Simple Harmonic Motion

vibration ----> a periodic back-and-forth motion ("oscillation") about some rest position

Periodic motion is any type of motion which repeats itself in equal time periods.

[ex.'s: rotation and revolution of earth, pendulum, tuning fork, guitar string, vocal cords]

>Musical tones result from periodic vibrations.

>Non-musical sounds are non-periodic ----> "noise" [howl, whistle, squel, rustle, rumble, and hum]
"shrill" [siren, whistle, nails on blackboard]

-A complete vibration is called a "cycle" ----> 360° of motion.

The simplest form of vibrating motion is called "simple harmonic motion." (SHM).

Two conditions for SHM;

1. Moving matter must have an "equilibrium position" ----> position when motionless.

2. Restoring force is linearly proportional to displacement.
[show overheads; hanging spring & weighted pencil with moving paper = sinusoidal curve]

Hooke's law of elasticity (1678): $\mathbf{F = -kx}$

> The deformation of a solid body is proportional to the force acting on it (up to the elastic limit).

> The restoring force of a spring is proportional to the displacement and the stiffness of the spring.

> Within the elastic limit of any body, the ratio of the stress to the strain produced is constant.

> The "stiffness coefficient" of the spring is known as "k" and is a constant (up to the the elastic limit). When stress is applied, the strain will correspond, and the ratio will be constant up to a limiting value of stress ----> "elastic limit."

> The minus sign indicates that the resistance force exerted by the spring is always directed opposite to the displacement, and towards the equilibrium position.
[*note!* Springs can be pushed *or* pulled from equilibrium.]

ex; A spring with (k) of 25 lb/in. is stretched 2 inches. What is the weight of the object hanging from it?

sol; w = mg = F = kx = (25 lb/in.)(2 in.) = **50 lb**

Dampening - when driving force (F) is removed, and energy is lost through friction.
ex; shock absorbers speed up the decrease of amplitude(A).

The # of cycles occurring in one second = frequency (f). [*a.k.a*...... v.p.s. *or* c.p.s. *or* Hertz (Hz)]

> (f)'s are inversely related to how big the object is that is vibrating.

Wave Anatomy :

[<u>terms</u>; amplitude (A), wavelength (λ), frequency (f), node* = equilibrium position, antinode = crest]

* When there is a "standing wave" there will be no motion in the string at the nodes, whereas all other locations oscillate vertically with the same frequency.

Since (f) = $^{\#\ cycles}/_{sec}$, and the time for one cycle is the period (T) of oscillation, then; $f = {}^{1}/_{T}$ $({}^{1}/_{sec.})$
[note that $T = {}^{1}/_{f}$]

ex; What is the frequency of a pendulum with a period of 2 s?

sol; $f = {}^{1}/_{2\ s}$ = **0.5 Hz**

ex; What is the period of a pendulum with a frequency of 0.75 Hz? sol; $T = {}^{1}/_{f} = {}^{1}/_{0.75\ Hz}$ = **1.33 s**

>The period of oscillation can also be expressed in terms of (m) & (k). $T = 2\pi\sqrt{{}^{m}/_{k}}$

ex; A mass of 0.10 kg oscillates on a spring with a stiffness (k) of 16 N/m. What is the period of oscillation?

sol; $T = 2\pi\sqrt{0.10\ kg / 16\ N/m}$ = **0.5 s**

ex; A spring stretches 3.9 cm when a 10 g mass is hung from it. If a total of 25 g is hung from this spring and is set into simple harmonic motion, then what will be the period of the motion?

sol; What is (k)? $F = -kx$ ----> $k = {}^{F}/_{x} = (0.01\ kg)(9.8\ m/s^2) / 0.039\ m = 2.51\ N/m$

$T = 2\pi\sqrt{0.025\ kg / 2.51\ N/m}$ = **0.627 s**

ex; The frequency of a 4 g mass oscillating on a spring is 5 Hz. What is the (k) constant of this spring?

sol; If $f = {}^{1}/_{T}$, then $f = {}^{1}/_{2\pi}\sqrt{{}^{k}/_{m}}$ ----> $k = 4\pi^2 f^2 m = 4\pi^2(5\ Hz)^2(0.004\ kg)$ = **3.95 N/m**