
WAVE AND ITS APPLICATIONS

Periodic Time (T): Time required to complete one complete oscillation is known as Periodic time.

It is denoted by T .

Its unit is $s(\text{second})$.

Frequency (f): the number of oscillations performed in one second is known as frequency.

It is denoted by f .

Its unit is Hz or s^{-1} .

Wave length (λ): the distance between two particles having same phase is known as wavelength.

It is denoted by λ .

Its unit is m .

For longitudinal wave, it is the distance between two consecutive compression (or rarefaction) is known as wavelength.

For transverse wave, it is the distance between two consecutive crests (or troughs) is known as wavelength.

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Amplitude (A): the maximum displacement performed by the particle in any one direction along the propagation is known as amplitude of the wave.

It is denoted by A .

Its unit is m .

Wave velocity (v): the displacement of wave done in unit second is known as wave velocity.

If the wave travels λ distance in time T then wave velocity is,

$$v = \frac{\lambda}{T} = \lambda \times \frac{1}{T}$$

But $f = \frac{1}{T}$ so,

$$v = f \cdot \lambda \Leftrightarrow f = \frac{v}{\lambda} \Leftrightarrow \lambda = \frac{v}{f}$$

It is denoted by v .

Its unit is m/s .

TYPE OF WAVES ACCORDING TO REQUIREMENT OF MEDIUM

Mechanical waves: A wave which **require a medium** to propagate is known as mechanical wave.

Sound wave, string wave are the examples of mechanical wave.

Non-Mechanical wave: A wave which **does not require a medium** to propagate is known as non-mechanical wave.

Light wave (Electromagnetic radiation) is the example of non-mechanical wave.

TYPE OF WAVES ACCORDING TO PROPAGATION

Longitudinal wave: If the direction of oscillation of particles is **same** as the direction of wave propagation, then such type of wave is known as Longitudinal wave.

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Sound waves is an example of longitudinal wave.

Transverse wave: If the direction of oscillation of particles is **perpendicular** to the direction of wave propagation, then such type of wave is known as Transverse wave.

String waves, light waves are the example of Transverse waves.

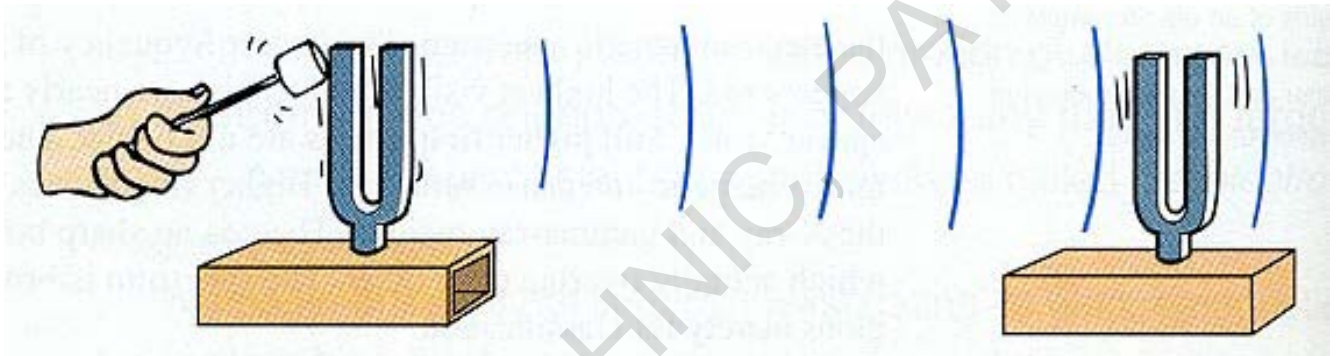
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Longitudinal wave	Transverse wave
In Longitudinal wave, the direction of oscillation of particles is same as the direction of wave propagation.	In Transverse wave, the direction of oscillation of particles is perpendicular to the direction of wave propagation.
Longitudinal wave cannot pass through vacuum .	Transverse wave can pass through vacuum .
Velocity of Longitudinal wave is lesser in air .	Velocity of Transverse wave is higher in air .
Longitudinal wave can pass through solid, liquid and gas medium.	Transverse wave can pass through only solid and liquid .
Longitudinal wave cannot be polarized .	Transverse wave can be polarized .
Longitudinal wave can propagate only in one direction .	Transverse wave can propagate in two or three directions .
During the propagation of Longitudinal wave, the density of medium does not change .	During the propagation of Transverse wave, the density of medium does change .
With increase in density of the medium, the velocity of Longitudinal wave also increases .	With increase in density of the medium, the velocity of Transverse wave decreases .
Propagation of Longitudinal wave occurs via compression and rarefaction .	Propagation of Transverse wave occurs via crest and troughs .
Sound waves, tuning fork waves, Ultrasonic waves, P-waves of earthquake are the most common examples of Longitudinal wave.	String waves, Light waves and S-waves of earthquake are the most common examples of Transverse wave.

