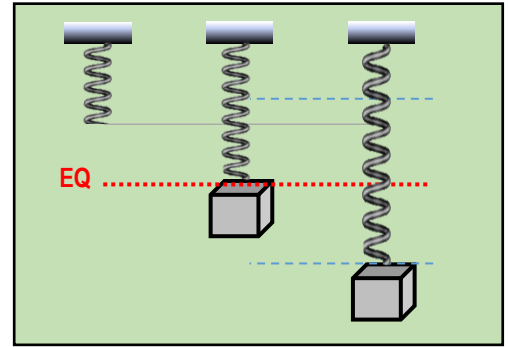


CONCEPT: Vertical Oscillations

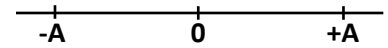
- Vertical mass-spring systems are very similar to horizontal, except:
 - Horizontal $\rightarrow$ Equilibrium at relaxed position ($x = 0$)
 - Vertical $\rightarrow$ Equilibrium where forces _____.

EXAMPLE: You hang a 0.5m spring from the ceiling. When you attach a 5kg mass to it, it stretches by 0.2m. You pull the mass-spring system down an additional 0.3m and release. Find (a) the springs's force constant.
(b) At its maximum height, how far from the ceiling is the block?



- $\Delta L =$ _____
- Equilibrium $\rightarrow$ _____ = _____
- A = additional push/pull, NOT _____

PRACTICE: A spring with spring constant 15 N/m hangs from the ceiling. A ball is attached to the spring and allowed to come to rest. It is then pulled down 6.0 cm and released. If the ball makes 30 oscillations in 20 s, what are its (a) mass and (b) maximum speed?



Mass-Spring SHM Equations	
$ F_S = F_A = kx$ $a = -\frac{k}{m}x$	$\rightarrow F_{\max} = \pm kA$ $\rightarrow a_{\max} = \pm \frac{k}{m}A$
$x(t) = + A \cos(\omega t)$ $v(t) = -A\omega \sin(\omega t)$ $a(t) = -A\omega^2 \cos(\omega t)$	$\rightarrow x_{\max} = \pm A$ $\rightarrow v_{\max} = \pm A\omega$ $\rightarrow a_{\max} = \pm A\omega^2$
$\omega = 2\pi f = \frac{2\pi}{T} = \sqrt{\frac{k}{m}}$ $N [\text{cycles}] = \frac{t [\text{time}]}{T [\text{Period}]} = t * f$	
$M.E. = \frac{1}{2}kA^2 = \frac{1}{2}mv_{\max}^2 = \frac{1}{2}kx_p^2 + \frac{1}{2}mv_p^2$ $v(x) = \omega\sqrt{A^2 - x^2}$	

EXAMPLE: An elastic cord is 65 cm long when a weight of 75 N hangs from it but is 85 cm long when a weight of 180 N hangs from it. What is the “spring” constant k of this elastic cord?

PRACTICE: A chair of mass 30 kg on top of a spring oscillates with a period of 2s. **(a)** Find the spring's force constant. You place an object on top of the chair, and it now oscillates with a period of 3s. **(b)** Find the object's mass.