Ratna Sagar

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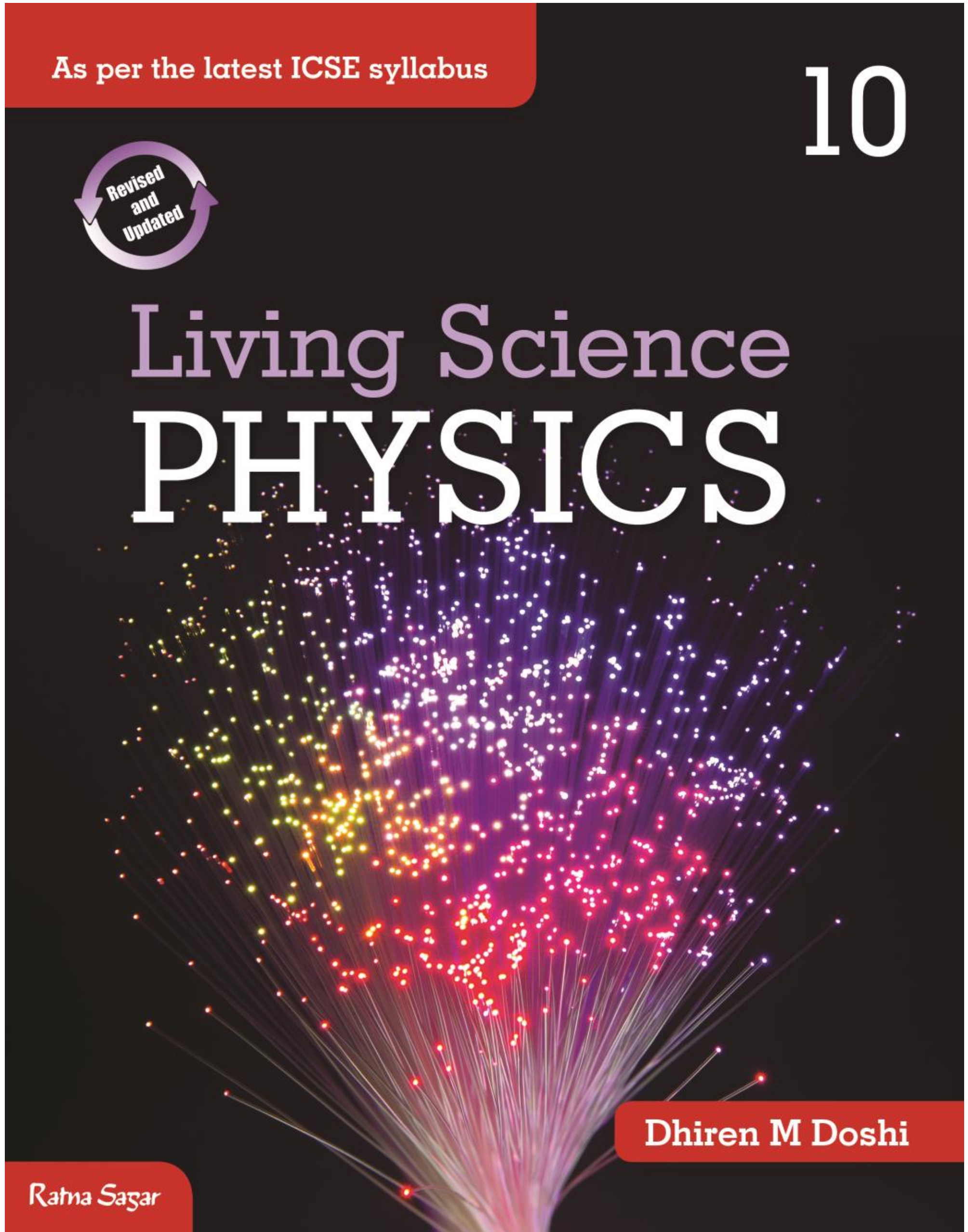
ICSE
Living Science
Physics

Class 10

Chapter-7 Sound


As per the latest ICSE syllabus
10
Revised and Updated
Living Science
PHYSICS
Dhiren M Doshi
Ratna Sagar

LEARNING OBJECTIVES

Reflection of Sound
- ❖Echo
- ❖Reverberations
- ❖RADAR

Free, Damped and Forced Vibrations, Resonance
- ❖Damped vibrations
- ❖Forced vibrations
- ❖Resonance

Characteristics of Sound
- ❖Loudness
- ❖Intensity
- ❖Pitch
- ❖Quality or timbre

Music and Noise

What is Sound?