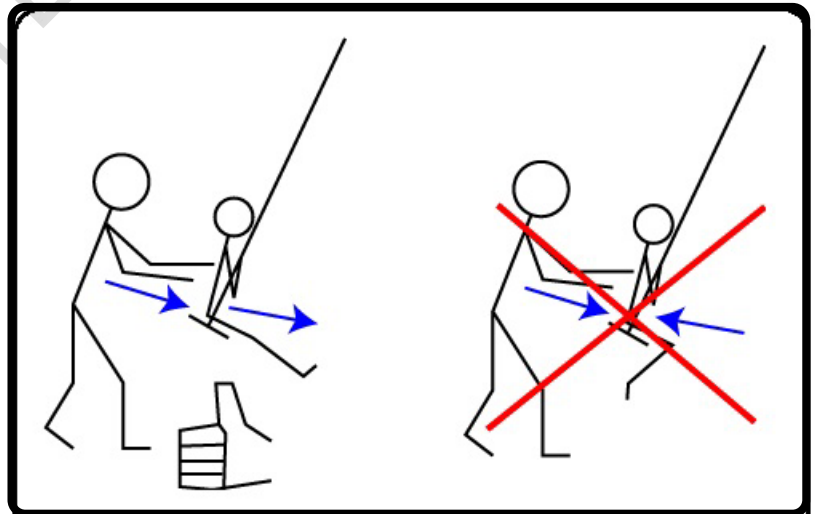
Resonance

When a system is vibrating with natural frequency and when an external force with same frequency is applied, the vibration of that system becomes maximum. Thus, the phenomenon of maximum vibration for a given frequency is known as Resonance.



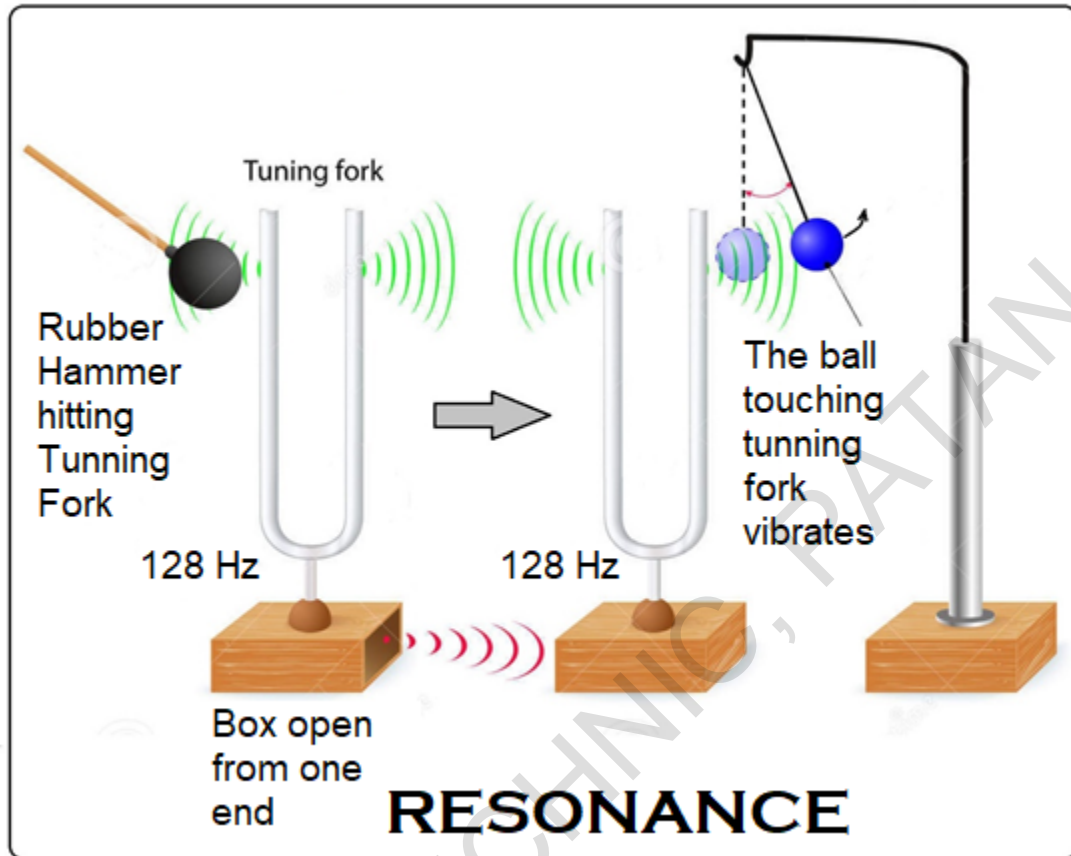
- When swings are forced by the same frequency as its natural frequency, the swing swings with maximum amplitude.

