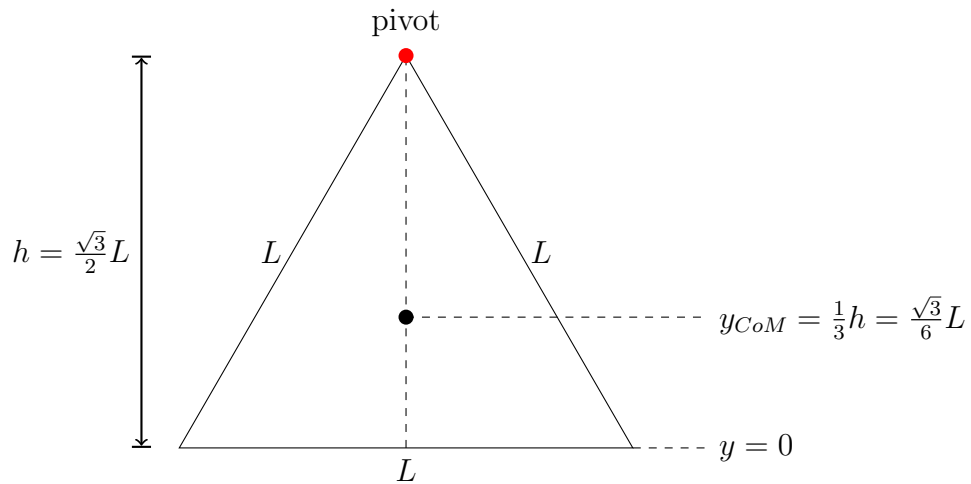


# University Physics 1A

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## Pendulum Lab



$$\begin{aligned}y_{CoM} &= \frac{1}{3} \frac{\sqrt{3}}{2} L \\ &= \frac{\sqrt{3}}{6} L\end{aligned}$$

$$\begin{aligned}I_{CoM} &= 3 \left[ \frac{1}{12} mL^2 + m \left( \frac{\sqrt{3}}{6} L \right)^2 \right] \\ &= \frac{1}{2} mL^2\end{aligned}$$

$$\begin{aligned}
I_{around\ pivot} &= I_{CoM} + 3\left(h - \frac{\sqrt{3}}{6}\right)^2 \\
&= \frac{1}{2}mL^2 + 3\left(\frac{\sqrt{3}}{3}L\right)^2 \\
&= \frac{3}{2}mL^2 \\
T &= \frac{2\pi}{\omega} \\
&= \frac{2\pi}{\sqrt{\frac{y_{CoM}Mg}{I_{around\ pivot}}}} \\
&= 2\pi\sqrt{\frac{I_{around\ pivot}}{y_{CoM}Mg}} \\
&= 2\pi\sqrt{\frac{\frac{3}{2}mL^2}{\frac{6}{\sqrt{3}}L(3m)g}} \\
&= 2\pi\sqrt{\frac{\sqrt{3}L}{2g}}
\end{aligned}$$

## Simple Harmonic Motion

Generally, we think of masses oscillating on a spring in terms of simple harmonic motion. This can be described with the following equation of motion:

$$\begin{aligned}
F &= -kx \\
a &= -\frac{k}{m}x \\
x &= A\cos(\omega t + \phi) \\
v &= -\omega A\sin(\omega t + \phi) \\
\omega &= \sqrt{\frac{k}{m}}
\end{aligned}$$

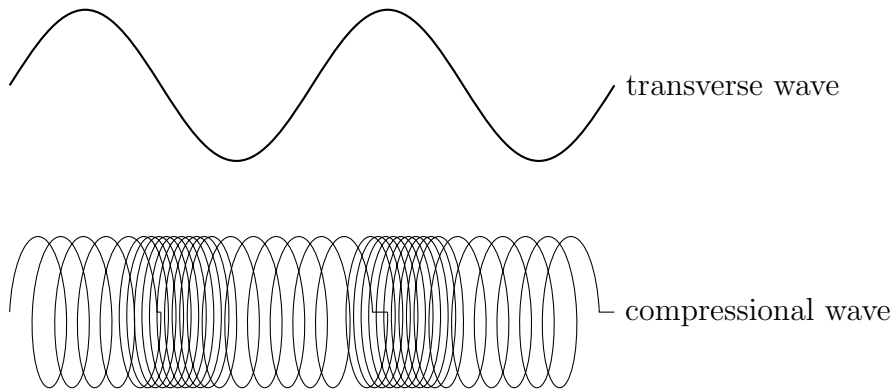
Total Mechanical Energy:

$$\begin{aligned} KE + PE &= \frac{1}{2}mv^2 + \frac{1}{2}kx^2 \\ &= \frac{1}{2}m\omega^2 A^2 \sin^2(\omega t + \phi) + \frac{1}{2}kA^2 \cos^2(\omega t + \phi) \\ &= \frac{1}{2}m\left(\frac{k}{m}\right)A^2 \sin^2(\omega t + \phi) + \frac{1}{2}kA^2 \cos^2(\omega t + \phi) \\ &= \frac{1}{2}kA^2 \left( \sin^2(\omega t + \phi) + \cos^2(\omega t + \phi) \right) \\ &= \frac{1}{2}kA^2 \end{aligned}$$

