MCQ Practice Test 3
Answer Key and Solutions

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Answer Key

1. C	11. C	21. B	31. D
2. D	12. D	22. B	32. B
3. A	13. B	23. C	33. B
4. B	14. A	24. A	34. D
5. D	15. C	25. B	35. A
6. C	16. D	26. D	36. A
7. C	17. D	27. C	37. D
8. C	18. B	28. D	38. A
9. D	19. D	29. C	39. A
10. B	20. A	30. A	40. C

Solutions are on the following pages

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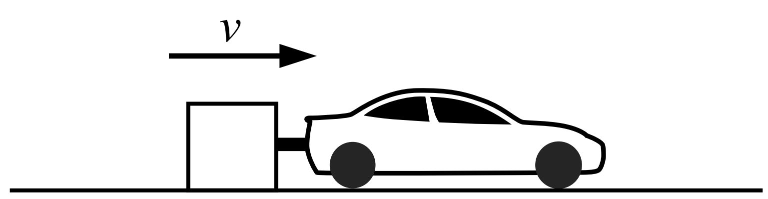


1. A block is attached to a car which pulls the block across the ground where the friction between the block and the ground is not negligible. The block is moving at a constant speed. Which of the following statements is true?

(A) The force exerted on the block from the car is greater in magnitude than the friction force on the block

(B) The force exerted on the block from the car is smaller in magnitude than the friction force on the block

(C) The force exerted on the block from the car is equal in magnitude to the friction force on the block

(D) The friction force on the block is zero

A Incorrect

B Incorrect

C **Correct**

There is a force exerted on the block from the car which acts to the right and a friction force exerted on the block from the ground which acts to the left. The net horizontal force on the block is the force from the car minus the friction force. The block is moving at a constant velocity (it is not accelerating) so the net horizontal force on the block is zero, and the force from the car is equal to the friction force.

Block: $\Sigma F_x = m a_x$ $\quad F_{car} - f = m(0)$ $\quad F_{car} = f$

D Incorrect

Related course pages: *2 - Newton's 1st Law & Forces, 2 - Friction*

2. A cart is sliding on a horizontal track and its motion is shown in the figure above. Which of the following statements about the cart's motion is true?

(A) The cart is not moving between 2 s and 6 s

(B) The speed of the cart is decreasing between 4 s and 6 s

(C) The cart is not moving between 0 s and 2 s

(D) The speed of the cart is increasing between 4 s and 6 s

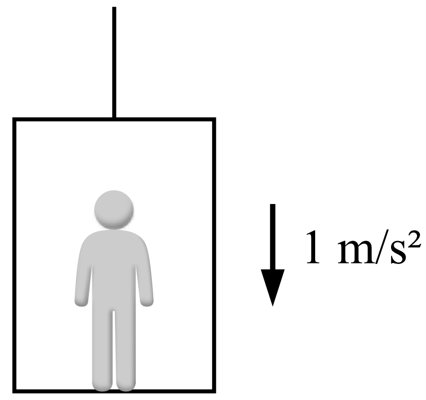
A Incorrect
The cart has a constant negative acceleration between 2 s and 6 s and it is moving (it has a non-zero velocity) during that period, except exactly at 4 s when the velocity is momentarily 0 m/s.

B Incorrect
The velocity is in the negative direction between 4 s and 6 s and the speed of the cart (the magnitude or absolute value of the velocity) is increasing.

C Incorrect
The cart has a constant positive velocity from 0 s to 2 s so the cart is moving.

D **Correct**
The velocity is in the negative direction between 4 s and 6 s and the speed of the cart (the magnitude or absolute value of the velocity) is increasing.

Related course pages: *1 - 1D Motion*



3. A person is standing in an elevator which is accelerating downwards at 1 m/s^2. Which of the following is true of the net force acting on the person?

(A) The net force on the person is downwards

(B) The net force on the person is upwards

(C) There is no net force acting on the person

(D) The direction of the net force cannot be determined

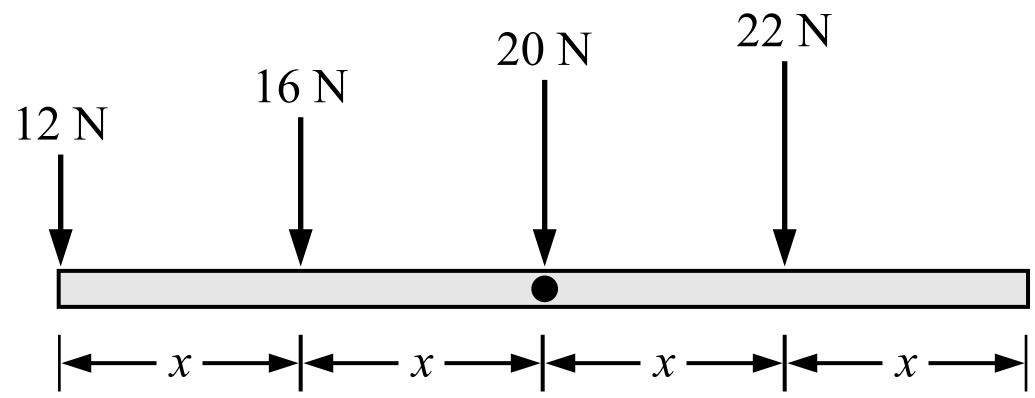
A **Correct**
The person is accelerating downwards so the net force acting on the person must be downwards (Newton's 2nd law of motion).

B Incorrect

C Incorrect

D Incorrect

Related course pages: *2 - Newton's 2nd Law*



4. Four forces are exerted on a rod which is free to rotate about its center. The forces are applied at evenly spaced distances as shown in the figure above. Which single force, if applied on its own, would cause the rod to rotate with the greatest angular acceleration (magnitude)?

(A) The 22 N force

(B) The 12 N force

(C) The 20 N force

(D) The 16 N force

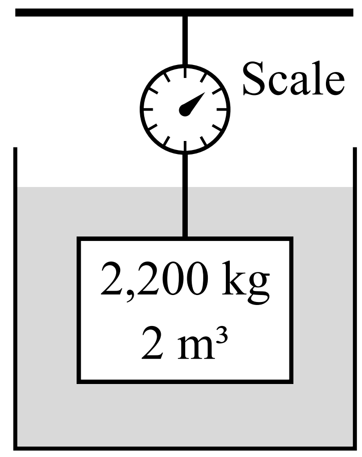
A Incorrect
The torque produced by the 22 N force is: $\tau = rF_{\perp} = (x)(22\text{ N}) = 22x$

B **Correct**
The angular acceleration of the rod is equal to the net torque acting on the rod divided by the rotational inertia of the rod about the point of rotation. The force which produces the greatest torque about the point of rotation (the center) will result in the greatest angular acceleration. The torque produced by a force is equal to the distance between the point of rotation and the point where the force is applied, multiplied by the component of the force which is perpendicular to the rod (all of the forces are perpendicular to the rod).
12 N force: $\tau = rF_{\perp} = (2x)(12\text{ N}) = 24x$

C Incorrect
The torque produced by the 20 N force is: $\tau = rF_{\perp} = (x)(20\text{ N}) = 0$

D Incorrect
The torque produced by the 16 N force is: $\tau = rF_{\perp} = (x)(16\text{ N}) = 16x$

Related course pages: *5 - Torque, 5 - Rotational Dynamics*



5. A block is suspended from a scale with a string and is fully submerged in a container of water as shown in the figure above. The block has a mass of 2,200 kg and a volume of 2 m^3. The density of the water is 1,000 kg/m^3. The reading on the scale is

(A) 20,000 N

(B) 22,000 N

(C) 0 N

(D) 2,000 N

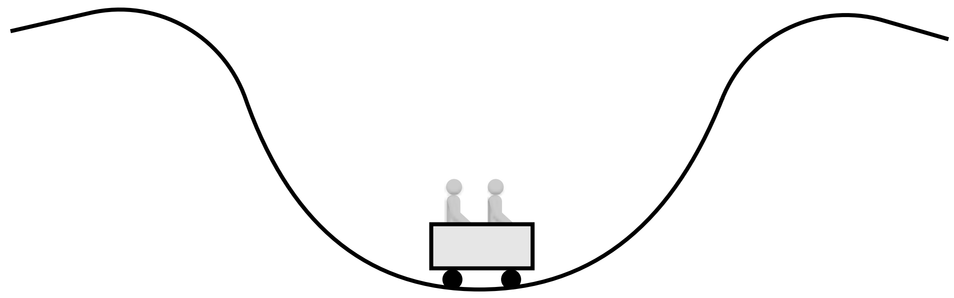
A Incorrect
This is the magnitude of the buoyant force on the block.

B Incorrect
This is the weight of the block. The tension in the string (and the reading on the scale) is not equal to the weight of the block because there is also an upwards buoyant force on the block.

C Incorrect
This answer may have been found by incorrectly assuming the upwards buoyant force on the block is equal to the weight of the block, or by using the density of the block instead of the density of the fluid to calculate the buoyant force.

