The displacement of a particle oscillating along the x axis is given as a function of time by the equation: 
\[ x(t) = 0.50 \cos(\pi t + \pi/2) \]. What is the magnitude of the maximum acceleration of the particle? (Ans: 4.9 m/s²)

A particle oscillates in simple harmonic motion according to the equation: 
\[ x = 0.20 \cos(\pi t) \]. What is the period of the motion? (Ans: 2.0 s)

An object undergoing simple harmonic motion takes 0.25 s to travel from one point of zero velocity to the next such point. The distance between those points is 40 cm. What are the amplitude and frequency of the motion? (Ans: 20 cm, 2 Hz)

The displacement of a particle moving with simple harmonic motion is given by: 
\[ x = 0.02 \cos (300 t - \pi/3) \], where \( x \) is in meters and \( t \) is in seconds. What is the maximum speed of the particle? (Ans: 6 m/s)

A block of mass \( m = 0.1 \) kg oscillates on the end of a spring with a spring constant \( k = 400 \) N/m in simple harmonic motion with a period \( T \). The position of the block is given by 
\[ x(t) = (10.0 \text{ cm}) \cos (\omega t) \]. What is the work done on the block by the spring as it moves it from \( t = 0 \) to \( t = T/8 \). Ignore friction. (Ans: 1.0 J)

A particle is in simple harmonic motion along the x axis. The amplitude of the motion is \( x_m \). At one point in its motion, its kinetic energy is \( K = 5 \) J and its potential energy (measured with \( U = 0 \) at \( x = 0 \)) is \( U = 3 \) J. When it is at \( x = x_m \), what are the kinetic and potential energies? (Ans: \( K = 0 \) and \( U = 8J \))

A 3.0-kg block, attached to a spring, executes simple harmonic motion according to 
\[ x = 2.0 \cos (50t) \], where \( x \) is in meters and \( t \) is in seconds. What is the spring constant? (Ans: 7500 N/m)

A 2.0-kg mass connected to a spring of force constant 8.0 N/m is displaced 5.0 cm from its equilibrium position and released. It oscillates on a horizontal, frictionless surface. Find the speed of the mass when it is 3.0 cm from its equilibrium position. (Ans: 0.08 m/s)

The displacement of a block-spring system is described by the equation: 
\[ x(t) = 0.2\cos (10t) \], where \( x \) is in meters, and \( t \) is in seconds. What is the speed of the block when its displacement is \( x = 0.1 \) m? (Ans: 1.73 m/s)

A block-spring system has an amplitude of 4.0 cm and a maximum speed of 0.60 m/s. What is the frequency of oscillation? (Ans: 2.39 Hz)

A 0.25-kg block oscillates on the end of the spring with a spring constant of 200 N/m. When \( t = 0 \), the position and velocity of the block are \( x = 0.15 \) m and \( v = 3.0 \) m/s. What is the maximum speed of the block? (Ans: 5.2 m/s)
12. A block of mass 0.50 kg is attached to a horizontal spring \((k = 160 \text{ N/m})\). The block is pulled a distance of 20 cm from its unstretched position on a frictionless horizontal surface. What is the magnitude of its maximum acceleration? (Ans: 64 m/s²)

13. The mechanical energy of a block-spring system executing simple harmonic motion is 8.0 J and the amplitude is \(x_m = 12 \text{ cm}\). When \(K = 6.0 \text{ J}\), what is the displacement of the block? (Ans: \(x = 6.0 \text{ cm}\))

14. A 0.500-kg block is connected to a spring \((k = 20.0 \text{ N/m})\) and oscillates on a horizontal frictionless table. Calculate the maximum kinetic energy of the block if the amplitude of the simple harmonic motion is 3.00 cm. (Ans: \(9.00 \times 10^{-3} \text{ J}\))

15. A block of mass 2.0 kg is attached to a spring and oscillates in simple harmonic motion along the \(x\) axis. The limits of its motion are \(x = -20 \text{ cm}\) and \(x = +20 \text{ cm}\) and it goes from one of these extremes to the other in 0.25 s. What is the mechanical energy of the block-spring system? (Ans: 6.3 J)

