Harmonics Encyclopedia Article

Harmonics

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A string tied at both ends will, if plucked, vibrate with certain frequencies. One way it can vibrate is if the entire string goes back and forth, with the only fixed points being on each end. But it is also possible to cause the string to vibrate in a way so that it has three fixed points, one on each end and one in the middle. This three-point vibration has a frequency twice that of the two-point vibration (which is the lowest frequency of this system), and is said to be a *harmonic* of the lowest frequency. The string can be vibrated in yet more complicated ways. In general, harmonics are modes of vibration which have a frequency that is some integer multiple of the lowest frequency.

The concept of harmonics originated in music, where sound waves correspond to the vibration of strings (as in a violin) or columns of air (as in a recorder). The increasingly higher frequencies form a harmonic series, the name coming from the harmonious relation of such sounds. In fact, the science of musical acoustics was once called harmonics.

Two important notions arise from the concept of harmonics. One is that of *simple harmonic motion*. A system exhibits simple harmonic motion if it oscillates back and forth through a midpoint, with the maximum displacement on one side equal to that of the other. Examples of such systems are an oscillating pendulum, a mass on the end of a spring, electrons in a wire carrying alternating current, and the vibration of air molecules in a sound wave. Simple harmonic motion is a consequence of *Hooke's law,* where the restoring force on the object is proportional to its distance from its midpoint, and in the opposite direction. Simple harmonic motion is at the heart of timekeeping.

Musical sounds are actually a combination of many simple harmonic waves corresponding to the many ways a musical instrument can oscillate. In fact, in 1822 the French mathematician Jean-Baptiste-Joseph Fourier proved mathematically that any regular periodic motion and any wave, no matter how complicated, can always be treated as the sum of a series of simple harmonic motions. This series is called the *Fourier series*, and it often allows for the mathematical solution of complicated systems that cannot be analyzed otherwise.