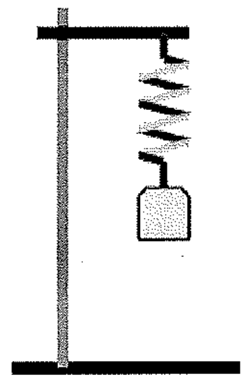
Question:



One end of a light spring with spring constant 10 N/m is attached to a vertical support, while a mass is attached to the other end, as shown. The mass is pulled down and released, and exhibits simple harmonic motion with a period of 0.2π. The mass is

a. 0.1 kg
b. 0.25 kg
c. 0.4 kg
d. 0.04 kg
e. 0.025 kg

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Answer:

The correct answer is ***a***. We can determine the mass by using the relationship

$$T_{pendulum} = 2\pi\sqrt{\frac{m}{k}}.$$

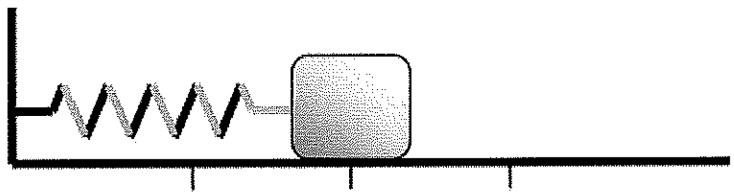
$$T_{pendulum} = 2\pi\sqrt{\frac{m}{k}}$$

Squaring both sides and rearranging:

$$\frac{kT^2}{4\pi^2} = m$$

$$m = \frac{kT^2}{4\pi^2} = \frac{(10)(0.2\pi)^2}{4\pi^2} = 0.1kg$$

Question:



A block of mass *m* sits on a horizontal frictionless surface, and is attached to a nearby vertical support by a spring as shown here. The spring, of negligible mass, is unstretched when the block is located at equilibrium position 0. The block is moved to position $+A$ and released, after which it oscillates with simple harmonic motion. Which of the following statements is true?

a. The block has maximum acceleration at A.
b. The block has maximum velocity at A.
c. The block has maximum displacement at 0.
d. The block has zero velocity at 0.
e. The block has zero displacement at A.

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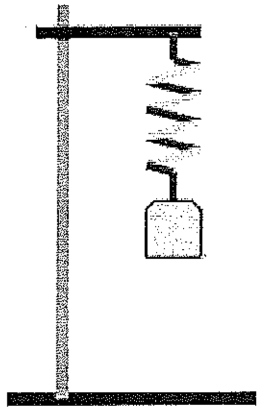
Answer:

The correct answer is ***a***. The maximum acceleration occurs then the spring is exerting its maximum force F, according to $\vec{\mathbf{F}} = m\vec{\mathbf{a}}$. This occurs when the spring is extended to its maximum displacement, according to Hooke's Law $F = -kx$.

Question:



One end of a light spring with spring constant 10 N/m is attached to a vertical support, while a mass is attached to the other end, as shown. The mass is pulled down from its equilibrium position and released, and begins to oscillate up and down in simple harmonic motion. As the mass passes its equilibrium position:

a. its speed is a maximum and its acceleration is a maximum
b. its speed is a maximum and its acceleration is a minimum
c. its speed is a minimum and its displacement is a minimum
d. its speed is a minimum and its acceleration is a maximum
e. its speed is a minimum and its acceleration is a minimum

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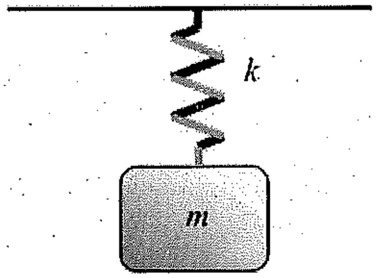
Answer:

The correct answer is ***b***. At the equilibrium position, the net Force acting on the mass is 0—the force of gravity down on the mass is equal to the force of the spring up on the mass—so its acceleration at this position is zero. Its speed is at a maximum, however, with the all of the spring's elastic potential energy converted to kinetic at this position.

