Sound

About sound

In the center of the body is the life-breath, in the center of the life-breath is sound; in the center of sound is musical sound. Sound is 'Nadabrahma' or God, the cause of entire creation. 'Sound being particular quality of Ether, akasa, which is the first element.'[5] In this universe there is no form of knowledge, which is not perceived through sound.

'Sound (Sabda) which is of nature of Nada resides in all living beings.'[6]

'Music can be regarded as a medium for expressing thoughts and feeling through tone.'[7]

As base of any kind of music is sound or tone, we must know basic things about sound, so I give few basic things about sound.

'Energy is familiar to us in many ways such as light, heat, kinetic and potential, electric and magnetic energy. In the same way sound is also a form of energy'.[8]

'The universe is called Jagat (That which moves) because nothing exists but by the combination of forces and movements. But every movement generates a vibration and therefore a sound peculiar to it such a sound, of course, may not be audible for our rudimentary ears, but it does exist as pure sound. Each element of matter producing a sound, the relation of element can be expressed by a relation of sounds, and therefore we can understand why Astrology, Alchemy, Geometry etc express themselves in terms of harmonic relations.'[9]

Let us start with Historical background of Sound starting from 1600.

HISTORICAL DEVELOPMENT

'Western writer on the history of music consider that Egypt was the oldest country that gave music to the world about two or three thousand B.C. They forget that India during the vedic times, which the most conservative estimate places at about five thousand B.C, possessed the most perfect scale from which other modes wer derived by a shift of tonic.'[10]

'Little was known about the science of sound until about 1600. Greek philosopher Pythagoras discovered that an octave represents a two-to-one frequency ratio and enunciated the law connecting consonance with numerical ratios. Galileo made a scientific study of sound and enunciated many of its fundamental laws. Galileo stated the relationship

[5] Introduction to the study of Musical Scale by Alain Danielou P.7
[6] Ibid P.7
[7] Nad by Sandeep Bagchee P.16
[8] Acoustics waves and oscillations by S.N.Sen, P.1
[9] Introduction to the study of Musical Scales by Alain Danielou P.1
[10] Studies in Indian Music by T.V. Subba Rao, P.5

between pitch and frequency and the laws of musical harmony and dissonance. He also explained theoretically how the natural frequency of vibration of a stretched string, and hence the frequency of sound produced by a string instrument, depends on the length, weight, and tension of the string. During the early 17th century, French mathematician Marin Mersenne determined the speed of sound. Newton calculated from theoretical considerations the speed of sound in air.

The 18th century was a period of theoretical development. In this era many scientists contributed to the knowledge of subjects including the pitch and quality of sound produced by a particular musical instrument and the speed and nature of transmission of sound in various media. German physicist Ernst Chladni made numerous discoveries in acoustics at the close of the 18th century, notably concerning the vibration of strings and rods.

The 19th century was primarily a period of experimental development. The first accurate measurements of the speed of sound in water were made in 1826 by French mathematician Jacques Sturm. The fundamental law that the speed is the same for sounds of different frequencies and depends on the density and elasticity of the medium.
The standardization of pitch occupied much attention in the 19th century'.[11]

In Britanica encyclopedia it is said about sound that 'Any tone with characteristics such as controlled pitch and timbre. The sounds are produced by instruments in which the periodic vibrations can be controlled by the performer.'[12]

In the book sound it is said about sound that 'Sound is a kind of energy, which is detected by the ears of living being. Sound travels in the form of waves through the material medium and reaches our ears. These waves make our eardrums vibrate. Eardrum passes electrical signal to our brain and we hear the sound. Sound cannot travel without a material medium.

Sound is produced only by the vibrating bodies but our ears cannot detect all the vibrations. Human ears are sensitive to the vibration in the frequency range from 20 Hz – 20,000 Hz. This range is called audible range. Beyond this range of vibration our ears are not sensitive. However, some animals and insects can hear the frequency beyond this range.

