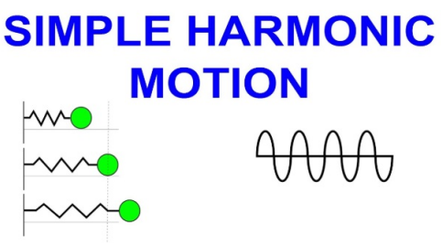
Physics 2204
Unit 3: Energy, Work and Power
Worksheet #10: Simple Harmonic Motion

Student Name:_____

Simple harmonic Motion (SHM)is periodic motion in the absence of friction and produced by a restoring force that is directly proportional to the displacement and oppositely directed.

An example of simple harmonic motion would be a mass attached to a spring moving back and forth Objects.

$$F = -k\Delta x$$

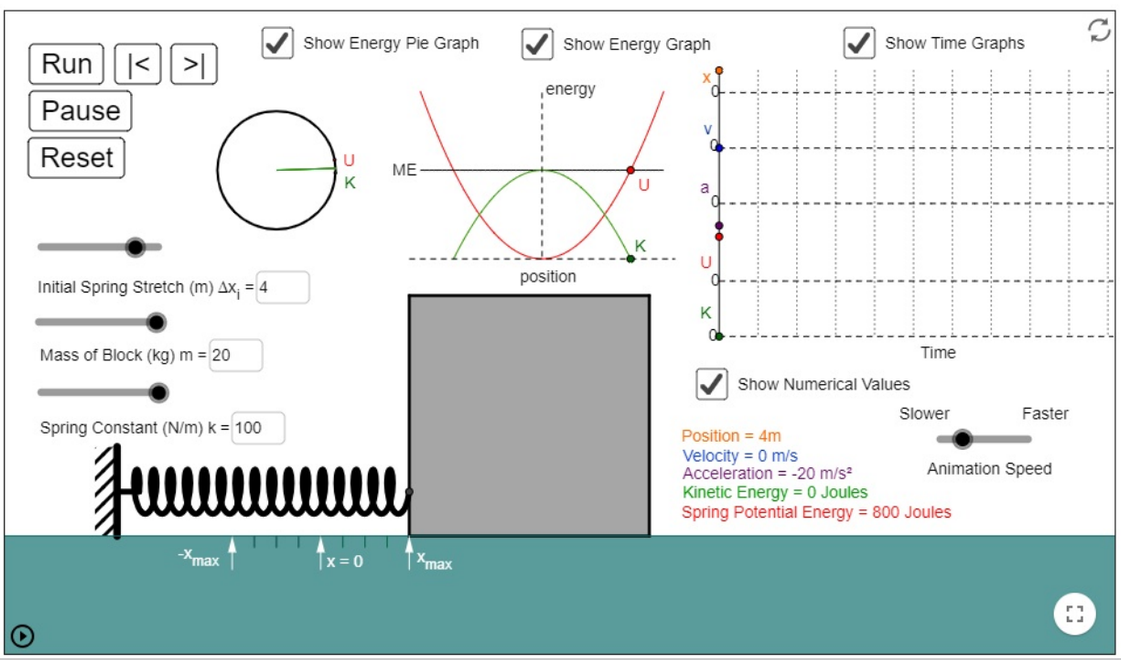


Below is a link to study simple harmonic motion:

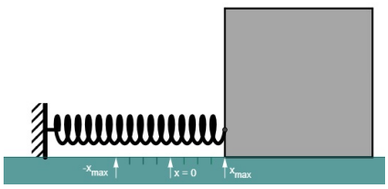
https://www.geogebra.org/m/pY4Hvugh

Use this link to get information about a mass undergoing simple harmonic motion.

Set Initial Stretch to 4 m

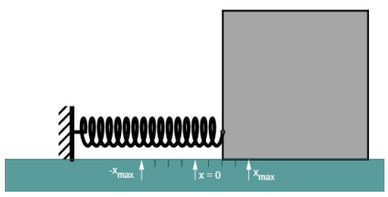


Position 1:At x = + X_{max}



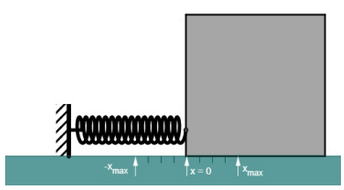
P_E	K_E	E_{total}	$\vec{x}$	$\vec{v}$	$\vec{a}$

Position 2:At x= + 2m moving left



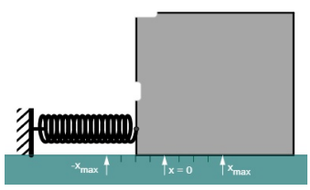
P_E	K_E	E_{total}	$\vec{x}$	$\vec{v}$	$\vec{a}$