Question:



A block of mass *m* is hung from a spring of negligible mass with spring constant *k*. When the block is displaced vertically by an amount *x* and released, it begins to oscillate with a frequency *f*. Under which circumstances will the block oscillate with the same frequency *f*?

I. When the block is hung from a second, identical spring, connected in parallel with the first one.
II. When the block is hung from a second, identical spring, connected in series with the first one.
III. When the block is given an initial displacement greater than *x*.

a. I only
b. II only
c. III only
d. I and II
e. I and III

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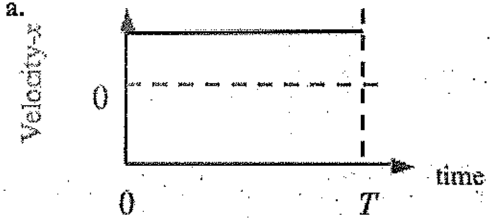
Answer:
The correct answer is *c*. The frequency of the mass's oscillation can be determined using $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$, so changing the mass or changing the spring constant *k* will alter the frequency of oscillation.
Adding a second spring in parallel with the first one doubles the effective spring constant of the system—two springs apply twice as much force for the same displacement.

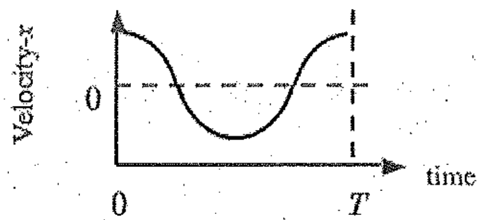
$$k = \frac{-F}{x}; \qquad k' = \frac{-2F}{x} = 2k$$

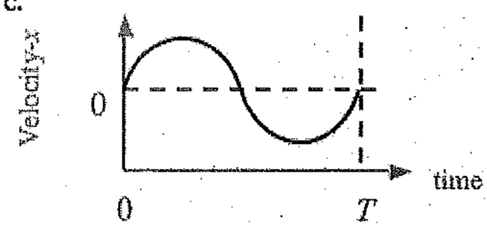
Connecting two springs in series produces a spring with an effective spring constant for the system that is half the *k* of the original springs. This can be seen by imagining a Force applied to the two springs in series: the force is transmitted through both springs, causing them both to stretch a distance *x*. With the same force producing a change in length that is twice as much as before:

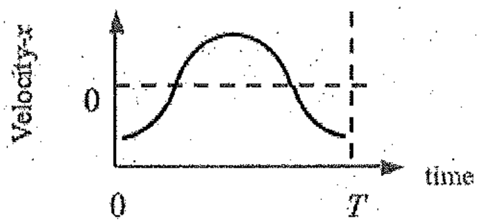
$$k = \frac{-F}{x}; \qquad k' = \frac{-F}{2x} = \frac{1}{2}k$$

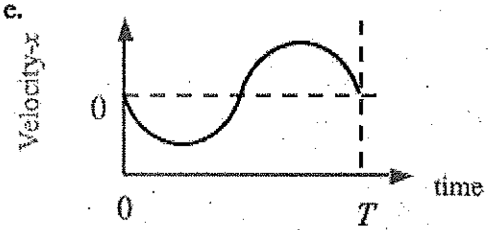
Question:
A particle moves constantly in a circle centered at the origin with a period T. If its position at time $t = 0$ seconds is $(A, 0)$ meters, which graph represents v_x, the x-component of the particle's velocity, as a function of time?

a.


b.


c.


d.


e.


