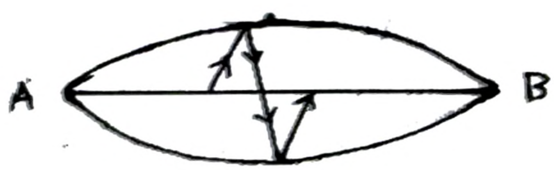
Physics of Music

Music is an application of Physics. If we want to know Science behind music we must understand certain terms used in Physics.

Mentioned below are some of the terms of Physics which has relevance to my research topic.

VIBRATION

'To and fro movement of a particle about a fix point is known as vibration.



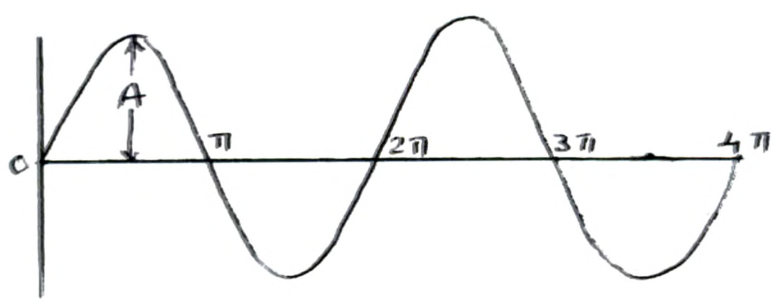
If we pluck string AB it moves up than come to original position than goes down and come back to original position which is shown by arrow. This whole movement of a string is known as one vibration.

There are two main properties of a regular vibration – the amplitude and the frequency – which affect the way it sounds.'[42]

'The side to side motion of a string, a struck surface, or air column, by which musical sound are produced.'[43]

AMPLITUDE:

'Amplitude is the size of the vibration, and this determines how loud the sound is larger vibration make a loud sound, shorter vibration makes a soft sound.



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[42] Shruti and Swar ,The Basis of Indian Music by Jashbhai Patel, P.9
[43] A New Dictionary Of Music by Aurther Jacobe, P.404

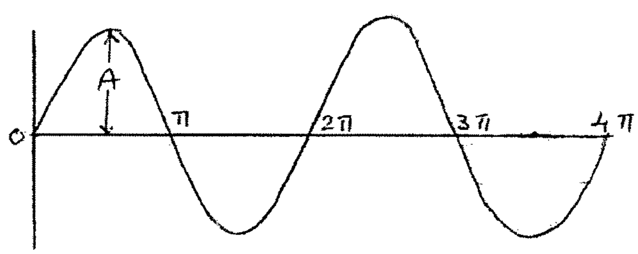
Amplitude is the distance between the middle and the top of a wave. In the above figure arrows shows the amplitude. It is represented by the symbol "A"

Amplitude is important when balancing and controlling the loudness of sounds. It is also the origin of the word amplifier.'[44]

'The amplitude of a wave is the maximum distance that the vibrating particle move from their resting position.'[45]

PERIOD:

'Period is the time taken for one complete event in a number of events when each event takes the same time for completion.



In the above figure period is 2π, because the wave pattern period is itself between 2π and 4π that is, it repeats every 2π.'[46]

'Period is the time taken for 1 oscillation. One oscillation is a swing from one side to the other and back to the starting position.'[47]

FREQUENCY

Any sound produce frequency either low or high. Frequency is the most important term because one can see from my subject title that I did analysis of all ragas with reference to frequency and from that frequency I found out interval.