- It is forbidden to allow a group of soldiers to 'march' through a hanging bridge made of wood. Because if the frequency of



external force exerted on the bridge by their feet during the march of the soldiers becomes equal to the natural frequency of the bridge, then the vibrates with the maximum amplitude. At this

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point there is a danger of breaking it. Sometimes the force exerted by the wind also breaks such a bridge.

Apart from this, Resonance also plays an important role in many places in everyday life.

- ✓ Radio Tuning
- ✓ Breaking of a glass during singing at a high pitch
- ✓ Most of the musical instruments
- ✓ Impedance Matching
- ✓ Electronics Circuit
- ✓ Formation of earthquake protected houses
- ✓ Nuclear Magnetic Resonance (NMR)

WAVE EQUATION

The position of particle in a wave at any instant of time can be deduced by following equation,

$$y = A \sin(\omega t \pm \kappa x)$$

Here, y = displacement of particle at any instant time

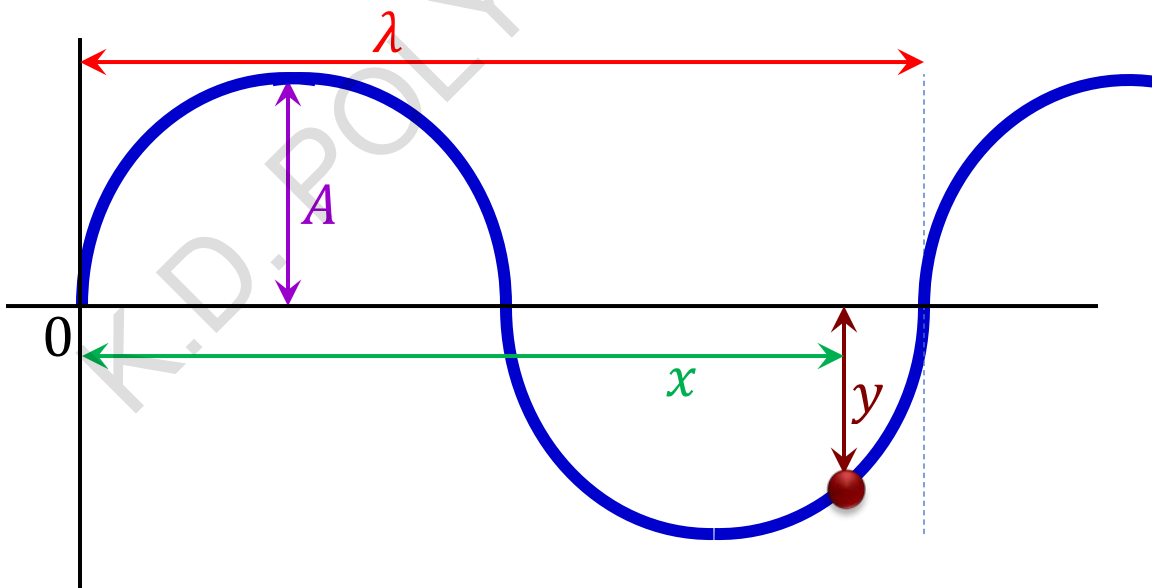
A = Amplitude of wave

