CH # 12 WAVES AND SOUND

VIBRATORY MOTION:

"If a particle in periodic motion moves back and forth (To and Fro) over the same path, then this type of motion is called vibratory or oscillatory motion".

VIBRATION (OSCILLATION):

"One complete round trip of vibratory body is called vibration or oscillation."

PERIODIC MOTION:

"A motion that repeats itself in equal interval of time is called periodic motion".

DISPLACEMENT:

"Distance of a vibrating body from the mean position to the instant either left or right side is called displacement."

- It is denoted by "X".

AMPLITUDE:

"Maximum Displacement of a vibrating body on its mean position is called amplitude of the vibration".

- It is denoted by "X_0"

TIME PERIOD:

"The time required to complete one vibration is called time period of vibrating body".

- It is denoted by "T".

Unit:

It is measured in seconds.

FREQUENCY:

"Number of vibration executed by a vibrating body in one second is called frequency".

- It is denoted by "f".
- Frequency is the reciprocal of time period.

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Mathematically:

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

$$f = \frac{\text{Number of vibration}}{t}$$

Unit Of Frequency

- Unit of frequency is 1/sec or sec^{-1} or Hertz (Hz).
- Hertz is also called vib/sec or cycle/sec.

SIMPLE HARMONIC MOTION (SHM):

"Type of vibratory motion in which acceleration of a body is directly proportional to its displacement and the acceleration is always directed toward the Mean position is called simple harmonic motion (SHM)."

Acceleration α – (Displacement)

$a \alpha - x$

Example of S.H.M:

1. Motion of simple pendulum.
2. Spring mass system.
3. Guitar wires.

CONDITIONS FOR SIMPLE HARMONIC MOTION:

- There must be elastic restoring force acting on the system.
- The system must have inertia.
- The acceleration of the system should be proportional to its displacement from mean position.
- The acceleration of the system always directed towards the mean position.

CHARACTERISTIC OF SIMPLE HARMONIC MOTION

OR

CHARACTERISTIC OF SIMPLE PENDULUM:

OR

CHARACTERISTIC OF SPRING MASS SYSTEM:

- A body executing SHM, all vibrates about its equilibrium position.
- Its acceleration is always directed towards its mean position.
- Its acceleration is directly proportional to its displacement from the mean position.
- Its velocity is max at the mean position and zero on the extreme position.

1. SIMPLE HARMONIC MOTION IN SPRING MASS SYSTEM:

Consider a mass "m" attached to the end of an elastic spring other end of the spring is fixed at the "a" firm support as shown in figure.

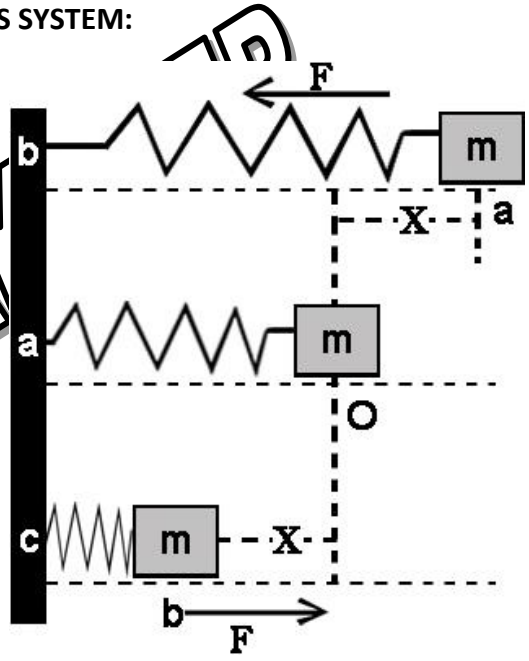
If we displace "m" to point "a" by applying an external force, it is displaced by "x" to its right, there will be elastic restoring force on the mass equal to "F" in the left side which is applied by the spring.

According to hook's law:

$$F = K x \text{ - - - - (1)}$$

Where, K= Spring constant

If we release mass "m" at point "a" it moves forward to "b" due to inertia and covers same displacement x. here once again elastic restoring force "F" acts upon it but in the right side. In this way it continues its motion form a to "b" and then b to a.