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Answer:
The correct answer is *e*. Based on the description of the particle's position at time $t = 0$, we know that the equation that describes the particle's x-coordinate as a function of time is

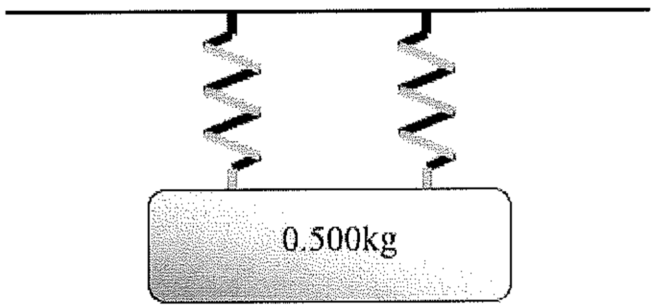
$$x = A\cos(\omega t)$$

To determine the x-component of the velocity, we take the time derivative of this function:

$$v_x = \frac{dx}{dt} = \frac{d}{dt}A\cos(\omega t) = -\omega A\sin(\omega t)$$

This is essentially a negative sine function, which matches the graph in answer *e*.
The problem may be solved conceptually, too, by considering the x-component of the rotating particle as a mass on a horizontally-stretched spring. The mass is released from a position $+A$ at time $t = 0$, at which point it begins to accelerate in the $-x$ direction, beginning a simple harmonic oscillation. This motion is consistent with answer *e*.

Question:



A mass of 0.500 kg is hung from two identical springs, of negligible mass. The mass causes each spring to stretch by 0.10 m. What is the approximate spring constant of each spring?

a. 2.5 N/m
b. 5.0 N/m
c. 25 N/m
d. 50 N/m
e. 100 N/m

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Answer:

The correct answer is *c*. The problem can be solved with a Hooke's Law analysis, and considering each spring to be supporting half of the total mass.

$$F = -kx$$

$$k = -\frac{F_g}{x}$$

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

$$k = \frac{(\frac{1}{2}0.50kg)(10m/s^2)}{0.10m} = 25N/m$$

Question:

An enormous pendulum-driven clock, located on the earth, is set into motion by releasing its 10-meter long simple pendulum from a maximum angle of less than 10° relative to the vertical. At what approximate time *t* will the pendulum have fallen to a perfectly vertical orientation?

a. $\frac{\pi}{10}$ seconds

b. $\frac{\pi}{5}$ seconds

c. $\frac{\pi}{4}$ seconds

d. $\frac{\pi}{2}$ seconds

e. π seconds

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Answer:

The correct answer is *d*. The period of a pendulum *T* is described by $T = 2\pi\sqrt{\frac{L}{g}}$. Here, we're attempting to find what the time $t = \frac{1}{4}T$ is.

$$t = \frac{1}{4}T = \frac{1}{4} \bullet 2\pi\sqrt{\frac{L}{g}}$$

$$t = \frac{\pi}{2}\sqrt{\frac{L}{g}}$$

$$t = \frac{\pi}{2}\sqrt{\frac{10m}{\sim 10m/s^2}} \approx \frac{\pi}{2}s$$

Question:

A simple harmonic oscillator has a period $T = \frac{2\pi}{3}$. If the amplitude of the oscillator's motion is 2 meters, what is its maximum acceleration during its motion?

a. 6 m/s^2
b. 18 m/s^2
c. 4/3 m/s^2
d. 8/9 m/s^2
e. 4 m/s^2

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Answer:

The correct answer is ***b***. The period of a harmonic oscillator is given by $T = \frac{2\pi}{\omega}$, so the equation in the problem reveals that the angular frequency ω is 3 rad/s.

The relationship between acceleration, angular momentum, and displacement is given by $a = -\omega^2 x$. The maximum acceleration occurs when the oscillator is at its maximum displacement, which we can calculate now:

$$a = -\omega^2 x$$

$$a = -(3s^{-1})^2 \Sigma 2m$$

$$a = -18m/s^2$$

The negative sign here simply indicates that the direction of the acceleration is in the direction opposite of the displacement. This makes sense if we consider the motion of a mass-spring system. When the mass is pulled in the positive-x direction, the spring applies a force (and thereby causes the mass to accelerate) in the *negative* x-direction.