A physiological sensation received by the ear is called sound. Sound is a form of energy. Sound is produced by the vibrations of a body in a medium. Sound travels at a speed of 343 m/s in air (at 20 °C).

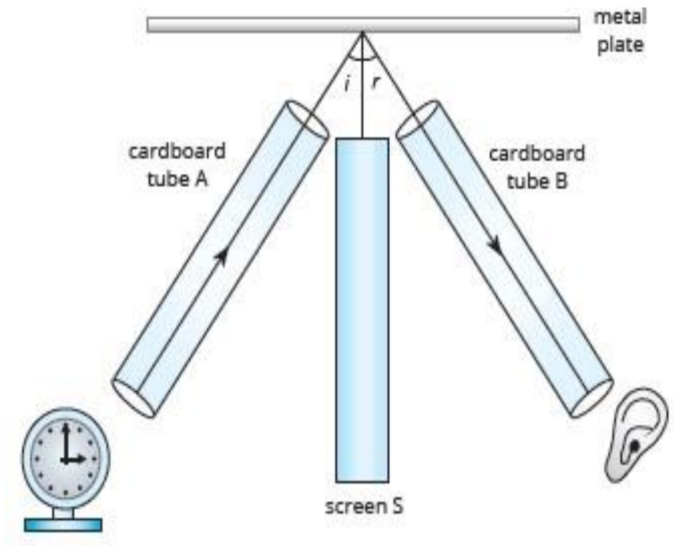
Reflection of Sound

The reflection of sound does not require a smooth and shining surface like that of a mirror. Sound can be reflected from any surface, whether smooth or rough, shining or dull.

According to the laws of reflection of sound:

1. The angle of incidence is equal to the angle of reflection of sound, i.e. $\angle i = \angle r$.

2. The incident sound, the normal and the reflected sound, all lie in the same plane.



The reflection of sound is utilised in the working of simple devices like megaphone, soundboards and ear trumpet.

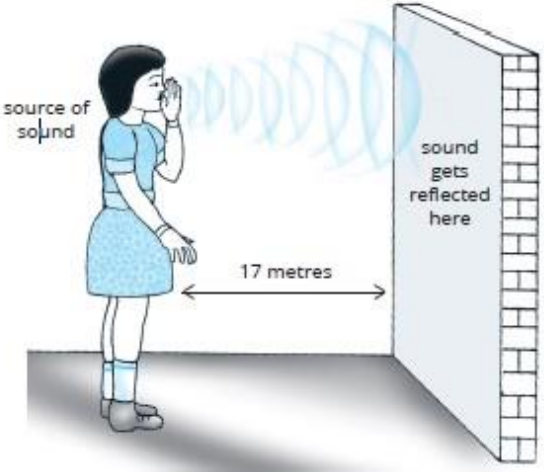
Echo

An echo is the repetition of the original sound heard after the sound is reflected from a distant, dense and rigid object (such as a high building and cliff).

Calculation of minimum distance to hear an echo

Speed = Distance travelled /Time taken

Distance travelled = 340 $\times$ 1/ 10 = 34 metres
Thus, the distance travelled by sound in going from us (the source of sound) to the sound reflecting surface (wall), and then coming back to us should be 34 metres. So our distance from the sound-reflecting surface (like a wall) to hear an echo should be half of 34 metres which is 34/2 = 17 metres.

