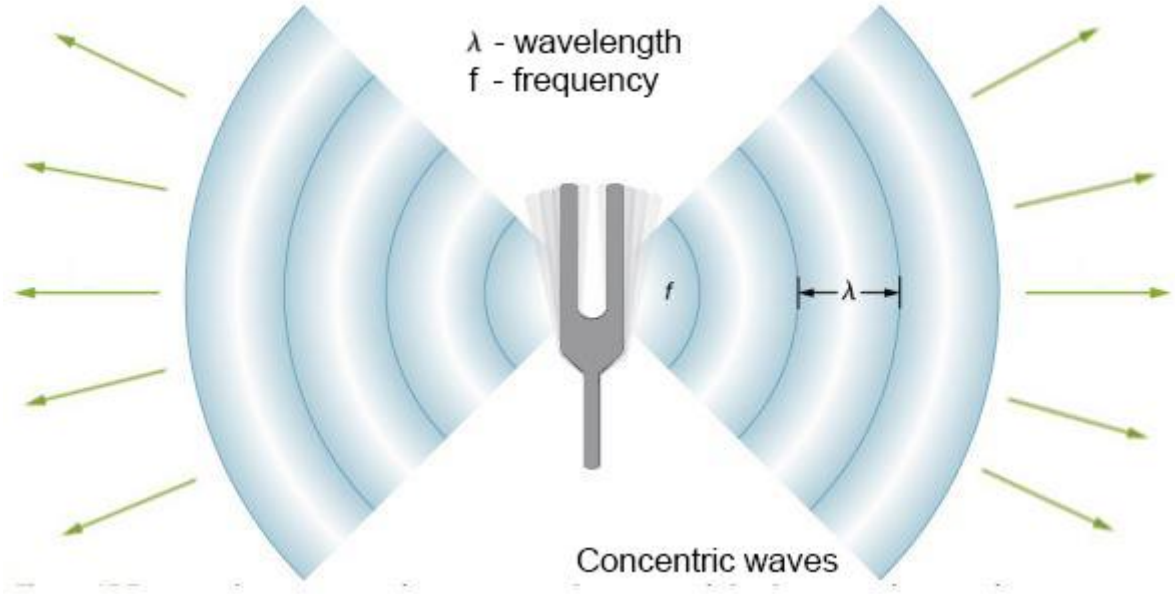
Sound

Sound is a sensation that surrounds us. We hear everything, be it the chirping of birds or the harsh traffic noise. We classify sound based on many qualities. We can describe sound as a form of energy that is caused by the vibration of objects. Vibration is rapid to and fro motion of any object or particle. We sense this vibration in our ears as a sound.

How is Sound Produced and Transmitted?

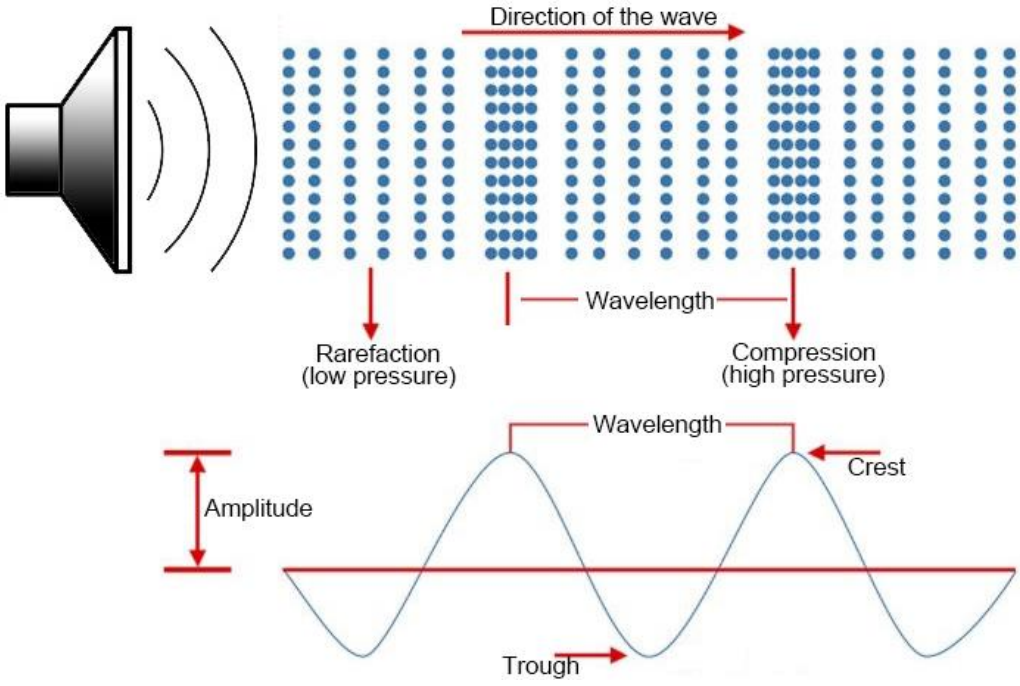
We saw that vibrations in an object produce sound. The air particles near the object vibrate and transfer this energy all around and away from the source in the form of waves. Sound waves travel through solids, liquids and gases. These waves travel as a series of concentric spheres. Once it reaches our ears, the waves hit the eardrum, causing it to vibrate. A unique mechanism in our ears carries this sensation to the brain to make the signal understandable.