Question:

A simple harmonic oscillator consists of a 4.0kg mass attached to the end of a spring with spring constant 1.0 N/m. If the speed of the mass as it passes the equlibrium position is 10 cm/s, what is the amplitude of the mass's oscillation?

a. 0.10 m
b. 0.20 m
c. 0.30 m
d. 0.40 m
e. 4.0 m

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Answer:

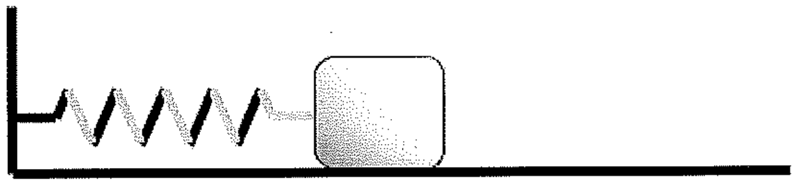
The correct answer is *b*. The mass has maximum kinetic energy as it passes through the equilibrium position, which is converted to maximum elastic potential energy at the maximum displacement (amplitude):

$$E_{total} = \frac{1}{2}kA^2 = \frac{1}{2}mv_0^{\,2}$$

$$A = v_0\sqrt{\frac{m}{k}}$$

$$A = (0.10m/s)\sqrt{\frac{4.0kg}{1.0N/m}} = 0.20m$$

Question:



A block of mass *m* rests on a frictionless surface, and is connected as shown to a vertical support by a spring with a known spring constant *k*. When the block is moved from rest from some point $x_{initial}$ to rest at another point x_{final}, the net Work done by the spring on the mass depends only on:

a. the mass *m* and the spring constant *k*
b. the mass *m* and the positions $x_{initial}$ and x_{final}
c. the spring constant *k* and the positions $x_{initial}$ and x_{final}
d. the mass *m*, the spring constant *k* and the positions $x_{initial}$ and x_{final}
e. the spring constant *k* and the path taken between positions $x_{initial}$ and x_{final}

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Answer:
The correct answer is *c*. The Work done by the spring is based on the difference in elastic potential energy ($U_{spring} = \frac{1}{2}kx^2$) between the two positions. Note that springs provide a *conservative force*, ie. one in which the path between two positions doesn't change the net Work done by the spring—only the initial and final positions are significant.

Question:
A particle moves constantly in a circle centered at the origin with a period of 4.0 seconds. If its position at time $t = 0$ seconds is (2,0) meters, two possible equations describing the particle's x- and y-components are:

a. $x = 2\cos\left(\frac{\pi}{2}t\right)$ $y = 2\sin\left(\frac{\pi}{2}t\right)$

b. $x = 2\cos\left(\frac{2}{\pi}t\right)$ $y = 2\sin\left(\frac{2}{\pi}t\right)$

c. $x = 2\sin\left(\frac{\pi}{2}t\right)$ $y = 2\cos\left(\frac{\pi}{2}t\right)$

d. $x = 2\sin\left(\frac{\pi}{2}\right)$ $y = 2\cos\left(\frac{\pi}{2}\right)$

e. $x = 2\pi\cos(2t)$ $y = 2\pi\sin(2t)$

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Answer:
The correct answer is *a*. Based on the circular path being centered at the origin and particle's original position at (2,0) meters, we can deduce that the amplitude A of the particle's motion is 2 meters. Its period of 4.0 seconds allows us to determine its angular velocity:

$$T = \frac{2\pi}{\omega}$$

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{4} = \frac{\pi}{2}$$

Equations that describe the components of circular motion are:

$$x = A\cos(\omega t + \phi);\ \ y = A\sin(\omega t + \phi)$$

Here, substituting in the values from above, and with $\phi = 0$, the possible equations are:

$$x = 2\cos\left(\frac{\omega}{2}t\right);\ \ y = A\sin\left(\frac{\omega}{2}t\right)$$

Note that we don't know whether the particle is moving in a counterclockwise or clockwise direction; the y equation is one possible solution (for a ccw motion). A clockwise motion would have the same equation describing the x component, but the y component would be given by $y = -A\sin(\omega t + \phi)$, or $y = -2\sin\left(\frac{\pi}{2}t\right)$.