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According to Newton's 2nd law of motion, force produces acceleration in the body is given by,

$$F = ma \text{ - - - - - (2)}$$

Comparing equation (1) & (2)

$$ma = -k x$$

$$a = -\frac{k}{m} x$$

Here k/m is constant term, therefore,

$$a = -(\text{constant})\, x$$

Or

$$a \alpha -x$$

This relation indicates that the acceleration of body attached to the end elastic spring is directly proportional to its displacement. *Therefore its motion is simple harmonic motion.*

TIME PERIOD OF SPRING MASS SYSTEM:

Mathematically, it can be proved that the time period T of the SHM of a mass m attached to a spring can be given by the following equation,

$$T = 2\pi \sqrt{\frac{m}{k}}$$

FREQUENCY OF SPRING MASS SYSTEM:

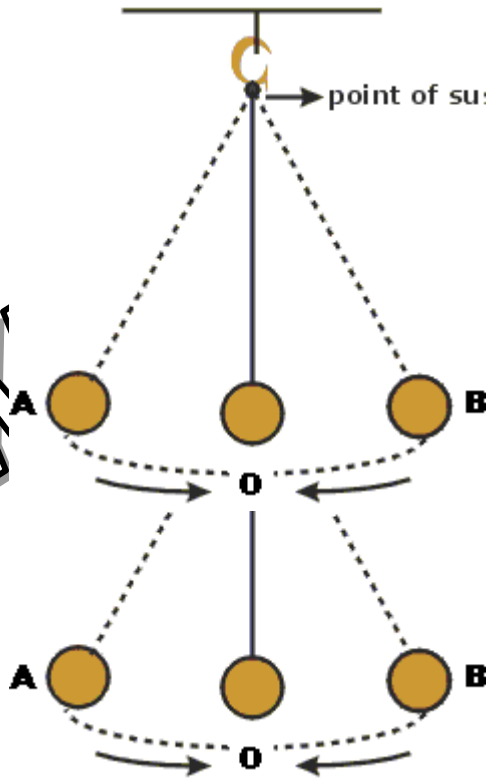
Frequency is the reciprocal of time period therefore,

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

$$f = \frac{1}{2\pi} \sqrt{\frac{m}{k}}$$

SIMPLE PENDULUM:

"An ideal simple pendulum consists of a heavy point mass suspended from a fixed support with the help of a weightless, inextensible and flexible string."



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2. SIMPLE HARMONIC MOTION IN SIMPLE PENDULUM:

An ideal simple pendulum consists of a heavy point mass suspended from a fixed support with the help of a weightless, inextensible and flexible string. In laboratory, a heavy small metallic bob suspended with the help of a fine string, is used as a simple pendulum.

When bob of the pendulum is not in motion its position of rest is known as equilibrium or mean position. If the bob is displaced from its mean's position "O" to a new position "A" and then released, it moves with a continuously increasing velocity towards "O" under the action of gravity. It does not come to rest at "O", but due to inertia it continues its motion towards another point "B". From "O" to "B" it moves against gravity, hence its velocity deceases and becomes zero at "B". Under the action of gravity it again falls towards "O" with increasing velocity and reaches point "A" on the other side. This process is repeated again and again after a definite interval of time. The pendulum vibrates with "A" and "B" as it's extreme or maximum displacement positions, hence, distance "OA" or "OB" represents its amplitude.

For small amplitude the acceleration of a simple pendulum at any instant is directly proportional to its displacement at that instant and is always directed toward it's mean position, *hence, motion of a simple pendulum is simple harmonic.*

TIME PERIOD OF SIMPLE PENDULUM:

Mathematically, it can be proved that the time period T of the SHM of a simple pendulum can be given by the following equation,

$$T = 2\pi \sqrt{\frac{l}{g}}$$

FREQUENCY OF SIMPLE PENDULUM:

Frequency is the reciprocal of time period therefore,

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

$$f = \frac{1}{2\pi} \sqrt{\frac{l}{g}}$$

SECOND PENDULUM:

"A pendulum whose time period is 2 sec is called second pendulum"

- Time period of second pendulum is 2 seconds.
- Frequency of second pendulum is 0.5Hz.
- Length of second pendulum is approx. 1m (or 99 cm).

RESONANCE:

"The tendency of a system to oscillate at greater amplitude at its natural frequencies is known as resonance".

Examples or Explanation:

- While crossing the hanging bridge, soldiers are ordered not march in step but to break their steps. The time period of periodic impulses happens to be equal to the natural time period of the bridge and the amplitude will be increased and bridge will get collapsed.

WAVE OR WAVE MOTION:

"The mechanism by which energy travels (Transfers) from one point to the other point is called as wave motion".

OR

"A wave motion may be defined as a disturbance which travels in the material medium and carry energy. Wave motion is one of the most important ways of transferring energy."

