X PHYSICS SHORT NOTES

7. Sound

A) REFLECTION OF SOUND WAVES AND ECHOES

- **Sound waves:**
  - **Range of audibility:** It is the range of frequency of vibrations between 20Hz to 20,000 Hz, perceptible by human ear.
  - **Ultrasonic vibrations:** They are sound vibrations having frequency **above** 20,000 Hz.
  - **Infrasonic vibrations:** They are sound vibrations having frequency **below** 20 Hz.
  - **Elastic or Mechanical waves:** They are waves travel in the medium through the vibrations of the medium particles about their mean position.
  - **Some technical terms of sound wave:**
    - **Amplitude:** The maximum displacement of a particle of the given medium on either side of its mean position, is called its **amplitude** (a).
    - **Time period:** The time taken by the particle of medium to complete one vibration is called its **time period** (T).
    - **Frequency:** The number of vibrations made by the particle of the medium in one second, is called its **frequency** (f).
    - **Wavelength:** The distance travelled by **consecutive crest and a trough** of a wave in one time period of vibration of the particle of a medium, is called its **wavelength** (λ).
    - **Velocity:** The distance travelled by the wave in one second is called its **velocity** (V).
    - $V = f\lambda$
    - $f = \frac{1}{T}$

- **The mechanical waves are of two kinds:**
  - Longitudinal waves and
  - Transverse waves.
  - **Longitudinal waves:** Longitudinal waves are the vibrations of the medium particles along the direction of propagation of the wave, forming alternate compressions and rarefactions in a medium.
  - **Transverse Waves:** Transverse waves are the vibrations of the medium particles which are normal to the direction of propagation, forming alternate crests and troughs in a medium.
  - **Speed of the waves:**
    - Speed depends on elasticity and density of the medium.
    - Speed of sound is **not affected** by change in pressure.

- **Electromagnetic waves:** They are waves formed by the periodic vibrations of the mutually perpendicular electric and magnetic fields in a plane normal to the direction of wave propagation.

- **Similarity between sound wave and electromagnetic waves:**
  - During refraction of both the waves; the speed, wavelength and intensity changes but its frequency does not change.
  - Both the waves change the direction of path of travel after refraction except for normal incidence.

- **Distinction of sound wave and electromagnetic waves:**

Sound wave	Electromagnetic waves
The vibrations of the body cause vibrations in the particles of the surrounding medium which travels in the form of waves with a certain speed depending on the density and elasticity of the medium.	It is formed by periodic vibrations of mutually perpendicular electric and magnetic fields in a plane normal to the direction of wave propagation.
These waves are Longitudinal waves and Transverse waves and need a medium to travel.	They are transverse waves and can travel through vacuum.
Energy transfer is through the vibrations of the medium particles about their mean positions.	Energy transfer is the form of photons.

- **Distinction between the light and sound waves:**

Light waves	Sound waves
They are electromagnetic waves.	They are mechanical waves.
They can travel in vacuum.	They require material medium for propagation.
The speed of light waves is very high (3×10^8 m s^{-1} in air).	The speed of sound waves is low (= 330 m s^{-1} in air).
The wavelength of light waves (visible) is very small, of the order 10^{-6}m.)	The wavelength of sound waves is in the range of (10^{-2} m to 10 m).
These waves are transverse.	These waves are longitudinal (through air).

- **Reflection of sound waves:**
  - **Definition:** The returning back of sound wave in the same medium after striking a surface like wall, metal sheet, wood etc., is called the **reflection of sound wave**.
  - **Uses:** Megaphone or speaking tubes, sound boards and ear trumpet.

➢ **Echo:**

- **Definition:** Echo is the sound heard distinctly after reflection from a distant rigid obstacle (like cliff, wall of a building, etc.) after the original sound has ceased.

- **Condition for an echo:**
  - The time period between the reflected sound heard and the original sound is at least **0.1 second OR** the minimum distance between the listener and the sound reflector in air must be **17 m**.
  - The size of the reflector should be larger than the wavelength of sound wave.
  - The intensity of sound waves should be sufficiently large so that the reflected sound is distinctly audible.

- **Reverberations:** The prolonged effect of sound produced due to repeated reflections at the reflecting surface is known as **reverberations**.

- **Determination of the speed of sound by echo method:**
  - $V = \frac{total\ distance\ travelled}{time\ interval} = \frac{2d}{t}$ m s^{-1}.

- Uses of echoes by bats, dolphins and fisherman.

