Exercise 14.2

Description: If an object on a horizontal frictionless surface is attached to a spring, displaced, and then released, it will oscillate. If it is displaced a distance \(0.115\) m from its equilibrium position and released with zero initial speed. Then after a time \(0.805\) s...

If an object on a horizontal frictionless surface is attached to a spring, displaced, and then released, it will oscillate. If it is displaced a distance \(0.115\) m from its equilibrium position and released with zero initial speed. Then after a time \(0.805\) s its displacement is found to be a distance \(0.115\) m on the opposite side, and it has passed the equilibrium position once during this interval.

Part A

Find the amplitude.

ANSWER:

\[ A = x = 0.115 \text{ m} \]

Part B

Find the period.

ANSWER:

\[ T = \frac{t}{2} = 1.61 \text{ s} \]

Part C

Find the frequency.

ANSWER:

\[ f = \frac{1}{2t} = 0.621 \text{ Hz} \]

Exercise 14.9

Description: A body of unknown mass is attached to an ideal spring with force constant \(123\) N/m. It is found to vibrate with a frequency of \(5.95\) Hz. (a) Find the period. (b) Find the angular frequency. (c) Find the mass of the body.

A body of unknown mass is attached to an ideal spring with force constant \(123\) N/m. It is found to vibrate with a frequency of \(5.95\) Hz.
Part A
Find the period.
ANSWER:
\[ T = \frac{1}{f} = 0.168 \text{ s} \]

Part B
Find the angular frequency.
ANSWER:
\[ \omega = 2\pi f = 37.4 \text{ rad/s} \]

Part C
Find the mass of the body.
Express your answer using two significant figures.
ANSWER:
\[ m = \frac{k}{(2\pi f)^2} = 8.8 \times 10^{-2} \text{ kg} \]

Exercise 14.11
Description: An object is undergoing SHM with period $T$ and amplitude 0.320 m. At $t = 0$, the object is at $x = 0.320$ m and is instantaneously at rest. (a) Calculate the time it takes the object to go from $x = 0.320$ m, to $x = 0.160$ m. (b) Calculate the time it...

An object is undergoing SHM with period 0.830 s and amplitude 0.320 m. At $t = 0$, the object is at $x = 0.320$ m and is instantaneously at rest.

Part A
Calculate the time it takes the object to go from $x = 0.320$ m, to $x = 0.160$ m.
Express your answer with the appropriate units.
ANSWER:
\[ t = \frac{T}{6} = 0.138 \text{ s} \]

Part B
Calculate the time it takes the object to go from \( x = 0.160 \text{ m} \), to \( x = 0 \).

Express your answer with the appropriate units.

ANSWER:

\[
t = \frac{T}{4} - \frac{T}{6} = 6.92 \times 10^{-2} \text{ s}
\]

---

Exercise 14.13

Description: A frictionless block of mass \( m \) kg is attached to an ideal spring with force constant \( k \) N/m. At \( t=0 \) the spring is neither stretched nor compressed and the block is moving in the negative direction at a speed of \( v \) m/s. (a) Find the amplitude. (b)...

A frictionless block of mass 2.15 kg is attached to an ideal spring with force constant 260 N/m. At \( t = 0 \) the spring is neither stretched nor compressed and the block is moving in the negative direction at a speed of 12.5 m/s.

---

Part A

Find the amplitude.

ANSWER:

\[
A = \frac{v}{\sqrt{k/m}} = 1.14 \text{ m}
\]

---

Part B

Find the phase angle.

ANSWER:

\[
\phi = 1.57 \text{ rad}
\]

---

Part C

Write an equation for the position as a function of time.

