CH 14 HW

Due: 11:59pm on Sunday, April 27, 2025

To understand how points are awarded, read the Grading Policy for this assignment.

A message from your instructor...

To receive full credit on homework assignments, students must show all steps and detailed reasoning for each solution. This includes writing out relevant equations, substitutions, and calculations, as well as clearly explaining your approach when applicable. Upload your solutions to Canvas by the homework's due date.

Exercise 14.2 - Enhanced - with Feedback

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 0.125 m from its equilibrium position and released with zero initial speed, then after a time 0.790 s its displacement is found to be a distance 0.125 m on the opposite side, and it has passed the equilibrium position once during this interval.

Part A

Find the amplitude.

Express your answer with the appropriate units.

ANSWER:

A = 0.125 m

Correct

Part B

Find the period.

Express your answer with the appropriate units.

ANSWER:

T = 1.58 s

Correct

Part C

Find the frequency.

Express your answer with the appropriate units.

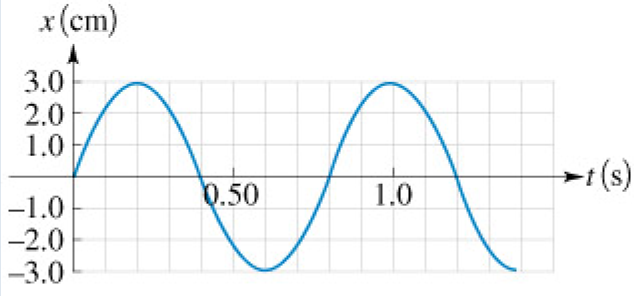
ANSWER:

f = 0.633 Hz

Correct

Exercise 14.7 - Enhanced - with Solution

A 2.37 kg ball is attached to an unknown spring and allowed to oscillate. shows a graph of the ball's position x as a function of time t.



For related problem-solving tips and strategies, you may want to view a Video Tutor Solution of Angular frequency, frequency, and period in shm.

Part A

For this motion, what is the period?

Express your answer to three significant figures and include the appropriate units.

ANSWER:

T = 0.800 s

Correct

IDENTIFY and SET UP: The period is the time for one cycle. A is the maximum value of x.

EXECUTE: From the figure with the problem, $T = 0.800\ \mathrm{s}$.

Part B

What is the frequency?

Express your answer to three significant figures and include the appropriate units.

ANSWER:

f = 1.25 Hz

Correct

$f = \frac{1}{T} = 1.25\ \mathrm{Hz}$

Part C

What is the angular frequency?

Express your answer in $\mathrm{rad/s}$ to three significant figures.

ANSWER:

ω = 7.85 $\mathrm{rad/s}$

Correct

$\omega = 2\pi f = 7.85\ \mathrm{rad/s}$

Part D

What is the amplitude?

Express your answer to three significant figures and include the appropriate units.

ANSWER:

A = $3.00 \times 10^{-2}\ \mathrm{m}$

Correct

From the figure with the problem, $A = 3.0\ \mathrm{cm}$.

Part E

What is the force constant of the spring?

Express your answer to three significant figures and include the appropriate units.

ANSWER:

k = 146 $\frac{\mathrm{N}}{\mathrm{m}}$

Correct

$T = 2\pi\sqrt{\frac{m}{k}}$, so $k = m\left(\frac{2\pi}{T}\right)^2 = (2.37\ \mathrm{kg})\left(\frac{2\pi}{0.800\ \mathrm{s}}\right)^2 = 146\ \mathrm{N/m}$.

EVALUATE: The amplitude shown on the graph does not change with time, so there must be little or no friction in this system.

Exercise 14.11 - Enhanced - with Solution

An object is undergoing SHM with period 0.820 s and amplitude 0.320 m. At t = 0, the object is at x = 0.320 m and is instantaneously at rest.

For related problem-solving tips and strategies, you may want to view a Video Tutor Solution of Angular frequency, frequency, and period in shm.

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 = 0.137 s

Correct

IDENTIFY: For SHM the motion is sinusoidal.

SET UP: $x(t) = A\cos(\omega t)$.

