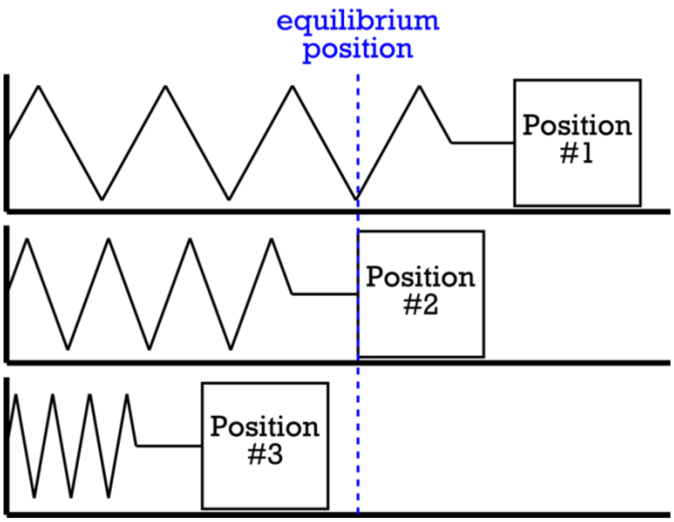
Flipping Physics Lecture Notes:
AP Physics 1 - Unit 7 Review - Oscillations - Exam Prep
http://www.flippingphysics.com/ap-physics-1-unit-7-review.html

This lecture is a free part of my AP Physics 1 Ultimate Review Packet. If you find this video useful, I suggest you invest in the rest of the packet.

Simple Harmonic Motion:
- Periodic motion is motion which is repeated in equal intervals of time.
- Simple Harmonic Motion, or SHM, is periodic motion which results from a restoring force acting on an object where that force is proportional to the displacement of the object from equilibrium or rest position.
    - Equilibrium or rest position is the location where the net force acting on the object is zero. This where the object can remain at rest.
    - A restoring force is always directed towards equilibrium or rest position.

Frequency and Period of Simple Harmonic Motion:
- The period of simple harmonic motion, T, is defined as the time it takes to go through one full cycle or oscillation.
- The amplitude of simple harmonic motion, A, is defined as the maximum distance from equilibrium position.
- The mass-spring system shown in the illustration passes through the arbitrarily numbered positions in the following order: 1, 2, 3, 2, 1, 2, 3, 2, 1, 2, 3, 2, 1, etc
    - The following are all examples of the positions the mass-spring system would move through during one full cycle:
        - 1, 2, 3, 2, 1
        - 2, 3, 2, 1, 2 or 2, 1, 2, 3, 2
        - 3, 2, 1, 2, 3
- Force, acceleration, velocity, and displacement of the mass-spring system for each position are:



a) x_1 = Amplitude; $v_1 = 0$
b) $\|F_{s1}\|$[1] and $\|a_1\|$ are at their maximum
c) F_{s1} and a_1 are directed to the left

d) v_2 is directed to the left or right
e) F_{s2} and $a_2 = 0$
f) $x_2 = 0$; $\|v_2\|$ is at its maximum

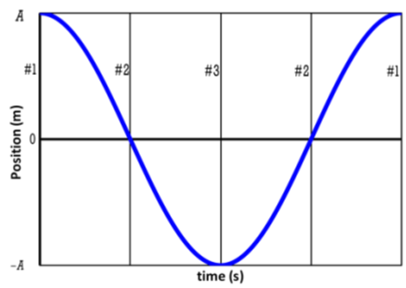
g) x_3 = -Amplitude; $v_3 = 0$
h) $\|F_{s3}\|$ and $\|a_3\|$ are at their maximum
i) F_{s3} and a_3 are directed to the right

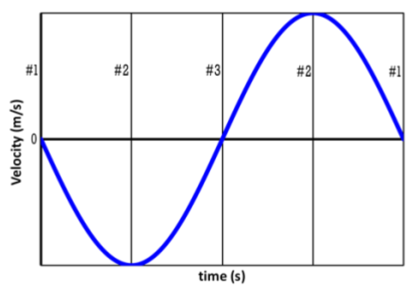
[1] Two vertical lines on either side of a variable in physics means "The magnitude of the variable".