16. A 2.0-kg block is attached to a spring and oscillates with simple harmonic motion according to the equation \(x = 0.20 \cos (10t + \pi/2)\), where \(x\) is in meters and \(t\) is in seconds. Find the total energy of the system. (Ans: 4.0 J)

17. A block-spring system is set in a simple harmonic motion. The block has a kinetic energy of 6 J and an elastic potential energy of 2 J when the displacement of the block is 2.0 cm from the equilibrium point. What is the amplitude of the simple harmonic motion? (Ans: 4 cm)

18. A simple harmonic oscillator is oscillating with an amplitude \(A\). For what value of the displacement does the kinetic energy equal the potential energy? (Ans: \(0.707A\))

19. A simple pendulum consists of a mass \(m = 6.00 \text{ kg}\) at the end of a light cord of length \(L\). The angle \(\theta\) between the cord and the vertical is given by: \(\theta = 0.08 \cos (4.43t + \pi), \) where \(t\) is in second and \(\theta\) is in radians. Find the length \(L\). (Ans: 0.50 m)

20. A mass \(m_1 = 1.0 \text{ kg}\) is connected to a spring (with spring constant equal to \(k\)) and oscillates on a horizontal frictionless table with a period of 1.0 s. When \(m_1\) is replaced with another unknown mass \(m_2\), the period changes to 2.0 s. Find the value of \(m_2\). (Ans: 4.0 kg)

21. A block attached to an ideal horizontal spring undergoes a simple harmonic motion about the equilibrium position \((x = 0)\) with an amplitude \(x_m = 10 \text{ cm}\). The mechanical energy of the system is 16 J. What is the kinetic energy of the block when \(x = 5.0 \text{ cm}\)? (Ans: 12 J)

22. Two identical springs of spring constant \(k = 500 \text{ N/m}\) are attached to a block of mass \(m = 0.1 \text{ kg}\), as shown in figure 1. The block is pulled to one side a small distance and let it oscillate. What is the angular frequency of oscillations on the frictionless floor? (Ans: 100 rad/s)

23. A simple pendulum of length \(L_1\) on Earth (E) oscillates with a period \(T\). Another pendulum of length \(L_2\) on the Moon (M) oscillates with a period of \(2T\). Find the ratio \(L_1/L_2\). (Take \(g_M = g_E/6\)) (Ans: 3/2)

24. A physical pendulum consists of a uniform solid disk (radius \(R = 10.0 \text{ cm}\)) supported in a vertical plane by a pivot located at a distance \(d = 5.0 \text{ cm}\) from the center of the disk. The disk is made to oscillate in a simple harmonic motion of period \(T\). Find \(T\). (Ans: 0.78 s)

25. The motion of a particle attached to a spring is described by \(x = 0.10 \sin (\pi t)\), where \(x\) is in meters and \(t\) in seconds. What is the earliest time at which the potential energy is equal to the kinetic energy? (Ans: 0.25 s)
26. The rotational inertia of a uniform thin rod about its end is $(ML^2)/3$, where $M$ is the mass and $L$ is the length. Such a rod is suspended vertically from one end and set into small angle oscillation. If $L = 1.0$ m this rod will have the same period as a simple pendulum of what length? (Ans: 67 cm)

27. A particle oscillates according to the displacement equation $x = (0.20 \text{ m}) \cos (2\pi t)$, where $x$ is in meters and $t$ in seconds. What are the speed and acceleration of the particle as it passes its equilibrium position $x = 0$? (Ans: 1.3 m/s, 0)

28. Consider a uniform rod of length $L$ suspended from one end and oscillating with period $T$. The slope of the graph of $T^2$ versus $L$ is $3 \text{ (s}^2/\text{m})$. What is the acceleration due to gravity in m/s$^2$ from the above information? (Ans: 8.8)