Sound Waves are Longitudinal Waves

Vibration causes pressure waves. It means that air particles get compressed and rarefied alternatively. So there are alternate regions of compact and rarified particles of the medium. These alternations in the regions make the waves move and transmit the energy. These kinds of waves are called longitudinal waves.

In a longitudinal wave, the particles vibrate in the same direction as the propagation of the wave. However, there is another type of wave called a transverse wave, where the particles vibrate perpendicular to the direction of propagation. Examples of transverse waves are water waves, light waves, electric waves, etc.



Qualities of Sound

Sound has specific characteristics or qualities that define the way we hear it.

Wavelength

It is the length between two adjacent areas of compression or rarefaction.
In transverse waves, it is the length between two adjacent peaks or two adjacent troughs.

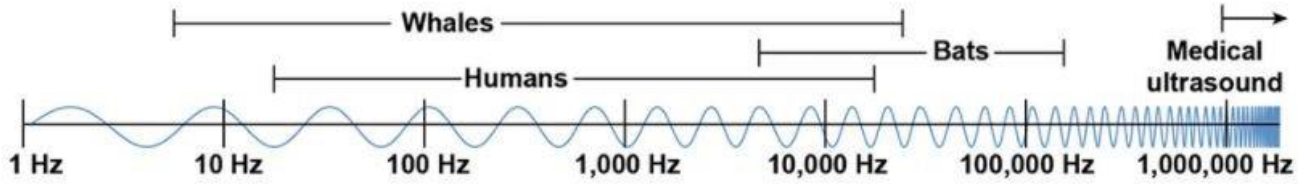
Pitch

How do we recognize a male voice or a female voice? Why is the sound of a baby different from that of an adult? These differences are due to the pitch in their voices.

Pitch is another term for frequency, which is the number of waves produced in one second. For example, a high pitch sound has more waves per second or more frequency. We use the words “shrill sound” for high pitch sounds. A baby has a higher pitch voice than an adult. We can distinguish between a man’s voice and a woman’s voice because women’s voices have higher pitch compared to men.

We measure the frequency of waves in the SI unit of hertz (Hz).

$$1\ Hertz = \frac{1\ wave\ or\ cycle}{1\ second}$$



We humans can hear sound frequencies in the range of 20 Hz to 20000 Hz. Sounds below 20 Hz is called infrasound, and sounds above 20000 Hz are called ultrasound. Animals such as dogs, bats, and dolphins can hear sounds above 20000 Hz. Elephants can hear infrasounds.

Loudness

We say that someone is talking loudly, the TV volume is high, the lion's roar is loud. A whisper, the ticking of a clock, banging of vessels are the different ranges of the loudness of sounds.

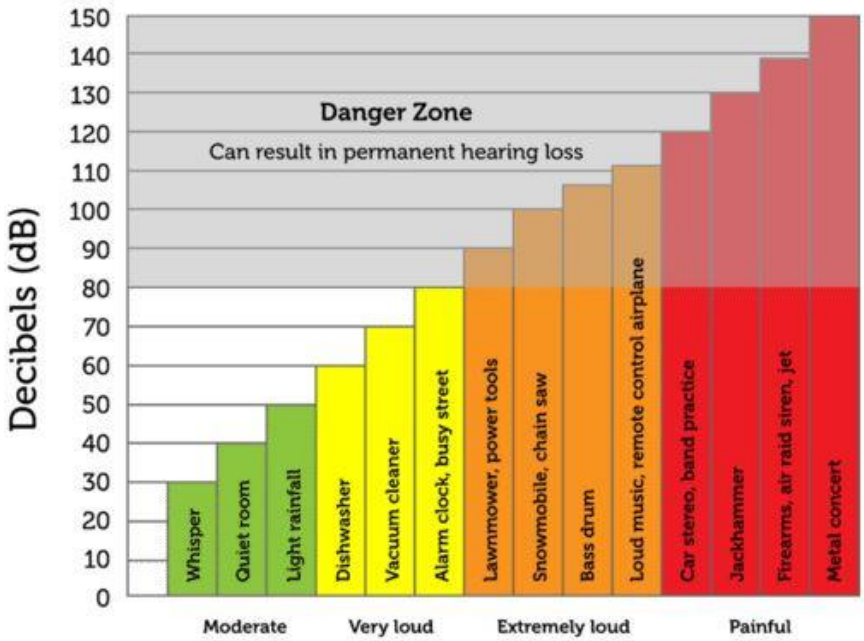
Loudness is the measure of the intensity or strength of the sound waves. In waves, it is another term for amplitude. Amplitude is the amount of displacement of the particles as they vibrate in the medium. The more the displacement, the more is the amplitude; that is, louder is the sound.