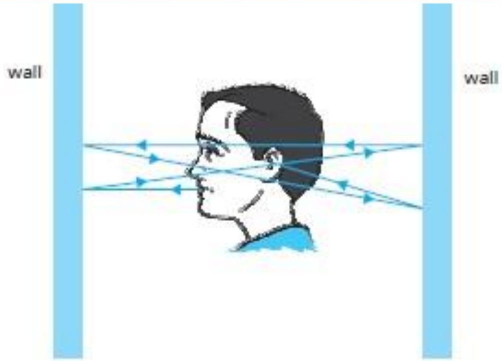


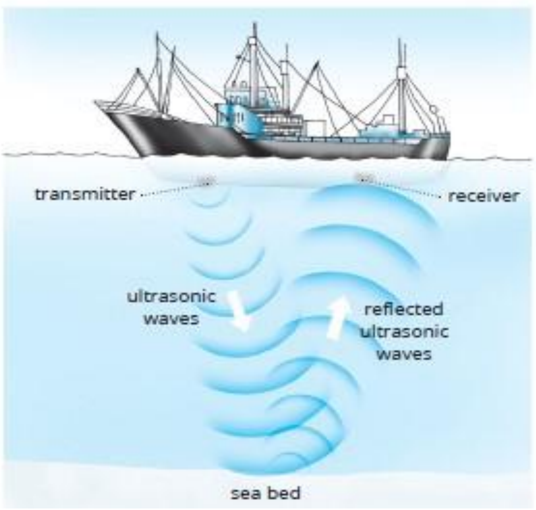
Conditions for the formation of echoes

1. The minimum distance between the source of sound and the reflector should be at least 17 metres (so that the echo is heard distinctly after the original sound is over or dies off).
2. The size of the reflector must be large (like tall mountains, hills and walls) compared to the wavelength of the incident sound (for reflection of sound to take place).
3. The intensity or loudness of the sound should be sufficient for the reflected sound reaching the ear to be audible.

Reverberations

When a number of echoes of the original sound are heard, each echo being fainter than the preceding one, such multiple echoes are called reverberations.





Uses of Echo

SONAR (stands for <u>SO</u>und <u>N</u>avigation <u>A</u>nd <u>R</u>anging)

Sonar is a device which is used to find the depth of sea, or to locate underwater objects like enemy's submarine, sunken ships and shoals of fish.

RADAR (stands for <u>RA</u>dio <u>D</u>etection <u>A</u>nd <u>R</u>anging)

In space, radar is used to detect the presence of obstacle and finding its distance (or range) by using the echo method. Air traffic control systems use radar. The tower emits radio waves which travel at 3×10^8 m/s. They are reflected from the aircraft and picked up by receivers in the tower. The time taken for the signal to return can be used to calculate the distance of the aircraft.

Use of echoes by animals in nature

Bats use echoes to locate their prey and to avoid obstacles in their path. They emit ultrasound and can judge the distance of the reflecting object from the time taken by the echo to return. This process of detecting obstacles is called **sound ranging**.

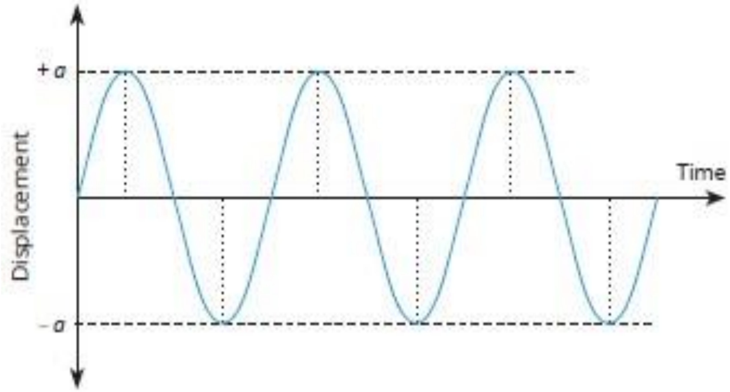
- Dolphins, Piranha fish and porpoises also use this method to detect their enemies, preys and obstacles.
- Ultrasonography is a medical technique in which doctors use sonar scanners to look inside the human body.
- Echoes are used by the engineers to detect flaws in machines. Echoes are also used by geologists to detect underground ores or oil deposits.
- The fishermen use trawlers (based on the principle of echo method) to find the direction and the distance of the shoals of fish.
- Ultrasonic spectacles for blind people .