$\omega = 2\pi f$ = angular velocity = angular frequency

t = time

$$\kappa = \frac{2\pi}{\lambda} = \text{wave vector}$$

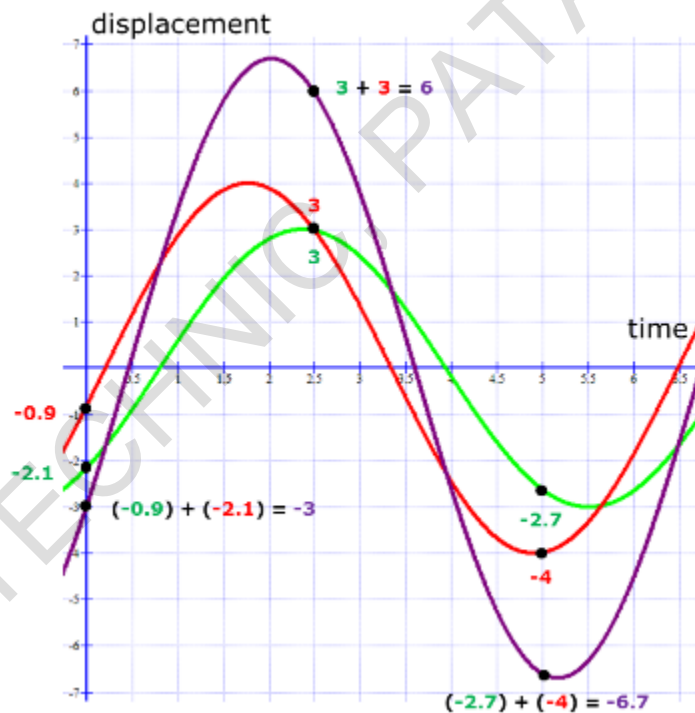
x = position of particle



INTERFERENCE

Principle of superposition: When two or more waves superimpose at a point, the displacement at that point is equal to the sum of the displacements of the individual waves.

For example, when time $t = 0$, the displacement of the red wave is -0.9 (signs must be taken into account as displacement is a vector quantity) and the displacement of the green wave is -2.1 .



As a result, the displacement of the resultant wave will be the vector sum of those, $(-0.9) + (-2.1) = -3$. This is simply the principle of superposition.

Types of Interference:

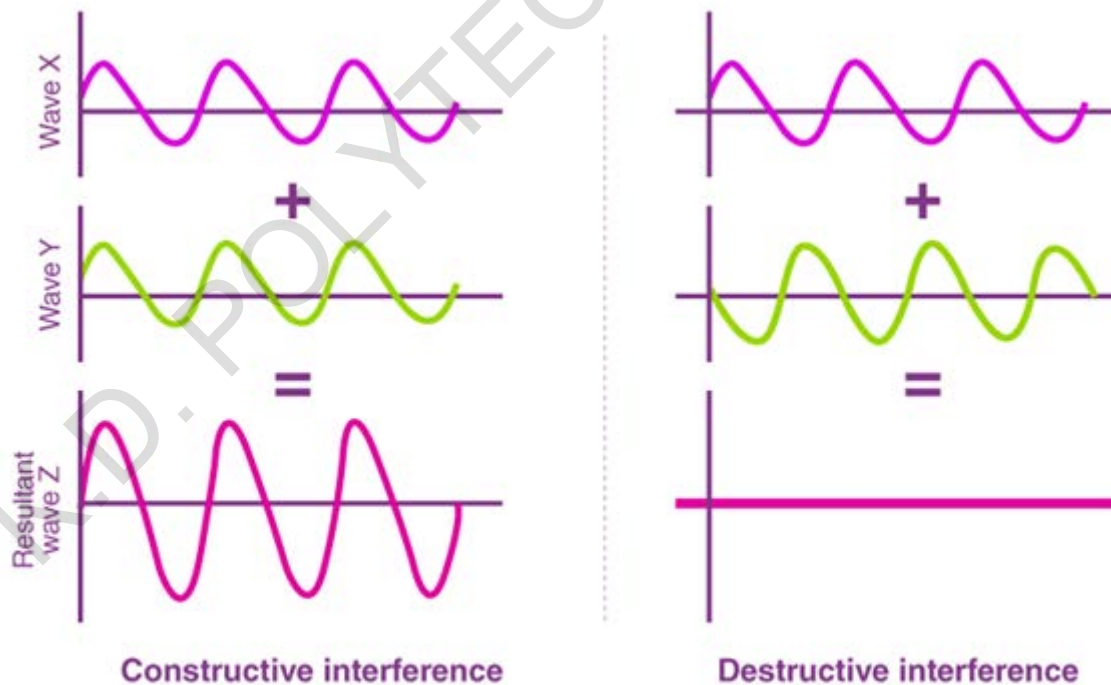
1. Constructive Interference
2. Destructive Interference

Constructive Interference:

When two waves travelling in the same direction and are in phase with each other superimpose each other, their amplitude gets added, such phenomenon is known as constructive interference.

