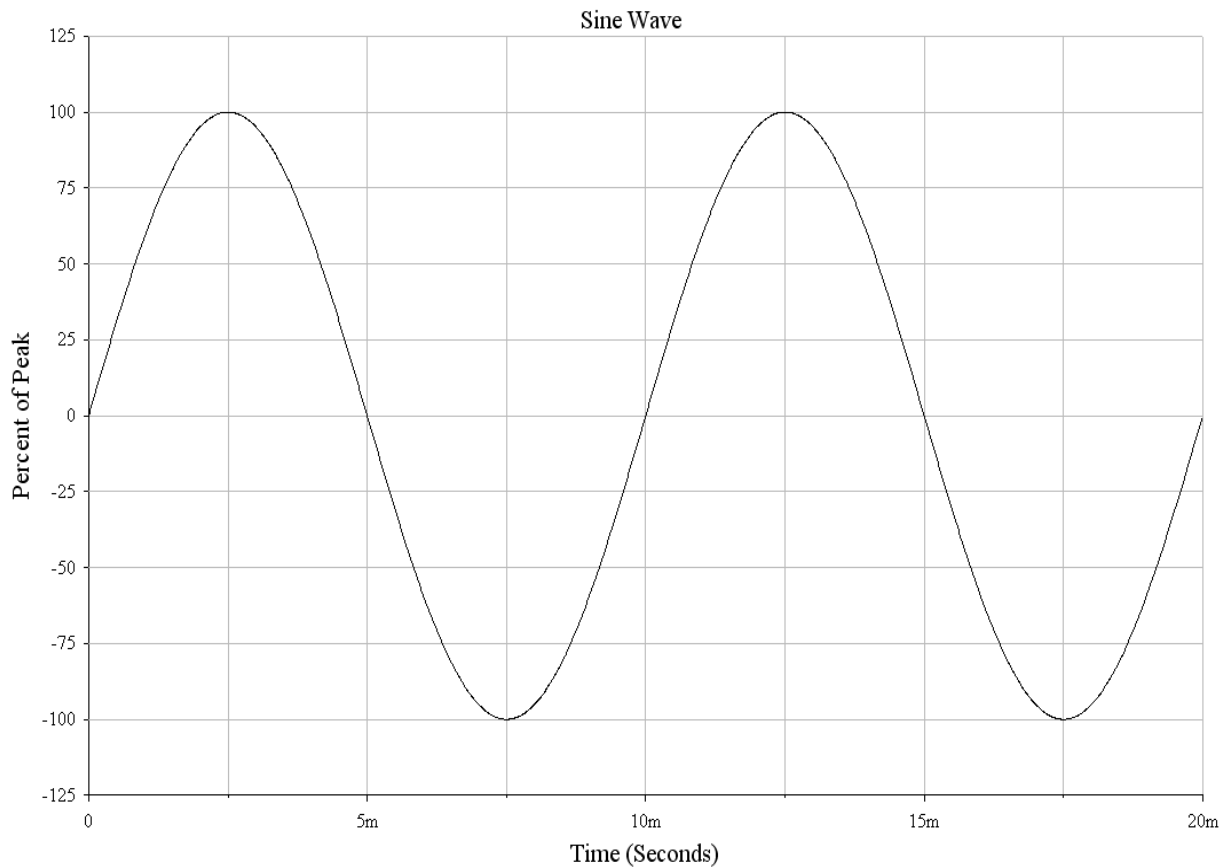


# Sine Wave Notes: Amplitude, Period, Frequency & Wavelength

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Above is a representation of a sine wave, the simplest wave that may be created. It represents the displacement of a simple rotating vector (such as the second hand of a clock). Along the horizontal is the time axis. The vertical axis is represented here in general as a percentage of maximum but would ordinarily be a measurement of voltage, current, sound pressure, etc. Note the smooth variation that starts at zero, rises to a positive peak, falls back through zero to a negative peak, and then rises again to where it started. The whole process then repeats. Each repeat is referred to as a *cycle*. In the diagram above, two complete cycles are shown. Sine waves exhibit *quarter wave symmetry*. That is, each quarter (in time) of the wave is identical to any other if you simply flip it around the horizontal axis and/or rotate it vertically about its peak. The time it takes to complete one cycle is called the *Period* and is denoted with the symbol  $T$  (T for Time). In the example above, the Period is 10 milliseconds, or  $T=10$  ms. The reciprocal of the Period is the *Frequency*,  $f$ . Thus,  $f = 1/T$ . The frequency indicates how many cycles exist in one second. To honor one of the 19<sup>th</sup> century researchers in the field, instead of calling the unit “cycles per second”, we use *hertz*, named after Heinrich Hertz and abbreviated *Hz*. In the example above,  $f = 1/10$  ms, or 100 Hz (100 cycles in one second).

Another item of interest is the speed of propagation of the wave. This varies widely. In the case of light in a vacuum (or to a close approximation, an electrical current in a wire), the velocity is about  $3 \times 10^8$  meters per second (i.e., 3 times ten to the eighth power, or 300,000,000) or about 186,000 miles per second. In the case of sound in air at room temperature, the velocity is around 344 meters per second (about 770 MPH or 1130 feet per second). Sound waves through other media such as steel or helium are considerably different (in the case of helium, almost three times faster). The velocity of sound waves will also change with temperature (it gets faster as the air warms up).

Given a velocity and a period, you can imagine how far apart the peaks of the wave are. This distance is called the *wavelength* and is denoted by the Greek letter lambda  $\lambda$ . Wavelength is equal to the velocity divided by the frequency,  $\lambda = v/f$ . Thus, for the 100 Hz waveform above, if this represents sound in air,  $\lambda = 344 \text{ m/s} / 100 \text{ Hz}$ , or 3.44 meters (a little over 11 feet). Notice that the higher the frequency, the shorter the wavelength. Also, note that the faster the velocity, the shorter the wavelength. This explains the common trick of “sounding like Donald Duck” by taking a breath of helium. The speed of sound in helium is much faster than that of air, so it can cover a given distance in less time. The distance in this case is the length of your vocal tract. The decrease in time corresponds to a shorter period and thus, a higher frequency. (This is a simplified explanation as the real situation is a bit more complicated, involving vocal tract resonances which alter the formants of the voice, and thus the timbre.)<sup>1</sup>

The amplitude (vertical) of the wave can be expressed as a peak quantity, which would be the change from the center zero line up to the most positive value. Amplitude may also be expressed as peak-to-peak, the distance from the most negative to the most positive. Note that for a sine wave this will always be twice the peak value, although for other sorts of waves which may be asymmetrical, that may not be the case. Alternately, amplitude may be given as an RMS (Root Mean Square) value. RMS is a special calculation used for finding equivalent DC power (very common, for example, with audio power amplifiers). **For sine waves, RMS is always the peak value divided by the square of two (approximately 1.414).** As one over the square root of two is approximately 0.707, the RMS value of any sine wave is approximately 70.7 percent of its peak value. Again, this ratio would not necessarily be true of non-sine waves, and we will not concern ourselves with computing those other ratios. Finally, the ratio of the peak value to the RMS value is called the *crest ratio*. This is a fixed value for sine waves (again, about 1.414), but can be over 10:1 for some kinds of audio signals.

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<sup>1</sup> Please do not play around with helium inhalation! It is possible to starve your brain of oxygen when doing this.