ANSWER:

- \( x = (-1.14 \text{ m}) \sin((11.0 \text{ rad/s})t) \)
- \( x = (-1.14 \text{ m}) \cos((11.0 \text{ rad/s})t) \)
- \( x = (-11.0 \text{ m}) \sin((1.14 \text{ rad/s})t) \)
- \( x = (-11.0 \text{ m}) \cos((1.14 \text{ rad/s})t) \)

---

Exercise 14.14
**Description:** A 2.00-kg, frictionless block is attached to an ideal spring with force constant 300 N/m. At $t = 0$ the block has velocity $-4.00$ m/s and displacement $+0.200$ m. (a) Find (a) the amplitude and (b) the phase angle. (b) ... (c) Write an equation for the ... 

A 2.00-kg, frictionless block is attached to an ideal spring with force constant 300 N/m. At $t = 0$ the block has velocity $-4.00$ m/s and displacement $+0.200$ m.

**Part A**

Find (a) the amplitude and (b) the phase angle.

**ANSWER:**

$$A = 0.383 \text{ m}$$

**Part B**

**ANSWER:**

$$\phi = 1.02 \text{ rad}$$

**Part C**

Write an equation for the position as a function of time.

Assume $x(t)$ in meters and $t$ in seconds.

**ANSWER:**

$$x(t) = 0.383\cos(12.2t + 1.02) \text{ m}$$

Also accepted: $0.383\cos\left(\sqrt{\frac{300}{2}}t + 1.02\right)0.3829\cos(12.25t + 1.021)$

**Exercise 14.21**

**Description:** A m mass on a spring has displacement as a function of time given by the equation $x(t) = (7.40 \text{ cm}) \cos((4.16 \text{ rad/s})t - 2.42 \text{ rad})$. (a) Find the time for one complete vibration. (b) Find the force constant of the spring. (c... 

A 1.30 kg mass on a spring has displacement as a function of time given by the equation $x(t) = (7.40 \text{ cm}) \cos((4.16 \text{ rad/s})t - 2.42 \text{ rad})$.

**Part A**

Find the time for one complete vibration.

**ANSWER:**

$$T = 1.51 \text{ s}$$
Part B
Find the force constant of the spring.
ANSWER:
\[ k = m \left(\frac{2\pi}{1.51}\right)^2 = 22.5 \text{ N/m} \]

Part C
Find the maximum speed of the mass.
ANSWER:
\[ v_{\text{max}} = 0.308 \text{ m/s} \]

Part D
Find the maximum magnitude of force on the mass.
ANSWER:
\[ F_{\text{max}} = m \left(\frac{2\pi}{1.51}\right)^2 \cdot 0.074 = 1.67 \text{ N} \]

Part E
Find the position of the mass at \( t = 1.00 \text{ s} \);
ANSWER:
\[ x = -1.25 \times 10^{-2} \text{ m} \]

Part F
Find the speed of the mass at \( t = 1.00 \text{ s} \);
ANSWER:
\[ v = 0.303 \text{ m/s} \]

Part G
Find the magnitude of acceleration of the mass at \( t = 1.00 \text{ s} \);
ANSWER:
Part H

Find the magnitude of force on the mass at $t = 1.00 \text{ s}$;

ANSWER:

$$F = 0.21565m = 0.280 \text{ N}$$

Also accepted: $0.216m = 0.281$

Exercise 14.27

Description: A toy of mass $0.130$-kg is undergoing SHM on the end of a horizontal spring with force constant $k = 350$ N/m. When the toy is a distance $0.0140$ m from its equilibrium position, it is observed to have a speed of $0.200$ m/s. (a) What is the toy's total...

A toy of mass 0.130-kg is undergoing SHM on the end of a horizontal spring with force constant $k = 350$ N/m. When the toy is a distance 0.0140 m from its equilibrium position, it is observed to have a speed of 0.200 m/s.

Part A

What is the toy's total energy at any point of its motion?

Express your answer with the appropriate units.

ANSWER:

$$E = \frac{1}{2} (kx^2 + mv^2) = 3.69 \times 10^{-2} \text{ J}$$

Part B

What is the toy's amplitude of the motion?

Express your answer with the appropriate units.