When a crest or trough of one wave meets a crest or trough of another wave of the same frequency, then the resultant amplitude is the sum of the individual amplitudes of the waves.

Constructive interference occurs when the phase difference between the waves is an even multiple of π (180°).



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Destructive Interference: When two waves travelling in the same direction and are in phase with each other superimpose each other, their amplitude gets cancelled, such phenomenon is known as destructive interference.

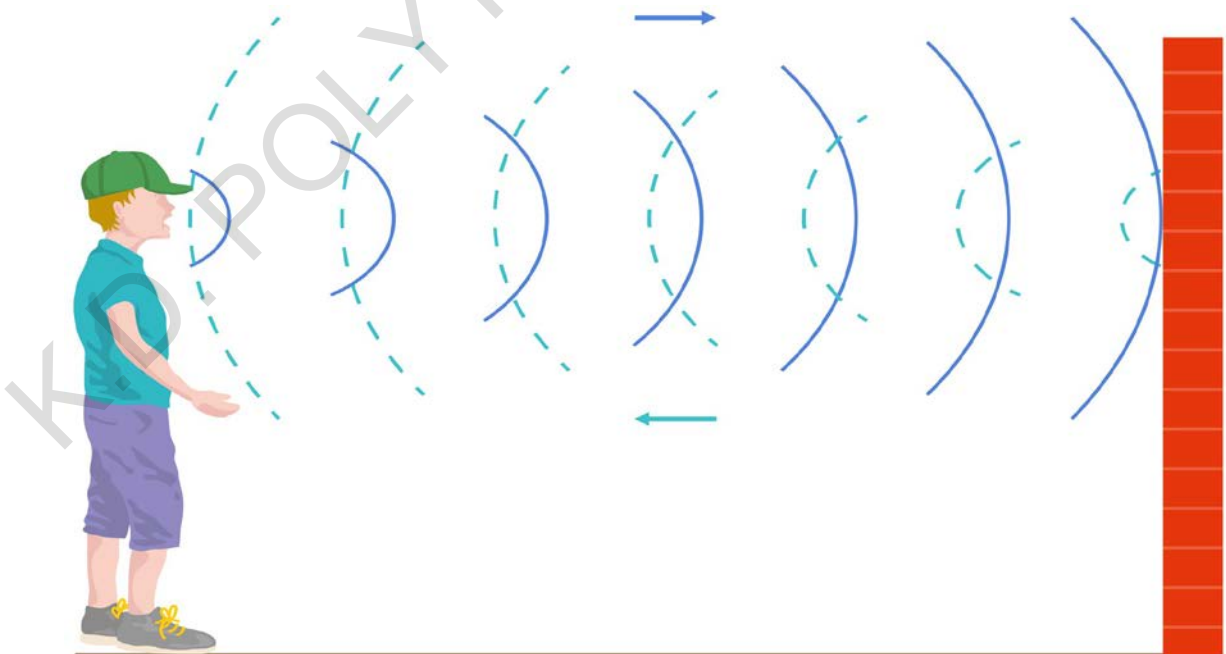
When a crest (or trough) of one wave meets a trough (or crest) of another wave of the same frequency, then the resultant amplitude is the subtraction of the individual amplitudes of the waves.

Destructive interference occurs when the phase difference between the waves is an even multiple of π (180°).

Acoustics of Buildings

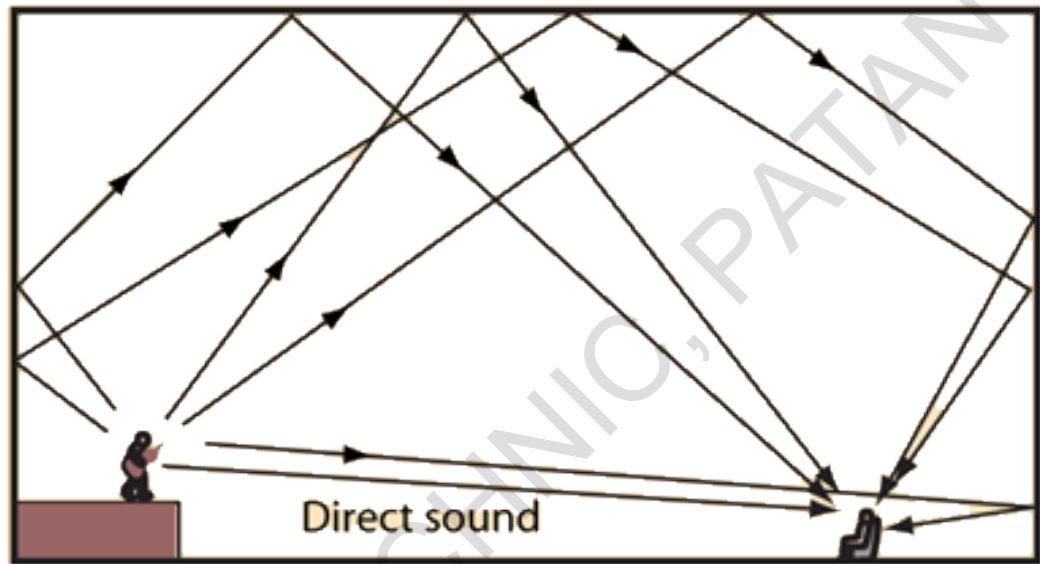
Echo: *The phenomenon of the original sound and the reflected sound being heard separately is called an echo.*