EXECUTE: $x(t) = A\cos(\omega t)$, where $A = 0.320\ \mathrm{m}$ and $\omega = \frac{2\pi}{T} = \frac{2\pi}{0.820\ \mathrm{s}} = 7.66\ \mathrm{rad/s}$.

$x = 0.320\ \mathrm{m}$ at $t_1 = 0$. Let t_2 be the instant when $x = 0.160\ \mathrm{m}$. Then we have $0.160\ \mathrm{m} = (0.320\ \mathrm{m})\cos(\omega \mathrm{t}_2)$.

$\cos(\omega t_2) = 0.500$. $\omega t_2 = 1.047\ \mathrm{rad}$. $t_2 = \frac{1.047\ \mathrm{rad}}{7.66} = 0.137\ \mathrm{rad/s}$.

It takes $t_2 - t_1 = 0.137\ \mathrm{s}$.

Part B

Calculate the time it takes the object to go from x = 0.160 m, to x = 0.

Express your answer with the appropriate units.

ANSWER:

t = 6.8×10^{-2} s

Correct

Let t_3 be when $x = 0$. Then we have $\cos(\omega t_3) = 0$ and $\omega t_3 = 1.571\ \mathrm{rad}$.

$t_3 = \frac{1.570\ \mathrm{rad}}{7.66\ \mathrm{rad/s}} = 0.205\ \mathrm{s}$. It takes $t_3 - t_2 = 0.205\ \mathrm{s} - 0.137\ \mathrm{s} = 6.8 \times 10^{-2}\ \mathrm{s}$.

EVALUATE: Note that it takes twice as long to go from $x = 0.320\ \mathrm{m}$ to $x = 0.160\ \mathrm{m}$ than to go from $x = 0.160\ \mathrm{m}$ to $x = 0$, even though the two distances are the same, because the speeds are different over the two distances.

Exercise 14.14 - Enhanced - with Feedback

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

Part A

Find the amplitude.

Express your answer to three significant figures and include the appropriate units.

ANSWER:

A = 0.383 m

Correct

Part B

Find the phase angle.

Express your answer in radians.

ANSWER:

ϕ = 1.02 rad

Correct

Part C

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

ANSWER:

- ○ $x(t) = 0.383 \cdot \cos(12.2t - 1.02)$
- ○ $x(t) = -0.383 \cdot \cos(12.2t - 1.02)$
- ○ $x(t) = -0.383 \cdot \cos(12.2t + 1.02)$
- ◉ $x(t) = 0.383 \cdot \cos(12.2t + 1.02)$

Correct

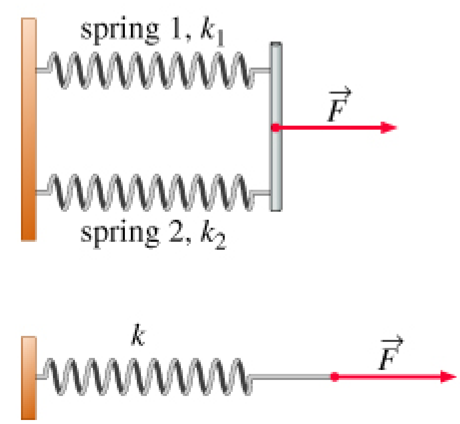
Springs in Parallel

In this problem you will study two cases of springs connected in parallel that will enable you to draw a general conclusion.

Two springs in parallel

Consider two massless springs connected in parallel. Springs 1 and 2 have spring constants k_1 and k_2 and are connected via a thin, vertical rod. A constant force of magnitude F is being exerted on the rod. The rod remains perpendicular to the direction of the applied force, so that the springs are extended by the same amount.

This system of two springs is equivalent to a single spring, of spring constant k.



Part A

Find the effective spring constant k of the two-spring system.

Give your answer for the effective spring constant in terms of k_1 and k_2.

Hint 1. Free-body diagram

Draw a free-body diagram for the rod, then use the fact that the rod is in equilibrium to find an equation for F in terms of k_1, k_2, and the extensions of the springs. (The extension of a spring is the spring's stretched length minus the spring's unstretched, equilibrium length.)

