Sound

Production of Sound

If somebody calls you from behind, you will quickly turn around. **What makes you do so?**

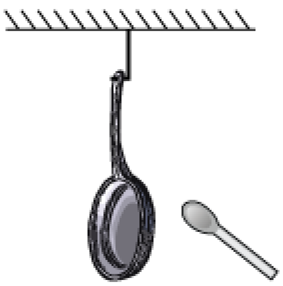
We turn back in response to a call because of the sound heard by us. We are able to talk to each other because of the sound produced by us. We are able to predict the distance of a train only by listening to the sound it produces. Similarly, we can distinguish between different musical instruments because of the sounds they produce.

How do you realize that an alarm bell is ringing?

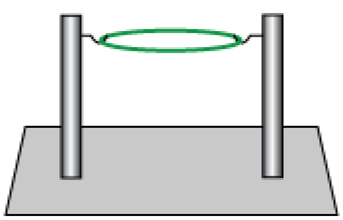
So, what is sound?

Sound is a form energy that produces the sensation of hearing in our ears and vibrating bodies produce sound.

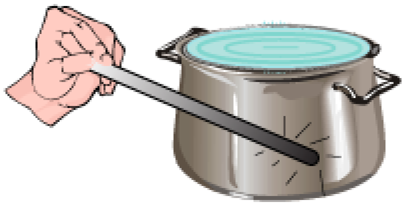
Do you know how a sound is produced? To find out, let us perform the following activities.



Take a frying pan and suspend it in air with the help of support. Hit the pan with a metal spoon. Now, touch the pan. **Can you feel the vibrations?** When you beat an object, you can feel its vibrations with the help of your sense of touch. Touch the pan when it is not producing any sound. **Can you feel the vibrations now?**



Take a rubber band and stretch it between two poles (as shown in the given figure). Now, pluck the rubber band in the middle. **Can you hear any sound? Does the rubber band vibrate when it produces a sound?** On plucking a stretched rubber band or a stretched string, it vibrates rapidly and produces a sound.



Take a cooking utensil and pour some water in it. Now, beat the utensil with a rod. You will hear a sound. Carefully, observe the surface of water in the utensil**. Do you see concentric circles moving on the water surface?** These are vibrations in water, produced by vibrations of the utensil body, on beating.

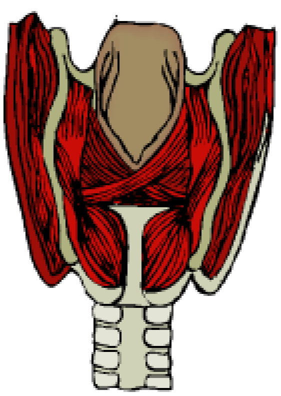
Therefore, it can be concluded that a vibrating body produces sound.

The back and forth movement of an object produces sound. An object moving back and forth is said to be in vibration. Hence, sound is produced by vibrating objects.

Sound Produced By Humans

While watching a group of children playing hide and seek, Himesh observed how a blind-folded boy was able to catch the other children by hearing the sounds produced by them. **This made him wonder how sounds are produced by humans.**

While singing a song, put your hand on your throat. You will find a part of your throat moving up and down. This part of your throat is known as the **voice box** or **larynx**. The larynx is responsible for producing sounds in humans. It moves when we swallow something.

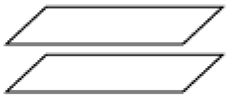


Voice box

We know that a vibrating object produces sound. **Then, which part of our body vibrates to produce sounds?**

The voice box consists of two vocal chords. These chords are arranged in such a manner that there is a small gap between them. This small gap allows air to pass through. When we speak, air is forced into this small gap by the lungs. This prompts our vocal chords to vibrate and hence, produce sounds.

Let us understand better by performing a small activity. Take a piece of paper and cut two small rectangles out of it. Now, put these two pieces of paper one above the other such that there is a small gap between them.



A rectangular slit

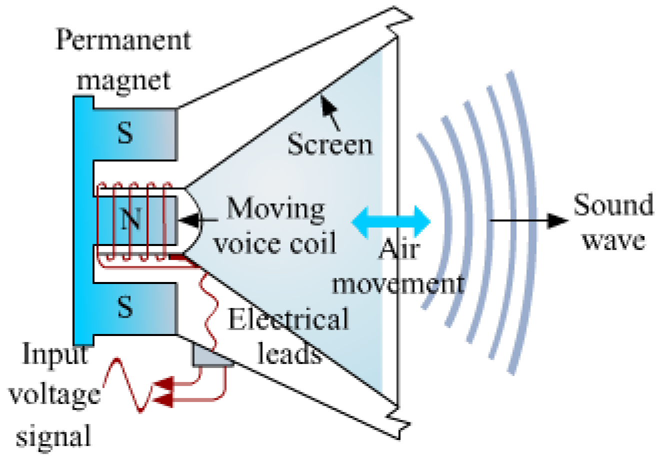
Now, blow air through this small gap. **Can you hear a sound?** Your voice box functions in the same way.

We can hold these pieces of paper tightly as well as loosely. In the same way, our vocal chords can be held tightly or loosely with the help of the muscles attached to them. Different people have different vocal chords. Due to this reason, we all have a different voice quality.

We have seen other devices too which produce sound. One of the examples is loudspeaker. Have you ever wondered how does it produce sound?

A loudspeaker consists of following parts:

- An electric coil wound on a permanent magnet.
- A conical shaped screen of the speaker connected to the coil.



Now, when variable current flows through the coil, magnetic field is produced around it due to electromagnetism and it behaves like an electromagnet. Because of this, the coil is repelled and attracted by the permanent magnet alternately. The screen attached to the coil moves back and forth due to the attraction and repulsion of the coil and produces sound.
The frequency and amplitude of movement of the coil and thus the screen depends on the variation of current through the coil.

Sound Requires Medium for Propagation

We are able to hear the bursting of crackers even when we are standing at a distance. **How is it possible? How does the sound produced by a cracker reach us?**

The sound of a bursting cracker reaches us through air. It shows that sound can travel through air.

Let us try to understand this better.

A material medium is necessary for the propagation of sound. Vacuum is devoid of any material. Hence, sound cannot travel through vacuum.

Outer space is devoid of any material medium. Hence, no sound can be heard in outer spaces. To communicate in such areas, astronauts use walkie-talkies. A walkie-talkie is an instrument, which uses radio waves for the transportation of messages.

