SOUND

Sound Waves :-

→ Sound is a form energy which is produced by Vibration of objects. When a body Vibrates, a disturbance is created in the medium by the particles. This disturbance travel's in the form of waves. This produce sound.

→ Sound is a mechanical energy which produces sensation of hearing. Sound is produced due to Vibration of different objects.

Sound wave propagates as compressions & rarefactions in the medium. Sound waves are most important example of longitudinal waves.

→ Sound waves are used to probe earth's crust for oil. Ships carry sound ranging gear (sonar) to detect underwater obstacles.

→ Submarines use sound waves to stalk other submarines largely by listening for the characteristic noises produced by propulsion system's

→ A computer processed image of a foetus head and arms etc. can be obtained with sound waves (ultra sound) and used to explore the soft tissues of the human body.

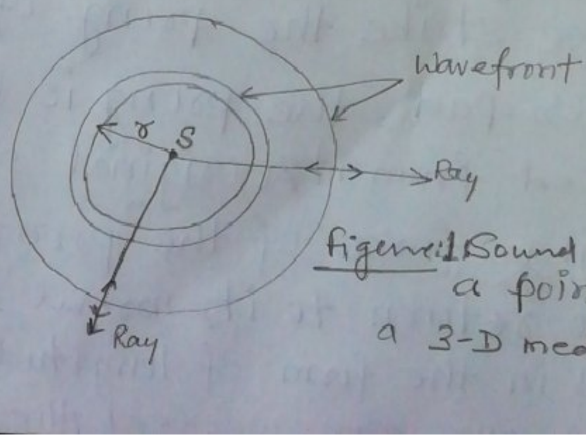
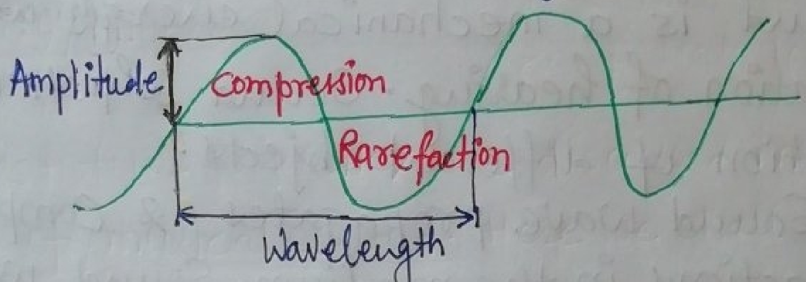


figure 1 Sound wave travels from a point source S through a 3-D medium.

* Production of Sound Waves :-

Sound is produced when something vibrates. The vibrating body causes the medium (water, air, etc.) around it to vibrate.

Vibrations in air are called traveling longitudinal waves, which we can hear. Sound waves consist of areas of high and low pressure called compressions and rarefactions, respectively.



In some cases the vibrations of the source may be so small or so large that it may not be possible to detect them. This act can be realised by the sound produced by various bodies such as tuning fork, drum, ringing bell, the string of a sitar, etc. Human voice originates from the vibrations of the vocal chords and the organ pipes sound is due to the vibration of the air columns.

Let us closely examine the vibrations producing sound such as a vibrating tuning fork. When we strike the prong of a tuning fork against a rubber pad, the prong is forced inwards and is displaced from its original position. Now due to the restoring force of the prong this displaced prong tries to return to its normal position. This disturbance travels in the form of longitudinal waves and when reaches our ear we feel the sensation of sound.

Let E be the position of the ear and P be the prong of the vibrating tuning fork. Let us consider a number of layers of air b/w the prong and ear. When the tuning fork is at rest all the layers are equidistant from each other. But when a vibrating tuning fork is brought near these layers and the prong of the tuning fork is in the extended position as shown in figure 2(a) the air is pushed and contracts towards right i.e. the air gets compressed and the pressure gets slightly increased. Due to this increase in pressure these layers expand towards right and push the neighbouring layers. Such an advancing compression is shown in figure 2(a).