D **Correct**
We assume the block is at rest because we are not told otherwise, and the density of the block is greater than the density of the water so the block does not float upwards. If the block is at rest then the net force on the block is zero (Newton's 1st law). There is an upwards buoyant force, a downwards weight force and an upwards tension force on the block from the string. The scale reads the tension force in the string.
$\Sigma F_y = F_B - F_g + T = 0 \qquad T = F_g - F_B = mg - \rho_f V_f g = (2{,}200 \text{ kg})g - (1{,}000 \text{ kg/m}^3)(2 \text{ m}^3)g = 2{,}000 \text{ N}$

Related course pages: *2 - Newton's 1st Law & Forces, 8 - Buoyant Force*



6. Two people are riding a roller coaster and the car enters a dip with a circular arc as shown in the figure above. When the car is at the position shown, the apparent weight of a rider is

(A) equal to their true weight

(B) less than their true weight

(C) greater than their true weight

(D) a comparison between their apparent weight and true weight cannot be determined

A Incorrect

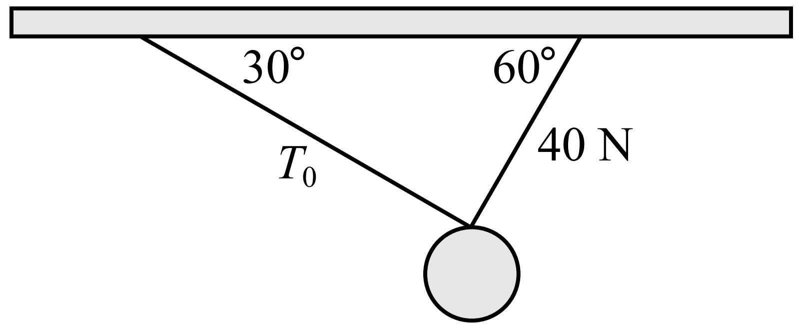
B Incorrect

C **Correct**

There is a downwards weight force and an upwards normal force acting on each person (from the seat or floor of the car). When the car is at the bottom of the circular arc the net force on each person is upwards because they are moving in circular motion and they are accelerating upwards at that moment. The upwards normal force, which is the apparent weight, is greater than the downwards weight force on each person.

D Incorrect

Related course pages: *2 - Gravity & Weight, 2 - Centripetal Acceleration and Force*



7. A ball is suspended from two cables as shown in the figure above. The ball is at rest and the tension in the cable on the right is 40 N. The tension T_0 in the cable on the left is most nearly

(A) 20 N
(B) 69 N
(C) 23 N
(D) 40 N

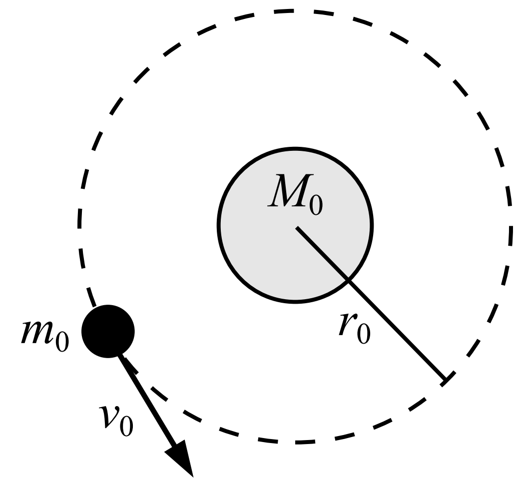
A Incorrect
This answer may incorrectly assume that the tension in the left cable is half of the tension in the right cable because the angle of the left cable with the horizontal is half of the angle of the right cable.

B Incorrect
This answer incorrectly uses $\sin(\theta)$ instead of $\cos(\theta)$ for the components of the tension forces that are equal in magnitude.

C **Correct**
The ball is at rest so the net force on the ball is zero. There is a downwards weight force acting on the ball and two tension forces acting on the ball in the direction of each cable. The net horizontal force on the ball is zero so the horizontal components of the two tension forces must be equal in magnitude and opposite in direction.
$\Sigma F_x = (40\text{ N})\cos(60°) - T_0\cos(30°) = m(0\text{ m/s}^2)$ $\quad T_0 = 23.1\text{ N}$

D Incorrect
This answer incorrectly assumes the tensions in both cables are the same.

Related course pages: *2 - Newton's 1st Law & Forces, 2 - Tension & Pulley Systems*



8. A satellite with a mass of m_0 is orbiting a planet with a mass of M_0. The satellite has a speed of v_0 and an orbital radius of r_0. If a second satellite has the same orbital radius but a mass of $2m_0$, what is the speed of the second satellite in terms of v_0?

(A) $4v_0$

(B) $2v_0$

(C) v_0

(D) $v_0/\sqrt{2}$

A Incorrect

B Incorrect

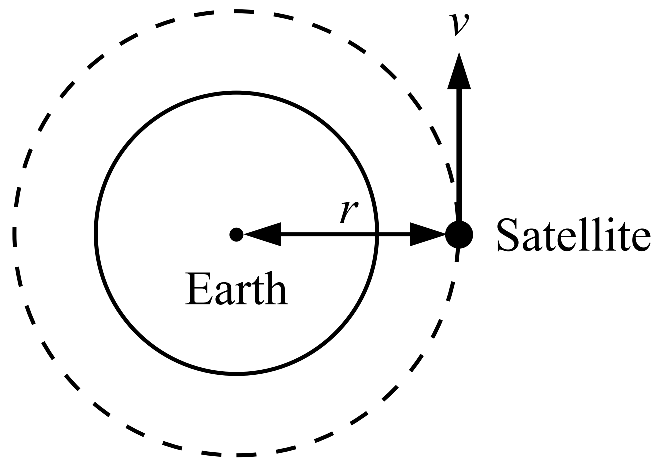
C **Correct**

The satellites are in uniform circular motion around the planet and the gravitational force is acting as the centripetal force. The speed of the satellite does not depend on the mass of the satellite.

$$F_c = F_g \qquad \frac{mv^2}{r} = \frac{GMm}{r^2} \qquad v^2 = \frac{GM}{r}$$

D Incorrect

Related course pages: *2 - Gravity & Weight, 2 - Centripetal Acceleration and Force, 2 - Orbital Motion*



9. A satellite follows a circular orbit around the earth at a constant speed as shown in the figure above. How long does it take to complete one orbit?

(A) $2\pi r$

(B) $\dfrac{r}{v}$

(C) $2\pi r v$

(D) $\dfrac{2\pi r}{v}$

A Incorrect

B Incorrect

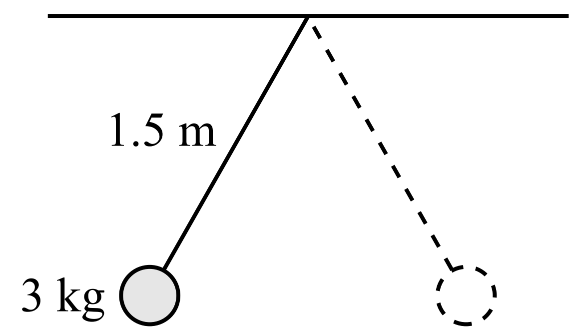
C Incorrect

D Correct

The speed of the satellite is equal to the distance the satellite travels (the linear distance or the arc length) divided by a period of time. The question is asking for the amount of time it takes the satellite to travel a distance of one circumference of its circular path.

$$v = \frac{d}{\Delta t} = \frac{\Delta s}{\Delta t} \qquad \Delta t = \frac{\Delta s}{v} = \frac{2\pi r}{v}$$

Related course pages: *2 - Circular Motion*



10. A 3 kg mass is attached to a 1.5 m long string with negligible mass as shown in the figure above. The mass is released from rest at the position shown. The time it takes for the mass to swing across to the other side, where the mass is at the same height, is most nearly

(A) 0.2 s

(B) 1.2 s

(C) 8.1 s

(D) 2.4 s

A Incorrect
This answer excludes the 2π in the equation for the period of the pendulum.

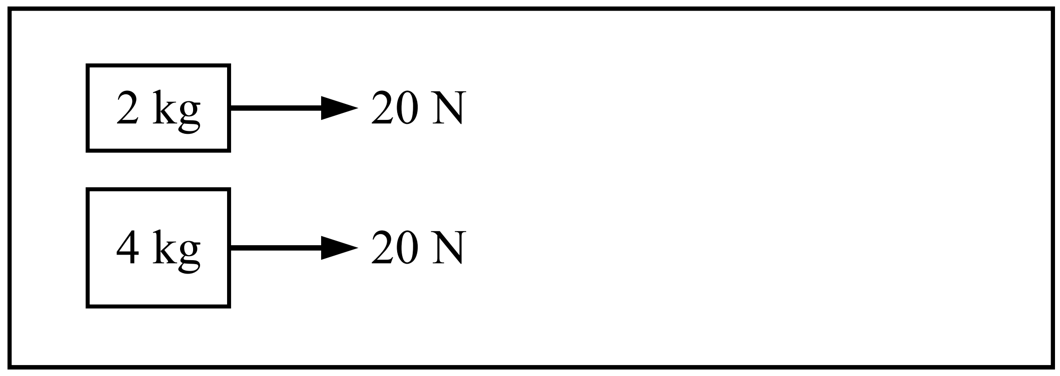
B **Correct**
The time it takes to swing from one side to the other is half of the period of the pendulum's motion, which is given by the equation below. The period does not depend on the mass.

$$T_p = 2\pi\sqrt{\frac{L}{g}} = 2\pi\sqrt{\frac{1.5\text{ m}}{g}} = 2.4\text{ s} \qquad t = \frac{2.4\text{ s}}{2} = 1.2\text{ s}$$

C Incorrect
This answer switches L and g in the equation for the period of the pendulum.

D Incorrect
This answer is the period of the pendulum. The question is asking for half of the period.

Related course pages: *7 - Simple Harmonic Motion*



11. Two blocks are sitting on a table where the friction between the blocks and the table is negligible. A 20 N force is then exerted on each block for a period of 5 seconds. Which block experiences a greater impulse during that time?

