Vibrations, oscillations, and repetitive motion

The maximum displacement from the equilibrium position during oscillatory motion is called the amplitude. The oscillation is described by the period, the time it takes to complete one full cycle. It is related to the frequency which is the number of oscillation cycles in a given amount of time. Frequency is often measured in units of cycles per second and is related to the frequency which defines the unit called the Hertz (Hz).

\[
f = \frac{1}{T}
\]

During the “spin cycle” of my washing machine, the drum makes 1,200 rotations per minute. What is the frequency of these rotations in Hz and the period in units of seconds?

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\[
f = \frac{1}{T}
\]

Note that \( f = N / time \) for \( N \) cycles

Natural Frequency

All physical systems that can vibrate will have a natural or resonance frequency.

Typically the resonant frequency is higher for smaller objects. For a pendulum of length \( L \), this frequency is

\[
f = \frac{1}{2\pi} \sqrt{\frac{g}{L}}
\]

What happens to the frequency and period of a pendulum as its length \( L \) gets longer?

Resonance

Large amplitudes can result when a periodic force is applied to a system at its natural frequency. A child on a swing, a wine glass, musical instruments, tuning forks, radio receivers, and atoms can all have large amplitude oscillations when driven at their resonance or natural frequency.

Two tuning forks that have the same natural frequency are said to be in resonance. The oscillations of one tuning fork will set the other tuning fork into vibration if their natural frequencies are identical.

Calculating the Period and Frequency

If a box of 12 pencils cost $2.40, what is the price per pencil?

If you go through 12 full cycles in 2.4 seconds, what is the time per cycle, i.e., the period?

Find the number of pencils per dollar?

Find the number of cycles per second, i.e., the frequency?

Note that \( f = N / time \) for \( N \) cycles

Waves

A wave is a vibration or oscillation that travels through space.

A periodic wave is characterized by its the repetition distance or wavelength.

The wave speed is the distance the wave moves per unit time.

\[
v = \frac{wavelength}{period} = wavelength \times frequency
\]

\[
v = \lambda / T = \lambda f
\]

If the breakers at the beach are separated by 6 m and hit the shore with a frequency of 0.2 Hz, what is the speed of the waves? What is their period?
Shorter wavelengths (and higher frequencies) are produced when the end of the rope is shaken more rapidly. How does the speed of sound in air change with increasing frequency?

**Transverse and Longitudinal Waves**

The wave on a string is transverse because the wave is moving to the right but the string is moving up and down.

A sound wave is an example of a longitudinal wave since the air molecules move parallel to the direction that the wave is moving.

Ultrasonic imaging is a common diagnostic tool in medicine. The high frequency sound waves are reflected from the interface between regions of different density to form an image.

**Standing waves**

Standing waves can occur when a wave is confined to a particular region. They have alternating node and antinode regions. At the positions of the nodes, the string is stationary. The standing wave in the diagram has exactly one-half of a wavelength that exactly fits on a string of length L.

(a) shake the rope until you set up a standing wave of just one segment. (L=1×λ/2)
(b) shake with twice the frequency to produce a wave with two segments. (L=2×λ/2)
(c) shake with three times the frequency to produce a wave with three segments. (L=3×λ/2)

A rope is tied between two posts separated by 6 m. If it is oscillating with the standing wave pattern shown in figure (c) above, what is the wavelength?

What is the fundamental frequency for the waves on a 3-m rope that is tied on both ends if the wave speed is 24 m/s?