Hint 2. Extension of two springs

How do the extensions of the two springs compare?

ANSWER:

- The extension of spring 1 is greater than the extension of spring 2.
- The extension of spring 1 is less than the extension of spring 2.
- The extensions of the two springs are the same.
- There is no way to tell from the information given.

Hint 3. Magnitude of $\vec{F}$

Suppose that the force $\vec{F}$ is stretching the two-spring system a distance x, measured from the system's unstretched length. What is F, the magnitude of the force?

Express your answer in terms of x and k, the effective spring constant of the two-spring system.

ANSWER:

F = kx

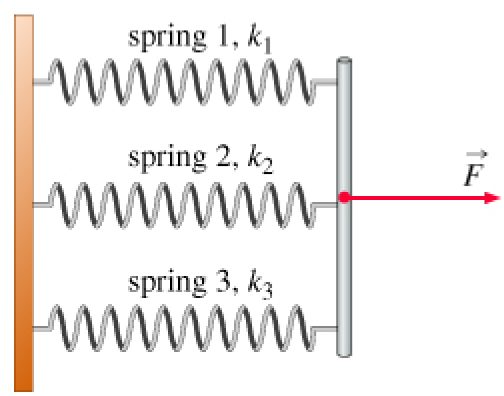
ANSWER:

k = $k_1 + k_2$

Correct

Three springs in parallel

Now consider three springs connected in parallel as shown. The spring constants of springs 1, 2, and 3 are k_1, k_2, and k_3. The springs are connected by a vertical rod, and a force of magnitude F is being exerted to the right.



Part B

Find the effective spring constant k' of the three-spring system.

Give your answer in terms of k_1, k_2, and k_3.

ANSWER:

k' = $k_1 + k_2 + k_3$

Correct

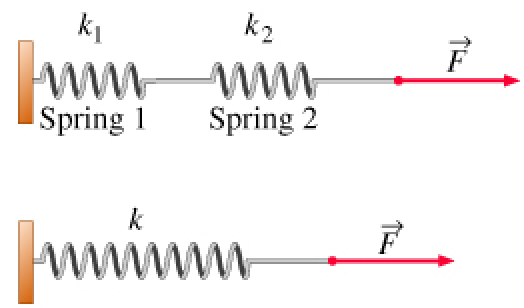
You have now seen that the general formula for the overall spring constant of a set of springs in parallel is the sum of the spring constants of the individual springs. You will see this again when you study electric circuits and learn about the total capacitance of capacitors in parallel.

Springs in Series

In this problem you will study two cases of springs connected in series that will enable you to draw a general conclusion.

Two springs in series

Consider two massless springs connected in series. Spring 1 has a spring constant k_1, and spring 2 has a spring constant k_2. A constant force of magnitude F is being applied to the right. When the two springs are connected in this way, they form a system equivalent to a single spring of spring constant k.



Part A

What is the effective spring constant k of the two-spring system?

Express the effective spring constant in terms of k_1 and k_2.

Hint 1. Free-body diagram

Draw a free-body diagram for spring 2. Notice that the system is in equilibrium. The free-body diagram should help you to

1. find the force, acting to the right, on spring 1, and
2. find the extension of spring 2, in terms of known quantities (including F).

Hint 2. Free-body diagram for spring 2

The free-body diagram for spring 2 is as shown here. At first, this may not look familiar, but recall that we would find this same free-body diagram if spring 2 were held by a wall or by any other fixed object. Use this fact to find the extension of spring 2.

Hint 3. Determine the extension of spring 2

What is the extension x_2 of spring 2?

Give your answer in terms of F and k_2

ANSWER:

x_2 = $\frac{F}{k_2}$

Hint 4. Determine the extension of spring 1

The free-body diagram for spring 1 is similar to the diagram for spring 2 (of course, the spring constants are different). What is the extension x_1 of spring 1?

Give your answer in terms F and k_1.

ANSWER:

x_1 = $\frac{F}{k_1}$

Hint 5. Determine the total extension of the two springs

If the extension of spring 1 is x_1, and the extension of spring 2 is x_2, what is the total extension x of a two-spring system?

