

# Every Musical Note is Associated with a Unique Frequency Indicating a Close Relationship between Music and Physics: A Study

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**Abstract:** *The attempt of this study is to reiterate the close relationship between music and physics. At the outset there seems to be no relationship between the two as they come from different genres. But on close analysis there is a functional relationship between musical instruments and the emission of sound waves. Besides sound waves, the study of amplitude and frequency is deeply embedded in the making of music. This paper looks closely at the association between the two.*

**Keywords:** music, physics, genre, sound wave

**Research question:** An attempt would be made to understand the relationship between music and physics. This would be taking into account the frequency notes that are used in playing music and relating them to the frequency of sound which is a concept studied in physics.

## 1. Introduction

Music is the art of arranging sounds in time through the elements of melody, harmony, and the character or quality of a musical sound or voice which could be distinct from each other in its pitch and intensity. It is the characteristic of an instrument or voice which arises from the reinforcement by individual singers or instruments of different harmonics. It is this 'harmonics' which is defined as an overtone accompanying a fundamental tone at a fixed interval. This is produced by the vibration of a string or a column of air in an exact fraction of its length. In this perspective one can understand the relationship between physics and music. The word harmony is intrinsic to any musician, be it a vocalist or one playing any instrument. It is the fundamental basis in a musician's life. The underlying study of physics then for a musician becomes essential in the production of a good music score.

## 2. Definition

The branch of acoustics that deals with the generation of sound by musical instruments and the transmission of the sound to the listener and finally the perception that this sound creates harmony and synchronization to give a pleasant sound is known as music. This requires a deep study on musical acoustics that is the study of musical instruments that vibrate and produce sound. Music as opposed to noise is a sound with discrete frequency and noise is something that is continuous.

Physics is that branch of science that is concerned with the nature and properties of matter and energy. Physics includes the study of mechanics, heat, light, radiation, sound, electricity, magnetism and the structure of atoms. Physics is one of the most fundamental scientific disciplines whose main goal is to understand the behavior of the universe.

## 3. Relationship between Music and Physics

The physics of music is really the physics of waves, amongst these the sound wave is most important. The wave theory is probably the most important concept in physics. Music is composed of sounds with the fundamental frequency and overtones, if we look at the notes that are used to write music then these necessarily involve mathematical ratios, harmonic resonators, beats and perception. The underlying theory of sound and the frequency of vibration is really what music is all about. As music is everything to do about sound and their relationship. The theory of sound is the most imperative essence in the creation of harmonic music.

## 4. Application of concept in the sound of music

An attempt would be made here to apply the various laws of sound to various instruments which are used in the creation of music. Physics, a science subject, and music, which to the layman seems totally unrelated to the sciences is in fact completely incorrect. There is a close association between the two.

## 5. String instruments

String instruments were one of the first on which principles of physics were seen to be clearly apparent. Most of the string instruments constituted of different materials which were commonly known as the base. This could be made of either wood or metal or any alloy in between. It was the material and shape of the base, and the tension of the wires which basically generated different types of sound. Amongst the most popular ones that come under the above mentioned category is the guitar.

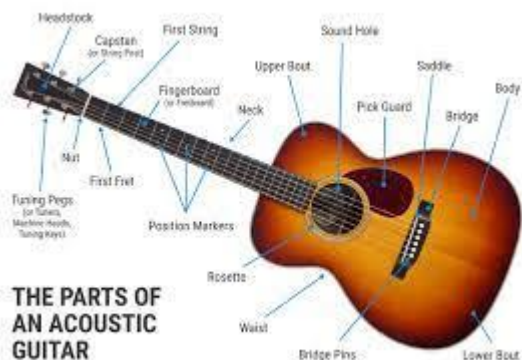
### 5.1 Guitar



**Figure 1:** Two halves of signed Jimi Hendrix lyric sheet reunited after 55 years | Jimi Hendrix | The Guardian  
**Source:** Google images