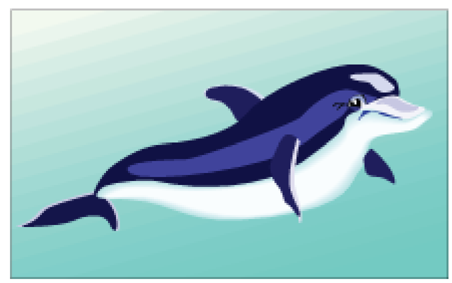
Can sound travel through liquids?

To find out whether sound can travel through liquids, let us perform the following activity.

Take a metal plate and spoon. Place them inside a bucket filled with water. Hit the plate with the spoon in such a way that it does not touch the body of the bucket.

Now, carefully place your ear near the surface of water. **Are you able to hear the sound produced?**

You can hear the produced sound. Sound reaches your ear after travelling through water. Hence, we can say that sound travels through liquids.

Dolphins communicate with each other by sending high pitched squalls. It shows that sound can travel through water.	

Can sound travel through solids?

Place your ear on one end of a long table. Ask your friend to tap the table from the other end. **Do you hear any sound?**

You can hear the produced sound. Sound reaches your ear after travelling through the table. This indicates that sound can travel through solids.

Stethoscope is an example of sound travelling through solids. Doctors use stethoscopes to listen to your heartbeat.	

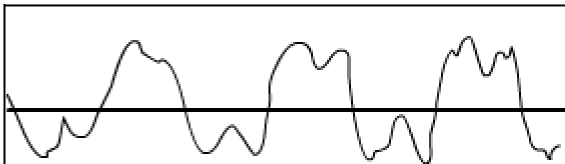
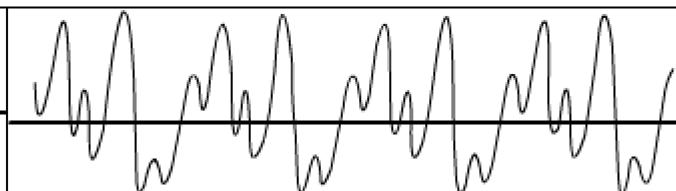
Sound can travel in solids, liquids, and gases. However, sound cannot travel in vacuum.

Characteristics of Sound Waves

Characteristics of Sound: An Overview

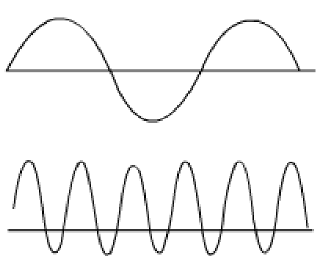
We can distinguish the sounds made by two men, two women, two musical instruments, two animals, etc. This is because sound waves differ in their quality or timbre. Quality is a characteristic of sound that enables us to distinguish between sounds with the same loudness and pitch.

The following figures show the sound waves produced by a violin and a flute.

	
Sound wave produced by a flute	Sound wave produced by a violion

A pleasant sound has a rich quality. The sound of a violin is more pleasant than that of a flute. This is evident from their respective sound waves.

These sound waves depict the voices of a boy and girl. **Can you identify the girl's sound wave?**



Did You Know?

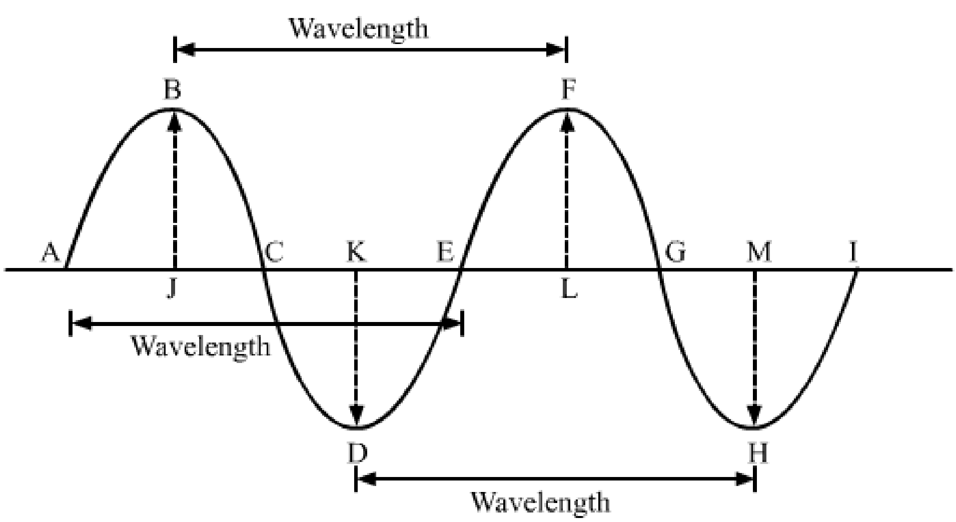
Two sounds with the same loudness, pitch and speed can be distinguished by their quality or timbre. If a sound is pleasant to hear, then it is said to have a rich timbre. An unpleasant sound has a poor timbre.

Characteristics of Sound

Sound is a **longitudinal wave**. A longitudinal wave manifests alternate regions of **compressions** and **rarefactions** while travelling through a medium. A longitudinal wave can be described by the five characteristics listed below.

- Amplitude
- Wavelength
- Frequency
- Time period
- Speed

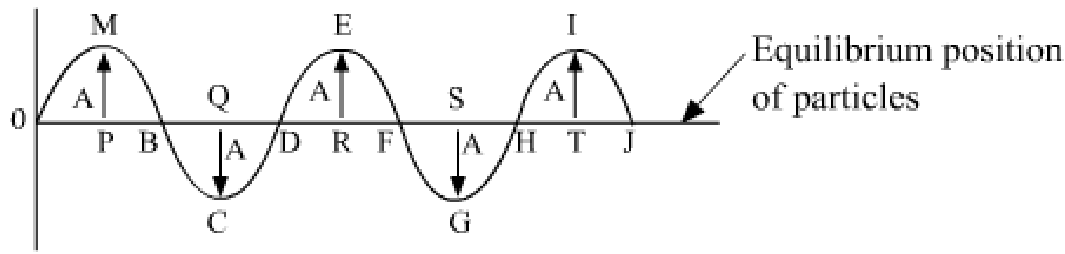
These five characteristics are demonstrated in the following figure with the help of a **transverse wave**. Note that the **crests** and **troughs** in a transverse wave are equivalent to the compressions and rarefactions in a longitudinal wave, respectively.