Give your answer in terms of x_1 and x_2.

ANSWER:

x = $x_1 + x_2$

Hint 6. Replace x_1 and x_2

Substitute the equations for x_1 and x_2 into your equation for x.

Give your answer in terms of F, k_1, and k_2.

ANSWER:

x = $\frac{F}{k_1} + \frac{F}{k_2}$

Hint 7. Determine the extension of the equivalent system

If the effective spring constant of the two-spring system is k, what is the total extension x of this system?

Give your answer in terms of F and k.

ANSWER:

x = $\frac{F}{k}$

Hint 8. Solving for k

You now have two equations for total extension x. Solve these equations for k by eliminating F.

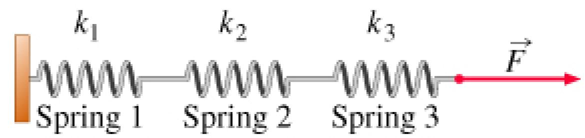
ANSWER:

$k = \frac{k_1 k_2}{k_1 + k_2}$

Correct

Three springs in series

Now consider three springs set up in series as shown. The spring constants are k_1, k_2, and k_3, and the force acting to the right again has magnitude F.



Part B

Find the spring constant k' of the three-spring system.

Express your answer in terms of k_1, k_2, and k_3.

ANSWER:

$k' = \left(\frac{1}{k_1} + \frac{1}{k_2} + \frac{1}{k_3}\right)^{-1}$

Correct

You have now found the pattern for the general form of the overall spring constant of a set of springs connected in series. This result will be similar to the one for the total capacitance of a set of capacitors attached in series that you will see when you study electric circuits.

Exercise 14.27 - Enhanced - with Feedback

A 0.250 kg toy is undergoing SHM on the end of a horizontal spring with force constant 300 $\mathrm{N/m}$. When the toy is 0.0160 m from its equilibrium position, it is observed to have a speed of 0.200 $\mathrm{m/s}$.

Part A

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

Express your answer with the appropriate units.

ANSWER:

$E = 4.34 \times 10^{-2}\ \mathrm{J}$

Correct

Part B

What is the toy's amplitude of the motion?

Express your answer with the appropriate units.

ANSWER:

$A = 1.70 \times 10^{-2}\ \mathrm{m}$

Correct

Part C

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

Express your answer with the appropriate units.

ANSWER:

$v_{\mathrm{max}} = 0.589\ \frac{\mathrm{m}}{\mathrm{s}}$

Correct

Exercise 14.43 - Enhanced - with Solution

You pull a simple pendulum of length 0.225 m to the side through an angle of 3.50° and release it.

For related problem-solving tips and strategies, you may want to view a Video Tutor Solution of A simple pendulum.

Part A

How much time does it take the pendulum bob to reach its highest speed?

Express your answer with the appropriate units.

ANSWER:

$t = 0.24\ \mathrm{s}$

Correct

IDENTIFY: $T = 2\pi\sqrt{L/g}$ is the time for one complete swing.

SET UP: The motion from the maximum displacement on either side of the vertical to the vertical position is one-fourth of a complete swing.

EXECUTE: To the given precision, the small-angle approximation is valid. The highest speed is at the bottom of the arc, which occurs after a quarter period, $\frac{T}{4} = \frac{\pi}{2}\sqrt{\frac{L}{g}} = 0.238\mathrm{s}$.

Part B

How much time does it take if the pendulum is released at an angle of 1.75° instead of 3.50° ?

Express your answer with the appropriate units.

ANSWER:

t = 0.24 s

Correct

The same as calculated in (a), 0.238 s . The period is independent of amplitude.

EVALUATE: For small amplitudes of swing, the period depends on *L* and *g*.

Exercise 14.47 - Enhanced - with Solution

After landing on an unfamiliar planet, a space explorer constructs a simple pendulum of length 50.0 cm. She finds that the pendulum makes 100 complete swings in a time of 130 s.

For related problem-solving tips and strategies, you may want to view a Video Tutor Solution of A simple pendulum.