29. A simple harmonic oscillator consists of a 0.80-kg block attached to a spring ($k = 200 \text{ N/m}$). The block oscillates on a frictionless horizontal surface about the equilibrium point $x = 0$ with a total mechanical energy of 4.0 J. What is the speed of the block at $x = 0.15$ m? (Ans: 2.1 m/s)

30. A 0.10-kg block oscillates back and forth along a straight line on a frictionless horizontal surface. Its displacement as a function of time is given by $x(t) = 0.10 \cos (10t + \pi/2)$, where $x$ is in meters and $t$ in seconds. What is the kinetic energy of the block at $t = 2.0$ s? (Ans: 8.3 mJ)

31. A horizontal block-spring system is set in a simple harmonic motion. The block has a kinetic energy of 8 J and an elastic potential energy of 4 J when the displacement of the block is 3.0 cm from the equilibrium point. What is the amplitude of this simple harmonic motion? (Ans: 5.2 cm)

32. Figure 4 shows the kinetic energy versus the displacement of a spring-mass system from its equilibrium position while undergoing a simple harmonic motion. What is the spring constant $k$? (Ans: 2000 N/m)

33. A mass-spring system is in simple harmonic motion in a horizontal plane. The position of the mass is given by $x = x_m \cos (\alpha t + \pi/3)$. What is the ratio of its potential energy to its total energy at $t = 0$ s. (Ans: 0.25)

34. Figure 5 shows the position as a function of time of a 100-gram block oscillating in simple harmonic motion on the end of a spring. What is the maximum kinetic energy of the block? (Ans: 1.97 J)

35. An object executes simple harmonic motion with an amplitude of 1.2 cm and a time period of 0.10 s. What is the total distance traveled by the object in 1.9 s? (Ans: 91 cm)

36. A simple harmonic oscillator has amplitude of 3.50 cm and a maximum speed of 28.0 cm/s. What is its speed when the displacement of the oscillator is 1.75 cm? (Ans: 24.2 cm/s)

37. What is the phase constant for the harmonic oscillator with the velocity function $v(t)$ given in figure 8 if the position function $x(t)$ has the form $x(t) = x_m \cos(\alpha t + \phi)$? The vertical axis scale is set by $v_s = 4.00 \text{ cm/s}$. (Ans: $-53.1^\circ$)

38. In Figure 9, a stick of length $L = 1.73 \text{ m}$ oscillates as a physical pendulum. What value of $x$ between the stick’s center of mass and its pivot point O gives the least period? (Ans: 0.50 m)

39. Figure 10 shows the kinetic energy $K$ of a simple pendulum versus its angle $\theta$ from the vertical. The vertical axis scale is set by $K_s = 20.0 \text{ mJ}$. The pendulum bob has mass 0.30 kg. What is the length of the pendulum? (Ans: 2.04 m)

40. A 0.500 kg mass attached to a spring of force constant 8.00 N/m vibrates in simple harmonic motion with an amplitude of 10.0 cm. Calculate the time it takes the mass to move from $x = 0$ to $x = 10.0$ cm. (Ans: 0.393 s)
41. A simple pendulum of length 12 cm is to be replaced by a hoop in one of the old clocks (see figure 12). What should be the radius of the hoop needed to produce the same period as that of the pendulum, while oscillating about point O? (Ans: 6.0 cm)

42. The velocity-time plot for a block-spring system performing a simple harmonic motion is shown in figure 13. The horizontal scale is set by \( t_s = 0.2 \, \text{s} \). Find the acceleration of the system at \( t = 0.1 \, \text{s} \). (Ans: 200 m/s\(^2\))

43. A block-spring system is in simple harmonic motion and its displacement as a function of time is given by the equation: \( x = 5.0 \cos \left(\frac{\pi}{3}t - \frac{\pi}{4}\right) \) (SI units). The mass of the block is 3.0 kg. Find the speed of the block when the kinetic energy is one-fourth the total energy. (Ans: 2.6 m/s)