Question:

A particle moves in a circular motion according to the functions $x = A\cos(\omega t)$ and $y = A\sin(\omega t)$, where A=2.0 meters and ω=3.0 rad/second. What is the magnitude of the particle's centripetal acceleration?

a. 2 m/s^2
b. 18 m/s^2
c. 24 m/s^2
d. 0
e. Cannot be determined without further information

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Answer:

The correct answer is ***b***. The acceleration of the particle in any given dimension, generally, is given by the second-derivative of the position function:

$$v = \frac{dx}{dt}; a = \frac{dv}{dt} = \frac{d^2x}{dt^2}$$

This problem can be though of in terms of Simple Harmonic Motion, where $a = -\omega^2 x$. Although this *x*-acceleration varies over time, its maximum occurs when *x* is at a maximum:

$$a = -\omega^2 A$$

$$a = -(3.0 rad/s)^2(2.0m)$$

$$a = 18m/s^2$$

Based on the fact that this object is traveling with a constant speed (based on the constant value of ω), we can conclude that the maximum *x*-acceleration is due only to its circular motion, and is a constant value everywhere along its path.

Question:

A simple harmonic oscillator consisting of a mass M attached to a spring with spring constant k is set into motion at the surface of the earth, and observed to have a frequency f. The same spring is then attached to a mass of $2M$, and moved to a location R above the surface of the earth, where R is the radius of the earth. What is the frequency of oscillation now?

a. f

b. $2f$

c. $4f$

d. $f/2$

e. $f/\sqrt{2}$

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Answer:

The correct answer is *e*. The location of the mass-spring system doesn't have any effect on its frequency of oscillation, but the mass $2M$ attached to the spring does:

$$f_{mass-spring} = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

$$f' = \frac{1}{2\pi}\sqrt{\frac{k}{2m}} = \frac{f}{\sqrt{2}}$$

Note that changing the location of a pendulum *does* affect the frequency of its oscillation, according to the equation

$$f_{pendulum} = \frac{1}{2\pi}\sqrt{\frac{L}{g}}$$

Question:
A simple pendulum has a period T on the earth. What is the period T' of this same pendulum on the moon, where the acceleration due to gravity is 1/6 that of the earth?

a. $\frac{T}{\sqrt{6}}$

b. $\frac{T}{6}$

c. $\sqrt{6}\ T$

d. $6T$

e. $36T$

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Answer:
The correct answer is *c*. The length of the pendulum hasn't changed, and the only other factor that determines the period of a pendulum is the acceleration due to gravity.

$$T' = 2\pi\sqrt{\frac{\ell}{g}}$$

$$T' = 2\pi\sqrt{\frac{\ell}{\frac{1}{6}g}}$$

$$T' = \sqrt{6}\left(2\pi\sqrt{\frac{\ell}{g}}\right)$$

$$T' = \sqrt{6}\ T$$

Question:

A simple pendulum is constructed by attaching a mass *m* to a thin rod of length ℓ. The pendulum is pulled back to some angle $\emptyset > 30°$ from the vertical and released. Which of the following techniques could be used to change the frequency *f* of this pendulum?

I. Changing the mass *m* on the end of the pendulum.
II. Changing the length ℓ of the pendulum.
III. Changing the angle Ø from which the pendulum is released.

a. I only
b. I and II only
c. II only
d. II and III only
e. I, II, and III

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Answer:

The correct answer is *d*. For small angles of Ø (typically less than 15°), the frequency of oscillation for a simple pendulum is approximately

$$f = \frac{1}{T} = \frac{1}{2\pi}\sqrt{\frac{g}{\ell}}$$

For increasingly large value of Ø, however, the acceleration no longer varies linearly with displacement. Thus, for larger angles, the frequency *f will be* affected by the angle of release Ø, as well as by the length of the pendulum.