Wave characteristics

Amplitude (*A*)

The **amplitude** (*A*) of a wave is the maximum displacement of the medium particles on either side of their original, undisturbed position. In the following figure, the transverse equivalent of a longitudinal sound wave is shown.



The maximum displacement of the medium particles is represented by the maximum heights MP, ER and IT, and the maximum depths QC and SG. This maximum displacement is the amplitude of the wave, i.e. MP = ER = IT = QC = SG = Amplitude of the wave.

•The SI unit of amplitude is metre (m).

•The loudness of a sound is directly related to its amplitude. The amplitude of a loud sound is larger than that of a soft sound.

•The amplitude of a sound wave determines the amount of energy it carries.

Did You Know?

The loudness of a sound is directly related to the amplitude of the wave. It is the measure of our ears' response to a sound. Our ears detect louder sounds better than softer ones. A loud sound has greater amplitude than a soft sound.

Whiz Kid

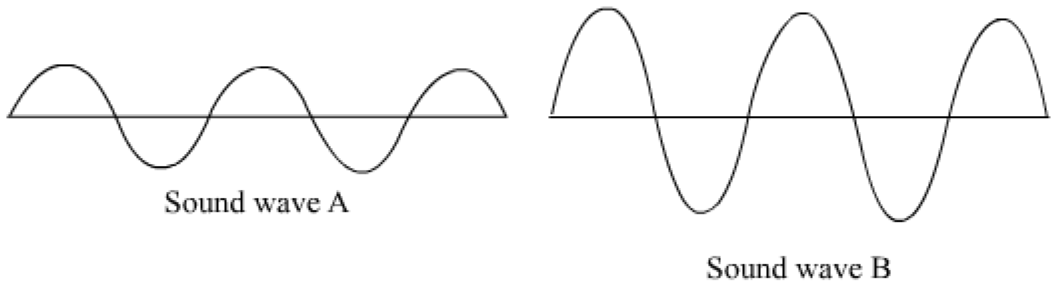
Loudness and Intensity

It is quite common to use the terms 'loudness' and 'intensity' interchangeably. However, the two are not the same.

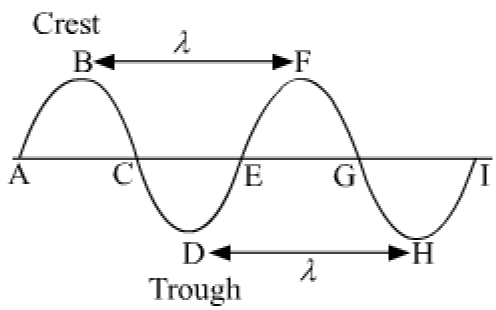
Loudness is the measure of the human ear's response to a sound. In contrast, intensity is the amount of energy passing per unit area per unit time.

•A sound may be louder than another owing to a difference in their intensities.

Can you say which sound wave corresponds to the louder sound?



Wavelength (*λ*)

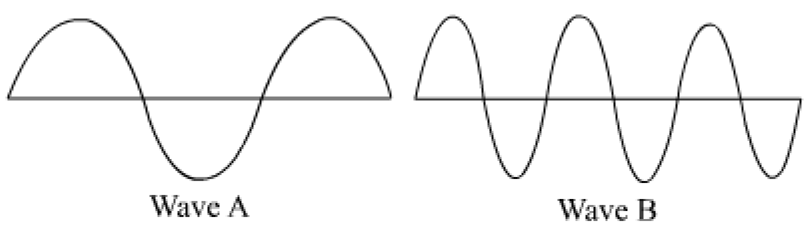


The distance between two consecutive compressions or rarefactions of a sound wave is its **wavelength** (*λ*). In case of a transverse wave, wavelength is the distance between two consecutive crests or troughs.

In the figure, the distances BF and DH represent the wavelength of the wave.

The SI unit of wavelength is metre (m).

Can you say which of these two waves has the longer wavelength?



Frequency (*f*)

The **frequency** (*f*) of a source of sound is the number of cycles or vibrations produced by it per second. It is the rate at which sound wave is produced by the source.

If five crests of a wave pass through a fixed point in one second, then the frequency of the wave is five cycles per second.

The SI unit of frequency is hertz (Hz).

One hertz is equal to one vibration per second. Sometimes a bigger unit of frequency—called kilohertz (kHz)—is used.

1 kHz = 1000 Hz

The frequency (*f*) of a wave is the reciprocal of its time period *T*, i.e.
$f = 1/T$

Note that the frequency of a wave is the same as the frequency of the vibrating body that produces the wave. For example, the frequency of a tuning fork is marked as 256 Hz. This means that it can produce a sound wave of frequency 256 Hz.

The frequency of a wave remains constant in any medium, but its speed and wavelength depend upon the nature of the medium.

Did You Know?

Pitch, Tone and Note

Pitch is defined as the shrillness of a sound. This highness or lowness of a sound is proportional to the frequency of the sound.

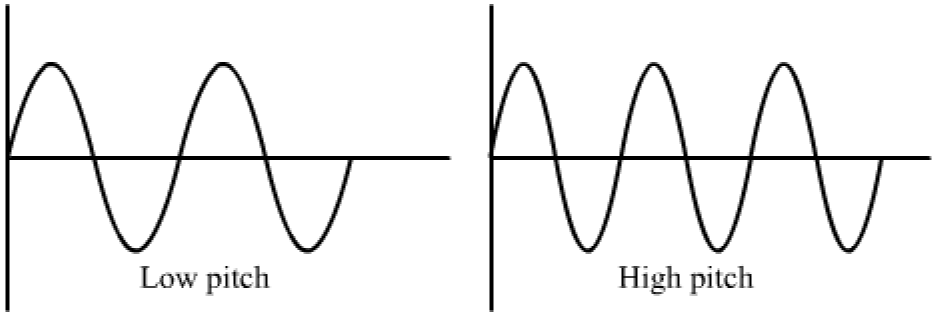
The sound produced by a flute is of a higher pitch compared to the sound produced by a drum. This is because the frequency of the former is higher than that of the latter. Similarly, women produce higher-pitched sounds than men.

Tone is defined as a sound that has a single frequency.