'A sound wave, like any other wave, is introduced into a medium by a vibrating object. The vibrating object is the source of the disturbance which moves through the medium. The vibrating object which creates the disturbance could be the vocal chords of a person, the vibrating string and sound board of a guitar or violin, the vibrating tines of a tuning fork, or the vibrating diaphragm of a radio speaker. Regardless of what vibrating object is creating the sound wave, the particles of the medium through which the sound moves is vibrating in a back and forth motion at a given frequency. The frequency of a wave refers to how often the

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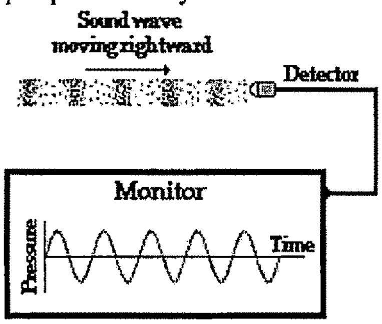
44 Shruti and Swar ,The Basis of Indian Music by Jashbhai Patel, P.9.
45 Coordinated Science-Physics by Mary Jones,P.112
46 Shruti and Swar ,The Basis of Indian Music by Jashbhai Patel, P.9.
47 Coordinated Science-Physics by Mary Jones,P.98

particles of the medium vibrate when a wave passes through the medium. The frequency of a wave is measured as the number of complete back-and-forth vibrations of a particle of the medium per unit of time. If a particle of air undergoes 1000 longitudinal vibrations in 2 seconds, then the frequency of the wave would be 500 vibrations per second. A commonly used unit for frequency is the Hertz (abbreviated Hz), where

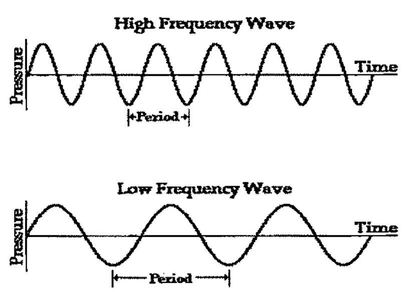
1 Hertz = 1 vibration/second

As a sound wave moves through a medium, each particle of the medium vibrates at the same frequency. This is sensible since each particle vibrates due to the motion of its nearest neighbor. The process continues throughout the medium; each particle vibrates at the same frequency. Moreover, the frequency at which each particle vibrates is the same as the frequency of the original source of the sound wave.

The frequency of a sound wave not only refers to the number of back-and-forth vibrations of the particles per unit of time, but also refers to the number of compression or rarefaction disturbances, which pass a given point per unit of time. A detector could be used to detect the frequency of these pressure oscillations over a given period of time. The typical output provided by such a detector is a pressure-time plot as shown in fig A.



A



B

Since a pressure-time plot shows the fluctuations in pressure over time, the period of the sound wave can be found by measuring the time between successive high pressure points (corresponding to the compressions) or the time between successive low pressure points (corresponding to the rarefactions). The frequency is simply the reciprocal of the period.

The diagram B shows two pressure-time plots, one corresponding to a high frequency and the other to a low frequency. The ears of humans (and other animals) are sensitive detectors capable of detecting the fluctuations in air pressure which impinge upon the eardrum.'[48]

'Frequency term in acoustic for the number of complete vibrations undergone by an air column or a resonating body in one second.'[49]

'The number of complete vibration, which occurs in a second, is called 'frequency' of the vibration.'[50]

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[48] http://www.glenbrook.k12.il.us/gbssci/Phys/Class/sound/u1112a.h
[49] A New Dictionary of Music by Aurthur Jacobs, P.137
[50] Science of Music by Sir James Jeans, P.21

FUNDAMENTAL AND HARMONICS

Now I will describe about overtones, which plays an important role in music. Musical sound produce fundamental frequency plus frequencies multiple of fundamental frequency. Each musical sound produces different kind of overtones, which is the cause of different tone of different instrument and human voice.

'The complete mathematical treatment of sound, however, depends on harmonic analysis, which was discovered by French mathematician Baron Jean Baptiste Joseph Fourier in 1822 and applied to sound by German physicist Georg Simon Ohm.'[51]

Fundamental note

'The primary or 'Parent' note of the Harmonic series.'[52]

Partials

'The number of Harmonic Series present in a musical note. The partials other than the fundamental are referred to as upper partials or more usually overtones.'[53]

'Sound is formed of one or several fundamental notes and other notes called Harmonics. The sounds utilized in music generally have only one fundamental note. The harmonics of this fundamental, according to their relative intensity, make the notes appear pure or nasal.

