Sound

- Continuous disturbance that transfers energy without any net displacement of the medium particles is called wave.

- Different types of waves on the basis of their production are mechanical wave, electromagnetic wave and matter wave.

- Different types of mechanical waves on the basis of their propagation transverse wave and longitudinal waves.

- Mechanical waves need a medium for its propagation.

- **Laws of reflections of sound:**

  (i) The incident sound, the reflected sound, and the normal to the screen at the point of incidence – all lie in the same plane.

  (ii) The angle of reflection of sound is always equal to the angle of incidence.

- **Echo**
  - Reflection of sound
  - Sensation of sound persists $\frac{1}{10} = 0.1\text{s}$ in the human brain
  - Minimum distance to hear echo

    $\frac{344 \times 0.1}{2} = 17.2 \text{ m}$

- **Reverberation**
  - Persistence of sound by repeated reflection

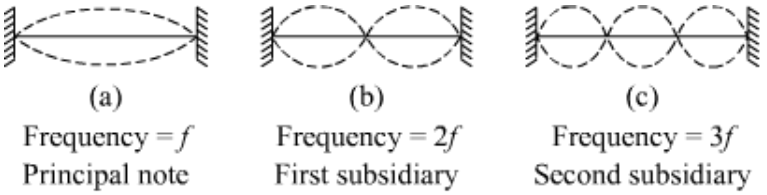
Uses of Echo

- For determination of speed of sound:
  - $v = \frac{\text{Total distance travelled by the sound}}{\text{Time interval in which echo reaches the place from where the sound}}$ t
- Bats and dolphins use echo to detect obstacle or enemy in their path Also, they use it to hunt their prey.
- Sonar is the acronym for **SO**und **NA**vigation and **R**anging. It is an acoustic instrument installed in ships to measure depth, direction and speed of underwater objects such as icebergs, sea rocks, shipwrecks and spy submarines. It uses high-frequency ultrasound for this purpose and works on the principle of echo.
- In medical field: Here, echo method of ultrasonic waves is used to view human organs and any foreign body inside it.

Natural vibrations

The periodic vibrations of a body in the absence of any external force on the body are known as natural or free vibrations. The frequency of the body in natural vibrations is called its natural frequency.

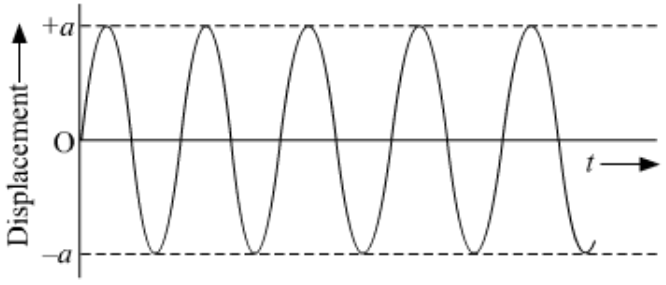
- Frequency of simple pendulum: It starts vibrating with its natural frequency given by $f = \frac{1}{2\pi}\sqrt{\frac{g}{l}}$.
- A load and spring system: Its frequency is given by $f = \frac{1}{2\pi}\sqrt{\frac{K}{m}}$.
- On plucking the strings of instruments like sitar, guitar, violin, etc, vibrations of a definite natural frequency are produced. This natural frequency is given as $f = \frac{1}{2l}\sqrt{\frac{T}{\pi r^2 d}}$.
- A string of a given length stretched between its ends under a given tension can be made to vibrate in different modes by plucking the string at different points.



Different modes of vibrations in a string

Nature of natural vibrations

The natural vibrations are the simple harmonic vibrations under the influence of restoring force for which the amplitude and frequency continue to remain constant. These natural vibrations are possible only in vacuum.



Displacement-time graph for natural or free vibration (in vacuum)

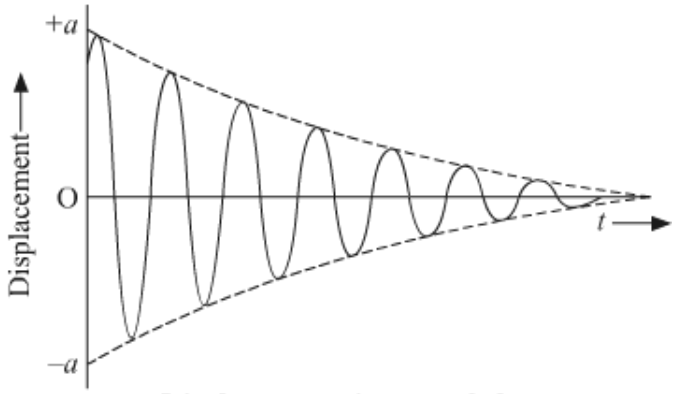
Damped vibrations

The periodic vibrations of a body of decreasing amplitude in the presence of any resistive force are called damped vibrations. Two forces which take part in damped vibrations are:

- the restoring force
- the frictional or resistive force

The rate of decrease of amplitude of vibrations depends on

- nature of the medium
- shape and size of the body in vibrations



Displacement-time graph for the damped vibrations

Few examples of damped vibrations:

- Thin branch of a tree when pulled and released produces damped vibrations.
- Tuning fork when struck on a rubber pad in the presence of air produces damped vibrations.
- Simple pendulum oscillating in air produces damped vibrations.
- Vibrations of a loaded spring in air are damped vibrations.