Position 3:At x=0 m moving left



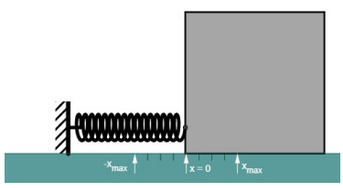
P_E	K_E	E_{total}	$\vec{x}$	$\vec{v}$	$\vec{a}$

Position 4: At x= -2 m moving left



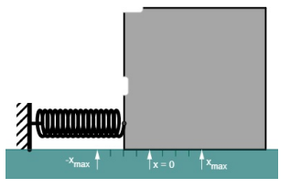
P_E	K_E	E_{total}	$\vec{x}$	$\vec{v}$	$\vec{a}$

Position 5: At x=- X_{max} moving left



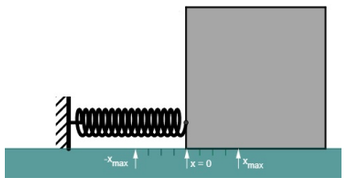
P_E	K_E	E_{total}	$\vec{x}$	$\vec{v}$	$\vec{a}$

Position 6: At x= -2 m moving to the right



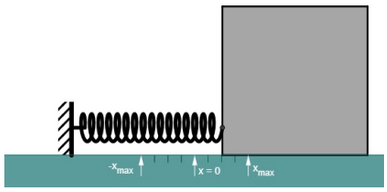
P_E	K_E	E_{total}	$\vec{x}$	$\vec{v}$	$\vec{a}$

Position 7:At x=0 m moving to the right



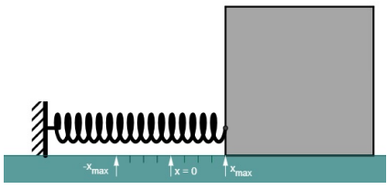
P_E	K_E	E_{total}	$\vec{x}$	$\vec{v}$	$\vec{a}$

Position 8:At x= + 2m moving to the right



P_E	K_E	E_{total}	$\vec{x}$	$\vec{v}$	$\vec{a}$

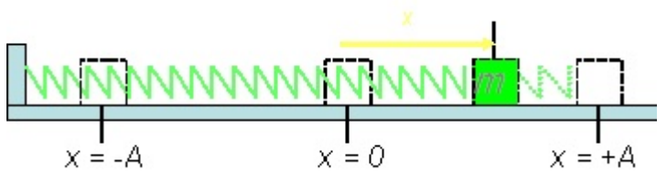
Position 9:At x= + X_{max}



P_E	K_E	E_{total}	$\vec{x}$	$\vec{v}$	$\vec{a}$

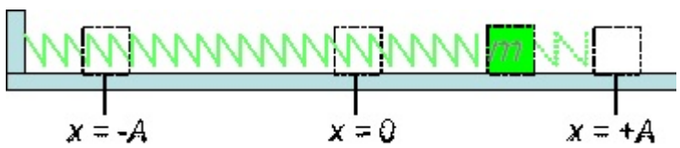
From the simulation:

Displacement in SHM:



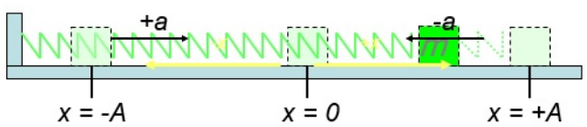
- Displacement is positive when the position is to the right of the equilibrium position (x = 0) and negative when located to the left.
- The maximum displacement is called the amplitude A.

Velocity in SHM



- Velocity is positive when moving to the right and negative when moving to the left.
- It is zero at the end points and a maximum at the midpoint in either direction (+ or -).

Acceleration in SHM:



- Acceleration is in the direction of the restoring force. (a is positive when x is negative, and negative when x is positive.)
- Acceleration is a maximum at the end points and it is zero at the center of oscillation.
- Acceleration is always opposite to displacement.

To calculate acceleration we use Newton's Second Law :

$$\vec{F} = m\vec{a}$$

Remember Hooke's Law for an elastic material: $\vec{F} = -k\vec{x}$, substitute into Newton's Second Law

$$-k\vec{x} = m\vec{a}$$

Rearrange this formula:

$$\vec{a} = -\frac{k\vec{x}}{m}$$

From the simulation, list the variables you put in and use the formula to calculate the acceleration:

From simulation: Calculation:

k = _____

m =_____

x = _____

a = _____

Your calculation (agreed / disagreed) with the simulation

Example 1:

A 2.0kg mass hangs at the end of a spring whose constant is k = 400 N/m. The mass is displaced a distance of 12 cm and released. What is the acceleration at the instant the displacement is x = +7.0 cm?