In the musical system in which the tonic is permanent and constantly present to the mind of listeners, each note has, by itself, significance, determined by the relation, which binds it to the tonic. The melody is thus composed of a succession of sounds with a perfectly definite meaning, and therefore, its significance is absolutely clear.'[54]

'The lowest resonant frequency of a vibrating object is called its fundamental frequency. Most vibrating objects have more than one resonant frequency and those used in musical instruments typically vibrate at harmonics of the fundamental. A harmonic is defined as an integer (whole number) multiple of the fundamental frequency. Vibrating strings, open cylindrical air columns, and conical air columns will vibrate at all harmonics of the fundamental. Cylinders with one end closed will vibrate with only odd harmonics of the fundamental. Vibrating membranes typically produce vibrations at harmonics, but also have some resonant frequencies which are not harmonics. It is for this class of vibrators that the term overtone becomes useful - they are said to have some non-harmonic overtones.
The nth harmonic = n x the fundamental frequency.'[55]

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[51] Microsoft ® Encarta ® Encyclopedia 2003. © 1993-2002 Microsoft Corporation.
[52] A New Dictionary of Music by Arthur Jacobs, p.139
[53] A Dictionary of Music by Robert Illing, P.206
[54] Introduction to the study of Musical Scales by Alain Denielou, P22, 23
[55] http://hyperphysics.phy-astr.gsu.edu/hbase/waves/funhar.html

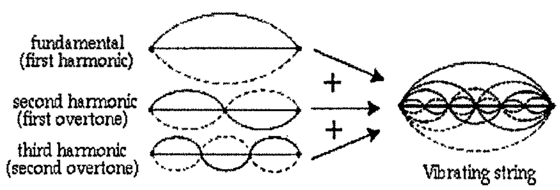
Overtones and Harmonics

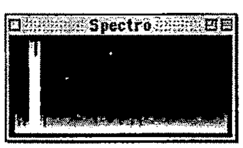
'The tone heard as pitch is called the fundamental tone or the first harmonic of a sound. Overtones are additional tones of higher pitch than, and superposed over, the fundamental tone. Rich, full sounds (violin, voice) have many overtones, pure; thin sounds (flute, triangle) have few overtones.'[56]

'The frequencies which are integral multiples of a fundamental frequency are called harmonics.

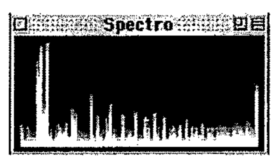
If 'n' is fundamental frequency,2n is second harmonic,3n is the third harmonic and so on.

Any frequency greater than a particular frequency (fundamental) is called the overtones. It may be or may not be the integral multiple of fundamental frequency. As such all harmonics are overtone, but all overtones are not harmonic.''[57]





frequency spectrum of pitch C4
sin wave tone
(note the fundamental)



frequency spectrum of pitch C4
square wave tone
(fundamental + overtones)

'The term harmonic has a precise meaning - that of an integer (whole number) multiple of the fundamental frequency of a vibrating object. The term overtone is used to refer to any resonant frequency above the fundamental frequency - an overtone may or may not be a harmonic. Many of the instruments of the orchestra, those utilizing strings or air columns, produce the fundamental frequency and harmonics. Their overtones can be said to be harmonic. Other sound sources such as the membranes or other percussive sources may have resonant frequencies which are not whole number multiples of their fundamental frequencies. They are said to have non-harmonic overtones.