The sound having frequency below 20 Hz are called Infrasonic while those having frequencies above 20,000 Hz are called Ultrasonic. Ultrasonic waves are very useful in scientific laboratories, diagnostic instruments and ultrasonic machines.'[13]

German scientist Hermann Helmholtz (1821-1894) made further contributions to music theory. Helmholtz wrote "On the Sensations of Tone" to establish the scientific basis of musical theory.

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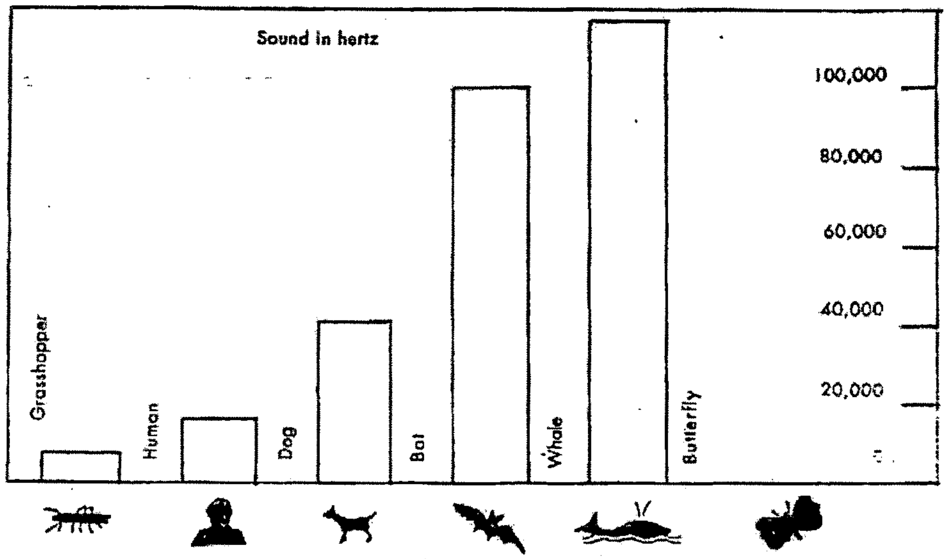
[11] Microsoft ® Encarta ® Encyclopedia 2003. © 1993-2002 Microsoft Corporation.

[12] Britanica encyclopedia CD,2004

[13] Sound By A.H.Hashmi,P.5



Most of the living beings produce different types of sound and can even hear them. Even though butterfly cannot produce any sound, it has the capacity to hear the sound of more than 100000 Hertz frequency. The ears of Bat and Whales are very sensitive. Compared to other creatures, the hearing capacity of human being is less.

According to Hermann Helmholtz 'The musical tone which can be used with advantage, and have clearly distinguishable pitch, have therefore between 40 and 4000 vibration in a second'.[14]

SOUND WAVES

Sound is propagated through a material medium as a wave. Sound moves as a pressure wave in the air – compressing and than rarefying the air.

'When a wave is propagated in a medium, each particle in the medium vibrates simple harmonically about its mean position. The energy of vibration is imparted to the succeeding particles, which also starts vibrating. Thus energy is transformed from one particle to another. This is termed as wave motion.'[15]

'A sound wave, on the other hand, is a longitudinal wave. As the energy of wave motion is propagated outward from the center of disturbance, the individual air molecules that carry the sound move back and forth, parallel to the direction of wave motion. Thus, a sound wave is a series of alternate increases and decreases of air pressure. Each individual molecule passes the energy on to neighboring molecules, but after the sound wave has passed, each molecule remains in about the same location.'[16]

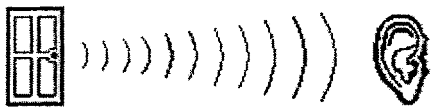
According to longman Illustrated Science dictionary, It is 'a longitudinal wave produced by vibrating object. As the object vibrates, it sends out (1) a wave of high pressure,

[14] On the sensation of the tone by Hermann Helmholtz, P.18
[15] A text book of Sound by M.N.srinivasan, P.18,
[16] Microsoft ® Encarta ® Encyclopedia 2003. © 1993-2002 Microsoft Corporation.