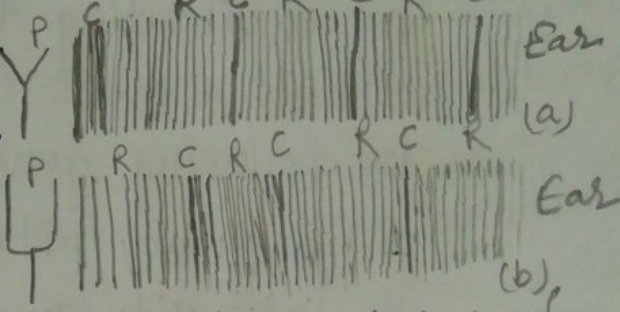


Figure 2 Sound waves from a tuning fork.

Now when the prong due to restoration force comes in a position as shown in figure 2(b) the pressure near the prong slightly decreases and as result the layer in front of the prong moves a little towards the left.

★ Properties of Sound Waves :-

The sound waves are generated by a sound source, such as a vibrating tuning fork or vibrating diaphram of a stereo speaker. Sound waves are usually characterized by following generic properties –

1. Frequency/pitch,
2. Intensity/sound level
3. Quality/timbre
4. Noise
5. Speed of sound
6. Duration
7. sonic texture
8. Spatial location

The first four properties are discussed in the following sections of musical sound. Here we shall discuss the remaining four.

 # Speed of sound :- The speed of sound depends on the medium through which the waves pass and is a fundamental property of the material. The expression for the speed of sound was first given by Newton and showed that speed of sound in a particular medium was equal to square root of pressure acting on its divided by its density i.e.

$$v = \sqrt{\frac{P}{\rho}}$$

Laplace a french mathematician later modified the formula assuming that the phenomenon of sound travelling is not isothermal as belived by Newton, but adiabatic. He added another factor in the above expression, and the modified equation was

$$v = \sqrt{\frac{\gamma P}{\rho}}$$

But $\gamma P = K$, is the bulk modulus of elasticity. So final formula is

$$v = \sqrt{\frac{K}{\rho}}$$

Duration :- It is perceived as how long or short a sound is and relates to the onset and offset of signals created by nerve responses of sound.

The duration of sound usually lasts from the time the sound is first noticed until the sound is identified as having changed or ceased. F example, in a noisy environment, gapped sounds can sound as if they are continuous because the offset messages are missed due to disruption from noises.

Sonic textures :- It relates to the number of sound sources and interaction between them. The word texture here relates to the separation of auditory objects. In music texture is generally referred to as the difference b/w unison, polyphony and homophony. The texture of an orchestral piece is very different from the texture of a brass quartet of the different numbers of players.

Spatial location :- It represents the placement of a sound in an environmental context, including the placement of sound on both horizontal and vertical plane, the distance from the sound source and the characteristics of sonic environment. In thick texture, it is possible to identify multiple sound sources using a combination of spatial location and quality identification. This is the main reason why we can pick the sound of an orchestra and the words of a single person at a crowded party.

* **Musical Sounds And Noise :-** Sounds are usually divided into two classes, musical sound and noise.

A sound which produces a pleasing effect on ear is called Musical Sound such as the sound produced by violin, guitar or flute.

On the other hand, a sound producing unpleasant effect to the ear is called noise, such as the sound of a fire cracker or that produced when two metal pieces are clapped together.

The distinction b/w musical sound and noise is not sharp as some musical sounds are not free from noise while some noises have somewhat musical character.

- **Characteristics of Musical Sound :-** There are three characteristics which distinguish one musical sound from another. These are :-

(i) **pitch/frequency :-** pitch is that characteristic of sound which enables us to distinguish b/w a high, acute or shrill note from a low, grave or flat note. Pitch depends upon the frequency of the note. Actually pitch of a sound note is the sensation conveyed to our brain by the sound waves falling on our ear which depends directly on the frequency of the incident sound waves. Greater is the frequency of the musical notes, higher is the pitch and vice versa.

• Frequency is measurable physical quantity but pitch is a sensation which corresp to and depends upon frequency.

