Name________________________________ **Date**_______

AP Physics 1

Simple Harmonic Motion and Springs

Hookean Spring

$$F_S = -k\Delta x$$

$$-W_S = U_S = -\tfrac{1}{2}k(\Delta x^2)$$

Simple Harmonic Motion of Spring

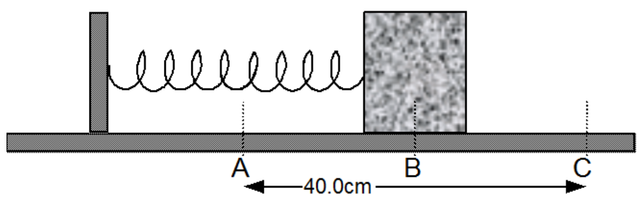
$$T = 2\pi\sqrt{\frac{m}{k}}$$

$$x = A\cos(\omega t) = A\cos(2\pi f t)$$

$$a = \frac{F}{m} = \frac{-kx}{m}$$

1. What are the two criteria for simple harmonic motion?

2. The diagram to the right shows a 2 kg block attached to a Hookean spring on a frictionless surface. The block experiences no net force when it is at position B. When the block is to the left of point B the spring pushes it to the right. When the block is to the right of point B, the spring pulls it to the left.



The mass is pulled to the left from point B to point A and released at time t = 0. The block then oscillates between positions A and C. Assume that the system consists of the block and the spring and that no dissipative forces act.

a) The block takes 40.0 s to make 20 oscillations. What is the "period of oscillation" for this system?

b) What is the frequency of this oscillating system?

c) What is the amplitude of vibration of this system?

d) Determine the spring constant of the spring.

e) Write an equation that describes the position of the mass as a function of time, starting from position A at time t =0.

f) Explain what would happen to the period and frequency of this system if you were to double the amplitude while keeping the mass and spring constant the same.

g) Explain what would happen to the period and frequency of this system if you were to double the mass while keeping the amplitude and spring constant the same.

h) Explain what would happen to the period and frequency of this system if you were to double the spring constant while keeping the amplitude and mass constant.

i) Determine the amount of energy of the oscillating spring and mass system.

j) Where does the block have maximum speed and what is the maximum speed?

k) Where does the block experience maximum acceleration and what is the maximum acceleration?

l) What would happen to the energy if the amplitude of oscillation were tripled while keeping the mass and spring constant unchanged?

m) What would happen to the maximum speed if the amplitude of oscillation were tripled while keeping the mass and spring constant unchanged?

3. A 5 kg mass is attached to a spring that is hanging vertically. The spring is stretched 0.25 m from its equilibrium position.
   a) What is the spring constant?

   b) What mass would be required to stretch the spring three times the distance?

   The 5 kg object hanging on the spring is allowed to come to its new equilibrium. It is then set in motion by stretching it a further 0.3m. The mass oscillates in simple harmonic motion

   c) What is the period of the oscillation?

4. A 4.0 kg mass on a spring is stretched and released. The period of oscillation is measured to be 0.46 s. What is the spring constant?

5. A weight in a spring-mass system exhibits harmonic motion. The system is in equilibrium when the weight is motionless. If the weight is pulled down or pushed up and released, it would tend to oscillate

freely if there were no friction. In a certain spring-mass system, the weight is 5 feet below a 10-foot ceiling when it is at rest. The motion of the weight can be described by the equation, $y = 3\sin(\pi t)$, where y is the distance from the *equilibrium point*, and t is measured in seconds.

