Physics of Music

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Author: Aia M. Harby

Abstract

Most people are aware of the importance of science and technology, and how they can contribute to making many aspects of our life easier, but why do some non-scientists have to learn science in some cases? This paper actually illustrates that Music, which is not considered more than an entertaining way by most people, can be deeply related to some branches of science like mathematics and physics. In fact, over the past years, studying music was considered as a science class; that's due to its relatable achievements in the scientific field, especially physics. Therefore, in this paper, some connections of Music to Physics are represented, ranging from Kepler's search for cosmic harmonies, Newton's theory of colors, and the Music of Electricity to the Analogies between overtones and spectral lines.

Keywords: Cosmic Harmonies, Color Notes, Tone Frequency, Spectral Lines, Atomic Musical Scale

I. Introduction

Albert Einstein was well-known for his obsession with the violin; Max Planck, Werner Heisenberg, and Edward Teller were also great pianists, so is there any relationship between Physics & Music? In reality, music doesn't refer to some random innovative ideas or inspiration, and songs are not just chaos; otherwise, they involve some characteristics that make them recognizable to the human ear, e.g., structure, pattern, and repetition.

Although many people today still believe in the importance of music to be a good way for entertainment, many of them don't really respect it as a scientific aspect; however, centuries ago, scientists considered studying music to be a branch of science. That's due to the reality of which music emerges from many physics and mathematics principles.

In addition, music has an important role in the development of modern science, especially in physics, so according to these considerations, examples of contributions of music to some of the physics achievements will be discussed in this paper. [1]

II. Kepler's Search for Cosmic Harmonies

Johannes Kepler is an astronomer, who changed our understanding of the planetary motion as he linked the harmonic motions of the cosmos to the possible future harmony of humans on Earth. He combined the classical idea of the Harmony of the Spheres with Copernicus' heliocentrism. In his *Mysterium Cosmographicum*, he placed the sun at the center of the universe, with the planets around it as already proposed before, but that was not enough for Kepler. He wasn't satisfied until he had shown why the planets moved in the orbits in which the latest observations and calculations had found them. He calculated the changing speeds of each planet and converted those speeds into tones, and his theory was that the music of the spheres was a continuous and everchanging song. Kepler did not hear the music he had created in the theory because he didn't have the technology to produce the sounds; in fact, he called the music of the spheres a continuous song for several voices, to be perceived by the intellect, not the ear.

Meanwhile, the professors, who had access to computers and synthesizers, were later able to make Kepler's music for the ear as well as the intellect.

To sum up, each planet's song is the direct result of the size, shape, and speed changing of its orbit. For example, Mercury buzzes like a shrill piccolo in a swiftly modulating tune that corresponds to its quick (88 Earth days) and irregular orbit. Venus and Earth, with almost circular orbits, have narrow melodic ranges as Venus hums within a range of quarter-tone, and Earth moans within minor seconds. On the other hand, Mars, which has a relatively irregular orbit, sings fast-moving tunes spanning a wide range of tones, and so on. [2]

III. Newton's Theory of Colors

Another connection of Music to Physics was when Isaac Newton first passed white light through a prism and observed it refracting into a rainbow; he identified seven constituent colors, which are red, orange, yellow, green, blue, indigo, and violet. Here, the most necessary part does not refer to the number of colors he watched, but it is that he thought the colors of the rainbow were similar to the notes of the musical scale. His idea was very interesting yet strange, but it does not have solid evidence; meanwhile, it just represents something he is considering based on the color spectrum by analogy with music. To perform that experiment, he had projected white light through a prism onto a wall and had a friend marking the boundaries between the colors. His diagrams showed how colors corresponded to notes, and he also introduced two colors, orange and indigo, corresponding to half steps in the octatonic scale. Newton's addition of those two colors had continuous consequences. "For those who came after, Newton's musical analogy is the source of the widely held opinion that orange and indigo are actually intrinsic in the spectrum, despite the great difficulty (if not impossibility) of distinguishing indigo from blue, or orange from yellow, in spectra." Peter Pesic said in his book: *Music and the Making of Modern Science.* [3]

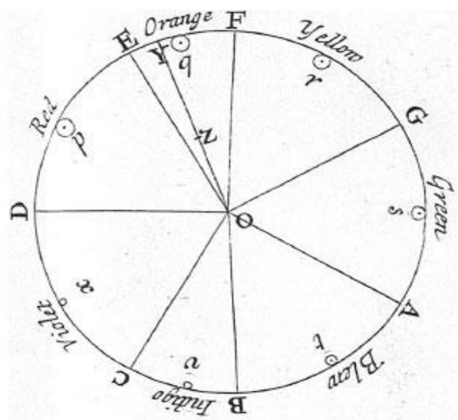

Figure (1): Newton's Color Wheel

Although Newton's color-music analogy broke down, his prism experiments showed that white light is actually a mix of different-colored lights, and this work was an important step towards understanding the nature of light much more deeply.