(ii) **Loudness :-** Loudness of the sound is defined as the degree of sensation produced on the ear and is related to a physically measurable quantity called intensity. The intensity of sound is the amount of energy of sound wave crossing per unit time through a unit area at right angle to the direction of the waves. Numerically $I \propto (A^2)$

The loudness is the characteristic which distinguishes a loud sound from a faint one, both having the same pitch.

(iii) **Quality** :- The quality of a musical sound is that characteristic which distinguishes b/w two sounds of the same pitch and loudness but emitted by different instruments. If a note of a particular pitch is played on a piano and then on a violin, we can immediately feel the difference in the overall sound which is due to difference in quality.

Energy And Intensity of Sound Waves :-

Power = F×V

$I = \left(\frac{Power}{area}\right)$

The intensity (I) of a sound wave at a point on a surface is defined as the average rate of flow of the sound energy through a unit area (A) situated normally to the direction of propagation at the point. We can write this in eq^n form as

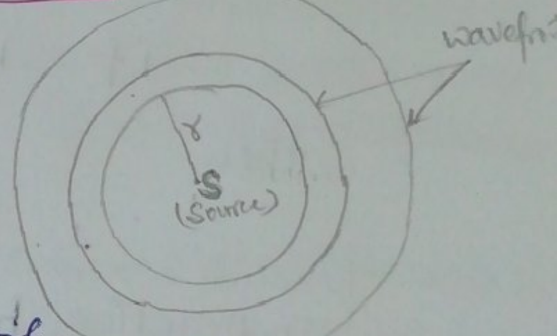
$$I = \frac{\Delta E}{A\,\Delta t} \quad \text{—— (1)}$$

If we recall that the rate transfer of energy is defined as power then eq^n (1) will be written -

$$I = \frac{Power}{area} = \frac{P}{A} \quad \text{—— (2)}$$

where P is the sound power passing through Area A, measured in watts and the intensity has the unit of Watt/m^2.

Variation of Intensity with Distance :-



$$I = \frac{Power}{Area}$$

$$I = \frac{P}{4\pi r^2}$$

Inverse square law :- The intensity of the sound is inversely proportional to the square of the distance of the wavefront from the signal source.

★ Measurement of Intensity :-

Decibel scale: The absolute intensity of sound wave is measured in terms of Watt/m^2. Instead of measuring absolute intensity, it is the relative intensity which has more practical significance :

$$\text{Intensity level of sound} = \frac{\text{Intensity}(I)}{\text{Standard Intensity}(I_0)}$$

where $I_0 = 10^{-12}$ watt/m^2 and is called as threshold intensity for sound wave of frequency 1000 Hz. The relation b/w loudness, which can be called as sound level and decibel level, β and intensity I is expressed as

$$\beta = k \log I$$

Let β_1 be the loudness of the sound intensity I and β_0 the standard or zero loudness corresponding to standard or zero intensity I_0, then

$$\beta_1 = k \log_{10} I \quad \text{and} \quad \beta_0 = k \log_{10} I_0$$

Now intensity level β is the difference in loudness given by

$$\beta = \beta_1 - \beta_0 = k \log_{10} I - k \log_{10} I_0$$
$$= k \log_{10}(I/I_0)$$

This relation is true for all frequencies. The loudness is measured in bel. if $K = 1$ and $I/I_0 = 10$

then $\boxed{\beta = 1 \times \log_{10}(10) = 1 \text{ bel}}$

if $K = 10$ and $I/I_0 = 10$,

then $\boxed{\beta = 10 \times \log_{10}(10) = 10 \text{ decibel (dB)}}$

$\therefore$ $\boxed{1 \text{ bel} = 10 \text{ decibel} = 10 \text{dB}}$

In practice, bel is too large unit and hence decibel is generally used. Decibel is (1/10) of a bel.

⁕ MUSICAL SCALE :-

A Series of notes whose fundamental frequencies have definite ratio and which produce a pleasing effect on the ear when sounded in succession constitute a musical scale.