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**Conceptual Problems**

1. A 5.0-kg mass stretches a spring by 10 cm when the mass is attached to the spring. The mass is then displaced downward an additional 5.0 cm and released. What is the equation for its position \( y \) from its equilibrium position?
   - A. \( y = 0.05 \cos (10t) \)
   - B. \( y = 0.10 \cos (10t) \)
   - C. \( y = 0.10 \sin (10t) \)
   - D. \( y = 0.10 \cos (5t) \)
   - E. \( y = 0.05 \sin (5t) \)

2. The frequency of small oscillations of a simple pendulum of length \( L \) on the surface of Earth is \( f \). What will be its frequency on the surface of the Moon if we increase its length to become \( 2L \)? \( (g_{\text{Moon}} = 0.17 \, g_{\text{Earth}}) \)
   - A. 0.29f
   - B. 3.4f
   - C. \( f \)
   - D. 2f
   - E. 0.085f

3. In simple harmonic motion, the magnitude of the acceleration is:
   - A. proportional to the displacement.
   - B. constant.
   - C. inversely proportional to the displacement.
   - D. greatest when the velocity is greatest.
   - E. never greater than \( g \).

4. A particle is in simple harmonic motion along the \( x \) axis. The amplitude of the motion is \( x_m \). At one point in its motion, its kinetic energy is \( K = 5 \, \text{J} \) and its potential energy is \( U = 3 \, \text{J} \). When it is at \( x = x_m \), the kinetic and potential energies are:
   - A. \( K = 0 \, \text{J} \) and \( U = 8 \, \text{J} \)
   - B. \( K = 5 \, \text{J} \) and \( U = 0 \, \text{J} \)
   - C. \( K = 8 \, \text{J} \) and \( U = 0 \, \text{J} \)
   - D. \( K = 5 \, \text{J} \) and \( U = 3 \, \text{J} \)
   - E. \( K = 0 \, \text{J} \) and \( U = -8 \, \text{J} \)
5. Which of the following equations represent a simple harmonic motion \([F = \text{force, } x = \text{displacement}]\)?

\[ 1. F = -2x \quad 2. F = 5x \quad 3. F = -10x \quad 4. F = 3x^2 \quad 5. F = -3x \]

A. 1 & 3  
B. 1, 3 & 5  
C. 2 & 4  
D. 2 only  
E. All of them

6. A block-spring system is oscillating with amplitude \(x_m\). The kinetic energy of the block is equal to the potential energy stored in the spring only when the displacement is:

A) \(\pm x_m/\sqrt{2}\)  
B) zero  
C) \(\pm x_m/4\)  
D) \(\pm x_m/2\)  
E) \(2x_m\)

7. A weight suspended from an ideal spring oscillates up and down with a period \(T\). If the amplitude of the oscillation is doubled, the period will be:

A. \(T\)  
B. \(T/4\)  
C. \(2T\)  
D. \(T/2\)  
E. \(4T\)

8. A horizontal spring is fixed at one end. A block attached to the other end of the spring undergoes a simple harmonic motion on a frictionless table. Which one of the following statements is correct?

A. The frequency of the motion is independent of the amplitude of oscillation.  
B. The frequency of the motion is proportional to the amplitude of oscillation.  
C. The acceleration of the block is constant.  
D. The maximum speed of the block is independent of the amplitude.  
E. The maximum acceleration of the block is independent of the amplitude.

9. A simple pendulum has length \(L\) and period \(T\). As it passes through its equilibrium position, the string is suddenly clamped at its midpoint (see figure 2). What is the new period of the motion?