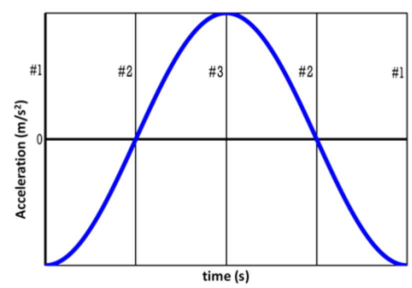
- The equation for the period of a mass-spring system is: $T_{\text{mass-spring}} = 2\pi\sqrt{\frac{m}{k}}$
    - If the mass of a mass in a mass-spring system is increased, the period of the mass spring system increases.
    - If the spring constant of a spring in a mass-spring system is increased, the period of the mass-spring system decreases.
    - If the amplitude of a mass-spring system is changed, the period of the mass-spring system remains the same.
    - If the magnitude of the gravitational field of a mass-spring system is oscillating in is changed, the period of the mass-spring system remains the same.
- The restoring force for a mass-spring system is the force of the spring acting on the mass.
- The equation for the period of a simple pendulum is: $T_{\text{pendulum}} = 2\pi\sqrt{\frac{L}{g}}$
    - A simple pendulum consists of a mass, or pendulum bob, hanging from a string and fixed at a pivot point at the top of the string.
    - "L" in this equation is the distance from the center of suspension to the center of mass of the pendulum bob. This is often referred to as the length of the pendulum.
    - If the length of the pendulum is increased, the period of the pendulum increases.
    - If the magnitude of the gravitational field a pendulum is oscillating in is increased, the period of the pendulum decreases.
    - A simple pendulum is considered to be in simple harmonic motion for small angles.
        - For AP Physics 1 that maximum angle can be as large at 15°.
            - You may see as low as 10°. We do not all agree on this number!
    - If the amplitude of a pendulum is increased, the period of the pendulum remains the same.
        - As long as the amplitude remains below 15°.
    - If the mass of a pendulum bob of a pendulum is increased, the period of the pendulum remains the same.
- The restoring force for a simple pendulum is the component of the force of gravity acting on the pendulum bob which is tangent to the direction of the motion of the bob.
- Frequency, f, of simple harmonic motion is defined as the number of cycles, or oscillations, per second.
    - The units for frequency typically are cycles per second which are called hertz, Hz.
    - Frequency and period are related via the following equation: $f = \frac{1}{T}$
        - This is because frequency and period are inverses of one another.

<u>Representing and Analyzing Simple Harmonic Motion:</u>

- An equation which can describe the position of an object in simple harmonic motion is: $x = A\cos(2\pi f t)$
    - When using this equation for simple harmonic motion, your calculator must be in radian mode.
    - T is for period; t is for time.
    - The only difference between using cosine and sine in this equation is that they are phase shifted from one another by a magnitude of 90° or $\pi/2$ radians.
    - In other words, when you use cosine the initial position of the object is the amplitude, and when you use sine, the initial position of the object is equilibrium position.
- The graphs of position, velocity, and acceleration of a mass-spring system moving through positions 1, 2, 3, 2, and 1 are:







Energy of Simple Harmonic Oscillators:

- The total mechanical energy of an object in simple harmonic motion is the sum of the kinetic energy and the potential energy of the system.
- Due to conservation of mechanical energy, the total mechanical energy of an isolated system in simple harmonic motion is constant.
- When a system in simple harmonic motion has its maximum kinetic energy, its potential energy is at its minimum.
- When a system in simple harmonic motion has its maximum potential energy, its kinetic energy is zero.
- The total mechanical energy of a horizontal, ideal mass-spring system in terms of its amplitude is:
  $$ME_t = \frac{1}{2}kA^2$$
  - If the amplitude of motion of a system in simple harmonic motion is increased, the total mechanical energy of the system is increased.
- The total mechanical energy of a horizontal, ideal mass-spring system in terms of its maximum speed is: $ME_t = \frac{1}{2}m{v_{\text{max}}}^2$
- We can set these two equations equal to one another to solve for the maximum speed of a horizontal, ideal mass-spring system:
  $$ME_t = \frac{1}{2}kA^2 = \frac{1}{2}m{v_{\text{max}}}^2 \Rightarrow kA^2 = m{v_{\text{max}}}^2 \Rightarrow v_{\text{max}} = \sqrt{\frac{kA^2}{m}} = A\sqrt{\frac{k}{m}}$$
  - If the amplitude of motion of a system in simple harmonic motion is increased, the maximum speed is also increased.