(A) The 2 kg block

(B) The 4 kg block

(C) The blocks experience the same impulse

(D) Cannot be determined

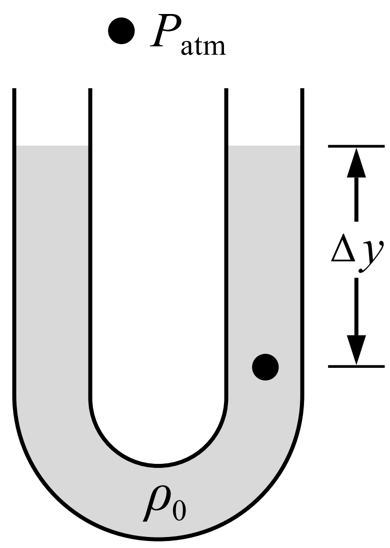
A Incorrect

B Incorrect

C **Correct**
The impulse exerted on a block is equal to the force applied multiplied by the period of time the force is applied. The same force is applied to each block for the same period of time so the impulses are the same.
$J = F\Delta t$

D Incorrect

Related course pages: *4 - Linear Momentum & Impulse*



12. A tube is partially filled with a liquid with a density of ρ_0 as shown in the figure above. The ends of the tube are open. Which of the following is a correct expression for the absolute pressure at the point shown in the liquid?

(A) $\rho_0 g \Delta y$

(B) $P_{atm} - \rho_0 g \Delta y$

(C) $\rho_0 g \Delta y - P_{atm}$

(D) $\rho_0 g \Delta y + P_{atm}$

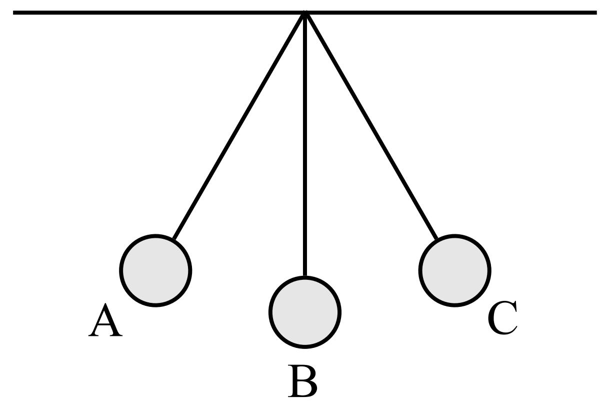
A Incorrect
This is the gauge pressure at the point shown due to the weight of the liquid above it. The absolute pressure is the gauge pressure plus the atmospheric pressure.

B Incorrect

C Incorrect

D Correct
The absolute pressure at a point in a fluid is equal to the gauge pressure plus the atmospheric pressure. The gauge pressure at a point below the surface of a fluid depends on the density of the fluid and the depth.
$P_{abs} = P_{gauge} + P_{atm} = \rho g h + P_{atm} = \rho_0 g \Delta y + P_{atm}$

Related course pages: *8 - Pressure*



13. A pendulum consists of a sphere attached to a string suspended from the ceiling. As the sphere swings across from position A to position C, what is the direction of the acceleration of the sphere at position B?

(A) 

(B) 

(C) 

(D) The acceleration is zero

Ⓐ Incorrect

Ⓑ **Correct**

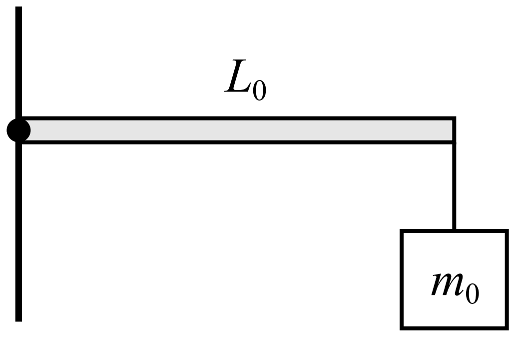
There are no horizontal forces acting on the sphere at position B so there is no acceleration in the horizontal direction. The sphere is following a circular path and the velocity of the sphere is constantly changing direction so the sphere is accelerating at position B (acceleration is the change in the velocity vector over time, which can be a change in the magnitude or direction of the velocity). The acceleration of the sphere at position B is the centripetal acceleration caused by the tension force in the string which keeps the sphere moving in a circular path. The acceleration points upwards at position B towards the center of the circular path.

$\Sigma F_y = T - F_g = m a_y$ and $a = \frac{v^2}{r}$

Ⓒ Incorrect

Ⓓ Incorrect

Related course pages: *2 - Centripetal Acceleration and Force*



14. A beam with negligible mass and a length of L_0 is attached to a wall at its left end. A block with a mass of m_0 is suspended from the right end of the beam by a string with negligible mass, producing a torque of τ_0 about the left end of the beam. If the length of the beam was changed to $L_0/3$ and the mass was changed to $2m_0$, the torque produced about the left end of the beam would be

(A) $2\tau_0/3$
(B) $6\tau_0$
(C) $3\tau_0/2$
(D) $\tau_0/3$

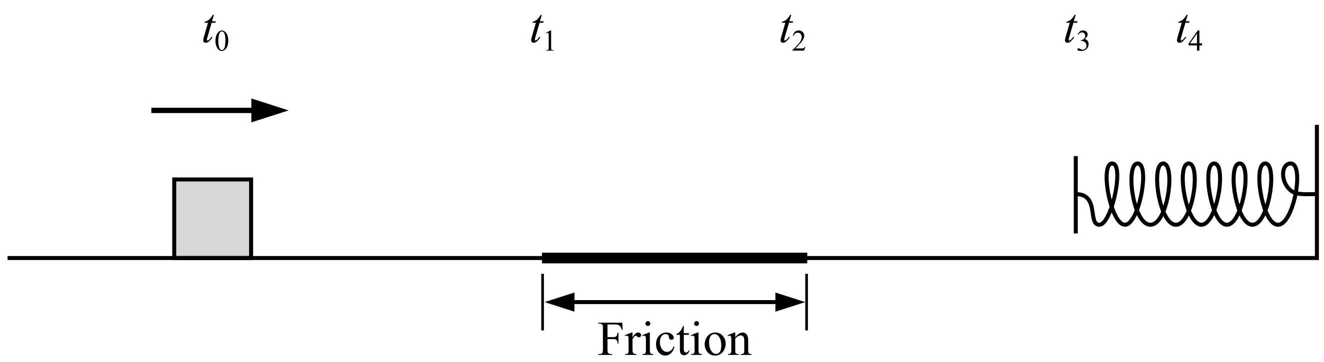
A Correct
The weight force on the block produces a torque about the left end of the beam which is equal to the length of the beam multiplied by the weight force of the block (which acts perpendicular to the beam). If the length of the beam is divided by 3 and the mass of the block is multiplied by 2 then the torque is multiplied by 2/3.
$\tau_0 = rF_\perp = L_0 m_0 g \qquad \tau = (L_0/3)(2m_0)g = 2\tau_0/3$

B Incorrect

C Incorrect

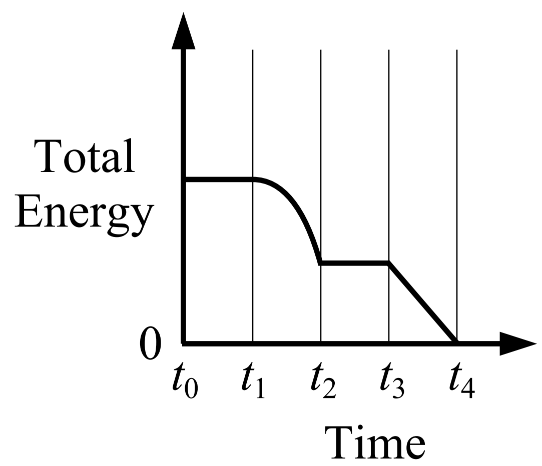
D Incorrect

Related course pages: *5 - Torque*

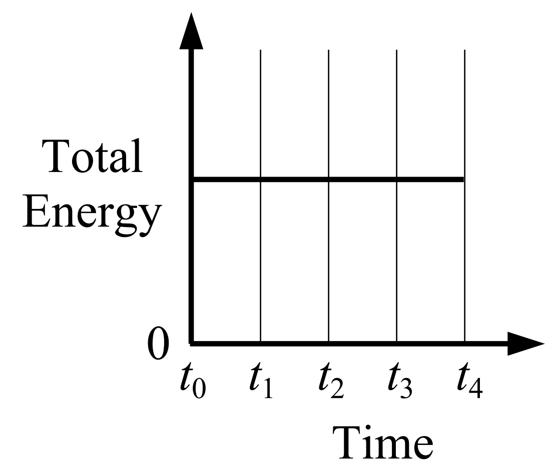


15. A block is sliding across a surface with negligible friction at a constant speed at time t_0. The block then slides over a patch where friction acts on the block from time t_1 to time t_2. The block then again slides across a surface with negligible friction from time t_2 to time t_3. The block comes into contact with a spring at time t_3 and compresses the spring until the block momentarily comes to rest at time t_4. Which of the following graphs show the total energy of the block-spring system over time?