Pluck the string of a guitar lightly. It vibrates with less amplitude giving out a low sound. Pluck it with more force. The sound is louder due to its higher amplitude.

Intensity is measured in Watts/m^2. We measure the loudness or amplitude of the sound in decibels (dB).

$$decibel\ (dB) = 10log\frac{I}{I_o}$$

where,
I is the intensity of the sound we are measuring.
I_0 is the intensity of a reference sound.



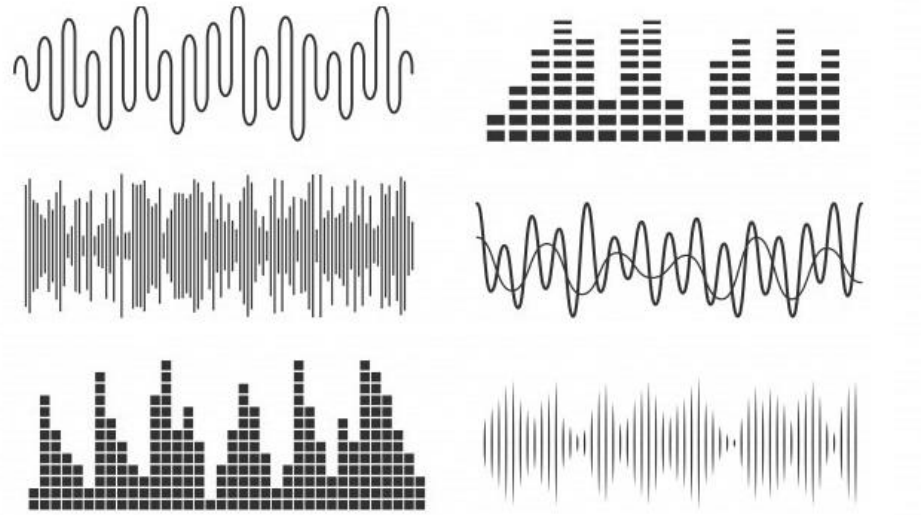
Sounds above a certain level are not bearable to our ears. The above graph shows the level of tolerance to different ranges of sounds.

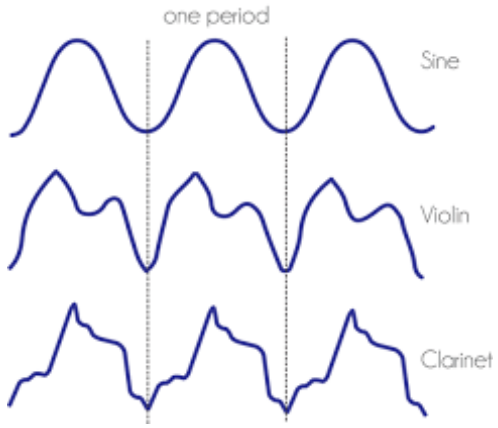
Timbre

In a musical concert, we can clearly hear the different sounds coming from the various musical instruments. For example, we can distinguish between the piano, drum, sitar, clarinet or flute. How is it possible?

It is possible because of a property of sound called timbre. In simple words, timbre means the quality of the sound. In a picture, each part has its own colour, and our eyes can distinguish between them. Therefore, timbre is equivalent to colour. Therefore, it is also called tone colour.

Two sounds from different sources can have the same pitch (frequency) and loudness (amplitude). But we can distinguish between them because of the difference in their timbres. This is because each sound has its own waveform or the shape of its wave. A waveform is formed by mixing up waves of different frequencies. So every object will create a sound with its own waveform. For example, the waveform of a flute is different from that of a veena.





Waves from musical sources are periodic waves as there is a repetitive pattern in them, as seen in the above graphs.

Speed of Sound

Speed of sound depends on factors like density, humidity and temperature. The speed of sound in air at 0 ℃ is 331 m/s.

