- Resonance takes place when:

Forced vibration frequency = Natural vibration frequency.

Uses of resonance

- Used in string and wind musical instruments: resonance enhances sound produced by strings in guitars and air columns.
- Used in ultrasound imaging: resonance of sound waves is used to visualize internal body organs and tissues.
- Used in speaker cabinets for sound amplification.

Resonance

Uses of resonance

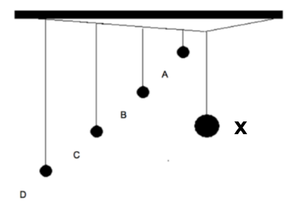
- Used in sensors to detect changes in mass, pressure, and other physical properties with high sensitivity.
- Skyscrapers and bridges have tuned mass dampers to counteract resonant vibration caused by wind or traffic.
- Used in resonance circuits which are used in radios and televisions to select specific frequencies.
- Other uses include a child's swing and a swinging bridge.

Demonstrating Resonance I

Using Barton's pendulum

The material that will be required are five pendulums A, B, C, D, and X.

a. Suspend the pendulums on a wooden ruler using a string as shown below:



Resonance

Demonstrating Resonance I (Conti..)

b. Make sure that pendulum X and C are of the same length.

c. Set pendulum X to oscillates perpendicular to the plane containing the other pendulum, and notice what happens.

- As X oscillates, it produces a periodic force on the string, this force is transmitted to the other pendulums, as such the other pendulums starts to vibrate with high amplitude since the exerted force by X arrives at the other pendulum at intervals each to the natural frequency of the pendulums.

In a short time the frequency of the other pendulums equals the frequency of pendulum X, so we say vibrations of X resonant vibrations of the other pendulums.

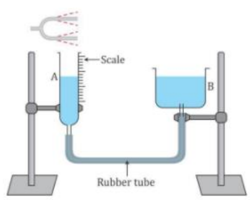
Note: Resonance can also be defined as a happening where one system in vibrating state induces vibrations to another system both of which vibrate with the same natural frequency.

Resonance

Demonstrating Resonance II

a. Vibrate a tuning fork of a frequency 400 Hz.

b. Hold the vibrating fork over the mouth of the tube with water as shown below:



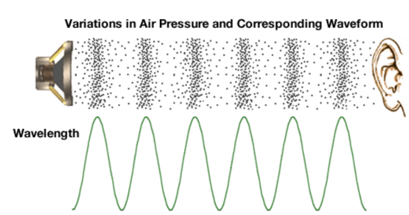
c. Change the depth of the water in the tube until the air column is made to resonate with the tuning fork.

When the vibrating tuning fork is brought on the mouth of the tube with no air column, no sound will be heard. But when the depth is water is decreased and the air column is at a certain level, a loud sound will be heard. This point is called the position of resonance.

Sound Propagation

- Propagation of sound, also known as the **spreading of sound**, refers to the way sound **travels** from where it is produced to where it is heard.
- Sound waves **can not** travel in a vacuum, as such it **requires a medium** such as a **solid**, a **liquid**, or a **gas**.
- When a string of a guitar is plucked, the vibrations **compress** then **stretch** the air particles, as such it creates **compressions** and **rarefactions** regions which transmit a longitudinal wave which we call sound.
- In this case our medium is **air**.

Transmission of sound in air



Question

- Describe an experiment that can be carried out to show that sound waves **does not** travel in a vacuum.

Sound Propagation

Speed of sound

- The speed of sound is different in solids, liquids, and gases.
- How fast sound can travel depends on the arrangement of particles in matter.
- Sound waves travel faster in solids, followed by liquids, and slowest in gases.
- Below are the reasons:
- **Solids**: Sound travels fastest due to the dense and orderly arrangement of particles, which facilitates the rapid transmission of vibrational energy.

Liquids: Sound travels slower than in solids but faster than in gases. The particles are less tightly packed than in solids, leading to slower energy transfer.