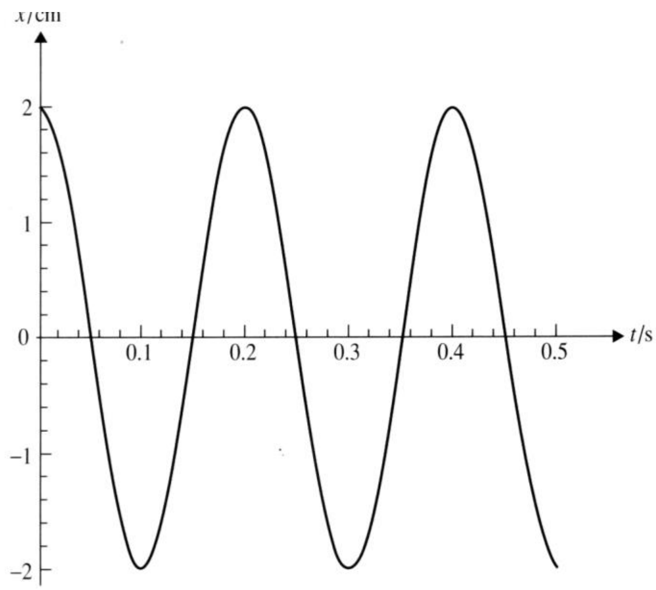
a) Find the period of the motion.

b) What is the frequency of the motion?.

c) Find the amplitude of the motion.

d) How far from the ceiling is the weight after 3.5 seconds?

6. The graph in the figure shows the displacement of a 0.040 kg particle from a fixed equilibrium position.



Use the graph to determine:

a) the period of motion

b) the maximum speed of the particle during oscillation,

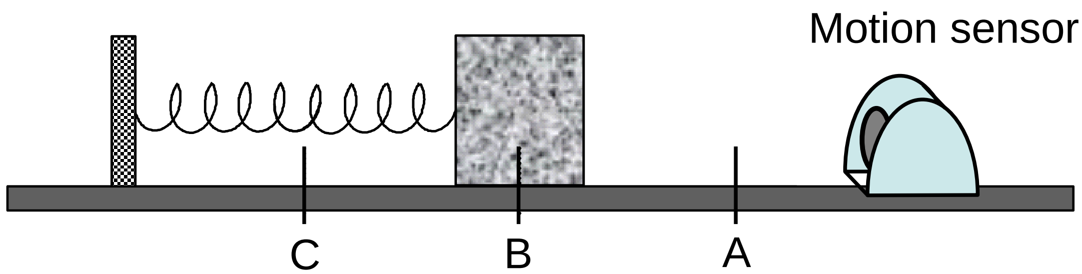
c) the maximum acceleration experienced by the particle.

On the graph, mark the following

a) a point where the velocity is zero (label this as Z)