- The effect of sound on a human's ear lasts for $\frac{1}{10}$ s. Therefore, if the reflected sound reaches a human's ear in less than $\frac{1}{10}$ s = 0.1 s, the echo cannot be heard.
- The speed of sound in the air is 343 m/s. Hence, the sound travels 34.3 m distance in 0.1 s.
- Thus, only if the distance between the two reflecting surfaces is greater than 17.15 m, the echo can be heard.
- For example, the sound is reflected from the surfaces of the wall, ceiling, ground floor, windows, etc. in the room.
- The sound reflecting from wall of large concert hall, Ravine, well, Deep cave, valley, mountain produces echo.

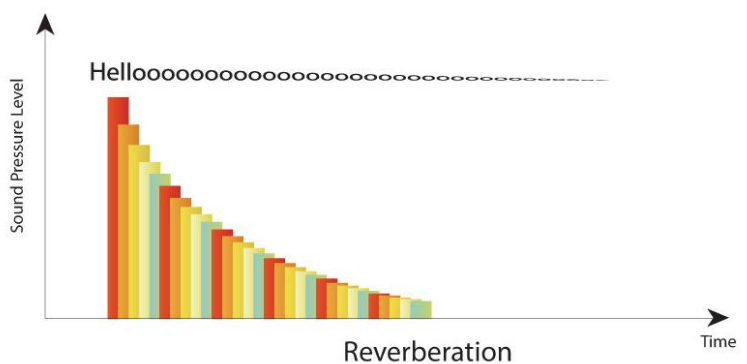
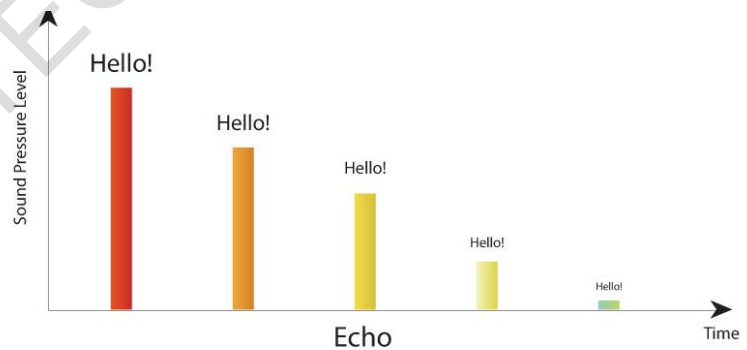


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Reverberation: Reverberation is the phenomenon of the persistence of sound after it has been stopped due to multiple reflections from the surfaces, such as furniture, people, walls etc., within closed surface.



- The main reason for generating the reverberation is the frequent reflection of the sound in the room.
- As time goes on, the amplitude of the sound produced decreases. In the end, the sound stops as the amplitude reduced to zero.



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Reverberation Time: *The time for which the sound is heard after the original sound has stopped being produced is called reverberation time.*

- The time taken to reduce the intensity of a sound to the fraction of a millionth of the intensity of the original sound once after sound production is stopped is reverberation time.
- The time taken for the intensity to decrease to 60 dB (decibels) once after the sound production is stopped is called reverberation time.

Absorption co-efficient of Sound:

The sound that is incident to the open window of the hall or room goes out. Therefore, an open window can be said to be a fully absorbing surface of sound.