Free, Damped and Forced Vibrations, Resonance

Free vibrations

When a body capable of oscillating is made to vibrate with its own natural frequency such that its amplitude and frequency remains constant, it is said to have natural (or free) vibrations.

Displacement-time graph for free vibrations



In the absence of frictional forces, the amplitude and frequency of a natural vibration remain constant. Such type of vibrations can be obtained only in vacuum and are not obtainable in practice due to frictional forces.

Damped Vibrations

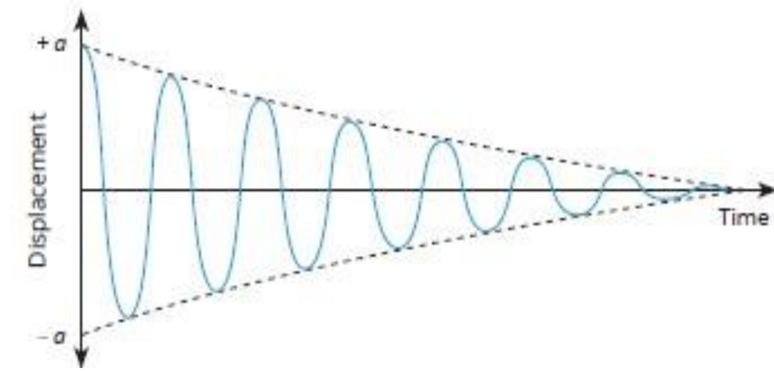
The vibrations whose amplitude decrease gradually with time are called damped vibrations.

Examples of damped vibrations

1. Simple pendulum oscillating in air 2. Sound waves in air
3. Vibrations of a tuning fork in air

Displacement–time graph for damped vibrations

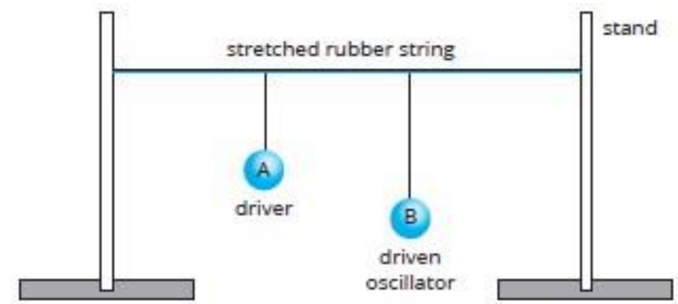
Due to the presence of frictional forces, the amplitude of vibrations of a body decreases gradually with time. Over a period of time, the motion of the vibrating body finally stops.



Forced Vibrations

The vibrations produced in a body due to external periodic force acting on it, the frequency of the force being different from the natural frequency of the body are called forced vibrations.

When a body oscillates with the help of an external periodic force with a frequency different from the natural frequency of the body, its oscillations are called forced vibrations.



Examples of forced vibrations

1. When the stem of a vibrating tuning fork is gently pressed against the top of the table, vibrations are set-up in the table top. These vibrations are forced vibrations. The table-top vibrates with the frequency of the tuning top.

It showed sudden rise in temperature indicating the existence of some invisible rays there, having the heating effect. From this he concluded that the sun emitted some invisible rays which could not be seen by the eyes but heated the objects on which they fell. These rays which exist beyond the red-end of the spectrum are called **infrared rays**.

Sources of Infrared Radiations

Infrared radiations sometimes are called **heat radiations**. Infrared radiations are produced by hot bodies such as fire, heated iron ball, etc. **Sun is the natural source of infrared radiations**.