Example 2:

A 150 g mass is attached to a spring and pulled 7.5 cm to the right with a force of 12.0 N. The system oscillates horizontally.

(A) Draw a rough sketch of the set-up. Calculate

(B) The maximum acceleration of the mass

(C) The acceleration when the mass is in the mid-point of the oscillation

(D) The acceleration 5.0 cm to the right of the equilibrium position

(E) The acceleration 6.0 cm to the left of the equilibrium position

Example 3:

A spring with a 0.250 kg mass attached is stretched 12.0 cm from equilibrium by a force of 7.5 N. Determine

(A) The amplitude of the oscillation

(B) The maximum velocity

(C) The magnitude of the velocity when the mass is at half-amplitude.

PART A: MULTIPLE CHOICE

Instructions: Shade the letter of the correct answer on the computer scorable answer sheet provided

1. A mass on a spring undergoes SHM. The maximum displacement from the equilibrium is called?

   (A) Amplitude
   (B) Frequency
   (C) Period
   (D) Wavelength

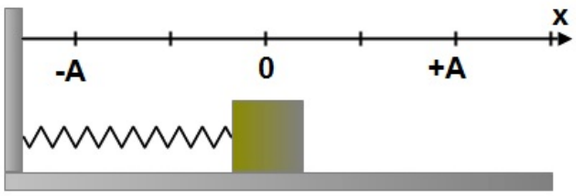
2. For simple harmonic motion which of the following statements is/are true?

   (A) The attached mass moves to the right of the equilibrium position the same distance it moves to the left of the position
   (B) The force exerted on the mass is inversely proportional to the displacement from its equilibrium position
   (C) The force is directed from the equilibrium position in the direction of the motion of the mass
   (D) The acceleration of the mass is not equal to zero at the equilibrium point.

3. In the following choices x = the position of the mass, and A = the amplitude of the SHM. Which of the following statements is/are true?

   (A) Maximum velocity occurs when x = A
   (B) Maximum velocity occurs when x = -A
   (C) Maximum velocity occurs when x = |A|
   (D) Maximum velocity occurs when x = 0

A mass in the diagram to the right undergoes simple harmonic motion. Use this diagram to answer questions 4 through 7.



4. When the mass reaches point x = +A its instantaneous velocity is?

(A) Less than maximum and positive
(B) Maximum and positive
(C) Maximum and negative
(D) Zero

5. When the mass reaches point x = 0 its instantaneous velocity is?

(A) Constant and doesn't depend on the location
(B) Maximum and can be positive or negative
(C) Slightly less than maximum and positive
(D) Zero

6. When the mass reaches point x = +A its instantaneous acceleration is?

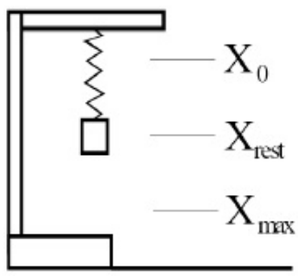
(A) Maximum and positive
(B) Maximum and negative
(C) Slightly less than maximum and positive
(D) Zero

7. When the mass reaches point x = - A its instantaneous acceleration is?

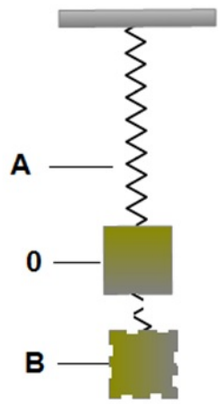
(A) Maximum and positive
(B) Maximum and negative
(C) Slightly less than maximum and positive
(D) Zero

8. A block on a spring demonstrates simple harmonic motion by bobbing up and down. Which statement about the block's energy is true as it travels from position X_o to X max?

(A) Elastic potential energy is constant.
(B) Gravitational potential energy is constant.
(C) Kinetic energy is constant.
(D) Total mechanical energy is constant



In the diagram to the right, a mass suspended at the end of an elastic spring undergoes SHM between point A and B. Use this diagram for questions 9 and 10.



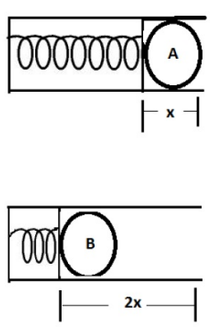
9. At which location of the mass the system has the maximum kinetic energy?

