Unit No.11 SOUND

Sound:

Sound is produced by vibrating body.

Characteristics of Sound:

There are four major characteristics of sound.

1. Loudness 2. Pitch 3. Quality 4. Intensity

1. Loudness:

Loudness is the characteristics of sound by which loud and faint sounds can be distinguished.

Loudness of a sound depends upon three major factors.

a. Amplitude of vibrating body
b. Area of vibrating body
c. Distance from vibrating body

a. Amplitude of vibrating body:

Loudness of sound is directly proportional to amplitude of vibrating body. It means that if amplitude of vibrating body is large than a loud sound is produced and if amplitude of vibrating body is small then a faint sound is produced.

Example:

The sound produced by a sitar will be loud if we pluck its wires more violently.

b. Area of vibrating body:

Loudness of sound is directly proportional to area of vibrating body. It means that if area of vibrating body is large than a loud sound is produced and if area of vibrating body is small then a faint sound is produced.

Example:

Sound produced by a large drum is louder than sound produced by a small drum. This is because the area of large drum is larger than the area of small drum.

c. Distance from vibrating body:

When the distance from the vibrating body increases than amplitude of the vibrating body decreases. Due to this decrease in amplitude the loudness of the sound also decreases.

2. **Pitch of Sound**:

The characteristics of sound by which we can distinguish between a shrill sound and a grave sound is called pitch of sound. Pitch of sound depends upon the frequency of sound. If the frequency of sound is high than its pitch will also be high. If the frequency of sound is low then its pitch will also be low. The frequency of the voice of ladies and children is higher than that of men. Due to this higher frequency their pitch is also high. Therefore due to high pitch and high frequency the voice of ladies is shrill.

Q. Why the voice of ladies and children is shrill than that of men?

Ans. The frequency of the voice of ladies and children is high. Due to this higher frequency their pitch is also high. Whereas the frequency of the voice of men is low. Due to this low frequency there pitch is also low. We know that if the frequency and pitch of sound is high then it will be shrill sound. Since the frequency and pitch of the voice of ladies and children is high therefore their voice is shrill.

3. **Quality of Sound**:

The characteristics of sound by which we can distinguish between two sounds of same loudness and pitch is called quality of sound.

Example:

If some notes (sounds) of a piano and a flute are being played inside the room then a person can easily distinguish between these two sounds by standing outside the room. This is because the quality of these two sounds is different.

4. **Intensity of Sound**:

Sound energy passing per second through a unit area held perpendicular to the direction of propagation of sound waves is called of intensity of sound.

Unit:

The unit of intensity of sound is watt per square meter. $\frac{W}{m^2}$ **OR** Wm^{-2}

Zero Bell:

The human ear can hear the sound of intensity ranging from 10^{-12} Wm^{-2} to more than $1Wm^{-2}$. For human ear 10^{-12} Wm^{-2} is the faintest audible intensity and it is known as zero bell.

Sound Intensity Level:

From different experiment it has been found that the loudness of sound is directly proportional to the logarithm of intensity.

$$L \propto I$$

$$L = (constant) Log\ I$$

constant = k

$$L = k\ Log\ I \ \rightarrow (i)$$

This relation is also known as Weber Fechner law.

If L_o is the loudness of faintest audible sound of intensity I_o and L is the loudness of an unknown sound of intensity I then we can write:

$$L_o = K\ Log\ I_o \ \rightarrow (ii)$$

Eq (i) - Eq (ii)

$$L - L_o = K\ Log\ I - K\ Log\ I_o$$

$$Taking\ 'K'\ common$$

$$L - L_o = K\ [Log\ I - Log\ I_o]$$

$$L - L_o = K\ Log\ \frac{I}{I_o}$$

Here '$L - L_o$' is called the intensity level of unknown sound. Therefore

$$Intensity\ Level = K\ Log\left(\frac{I}{I_o}\right)$$

Value of K:

The value of K depends upon units of I and I_o as well as unit of intensity level. If the intensity I of any unknown sound is 10 times greater than the intensity I_o of the faintest audible sound [$I = 10I_o$]. Than value of K becomes 1 therefore intensity level becomes.

$$Intensity\ level = K\ Log\ \frac{I}{I_o}$$

Here K=1 bel, so

$$Intensity = (1) Log\ \frac{I}{I_o} (bel)$$

Bel is very large unit of intensity level. Generally a smaller unit decibel is used. 1 bel is equal to 10dB.