Question:
A clock driven by a simple pendulum is designed to function correctly on the moon, where $a_{gravity} = g/6$. If the pendulum for this clock has a period of 1.00 s, what is the approximate length of the pendulum?

a. $\frac{1}{2} m$

b. $\frac{1}{4} m$

c. $\frac{1}{8} m$

d. $\frac{1}{16} m$

e. $\frac{1}{24} m$

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Answer:
The correct answer is *e*. The period of a pendulum is determined according to the relationship $T = 2\pi\sqrt{\frac{\ell}{g}}$.

$$T = 2\pi\sqrt{\frac{\ell}{g}}$$

$$\ell = \left(\frac{T}{2\pi}\right)^2 g$$

$$\ell = \left(\frac{1s}{2\pi}\right)^2 \frac{10m/s^2}{6}$$

$$\ell = \frac{10m}{4 \bullet 6 \bullet \pi^2} = \frac{1}{24} m$$

Question:

A bob of mass m is attached to the end of a light rod of length L to make a simple pendulum that oscillates with a frequency f. Now a bob of mass $4m$ is attached to a light rod of length $4L$. The frequency of oscillation for this new pendulum is:

a. $\frac{f}{\sqrt{2}}$

b. $\frac{f}{2}$

c. $\frac{f}{4}$

d. $2f$

e. $4f$

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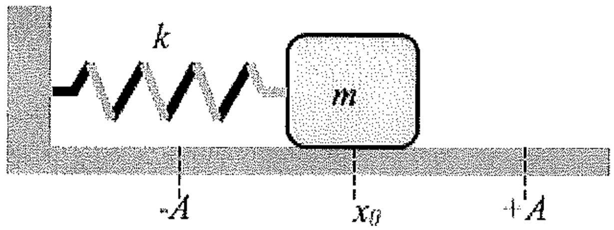
Answer:

The correct answer is *b*. The mass of a pendulum bob does not effect its frequency of oscillation, but the length of the pendulum itself does. The new frequency can be calculated as follows:

$$f = \frac{1}{2\pi}\sqrt{\frac{g}{L}}$$

$$f' = \frac{1}{2\pi}\sqrt{\frac{g}{4L}} = \frac{f}{2}$$

Question:



A spring with negligible mass and spring constant *k* is attached on one end to a block of mass *m*, and fastened at the other end to a wall. The block is pulled back a distance *A* from its equilibrium position and released so that it oscillates on the frictionless, horizontal surface. What is the velocity *v* of the mass as it passes the equilibrium position x_0?

a. $\sqrt{\frac{2kA}{m}}$

b. $\frac{k}{m}x^2$

c. $\frac{k}{m}A^2$

d. $A\sqrt{\frac{k}{m}}$

e. $A\sqrt{\frac{2k}{m}}$

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Answer:
The correct answer is *d*. This is a conservation of energy problem, with the mass-spring's elastic potential energy at the endpoints, $U_{spring} = \frac{1}{2}kx^2$, converting completely to kinetic energy at the midpoint, $K = \frac{1}{2}mv^2$.

$$U_s = K_0$$

$$\frac{1}{2}kA^2 = \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{kA^2}{m}} = A\sqrt{\frac{k}{m}}$$

Question:

A simple harmonic oscillator consists of a 4.0kg mass attached to the end of a spring with spring constant 1.0 N/m. If the speed of the mass as it passes the equlibrium position is 10 cm/s, what is the amplitude of the mass's oscillation?

a. 0.10 m
b. 0.20 m
c. 0.30 m
d. 0.40 m
e. 4.0 m

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Answer:

The correct answer is *b*. The mass has maximum kinetic energy as it passes through the equilibrium position, which is converted to maximum elastic potential energy at the maximum displacement (amplitude):