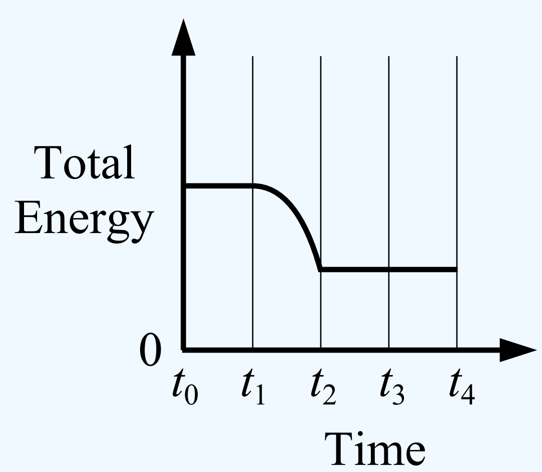
(A)



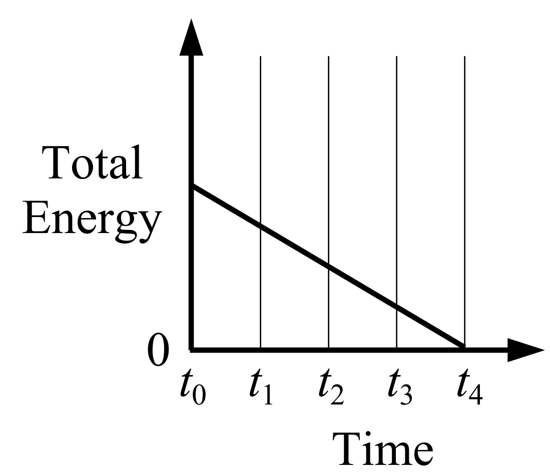
(B)



(C)



(D)



A Incorrect

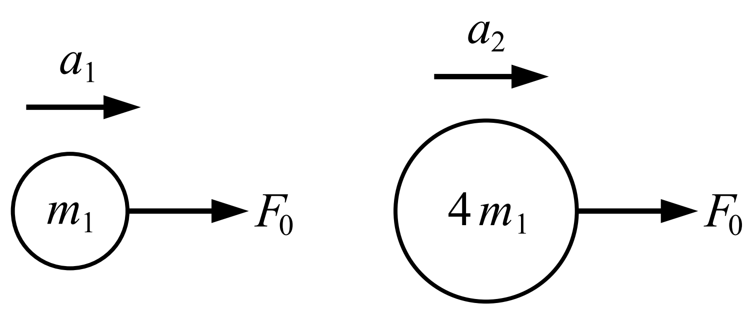
B Incorrect

C Correct

The block-spring system has kinetic energy and spring potential energy in this scenario. From t_0 to t_1 the block has a constant speed and constant kinetic energy. From t_1 to t_2 there is a friction force acting on the block which does negative work on the system so the system loses energy (kinetic energy). From t_2 to t_3 the block has a constant speed and constant kinetic energy. From t_3 to t_4 kinetic energy is converted into spring potential energy, but the system includes the block and the spring so energy is conserved.

D Incorrect

Related course pages: *3 - Conservation of Energy, Work & Power*



16. A force with a magnitude of F_0 acts on an object with a mass of m_1, causing it to move with an acceleration of a_1. The same force is applied to an object with a mass of $4m_1$, causing it to move with an acceleration of a_2. Which of the following is the correct expression for a_2 in terms of a_1?

(A) a_1

(B) $4a_1$

(C) $\frac{a_1}{16}$

(D) $\frac{a_1}{4}$

A **Incorrect**
This answer incorrectly assumes the acceleration is the same if the force is the same.

B **Incorrect**
This answer incorrectly assumes that mass and acceleration are directly proportional and that multiplying the mass by 4 means that the acceleration is multiplied by 4.

C **Incorrect**
This answer incorrectly assumes that acceleration is inversely proportional to m^2.

D **Correct**
The relationship between the force, mass and acceleration of an object is given by Newton's 2nd law of motion: $F = ma$. The mass and the acceleration are inversely proportional. If the force remains the same but the mass is multiplied by 4, the acceleration must be divided by 4. The acceleration can also be found by setting up a system of equations and solving for a_2:
$F_0 = m_1 a_1$ and $F_0 = 4m_1 a_2$, so $m_1 a_1 = 4m_1 a_2$ and $a_1/4 = a_2$

Related course pages: *2 - Newton's 2nd Law*

17. Two blocks are sliding towards each other on a surface with negligible friction as shown in the figure above. The blocks collide and stick together. Which direction do the blocks move after the collision?

(A) Right

(B) Left

(C) They do not move after the collision

(D) Cannot be determined

A Incorrect

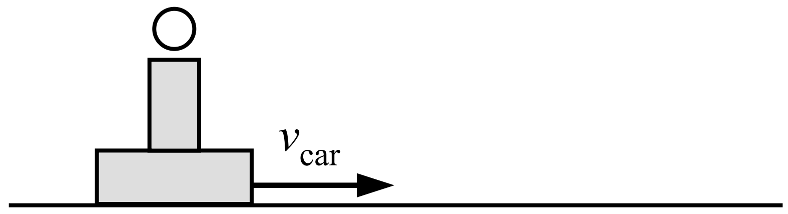
B Incorrect

C Incorrect

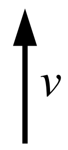
D **Correct**

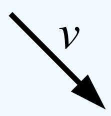
The total momentum of the two block system is conserved during the collision so the direction of the total momentum does not change. The mass of each block must be known in order to find the momentum of each block and the direction of the total momentum of the system.

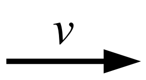
Related course pages: *4 - Conservation of Momentum & Collisions*

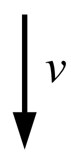


18. A ball is in a spring-loaded gun mounted on the top of a small car which is moving on a frictionless track as shown in the figure above. While the car is moving with a constant speed the ball is launched directly upwards relative to the car. The ball lands back in the gun 3 seconds later. The direction of the ball's velocity vector 2 seconds after being launched (relative to the ground) is most nearly

(A) 

(B) 

(C) 

(D) 

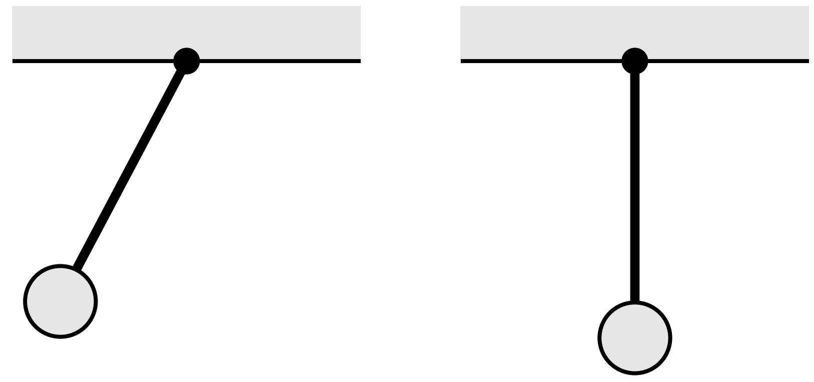
A Incorrect
This answer is the direction of the ball's initial velocity vector relative to the car.

B Correct
The initial velocity vector of the ball (relative to the ground) has the same horizontal velocity component as the car's velocity and it has a vertical velocity component from being launched upwards. The ball follows a parabolic trajectory through the air (similar to a projectile launched at an angle) and ends at the same height after 3 seconds. The ball is at the maximum height in the trajectory in half of that time, 1.5 seconds. At 2 seconds the ball is falling down so it has a downwards vertical component and the initial horizontal component.

C Incorrect
This answer is the direction of the car's velocity, the ball's horizontal velocity component at any time, and the ball's velocity when it's at the maximum height in the trajectory (at 1.5 seconds).

D Incorrect
This answer is the direction of the vertical component of the ball's velocity between 1.5 seconds and 3 seconds but the ball's velocity also has a horizontal component.

Related course pages: *1 - Projectile Motion*



19. A pendulum consisting of a rod and a sphere is free to pivot about the point where the rod is attached to the ceiling as shown in the figure above. The pendulum is released from rest at the position shown at time t_1. The pendulum swings back and forth and is momentarily vertical at a later time t_2. Which of the following correctly describes how the angular speed of the pendulum is changing at time t_1 and time t_2?

(A)

Angular speed at t_1	Angular speed at t_2
Not changing	Not changing

(B)

Angular speed at t_1	Angular speed at t_2
Increasing	Increasing

(C)

Angular speed at t_1	Angular speed at t_2
Decreasing	Increasing

(D)

Angular speed at t_1	Angular speed at t_2
Increasing	Not changing

A Incorrect

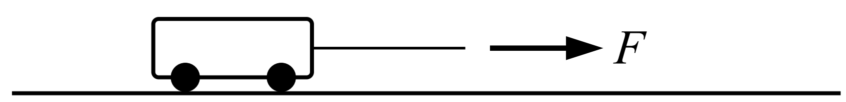
B Incorrect

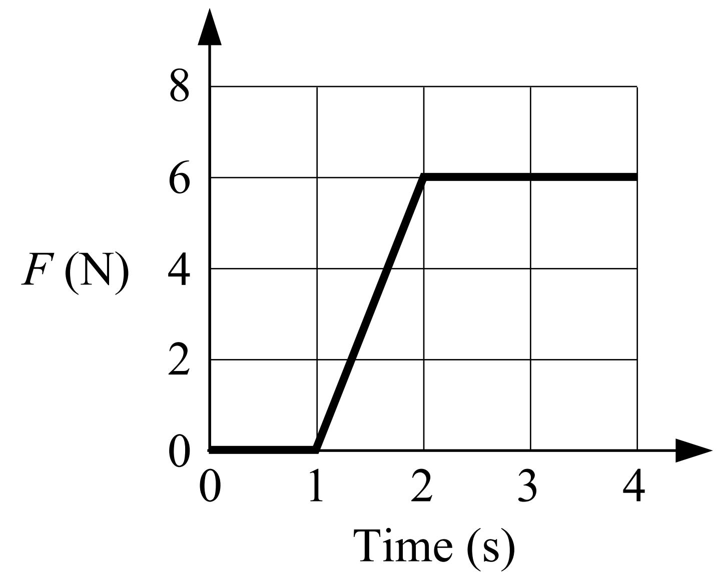
C Incorrect

D **Correct**

The weight forces acting on the rod and the sphere can produce a net torque on the pendulum about the point of rotation (the top of the rod). A net torque causes the pendulum to rotate with an angular acceleration, $\Sigma\tau = I\alpha$, and an angular acceleration is a change in the angular velocity (or speed). A torque is produced at time t_1 because the weight forces have a component that is perpendicular to the rod (the weight forces are at an angle to the rod and not parallel to it), so there is an angular acceleration which causes the angular speed to increase (the pendulum starts at rest). There is no torque on the pendulum at time t_2 because the weight forces are parallel to the rod and the line of force passes through the point of rotation, so there is no angular acceleration and the angular speed does not change at that moment.

