Applications of Resonance Phenomenon in Real Life

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Introduction

In this scientific writing assignment we will look at the different applications of the resonance phenomenon in real life.

Concept and Construction of Guitars

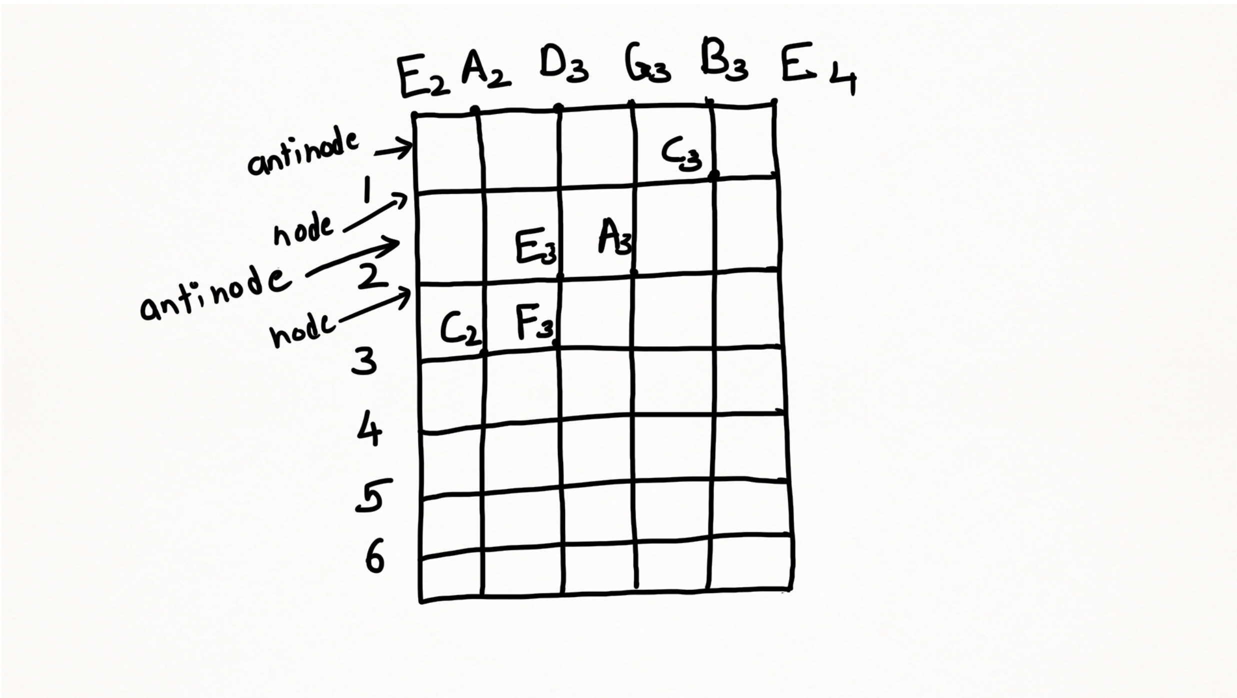
The concept of guitar and it's tone is a direct application of resonance phenomenon. The acoustic guitar normally consists of 6 strings made from stainless steel for playing with a plectrum or a pick. The classical guitar consists of 6 strings made out of nylon for playing the strings using fingers. The electric guitar has 6 strings made of nickel. The strings are tuned at standard tuning which consists of the notes starting from the 6th to 1st in order respectively as E2-A2-D3-G3-B3-E4. These strings are different in their frequencies stated here for the acoustic guitar ranging from the sixth string E2 at 82.41 Hz, then the fifth string A2 at 110 Hz, the 4th D3 at 146.83 Hz, the 3rd string G3 at 196 Hz, the 2nd string B3 at 246.94 Hz, and the 1st string E4 at 329.63 Hz. These frequencies of these strings are known as the fundamental frequency of these strings. These can also be called the normal mode frequencies of these strings.

Application of Resonance in Guitars

The application of resonance in guitars has to be understood first by understanding the phenomenon of resonance itself. Resonance refers to the phenomenon of a sound wave of frequency hitting another object that is oscillating at its resonance frequency which inturn amplifies the amplitude of the oscillating object. This phenomenon is clearly observed in guitar strings and is the conceptualization of the acoustic guitar. A further understanding of the working of resonance requires an understanding of the fundamental and harmonic properties of waves that are discussed below.

