RADIANT 2026

Physics

Sound

Lecture - 02

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Topics *to be covered*

1. Displacement-Time Graph
2. Speed of Sound in Different Media
3. Factors Affecting the Speed of Sound In a Gas
4. Factors Not Affecting the Speed of Sound In a Gas
5. Comparison of Speed of Sound With Speed of Light

Topics *to be covered*

6. Infrasonic, Sonic and Ultrasonic Frequences
7. Ultrasound and Its Applications
8. Difference between ultrasonic and supersonic
9. Numerical

10) Speed and Types of Sound

Recap *of previous lecture*

1. Sound
2. Sound Propagation Requires a Material Medium
3. Speed of Sound in Different Media
4. ...
5. ...


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Factors Affecting the Speed of Sound In a Gas

The speed of sound in a gas is affected by the change in (i) density, (ii) temperature, (iii) humidity, and (iv) direction of wind.

(i) Effect of density:

$$V = \sqrt{\frac{\gamma P}{\rho}} \qquad V \propto \frac{\sqrt{\gamma}\sqrt{P}}{\sqrt{\rho}}$$

Form relation $V = \sqrt{\frac{\gamma P}{\rho}}$ it is clear that From relation $V \propto \frac{1}{\sqrt{\rho}}$ *i.e*, the sound is inversely proportional to the square root of density of the gas. The density of oxygen is 16 times the density of hydrogen. therefore the speed of sound in hydrogen is four times the speed of sound in oxygen*.

Factors Affecting the Speed of Sound In a Gas

(ii) Effect of temperature:

The speed of sound in a gas increases with the increase in temperature of the gas. The reason is that with the increase in temperature, the density of gas decreases and consequently the speed of sound increases. In fact, the speed of sound is directly proportional to the square root of temperature of the medium *i.e.*, $V \propto \sqrt{T}$ where T is the temperature of the gas on the Kelvin scale.

Factors Affecting the Speed of Sound In a Gas

The speed of sound in air increases by about 0-61 m s^{-1} (or 61 cm per second) for each degree celsius rise in temperature (provided that the rise in temperature is not very large). *i.e.*,

$$V_1 = V_0 + 0.61\,t$$

$$V_t = V_0 + 0.61t$$

Example

The speed of sound in the dry still air at 0°C is 330 m s^{-1} At 25°C the speed of sound in this air will be

Factors Affecting the Speed of Sound In a Gas

(iii) Effect of humidity:

The speed of sound in air increases with the increase in humidity in air. The density of water vapour is about $\frac{5}{8}^{\text{th}}$ times the density of dry air at ordinary temperature, therefore the increase of moisture in air tends to decrease the density of air. Hence the speed of sound in the humid air is greater than the speed of sound in dry air. In other words, the sound travels faster in humid air than in dry air.

Factors Affecting the Speed of Sound In a Gas

(iv) Effect of direction of wind:

The speed of sound increases or decreases according to the direction of travel of wind. If wind is blowing in the direction of propagation of sound, the speed of sound increases, while if it is blowing.

Factors Not Affecting the Speed of Sound In a Gas

The speed of sound in a gas is not affected by the change in

(i) pressure,

(ii) amplitude of wave, and

(iii) wavelength or frequency of wave.

Factors Not Affecting the Speed of Sound In a Gas

(i) Effect of pressure:

The speed of sound in a gas is independent of pressure. In the formula $V = \sqrt{\frac{\gamma P}{\rho}}$ the ratio $\frac{P}{\rho}$ remains unchanged with the change in pressure. When pressure increases, volume decreases, but mass remains unchanged, so density increases, such that the ratio P/ρ remains constant. For example, if pressure P of a gas is doubled, volume becomes half, so density ρ gets doubled (mass is constant). As a result, the ratio P/ρ does not change. Thus, the speed of sound in a gas is independent of pressure.

Factors Not Affecting the Speed of Sound In a Gas

(ii) Effect of amplitude of wave:

The speed of sound does not depend on the amplitude of sound wave.

Factors Not Affecting the Speed of Sound In a Gas

(iii) Effect of wavelength (or frequency) of wave:

The speed of sound does not depend on the wavelength (or frequency) of sound wave.

Question

Which of the following properties does not affect the speed of sound in a solid?

(A) Elasticity of the solid

(B) Density of the solid

(C) Temperature of the solid

(D) Shape of the solid

Answer **(D) Shape of the solid**

Examples showing that the speed of sound in steel is more than that in air

(1) If sound is produced at one end of a very long steel bar, two sounds are heard at the other end. One which reaches first, is propagated through steel and the other which is heard later, is through air.