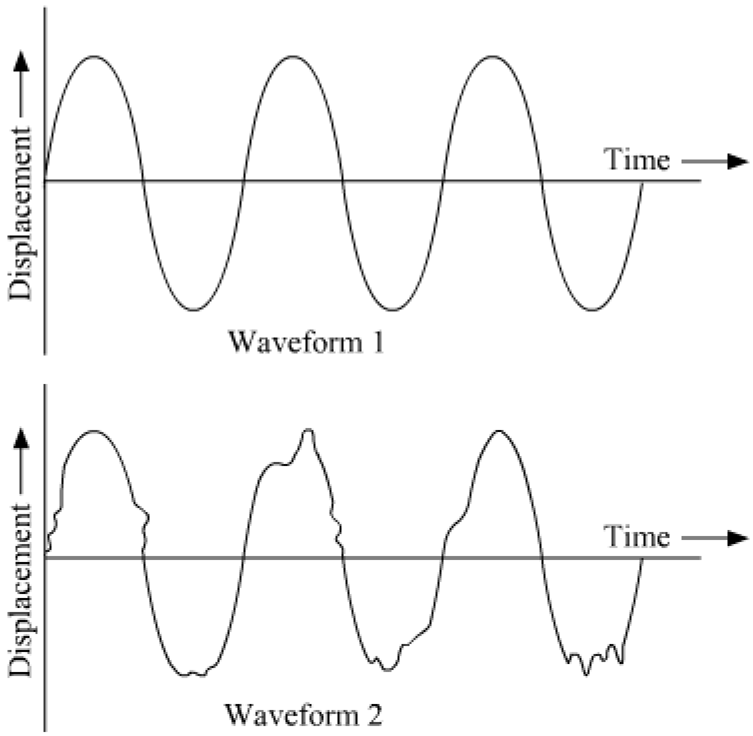
Note is defined as a sound that has a mix of different frequencies.

Suppose two sounds, produced from two different sources, have the same amplitude and speed. In this case, one sound can be distinguished from the other by its pitch, which is directly related to its frequency.

The female voice is high-pitched while the male voice is low-pitched.



Quality or Timbre is that characteristic of a sound that helps in distinguishing various types of sounds having same amplitude and frequency, but emitted from different sources. Quality of sound depends on its waveform.



Both the sounds shown above have different quality as their waveforms are different.

Whiz Kid

Take a wide tub filled with water. Drop a pebble at the centre of the tub from a height. You will observe ripples moving outwards in a transverse-wave-like motion. Count the number of crests that hit a particular side of the tub. Note the time using a stopwatch. Then, calculate the frequency of this wave. Share your result with friends.

Know Your Scientist

Heinrich Rudolph Hertz (1857-1894) was a German scientist. He was educated at the University of Berlin. He confirmed James Clark Maxwell's electromagnetic theory through his experiments. He laid the foundation for the future development of the radio, telephone, telegraph and television. He died quite young, less than a month before his thirty-seventh birthday. The SI unit of frequency is named in his honour.

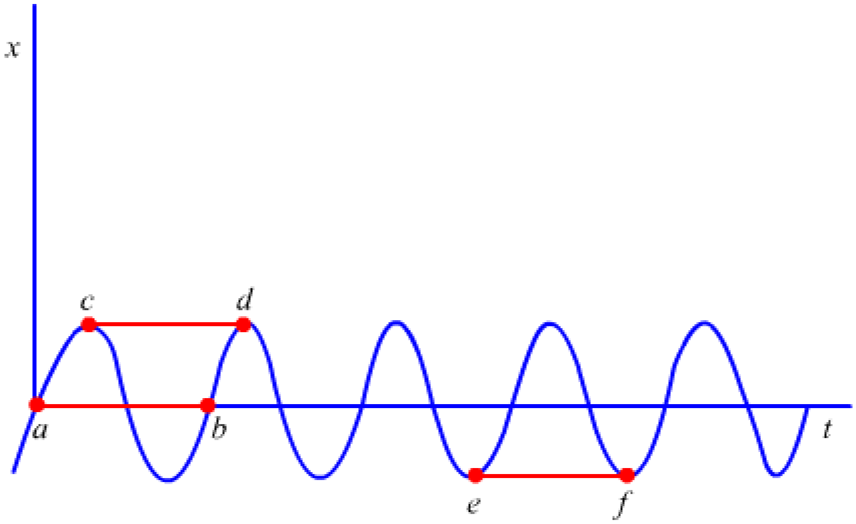
Sonic Boom

Sonic boom occurs when an aircraft breaks the sound barrier. An aircraft travelling with a supersonic speed will produce a pressure wave of sound in the shape of a cone whose vertex will be formed at nose of the aircraft and its base will be behind the aircraft. So, when the edge of the cone intersects with our ears, we hear a loud sound known as sonic boom.

Time Period (*T*)

The time required to complete one complete oscillation or cycle is called the **time period** (*T*). It is also defined as the time interval between two consecutive crests or troughs of a wave.

- The SI unit of time period is second (s).
- It is the inverse of the frequency of a wave, i.e. T = 1/f.



A flat sound is a low-pitched sound.

This is a periodic wave. Its time period is represented by length on the time axis, e.g. *ab*, *cd* and *ef*.

Solved Examples

Easy

Example 1:

The frequency of a source of sound is 400 Hz. Calculate the number of times the source vibrates in one minute. Also calculate the time period.

Solution:

Frequency of the source of sound = 400 Hz

Number of vibrations of the source per second = 400

Number of vibrations of the source per minute = 400 × 60 = 24000

We know that time period (*T*) is the inverse of frequency (*f*). So,

$$T = \frac{1}{f}$$
$$= \frac{1}{400}$$
$$= 0.0025 \text{ s}$$

Speed

The distance travelled by a wave in a given interval of time is called its **speed** (v). Its SI unit is metre per second (m/s). Hence, we can write:

$$\text{Speed} = \frac{\text{Distance travelled}}{\text{Time taken}}$$

Suppose a wave can travel a distance λ in T seconds with a speed v. Then, these terms are related as follows:

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

We know that

f=1Tf=1T

So,

$v = f \times \lambda$

Therefore, speed is the product of frequency and wavelength.

Now, the sound travels with much greater speed in solids than in liquids and than in gases.