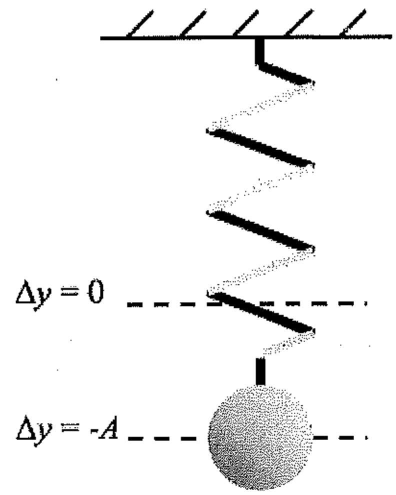
$$E_{total} = \frac{1}{2}kA^2 = \frac{1}{2}mv_0^{\,2}$$

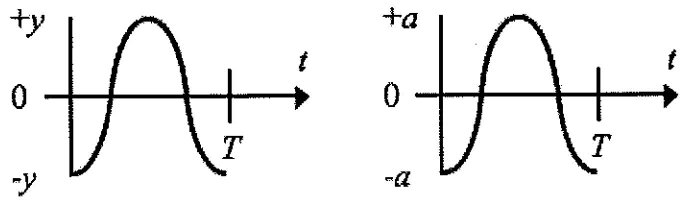
$$A = v_0\sqrt{\frac{m}{k}}$$

$$A = (0.10m/s)\sqrt{\frac{4.0kg}{1.0N/m}} = 0.20m$$

Question:

A simple harmonic oscillator is created by suspending a mass from an ideal spring attached to a support. The mass is pulled from its equilibrium position a distance A in the negative-y direction as shown, and released from rest at time $t = 0$. The mass oscillates up and down with a period T. Which are the correct *displacement-time* and *acceleration-time* graphs for this oscillator?



a.


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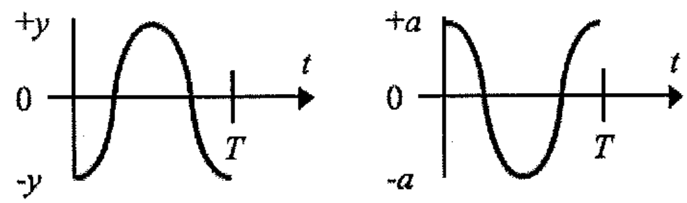
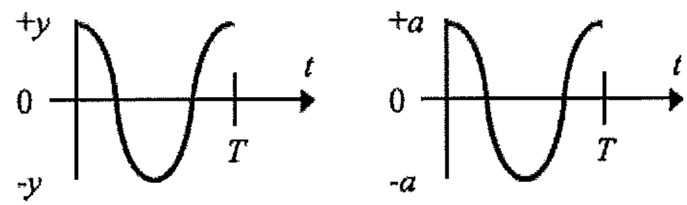
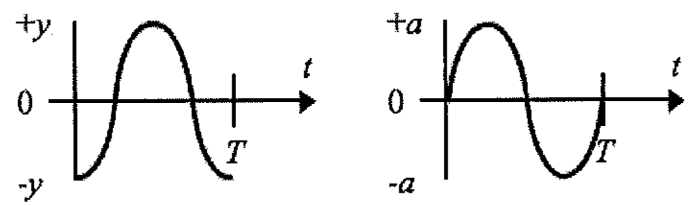
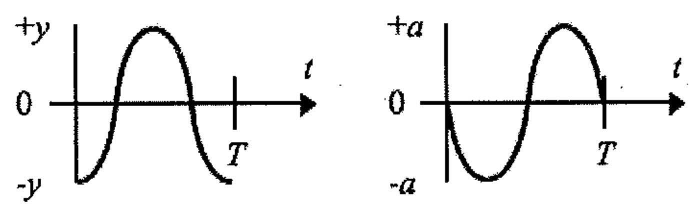


c.


d.


e.