ANSWER:

$$A = \sqrt{x^2 + \frac{v^2}{k}} = 1.45 \times 10^{-2} \text{ m}$$

Part C

What is the toy's maximum speed during its motion?

Express your answer with the appropriate units.

ANSWER: $0.216 \text{ m/s}^2$
Exercise 14.41

Description: A certain alarm clock ticks four times each second, with each tick representing half a period. The balance wheel consists of a thin rim with radius \( r \), connected to the balance staff by thin spokes of negligible mass. The total mass of the balance...

A certain alarm clock ticks four times each second, with each tick representing half a period. The balance wheel consists of a thin rim with radius 0.56 cm, connected to the balance staff by thin spokes of negligible mass. The total mass of the balance wheel is 0.95 g.

Part A

What is the moment of inertia of the balance wheel about its shaft?

Express your answer using two significant figures.

ANSWER:

\[
I = mr^2 = 3.0 \times 10^{-8} \text{ kg} \cdot \text{m}^2
\]

Part B

What is the torsion constant of the hairspring?

Express your answer using two significant figures.

ANSWER:

\[
\kappa = (4\pi)^2 mr^2 = 4.7 \times 10^{-6} \text{ N} \cdot \text{m/rad}
\]

Exercise 14.48

Description: A certain simple pendulum has a period on the earth of \( T \). (a) What is its period on the surface of Mars, where \( g = 3.71 \text{ (m/s)}^2 \)?

A certain simple pendulum has a period on the earth of 2.00 s.

Part A

What is its period on the surface of Mars, where \( g = 3.71 \text{ m/s}^2 \)?

ANSWER:
Exercise 14.56

Description: A 1.80-kg monkey wrench is pivoted 0.250 m from its center of mass and allowed to swing as a physical pendulum. The period for small-angle oscillations is 0.940 s. (a) What is the moment of inertia of the wrench about an axis through the pivot? (b)...

A 1.80-kg monkey wrench is pivoted 0.250 m from its center of mass and allowed to swing as a physical pendulum. The period for small-angle oscillations is 0.940 s.

Part A

What is the moment of inertia of the wrench about an axis through the pivot?

ANSWER:

\[ I = 9.87 \times 10^{-2} \text{ kg} \cdot \text{m}^2 \]

Part B

If the wrench is initially displaced 0.400 rad from its equilibrium position, what is the angular speed of the wrench as it passes through the equilibrium position?

ANSWER:

\[ \Omega_{\text{max}} = 2.66 \text{ rad/s} \]

Exercise 14.58

Description: A holiday ornament in the shape of a hollow sphere with mass $\# \# \text{ kg}$ and radius $\# \# \text{ m}$ is hung from a tree limb by a small loop of wire attached to the surface of the sphere. If the ornament is displaced a small distance and released, it swings back and...

A holiday ornament in the shape of a hollow sphere with mass $1.0 \times 10^{-2} \text{ kg}$ and radius $5.5 \times 10^{-2} \text{ m}$ is hung from a tree limb by a small loop of wire attached to the surface of the sphere. If the ornament is displaced a small distance and released, it swings back and forth as a physical pendulum.

Part A

Calculate its period. (You can ignore friction at the pivot. The moment of inertia of the sphere about the pivot at the tree limb is $5MR^2/3$.)

Take the free fall acceleration to be $9.80 \text{ m/s}^2$. Express your answer using two significant figures.

ANSWER:
Problem 14.68

Description: A block with mass $M$ rests on a frictionless surface and is connected to a horizontal spring of force constant $k$. The other end of the spring is attached to a wall (the figure). A second block with mass $m$ rests on top of the first block. The coefficient of static friction between the blocks is $\mu_s$.

A block with mass $M$ rests on a frictionless surface and is connected to a horizontal spring of force constant $k$. The other end of the spring is attached to a wall (the figure). A second block with mass $m$ rests on top of the first block. The coefficient of static friction between the blocks is $\mu_s$.

Part A

Find the maximum amplitude of oscillation such that the top block will not slip on the bottom block.