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TYPES OF WAVES:

LONGITUDINAL WAVES:

"The wave in which the disturbance of medium particle is parallel to the direction of travel of wave is called longitudinal wave"

Example:

Sound waves, waves setup in spring etc.

Compressions:

"The compress region of the longitudinal wave is called compression."

Rarefactions:

"The rarefied region of the longitudinal wave is called rarefaction."

TRANSVERSE WAVES:

"The type of motion in which particles of medium vibrates to and fro or execute S.H.M in the direction perpendicular to the direction of propagation of wave is called transverse waves."

Example:

Water waves, Light wave, radio waves, microwaves etc.

Crest:

"The elevation of the transverse wave is called crest."

Trough:

"The depression of the transverse wave is called trough."

ELECTROMAGNETIC WAVES:

"Such type of wave which does not require a medium for their propagation like radio wave, x-ray etc. is known as electromagnetic wave".

MECHANICAL WAVES

"Such type of wave which requires a medium for their propagation like sound waves etc is known as electromagnetic wave".

CHARACTERISTIC OF WAVES

1. **FREQUENCY:**

"The number of waves generated by a source in unit time is known as frequency".

Mathematically:

$$\text{Frequency} = \frac{\text{Number of waves}}{\text{Unit time}}$$

$$f = \frac{\text{Number of waves}}{t}$$

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Unit Of Frequency

*Unit of frequency is 1/sec or Hertz (Hz).

*Hertz is also called vib/sec or cycle/sec or Waves/Sec.

2. **TIME PERIOD:**

"The time taken by an oscillation particle to complete one up and down cycle as one cycle of wave is called frequency"

*Time period is the reciprocal of frequency.

3. **AMPLITUDE:**

"The distance between the crest (Highest point on the wave graph) and the normal (undisturbed point on the wave graph) is called amplitude".

4. **WAVE LENGTH:**

""Distance between two consecutive crests or troughs on the wave is called wavelength".

*It is denoted by Greek letter lambda "λ" (Lambda).

5. **WAVE VELOCITY:**

"The distance travel by the wave in a unit time in the direction of propagation is called wave velocity"

MATHEMATICALLY:

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

For wave,

$$\text{Velocity} = \frac{\text{Wave length}}{\text{Time period}}$$

$$V = \frac{\lambda}{T}$$

RELATION BETWEEN WAVE VELOCITY (V), FREQUENCY (F) AND WAVE LENGTH (λ):

Consider a wave of wave length λ and frequency f is travelling with velocity V in the elastic medium. The period T is the time required for the wave to travel distance of one wave length so that the velocity of wave will be:

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

Since time period "T" is the time in which a wave travels a distance equal to its wave length "λ".

$$\text{Velocity} = \frac{\text{Wave length}}{\text{Time period}}$$

$$V = \frac{\lambda}{T}$$

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

But frequency "f" is equal to the reciprocal of time "T"

$$V = f\lambda$$

Hence the product of wave length "λ" and frequency is equal to wave velocity.

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REFLECTION OF WAVES:

"Bouncing back of the wave in the same medium after striking a barrier or obstacle is called reflection of waves."

INTERFERENCE OF WAVES:

"The phenomenon in which two identical waves travelling in same direction reinforce each other at same point and cancelled the effect of each other at same different points is called interference of wave".

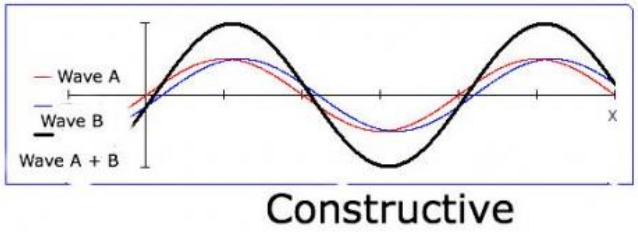
TYPES OF INTERFERENCE OF WAVES:

There are two types of interference of wave.

i. Constructive interference.
ii. Destructive interference.

i. CONSTRUCTIVE INTERFERENCE:

"The type of interference in which two waves overlap each other in such a way that they reinforce or increases the effect of each other is called constructive interference".