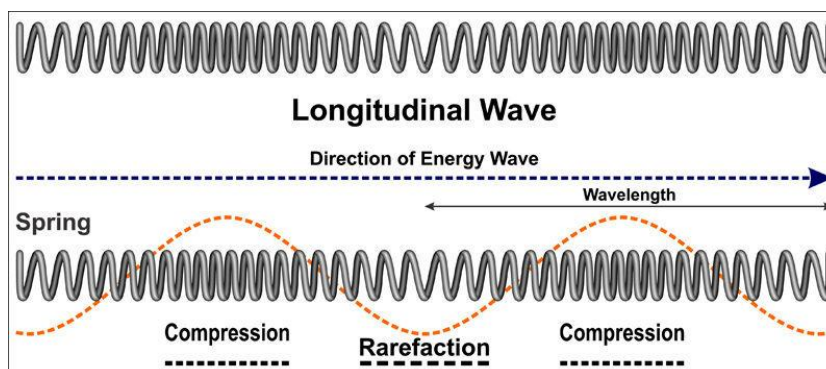
As the guitar string vibrates it results in vibration of the surrounding air molecules, the frequency with which these air molecules vibrate is the same as which the musician plays on the strings of the guitar. As the string of the guitar is plucked the vibration thus generated is transmitted from the bridge (The bridge of a guitar is a device that basically supports the strings), and when the strings are plucked, the vibration is then transmitted to another solid component of the instrument being played. This is then transmitted through the air and finally sound emerges from the instrument that is music to the audience.

Normally the type of sound wave that is produced from the guitar is either a transverse wave or a longitudinal wave. A transverse wave is one where the particles vibrate in a perpendicular direction of the propagation of the wave. As one continues to produce music the back - and - forth vibrations of the air molecules creates a pressure wave and these further lead to compression and rarefactions. Compressions, as the word indicates, are those areas where the molecules are compressed into a very small space. This is a high - pressure region. Rarefactions are those regions where the molecules are spread apart and are regions of low pressure.



**THE PARTS OF AN ACOUSTIC GUITAR**

**Figure 2:** Parts of a guitar  
**Source -** Google images



**Figure 3:** Description of compression and rarefaction  
**Source -** Google images

A guitar string vibrating by itself does not create a very loud sound, but the fact that it is connected to a solid like a wooden sound box, results in the vibration of the string being passed to the vibration of the sound box. This leads to the sound box moving at the same frequency as the string which then forces the air molecules surrounding it to also move in the same manner. As the surface area of the wooden box is much more than the string the resulting affected air around it is also of a larger area, which then produces an audible, musical sound to the ear. While tuning the guitar the tension of the string changes, if we tighten the string the pitch increases. Pressing down on the fretboard (neck of the guitar) impacts the amount of string that is free to vibrate. If the fret is closer to the sound hole, the shorter the vibrating string - the higher the pitch and vice versa.

## 6. Percussion Instruments

These musical instruments use the principles of physics with respect to sound amplification and pitch. They depended on a number of small parts that constitute the musical instrument. Each part of the instrument uses elements of physics to generate different sounds. When they all come together, they are known as music. The type of sound that is generated depends on the material used in various parts of the instrument. The shape, size of the instrument and the tension of the material used in the manufacture of the instrument also impact the type of sound that is generated. The final sound that is emitted, thus depends on all of the above as well as the manner in which the instrument is struck by the musician.

### 6.1 Drums

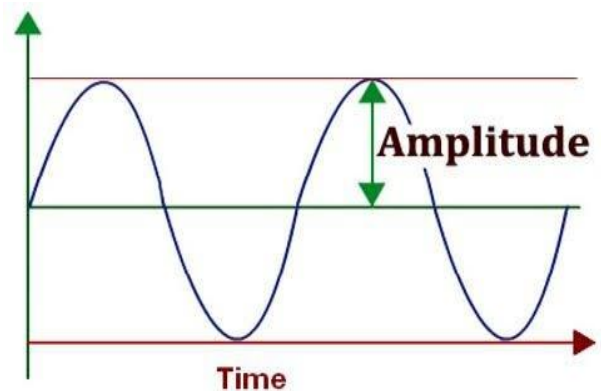


**Figure 4:** Metallica's Lars Ulrich on the return of concerts from Covid stoppages

Source: CNBC, November 10, 2020

A drum set consists of drumstick, the cymbals and the drums, throne, and pedal

Percussion instruments like the drums make a sound by being hit. Drums have a hollow body with a stretched membrane, the moment a stretched membrane is hit there is amplification of a sound. The basic system on which it works is due to the compression and expansion of air on either side of the membrane. When one strikes the membrane with a drumstick the air is compressed and it leads to pressing of the membrane and changing its shape, these subsequently are transmitted to the drum shell and reflected back. As one continues to strike the membrane this process is being repeated and creates a vibration.



**Figure 5**

Source: Google Images

The sound varies with the depth of the drum, as well as the tightness of the drum head. the tighter the drum head the faster the vibrations on the membrane, the lower the amplitude (It is the measurement of the point of maxima from the line of equilibrium, as indicated in figure 5) and higher the frequency. This results in a higher pitch sound, if

a drum head is loose, it would lead to the pitch being much lower. The greater the depth of the drum the longer the standing wave between the heads. This causes a lower tone and a higher volume because there is a higher amplitude.