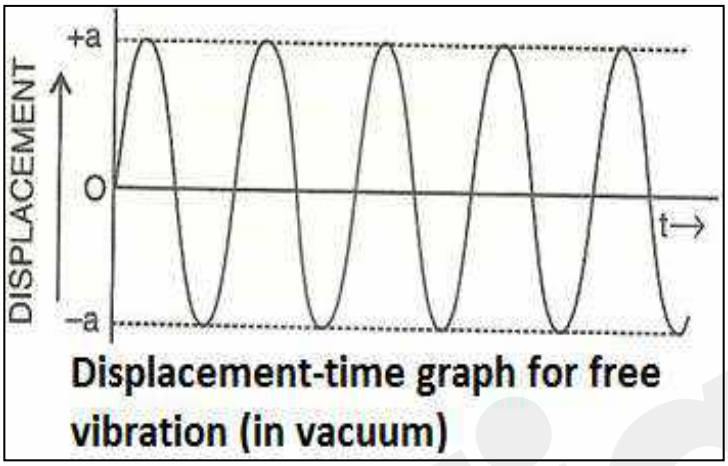
- **Other Uses of echo:**
  - Ultrasonic waves are used for sound ranging and echo depth sounding.
  - **Sound ranging or echo depth sounding:** The process of detecting obstacles by echo method is called **sound ranging or echo depth sounding**.
  - Ex: SONAR and Radar.
- **Medical use of echoes:**
  - Ultrasonography.
  - Echo cardiography.
- **Use of infrasonic waves:**
  - Detects the coming of earthquake.
  - Charting rocks and petroleum formations below the earth.

FORMULAE:

1. $t = \frac{Total\ distance\ travelled}{Speed\ of\ sound} = \frac{2d}{v}$
2. $f = \frac{1}{T}$
3. $T = \frac{1}{f}$
4. $d = \frac{vt}{2} = \frac{v}{2f}$
5. $v = \frac{2d}{t} = 2df$
6. $v = f\lambda$
7. $l_1f_1 = l_2f_2$
8. $f_1\lambda_1 = f_2\lambda_2$

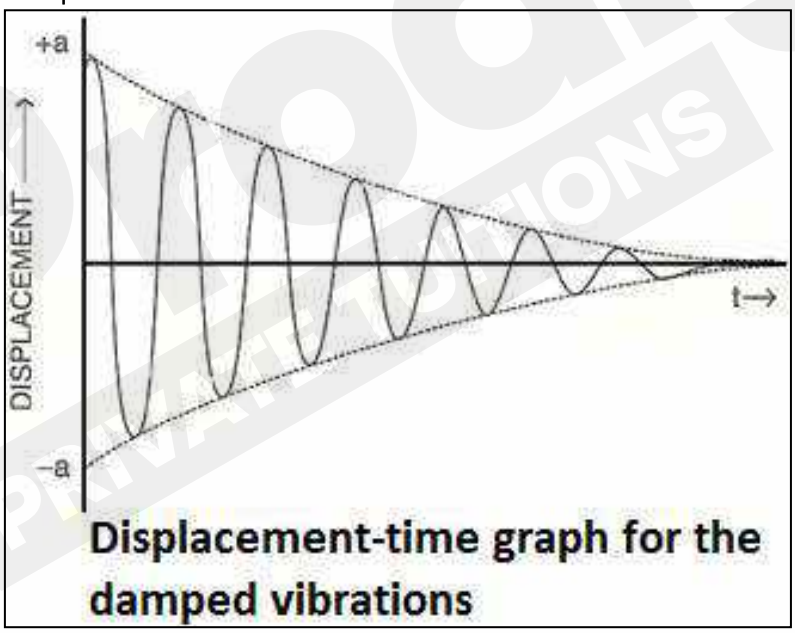
B) NATURAL, DAMPED & FORCED VIBRATIONS; RESONANCE

- **Free or natural vibrations:**
  - **Definition:** Natural vibrations are periodic vibrations of a body of constant amplitude in the absence of any external force on it.



Displacement-time graph for free vibration (in vacuum)

- **Damped vibrations:**
  - **Definition:** Damped Vibrations are periodic vibrations of a body of decreasing amplitude in presence of a resistive force.



Displacement-time graph for the damped vibrations

- **Difference between natural/free and damped vibrations:**

Natural/Free vibrations	Damped vibrations
The amplitude of free vibrations remains constant and the vibrations continue endlessly.	The amplitude of damped vibrations decreases with time and ultimately the vibrations stops.
There is no loss of energy in free vibrations.	In each vibration there is some loss of energy as heat.
The vibrations are under restoring force, no external force acts on the vibrating body.	The frictional or damping force acts to oppose motion.
The frequency of vibration remains constant equal to its natural frequency.	The frequency of vibration is lesser than the natural frequency.