Forced vibrations

The vibrations of a body which take place under the influence of an external periodic force acting on it, are called the forced vibrations. The forces which take part in forced vibrations are:

- the restoring force
- the frictional or resistive force
- the external periodic force or driving force

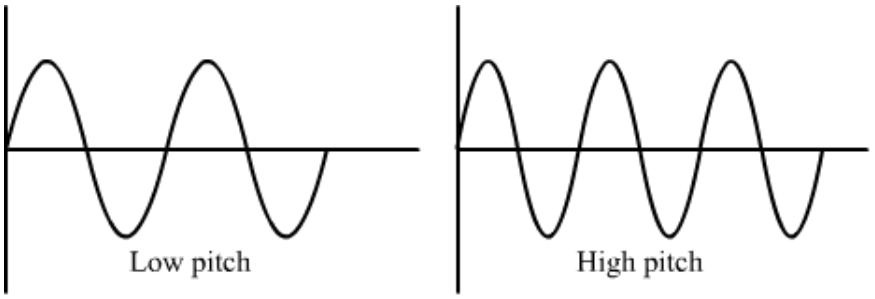
Few examples of forced vibrations:

- Vibrations produced in the table top when a vibrating tuning fork is pressed against it are forced vibrations.
- Vibrations produced in the microphone's diaphragm with the frequencies corresponding to the speech of the speaker is an example of forced vibrations.
- In string instruments like guitar, an artist applies the periodic force on the strings to produce forced vibration in them.

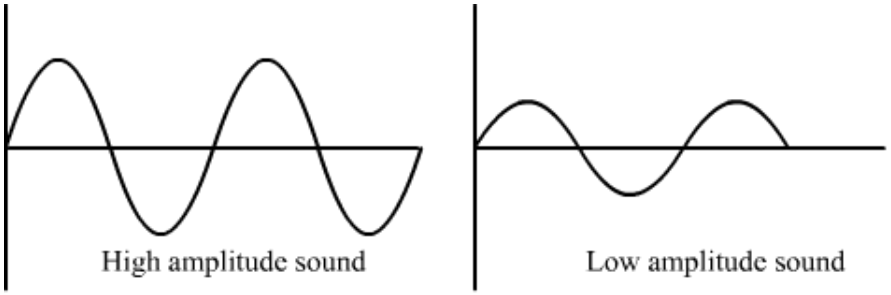
Resonance

It is a special case of forced vibration in which the frequency of the externally applied periodic force on an object is equal to its natural frequency. In this case, the body begins to vibrate with an increased amplitude. This phenomenon is known as resonance.

- **Characteristics of sound waves**
    - **Amplitude –** Magnitude of maximum displacement from mean position
    - **Wavelength (λ)** – Distance between two consecutive compressions or two consecutive rarefactions
    - **Frequency (Unit - Hertz, Hz)** – Number of oscillations per unit time
    - **Time period** – Time taken by two consecutive compressions or rarefactions to cross a fixed point
        - Frequency = $\frac{1}{\text{Time period}}$
- **Pitch** – Higher the frequency, higher the pitch



- **Loudness** – Determined by amplitude



- **Tone** – Sound of a single frequency
- **Quality or timbre**

Differentiate between two sounds of same pitch and loudness

- If the notes produce an unpleasant sound in the ear, then it is a **dischord** or **dissonance**.
- **Harmony -** Harmony is the pleasant effect produced due to concord, when two or more notes are sounded together.
- **Melody** - Melody is the pleasant effect produced by two or more notes when they are sounded one after another.
- **Musical intervals** - Musical interval is the ratio of frequencies of two notes in the musical scale.
- **Musical scale** - Musical scale is the series of notes separated by a fixed musical interval. Keynote is the starting note of a musical scale.
- **Diatonic** scale
- When two notes are sounded simultaneously and produce pleasant sensation in the ear, then it is **concord** or **consonance**.
- It contains series of eight notes.
- **Octave** is the interval between the keynote and the last tone.
- **Advantages of a diatonic scale**
    - This scale provides the same order and the duration of chords and intervals, which succeed each other, that are required for a musical effect.

- This scale can produce musical compositions with the lower and higher multiples of frequencies of the notes.

Speed of sound

- Speed of sound $v = \nu \times \lambda$
- Speed in solid > Speed in liquid > Speed in gas
- Speed depends on temperature, pressure, humidity and nature of the material of the medium.
- Speed increases with increasing temperature.
- In air, speed of sound is 344 m s^{-1} at 22 °C
- Supersonic – The rate of distance travelled by the object is more than the speed of sound.
- Sonic boom - loud noise produced by supersonic object is sonic boom

Loudness is the characteristic of sound by virtue of which a loud sound can be distinguished from a feeble one, both having the same pitch and timbre. It depends upon the amplitude of the wave. The unit of loudness is phon and decibel (dB).

Loudness of sound

- is directly proportional to the square of amplitude
- inversely varies with the square of distance from the source
- is directly proportional to the surface area of vibrating body
- is directly proportional on the density of the medium
- increases with the presence of resonating bodies near the vibrating body

Intensity of sound

It is the amount of sound energy passing per second normally through the unit area around a point in a medium. Its unit is watt per $meter^2$.

The intensity of sound wave is proportional to

- square of the amplitude of vibration
- square of the frequency of vibration
- density of air

Relationship between loudness and Intensity

According to Weber and Fechner, the relationship between loudness and intensity is $\boldsymbol{L = K \log_{10} I}$. Here, K is the constant of proportionality.

Noise pollution

Noise pollution is the disturbance produced by noise which has harmful impact on humans and animals. When sounds of level above 120 dB is produced from various sources such as loudspeakers, moving vehicles etc., then such sounds are reffered as noise.