(A) Only point A
(B) Only point B
(C) Only point 0
(D) Point A and B

10. At which location of the mass the system has the maximum elastic potential energy?

(A) Only point A
(B) Only point B
(C) Only point 0
(D) Point A and B

11. Two balls with the same mass are placed on springs with the same spring constant. If spring B is compressed twice as much as spring A, how will the speed of ball B compare with the speed of ball A when they leave the springs?



(A) 1/4 times as large
(B) 1/2 times as large
(C) 2 times as large
(D) 4 times as large

12. An object with a mass of 1.0 kg on a frictionless table is attached to a spring with a spring constant of 16 N/m. The object is pulled 0.50 m from the equilibrium position and released. What is the maximum kinetic energy of the object?

(A) 0.50 J
(B) 1.0 J
(C) 2.0 J
(D) 4.0 J

13. A 1.0 kg mass is attached to the end of a vertical ideal spring with a force constant of 400 N/m. The mass is set in simple harmonic motion with an amplitude of 10 cm. What is the speed of the 1.0 kg mass at the equilibrium position?

(A) 2.0 m/s
(B) 4.0 m/s
(C) 2.0×10^{1} m/s
(D) 40×10^{1} m/s

14. A 275 g mass is attached to a spring and pulled 9.5 cm to the left with a force of 15.0 N. The system oscillates horizontally. What is the acceleration of the mass at -9.5 cm?

(A) $-0.52\ m/s^2$
(B) $-55\ m/s^2$
(C) $+0.52\ m/s^2$
(D) $+55\ m/s^2$

Part B: Written Response

1. A horizontal spring having a spring constant of 40.0 N/m undergoes simple harmonic motion when a 1.20 kg mass stretches it 20.0 cm from its rest position. Calculate the speed of the mass when it is 5.00 cm from the rest position. June 2010

2. A 5.00×10^2 g mass is attached to a vertical spring of force constant 40.0 N/m.

   a) How far below the bottom of the empty spring will the rest position be?
   [Answer is 0.123 m]

   b) If the spring is stretched a further 35 cm, how much stored energy will the spring have?
   [Answer is 2.45 J]

   c) What is the maximum velocity of the mass? **[Answer is 3.13 m/s]**

3. A spring stretches 0.150m when a 0.30 kg mass is hung from it. The spring is then stretched an additional 0.100 m from this equilibrium point and then released.

   a) What is the spring constant? **[Answer is 19.6 N/m]**

   b) The maximum velocity**[Answer is 0.81 m/s]**

   c) The when the mass is 0.050m from the equilibrium motion. **[Answer is 0.70 m/s]**

   b) The maximum acceleration of the mass **[Answer is 6.5 m/s^2]**

4. A 500-g puck is connected to the side of an air table by a spring. A force of 1.4 N is applied to pull the puck 8.0 cm to the right. Then, the puck is released.

   a) What is the maximum acceleration of the puck? **[Answer is -2.8 m/s^2]**

   b) What is the acceleration of the puck as it passes its original rest position? **[Answer is 0 m/s^2]**

5. A spring with a spring constant of 80.0 N/m has a 1.5-kg block attached to its free end. If the block is pulled out 50.0 cm from its rest position and released, what is its speed when it returns to the equilibrium position? Assume there is no friction. **[Answer is 3.7 m/s]**

6. If a spring with k 12 N/m is connected to a mass of 230 g and set in motion with an amplitude of 26 cm, calculate the speed of the mass as it passes the equilibrium point.

7. A 2.0-kg mass on a spring is extended 0.30 m from the equilibrium position and released. The spring constant is 65 N/m.

   a) What is the initial potential energy of the spring?**[Answer is 2.93 J]**
   b) What maximum speed does the mass reach?**[Answer is 1.71 m/s]**
   c) Find the speed of the mass when the displacement is 0.20 m.**[Answer is 1.27 m/s]**

8. Consider a spring of k 16 N/m connected to a block mass (m) and having an amplitude of motion of 3.7 cm. What is the total energy of this system? **[Answer is 0.011 J]**

9. A 5-g bullet is discharged at 350 m/s into a mass spring system. If the mass is 10 kg and the spring constant is 150 N/m, how far will the spring be compressed if the bullet stays in the mass? **[Answer is 3.3 x 10^{-4} m]**

10. A 20 kg box is attached to a compressed spring that has a spring constant of 300 N/m. The box is resting on a frictionless surface and the spring is compressed 30 cm.

    a. What is the EPE of the spring? **[Answer is 13.5 J]**
    b. What will be the KE of the box when the spring expands back to its natural length? **[Answer is 13.5 J]**
    c. How fast will the box be moving after the spring releases the box? **[Answer is 1.2 m/s]**