To put it simply:

Greater the depth = lower tone + higher volume due to higher amplitude

Lower the depth = higher tone + lower volume due to less amplitude

A standard drum set consists of a minimum of 5 drums of varying sizes and heights. Professional musicians normally play on a larger number of drums. To produce music, the size of the drum is imperative, the bigger the size, normally is associated with loose tension resulting in low tone and pitch, the smaller the drum the tighter the tension resulting in high tone and pitch.

Besides the drum, the drum - head is an extremely important part of the drum set. The material used would generate different type of music, most drum - heads are made of wood, the thickness of wood affects the vibrations that resonate in the shell. The greater the energy used in the drum - head the greater impact in the creation of sound waves leading to a higher volume. When the shell vibrates less, less energy is used to create sound waves and thus the resulting sound is of a lower volume.

Musicians who play rock tend to use thicker shells while those playing jazz use thinner shells. The two ways that the drummer can create a louder volume is by using a heavier drumstick with heavier greater force.

The third part of the drum set are cymbals which vibrate and radiate sound, these are made through spin forming, hammering and lathing.

## 6.2 Tabla

A disc of black tuning which is placed on the skin of each drum, affects the pitch and generates overtones which is characteristic of the drum sound. Sound is produced on the tabla through a variety of different finger and hand strokes. The black leather surface is the membrane that generates the vibration. The *dayan* is the right - hand drum (RHD) and the *bayan* is the left - hand drum (LHD), both of them are made of leather skin which is stretched onto a vessel like structure made of wood. The *dayan* (RHD) produces the treble in music and is tune to tonic scales while the *bayan* (LHD) produces the base. When either of them is struck vibrations pass through the body and sound s produced due to the tension in the drums. The tension is adjusted from the sides and this impacts the membrane. Besides the membrane there is a black spot at the center called *Syahi* that produces a wide repertoire of sounds. The sound of the tabla is adjusted by using the *hammer* or a tuner. The tabla player tightens the membrane to increase the pitch of the sound.

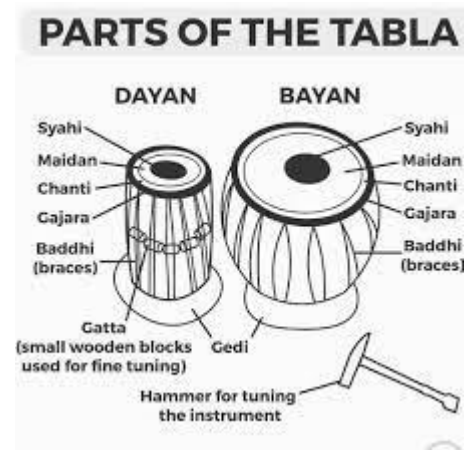


Figure 6

Source: Google Images

The vibration modes can be related to the acoustic components of the tabla stroke, this has been investigated and scientific attempts have been made by a Laser Doppler Vibrometry to indicate the relationship between this instrument and vibration of sounds in physics.

## 7. Impact of concepts of Physics on Music

Songs and sounds are not a system of chaos but they involve structure pattern repetition and a whole lot of other characteristics that sound melodious to the human ear and which we recognize as music. All music emerges from physics, in physics the theory of sound is most apt for music as it consists of waves (mechanical, longitudinal and pressure waves). It is the vibration of objects that create these waves which further travel to various mediums like air or water. When music emerges from the vibration of an instrument, it vibrates the air around it further creating a ripple effect that makes it audible at a distance. Sound waves are further made - up of peak and trough. As they move through any medium, they compress the air particles thus creating pressure waves.

The shape and size of the instrument of the instrument determines the sound it creates. When a new song is played the audience instinctively start to understand the structure of the song as well as its pattern and timing indicating the interconnectedness between all of the above. This again leads us to quantum mechanics, another branch of physics where music and physics merge with each other.

## 8. Conclusion

Thus, we see that the physics of music is really the physics of waves. The basic theory of sound waves in terms of vibration, frequency of vibration, quality of material used on various musical instruments as well as how tightly they have been spread over the wooden object, impact the type of sound that is emitted from the instrument. For melodious music to be produced the repetition of various notes in a synchronized pattern results in different types of music. Whether the type of music is in the form of rap or soul or jazz or rock or romance or a ballad are all based on the basic theory of sound waves, patterns in the waves as well as the extent of amplification of sound. The last would be based on

the material as well as the tension of either the string or the material that would affect the type of music that is generated.

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