Fundamental and Harmonic Frequencies of a Standing Wave

The phenomenon of resonance creates a certain form of waves known as standing waves where the incident sound wave and the oscillating sound waves create constructive and destructive interferences with each other. At the point where the resonance frequency and the frequency of the incoming sound wave are coherent the first frequency for which this happens is called the fundamental frequency of the standing wave. A string that is fixed at both ends creates a standing wave but an acoustic guitar string produces multiple standing waves which then proceed to create the fundamental and harmonics of the guitar string. The open string is the fundamental frequency of the acoustic guitar and the six strings have different fundamental frequencies as mentioned above. The frets on the guitar signify different frequencies at which constructive interference or harmonic frequencies of the strings which are then used to produce. The first fret represents the first node of the standing wave of the guitar string and so on. The sound hole inside the acoustic guitar and the classical allow the sound of the string to oscillate and are kept in such a way that the sound produced from the string after hitting the sound board oscillates at the resonance frequency of the string thus amplifying the sound. The guitar when played through the middle of the fretboard has odd harmonics whereas the guitar when played from the fingerboard has even harmonics. The guitar strings also consist of overtones which basically are the fundamental frequency just amplified much like the phenomenon of resonance. These overtones for a guitar repeat periodically and are called octaves in musical notation and terminology. The notes from the fundamental frequency to the first overtones are collectively called a scale.



Here the tops represent the open string notes. After that every single fret represents the different nodes and antinodes or the positions for destructive and constructive interference for a standing wave. In guitar all of these nodes and antinodes along with the different harmonic frequencies are played at the same time when the string is plucked and then the sound is amplified by resonance. Thus the acoustic guitar and classical guitar without the use of any external sound system produce loud sounds due to the application of resonance. In electric guitars these sound holes are replaced with pickups that use the principle of electromagnetic induction to create electric currents out of the vibrating strings and then passing the electric currents from the guitar to an electric amplifier that again uses the principle of resonance to modulate and amplify the electric signal into pressure waves of sound that comes out from the speakers of the amplifier. Different instruments have different fundamental frequencies for the same notes and thus when the same note is played by using different instruments a richer tone is produced again by the principle of resonance by different instruments playing the same tone with different fundamental frequencies. The harmonic frequencies of the strings of a guitar are given by the expression $F_n = nv/2L$ where F_n is the harmonic represented by the number n which can have an integer value with n = 1 corresponding to the first harmonic, v = speed of sound in the medium and L is the length of the guitar string that we are using. The frets are divided in such a way that the overtones are divided into 1/12 nodes and antinodes and thus after every 12 frets the frequency is a direct overtone of the fundamental frequency.

Electrical Circuits

The phenomenon of resonance is also very useful in the physics of electrical circuits. The LCR circuits are the best example of explaining resonance phenomenon in electrical circuits. For LCR we define impedance which is the vector sum of the resistance, reactance of the capacitor and reactance of the inductor as zero due to which the circuit becomes a purely resistive circuit and the frequency of the circuit is known as the resonance frequency of the circuit. The direct application of this circuit is the tuning circuit of a Television or radio. Different stations transmit signals at different frequencies. The antenna or the receiver for these frequencies receives these frequencies and then drives a current in the tuning circuit. The signal corresponding to the resonant frequency is the only one that is able to drive appreciable current and is further processed. When we tune a radio we change the capacitance of the tuning circuit and thus we change the resonant frequency of the circuit. When this resonance frequency matches with the frequency of the desired station, the tuning of the radio or channel is complete.

Microwaves

Microwaves use the phenomenon of resonance to cook the food that is placed in the microwave oven. The microwaves that are emitted by the microwave resonate with the frequency of the oscillation of the water molecules present inside the food and thus by exciting the water molecules generate heat energy which is used to heat up the food that is kept in the microwave. The microwave contains three main parts - a vacuum tube called magnetron that generates the energy that heats food, a waveguide that is hidden in the wall that is used to propagate the microwave throughout the chamber and a holding panel that contains the microwave radiation and doesn't let it harm anyone. The microwave produces a standing wave usually at a frequency of 2.45 gigahertz (GHz) with a wavelength of 122 millimeters through the food. Microwave radiation is between the common radio and infrared frequencies. The walls of the microwave reflect waves that fit inside the oven and thus only some portion of the food gets heated while it is kept in the microwave. The defrost feature of the microwave works in a similar fashion as the microwave turns on and off repeatedly during the cycles because ice does not resonate with the same frequency as water does and thus by stopping in between the cycles the microwave allows for the ice to melt into water by heating and thus speeding up the defrosting process. The different temperatures of the microwave signify different resonant frequencies and the higher the temperature the lesser the wavelength of the wave. The walls of the microwave are also responsible for having nodes and antinodes for the standing wave produced due to the walls of the microwave. The food heats up at antinodes and there is no heating at the nodes of the wave. As explained above this happens due to the constructive and destructive between the two ends of the standing wave which in this case are the microwave walls. Thus the microwave is used to heat the food using the principle of resonance.

Swings

Swings also work on the principle of resonance. The person who is swinging can be seen as the frequency of oscillation of a wave and the person who is pushing the swing from the back can be considered as the external driving force of the swing. A swing can be considered as a pendulum and if an external force matching the resonant frequency of the swing is applied then the maximum amplitude of the swing can be reached. If the force is applied other than that of the resonant frequency of the swing then destructive interference occurs as explained above and the amplitude of the swing starts to diminish. Thus resonance is very important to understand the working of a swing as an application of resonance.

Conclusion

Thus there are various applications of resonance in daily life which help us in our day to day tasks like having fun on a swing, heating our food, listening to music on radio or playing a musical instrument.

Citations

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