A. \(T/\sqrt{2}\)  
B. \(T\)  
C. \(T/2\)  
D. \(2T\)  
E. \(\sqrt{2}T\)

10. A vertical spring stretches 10 cm when a 5.0-kg block is suspended from its end. The block is then displaced an additional 5.0 cm downward and released from rest to execute simple harmonic motion. Take equilibrium position of spring-block system as origin and the upward-vertical direction to be positive. The block position as a function of time is given by:

A. \(y = -0.05 \cos (9.9 \, t) \, \text{m}\)  
B. \(y = -0.15 \sin (9.9 \, t) \, \text{m}\)  
C. \(y = -0.10 \cos (9.9 \, t) \, \text{m}\)  
D. \(y = -0.10 \sin (9.9 \, t + 9) \, \text{m}\)  
E. \(y = -0.15 \sin (9.9 \, t + 5) \, \text{m}\)
11. A mass at the end of an ideal spring vibrates with period $T$. If an identical spring is attached to the end of the first spring and the same mass is hanging from the combination, the new period of oscillation is:

A. $\sqrt{2}T$
B. $2T$
C. $T/4$
D. $T/2$
E. $T/\sqrt{2}$

12. The acceleration $a$ of a particle undergoing simple harmonic motion is graphed as a function of time in figure 3. Which of the labeled points corresponds to the particle at $-x_m$, where $x_m$ is the amplitude of the motion?

A. 3
B. 1
C. 2
D. 4
E. 5

13. Which one of the following relationships between the acceleration $a$ and the displacement $X$ of a particle represents simple harmonic motion:

A. $a = -2X$
B. $a = +2X$
C. $a = -2X^2$
D. $a = +2X^2$
E. None of the others

14. If the amplitude of oscillation of an object in simple harmonic motion is increased, then

A. the total mechanical energy of the object will increase
B. the period of oscillations of the object will increase
C. the frequency of oscillations of the object will increase
D. the frequency of oscillations of the object will decrease
E. the maximum kinetic energy of the object will decrease

15. A solid circular disk oscillates with period $T$ in a vertical plane about pivot point P, as shown in figure 6. If the disk is made four times heavier but still having the same radius, what will be its period of oscillation?

A. $T$
B. $2T$
C. $T/2$
D. $T/4$
E. $4T$

16. A simple pendulum of length $L_1$ has time period $T_1$. A second simple pendulum of length $L_2$ has time period $T_2$. If $T_2 = 2T_1$, find the ratio $L_1/L_2$.

A. $1/4$
B. $1/2$
C. 4
D. 2
E. 1

17. A simple pendulum of length $L$ has frequency $f$. In order to increase its frequency to $2f$ we have to:

A. decrease its length to $L/4$
B. increase its length to $2L$
C. decrease its length to $L/2$
D. increase its length to $4L$
E. decrease its mass to $M/4$
18. In figure 7, the horizontal block-spring system has a kinetic energy of $K = 5.0 \text{ J}$ and an elastic potential energy of $U = 3.0 \text{ J}$, when the block is at $x = +2.0 \text{ cm}$. What are the kinetic and elastic potential energy when the block is at $x = -x_m$?

A. $K = 0$ and $U = 8 \text{ J}$
B. $K = 5 \text{ J}$ and $U = 3 \text{ J}$
C. $K = 5 \text{ J}$ and $U = -3 \text{ J}$
D. $K = 8 \text{ J}$ and $U = 0$
E. $K = 0$ and $U = -8 \text{ J}$

19. If the phase angle for a block-spring system in SHM is $\pi/6 \text{ rad}$ and the block’s position is given by $x(t) = x_m \sin(\omega t + \phi)$, what is the ratio of the kinetic energy to the potential energy at time $t = 0$?

A. 3
B. 1/3
C. 9
D. 1/9
E. 5

20. Figure 11 shows plots of the kinetic energy $K$ versus position $x$ for three linear simple harmonic oscillators that have the same mass. Rank the plots according to the corresponding period of the oscillator, greatest first.

A. C, B, A
B. A, B, C
C. B, A, C
D. A, C, B
E. B, C, A

21. A mass-spring system executing simple harmonic motion has amplitude $x_m$. When the kinetic energy of the object equals twice the potential energy stored in the spring, what is the displacement ($x$) of the object from the equilibrium position?

A) $x_m/\sqrt{3}$
B) $\sqrt{3} x_m$
C) $x_m$
D) $x_m/2$
E) $x_m/3$