Related course pages: *5 - Torque, 5 - Rotational Dynamics*





20. A cart is pulled along a horizontal track with negligible friction by a varying force F. A graph of the applied force over time is shown in the figure above. What is the change in momentum of the cart between 0 seconds and 3 seconds?

(A) 9 kg·m/s

(B) 12 kg·m/s

(C) 18 kg·m/s

(D) Cannot be determined

A Correct

The change in momentum of the car (the impulse exerted on the cart) between 0 seconds and 3 seconds is the average force during that time multiplied by the period of time, which is also equal to the area under the force-time graph from 0 seconds to 3 seconds. The area can be split into a triangle from 1-2 seconds and a rectangle from 2-3 seconds.

$\Delta p = F_{avg}\Delta t =$ area under force-time graph

$$\Delta p = A_{1\text{-}2s} + A_{2\text{-}3s} = \frac{1}{2}(2\text{ s} - 1\text{ s})(6\text{ N}) + (3\text{ s} - 2\text{ s})(6\text{ N}) = 9\text{ N·s} = 9\text{ kg·m/s}$$

B Incorrect

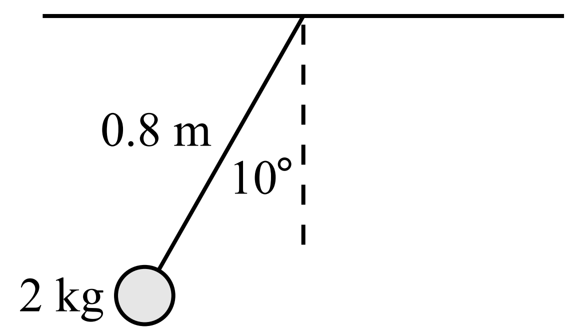
This answer incorrectly multiplies 6 N by 2 seconds.

C Incorrect

This answer incorrectly multiplies 6 N by 3 seconds.

D Incorrect

Related course pages: *4 - Linear Momentum & Impulse*



Note: Figure not drawn to scale.

21. A 2 kg sphere is attached to a 0.8 m long cable with negligible mass to form a pendulum as shown in the figure above. The pendulum is released from rest at the position shown. The speed of the sphere at the lowest point in the motion is most nearly

(A) 4.0 m/s
(B) 0.5 m/s
(C) 3.6 m/s
(D) 1.7 m/s

A **Incorrect**
This answer incorrectly uses 0.8 m for the change in height of the sphere.

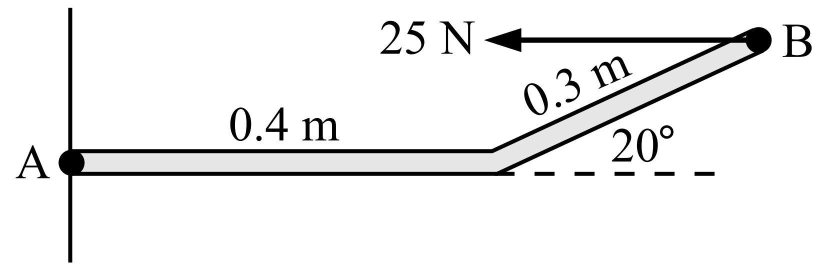
B **Correct**
The total energy of the sphere-earth system is conserved (the tension force from the cable acts perpendicular to the velocity of the sphere so it does not do work on the system). The sphere has no kinetic energy at the position shown since the sphere is at rest, and we can establish the reference height for zero gravitational potential energy when the sphere is at the lowest point in the motion.

$E_i = E_f \qquad U_{gi} = K_f \qquad mgh = \frac{1}{2}mv^2 \qquad g((0.8\text{ m}) - (0.8\text{ m})\cos(10°)) = \frac{1}{2}v^2 \qquad v = 0.5\text{ m/s}$

C **Incorrect**
This answer incorrectly uses $\sin(10°)$ instead of $\cos(10°)$ in the expression for the change in height.

D **Incorrect**
This answer incorrectly uses $(0.8\text{ m})\sin(10°)$ for the change in height of the sphere.

Related course pages: *3 - Conservation of Energy, Work & Power*



22. A rod consisting of a 0.4 m long segment and a 0.3 m long segment is attached to a wall at point A as shown in the figure above. A 25 N force acts horizontally at point B on the rod. The magnitude of the torque produced by the 25 N force about point A is

(A) 10 N·m

(B) 2.6 N·m

(C) 6.0 N·m

(D) 3.4 N·m

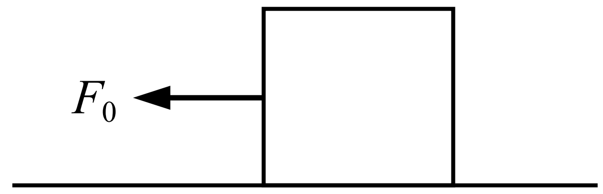
A Incorrect
This answer incorrectly calculates the torque as $\tau = (0.4\text{ m})(25\text{ N})$.

B **Correct**
The magnitude of the torque produced by a force can be calculated in two ways. First, $\tau = rF_{\perp}$ where r is the straight-line distance between the point of rotation and the point where the force is applied (the straight-line distance between points A and B which is not 0.7 m) and $F_{\perp}$ is the component of the force that is perpendicular to the radial line (a straight line betwen points A and B). Those values could be found using geometry. The second method would be easier: $\tau = r_{\perp}F$ where $r_{\perp}$ is the distance between the point of rotation and the line of force (a line that extends from the force vector), and F is the magnitude of the force.
$\tau = r_{\perp}F = (0.3\text{ m})\sin(20°)(25\text{ N}) = 2.6\text{ N·m}$

C Incorrect
This answer incorrectly calculates the torque as $\tau = (0.7\text{ m})(25\text{ N})\sin(20°)$.

D Incorrect
This answer incorrectly calculates the torque as $\tau = (0.4\text{ m})(25\text{ N})\sin(20°)$.

Related course pages: *5 - Torque*



23. A block is sitting on a floor and the friction force between the block and the floor is not negligible. A force is applied to the block as shown in the figure above and the block remains at rest. Which of the following is true about the friction force acting on the block from the floor while the force is applied?

(A) The magnitude of the friction force is less than the magnitude of F_0

(B) The magnitude of the friction force is greater than the magnitude of F_0

(C) The magnitude of the friction force is equal to the magnitude of F_0

(D) The relationship between the magnitude of the friction force and the magnitude of F_0 cannot be determined

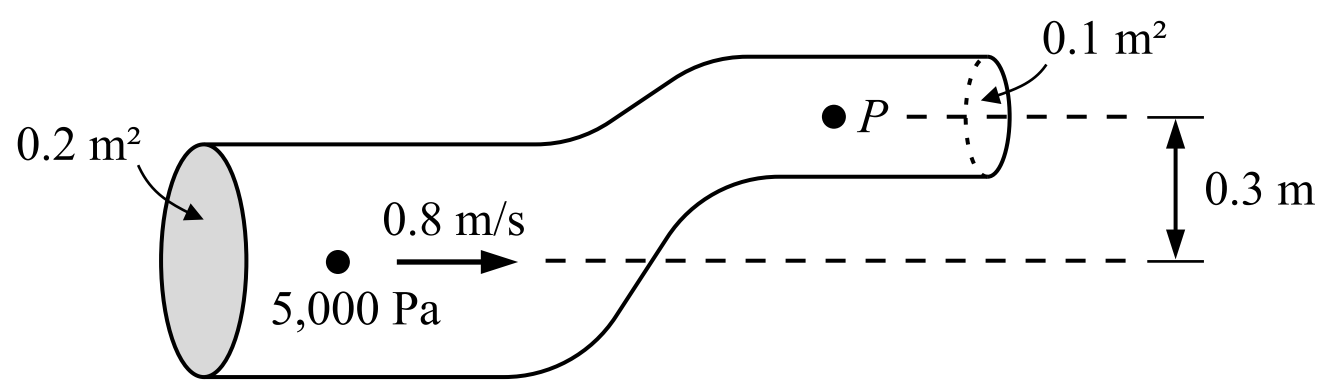
A Incorrect

B Incorrect

C **Correct**
The block remains at rest so the net horizontal force on the block is zero and the static friction force must be equal in magnitude and opposite in direction to the applied force F_0.

D Incorrect

Related course pages: *2 - Newton's 1st Law & Forces, 2 - Friction*



24. Water is flowing through the tube shown in the figure above. What is the pressure P at the point shown in the figure? The density of the water is 1,000 kg/m³.

