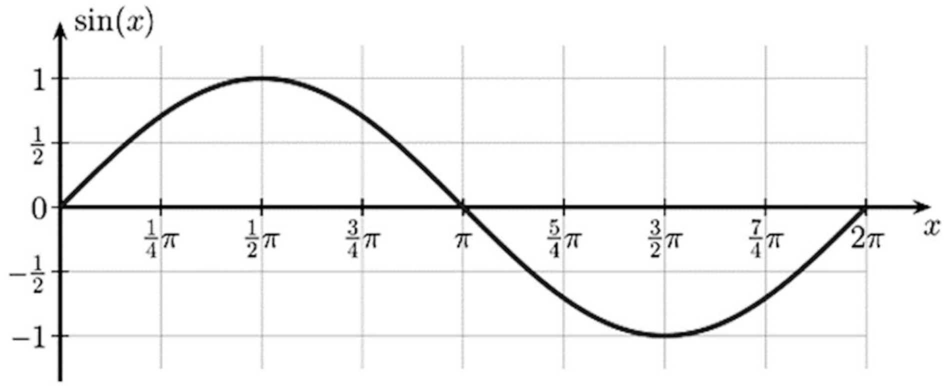
Alternating Current

Getting back to AC electric power, "alternating" means that the polarity of the voltage changes on a cyclic basis, causing the direction of the current to switch back and forth.

One complete cycle includes the time that the current flows first one way, and the time that it flows the other. The total number of *cycles per second* (cps) is called the *frequency*, and in the U.S. that is 60cps.

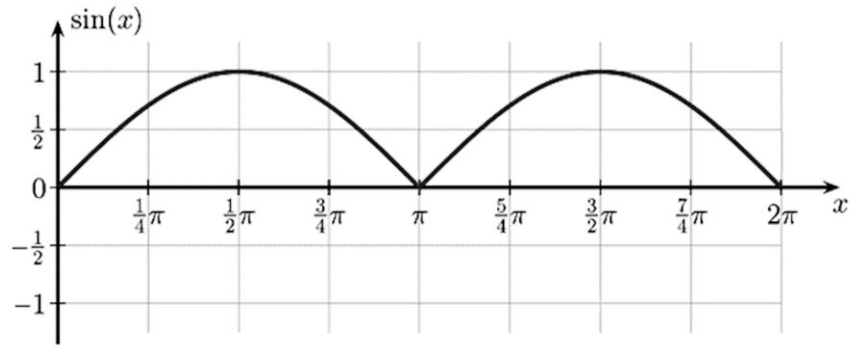
In 1960, when the world thought it would be nice to have everyone change over to the metric system, the terminology was changed from "cycles per second" to *Hertz* (Hz) in honor of the German physicist who was first to prove the actual existence of electromagnetic waves.

Alternating voltage changes in direction and amplitude smoothly as a function of the generating equipment. When graphed, it takes the form of the trigonometric *sine* function, so the electrical wave shape is called a *sine wave*.



Looking at this curve, you can see that the average voltage during one complete cycle will be zero. So how do we come up with “120-volts”?

Current direction is not relevant when it comes to resistive loads. Light bulbs, for example, don’t care which way the current is going. To resistive loads, the power simply appears to be pulsating …



From this point of view, the average amplitude is not zero. Arithmetically it's equal to 63.6% of its maximum, or *peak*, value …

$$E_{ave} = 0.636 \times E_{pk}$$

But this doesn't actually correspond to the power delivered to the load.

The *effective value* of the AC voltage is the value that delivers the same power to a resistive load as an equivalent constant voltage. Mathematically, this turns out to be equal to the sum of the squares of all the instantaneous values of the voltage during one alternation — its *root mean square* (rms) value. That turns out to be 70.7% of the peak value …

$$E_{eff} = 0.707 \times E_{pk}$$

$$E_{rms} = E_{eff}$$

120-volts is the *nominal* effective, or rms, value of the power delivered to your home's electrical service. The actual measured voltage is likely to vary slightly depending on your particular service, but not by more than ±5%.

Knowing the rms value, the peak value can easily be calculated …

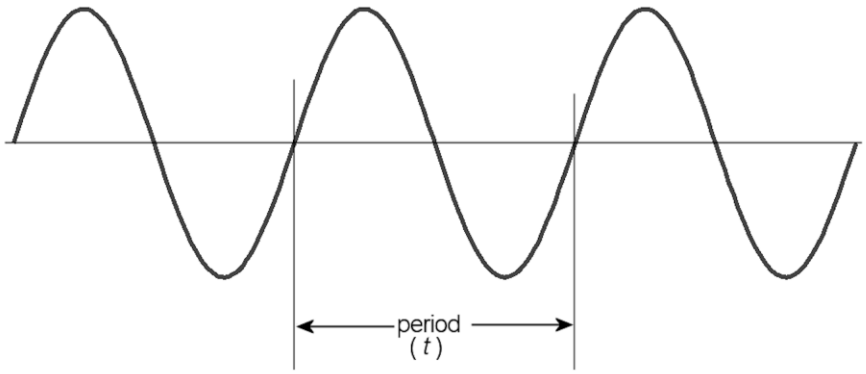
$$E_{pk} = E_{rms} \times \frac{1}{.707} = 1.414 E_{rms}$$