IV. The Music of Electricity

Have you ever considered how can electricity make a sound? That's because electricity, like light, heat, sound, and most other forces of nature, comes to us in waves. This electricity's characteristic was first theoretically stated by Professor Maxwell, though the original suggestion had been made by Faraday in 1832; he predicted that these electrical waves had the same speed as those of light, but he didn't put actual proof to his assumption; however, the waves were identified by Hertz in 1887. He found that as they had the speed of light (186,000 miles a second), their rate of travel would be far from that of sound, and they were therefore inaudible to the human ear, but how are these very high-speed waves able to be made audible? It was discovered by chance when William Duddell was experimenting in 1899 with the electric arc-lamp, in which light is produced by combustion between two carbon points. He coupled another circuit of electric current to that of his arc-lamp, having placed in that oscillating circuit a condenser and a coil; by these means, he could regulate the speed or frequency of the current. Thus, he found that not only did the arc-light give a musical note, but also that the note of his "singing lamp" was altered in pitch by changing the capacity of the condenser and so the force of the electric energy. He had brought the high speed of the electrical impulses or waves within the range of audible sounds. He had given them "tone-frequency." To illustrate how he did that, an example of tuning a piano or an organ may be useful; if two strings or two pipes for the same note are not exactly in tune (i.e., when their vibrations are not at the same rate), a beating effect is produced because at certain regular intervals, the two different wave-speeds coincide and the intensity of the sound turns into a "beat", easily recognized by the tuner. The farther apart they are in pitch, the quicker the beat; the nearer they are to unison, the slower it becomes. Thus, with Duddell's electric currents, passing at different speeds of vibration, a beat occurred when they overlapped, and that, at a rate that corresponded to the difference between the two speeds and so infinitely slower than their separate speed-rates.

However, there other ways in which the music of electricity can be produced. One of them is that by considering the vibrations of existing sound waves, we may use them on an acoustical basis, converting them into electrical waves and returning them again to audible sounds. This can be made possible by means of the electro-magnetic microphone, amplifier, and loud-speaker on simplified broad-casting lines. [4]

V. Analogies Between Overtones and Spectral Lines

Atoms of a selected element vibrate at specific frequencies; the color we see is the combination of all the emitted visible wavelengths entering our eyes at the identical time. It can then be expressed as a Fourier transform, within which the brightness of every spectral line indicates the amplitude of the corresponding component wavelength. The lines are often considered as a recipe for the color: the wavelengths are the ingredients, and also the amplitudes are the amounts. As any atom will be identified by its spectrum, any sound is often identified by its Fourier transform. The differences between transforms determine the perception that a note was produced by. Although the harmonics produced are similar, the relative amplitudes of every harmonic differ from one instrument to the other.

There is a detailed similarity between the way atoms produce their colors and the way complex audible tones are formed, as an example, the octave arises from combining two audible sinusoids with a frequency ratio of 2:1. That was first observed by Pythagoras, who organized a musical-scale system that supported those harmonics. Because both audible tones and also the atomic spectra are built up from identical mathematical relations, a scale for atoms may be created. Then, we are able to exhibit a music-synthesis program, like audacity, to come up with sounds that correspond to particular component frequencies.

To make this, the range of frequencies of the emitted photons is required to be identified, as an example, we will prefer to limit the range to that of visible photons. The corresponding frequency scale becomes 4.3×10^{14} Hz (red) – 7.5×10^{14} Hz (blue). Standard written music is really a semilogarithmic graph of frequency versus time; the quality musical staff relies on the foremost commonly used notes, up to a frequency of about 700 Hz. The scale shown within the figure below places the spectrum and also the most typically used audible tones. The audible scale is extended slightly below and above the quality musical staff, from 20 Hz (the minimum threshold of frequencies audible to humans) to 1046.5 Hz (the first C note above standard written music).

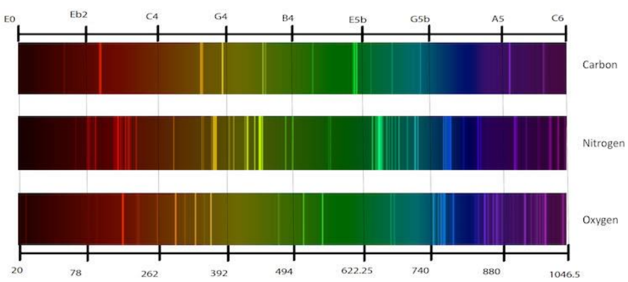

Figure (2): Atomic Musical Scale

Every spectral line represents a single sinusoid that can form complex tones whenever it combines with others. As with keys on a piano, the keys we hit and the tempo at which we hit them can produce a countless number of songs. One doesn't need to know a B_4 from an A_6 to create atom songs because the programs require only an input frequency to produce a tone, so the traditional rules of music are gone; the brighter lines will be the dominant notes of the scale, while the lesser lines add complexity. It is not difficult to adjust the amplitude of each input frequency on any of the available programs. [5]

VI. Conclusion

As shown in the whole paper, Music was an important part of many physics' theories; in fact, it has a countless number of contributions to the scientific community. It helped in changing our understanding of the planetary motions when Kepler linked the harmonic motions of the cosmos to the possible future harmony of humans on Earth. Newton also inspired his color wheel by the notes of the musical scale. Music has also many relationships with electromagnetism; in addition, the overtones have some similarities with the spectral line; therefore, this assumption can be helpful while exhibiting the music-synthesis programs. These are only some sorts of the major connections of Music to Physics, but there are more incredible ones.

VII. References

[1] Crease, R. P., & Pesic, P. (2014). Physics and Music. *Physics in Perspective, 16(4), 415–416*.doi:10.1007/s00016-014-0147-3

[2] Rothman, A. (2020). Johannes Kepler's pursuit of harmony. *Physics Today*, *73*(1), *36–42*.doi:10.1063/pt.3.4388

[3] Pesic, P. (2014). Newton and the Mystery of the Major Sixth. In *Music and the Making of Modern Science* (pp. 121-132). Cambridge, Massachusetts; London, England: The MIT Press. Retrieved from: http://www.jstor.org/stable/j.ctt9qf97s.11

[4] Galpin, F. (1937). The Music of Electricity. A Sketch of Its Origin and Development. Proceedings of the Musical Association, 64, 71-83.

[5] Composing atom music. (2019). *Physics Today*.doi:10.1063/pt.6.5.20190125a