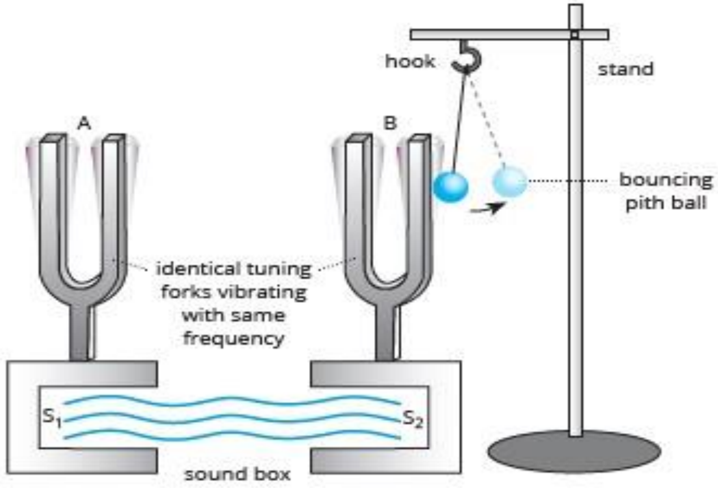
Uses of Infrared Radiations

1. Infrared rays produce heating effect, as a result of this property they are used by doctors to treat muscular strains (medical therapy).
2. Infrared rays have a high penetrating power and are least scattered by fog and mist (as it has a long wavelength). So they can penetrate thick columns of fog and smoke. Therefore, they can be used for taking photographs over long distances even in foggy weather. For the same reason, they are used in photography at night.
3. They are used for producing dehydrated fruits.
4. They are used in greenhouses to keep the plants warm.

2. In stringed musical instruments like sitar, guitar and violin, strings are stretched on a wooden box covering a hollow box. When the strings are made to vibrate by plucking, air molecules inside the hollow box are set into forced vibrations. This increases the intensity of the sound emitted by the strings.

Resonance

When a body oscillates with its own natural frequency with the help of an external periodic force whose frequency is equal to (or an integral multiple of) the natural frequency of the vibrating body, the oscillations of such a vibrating body with a large amplitude is known as resonance.



Demonstration of resonance using tuning forks

Note: The differences between forced vibrations and resonance are given in Table 7.1. P-140

Conditions for the occurrence of resonance

1. The vibrating body must produce sufficient external periodic force, so as to set the other body into vibrations.

2. The body oscillates with its own natural frequency with the help of an external periodic force whose frequency is either equal to (or is an integral multiple of) the natural frequency of the vibrating body.

Characteristics of Sound

There are three fundamental characteristics of a sound.

1. Loudness **2.** Pitch **3.** Quality or timbre

Loudness

Loudness is the characteristic of a sound by which a loud sound can be distinguished from a faint sound even though both have the same pitch and quality.

Intensity

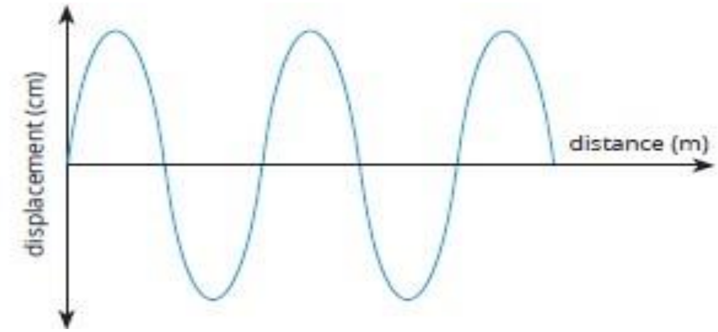
The intensity of a sound wave at any point in space is defined as the amount of energy passing per unit time per unit area in a direction perpendicular to the area. Intensity, I = energy/ area x time = power/ area [as power = energy time]

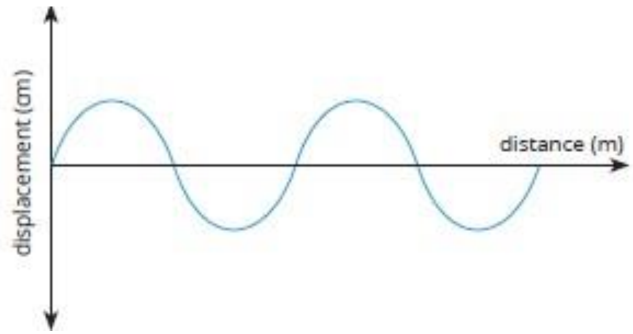
The unit of intensity is watt/metre^2 or W/m^2.