The simplest musical scale called the diatonic scale has eight notes comprising an octave. The frequency ratio of the eight and first note is 2:1. Conventionally the fundamental frequency of the first note is taken to be 256 Hz and that of the last 512 Hz.

A musical scale represents a division of the octave space into a certain number of scale steps, a scale step being the recognizable distance or interval b/w two successive notes of the scale.

A measure of the width of each scale step provides a method to classify scales. Based on their interval patterns, scales are put into categories e.g. diatonic, chromatic, major, minor, semitone and others. A specific scale is defined by its characteristic interval pattern and by a special note.

Consonance and Dissonance :-

When two or more than two notes are sounded together or one after other, the resultant note is called 'chord'. When the effect produced by a chord on the ear, is pleasant, then it is said a consonance or concord. If, on the other hand, the effect produced by the chord is jarring or unpleasant it is called a dissonance or discord.

When two or more than two notes are sounded simultaneously to produce a pleasing effect on the ear, then we have what is called harmony. If they produce pleasing effect only when sounded one after the other they are said to produce melody.

Let us examine few musical intervals in the following simplifying assumptions.

(i) The fundamental and overtones of each note from a full Harmonic series

(ii) Overtones above 5^{th} are neglected and

(iii) The effect of combination tones is neglected.

(1) Unison 1:1

	Fundamental	Overtone				
First note	n	2n	3n	4n	5n	6n
Second note	n	2n	3n	4n	5n	6n

As each component of the first note is in unison with the corresponding component of second note, hence the consonance is perfect.

(2) Octave 2:1

First note	n	2n	3n	4n	5n	6n
Second note	2n	4n	6n	8n	10n	12n

hence the Consonance is again perfect.

Diatonic Musical Scale

Diatonic Musical scale is the one most commonly used. It consists of a series of Eight notes, the interval b/w the first and last being an octave. The note of the lowest frequencies is called the fundamental or keynote or tonic. The various notes with their relative frequencies are indicated as below:

Name :	Sa	Re	Ga	Ma	Pa	Dha	Ni	Sa'
Indication:	C	D	E	F	G	A	B	C'
Ratio :	1	9/8	5/4	4/3	3/2	5/3	15/8	2
Successive ratio:	9/8	10/9	16/15	9/8	10/9	9/8	16/25	
Relative frequencies:	24	27	30	32	36	40	45	48

The names of the intervals of successive notes with C as base are as follows :

(i) Interval b/w D and C is called major second or major tone = 9/8

(ii) Interval b/w E and C is called major third = 5/4

(iii) Interval b/w F and C is called major fourth = 4/3

and so on. The interval 2/1 b/w the eight and the fundamental is called as an octave.

→ It is to be noticed that these intervals are of different sizes, the largest 9/8 is the **major** tone, the next 10/9 is a major tone and the smallest 16/15 being a semitone.

→ The sequence of intervals b/w successive notes in the major diatonic scale is major tone, minor tone, major tone, semi tone, i.e., three major tones, two minor tones and two semitones. The scale is often called the major diatonic scale due to the predominance of major tone in the above successive intervals.

ACOUSTICS OF BUILDING AND BASIC REQUIREMENTS

The buildings were generally found defective accoustically and any speaker could hardly make his words audible to his audience. The branch of the science which deals with the planning of a building with a view to provide best audible sound to the audience is called acoustics of building.

Professor W. C. Sabine, Harward University was the first to tackle this problem and laid down the following basic features for good acoustics of buildings.

(i) The sound heard must be sufficiently loud in every part of the hall and no echoes should be present.

(ii) The total quality of the speech/music must be unchanged i.e. the relative intensities of several components of a complex sound must be maintained.

(iii) For the sake of clarity, the successive syllables must be clear and distinct i.e., there should be no confusion due to overlapping of syllables.

(iv) The boundaries should be sufficiently sound proof to exclude extraneous noise.

(v) There should be no Echelon effect.

(vi) There should be no concentration of sound in any part of the hall/building.

References: (i) Google e-book and e-content material
(ii) S.P. Taneja book