(A) 1,040 Pa
(B) 2,320 Pa
(C) 2,000 Pa
(D) 3,000 Pa

A Correct

We need to use Bernoulli's equation to find the pressure P but we first need to find the speed of the flow at that point using the conservation of flow rate equation.

$A_1 v_1 = A_2 v_2 \qquad (0.2\text{ m}^2)(0.8\text{ m/s}) = (0.1\text{ m}^2)v_2 \qquad v_2 = 1.6\text{ m/s}$

Then we can use Bernoulli's equation to find the pressure at point 2 and set $y = 0\text{ m}$ at the first point.

$$P_1 + \rho g y_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g y_2 + \frac{1}{2}\rho v_2^2$$

$$(5{,}000\text{ Pa}) + (1{,}000\text{ kg/m}^3)g(0\text{ m}) + \frac{1}{2}(1{,}000\text{ kg/m}^3)(0.8\text{ m/s})^2 = \ldots$$

$$\ldots\ P + (1{,}000\text{ kg/m}^3)g(0.3\text{ m}) + \frac{1}{2}(1{,}000\text{ kg/m}^3)(1.6\text{ m/s})^2$$

$P = 1{,}040\text{ Pa}$

B Incorrect

This answer incorrectly assumes the speed at the second point is 0 m/s.

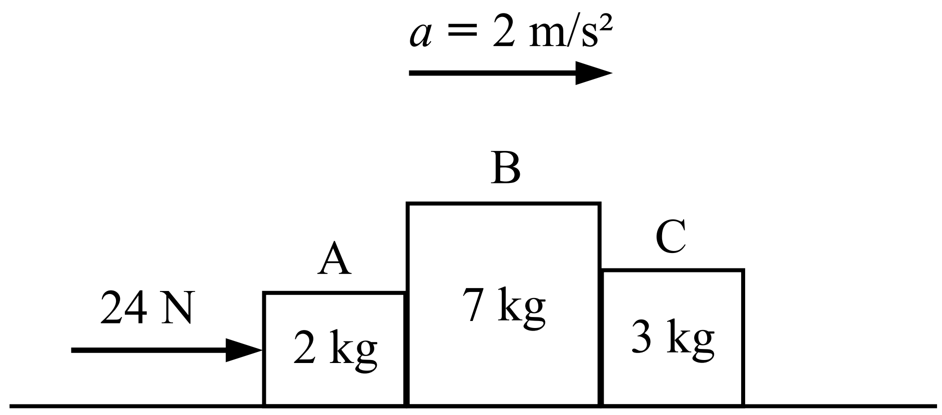
C Incorrect

This answer incorrectly finds the pressure at the second point due to the difference in height only, which is only true if the fluid is not moving (static).

D Incorrect

This answer incorrectly finds the pressure at a depth of 0.3 m in water that is not moving (static).

Related course pages: *8 - Flow*



25. A force is applied to the left of three blocks with different masses which are sliding on a frictionless surface as shown in the figure above. The three blocks accelerate together without losing contact. What is the magnitude of the force that block C exerts on block B?

(A) 0 N
(B) 6 N
(C) 8 N
(D) 24 N

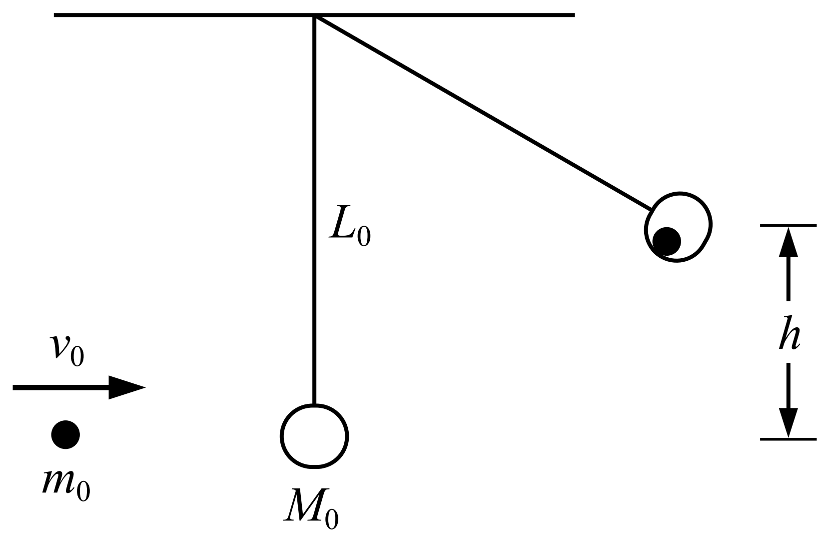
A Incorrect
This answer incorrectly assumes that the only force involved is the 24 N force on block A.

B **Correct**
Newton's 2nd law can be applied to blocks A and B to find the force that block C exerts on block B. But since the force that block C exerts on block B is equal in magnitude to the force that block B exerts on block C (Newton's 3rd law), Newton's 2nd law can just be applied to block C to find that force:
Block C: $\Sigma F_x = m_C a_C$ $\quad F_{B\text{ on }C} = (3\text{ kg})(2\text{ m/s}^2) = 6\text{ N} = F_{C\text{ on }B}$

C Incorrect
This answer incorrectly divides the 24 N force by 3 because there are 3 blocks.

D Incorrect
This answer incorrectly assumes the 24 N force is being applied to each block, or that the normal forces between each block must be equivalent to the 24 N force.

Related course pages: *2 - Newton's 2nd Law, 2 - Newton's 3rd Law & Normal Force*



26. A small sphere of mass m_0 is shot at a ball of clay of mass M_0 which is suspended by a string with negligible mass. The ball of clay is initially at rest when the sphere impacts the ball of clay with a speed of v_0. The sphere sticks to the ball of clay and they swing upwards. What is the maximum height h that the sphere and ball of clay swing?

(A) $\dfrac{m_0 v_0}{m_0 + M_0}$

(B) $\frac{1}{2} m_0 v_0^2$

(C) $\dfrac{m_0 v_0^2}{2g(m_0 + M_0)}$

(D) $\dfrac{1}{2g}\left(\dfrac{m_0 v_0}{m_0 + M_0}\right)^2$

A Incorrect
This answer is the final speed of the sphere and clay immediately after the collision.

B Incorrect
This answer is the kinetic energy of the sphere before the collision.

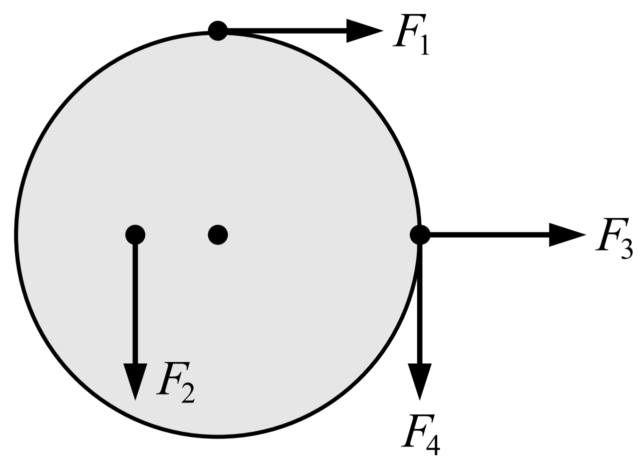
C Incorrect
This answer incorrectly assumes that energy is conserved throughout the entire motion, and that the initial kinetic energy of the sphere is equal to the final gravitational potential energy of the sphere and clay. Energy is not conserved during the collision.

D **Correct**
This problem is solved in two parts. The sphere and the clay collide in a perfectly inelastic collision so kinetic energy is not conserved during the collision and therefore not conserved between the time before the collision and the time when the sphere and clay reach a maximum height. Momentum is conserved during the collision and energy is conserved between the moment after the collision and the time when the objects reach the maximum height, so both conservation equations must be used for different periods of time.

Collision: $p_i = p_f \qquad m_0 v_0 + M_0(0 \text{ m/s}) = (m_0 + M_0) v_{f1} \qquad v_{f1} = \dfrac{m_0 v_0}{m_0 + M_0}$

Swing: $E_i = E_f \qquad K_i = U_{gf} \qquad \frac{1}{2} m v_i^2 = m g h_f \qquad h_f = \dfrac{1}{2g} v_i^2 = \dfrac{1}{2g}\left(\dfrac{m_0 v_0}{m_0 + M_0}\right)^2$

Related course pages: *3 - Conservation of Energy, Work & Power, 4 - Conservation of Momentum & Collisions*



27. Four forces with equal magnitudes are exerted on a wheel as shown in the figure above. Which of the following correctly ranks the forces by the magnitude of the torque produced by each force about the center of the wheel?

