WAVE – Extended Definition

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Agreeing on a single, all-encompassing definition for the term wave is non-trivial. A vibration can be defined as a back-and-forth motion around a point of rest (*e.g.* Campbell & Greated, 1987: 5) or, more generally, as a variation of any physical property of a system around a reference value. However, defining the necessary and sufficient characteristics that qualify a phenomenon to be called a wave is, at least, flexible. The term is often understood intuitively as the transport of disturbances in space, not associated with motion of the medium occupying this space as a whole. In a wave, the energy of a vibration is moving away from the source in the form of a disturbance within the surrounding medium (Hall, 1980: 8). However, this notion is problematic for a standing wave (*e.g.* a wave on a string), where energy is moving in both directions equally, or for electromagnetic / light waves in a vacuum, where the concept of medium does not apply.

For such reasons, wave theory represents a peculiar branch of physics that is concerned with the properties of wave processes independently from their physical origin (Ostrovsky and Potapov, 1999). The peculiarity lies in the fact that this independence from physical origin is accompanied by a heavy reliance on origin when describing any specific instance of a wave process. For example, acoustics is distinguished from optics in that sound waves are related to a mechanical rather than an electromagnetic wave-like transfer / transformation of vibratory energy. Concepts such as mass, momentum, inertia, or elasticity, become therefore crucial in describing acoustic (as opposed to optic) wave processes. This difference in origin introduces certain wave characteristics particular to the properties of the medium involved (*e.g.* in the case of air: vortices, radiation pressure, shock waves, *etc.*, in the case of solids: Rayleigh waves, dispersion, *etc*., and so on).

Other properties, however, although they are usually described in an origin-specific manner, may be generalized to all waves. For example, based on the mechanical origin of acoustic waves there can be a moving disturbance in space-time if and only if the medium involved is neither infinitely stiff nor infinitely pliable. If all the parts making up a medium were rigidly bound, then they would all vibrate as one, with no delay in the transmission of the vibration and therefore no wave motion (or rather infinitely fast wave motion). On the other hand, if all the parts were independent, then there would not be any transmission of the vibration and again, no wave motion (or rather infinitely slow wave motion). Although the above statements are meaningless in the case of waves that do not require a medium, they reveal a characteristic that is relevant to all waves regardless of origin: within a wave, the phase of a vibration (*i.e.* its position within the vibration cycle) is different for adjacent points in space because the vibration reaches these points at different times. Similarly, wave processes revealed from the study of wave phenomena with origins different from that of sound waves can be equally significant to the understanding of sound phenomena. A relevant example is Young's principle of interference (Young, 1802, in Hunt, 1978: 132). This principle was first introduced in Young's study of light and, within some specific contexts (*e.g.* scattering of sound by sound), is still a researched area in the study of sound. As another example, the phenomenon of dispersion demonstrates that wave modulations behave as regular waves. When modulations propagate in media where the speed of wave propagation depends on frequency, they separate from the complex wave they belonged to and travel independently carrying energy, similarly to the rest of the frequency components of the complex wave. It is true that this separation will never happen in a non-dispersive medium such as air, where all frequencies move with the same speed. Nonetheless, the important point is that the dispersive case serves to illustrate that modulations in general and amplitude fluctuations in particular behave as waves. Dispersion provides a case where modulations are isolated from the waves that carry them and can therefore be studied easier (assuming that the only characteristic that changes during dispersion is the modulations' velocity). In addition, systems with dispersion provide better cases for the mathematical analysis of the kinematic properties of waves (*i.e.* frequency, wavelength, phase and group velocities). In the case of sound waves, diffraction, absorption, reverberation, and interference are examples of phenomena that have been better understood with the aid of dispersion theory.

To summarize, the term wave implies three general notions: vibrations in time, disturbances in space, and moving disturbances in space-time associated with the transfer/transformation of energy. Based on these notions, the following origin-specific definition may be adopted for sound waves in air (Vassilakis, 2001):
"Sound-waves in air represent a transfer of vibratory energy characterized by: i) rate (frequency), ii) starting position (phase), and iii) magnitude (amplitude) of vibration. In general, amplitude can be expressed equivalently in terms of maximum displacement, velocity, or pressure relative to a reference value. Sound waves in air are manifested as alternating air-condensations and rarefactions that spread away from the vibrating source with a velocity usually not related to the velocity amplitude of the vibration. They result in pressure/density disturbance patterns in the surrounding medium, which, in general, correspond to the signal that plots the vibration of the source over time."
This definition may serve as an initial operational definition of sound waves in air to which further qualifications may be added as needed.

References

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