Factors affecting the loudness of sound

1. Amplitude of vibration of the source: It has been found that greater the amplitude of vibration of the source, the greater is the intensity (and hence loudness) of sound and vice versa.

a. Smaller amplitude produces a soft sound





b. Larger amplitude produces a loud sound

2. Surface area of the vibrating body: The greater the surface area of the vibrating body, the greater is the loudness of sound.

3. Distance from the vibrating body: Loudness depends on the distance between the listener and the source. The lesser the distance between the listener and the source, the louder is the sound heard by the listener and vice versa.

4. Density of the medium: The loudness of sound is directly proportional to the density of the medium through which it propagates, i.e. greater the density of the medium, louder is the sound.

5. Presence of resonant bodies: The loudness of sound is increased due to the presence of other resonant bodies near the source of sound.

6. Motion of the medium: If wind is blowing in the direction of propagation of sound, loudness is increased. On the other hand, if wind is blowing in a direction opposite to the propagation of sound, loudness is decreased.

Relationship between intensity and loudness

The quantity of sound energy flowing through unit area of cross section in one second is called the **intensity** of sound.The loudness of a sound *L* is directly proportional to the logarithm of the intensity *I* of the sound.

$L \propto \log I$

or, $L = K \log I$ where, K is a constant.

Units of loudness and sound level

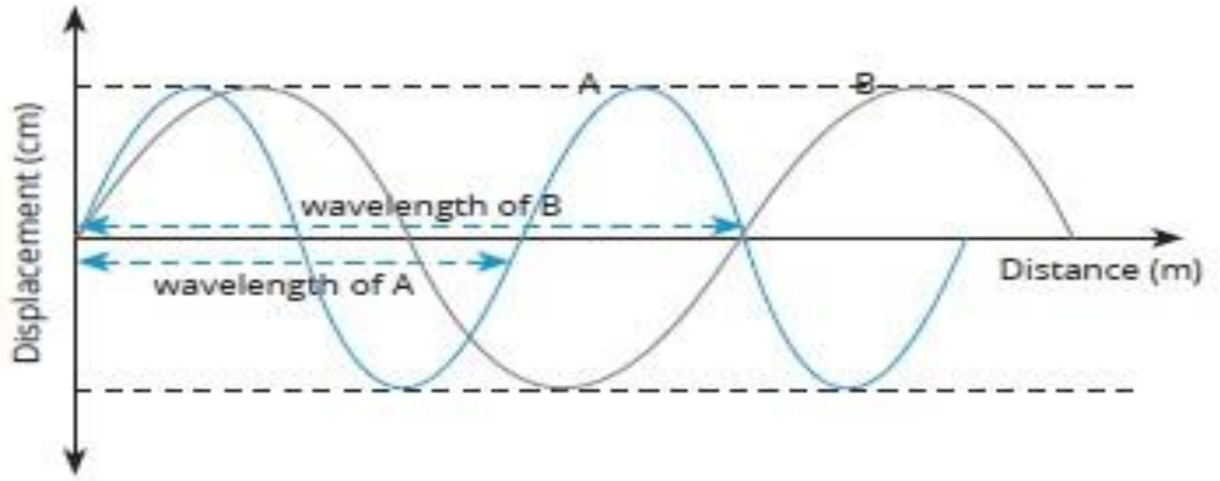
The unit of loudness level is the phon. The intensity level of sound is expressed in decibel (dB). One phon is the loudness level of a pure tone of 1000 Hz whose sound intensity level is one decibel. One phon is equal to one decibel at 1000 Hz. The zero point on the decibel scale is not 'no sound' but rather the lowest sound that can be heard by the human ear. This is sometimes called the threshold of hearing. Every time another 10 dB is added to the sound level, the loudness is multiplied by 10.