Because of the properties of the sinusoidal curves, the maximum kinetic energy occurs at  $\omega t + \phi = \frac{\pi}{2}, \frac{3\pi}{2}, \frac{5\pi}{2}, \dots$  and the maximum potential energy at  $\omega t + \phi = 0, \pi, 2\pi, \dots$

## Waves

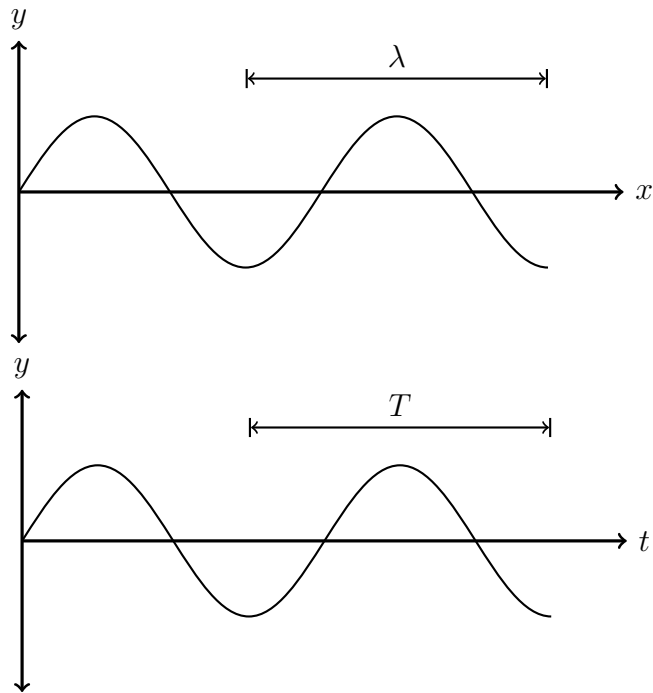
Mechanical waves occur in the form of oscillating springs, strings, and ropes. In nature we can observe seismic waves, water waves, and sound waves. Waves also occur as electromagnetic waves where energy and magnetism oscillate. They occur as transverse or longitudinal waves.



Waves are represented using the following equation:

$$y = y_{max} \cos(kx - \omega t)$$

where  $y_{max}$  is the amplitude,  $k$  is the angular wave number in radians per meter, and  $\omega$  is the angular frequency in radians per second. The distance between one part of the wave to the next identical part in the wave is the wavelength, represented by  $\lambda$ . The time between those occurrences at one position is the period  $T$ .



$$2\pi = k\lambda$$

$$k = \frac{2\pi}{\lambda}$$

$$2\pi = \omega T$$

$$T = \frac{2\pi}{\omega} = \frac{1}{f}$$

We can derive the position function to determine the velocity of a particle in the wave.

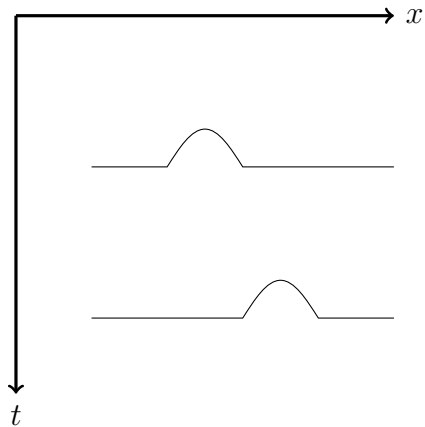
$$y = y_{max} \cos(kx - \omega t)$$

$$v = \frac{dy}{dt}$$

$$= \omega y_{max} \sin(kx - \omega t)$$

## Wave Pattern

The wave is a pattern that moves.



$$y = y_{max} \cos(kx - \omega t)$$

$$\frac{d}{dt}(kx - \omega t) = 0$$

$$k \frac{dx}{dt} - \omega = 0$$

$$\frac{dx}{dt} = \frac{\omega}{k}$$

The points in the wave stay constant as the wave moves. This derivative in terms of time is the speed of the wave pattern.  $y = y_{max} \cos(kx - \omega t)$  represents the wave moving in the positive direction and  $y = y_{max} \cos(kx + \omega t)$  represents the wave moving in the negative direction.

You can find all my notes at <http://omgimanerd.tech/notes>. If you have any questions, comments, or concerns, please contact me at [alvin@omgimanerd.tech](mailto:alvin@omgimanerd.tech)