If the intensity level is measured in decibel then

$$Intensity\ level = 10\ Log\left(\frac{I}{I_o}\right)\ (dB)$$

Echo OR Reflection of Sound:

When sound is incident on the surface of the medium and it bounces back into the first medium then it is called reflection of sound or echo.

Explanation:

To hear a clear echo the time interval between a sound and reflected sound must be at least 0.1sec. It means if we consider the speed of sound to be $340m^{-2}$ at normal temperature in air. Then we will hear the echo after 0.1sec. The total distance covered from the sound from the point of generation to the reflecting surface and back to the point of generation should be.

Distance = Speed x Time
= (340) (0.1)
= 34m

To hear the clear echo the minimum distance of the obstacle from the source of sound must half of this distance.

$$i.e = \frac{34}{2} = 17m$$

Audible Frequency Range:

The range of the frequency which a human ear can hear is called the audible frequency range.

Explanation:

A normal human ear can hear a sound only if its frequency lies b/w 20Hz to 20,000Hz. It means that a human ear neither hears a sound of frequency less than 20Hz nor a sound of frequency more than 20,000Hz. This frequency range decreases age. Young children can hear a sound of frequency 20,000Hz but old people cannot hear sounds above 15,000Hz.

Infra Sonics:

Such sounds whose frequency is less than 20Hz are called infra sonics.

Ultra Sonics OR Ultra Sound:

Sounds of frequency higher than 20,000Hz which are in audible to normal human ear are called ultra sound or ultra sonics.

Uses of Ultra Sound:

- **i.** Ultra sonic waves carries more energy and higher frequency than audible sound waves. Due to more energy and high frequency their wavelength is very small. This small wavelength is useful for detecting very small objects.
- **ii.** Powerful ultra sonic waves are used to remove blood clots formed in the arteries.
- **iii.** Ultra sonic waves are used to get the pictures of thyroid gland for diagnosis purposes.
- **iv.** Ultra sonic waves are used to locate the under water depths.
- **v.** Ultra sonic waves are used to locate the objects lying deep on the ocean floor. For this purpose a special technique is used which is called **SONAR (sound navigation and ranging).** In this technique sound waves are sent from a transmitter and then reflected sound is received through a receiver. The time taken by the wave to come back is calculated and then by using formula of speed distance from the ocean surface can be calculated.

$$Speed = \frac{Distance}{Time}$$

OR

Distance = Speed x Time

- **vi.** SONAR ranging is also used to see the shape and size of an object in deep water.
- **vii.** High intensity ultra sonic waves are used to destroy germs and bacteria in liquids.
- **viii.** In medical field ultra sonic waves are used to diagnose and treat different ailments for diagnosis of different diseases ultra sonic waves are made to enter the human body through transmitters. These waves are reflected and then amplified to form an image of the internal organs of the body on the screen. These images are used to detect the defect in these organs.

ix. Cracks appear in the internal parts of high speed heavy machines such as turbines, engines of ships and airplanes. These cracks are not visible from outside but they can be very dangerous. Such cracks can be detected by using ultra sonic waves. A powerful beam of ultra sonic waves is made to pass through these defective parts. These waves are reflected back after striking different parts. By the comparison of the ultra sonic waves reflective from cracks and from the other parts give a value of the existence of the cracks.

Review Questions:

11.1. What is the necessary condition for the production of sound?

Ans. There are two basic conditions required for the production of sound.

1. The body must vibrate so that the sound is produced because we know that sound is produced by vibrating body.
2. A certain medium is required for the propagation of sound waves.

11.2. What is the effect of the medium on the speed of sound? In which medium sound travels more faster, air, solid or liquid. Justify your answer.

Ans. We know that sound waves are mechanical waves and they need a certain medium for their propagation. Different mediums will have different affects on the speed of sound. In general the speed of sound in liquid is five times than in gases and speed of sound in solid is about fifteen times the speed in gases. Therefore we can say that the speed of sound in solids is greater as compared to the speed of sound in liquids or gases.

