Chapter 15: Oscillations

- periodic motion: motion that repeats itself at regular time intervals
- period (*T*): time to complete one oscillation (seconds)
- frequency (ν): number of oscillations per unit time (Hz, one cycle/second)
- simple harmonic motion: oscillations in which the acceleration (+ net force) of a system is proportional to the displacement and acts in the opposite direction of the displacement ex/ a spring on a frictionless surface with mass *m* attached
- equilibrium position: position where the spring is neither stretched nor compressed (typically x = 0)
- With vertical spring motion, the force of gravity acts to change the equilibrium position of the spring. Both Fg and Fs act on the spring.
- Total mechanical energy of a horizontal spring system = U + K = $\frac{1}{2}Kx^2 + \frac{1}{2}mv^2 = \frac{1}{2}KA^2$
- stable equilibrium point = forces on either side of eq point act to return an object to a stable eq point
- unstable equilibrium = forces on either side of eq point act to move object away from unstable eq point
- physical characteristics of springs
  - if cut in half, the spring constant on each new spring doubles (series combination)
  - if the length is doubled, the new spring constant will halve
  - if two springs are placed next to each other, the new spring constant will be k1 + k2 (parallel combination)

Equations

$F = -kx$

spring force; spring constant; displacement

$U = \frac{1}{2}k(\Delta x)^2$

spring potential energy

$-kx = ma_x$

$-kx = m\frac{d^2x}{dt^2}$

$\frac{d^2x}{dt} + \left(\frac{k}{m}\right)x = 0$

characteristic equation of simple harmonic motion

$x = A\cos(\omega t + \phi)$

amplitude (max displacement); rad/sec; sec; phase shift: when starting at a $\theta \neq 0$, shifts x coordinate

so $x_{max} = A$

where $v = -\omega A \sin(\omega t + \phi) \rightarrow v_{max} = \omega A$ (occurs at equilibrium)

and $a = -\omega^2 A\cos(\omega t + \phi) \rightarrow a_{max} = \omega^2 A$ (occurs at extremes)

remembering that $\omega = 2\pi\nu$ and $T = \frac{1}{\nu}$

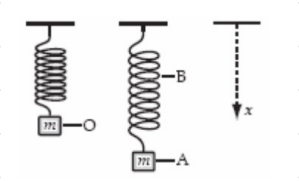
$\omega = \sqrt{\frac{k}{m}}$

$E = \frac{1}{2}kA^2$

total mechanical energy; amplitude (max displacement)

Practice Problems

1. (easy) A light flashes every 8.00e-5 seconds. What is the frequency of the flashes?
2. (medium) When an 80.0-kg man stands on a pogo stick, the spring is compressed 0.120 m.
   a) What is the spring constant?
   b) Will the spring be compressed more when he hops down the road?
3. (hard) A weight of mass m is at rest at O when suspended from a spring, as shown. When it is pulled down and released, it oscillates between positions A and B.
   a) At what point does the rate of change of its momentum have the greatest magnitude?
   b) Where is the point of greatest gravitational potential energy?
   c) Where is the point of least elastic potential energy?



Solutions

1. $T = 8 * 10^{-5}$

   $V = \frac{1}{T} = \frac{1}{8 * 10^{-5}} = 12,500 \text{ Hz}$

2. a) $F = ma = -K\Delta X$

   $mg = -K\Delta X$

   $(80)(9.8) = -K(0.120)$

   $K = 6533$

   b) Yes. When the man is at his lowest point in his hopping the spring will be compressed the most.

3. a) A and B
   b) B
   c) O