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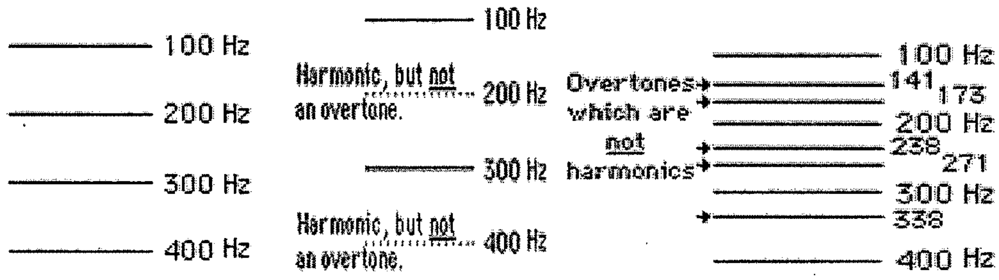
[56] www.csse.monash.edu.au/~cema/courses/CSE3325/lect22.html
[57] Basic Facts and Formulae-Physics by Dr.Kamal Chowdhry, P.207

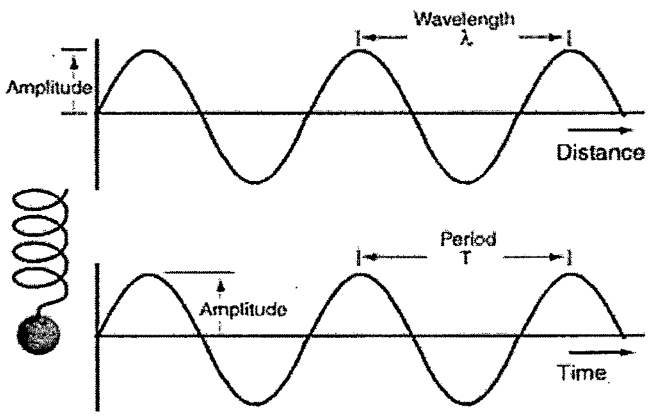


All harmonics are overtones for an open air column or a string. Closed produce only odd harmonics.

A rectangular membrane produces harmonics, but also some other overtones.'[58]

Sinusoidal Waves

To do experiment with Physics instruments this term is helpful to understand type of wave.



'Sine waves can be represented mathematically and it can be shown that any wave can be constructed from an appropriate combination of sine waves (Fourier synthesis)

Any single- frequency traveling wave will take the form of a sine wave. This transverse wave is typical of that caused by a small pebble dropped into a still pool.

The position of an object vibrating in simple harmonic motion will trace out a sine wave as a function of time. (Or if a mass on a spring is carried at constant speed across a room, it will trace out a sine wave.)'[59]

[58] http://hyperphysics.phy-astr.gsu.edu/hbase/music/otone.html
[59] http://hyperphysics.phy-astr.gsu.edu/hbase/waves/funhar.html

Resonance

Resonance is very important in music. Without resonance singing, playing instrument or production of simple sound would have been difficult.

'Resonance was first investigated in acoustical systems such as musical instrument and the human voice I.e. vibration induced in a Violin or Piano string of a given pitch when a musical note of the same pitch is sung or played nearby.'[60]

'Musical instruments are set into vibrational motion at their natural frequency when a person hits, strikes, strums, plucks or somehow disturbs the object. Each natural frequency of the object is associated with one of the many standing wave patterns by which that object could vibrate. The natural frequencies of a musical instrument are sometimes referred to as the harmonics of the instrument. An instrument can be forced into vibrating at one of its harmonics (with one of its standing wave patterns) if another interconnected object pushes it with one of those frequencies. This is known as resonance - when one object vibrating at the same natural frequency of a second object forces that second object into vibrational motion.

The word resonance comes from Latin and means to "resound" - to sound out together with a loud sound. Resonance is a common cause of sound production in musical instruments.'[61]

'The Phenomenon of producing oscillatory motion in a system by the influence of an external periodic force having the same frequency as the natural frequency of the system is called resonance.'[62]

[60] The New Encyclopedia Britanica micropaedia Vol.9, P.1040
[61] http://www.glenbrook.k12.il.us/gbssci/phys/Class/sound/u1115a.html
[62] Basic Facts and Formulae-Physics by Dr.Kamal Chowdhary,P.191