Medium	Speed of sound (m/s)
Solid (Iron or steel)	5000
Liquid (Water)	1500
Gas (Air)	330

Did You Know?

According to Albert Einstein's special theory of relativity, nothing can travel faster than the speed of light. The speed of light in air (3×10^8 m/s) is about 10,00,000 times greater than the speed of sound in air (344 m/s).

Solved Examples

Easy

Example 1:

What is the speed of sound with frequency 20 Hz and wavelength 0.2 m?

Solution:

Speed (v) = Frequency (f) × Wavelength (λ)

= 20 × 0.2 = 4 m/s

Example 2:

If twenty pulses are produced per second, then what is the frequency of the wave in hertz?

Solution:

The frequency of a wave in hertz is equal to the number of pulses produced per second.

Number of pulses produced by the wave per second = 20

Frequency of the wave = 20 Hz

Medium

Example 3:

A sound wave travelling at a speed of 330 ms^{-1} has a wavelength of 2 cm. Calculate the frequency of the wave. Will it be audible to humans?

Solution:

Speed of the sound wave = 330 m/s

Wavelength = 2 cm = 0.02 m

We know that

$v = f \times \lambda$

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

$$= \frac{330}{0.02} = 16500\ \text{Hz} = 16.5\ \text{kHz}$$

Hence, the frequency of the sound wave is 16.5 kHz.

Now, we know that human hearing ranges from 20 Hz to 20 kHz. Since the frequency of the given sound wave is 16.5 kHz, it will be audible to humans.

Example 4:

Sound waves travel at a speed of 330 m/s. Calculate the frequency of a sound wave whose wavelength is 0.75 m.

Solution:

- **Distance from the source**

Given:

Speed (v) of the wave= 330 m/s

Wavelength λ = 0.75 m

We have to find the frequency (f) of the wave.

We know that

$v = f \times \lambda$

$$f = \frac{v}{\lambda}$$
$$= \frac{330}{0.75} = 440\ \text{Hz}$$

Hence, the frequency of the sound wave is 440 Hz.

Hard

Example 5:

A wave pulse on a string moves a distance of 10 m in 0.05 s. Find the velocity of the pulse and the wavelength of the wave if its frequency is 300 Hz.

Solution:

We know that

$$\text{Speed} = \frac{\text{Distance travelled}}{\text{Time}}$$

In the given case:

Distance travelled = 10 m

Time taken = 0.05 s

v = 10/0.05

∴ v = 200 m/s

Therefore, the speed or velocity of the pulse is 200 m/s.

We also know that
Speed = frequency × wavelength

In the given case:

Frequency = 300 Hz

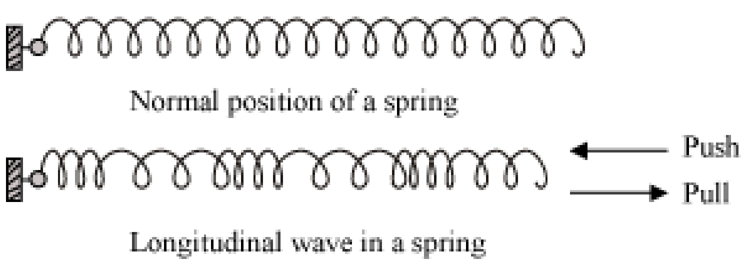
$$\lambda = \frac{v}{f}$$
$$= \frac{200}{300} = 0.67\ \text{m}$$

Therefore, the wavelength of the wave is 0.67 m.

Whiz Kid

Attach one end of a coiled spring to a wall. Compress the spring and then release it. You will observe a longitudinal wave produced in the spring, with alternating compressions and rarefactions.

Count the number of compressions or rarefactions passing from the fixed point. Note the time using a stopwatch. Then, calculate the frequency of this wave.



Factors Affecting the Speed of Sound

We know that sound waves require a medium to travel. The temperature, humidity and nature of a medium affect the speed of sound travelling through it. Let us see how.

Temperature

The temperature of a medium is directly related to the speed of sound travelling through it. The speed of sound increases with an increase in the temperature and decreases with a decrease in the temperature. For example, the speed of sound in air at 0°C is about 332 m/s whereas its speed in air at 25°C is about 346 m/s.

Humidity

Like temperature, humidity is directly related to the speed of sound. For example, the speed of sound in dry air is 334 m/s; in moist air, it is 338 m/s.

Nature

The speed of sound varies according to the nature of the medium it travels through. The speed of sound in a gaseous medium is less than that in a liquid medium. Also, the speed of sound in a liquid medium is less than that in a solid medium.

For example, at 25°C, the speeds of sound in hydrogen, water and iron are about 1284 m/s, 1500 m/s and 5130 m/s respectively. Hence, we can conclude that

$v_g < v_l < v_s$

Here, v_g = Speed of sound in a gaseous medium; v_l = Speed of sound in a liquid medium; v_s = Speed of sound in a solid medium

Whiz Kid

The given table lists the speeds of sound in various materials at different temperatures.

Medium	Temperature (°C)	Speeds of sound (in m/s)
Dry air	0	332
Dry air	20	344
Dry air	25	346
Hydrogen	0	1280
Hydrogen	25	1284
Distilled water	20	1498

Sea water	37	1531
Blood	20	1570
Copper	20	3750
Aluminium	20	5100
Aluminium	25	6420
Iron	20	5130
Glass	20	5170

Did You Know?

Here is an interesting natural phenomenon related to the speed of sound. When lightning strikes, the flash is seen a few seconds before the sound is heard. **Why does this happen?**

This happens because the speed of sound in air (332 m/s) is much less than that of light (300000000 m/s). Hence, there is a difference between the time taken by the two to cover the same distance.

Here are two other phenomena indicating that light travels faster than sound.

1. When a cracker bursts, we first observe the light and then hear the sound.
2. When a gun is fired from a distance, we first notice the flash of the gun and then hear the gunshot.

Solved Examples

Easy

Example 1:

A person hears a thunder four seconds before the flash of lightning. What is the distance between the person and the point where lightning occurs in the sky?
(Speed of sound in air = 330 m/s)

Solution:

We know that

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

In this case:

Speed = 330 m/s

Time = 4 s

Distance = Speed × Time

= 330 × 4 = 1320 m

Hence, the distance between the person and the point of lightning in the sky is 1320 m or 1.32 km.