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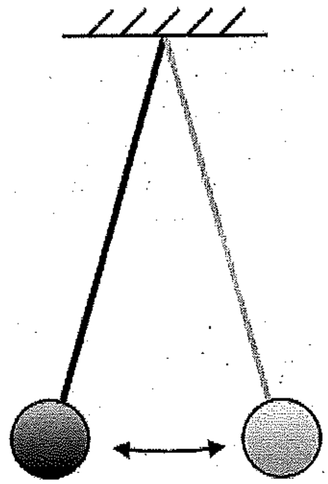
Answer:

The correct answer is *b*. When the mass has its maximum displacement in the negative-y direction, the spring is stretched to its maximum, where it is applying its maximum force on the mass in the opposite direction of the displacement, as described by Hooke's Law $\mathbf{F} = -k\mathbf{x}$. The acceleration of the mass, thus, is always at a maximum when displacement is at a maximum, but in the opposite direction of the displacement.

This can be described mathematically by the equations $y = A\cos(\omega t + \phi)$, where $\phi = \pi$, and $a = \frac{d^2y}{dt^2} = -\omega^2 y$. Answer *b* is consistent with these two functions.



Question:
A pendulum swings from left to right as shown in 0.25 seconds. The frequency of the pendulum is

a. 0.25 s
b. 0.50 s
c. 0.25 Hz
d. 1.0 Hz
e. 2.0 Hz.

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Answer:
The correct answer is *e*. *Frequency* is the number of "cycles per second," or "waves per second," where one cycle is a full back-and-forth displacement. Here, it takes 0.25 seconds for the pendulum to swing to the left, and another 0.25 s to return to the original position. That's one cycle per half-second, or two cycles per second, i.e. 2.0 Hz.

A formula-based approach to answering the question would involve determining the period $T = 0.50$ seconds as above, and then calculating frequency by taking the inverse of period:

$$f = \frac{1}{T}$$

$$f = \frac{1}{0.50s} = 2.0s^{-1} = 2.0Hz$$

Question:

A mass *m* is attached to the bottom of a string of negligible mass and length L to form a simple pendulum. The mass is pulled back a small angle Ø and released so that the pendulum swings back and forth with simple harmonic motion. Which of the following statements is true of this pendulum?

a. The acceleration of *m* is a minimum when displacement Ø is a minimum.
b. The period of the pendulum varies as a function of *m*.
c. The kinetic energy of the pendulum is a maximum when its displacement is a maximum.
d. The frequency of the pendulum varies with angle Ø.
e. The length of the string L has no effect on the period of the pendulum.

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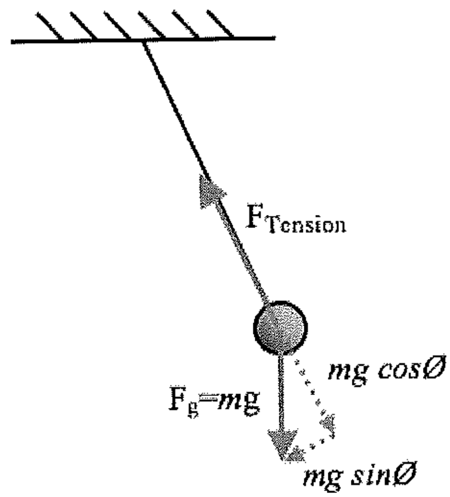
Answer:

The correct answer is *a*. The pendulum's motion is described by the formula $T = 2\pi\sqrt{\frac{L}{g}}$, as long as the initial displacement angle Ø is not too great. The acceleration of the pendulum during its motion is described by the relationship $a = g\sin\varnothing$, with maximum acceleration at the either end of the swing, and an acceleration of 0 when the pendulum passes the equilibrium position.



Note that the mass *m* of the pendulum bob does not affect the pendulum's frequency. The pendulum's maximum gravitational potential energy U occurs at maximum displacement (either end of the swing), and its maximum kinetic energy occurs at the equilibrium position, when the pendulum is hanging straight down.