(A) $F_2 < (F_1 = F_3 = F_4)$

(B) $F_3 < F_4 < F_1 < F_2$

(C) $F_3 < F_2 < (F_1 = F_4)$

(D) $F_2 < F_4 < (F_1 = F_3)$

A Incorrect

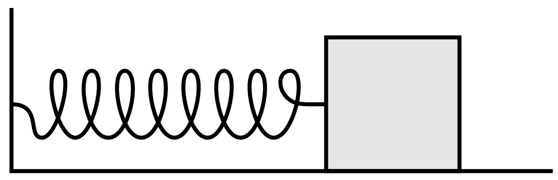
B Incorrect

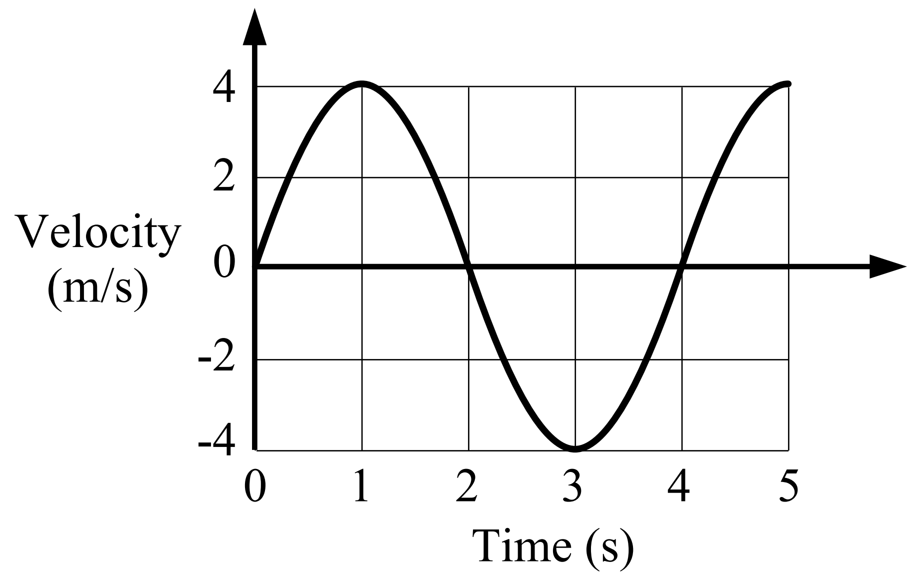
C **Correct**

The torque produced by a force about the center of the wheel is $\tau = rF_{\perp}$, the distance between the center of the wheel and the point where the force is applied multiplied by the component of the force that is perpendicular to the radius. F_3 does not produce a torque about the center because it is in line with the radius. F_2 is perpendicular to the radius but it acts at a smaller radius (a shorter distance from the center) than F_1 and F_4, which are both perpendicular to the radius and act at the same a larger radius.

D Incorrect

Related course pages: *5 - Torque*





28. A mass is attached to a spring and moves back and forth on a surface with negligible friction. A graph of the motion of the block is shown in the graph above. At which of the following times is the magnitude of the spring force on the block the greatest?

(A) 1 s

(B) 3 s

(C) 1.5 s

(D) 2 s

A **Incorrect**

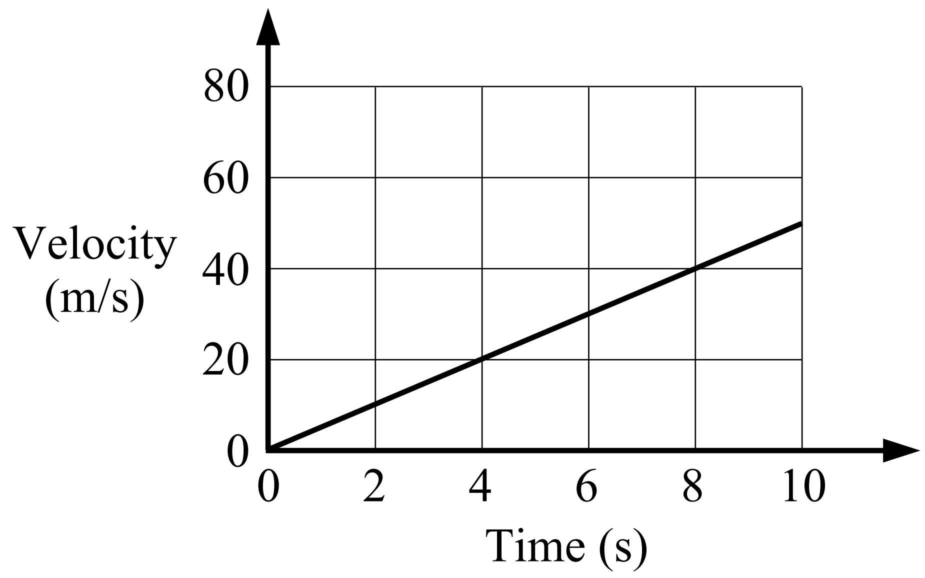
B **Incorrect**

C **Incorrect**

D **Correct**

The magnitude of the spring force on the block is greatest when the block is at one of the position amplitudes and the spring displacement is at a maximum. The velocity of the block is zero when it is at an amplitude and the velocity is zero at 2 seconds. Also, the acceleration of the block will be at a maximum when the spring force (the only horizontal force) is at a maximum. Acceleration is the slope of the velocity-time graph and the magnitude of the slope is greatest at 2 seconds.

Related course pages: *7 - Simple Harmonic Motion*



29. A racing team wants to determine the maximum acceleration of their car on a straight track. They record the motion of the car during a period of time, which is shown in the graph above, and they calculate the acceleration. The car then participates in a 250 m long race on a straight track. If the car starts from rest and accelerates at this rate the entire time, the time it takes the car to finish the race is most nearly

(A) 7 s

(B) 14 s

(C) 10 s

(D) 50 s

A **Incorrect**

This answer incorrectly uses a value of 10 m/s² for the acceleration.

B **Incorrect**

This answer incorrectly uses a value of 2.5 m/s² for the acceleration.

C **Correct**

The acceleration of the car is the slope of the velocity-time graph which can be found using several pairs of points, such as the points at 0 s and 8 s. That acceleration can be used to find the time it takes the car to travel a displacement of 250 m when starting with an initial velocity of zero. The value of t can be found using the quadratic formula if needed.

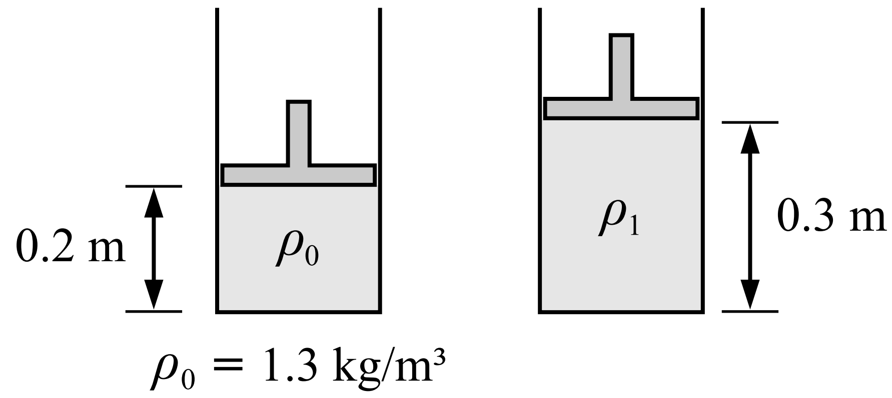
$$a = \frac{\Delta v}{\Delta t} = \frac{40\text{ m/s} - 0\text{ m/s}}{8\text{ s} - 0\text{ s}} = 5\text{ m/s}^2$$

$$\Delta x = v_0 t + \frac{1}{2} a t^2 \qquad (250\text{ m}) = (0\text{ m/s})t + \frac{1}{2}(5\text{ m/s}^2)t^2 \qquad t = 10.0\text{ s}$$

D **Incorrect**

This answer incorrectly divides the displacement by the acceleration to find the time.

Related course pages: *1 - 1D Motion*



30. A volume of gas is contained in a cylinder below a piston as shown in the figure above. The density of the gas is 1.3 kg/m³. When the piston is raised to the new position shown in the figure, the density of the gas is most nearly

(A) 0.9 kg/m³
(B) 2.0 kg/m³
(C) 1.3 kg/m³
(D) Cannot be determined

A Correct

The mass of the gas in the cylinder remains the same but the volume of the gas increases, so the density of the gas decreases. We can relate the densities and volumes of the gas at the two different states by setting the mass in each state as equal. We are not given the shape or dimensions of the cylinder so we can represent the cross sectional area of the cylinder with the variable A which is the same for both states and will cancel out, allowing us to relate the density with the height of the piston.

$$\rho_0 = \frac{m}{V_0} \qquad m = \rho_0 V_0 \qquad \rho_1 = \frac{m}{V_1} \qquad m = \rho_1 V_1$$

$$m = m \quad \rho_0 V_0 = \rho_1 V_1 \quad \rho_0 A h_0 = \rho_1 A h_1 \quad \rho_0 h_0 = \rho_1 h_1 \quad (1.3\ \text{kg/m}^3)(0.2\ \text{m}) = \rho_1 (0.3\ \text{m}) \quad \rho_1 = 0.9\ \text{kg/m}^3$$

B Incorrect

This answer incorrectly relates the densities and volumes as $\rho_0 V_1 = \rho_1 V_0$.

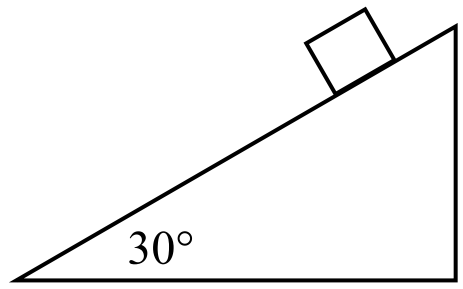
C Incorrect

This answer incorrectly assumes the density of the gas does not change.

D Incorrect

This answer may incorrectly assume that the cross sectional area of the cylinder must be known.

Related course pages: *8 - Fluids & Density*



31. A block is held on an incline with negligible friction near the surface of planet X, where there is no air resistance and the gravitational acceleration is different from earth. The block is released from rest. After the block slides 2 m along the incline it is moving at a speed of 2.8 m/s. The gravitional acceleration near the surface of planet X is most nearly what percent of the gravitational acceleration near the surface of earth?