Constructive

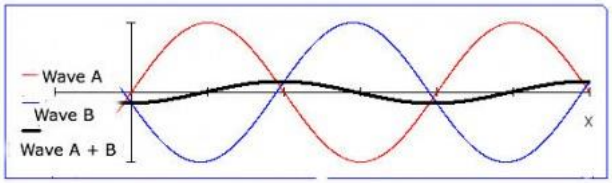
*In constructive interference crest of one wave coincides that crest of other and trough

coincides with trough.

ii. DESTRUCTIVE INTERFERENCE:

"The type of interference in which two waves overlap each other in such a way that they cancel effect of each other is called destructive interference"

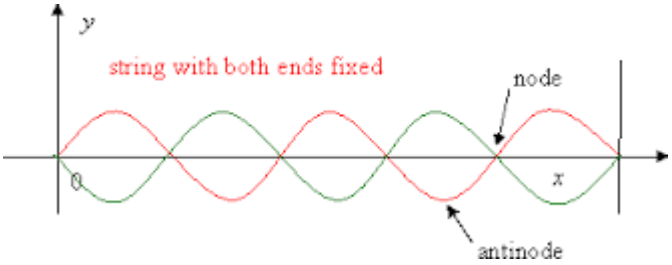
*In destructive interference crest on wave coincide the other trough the other wave.



Destructive

STATIONARY WAVE:

"When two identical progressive waves with same amplitude and frequency travel through a medium with equal velocity in opposite direction, they super impose over each other and produce a new type of wave which is known as stationary waves."



CHARACTERISTIC OF STATIONARY WAVE:

i. ENERGY:

In stationary wave there is no flow of energy along the wave.

ii. LOOPS:

When stationary waves are set up in medium, the medium vibrates in several segments called loops.

iii. NODE:

The point of destructive is called node, at nodes displacement is zero.

iv. ANTINODE:

The point of constructive interference is called antinodes, at antinodes displacement is maximum.

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SOUND:

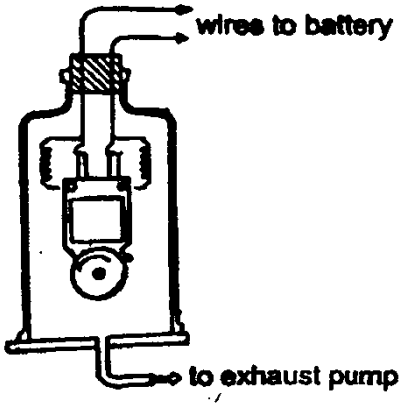
"The longitudinal waves that are due to a vibrating source and that are capable of producing a sensation in the auditory system are called sound waves".

HOW SOUND IS PRODUCE:

- Sound is produce by a vibrating body.
- The waves thus produce are longitudinal and cannot travel through vacuum.
- Sound waves are longitudinal and mechanical waves.
- Sound waves can only travel through an elastic medium (solid, liquid or gas).
- When a body vibrates it produce compressions and rarefactions in the surrounding air.
- When these compressions and rarefactions collide with our ear drum sensation of sound is produced.
- Hence a vibrating body, a medium and a detector (ear) are necessary for the production, propagation and detection of sound.

WHY MEDIUM IS NECESSARY FOR THE PROPAGATION OF SOUND:

If an electric bell is suspended inside a jar and is switched on, sound produce by it is audible as long as there is air inside the jar. If the air is pumped out with the help of a vacuum pump, sound gradually become faint and finally no sound is heard as soon as a good vacuum is achieved. If the ringing bell is now touched to the side of the jar sound is heard again.
The simple experiment shows that the presence of a material medium is necessary for the propagation of sound.



CHARACTERISTICS OF MUSICAL SOUND:
Musical sound ha the following characteristics.

1. **LOUDNESS OF SOUND:**

"Loudness is that characteristics of musical sound which enables us to distinguish between a faint sound and a loud sound."

OR

"Loudness is defined as the auditory sensation produced by the sound in ear."

- Loudness of sound depends upon the intensity of sound.
- Loudness is actually a sensation of human consciousness.
- It is denoted by "L".

FACTORS ON WHICH LOUDNESS DEPENDS

i. AREA OF VIBRATING BODY:
The larger the area of vibrating body the louder the sound produces. For example a DHOOL produces a loud sound due to larger area. Similarly a small DHOLAC or CONGO produces a small loudness.

ii. AMPLITUDE OF VIBRATING BODY:
The greater the amplitude of vibrating body, the louder the sound produced.

iii. DISTANCE B/W SOURCE AND LISTENER:
Smaller the distance between source of sound and the listener greater is the loudness of sound heard by the listener.

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iv. INTENSITY OF SOUND WAVES:
Loudness depends on the intensity of the sound waves. Intensity is the energy carried by the sound waves through a unit area placed perpendicular to the direction of perpendicular of waves per second.

