

## 4.1 Kinematics of SHM (May 31).notebook

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So what is simple harmonic motion and what is the defining equation?

Consider the force acting on a body executing SHM (a bob oscillating on a horizontal spring, for example):

Bob is to the right of equilibrium. Spring is stretched. Force is to the left (-). Acceleration is to the left (-). Position is to the right (+).

Bob is at equilibrium. No displacement, hence no force.

Bob is to the left of equilibrium. Spring is compressed. Force is to the right (+). Acceleration is to the right (+).

Recall Hooke's Law  $\rightarrow$  force is proportional to the displacement from equilibrium.

$F = -kx$  (negative)

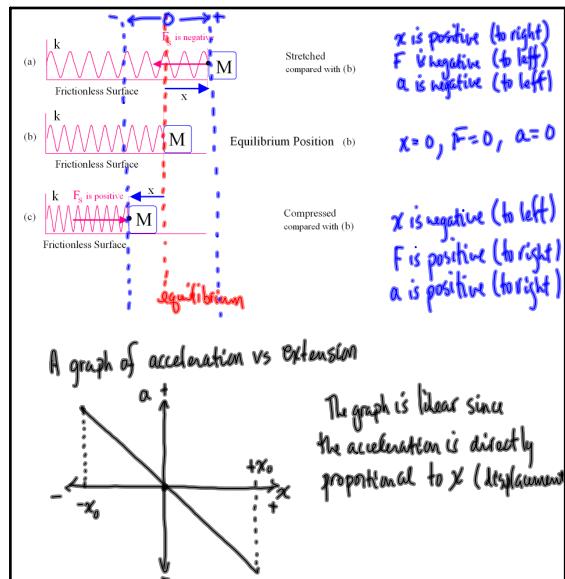
When  $k$  is the spring or force constant:

Recall Hooke's 2nd Law:  $F = -kx \Rightarrow$  when  $x$  is the displacement after  $x_0$ ,  $a$  is the acceleration.

$a = -kx/m$

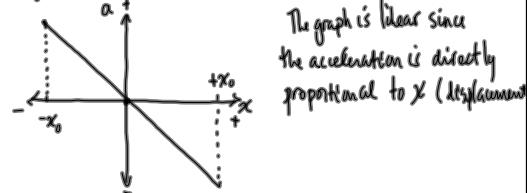
Acceleration is directly proportional to the displacement but in the opposite direction (i.e. towards the equilibrium).

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A graph of acceleration vs extension



**Definition of Simple Harmonic Motion**

SHM is oscillatory motion in which the acceleration is:

- proportional to the displacement and
- is directed toward the equilibrium.

Show the acceleration is directly proportional and in the opposite direction, we can write a proportionality statement:

$$a \propto -x$$

Defining Equation for SHM

$$a = -\omega^2 x$$

where  $x$  is the displacement  
 $a$  is the acceleration  
 $\omega^2$  is the proportionality constant

In this case (in lab situation), how about the significance of  $\omega^2$  amplitude?

$a = -\frac{\omega^2}{m} x$   
 $a = -\omega^2 x$   
 $so \quad \omega^2 = \frac{k}{m}$

**Note:**

- We often kinematics problems involving SHM using our "usual" equations because the acceleration is NOT constant during SHM. The acceleration is continually changing!
- The significance of the kinematics graphs ( $s-t$ ,  $v-t$ ,  $a-t$ ) are still valid!

(1) (2) (3)

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To show that an oscillatory motion IS simple harmonic motion, then we must show that:

$$a \propto -x$$

Consider the pendulum: It has oscillatory motion, but is it SHM???

restoring force

$$F_{\text{rest}} = mg \sin \theta$$

$$F_{\text{rest}} = mg \frac{x}{l}$$

$$ma = \frac{mg}{l} x$$

$$a = \frac{g}{l} x$$

insert -ve since acc is opp  $x$

Recall:  $a = -\omega^2 x$  ← since the acceleration of the pendulum fits the defining equation for SHM, then its oscillatory motion is indeed SHM.

$$\therefore \omega^2 = \frac{g}{l}$$

$$v = \omega x \quad \omega = \frac{v}{x}$$

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