For example, the peak voltage for a 120-volt service is …

$$E_{pk} = 1.414 \times 120 = 169.7v$$

Period and Wavelength

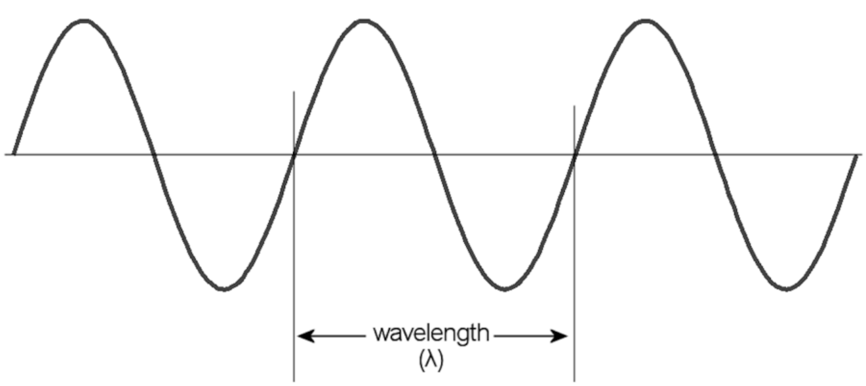
The time for one complete cycle of a continuous waveform is called its *period* …



… and is equal to the reciprocal of its frequency. For a 60Hz signal …

$$t = \frac{1}{f} = \frac{1}{60} = 0.167\ sec$$

The speed of an electric current through a conductor is the same as the speed of radio waves through the air — 186,000 miles per second (or 300-million meters per second). This gives rise to the concept of *wavelength*.



A wavelength, λ, is the physical distance between two successive identical points on the wave as it travels along the conductor, or through space, and is usually expressed in *meters*. Knowing the frequency of the wave, the wavelength is easy to determine …

$$\lambda = \frac{v}{f}$$

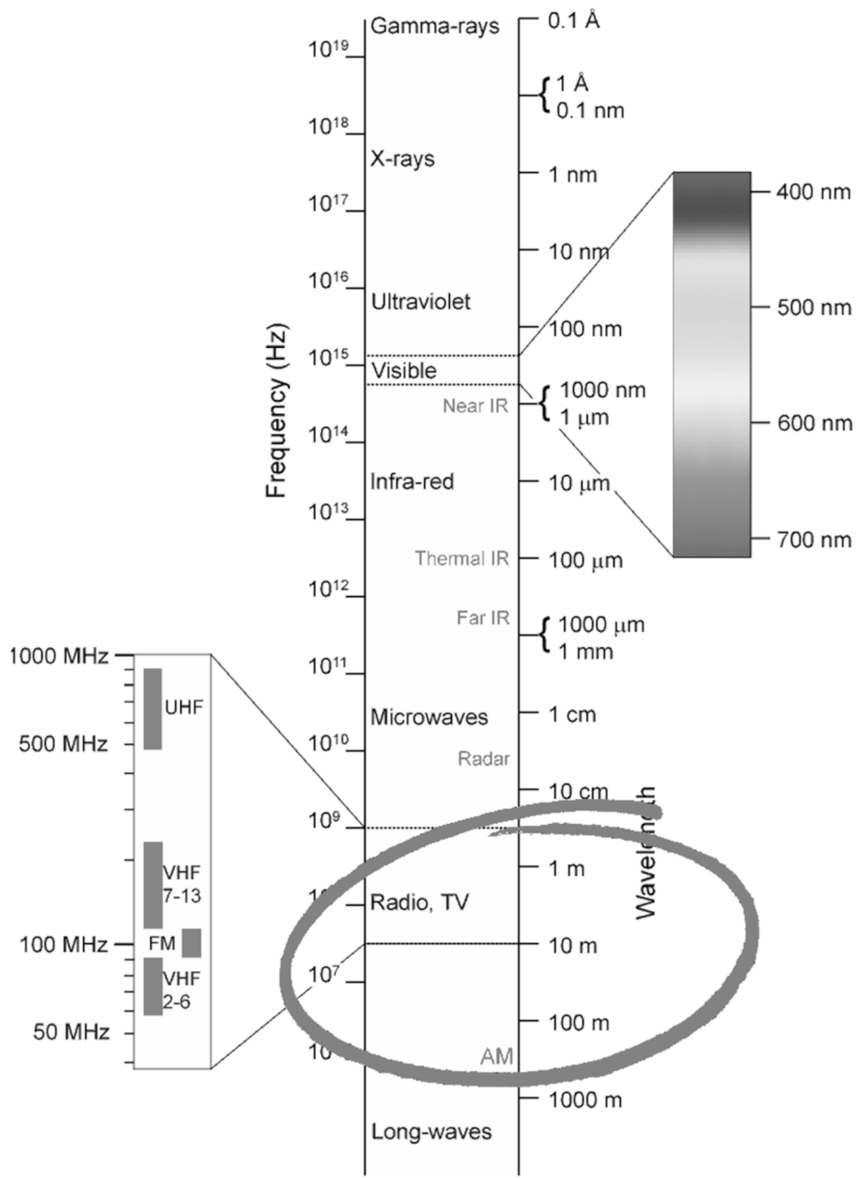
… where "v" equals its velocity of propagation, and "f" equals its frequency. The wavelength of a 60Hz signal is therefore …

$$\lambda = \frac{186{,}000}{60} = 3{,}100\ miles$$

… or 4,989 kilometers.

This is given only as an example of how the calculation is done. The wavelength of electric power voltages has very little relevance in the real world.

Wavelength is a concept that is more relevant to electromagnetic radiation because of its influence on antenna design, and so on. For example, amateur radio operators operating on frequencies between 28.0 and 29.7MHz would commonly refer to that as the “10-meter band”.



So much for our discussion of electric power and alternating voltages. We got into this because understanding the nature of alternating voltages will be important to our learning about concepts of inductance and capacitance.

We're now ready to proceed with that.