Express your answer in terms of the variables $m$, $M$, $k$, $\mu_s$, and appropriate constants.

ANSWER:

$$\frac{\mu_s (m + M) g}{k}$$

Problem 14.74

Description: An object with mass $m$ kg is acted on by an elastic restoring force with force constant $k$ N/m. The object is set into oscillation with an initial potential energy of $U$ J and an initial kinetic energy of $K$ J. (a) What is the amplitude of...

An object with mass 0.190 kg is acted on by an elastic restoring force with force constant 10.7 N/m. The object is set into oscillation with an initial potential energy of 0.140 J and an initial kinetic energy of $6.20 \times 10^{-2}$ J.

Part A

What is the amplitude of oscillation?

ANSWER:
\[ A = \sqrt{\frac{2(U + K)}{k}} = 0.194 \text{ m} \]

**Part B**

What is the potential energy when the displacement is one-half the amplitude?

ANSWER:

\[ U = \frac{U + K}{4} = 5.05 \times 10^{-2} \text{ J} \]

**Part C**

At what displacement are the kinetic and potential energies equal?

ANSWER:

\[ x = \frac{\sqrt{U + K}}{k} = 0.137 \text{ m} \]

**Part D**

What is the value of the phase angle \( \phi \) if the initial velocity is positive and the initial displacement is negative?

ANSWER:

\[ \phi = \tan^{-1}\left(\frac{\sqrt{K}}{U}\right) + \pi = 3.73 \text{ rad} \]

Also accepted: \( \tan^{-1}\left(\frac{\sqrt{K}}{U}\right) - \pi = -2.55 \)

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**Problem 14.77**

**Description:** A partridge of mass \( 5.10 \text{ kg} \) is suspended from a pear tree by an ideal spring of negligible mass. When the partridge is pulled down \( 0.100 \text{ m} \) below its equilibrium position and released, it vibrates with a period of \( 4.25 \text{ s} \). (a) What is its speed as it...

A partridge of mass \( 5.10 \text{ kg} \) is suspended from a pear tree by an ideal spring of negligible mass. When the partridge is pulled down \( 0.100 \text{ m} \) below its equilibrium position and released, it vibrates with a period of \( 4.25 \text{ s} \).

**Part A**

What is its speed as it passes through the equilibrium position?

ANSWER:
\[ v = \frac{2\pi \cdot 0.100}{T} = 0.148 \text{ m/s} \]

Part B

What is its acceleration when it is 0.050 m above the equilibrium position?

ANSWER:

\[ a = -\left(\frac{2\pi}{T}\right)^2 \cdot 0.050 = -0.109 \text{ m/s}^2 \]

Part C

When it is moving upward, how much time is required for it to move from a point 0.050 m below its equilibrium position to a point 0.050 m above it?

ANSWER:

\[ t = \frac{T}{6} = 0.708 \text{ s} \]

Part D

The motion of the partridge is stopped, and then it is removed from the spring. How much does the spring shorten?

ANSWER:

\[ |\Delta l| = \frac{9.8}{\left(\frac{2\pi}{T}\right)^2} = 4.48 \text{ m} \]

Problem 14.83

Description: A rifle bullet with mass \( m \) and initial horizontal velocity \( v \) strikes and embeds itself in a block with mass \( m_b \) that rests on a frictionless surface and is attached to one end of an ideal spring. The other end of the spring is...

A rifle bullet with mass 7.00 \( \text{ g} \) and initial horizontal velocity 250 \( \text{ m/s} \) strikes and embeds itself in a block with mass 0.993 \( \text{ kg} \) that rests on a frictionless surface and is attached to one end of an ideal spring. The other end of the spring is attached to the wall. The impact compresses the spring a maximum distance of 14.0 \( \text{ cm} \). After the impact, the block moves in SHM.

Part A

Calculate the period of this motion.

Express your answer with the appropriate units.

ANSWER:
\[ T = \frac{2\pi d m + m_t}{v m} = 0.503 \text{s} \]