Infrasonic, Sonic and Ultrasonic Frequences

- The sound of frequencies in the range 20 Hz to 20 kHz is called the sonic or audible sound;
- the sound of frequency less than 20 Hz is known as *infrasonic sound* (or simply infrasonic), while the sound of frequency greater than 20 kHz is known as ultrasound (or *ultrasonic*).

Infrasonic, Sonic and Ultrasonic Frequences

- Animals can produce and hear sounds of frequencies below 20 Hz as well as above 20 kHz.
- Different animals have different ranges of audible frequencies.
- Elephants and whales can produce infrasonic sounds of frequencies less than 20 Hz. Some fishes can hear sounds of frequencies in the range of 1 Hz to 25 Hz. Some animals can produce ultrasonic sounds and communicate in them.
- A dog can hear sounds of frequencies up to nearly 50 kHz, a bat up to about 100 kHz, while Dolphins can hear sounds of even higher frequencies up to 150 kHz.

Infrasonic, Sonic and Ultrasonic Frequences

Frequency ranges for hearing and speaking by human and animals

	Object	Frequency range of hearing and speaking
1.	Bat	10Hz – 100kHz
2.	Cat	80Hz – 60kHz
3.	Dog	20Hz – 50kHz
4.	Dolphins	200Hz – 150kHz
5.	Grasshopper	90Hz – 1.0kHz
6.	Human	20Hz – 20kHz

Ultrasound and Its Applications

Properties of ultrasound

Ultrasound has all properties similar to that of ordinary sound, but because of high frequencies, ultrasound has the following two additional properties which the audible sound does not possess.

(i) The energy carried by ultrasound is very high.

(ii) The ultrasound can travel along a well defined straight path. It does not bend appreciably at the edges of an obstacle because of its small wavelength (*i.e.*, it has high directivity).

The above two properties of ultrasound makes it very useful to us for many purposes.

Ultrasound and Its Applications

Applications of ultrasound

Few applications of ultrasound are given below.

(1) Bats avoid obstacles in their path by producing and hearing the ultrasound. They produce ultrasound which returns after striking an obstacle in their way. By hearing the reflected sound, they can judge the direction where the obstacle is in their way and from the time interval (when they produce ultrasound and then receive them back), they can judge the distance of the obstacle.

Ultrasound and Its Applications

(2) Ultrasound is used for drilling holes or making cuts of desired shape in materials like glass.

(3) For cleaning the minute objects such as the parts of watches and electronic components, ultrasound is used. The objects are placed in a cleaning solution and the ultrasonic waves are sent into the solution. This causes high frequency vibrations in the solution and makes the cleaning easier.

Ultrasound and Its Applications

(4) For detection of defects in metals, ultrasound is used. Ultrasound will pass through the object if there is no defect (such as crack or cavity), in the object. But if there is some defect, a part of ultrasound will get reflected back.

Difference between ultrasonic and supersonic

The word ultrasonic is used for ultrasound (*i.e.*, sound of frequency above 20 kHz), while supersonic is used for object which travels with a speed greater than the speed of sound in air (*i.e.*, 330m S^{-1}) *e.g.* concord jet planes and fighter planes.

Question

A bat can hear sound of frequencies up to 120 kHz. Determine the minimum wavelength of sound which it can hear. Take speed of sound in air to be 344 m s^{-1}.

$f = 120 \times 10^3$ Hz

$\lambda = ?$

$V = 344$ m/s

$V = f\lambda$

$344 = 120 \times 10^3 \times \lambda$

$\lambda = 2.87$ mm

Solution

Given,

$f = 120\text{kHz} = 120 \times 10^3 \text{ Hz}, V = 344\text{m s}^{-1}.$

From relation $V = f\lambda$

Wavelength $\lambda = \frac{V}{f} = \frac{344}{120 \times 10^3}$

$= 2.87 \times 10^{-3}$ m (or 2.87 mm)

i.e., the bat can hear sound of minimum wavelength 2.87 mm

Question

Ocean waves of time period 10 s have wave velocity 15 m s–1. Find: (i) the wavelength of these waves, (ii) the horizontal distance between a wave crest and its adjoining wave trough.