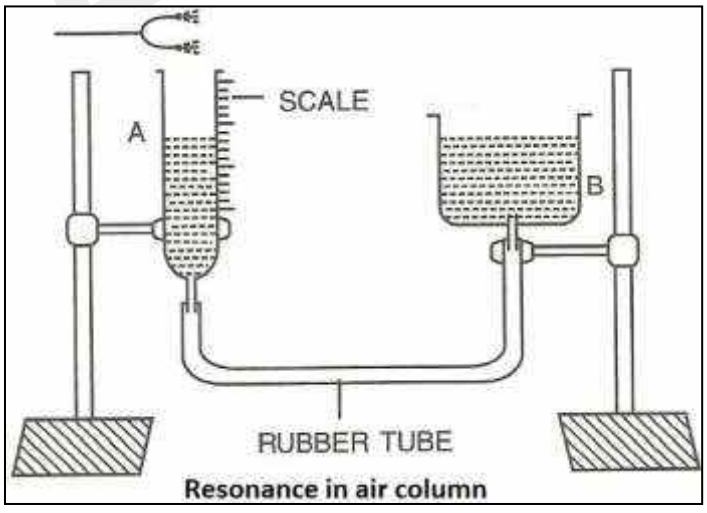
- **Forced vibrations:**
  - **Definitions:** Forced Vibrations are vibrations of a body which take place under the influence of an external periodic force acting on it.

- **Difference between the natural (free) and forced vibrations:**

Free vibrations	Forced vibrations
They are vibrations of a body in absence of any resistive force.	They are vibrations of a body in presence of an external periodic force.
The frequency of the vibrations depends on the structure (shape and size) of the body.	The frequency of the vibration is equal to the frequency of the externally applied force.
The frequency of vibrations remains constant.	The frequency of vibrations changes with change in the frequency of the applied force.
The amplitude of vibration is constant.	The amplitude of vibration is very small if frequency of applied force differ from the natural frequency of the body.

- **Resonance:**
  - **Definition:** Resonance is a phenomenon, in which, the frequency of an externally applied periodic force on a body is equal to the natural frequency of another vibrating body and it vibrates with an increased amplitude.
  - Resonance is a special case of forced vibrations.
  - **Conditions for resonance:** Resonance occurs when the frequency of the applied force on one body is exactly equal to the natural frequency of another vibrating body.
  - **Property of resonance:** At resonance, a compression of one wave falls on a compression of another wave and a rarefaction on a rarefaction, thus increasing the amplitude of the vibrating particles. Since the intensity is directly proportional to the square of the amplitude a **loud sound** is heard at resonance.
  - **Demonstration of resonance:** The phenomenon of resonance can be demonstrated by the following experiments:

- **Experiment (3) – Resonance in air column:**



Resonance in air column

- **Observation:**
- A loud sound is heard at a certain level of water.
- On lowering the level of water in tube A, when the length of air column becomes three times the previous one, again a loud sound is heard.

➢ **Difference between the forced and resonant vibrations:**

Forced vibration	Resonant vibrations
The vibrations of the body under an external periodic force of frequency different than the natural frequency of the body, are called forced vibrations.	The vibration of body under an external periodic force of frequency equal to the natural frequency of the body, are called the resonant vibrations.
The amplitude of vibration is usually small.	The amplitude of vibration is very large.
The vibrations of the body are not in phase with the external periodic force.	The vibrations of the body are in phase with the external periodic force.
These vibrations last for a very small time after the periodic force ceases to act.	These vibrations last for a long time after the periodic force ceases to act.

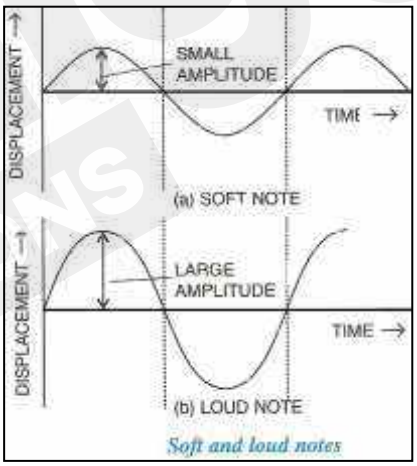
➢ **Some examples of resonance:**

- Sympathetic vibrations of pendulums
- Resonance in machine parts
- Resonance in sonometer or stretched strings of a musical instruments
- Resonance in air column with a tuning fork
- Resonance in a bridge
- Resonance in radio and TV receivers

C) CHARACTERSTICS OF SOUND & THEIR SUBJECTIVE & OBJECTIVE NATURE.

- **Characteristics of sound:**
  Three attributes used to distinguish two sounds:
  - Loudness.
  - Pitch or shrillness
  - Quality or timbre.