Absorption co-efficient of Sound: *The ratio of sound energy absorbed by the surface to the sound energy that is incident on that surface is called the acoustic absorption co-efficient of that surface.*

$$\begin{aligned} \text{Absorption co – efficient } (\alpha) \\ = \frac{\text{Sound energy absorbed by the surface}}{\text{Sound energy incident on the surface}} \end{aligned}$$

Open Window unit (O.W.U): *The unit of acoustic absorption co-efficient is known as open window unit (O.W.U).*

- For an open window, the value of O.W.U. is taken as 1.0

Sabine's Formula for Reverberation of Sound: In 1900, Professor Sabine gave the formula to find the reverberation time based on experiments.

$$T = \frac{0.165 * V}{\sum_{i=1}^n \alpha_i S_i}$$

T = reverberation time

α = Absorption co – efficient

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$S = \text{Area of surfaces}$

$V = \text{Volume of Hall}$

$$\sum_{i=1}^n \alpha_i S_i = \alpha_1 S_1 + \alpha_2 S_2 + \alpha_3 S_3 + \dots + \alpha_n S_n$$

= summation of product of absorption coefficients and respective surfaces

Value of Reverberation Time: For a normally generated sound, one likes to listen sound only if the reverberation time is 0.5 s to 2.5 s. A sound with more or less than that does not sound melodious.

- The value of the reverberation time also depends on the purpose for which the hall is to be used, and what musical instruments are to be used in it.

Features of a good auditorium in terms of acoustics:

- According to the size of the auditoriums, the reverberation time of the should be of the right value.
- The sound should be heard in every part of the hall and the echoes should not be produced.
- The sound should not concentrate at any point or place or any part of the room.
- The depth of the balcony should be less and the height should be higher.

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- Echelon effect should not produce due to the steps in the auditorium.
- Excess sound from outside should not be enter inside.
- There should not be a vibration in the hall due to resonance.
- It should be avoided to make the concave shape of the wall.
- The quality of speech and music should not change.
- The words or parts of the words should not interfere with each other.
- The walls, ceilings as well as ground floors should be sound proof to prevent additional noise.
- The seating arrangement in the auditoriums should be curved so that the distribution of sound intensity can be done properly.

Factors affecting Acoustics of the auditorium:

- **Echo:** If the distance between the two walls of the hall is more than 17 m, the echoes are produced. Therefore, the sound cannot be heard properly in the hall. For this, the noise can be removed by applying acoustic materials on the walls of the hall.
- **Reverberation:** If the value of the reverberation time is not ideal, then the sound cannot be heard properly in the hall.

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For this, the ideal value of the reverberation time can be obtained by keeping the dimension of the hall.

- **Dead spots:** At some places in the auditorium, this happens where there is an absence of sound waves. Such a place is called dead dots. This defect can be solved by applying reflective objects in the auditorium.
- **Inadequate loudness:** At certain points in auditorium sound intensity reduces, so that the sound cannot be heard properly. This defect can be prevented by applying reflective objects to the auditorium.
- **Noise:** The auditoriums should be built away from noisy areas such as bus stops, railway stations, schools, colleges, markets etc. This problem can be solved by installing sound absorbing materials such as wood, rubber, foam sheets or curtains on the walls of the auditorium.
- **Echelon effect:** Frequent reflection of sound from the steps in the auditorium increases the intensity of the sound, thus making the sound vague and noisy. This phenomenon is called the Echelon effect. This effect can be reduced by laying the carpet on the steps or placing a slope in place of the steps.
- **Focusing of Sound:** If the walls or ceilings of the halls are in the shape of concave surface, the concentration of sound at a single point greatly increases the intensity of the sound

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in that place. For this, concave walls or roofs must be avoided.

- **Seating arrangement:** By keeping the seating arrangement in the auditoriums as a curve or arc, the distribution of sound strength is done properly, so that all listeners can hear a sound of the same intensity.

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ULTRASONICS – DEFINITIONS

1. **Audible sound:** A sound which has frequency ranging from 20 Hz to 20,000 Hz is known as audible sound. Humans can listen only this range of frequency.
2. **Infrasonic Sound:** A sound which has frequency less than 20 Hz is known Infrasonic Sound. Human cannot hear this sound.

Elephants, Blue Whales and some other creatures can hear infrasonic sound.

The sound produced during Vulcanic eruptions, Tornado, Tsunami waves are in the range of Infrasonic sound.

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3. **Ultrasonic Sound:** A sound which has frequency greater than 20,000 Hz is known as ultrasonic sound. Bats, Dogs, Mosquitos, dolphins and some bugs can listen ultrasonic sound.