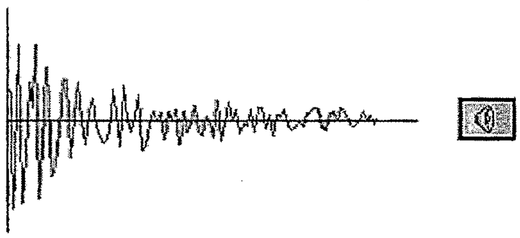
known as compression (2) a wave of low pressure, a rarefaction. Sound needs material medium for its propagation. A sound wave has a speed of about 331m/s in air. The wavelength of a sound wave is the distance between one compression and the next.'[17]

According to the book, Coordinated Science-Physics 'Sound is a longitudinal wave. The compression and rarefactions is region of high and low pressure.[18]

'Sound is the vibration of air particles, which travel to your ears from vibration of the object making the sound. These vibrations of sound in the air are called sound waves When a door is slammed the door vibrates, sending waves through the air.

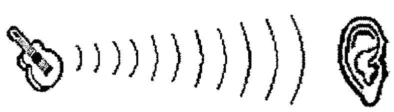


Wave form of a door slamming looks something like this.

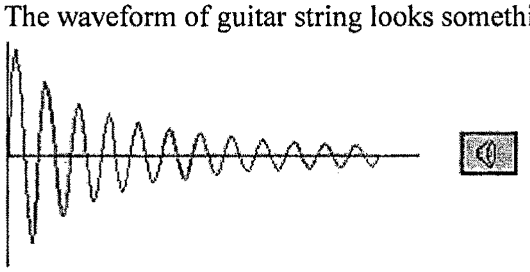


This wave form is jerky and irregular, resulting in a harsh sound. It is loud at the start, but becomes soft as it dies away.

When a guitar string is plucked, the string vibrates the soundboard, which sends sound waves through the air.



The waveform of guitar string looks something like this.



The guitar string makes a continuous, regular series of repeated cycles which we hear as smooth and constant musical note.'[19]

[17] The longman illustrated Science Dictionary
[18] Coordinated Science-Physics by Mary Jones, P.100
[19] http://www.chordwizard.com/hmw101.asp

MUSICAL SOUND AND NOISE

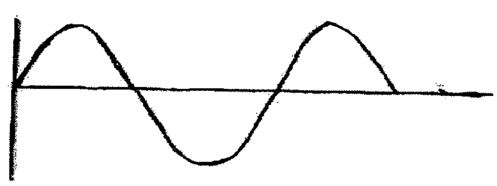
There are two kind of sound. some sound are sweet, agreeable and pleasing to the ear and appeals to the listeners while some sound produce unpleasant auditory sensation and does not appeal to the listeners. First type is known as musical sound and other type is known as noise or unmusical sound and consists of a mixture of many different frequencies within certain range.

'Most sounds, however, contains a mixture f frequencies. If the frequencies are simple multiple of each other they are called Harmonics. Musical instrument tend to produce notes, which consist of a basic, or fundamental frequency and a number of harmonics. Our brain hears these sounds as 'Musical".'[20]

'If a sound contains a mixture of frequencies which are not related to each other, it does not sound musical. A sound with a large number of unrelated frequency will just sound like 'noise'.

'The nature, and the difference, of musical sounds and noise can scientifically be explained by the curves shown in following figure.