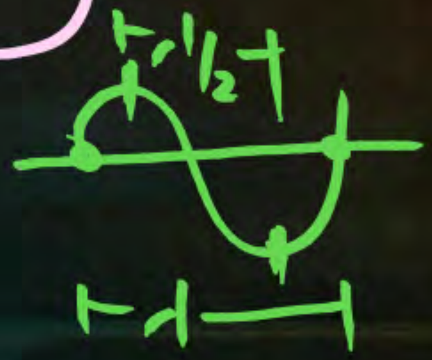
$t = 10 \text{ sec}$ $V = 15 \text{ m/s}$

(1) $\lambda = v \times t$

$\lambda = 15 \times 10$

$\lambda = 150 \text{ m}$

$\frac{\lambda}{2} = 75 \text{ m}$



Solution

Given,

$T = 10\text{s}$ $V = 15 \text{ m s}^{-1}$

(i) From relation $V = \frac{\lambda}{T}$,

Wavelength of wave $\lambda = V \times T$

or $\lambda = 15 \times 10 = 150\text{m}$

(ii) The distance between a wave crest and its adjoining wave trough

$= \frac{\lambda}{2} = \frac{1}{2} \times 150 \text{ m} = 75\text{m}.$

Question

The speed of sound in air at 0° C is nearly:

(A) $1450\ m\ s^{-1}$

(B) $450\ m\ s^{-1}$

(C) $5100\ m\ s^{-1}$

(D) $330\ m\ s^{-1}$

Question

The S.I. unit of wavelength is :

(A) metre

(B) hertz

(C) second

(D) m/s

Question

The time taken by a particle of a medium to complete its one vibration is called:

(A) frequency

(B) time period

(C) wave velocity

(D) amplitude

Question

How do the following factors affect, if at all, the speed of sound in air

(i) frequency of sound

(ii) temperature of air $v \propto \sqrt{T}$

(iii) pressure of air

(iv) moisture in air?

Solution

(i) **Frequency of sound:** The speed of sound does not depend on the frequency (or wavelength) of sound wave. Hence, there is no effect on sound when the frequency of sound changes.

(ii) **Temperature of air:** The speed of sound in a gas increases with an increase in the temperature of the gas.

(iii) **Pressure of air:** The speed of sound in a gas is independent of pressure. Hence, there is no effect on sound when the pressure of air is changed.

(iv) **Moisture in air:** The speed of sound in air increases with an increase in the moisture level of air.

Question

The time period of a simple pendulum is 2 s. Find it's frequency.

Solution

Given,

time $(t) = 2$ s

frequency = ?

As,

Frequency $(f) = \frac{1}{f}$

Substituting the values, we get,

$f = \frac{1}{2}$

$f = 0.5$ Hz

Hence, $f = 0.5$ Hz

$T = 2s$

$f = \frac{1}{T} = \frac{1}{2}$

$f = 0.5 Hz$

Question

The separation between two consecutive crests in a transverse wave is 100 m. If wave velocity is 20 m s^{-1}, find the frequency of wave.

$\lambda = 100 m \quad V = 20 m/s \quad \nu = ?$

$V = f \times \lambda$

$20 = f \times 100$

$\frac{1}{5} = f$

$f = .2 Hz$

Solution

Given,

wavelength (λ) = 100m

wave velocity (V) = 20 m s^{-1}

Frequency (f) = ?

As we know, Wave velocity (V) = Frequency (f) × Wavelength (λ)

Substituting the values, we get,

$20 = f \times 100$

$\Rightarrow f = \frac{20}{100}$

$f = 0.2$ Hz

Hence, $f = 0.2$ Hz

Question

State two applications of ultrasound.

Question

State two applications of ultrasound.

Solution

The applications of ultrasound are as follows

1. Ultrasound is used in surgery to remove cataract and in kidney to break the small stones into fine grains.
2. Ultrasound is used for drilling holes or making cuts of desired shapes in materials like glass.

Question

Differentiate between infrasonic, sonic, ultrasonic and supersonic sounds.

Solution

Infrasonic sounds	Sonic sounds	Ultrasonic sounds	Supersonic sounds
The sound of frequency less than 20 Hz is called infrasonic sound.	The sound of frequency in the range 20 Hz to 20 kHz is called the sonic or audible sound.	The sound of frequency greater than 20 kHz is called ultrasonic sound.	Supersonic sound refers to sound waves generated by a source that travels faster than the speed of sound in a particular medium.
Infrasonic sound is produced by some animals (e.g. Elephants, Whales) and certain industrial processes.	Sonic sounds are within the range of human hearing. Day to day sounds that we hear like speech, music, and environmental noises are examples of sonic sounds.	Ultrasonic sounds are used in medical imaging, industrial testing and cleaning processes. Some animals, such as bats and dolphins produce ultrasonic sound for communication and navigation.	Supersonic sounds are produced by aircraft or bullet train travelling faster than the speed of sound and certain experimental situations.


Thank You