NUMERICAL PROBLEMS

11.1) A normal conversation involves sound intensities of about 3.0 x 10^{-6} Wm^{-2}. What is the decibel level for this intensity? What

11.2) If at Anarkali Bazar Lahore, intensity level of sound is 80dB, what will be the intensity of sound there?

Given:

is

the intensity of sound for 100dB?

Given:

i. Intensity of sound = I = 3 x 10^{-6} Wm^{-2}

Decibel level (sound level) = ?

ii. Decibel level (sound level) = 100dB

Intensity of sound = I = ?

Solution:

i. **We know that**

Sound level = K log $\left(\frac{I}{I_o}\right)$

these K = 10 & $I_o = 10^{-12} Wm^{-2}$

Now by putting values

$$Sound\ Level = 10\log\left(\frac{3\times10^{-6}}{10^{-12}}\right)$$

$$= 10\log(3\times10^{-6}\times$$

$$1012$$

$$= 10\log(3\times10^{-6+12})$$

$$= 10\log(3\times10^{6})$$

$$= 10[\log 3 + \log 10]$$

$$= 10[\log 3 + 6(\log 10)]$$

$$= 10[0.4771 + 6(1)]$$

$$= 10[0.4771 + 6]$$

$$= 10[6.4771]$$

$$Sound\ level = 64.771\ dB$$

ii. **We know that**

Sound level = K log $\frac{I}{I_o}$

Intensity level = 80dB

Intensity of sound = I = ?

Solution:

We know that

Intensity level = K log $\frac{I}{I_o}$

There K = 10 & $I_o = 10^{-12} Wm^{-2}$

So by putting values

$$80 = 10\log\left(\frac{I}{10^{-12}}\right)$$

$$\frac{80}{10} = \log(I\times10^{12})$$

$$8 = \log I + log^{12}$$

$$8 = \log I + 12\log 10$$

$$8 = \log I + 12(1)$$

$$8 = \log I + 12$$

$$8 - 12 = \log I$$

$$Log\ I = -4$$

Taking Antilog on both sides:

Antilog (log I) = Antilog (-4)

I = 0.0001Wm^{-2}

Here $K = 10$ & $I_o = 10^{-12} Wm^{-2}$

Now by putting values

$$\text{Sound level} = K \log \frac{I}{I_o}$$

$$100 = 10 \log\left(\frac{I}{10^{-12}}\right)$$

$$\frac{100}{10} = \log(I \times 10^{12})$$

$$10 = \log I + log^{12}$$

$$10 = \log I + 12 \log 10$$

$$10 = \log I + 12(1)$$

$$Log\ I = -12 + 10$$

$$\log\ I = -2$$

Taking Antilog on both sides:

Antilog (log I) = Antilog (-2)

$I = 0.01 Wm^{-2}$

11.3) At a particular temperature, the speed of sound in the air is 330 ms^{-1}. If wavelength of a note is 5cm.

<u>Given</u>:

Speed of sound = V = 330 m/s

Wavelength = λ = 5cm = $\frac{5}{100}$ = 0.05m

Frequecy = f = ?

Solution:

We know that

$$V = f\lambda$$

$$330 = f\,(0.05)$$

$$\frac{330}{0.05} = \lambda f$$

11.4) A doctor counts 72 heartbeats in a 1 min. Calculate the frequency and time period of the heartbeats.

<u>Given</u>:

Number of heart beats = 72

Time = t = 1min = 60sec

Frequecy = f = ?

Time period = ?

Solution:

We know that

$$\text{Frequency} = \frac{Number\ \ of\ beats}{time}$$

By putting values:

$$6600\ Hz = f$$

This frequency lies within the range of 20Hz & 20,000Hz, so this frequency lies with in the audible range of human ear.

$$f = \frac{72}{60}$$

$$f = 1.2\ Hz$$

Now $$T = \frac{1}{f}$$

$$T = \frac{1}{1.2}$$

$$T = 0.833\ sec$$

11.5) A marine survey ship sends a sound wave straight to the sea bed. It receives an echo 1.5s later. The speed of sound in sea water is 1500 ms^{-1}. Find the depth of the sea at this position.