Figure A:



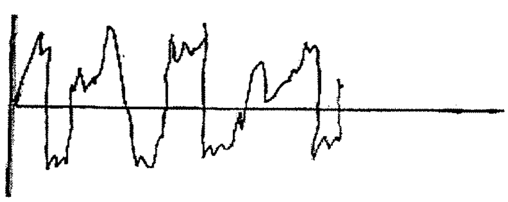


Figure B

The wave shown in A emitted by a tuning fork and flute. They are periodic in nature and possess regularity. They also possess similarities of shape, amplitude etc, and are simple in character with no sudden variation in pitch, amplitude and such other characteristics. On the other hand the curve shown in figure B represents the wave disturbance associated with noise. As shown in the figure, it is neither periodic nor does it possess any kind of regularity or continuity.'[21]

'Musical sound is the result of regular vibrations,as contrasted with noise, which is produce by irregular vibrations.'[22]

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[20] Coordinated Science-Physics by Mary Jones, P.113
[21] Indian Music and its Scientific aspects by Meera mathur
[22] Nad by Sandeep Bagchee P.17

Characteristic of Musical Sound

We have to bear in mind three things with reference to Sound. Musical sound distinguished from each other only by three characteristics i.e. Pitch, loudness and timbre; irrespective of their origin.

I am writing details about these characteristics as it forms an important part of sound.

'Any simple sound, such as a musical note, may be completely described by specifying three perceptual characteristics: pitch, loudness (or intensity), and quality (or timbre).
The sound is composed of three elements:

1. Loudness
2. Pitch
3. Timbre

These elements are the three fundamental qualities of sound that scientists, audio professionals, and equipment manufacturers use to understand, measure, and control the audio production process.'[23]

1. Loudness

'Loudness is a product of the intensity of that motion. Duration is the length of time that atone persists.'[24]

'Loudness, or volume, is the perception of the strength or weakness of a sound wave resulting from the amount of pressure produced. Sound waves with more intensity or larger variations in air pressure produce louder sounds. Sound waves with smaller fluctuations in air pressure produce quieter sounds, as shown in Figure 2-4.

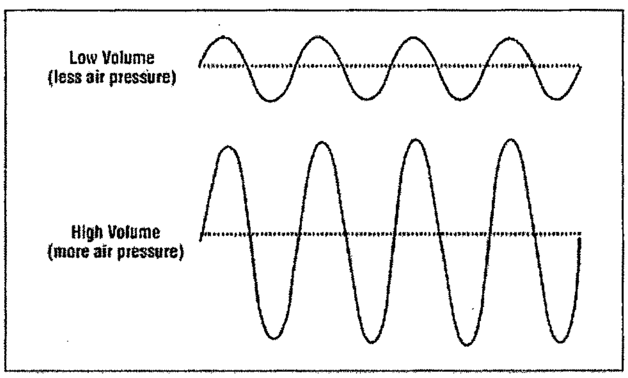

Figure 2-4. An example of a "quieter" sound wave with less air pressure versus a "louder" sound wave with more air pressure.'[25]

[23] Microsoft ® Encarta ® Encyclopedia 2003. © 1993-2002 Microsoft Corporation

[24] Britanica Encyclopedia CD,2004

[25] *linuxalpha1.eicn.ch/OReilly_books/books/Web_Design/audio/ch02_01.htm*

Loudness and amplitude

'Sound waves with large amplitude tend to sound louder to us than ones with small amplitude.

Loudness is not to be confused with amplitude. Loudness refers to the human perception of sound, while amplitude refers to quantifiable measurements of air pressure variations. Amplitude is the change in air pressure over time and is universally measured in decibels (dB).'[26]

'Intensity is the relative strength of the sound, whether soft or vigorous.'[27]

2. Pitch

'Pitch depends solely on the length of time in which each single vibration is executed, or which comes to the same thing, on the number of vibrations completed in a given time.'[28]

'Pitch is directly proportional to the number of vibrations.'[29]

'Relative 'highness' or 'lowness' of a sound measured against a standard scale(high tone, lower tone)

High pitched tones (jet engine whine) perceived by the ear are high frequency oscillations of the air.Low pitched tones (thunder) are low frequency oscillations of the air.