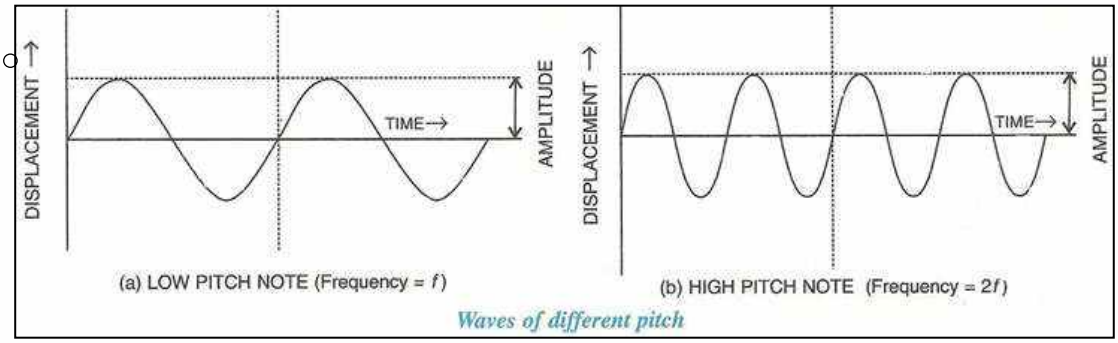
- **Loudness and intensity:**
  - **Definition: Loudness** is the property by virtue of which a loud sound can be distinguished from a faint one, both having the same pitch and quality.
  - **Intensity:**
    - **Definition:** The intensity at any point in the medium is the amount of sound energy passing per second normally through a unit area at that point.
    - S. I. Unit = watt per meter square = W/m^2
    - The intensity of a sound wave in air is **directly proportional** to:
      - The square of amplitude of vibration.
      - The square of frequency of vibration.
      - The density of air.
      - Velocity of sound in air.



Soft and loud notes

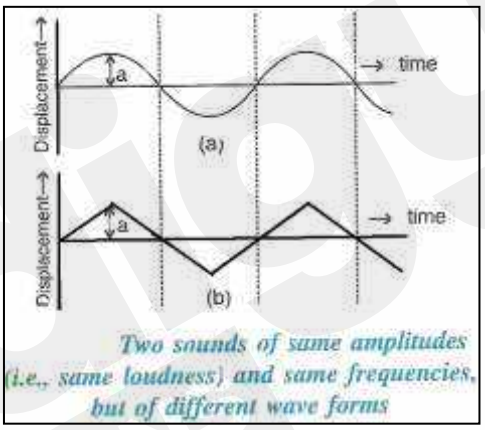
  - **Noise pollution:**
    - **Definition:** Noise Pollution is the disturbance caused in the environment due to undesirable loud and harsh sound from various sources like loudspeaker, siren, vehicles etc. of level above 120 dB.

- **Pitch or shrillness:**
  - **Definition:** Pitch is the characteristic of sound by which an acute or shrill note can be distinguished from a grave or flat note of equal loudness.
  - If the pitch is **higher**, the sound is perceived as **shrill** and if the pitch is **lower**, the sound is perceived as **flat**.
  - Two waves of same amplitude but different frequencies obtained on a C.R.O. are shown in the diagram below:



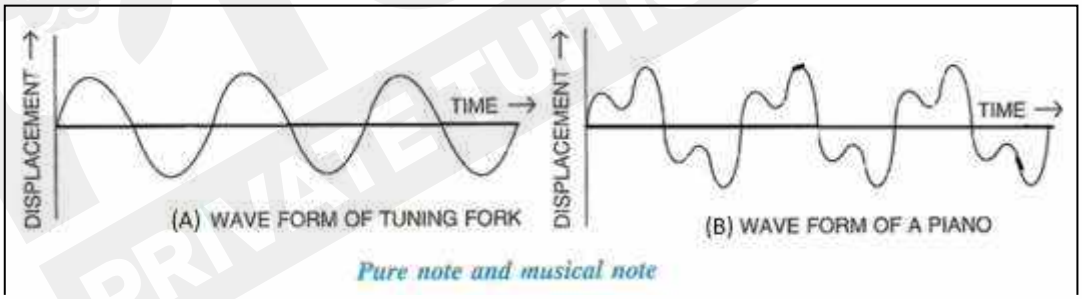
Waves of different pitch

- **Quality (or timbre) and wave form:**
  - **Definition:** Quality or timbre of a sound is that characteristic which distinguishes the two sounds of the same loudness and same pitch, but emitted by two different instruments.
  - **The quality of a musical sound depends on the wave form.**



Two sounds of same amplitudes (i.e., same loudness) and same frequencies, but of different wave forms

  - The tuning fork of 256 Hz and a piano note of 256 Hz both are charted on a C.R.O. to produce the following diagram.



Pure note and musical note

- **Summary of attributes and its factors:**

Attributes	Factors
Loudness	Amplitude of wave
Pitch	Frequency of wave
Timbre or quality	Waveform of the wave