Part A

What is the value of g on this planet?

Express your answer with the appropriate units.

ANSWER:

g = 11.7 $\frac{\mathrm{m}}{\mathrm{s}^2}$

Correct

IDENTIFY: Apply $T = 2\pi\sqrt{L/g}$

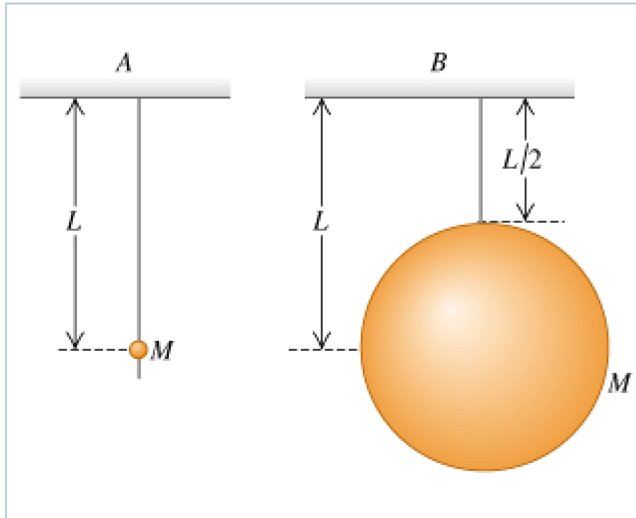
SET UP: The period of the pendulum is $T = (130\ \mathrm{s})/100 = 1.30\ \mathrm{s}$.

EXECUTE: $g = \dfrac{4\pi^2 L}{T^2} = \dfrac{4\pi^2(0.500\mathrm{m})}{(1.30\mathrm{s})^2} = 11.7\ \mathrm{m/s^2}$.

Exercise 14.53 - Enhanced - with Solution

The two pendulums shown in each consist of a uniform solid ball of mass M supported by a massless string, but the ball for pendulum A is very tiny while the ball for pendulum B is much larger.

For related problem-solving tips and strategies, you may want to view a Video Tutor Solution of Physical pendulum versus simple pendulum.



Part A

Find the period of pendulum A for small displacements.

Express your answer in terms of the variables M, L, and appropriate constants.

ANSWER:

$T_A = 2\pi\sqrt{\dfrac{L}{g}}$

Correct

IDENTIFY: Pendulum *A* can be treated as a simple pendulum. Pendulum *B* is a physical pendulum. Use the parallel-axis theorem to find the moment of inertia of the ball in *B* for an axis at the top of the string.

SET UP: For pendulum *B* the center of gravity is at the center of the ball, so $d = L$. For a solid sphere with an axis through its center, $I_{cm} = \frac{2}{5}MR^2$ and $I_{cm} = \frac{1}{10}ML^2$.

EXECUTE: Pendulum *A*: $T_A = 2\pi\sqrt{\frac{L}{g}}$.

Part B

Find the period of pendulum B for small displacements.

Express your answer in terms of the variables M, L, and appropriate constants.

ANSWER:

T_{B} = $2\pi\sqrt{\frac{11L}{10g}}$

Correct

Pendulum *B*: The parallel-axis theorem says $I = I_{cm} + ML^2 = \frac{11}{10}ML^2$.

$$T = 2\pi\sqrt{\frac{I}{mgd}} = 2\pi\sqrt{\frac{11ML^2}{10MgL}} = \sqrt{\frac{11}{10}}\left(2\pi\sqrt{\frac{L}{g}}\right) = \sqrt{\frac{11}{10}}T_A = 1.05T_A.$$

Part C

Which ball takes longer to complete a swing?

ANSWER:

- ○ pendulum A
- ◉ pendulum B

Correct

It takes pendulum *B* longer to complete a swing.

EVALUATE: The center of the ball is the same distance from the top of the string for both pendulums, but the mass is distributed differently and *I* is larger for pendulum *B*, even though the masses are the same.

Score Summary:

Your score on this assignment is 143%.
You received 7 out of a possible total of 7 points, plus 3 points of extra credit.