Pitch is the psychoacoustic term for how high or low a sound is perceived by the human ear. Pitch is determined by a sound's frequency, or rate of repetition. Figure 2-6 shows a one-second duration waveform and the frequency rate for two different instruments. Middle C on the piano, for example, vibrates at 261 cycles per second. Frequency is measured in hertz or Hz (also known as cycles per second). The higher the frequency, the higher the pitch. The lower the frequency, the lower the pitch. Figure 2-7 shows waveforms of relatively lower- and higher-frequency sounds.

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[26] Coordinated Science-Physics by Mary Jones, P.112
[27] Northern Indian Music by Alain Denielou, P.38
[28] On the Sensations of Tone by Hermann Hemholtz,P.11
[29] Theory of Indian music by Rai Bahadur Bishan Swarup,P.12

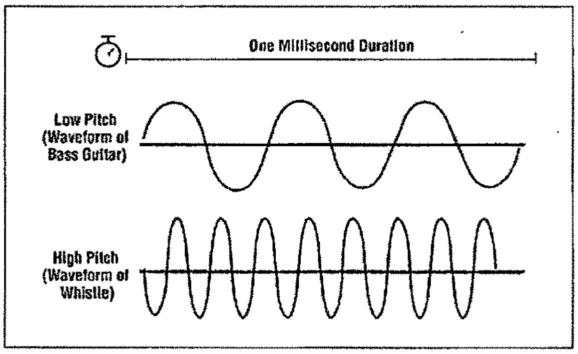

Figure 2-6. Two different waveforms and their approximate frequency rate
Notice that it requires more cycles in the same period of time to reproduce a high-pitch sound than it does to reproduce a low-pitch sound, as shown in Figure 2-7.

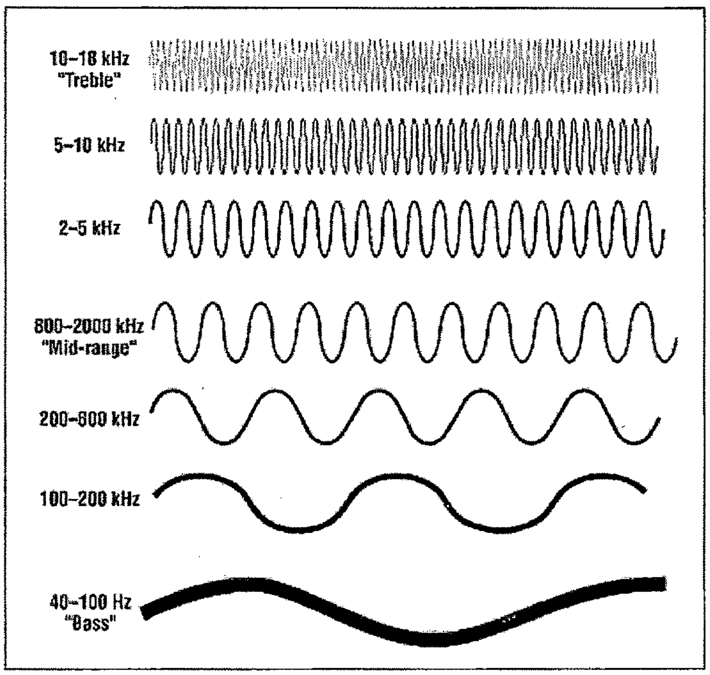

Figure 2-7. Rapid vibrations of air molecules create a high-pitched sound (treble); a slower rate of vibration creates a low-pitched sound (bass).'[30]

It is also important to note that most sounds are a mixture of waves at various frequencies.

'The pitch, or high-low aspect, created by each of these vibrating bodies is most directly a product of vibrational frequency.'[31]

[30] www.csse.monash.edu.au/~cema/courses/CSE3325/lect22.html
[31] Britanica Encyclopedia CD, 2004

3. Timbre

'Tone quality or colour, used to determine (for example) the difference between a tone played by a bell and a tone played on a trumpet. Timbre is created by the kind and number of overtones.