Hard

Example 2:

Ravinder throws a stone vertically upward with a velocity of 50 m/s. It hits a bell hanging at a height of 125 m. The bell rings as the stone hits it. How long after his throw will Ravinder hear the ring of the bell? (Take the speed of sound as 344 m/s and acceleration due to gravity as 10 m/s^2.)

Solution:

Let us first calculate the time taken (*t*) by the stone to reach a height of 125 m.

We have the following motion relation:

$$s = ut + \frac{1}{2}at^2$$

Where, u = 50 m/s and s = 125 m

Hence, we can write:

$$125 = 50t - \frac{1}{2} \times 10t^2$$
$$\Rightarrow t^2 - 10t + 25 = 0$$
$$\Rightarrow t^2 - 5t - 5t + 25 = 0$$
$$\Rightarrow t(t-5) - 5(t-5) = 0$$
$$\Rightarrow (t-5) = 0$$
$$\Rightarrow t = 5 \text{ s}$$

Now, let us calculate the time taken (*t*') by the sound of the ring to reach the ground. We can do so by dividing the height of the bell by the speed of sound.

$$t' = \frac{125}{344} = 0.36$$

Hence, Ravinder will hear the sound of the ring 5.36 (5 + 0.36) seconds after his throw.

Musical Sound

Sound maybe of two types: noise and musical sound. Musical sounds are produced by musical instruments like flute, guitar, violin, etc. They produce a pleasant effect on the listener. On the other hand, noise is produced by a person's shouts, thunderstorm etc. They produce an unpleasant effect on the listener.

Characteristics of musical sound:

(i) Loudness - This characteristic property of sound distinguishes two sounds of same frequency. It depends upon the intensity of vibration, which is proportional to the square of amplitude. So, larger the amplitude, louder is the sound. Loudness also depends on the following factors:

- Density of air
- Sensitivity of the ear
- Distance from the source
- Velocity and direction of wind

(ii) Pitch - Pitch is the characteristic of sound which differentiates the notes. Pitch of the sound depends on the frequency of the sound. A sound is said to have high pitch or is shrill if it is produced by a vibrating body of high frequency. If a body vibrates with low frequency, then it produces a flat sound. For example, a male voice is flat while a female voice is shrill.

(iii) Quality - Quality is the characteristic of sound that differentiates two sounds of same pitch and loudness. The sound produced by the musical instruments are made up of waves of definite frequency but contain a series of tones of different frequencies. They are called **Overtones** and the tone of smallest frequency is called the fundamental tone. Larger the number of overtones, higher is the quality of sound.((i

Musical scale:

When two notes are sounded simultaneously and produce a pleasant sensation in the ear, then it is a **concord** or a **consonance**.
If the notes produce an unpleasant sound in the ear, then it is a **dischord** or a **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 the 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.
A **diatonic** scale contains a series of eight notes.
An **octave** is the interval between the keynote and the last tone.

Advantages of a diatonic scale

- This scale provides the same order and duration of chords and intervals, which succeed each other, that are required for a musical effect.
- This scale can produced a musical composition with the lower and higher multiples of frequencies of the notes.

Hearing Range of Humans and Other Organisms

Hearing Range

Whether it is a falling leaf or a falling apple, a collapsing building or a flying bat—everything around us that can vibrate makes sound. But how many of these sounds can we actually hear?

We can hear only those sounds whose frequencies lie in the range 20 Hz−20000 Hz. This range is also known as the **hearing range of humans**.

If the frequency of a sound is greater than 20000 Hz, then it is called **ultrasound**. If the frequency of a sound is less than 20 Hz, then it is called **infrasound**.

Organisms	**Hearing ranges (Hz)**
Humans	20−20000
Elephants	16−12000
Cows	23−35000
Rats	200−76000
Bats	2000−110000
Horses	55−33500
Dogs	67−45000

Rabbits	360−42000

Did You Know?

Children can hear ultrasound having frequency up to 25000 Hz. As humans grow older, their sensitivity towards ultrasound decreases. In adults, the upper limit of hearing frequency is about 20000 Hz.

Hearing Range in Humans

‘A Day in My Life’ is a famous song by The Beatles. Paul McCartney, a band member, recorded the sound of an ultrasonic whistle at the end of this song for his dog. This is because, unlike humans, dogs can hear sounds of this frequency.

As humans grow older, their hearing range changes. The given table lists the hearing range of humans at different stages of their life.

Childhood	15 Hz−25000 Hz
Adulthood	20 Hz−20000 Hz
Old age	50 Hz−8000 Hz

The most sensitive hearing range of humans is 1,000 Hz to 4,000 Hz.

Animals using sound beyond human's audible range:

Infrasound Communication

Rhinoceroses can produce sounds of frequency as low as 5 Hz. They use these low-frequency sound waves to communicate among themselves.

Sensory Antennae of Animals

Dolphins, bats and porpoises are mammals that can produce ultrasound. It helps them in navigation and finding the exact location of food.

Hearing Aid

A hearing aid is a device that amplifies sound and compensates for the poor hearing ability of the hearing-impaired. It consists of a microphone, an amplifier and a speaker.The functions of these parts are tabulated below.

Parts of a hearing aid	Functions
Microphone	Converts sound into electrical signal
Amplifier	Amplifies the electrical signal
Speaker	Converts the amplified electrical signal back into sound

A hearing aid does not cure hearing loss or restore hearing to normal. It only improves a person's hearing and speech comprehension.

Echo and Reverberation

Reflection of Sound

When you sing in the bathroom or shout in an open field, your sound gets reflected off various obstacles. This reflection of sound results in echo and reverberation. There is an old wives' tale that a duck's quack has no echo. The tale would be true if the duck quacks in your living room. However, in suitable conditions, a duck's quack will surely echo.

When sound falls on a hard surface (solid or liquid), it bounces and changes its direction—just like light or a rubber ball. This bouncing back of sound on striking a surface is called **reflection of sound**.

Hard surfaces such as a metal box and concrete wall are good reflectors of sound waves. Soft surfaces such as a cushion are bad reflectors of sound because they absorb sound.

Laws of reflection of sound:

(i)The incident sound wave, the reflected sound wave and the normal to the surface at the point of incidence, all lie in the same plane, i.e., reflection is a two-dimensional phenomenon.

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

Quick Questions

Question 1: Is the law of reflection of sound similar to the law of reflection of light?