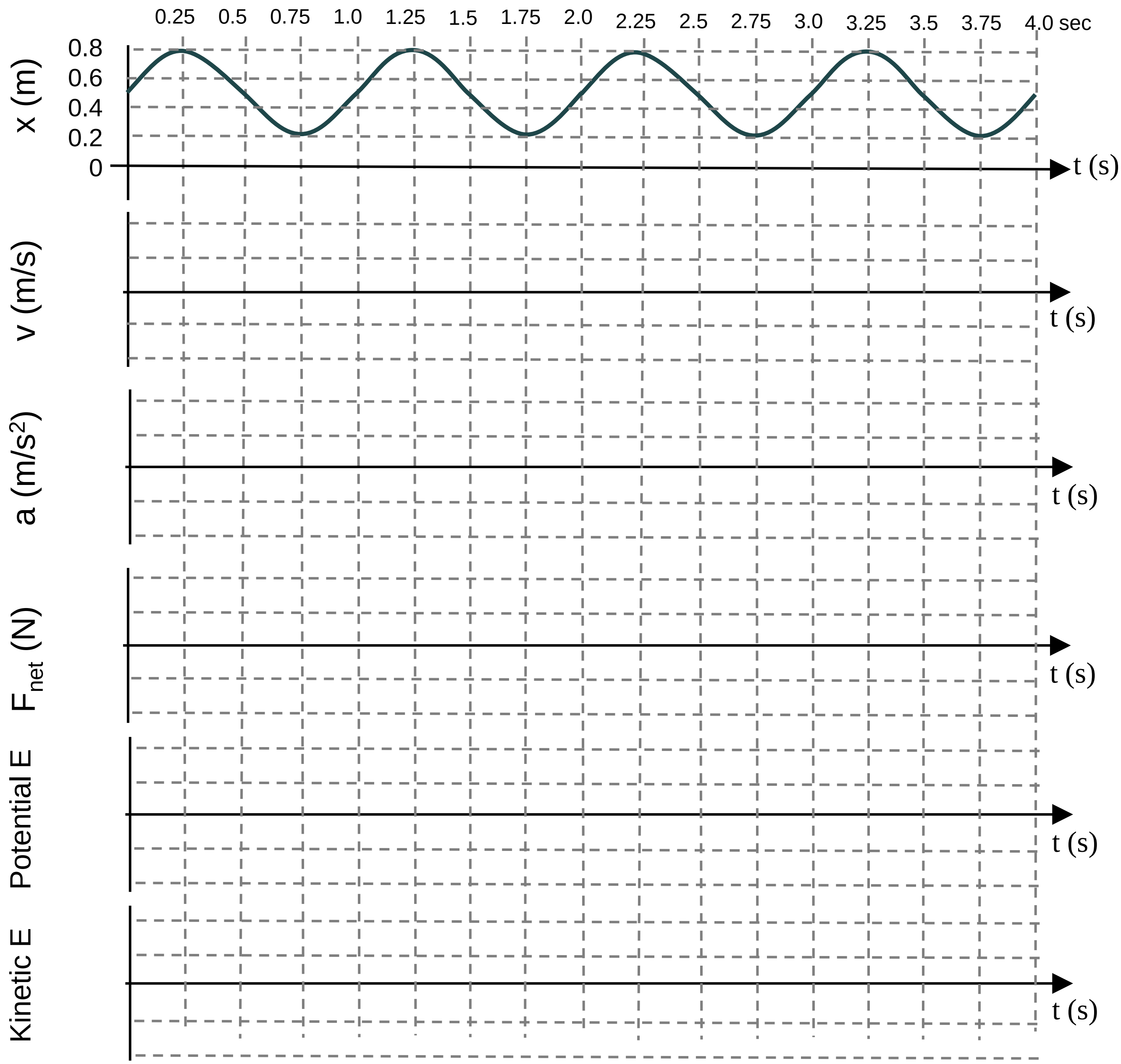
b) a point where the velocity is positive and has the largest magnitude (label this as V)

c) a point where the acceleration is positive and has the largest magnitude (label this as A).



7. The diagram above shows a 2 kg block attached to a Hookean spring on a frictionless surface. The block experiences no net force when it is at position B. When the block is to the left of point B the spring pushes it to the right. When the block is to the right of point B, the spring pulls it to the left.

   The mass is pulled to the left from point B to point A and released. The block then oscillates between positions A and C. A motion sensor placed to the right of position A gathers position-time data for the oscillating block. The position vs. time graph below describes the motion of this system for four cycles.



a) What is the period of oscillation for this system?

b) What is the frequency of this oscillating system?

c) What is the amplitude of vibration of this system?

d) Determine the spring constant of the spring

e) Complete sketches for the other graphs shown based on the position vs. time graph. Label maxima and minima with numerical values on the axes.
Some things to consider when you sketch the graphs:
- You can make qualitative v-t and a-t sketches by considering the slopes of appropriate graphs
- Remember that $Us = ½\, k\Delta x^2$ where $\Delta x = x-x_0$ is displacement from equilibrium ($x_0 = 0$ at the equilibrium position) Us is NOT $½\, kx^2$ when $x_0 = 0$ at the motion sensor.
- Remember that $a = Fnet/m = (-kx)/m$

Show calculations necessary to label the graphs (max and min values of each variable)

f) What is the average velocity of the block during one cycle?

g) What is the average speed of the block during one cycle?

h) If the frequency of the oscillation were doubled, what would the average speed of the block be during one cycle?

Answers

2a) 2 s b) 0.5Hz c) 0.2m d) 19.7 N/m f) no change g) T increases 1.41x h) T goes to 0.71xs

2i) 0.394J j) 0.63m/s k) 1.97m/s^2 l) increases 9xs m) triples

3a) 196 N/m b) 3xs c) 1.00s

4. 746N/m

5a) 2s b) 0.5 Hz c) 3ft d) 8ft

6a) 0.2s b) 63.2m/s c) 2000m/s^2

7a) 1.0s b) 1.0s c) 0.3m d) 78.7N/m f) 0m/s g) 1.2m/s h) 2.4m/s