Unlike loudness or amplitude, measured in dB, and pitch or frequency, measured in Hz, timbre is difficult to quantify. Timbre is loosely defined as the tone, color, or texture that enables the brain to distinguish one type of instrument sound from another. The term generally encompasses all the qualities of a sound besides loudness and pitch, such as "smooth," "rough," "hollow," "peaceful," "shrill," "warm," and so on. In simple terms, timbre is the sonic difference between a violin and a trumpet playing the same note at the same loudness or amplitude level.'[32]

'Timbre defined as characteristic quality of sounds produced by each particular voice or instrument, depending on the number & the character of the overtones.'[33]

'Timbre depends on the harmonics co-existing with the fundamental tone and their relative intensities.'[34]

'Timbre (tone colour) is a product of the total complement of simultaneous motions enacted by any medium during its vibration.'[35]

'As illustrated in the Harvard Brief Dictionary of Music Timbre indicates the difference between two tones of the same pitch duration and intensity is performed on. e.g. Violin and Flute. The tone colour (also called quality or timbre) is determined by the Harmonics.'[36]

Interference of Sound

'Two traveling waves which exist in the same medium will interfere with each other. If their amplitudes add, the interference is said to be constructive interference, and destructive interference if they are "out of phase" and subtract.

Interference of incident and reflected waves is essential to the production of resonant standing waves.

Interference has far reaching consequences in sound because of the production of "beats" between two frequencies which interfere with each other.' [37]

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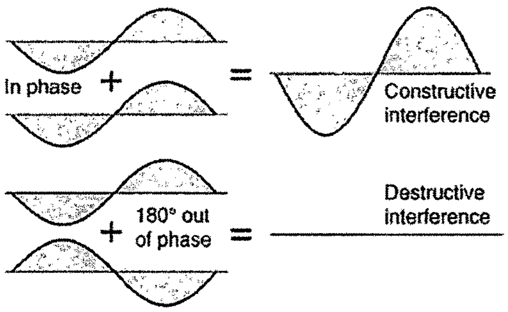
[32] www.csse.monash.edu.au/~cema/courses/CSE3325/lect22.html
[33] The Concise oxford Dictionary by H.W.Fowler and F.G. Fowler, P.1357
[34] Theory of Indian music by Rai Bahadur Bishan Swarup,P.13
[35] Britanica Encyclopedia CD, 2004
[36] The Harvard Brief Dictionary of Music by Willi Apel and Ralph T Daniel, P.305
[37] www.hyperphysics.com

Interference and Phase



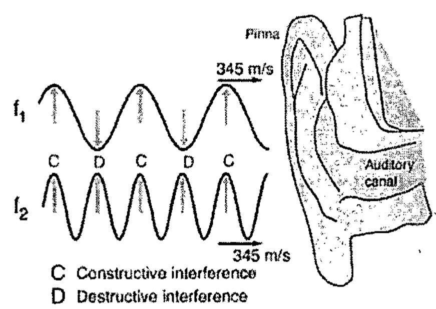
Beats

'Variations in sound, called beats, inherent in sound waves, were discovered about 1740 by Italian violinist Giuseppe Tartini and German organist Georg Sorge.'[38]

'When two sound waves of different frequency approach your ear, the alternating constructive and destructive interference causes the sound to be alternatively soft and loud - a phenomenon which is called "beating" or producing beats. The beat frequency is equal to the absolute value of the difference in frequency of the two waves.'[39]

The number of beats per second is equal to the difference in frequency.

$$\boxed{f_{beat} = |f_2 - f_1|}$$



'The number of beats is the difference between the frequencies of two notes.'[40]

'This type of same description is given in the book of Sound by A.H.Hashmi, P.22 '[41]

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[38] Microsoft ® Encarta ® Encyclopedia 2003. © 1993-2002 Microsoft Corporation.
[39] www.hyperphysics.com
[40] Nad by Sandeep Bagchee P.18
[41] Sound by A.H.Hashmi, P.22