Solution: Yes, the two laws are similar.

Question 2: Does the frequency of sound change after reflecting off a surface?

Solution: No, it does not. The frequency of sound depends only on the source of sound.

Activity to Show the Reflection of Sound

Echo

The repetition of sound caused by its reflection off a hard surface is known as **echo**. If you shout once in an auditorium, then you will hear the original sound at first and then the reflected sound. This reflected sound is the echo of the original sound.

Echo

The sensation of a sound exists in the human brain for about 0.1 s. This means that if two sounds reach our ears within one-tenth of a second, then we will not hear them as separate sounds. So, if a reflected sound is to be heard separately from the original sound, there needs to be a time interval of at least one-tenth of a second (i.e., 0.1 s) between them

Now, we know that:

$$\text{Speed} = \frac{\text{Distance travelled}}{\text{Time taken}}$$

The speed of sound in air at 20°C is about 344 m/s.

The minimum time difference needed between a sound and its reflection for the echo to be heard is 0.1 s.

Therefore, the total distance travelled by the sound and its reflection to produce the echo is given as:

Total distance = Speed × Time

= 344 × 0.1 = 34.4 m

So, the sound travels 34.4 m during the time between which it is transmitted and the echo is heard. This distance is twice the actual distance between the source of the sound and the reflector of the sound. Therefore, the actual distance between the source of the sound and the reflector of the sound is 17.2 m.

Project Ideas

Visit your school auditorium with a friend. One of you should stand at a corner and the other should stand at the adjacent corner that is farther from it. One of you should clap. The other should measure the time interval between the clap and its echo using a stopwatch. Then, taking the speed of sound to be 330 m/s, calculate the distance between the two of you. Find out the actual length of the auditorium and compare it with the distance calculated.

Solved Examples

Medium

Example 1:

A person is standing between two vertical cliffs. He is 540 m away from the nearest cliff. He shouts and hears the first echo after 3 s. Calculate the speed of sound in air.

Solution:

Total distance covered by the sound and its reflection = 2 × 540 m

Time taken for the echo to be heard = 3 s

Let the speed of sound in air be *v*.

We know that:

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$
$$\Rightarrow v = \frac{2\times540}{3}$$
$$\therefore v = 360 \text{ m/s}$$

Example 2:

Rajeev claps his hands near a mountain and hears the echo of the sound after 6 s. If the speed of sound in air is 346 m/s, then calculate the distance between Rajeev and the mountain.

Solution:

Time taken for the echo to be heard = 6 s

The time taken by the sound to reach the mountain is half of the time taken for the echo to be heard, i.e., 3 s.

Speed of sound in air = 346 m/s

Let the distance between Rajeev and the mountain be *s*.

We know that:
Distance = Speed × Time

$$\Rightarrow s = 346 \times 3$$
$$\therefore \ s = 1038 \text{ m}$$

Reverberation

A sound produced in an auditorium exists for some time because it undergoes multiple reflections off the walls, ceiling and floor. This is called **reverberation**. The duration of an echo in this case is so short that several echoes overlap with the original sound. If the reverberation is too long, then the sound becomes distorted, noisy and confusing.

Solved Examples

Easy

Example 1:

A fishing boat using sonar detects a school of fish 150 m below it by transmitting an ultrasound signal. How much time elapses between the transmission of the signal and its return to the boat? (Speed of sound in sea water = 1500 m/s)

Solution:

It is given that:

Speed of sound in sea water = 1500 m/s

Distance between the boat and the fish = 150 m

Distance covered by the ultrasound signal = (2 × 150) m = 300 m

Let the time taken by the signal to return to the boat be *t*.

We know that:

$$\text{Time} = \frac{\text{Distance}}{\text{Speed}}$$
$$\Rightarrow t = \frac{300}{1500}$$
$$\therefore t = 0.2 \text{ s}$$

Medium

Example 2:

A man standing at a point between two parallel walls fires a pistol. He hears the first echo after 0.5 s and the second one after 0.7 s. Find the distance between the walls. (Speed of sound in air = 340 m/s)

Solution:

It is given that:

Speed of sound in air = 340 m/s

Time taken for the first echo to be heard = 0.5 s

Let the distance between the man and one of the walls be *x*. The sound and its echo travel double this distance.

We know that:
Distance = Speed × Time

$$\Rightarrow 2x = 340 \times 0.5$$
$$\Rightarrow x = \frac{340 \times 0.5}{2}$$
$$\therefore x = 85 \text{ m}$$

Now,

Time taken for the second echo to be heard = 0.7 s

Let the distance between the man and the other wall be *y*. The sound and its echo travel double this distance.

So,
Distance = Speed × Time

$$\Rightarrow 2y = 340 \times 0.7$$
$$\Rightarrow y = \frac{340 \times 0.7}{2}$$
$$\therefore y = 119 \text{ m}$$

Thus, distance between the two walls = $x + y$ = 85 m + 119 m = 204 m

Hard

Example 3:

A woman, standing at a distance from a hill, fires a gun. She hears its echo after 3 s. Then, moving 350 m away from the hill, she fires again. This time she hears the echo after 5 s. Calculate the speed of sound in air.

Solution:

It is given that the first echo is heard after 3 s.

Let the distance between the woman and the hill be *x*. The sound and its echo travel double this distance.

Let the speed of sound in air be *v*.

We know that:

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$
$$\Rightarrow v = \frac{2x}{3} \text{ m/s} \qquad \text{...(i)}$$

The woman then moves 350 m away and fires again. The time taken for the this echo to be heard is 5 s.

Let the new distance between the woman and the hill be $x + 350$. The sound and its echo travel double this distance.