Gases: Sound travels slowest because the particles are widely spaced, resulting in less efficient transmission of vibrational energy.

Sound Propagation

Speed of sound in air

- The speed of sound in air can be determined by a property of waves called **reflection**.
- Reflection of sound refers to the bouncing off of a sound wave when it strikes an obstacle.
- When a sound wave strikes an obstacle it produces an **echo**, which is just a reflected or bounced off sound wave.
- The method of determining the speed of sound in air by using reflection is also called the **echo method**.

Determining the speed of sound in air

Materials that will be required are a whistle, tape measure, stop watch, and a high wall (obstacle).

a. Using the tape measure, measure a distance from point A to the high wall (point B).
b. Stand at point A, and blow the whistle, and at the same time start the stop watch.
c. Stop the stop watch as soon as you heard the echo and record the time taken.

Sound Propagation

Determining the speed of sound in air

d. Let the distance from point A to point B be ***d***, and the time taken for the echo to be heard be ***t***.

Since the sound wave travel the same distance twice, then total distance travelled = ***2d***

Workout the speed of the sound using the formula:

Speed = distance / time taken

Speed of sound = 2d / t

Example:

If it takes 0.70s for a person to hear an echo of his/her own clap from a distance of 90m from an obstacle. Calculate the speed of sound in air.

Solution

Speed of sound = 2d / t

*d = 2 * 90m = 180m*

t = 0.70s

Speed of sound = 180s / 0.70s = ***257.14m/s***

Sound Propagation

Speed of sound in other media

- Sound have the following speeds in different media listed below:
  - Dry **air** at 0 degrees Celsius = **330m/s**
  - In **water** at 0 degrees Celsius = **1400 m/s**
  - In **solids** ~ **5000 m/s**
- **Note:** the speed of a sound **without an echo** is calculated using the normal speed formula, thus:

Speed = distance / time taken

Solve

A woman saw a lightening flash and hears the thunder sound after 3.2 seconds. If the distance the lightening cloud to the woman is 2000m, calculate the speed of the thunder sound in air.

Sound Propagation

Speed of sound using the wave equation

- The speed of sound can also be calculated by using the wave equation, thus:

speed or velocity

$$v = f\lambda$$

wavelength (m)

frequency (Hz)

Example

Workout the speed of a sound wave which has a wavelength of 3.2 m and a frequency of 98 Hz.

Solution

V = f * λ

f = 98 Hz

λ = 3.2 m

V = 98 Hz * 3.2 m = ***313.6 m/s***

Factors that affect the speed of sound

- **Medium:** The type of medium (solid, liquid, or gas) significantly affects the speed of sound. Sound travels fastest in solids, slower in liquids, and slowest in gases due to the differences in particle arrangement.
- **Temperature:** In gases (air), the speed of sound increases with temperature. Higher temperatures cause gas molecules to move faster and become less dense, facilitating quicker transmission of sound waves.
- **Pressure:** The speed of sound is not affected by changes in pressure provided temperature is kept constant.
- **Direction of wind:** In air sound travels faster when it is travelling in the direction of the wind.
- **Humidity**: In air, higher humidity increases the speed of sound. Moist air is less dense than dry air, allowing sound waves to travel faster.
- **Density**: The denser the medium, the slower the speed of sound. In gases, an increase in density usually decreases the speed of sound.

Quiz

1. Define sound.
2. Describe how sound is produced.
3. What is the difference between forced frequency and natural frequency.
4. With the aid of a well labelled diagram describe the relationship between pitch and frequency of a sound wave.
5. Define the term resonance.
6. Why is sound faster in solids than in air?
7. Calculate the number of cycles produced by a tuning fork in 2.5 seconds, if the wavelength of the sound it produces is 3.4 m and its speed is 340 m/s.
8. A person standing 150 m from the foot of a cliff shouts and hears an echo after a second. What is the speed of the sound in air?