Pitch

It is the characteristic of a sound by which we can distinguish a shrill sound from a grave (hoarse) sound even though the two sounds have the same loudness. It is a subjective quantity and cannot be measured by instruments. The **pitch of a sound depends upon the frequency of vibration**.

The sound produced by an object vibrating with a low frequency (or high wavelength, since frequency α 1/ wavelength), has low pitch and the sound is described as grave or flat sound.

The sound produced by an object vibrating with a high frequency (or low wavelength) has a high pitch and the sound is described as shrill sound. Thus, higher the frequency of a sound, higher is its pitch and vice versa.



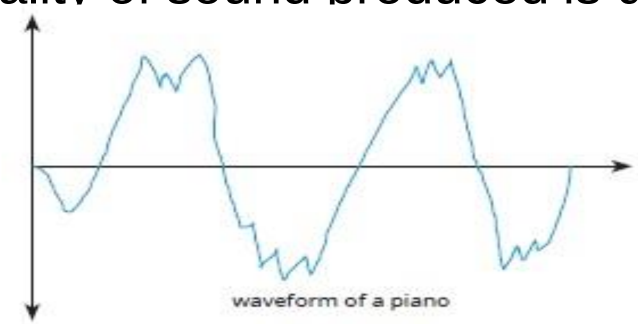
Two different waves A and B having same amplitude but different wavelengths

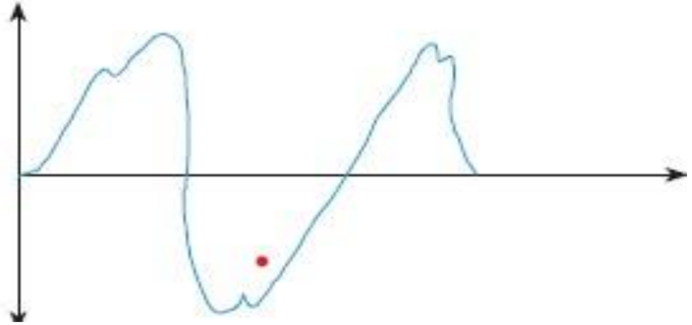
Quality or timbre

It is the characteristic of sound that enables us to distinguish between two sounds of the same pitch and loudness produced by two different sources. **It depends upon the waveform of the sound**.

The sound from an instrument does not contain note of a single frequency but contains vibrations of different frequencies and different amplitudes. The vibration of the lowest frequency has the greatest amplitude and is called the **principal or fundamental vibration** while the vibration of frequencies which are simple multiples of each other are called **harmonics** (since their amplitudes are very small).

The quality of a sound depends upon the number of harmonics and their prominence. Different instruments emit different harmonics and hence the quality of sound produced is different.



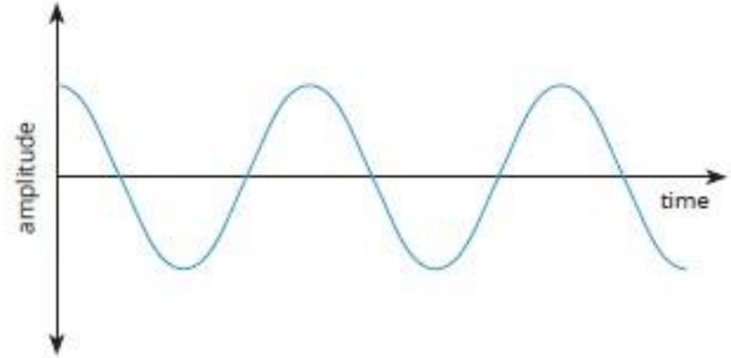


Wave form with a large number of harmonics (better quality sound)