2. **PITCH OF SOUND:**

"The characteristic of sound by which a shrill sound can be distinguished from a grave sound known as pitch."

Effect of pitch on sound waves frequency:

- Pitch of sound depends upon the frequency of sound. The greater the frequency. The higher is the pitch and vice versa.
- Sound of a woman is shrill due to high pitch. Sound of dog is grave due to low pitch.

3. QUALITY OR TIMBER:

"The property of sound by virtue of which we can distinguish between two sounds of the same pitch and the loudness originating from two different musical instruments."

The sound produced by two different instruments is usually complex. It is a mixture of several tones. The tone of lowest frequency is called *Fundamental frequency* and other tones are known as *Overtones* or

VELOCITY OF SOUND WAVES:

"The distance travelled by sound waves in unit time is known as the velocity of sound."

The velocity of sound at normal temperature and pressure is 340 m/s.

ECHO:

"The sound heard after reflection from an obstacle is called echo."

TIME INTERVAL FOR ECHO:

- Effect of the sound remains on the drum of our ear for $1/10^{th}$ second.
- If some sound enters the ear within $1/10^{th}$ second then it will become the part of previous sound and we will not able to hear the echo.
- Hence to hear after the echo the reflected wave must reach after $1/10^{th}$ second.

DISTANCE BETWEEN THE PERSON AND OBSTACLE FOR ECHO:

- For hear echo time elapsed between the production of the sound waves and the hearing of its echo is equal to or more than $1/10^{th}$ of a second.
- In order to calculate he least distance between the obstacle and the listener to echo suppose that distance is 'd':

Distance covered by the sound waves = S = 2d

Velocity of sound waves = V = 340m/s

Time = t = $1/10^{th}$ sec

$S = V \times t$

By putting values,

$$2d = 340 \times \frac{1}{10}$$

$$d = 34 \times \frac{1}{2}$$

d = 17 meter

Hence in order to hear the echo the distance in between the obstacle and listener must be 17 meter approximately.

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TYPES OF SOUND:

1. MUSICAL SOUND:

"Sound which produce pleasant effect on the drum of the ear is called musical sound."

2. NOISE:

"Sound which produce unpleasant effect on the drum of the ear is called noise."

BEATS:

"The periodic variation in intensity of sound at a given point due to the super imposition of two waves having slightly different frequencies is called beat."

CAUSE OF PRODUCTION OF BEATS:
Beats are produce because of interference of sound waves of slightly different frequencies.

BEAT FREQUENCY:
"The number of beats one hears per second is called beat frequency. It is equal to the difference in frequency between two sounds."

BEAT FREQUENCY OF HUMAN EAR:
The maximum beat frequency that human ear can detect is 7 beats per second.

AUDIBLE SOUND WAVES:
"Sounds waves which are detected easily by our ears are called audible sounds."
Sound waves having frequencies 20Hz to 20,000Hz are known as audible waves.

INFRASONIC SOUND WAVES:
"A longitudinal wave whose frequencies are below the audible range is called infrasonic waves."

ULTRASONIC'S:
"The longitudinal waves with frequencies above the audible range are known as ultrasonic."

PRODUCTION OF ULTRASONIC:
Ultrasonic are produced by vibration quartz crystals electricity. With the help of this device very high frequency range (10^9Hz or more) ultrasonic waves can easily be produced.

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CHARACTERISTICS OF ULTRASONIC WAVES:
- Their wave length is much shorter than the normal sound waves.
- They can penetrate deeper into the sea.

USES OF ULTRASONIC:

IN MEDICINE:
- ⇨ Ultrasonic is now widely used as diagnostic therapeutic and surgical tool in medicine.
- ⇨ Ultrasonic is preferred over x-rays due to safety.
- ⇨ Ultrasonic waves is use to kill microbes in liquids.
- ⇨ Ultrasonic waves is use to examine the fleshy parts of the body.
- ⇨ Ultrasonic waves is use to obtain cross sectional pictures of patients.
- ⇨ Ultrasonic waves is use to make ultrasound guidance devices for blinds.

IN INDUSTRY:
- ⇨ To find cracks in metal structures.

IN TECHNOLOGY:
- ⇨ They are used in echo-depth sounding devices for determining depth of sea.
- ⇨ In under water navigation ultrasonic is used instead of RADAR.

IN GENERAL:
- ⇨ In guidance devices for blind persons.

- ⇨ To clean places which cannot be cleaned in a normal way.
- ⇨ To clean the jewelry.
- ⇨ To clean delicate instruments and materials.

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