The relation between speed (v), frequency (f) and wavelength (λ) of a wave is given by-

$$v = f\lambda$$

Since speed is nearly the same in a particular medium, the higher the wavelength, the lower is the frequency or vice versa.

Noise and Music

Both noise and music are sounds. So why do we like one and dislike the other?

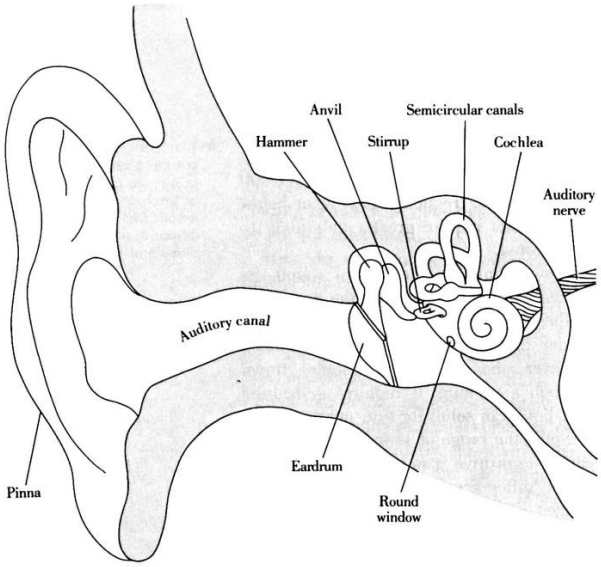
Music has an organized structure in its waveform, as we saw in the wave diagrams above. This makes it pleasant to listen to.
We can define noise as a random set of waves that causes unpleasantness when we hear it. Multiple waves of different frequencies and amplitudes get mixed up, giving a jarring effect when we listen to it. Sounds of machines, traffic, and crowded places are examples of sources of noise. When this disorganized sound becomes too loud, it is noise pollution and may lead to health disorders.

Reflections of Sound

Sound gets reflected just like light. It is called echo. Sound waves follow the laws of reflection, where the angle of incidence equals the angle of reflection. For our brain to distinguish between the original sound and the reflected sound, there must be a time gap of at least 0.1 second. Given the speed of sound, the distance between the source of sound and the reflecting surface must be more than 17.2 metres. This is why we do not hear echoes in a small room. We hear echoes in hilly areas where our loud shouts are reflected back by distant hills.

A studio such as radio station or a recording studio will have walls covered with curtains, carpets, wooden panels, or foam to absorb sound, or have rough surfaces to scatter away sound waves. Electronic equipment are highly sensitive and can pick up reflected sounds also, even in limited spaces.

Structure of the Ear



- Pinna is the outer structure of the ear. It is shaped such that it funnels the sound waves into the auditory canal.
- The eardrum is at the end of the auditor canal. It vibrates on sound waves hitting it.
- Hammer, anvil and stirrup are three bones connected like a chain. They are the smallest bones of the body. They vibrate and amplify the vibrations passed on to them by the eardrum.
- Cochlea is a spiral shaped tube containing a fluid and hair-like structures. It converts the mechanical vibrations into electrical signals, that are picked up by the auditory nerve, which carries them to the brain for processing.

Summary

a. The pitch of a sound is the frequency of the sound waves.
b. The loudness of sound is the amplitude of the waves.
c. Timbre is based on the shape of the waves.
d. The speed of sound in air at 0 ℃ is 331 m/s.
e. Music is a set of organized waves, while noise is disorganized.

Sample Problem

1. What is the wavelength of a sound wave whose frequency is 2000 Hz and speed is 350 m/s.

Solution:
Given,

$$f = 2000 \text{ Hz}$$
$$v = 350 \text{ m/s}$$

Speed v is given by the equation,

$$v = f\lambda$$

Wavelength, λ

$$\lambda = \frac{v}{f} = \frac{350}{2000} = 0.175 \text{ m or } 17.5 \text{ cm}$$

FAQs

1. Can we hear sound on the moon?

Ans: No. Sound needs a medium to propagate or pass through. There is no air on the moon to propagate sound.

2. How is the sound of a man and woman different?

Ans: Sound differs by pitch or frequency. The pitch of women's voices is higher than that of men.

3. How can we distinguish between the sound of a crow and a cuckoo?

Ans: Each sound has its own timbre. It depends on the waveform or shape of the wave. It is different for each source of the sound.

4. Does the speed of sound increase with an increase in temperature?

Ans: Yes. Speed increases with an increase in temperature.

5. What are the factors on which qualities of sound depend on?

Ans: Sound is produced and transmitted as waves. Sound pitch, loudness, timbre depend on the frequency, amplitude and shape of the wave.