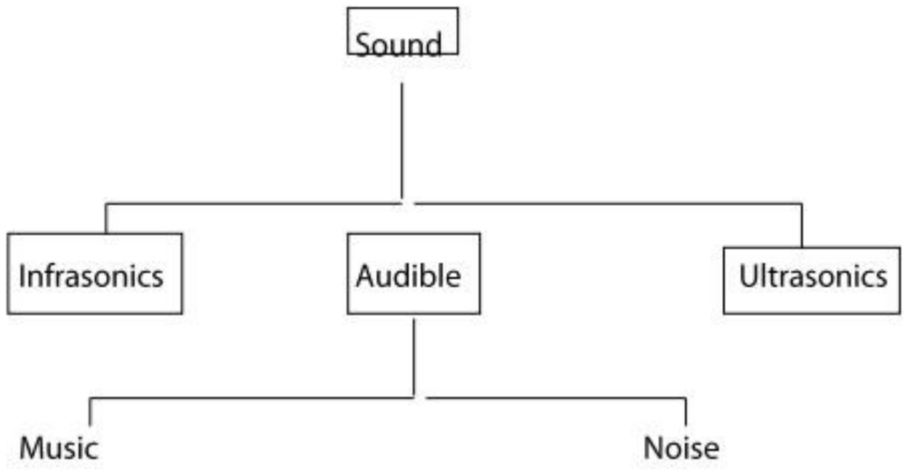
# Characteristics of Sound

Sound is a form of energy.
Sound is produced by the vibration of the body.
Sound requires a material medium for its propagation and can be transmitted through solids, liquids and gases.
When sound is conveyed from one medium to another medium there is no bodily motion of the medium.
Sound requires a definite interval of time to travel from one point to another point in a medium and its velocity is smaller than the velocity of the light.
Velocity of sound is maximum is solids, which have higher bulk modules and least in gases.
Sound may be reflected, refracted, or scattered. It exhibits diffraction and interference.In transverse mode it exhibits polarization also.

# Classification of Sound

- Sound waves of frequencies below 20 Hz are termed as Infrasonic (inaudible)
- Sound waves of frequencies above 20000 Hz are termed as Ultrasonic (inaudible)
- Sound waves of frequencies 20 Hz to 20,000 Hz are termed as audible sound

Further the audible sound is classified as Musical Sounds and Noise. the sounds which products effect on the ear are called musical sound and that which produces jarring and unpleasing effect are called noises.




sound
1)Infrasonics
2)Audible
Music
Noise
3)Ultrasonics

## 1 Characteristics of Musical Sound

There are three characteristics of Musical Sound

- Pitch or Frequency
- Quality or Timbre
- Intensity or Loudness

**a. Pitch or frequency:**

Pitch is the characteristic of sound which is the sensation conveyed to our brain by thesound waves falling in our ears. It depends directly on the frequency of the incident soundwaves. Though the pitch is directly related to frequency, they are not the same; in generalthe frequency is a physical quantity whereas the pitch is a physiological quantity.
Example: sound of mosquito produces high pitch than the sound of lion which is a lowpitch.

**b. Quality or Timbre**

The quality of the sound is the one which helps us to distinguish between the musical
notes emitted by the different instruments or voices, even though they have the same
pitch and loudness.

**c. Intensity or loudness**

The intensity of sound at a point is defined as the average rate of flow of acoustic energy(Q) per unit area situated normally to the direction

$$I = \frac{Q}{A}$$

of und wave.

The intensity depends upon the following factors

$$I \propto \frac{n^2 a^2 \rho \upsilon}{x^2}$$

Where n=Frequency of the sound wave
a=amplitude of the wave
p=density of the medium
v=velocity of sound in that medium
x=distance from the source of sound to the receiving end

or Intensity per unit area per unit time

$$I = 2\pi^2 a^2 n^2 \rho \upsilon$$

## 2 Loudness - Weber Fechner Law

Loudness of the sound is defined as the degree of sensation produced on the ear. The
loudness varies from one observer to another. It is a physiological quantity and therefore itis difficult to measure loudness. But, it can be measured a logarithmic value of intensity

$$L \propto LogI$$

$$L \propto KLogI \longrightarrow 1$$

Equation 1 is known as WEBER - FECHNER law.
Differentiating equation 1, we have

$$\frac{dL}{dI} = \frac{k}{I}$$

Where $\frac{dL}{dI}$

is called Sensitiveness of ear. Therefore the sensitiveness decreases with the increase in Intensity. For example more sound in an auditorium will not be hard properly.

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1 It refers to the external measurement
2) It is common to hear
3) t can be measureddirectly
LOUDNESS
1) It is just a sensation produced on the ear.
2) It depends upon individual listener
3) It is measured only with respect to intensity.

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## 3 UNIT OF LOUDNESS

If L, is the Loudness of sound of intensity I and L is the loudness corresponding to thestandard reference intensity 1 = 10 watts/m, then according to Weber-Fechner law,
we have

Now, the intensity level (I) which is equal to the difference in Loudness,

$$I_L = L_1 - L_0 = k\log_{10} I_1 - k\log_{10} I_0$$

$$I_L = k\log_{10}\frac{I_1}{I_0}$$

If k is taken as 1, the intensity level or difference in loudness is expressed in bels, a
unit named after Alexander Graham Bell, the inventor of Telephone

$$I_L = 1\times\log_{10}\frac{I_1}{I_0}\,bel$$

## 4 Decibel

The unit of Bel is however quite large and hence I is expressed by another standard unitcalled decibel 1 bel = 10 decibels.