So,

$$v = \frac{2(x+350)}{5} \text{ m/s} \qquad \text{...(ii)}$$

On comparing expressions (i) and (ii), we obtain:

$$\frac{2x}{3} = \frac{2(x+350)}{5}$$

$$\therefore x = 525 \text{ m}$$

On substituting the value of x in expression (i), we obtain:

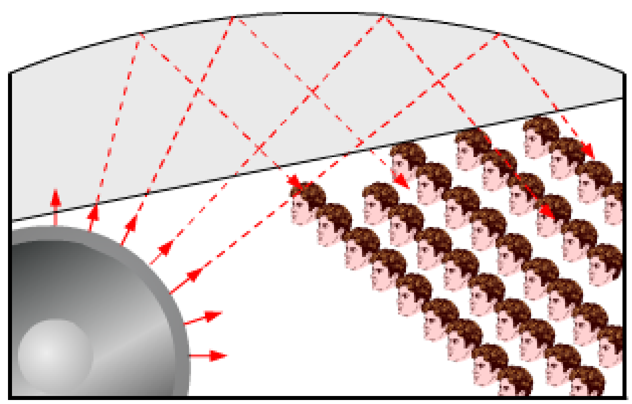
$$v = \frac{2\times525}{3}$$

$$\therefore v = 350 \text{ m/s}$$

Application of Reflection of Sound

Multiple Reflections of Sound

Bat is the only mammal that can fly. Unlike birds, bats do not use their eyes to navigate. They use sound to find their way and to locate their prey. Have you ever heard a bat scream? Well, you wouldn't have. This is because a bat's screaming sound cannot be detected by the human ear. There are scientific instruments, too, which use the bat's technique.



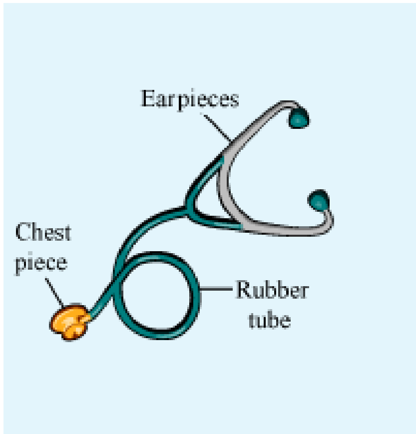
Curved ceiling of a conference hall

The principle of reflection of sound is used in making sound-producing devices such as the megaphone and bulb horn, and other devices such as the stethoscope and soundboard. All these devices involve multiple reflections of sound waves.

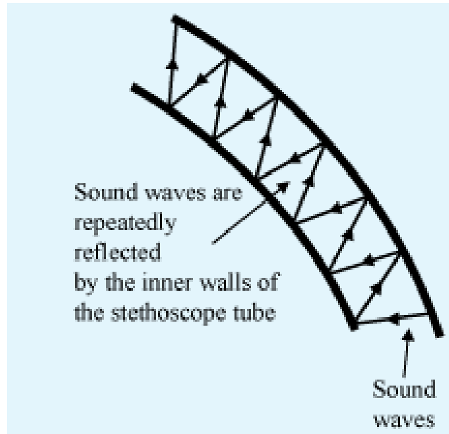
Stethoscope

It is a medical instrument used for checking the pulse rate and heartbeat. It comprises a chest piece and a pair of earpieces connected to one another by a rubber tube. The chest piece consists of a sensitive membrane that vibrates when brought in contact with the chest.

As a result of the vibration caused in the membrane, the air particles within the rubber tube vibrate with the frequency of its source, i.e., the heartbeat. Sound waves undergo multiple reflections inside the rubber tube before reaching the earpieces.



(a) Stethoscope



(b) Multiple reflections of sound waves in the stethoscope tube

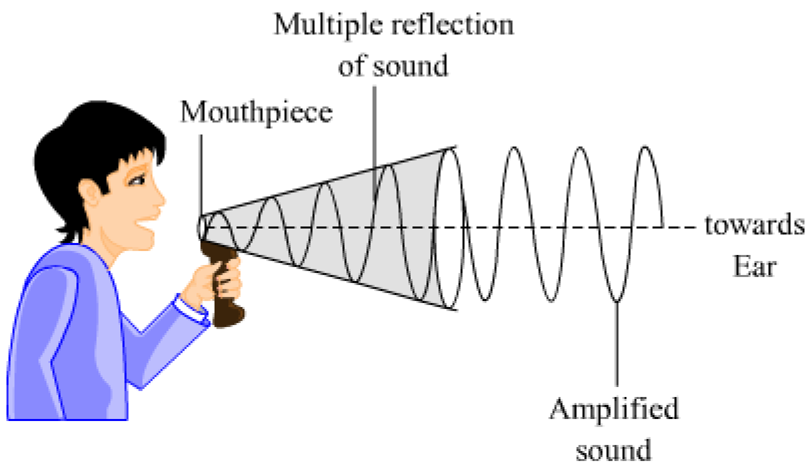
The stethoscope was invented in 1816 by a French doctor named Rene Laennec. The purpose of his invention was to hear the sound made by the heartbeat and the lungs.

Know Your Scientist

Rene-Theophile-Hyacinthe Laennec (1781−1826) was a French physician. He studied medicine in Paris under many famous doctors such as Dupuytren and Nicolas Corvisart desMarest. He is known for the invention of the stethoscope in 1816 while working at Hopital Necker(a hospital for sick children). He died in 1826 because of tuberculosis. At the time of his death, he was working as a professor at the College de France.

Loudspeaker

The loudspeaker or the megaphone is an instrument that amplifies and enhances incoming sound waves through multiple reflections. It is a cone-shaped device designed to send sound in a particular direction. Its narrower end acts as the mouthpiece. Amplified sound is sent out from the wider end. The multiple reflections of sound inside the funnel enable the speaker's voice to be heard across a large distance.



As shown in the figure, the multiple reflections of sound move through the loudspeaker and out from it in the form of transverse waves. It is clear from the figure that the sound heard by the listener will be louder than the one produced by the speaker near the mouthpiece. This is because the amplitude of the sound is greater near the wider end than it is near the narrower end.

Whiz Kid

Have you ever wondered as to why the ceilings of big halls such as concert halls, cinema halls and auditoriums are curved?

Sound waves transmitted by the source in a big hall get absorbed by the walls, floor, seats and even the clothes of the crowd sitting inside the hall. Hence, the ceiling of the hall is curved to reduce this problem.

The working of several musical instruments such as the trumpet and *shehanai* is based on the multiple reflections of sound.

Can you explain why one of the ends of the bulb horn is wider than the other?

Loudspeaker

Soundboard

In a big hall like an auditorium, the ceiling and the walls cause sound to undergo multiple reflections before reaching the audience. This hampers the quality of the produced sound. A soundboard, placed behind the source of sound, is used for countering this problem.

The source of sound is located at the focus of the concave soundboard. The concave surface reflects the produced sound waves towards the audience, thereby preventing sound from spreading in various directions. Consequently, the audience gets a parallel beam of powerful sound.