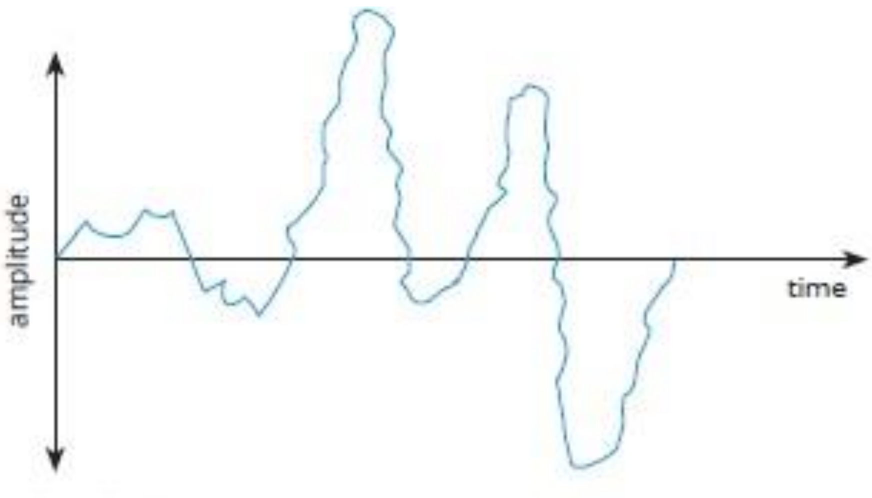
Waveform with a few harmonics (mellow sound)

Music and Noise

Musical sound: A continuous and uniform sound produced by regular and periodic vibrations producing pleasing effect to our ears is called musical sound**.** Sounds produced by musical instruments like piano, violin and flute are musical sounds.



Regular, periodic and continuous vibrations are characteristics of waveform of musical sound.



Irregular, non-periodic and non-continuous vibrations are characteristics of waveform of noise.

Noise: A discontinuous and non-uniform sound produced by irregular and non-periodic disturbances producing unpleasant effect to our ears is called noise. Sound produced by a falling brick, machines in a factory, etc. are noises.

Note: Refer Table 7.4 P-148 for Differences between musical sound and noise

SUMMARY

1. **Sound:** It is a form of energy produced by a vibrating body.

2. **Echo:** It is the repetition of the original sound heard after the sound is reflected from a distant, dense and rigid object.

3. **Conditions for echo formation: a.** The minimum distance between the source of sound and the reflector should be at least 17 metres. **b.** The size of the reflector must be large as compared to the wavelength of the incident sound.

4. **Reverberations:** When a number of echoes of the original sound are heard, each echo being fainter than the preceding one such as in a closed room, are called reverberations.

5. **Application of echoes: a.** Sonar **b.** Radar **c.** Sonar scanners.

6. **Natural vibrations:** When a body capable of oscillating is made to vibrate with its own natural frequency, it is said to have natural or free vibrations.

7. **Damped vibrations:** The vibrations whose amplitude decreases gradually with time are called damped vibrations.

8. Forced vibrations: Vibrations produced in a body due to periodic force acting on it, the frequency of the force being different from the natural frequency of the body, are called forced vibrations.

9. Resonance: When a body oscillates with its own natural frequency with the help of an external periodic force whose frequency is equal to (or in an integral multiple of) the natural frequency of vibrating body, the oscillations of such vibrating body with a large amplitude are known as resonance.

10. Characteristics of sound: a. Loudness **b.** Pitch **c.** Quality.

11. Loudness: It is the characteristic of sound by which a loud sound can be distinguished from a faint sound.

12. Pitch: It is the characteristic of sound by which we can distinguish a shrill sound from a grave sound.

13. Quality: It is the characteristic of sound that enables us to distinguish between two sounds of the same pitch and loudness produced by two different sources.

14. Musical sound: A continuous and uniform sound produced by regular and periodic vibrations producing pleasing effect on our ears is called musical sound.

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THANK YOU