$$I_L = 10\times\log_{10}\frac{I_1}{I_0}\,dB \longrightarrow 1$$

Case 1.
If I=0dB, then equation 1 becomes

$$I_L = \log_{10}\frac{I_1}{I_0} \; or \; \frac{I_1}{I_0} = 10^0$$

$$or \; \frac{I_1}{I_0} = 1 \longrightarrow \quad 2$$

Case 2:

If I = 1dB, then equation 1 becomes

$$I_L = \log_{10}\frac{I_1}{I_0} = \frac{1}{10} \; or \; \frac{I_1}{I_0} = 10^{\frac{1}{10}}$$

$$\therefore \frac{I_1}{I_0} = 1.26 \longrightarrow \quad 3$$

Subtracting equation 2 from 3, we get

1.26-1=0.26

For a change in intensity level of 1 dB, the intensity changes to about 26%.

When $I_1 = 100\ I_o$ ;$I_L$=20dB

When $I_1 = 1000\ I_o$ ; $I_L$=30dB

To build up a scale of business, zero on the scale is taken as the threshold of hearing, which corresponds to $I_o = 10^{12}$ W/m$^2$. The maximum intensity with which an earcan tolerate is I = 1W/m$^2$

The maximum intensity level an ear can hear is

$$I_L = 10\log_{10}\frac{1}{10^{-12}}\,dB$$
$$= 120dB$$

| S.NO | SOURCE | INTENSITY LEVEL IN dB |
|---|---|---|
| 1. | Threshold of hearing | 0 |
| 2. | Rustle of leaves | 10 |
| 3. | Whisper | 15-20 |
| 4. | Average house | 40 |
| 5. | Ordinary conversation | 60-65 |
| 6. | Motors or heavy traffic trucks | 70-80 |
| 7. | Roaring of lion at 20 feet | 90 |
| 8. | Thunder | 100-110 |
| 9. | Painful sound | 120 and above |

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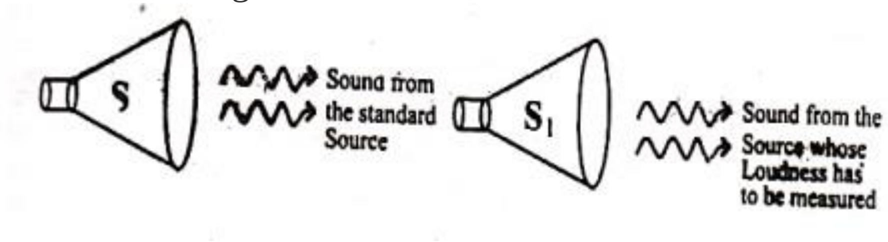
## 5 PHON

we have expressed the loudness in dB, on the assumption that the threshold of audibilityis constant for all frequencies. But it is found that threshold of audibility varies withfrequency. Sounds of same intensity but of different frequency differ in loudness. Hence adifferent unit called PHON is used to measure loudness level or equivalent loudness.

**Definition:** The meausre of loudness in Phons of any sound is equal to loudness in
decibels of an equally loud pure tone of frequency 1000Hz.

**Explanation:** Let us consider two sources 'S' the standard source and S, the source ofsound for which loudness is to be measured. The two sounds are heard alternatively andthe intensity of S is adjusted to be equal to the loudness of the S as shown in the figure.




Now the intensity level of S is measured, If it say 'n' decibels above the standard intensity,then the equivalent loudness is 'n' Phons
The expression for loudness in Phon (L) is given by

$$L_P = 10 \log \frac{I}{I_0}$$

Here $I_0 = 10^{-12}$ W/m$^2$.

$$\therefore L_P = 10 \log I - 10 \log 10^{-12}$$
$$L_P = 10 \log I + 120$$

Where I is the intensity of sound in dB

## 6 SONE

Sone is another unit to measure the loudness in terms of Phon or dB. It is used to measurevery high loudness, especially between the ranges of 40 Phons to 100 Phons.

i.SONE in terms of PHON

**Definition:** The measure of loudness in some of any sound in equal to the loudness
of that particular sound having a loudness level of 40 PHons.

Explanation: Suppose a source of sound is having the loudness or 40 Phons then it
can be assumed to have a loudness of 1 Sone.
Expression for Loudness in Sone is empirically given by

$$\log L_S = 0.333 (L_P - 40)$$

$L_S$ = Loudness in Sone

$L_P$ = Loudness in Phon

Example:

Suppose if the loudness in Phon is 40 Phons, then the loudness in Sone in given by

$$\log L_S = 0.033(40 - 40)$$
$$\log L_S = 0$$
$$L_S = 10^0$$
$$L_S = 1 Sone$$

ii.Sone in terms of Decibel

**Definition:** In terms of decibels the Sone is defined as the loudness of an equally loud pure tone of frequency 1000Hz with 40dB if intensity level.

**Explanation:** It is similar to that of the measurement of loudness in Phon in terms of dB, but the increase in intensity level should be 40dB above the standard intensity, then the equivalent loudness is 1 Sone.

We know that

$$\log L_S = 0.333(L_P - 40)$$

Substituting for $L_P = 10 Log I + 120$, we get

$$\log L_S = 0.033(10 \log I + 120 - 40)$$
$$\log L_S = 0.033(10 \log I + 80)$$
$$\log L_S = 0.33 \log I + 2.64$$
$$\log L_S = \log (I)^{0.33} (10)^{2.64}$$
$$L_S = (I)^{0.33} 436.5$$
$$L_S = 437 (I)^{0.33}$$

$L_S$ = Loudness in Sone

I = Intensity of Sound in dB.