Given:

Time to receive echo = t = 1.5 sec

Speed of sound = V = 1500 m/sec

Depth of sea = Distance = d = ?

Solution:

We know that

$$Speed = \frac{Distance}{Time}$$

Now by putting values:

$$1500 = \frac{Distance}{1.5}$$

$$(1500)(1.5) = Distance$$

$$2250\ m = Distance$$

This is the distance covered by sound, straight into the sea bed & again comeback into the sea level. But depth of sea is equal to half of the

11.6) A student dapped his hands near a cliff and heard the echo after 5s. What is the distance of the cliff from the student if the speed of the sound is taken as 346 ms^{-1}?

Given:

Time to receive echo = t = 5 sec

Speed of sound = V = 346 m/sec

Depth of cliff from student = ?

Solution:

We know that

$$Speed = \frac{Distance}{Time}$$

Now by putting values:

$$346 = \frac{Distance}{5}$$

$$Distance = (5)(346)$$

$$Distance = 1730m$$

This is the distance covered by the sound to go t strike the cliff and after reflection comeback to the same person. But the distance

distance.

$$\text{Depth of sea} = \frac{Distance}{2}$$

$$\text{Speed} = \frac{2250}{2}$$

$$= 1125 \text{ m}$$

of cliff from the student is equal to half of this distance.

$$\text{Depth of Cliff from student} = \frac{Distance}{2}$$

$$= \frac{1730}{2}$$

$$= 865 \text{ m}$$

11.7) If ships sends out ultrasound that returns from the seabed and is detected after 3.42s.If the speed of ultrasound through seawater is 1531 ms^{-1}. What is the distance of the seabed from the ship?

<u>Given</u>:

Time to return = t = 3.42 sec

Speed of sound = V = 1531 m/sec

Solution:

We know that

$$\text{Speed} = \frac{Distance}{Time}$$

Now by putting values:

$$1531 = \frac{Distance}{5}$$

Distance = (1531)(342)

Distance = 5236.02 m

This is the distance covered by the sound to go down to seabed and after reflection comeback to the same point. But distance of the seabed is equal to half of the distance.

$$\text{Depth of seabed to ship} = \frac{Distance}{2}$$

$$= \frac{5236.02}{2}$$

11.8) The highest frequency sound a human can hear is 20,000 Hz. What is the wavelength of sound in air at this frequency at a temperature of 20°C? What is the wavelength of the lowest sounds we can hear of about 20 Hz. Assume the speed of sound in air at 20°C is 343 ms^{-1}.

<u>Given</u>:

Highest frequency = f_1 = 20,000 Hz

Speed of sound = V_2 = 343 m/sec

Wavelength at highest frequency = λ_1 = ?

Lowest frequency = f_2 = 20 Hz

Speed of sound = V_2 = 343 ms^{-1}

Wavelength at lowest frequency = λ_2 = ?

Solution:

We know that

$$V = f\lambda$$

Here,

= 2618.01 m

$V_1 = f_1 \lambda_1$

By putting values

$343 = (2000) \lambda_1$

$\frac{343}{2000} = \lambda_1$

$\lambda_1 = 0.017m$

$V_2 = f_2 \lambda_2$

By putting values

$343 = (20) \lambda_2$

$\frac{343}{20} = \lambda_2$

$\lambda_2 = 17.2$ m

11.9) A sound wave has a frequency of 2 KHz and wavelength 35cm. How long will it take to travel 1.5km?

Given:.

Frequency = f = 2 KHz

= 2 x 1000 Hz = 2000 Hz

Wavelength = λ = 35cm

$= \frac{35}{100} = 0.35m$

Time = t = ?

Distance = d = 1.5 km

= 1.5 x 1000cm = 1500m

Solution:

We know that

$V = f \lambda$

$V = (2000) (0.35)$

$V = 700 \text{ ms}^{-1}$

Now

$\text{Speed} = \frac{Distance}{Time}$

$V = \frac{d}{t}$

By putting values:

$700 = \frac{1500}{Time}$

$Time = \frac{1500}{700}$

Time = 2.14 seconds

So, The sound wave will take 2.142 seconds to travel 1.5km distance.