ULTRASONICS – APPLICATIONS

Medical field:

1. **Ultrasonic Angiology:** Used for detection of arterial and venous diseases.
2. **Cardiology:** Ultrasonic is also used to check heart rate and rhythm.
3. **Gastroenterology:** Ultrasonic is used to diagnose stomach and intestinal disorders.
4. **Cancer:** Ultrasound is used to detect cancer in the thyroid gland.
5. **Neurology:** Ultrasound is used to examine the internal nerves of the brain, blood flow in its arteries and internal bleeding.

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6. **Obstetrics:** Ultrasound is used to check fetal growth and defects during pregnancy.
7. **Musculoskeletal:** Ultrasonic is used as a good alternative to X-ray for bone fracture, muscle, joint examination in children.
8. **Cataract Surgery:** Ultrasonic waves are used for cataract and other eye surgeries.
9. **Liposuction:** Ultrasonic is also used to remove excess fat from the body.
10. **Dentistry:** Ultrasonic is used in teeth for gum treatment and cleaning.
11. **Lithotripsy:** Ultrasonic is used to break up kidney (bladder) stones.
12. **Sterilization:** Ultrasonic is used to sterilize instruments used in surgery.

Industrial Field:

1. **NDT (Non-Destructive Testing):** Ultrasonic is used to detect internal cracks in oil carrying pipes, boilers etc. without causing any damage.
2. **SONAR (Sound and Navigation Ranging):** SONAR is used to determine the location of underwater objects or water bodies. Ships or submarines floating in the sea can determine the position of other ships or submarines and know their speed through this method.
3. **USID (Ultrasonic Identification):** Ultrasonic is used to check the illegal presence of an unknown object in a fixed area.

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- Cleaning:** Usually cleaning is done with soap or detergent. But very small and irregularly shaped items, parts of the rod, some spare parts of the engine etc. cannot be cleaned by hand or brush. Hence such items are placed in a container filled with a solution. By passing the ultrasonic waves in this vessel, the debris or oily substance like grease on these objects is dislodged from the objects and mixed into the solution. And things are thoroughly cleaned.
- Drilling:** A simple drill cannot work for drilling in glass, fiber or metals. Hence, a metal rod is attached to an ultrasonic vibrator and the rod is agitated with ultrasonic frequency. Hence these rods act like a hammer.
- Welding:** Welding of materials like plastic cannot be done with conventional welding equipment. The surface of materials such as plastics can be melted and welded with high-frequency ultrasonic waves.
- Emulsion:** Normally oil and water are immiscible. Water and oil can be combined with ultrasonic extraction. E.g., Usually, honey crystallizes after some time. Ultrasonically treated honey does not develop this problem.

Food Industry:

- Quality Control:** Ultrasonic is used for checking the quality of food products being prepared and also for detection of inedible substances mixed in food products.
- Cold Pasteurization:** Pasteurization is usually used to sterilize food by killing some of the microorganisms and bacteria that are useful to the body. After keeping the juice of the fruits for some time, the juice floats

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separately on the upper side and the pulp below. In contrast, cold pasteurized juice and pulp remain intact for months. High Power Ultrasonic (HPU) is used for this.

3. **Irradiation:** Pesticides sprayed on fruits and vegetables are extremely harmful to health. Normal washing with warm water does not remove the pesticides. Irradiate with ultrasonic waves to remove harmful insects and pesticides from fruits and vegetables.

4. **Tenderization:** Ultrasonic waves are used to soften food items such as meat in the food industry to make them easier to cook and digest before packing.

5. **Ripening:** Ultrasonic waves are used to ripen unripe fruits.

6. Ultrasonic waves are used for mixing, dispersing, equilibrating, dissolving, crystallizing and preserving some foods.

Biomedical Field:

1. **Cell Destruction:** Bacteria attacking living cells form a protective shield around themselves. This protective shield is formed when ultrasonic waves are applied to bacteria living in tissue that are kept in specific chemicals, which is used in medicines.

2. **Solution maker:** While making some medicines some chemicals are not soluble in its solution. Hence, they can be easily dissolved in solution with the help of ultrasonic waves.

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3. **Activation of Enzymes:** In some biochemical processes ultrasonic waves are used for activation or inactivation of enzymes to speed up the process.
4. To make milk-cream from animal products like milk, ultrasonic waves are used to release only the fat.
5. Ultrasonic waves are used to break apart the cells of living cells and release the cellular fluid needed to make biochemical substances from them.

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