PhyzGuide: Anatomy of a Wave

A **wave** can be thought of as a disturbance traveling through a medium. The disturbance transports *energy* through the medium without causing a permanent displacement of the medium itself. (Particles in the medium *do* undergo motion, but they undergo simple harmonic motion—SHM—so there is no *net* translation.) There are four fundamental components involved in wave production, each with its own set of quantifiable characteristics.

I. THE SOURCE

For a wave to be propagated, something has to vibrate. That something is therefore the **source** of the waves. The source might be an oscillating hand holding one end of a rope, an oscillating speaker disturbing the air in front of it, or an oscillating electric field on an antenna of a radio station. The source can be described quantitatively through the following attributes.

Amplitude is a measure of how much the source deviates from equilibrium during its vibrations. The amplitude of an oscillation indicates how much energy is involved in the vibration: more energy results in greater amplitude.

The amplitude of the source is denoted $\mathrm{A_s}$. *The units of amplitude depend on the type of wave being produced.*

Source frequency is a measure of how many times per second the source oscillates. Frequency is inversely related to the **period** T_s of the source's motion ($f=1/T$ and $T=1/f$). So a quickly vibrating source has a short period (one oscillation doesn't take much time) and a high frequency (many oscillations are completed in one second).

The frequency of the source is denoted $\mathrm{f_s}$ *or* ν_s *[*ν *is the lowercase Greek letter nu, so when someone says, "What's nu?" you can respond, "Frequency, silly!"] The units of frequency are 1/s or* s^{-1}*, which have been given the alternate abbreviation Hz (hertz, after Heinrich Hertz, 19th century German physicist).*

Source velocity is (surprisingly enough) the velocity of the source. This is the overall translational velocity of the source, not the vibrational speed of the wave-emitting object. A stationary source is a vibrating object that has no overall translational motion. The motion of the source affects the wavelength of the wave it produces.

The source velocity has no effect on the wave velocity. There is no relationship between source velocity and wave velocity. The source velocity and the wave velocity are unrelated. The wave velocity has no dependence on source velocity. Read this paragraph repeatedly until the independence of source velocity and wave velocity is clear.

Source velocity is denoted $\mathrm{v_s}$ *and is measured in meters per second (m/s).*

II. THE MEDIUM

The **medium** is what the source disturbs. The disturbance propagates through the medium at a specific speed. This speed is called the **wave speed**.

Wave speed *is a characteristic of the medium only*. Low amplitude waves travel at the same speed as high amplitude waves in a given medium. Waves created by a low frequency oscillator propagate at the same speed as those emanating from a high frequency oscillator. Waves travel faster in stiffer materials (in which the molecules are bound more tightly throughout—when one molecule is disturbed from equilibrium, it quickly disturbs its neighbor, and so on... hey, this sounds like my apartment complex).

Wave speed is denoted v_w *and is measured in meters per second (m/s).*

III. THE WAVE

The disturbance itself has certain quantifiable features, too.

Amplitude is a measure of how much the wave disturbs the medium, and is an indication of the **energy** being transported by the wave.

Amplitude is denoted by an A.

Wavelength is the distance between consecutive wave crests. Wavelength depends on two quantities: the frequency of the source f_s, and the wave speed in the medium v_w. If the source vibrates quickly (high frequency), then many waves will be loaded into the medium each second, and the waves will therefore be closely packed (small wavelength). So $\lambda \propto 1/f_s$. If waves travel quickly through the medium, one wave will be carried a great distance before the next one is loaded. So $\lambda \propto v_w$. Taken together, we can conclude that the wavelength of a wave is proportional to wave speed and inversely proportional to the frequency of the source: $\lambda = v_w/f_s$.

Wavelength is denoted by a λ, *lowercase Greek lambda, and is measured in meters (m).*

IV. THE OBSERVER

As the wave propagates outward, it transmits part of its energy to objects in the medium. An **observer** sensitive to the waves is forced into oscillation by the waves. The **energy** of the **source** is thereby transmitted to the **observer** via the **wave.**

Observed frequency is a measure of how many waves pass the observer per second. Each wave induces one complete oscillation in the observer.

Observed frequency is denoted f_{obs} *or* ν_{obs} *and is measured in 1/s or Hz. Of course, one may also refer to the* ***period*** *of oscillation of the observer,* T_{obs}. *Any type of period is measured in seconds (s).*