(A) 10%
(B) 20%
(C) 23%
(D) 40%

A Incorrect
This answer incorrectly switches a and g_{planet} in the vector relationship $a = g_{planet}\sin(30°)$.

B Incorrect
This answer incorrectly uses the acceleration of the block as the magnitude of the gravitational acceleration on the planet.

C Incorrect
This answer incorrectly uses $\cos(30°)$ instead of $\sin(30°)$ in the vector relationship $a = g_{planet}\sin(30°)$.

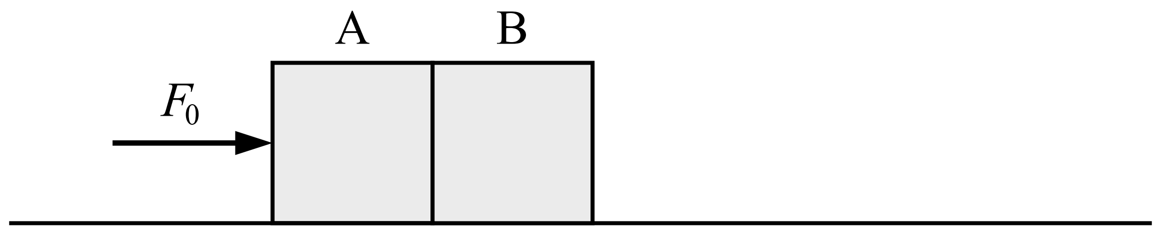
D Correct
This can be solved using kinematics or conservation of energy. Using kinematics, the acceleration of the block (which is the component of the gravitational acceleration that is parallel to the incline) can be found using the kinematic equation below. Then the magnitude of the gravitational acceleration can be found.

$$v^2 = v_0^2 + 2a\Delta x \qquad (2.8\text{ m/s})^2 = (0\text{ m/s})^2 + 2a(2\text{ m}) \qquad a = 1.96\text{ m/s}^2$$

$$(1.96\text{ m/s}^2) = g_{planet}\sin(30°) \qquad g_{planet} = 3.92\text{ m/s}^2$$

$$\frac{g_{planet}}{g_{earth}} = \frac{3.92\text{ m/s}^2}{10\text{ m/s}^2} = 0.4$$

Related course pages: *1 - 1D Motion, 1 - 2D Motion & Vectors, 2 - Gravity & Weight*



32. Two blocks A and B are on a frictionless surface. At an initial time t_1 a force F_0 acts on block A as shown in the figure above. At a later time of t_2 the force F_0 has been removed. How does F_{BA}, the force of block B on block A, compare between the two times?

(A) F_{BA} at time t_1 = F_{BA} at time t_2

(B) F_{BA} at time t_1 > F_{BA} at time t_2

(C) F_{BA} at time t_1 < F_{BA} at time t_2

(D) Cannot be determined

A Incorrect

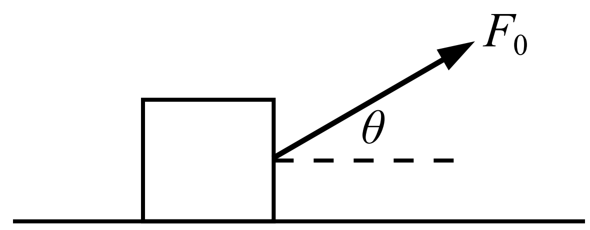
B **Correct**

At time t_1 the force acting on block A causes both blocks to accelerate to the right. Block A exerts a force on block B (causing it to accelerate) and block B exerts an equal and opposite force on block A according to Newton's 3rd law of motion. At time t_2 blocks A and B are no longer accelerating and they move to the right with the same velocity. Since neither block is accelerating the net horizontal force on each block is zero, which means the normal force between the two blocks is zero (there are no other horizontal forces).

C Incorrect

D Incorrect

Related course pages: *2 - Newton's 1st Law & Forces, 2 - Newton's 2nd Law, 2 - Newton's 3rd Law & Normal Force*



33. A block is sitting on the floor and the friction between the block and the floor is not negligible. A force is then applied to the box at an angle θ above the horizontal as shown in the figure above and the box slides across the floor. If the angle θ is increased but the magnitude of the force remains the same and block continues sliding then

(A) the magnitude of the friction force on the block will increase

(B) the magnitude of the friction force on the block will decrease, but not to zero

(C) the magnitude of the friction force on the block will not change

(D) the magnitude of the friction force on the block will be zero

A Incorrect

B **Correct**

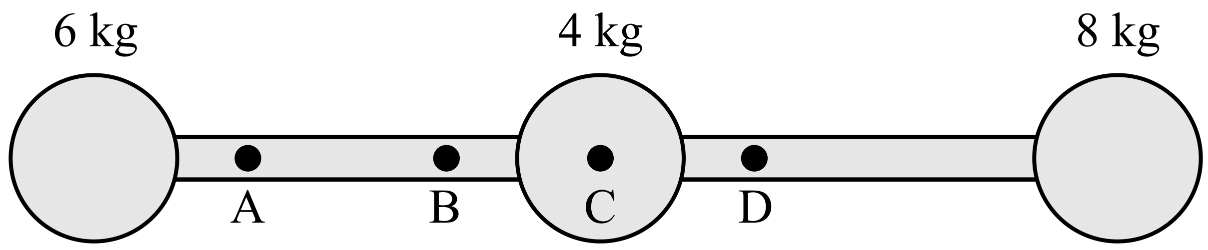
The block is sliding across the floor so the friction force acting on the block is kinetic friction. The magnitude of the kinetic friction depends on the coefficient of kinetic friction and the normal force exerted on the block by the floor. The net force in the vertical direction is zero because the block does not accelerate in the vertical direction so the normal force (and therefore the kinetic friction force) decreases if θ increases.

$\Sigma F_y = F_0 \sin(\theta) + F_n - F_g = m(0 \text{ m/s}^2)$ $\quad F_n = F_g - F_0 \sin(\theta)$ $\quad f_k = \mu_k F_n$

C Incorrect

D Incorrect

Related course pages: *2 - Newton's 1st Law & Forces, 2 - Friction*



34. A system consists of a three spheres connected by two rods with equal length and uniform mass as shown in the figure above. The center of mass of the system is closest to which of the points shown?

(A) Point A

(B) Point B

(C) Point C

(D) Point D

A Incorrect

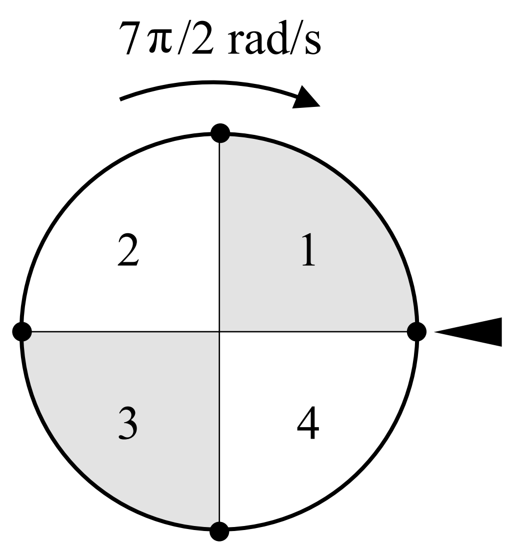
B Incorrect

C Incorrect

D **Correct**

The center of mass of a system depends on the position and mass of each object, or the distribution of the mass of a single object. If the spheres at the right and left end of the rods had the same mass then the center of mass of the system would be at point C. The right sphere has a greater mass so the center of mass is closer to the right sphere than the center.

Related course pages: *2 - Center of Mass*



35. A wheel is divided into 4 equal sections as shown in the figure above. The wheel is given a spin and released so that the initial angular speed of the wheel is $7\pi/2$ rad/s when the wheel is in the orientation shown above. The wheel slows down at a rate of $-\pi/2$ rad/s^2. What numbered section is the arrow on the right pointing to when the wheel stops?

(A) 1

(B) 2

(C) 3

(D) 4

A Correct

The angular displacement of the wheel can be found using the kinematic equation below. The wheel turns 6 full revolutions and then 1/8 of a revolution so it ends at the middle of section 1.

$\omega^2 = \omega_0^2 + 2\alpha\Delta\theta \qquad (0\text{ rad/s})^2 = (7\pi/2\text{ rad/s})^2 + 2(-\pi/2\text{ rad/s}^2)\Delta\theta \qquad \Delta\theta = 49\pi/4\text{ rad}$

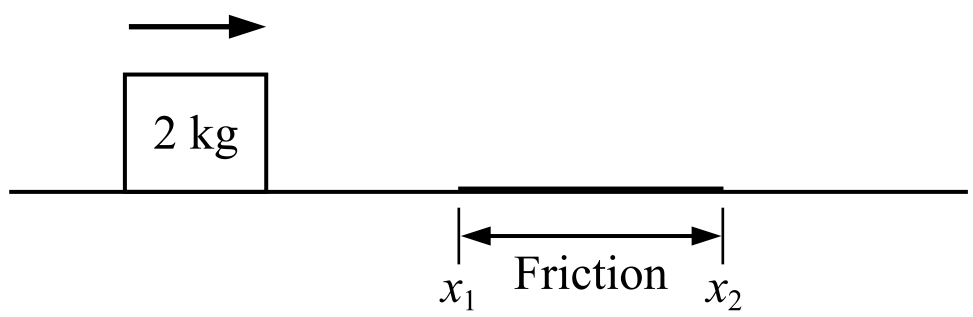
$$\Delta\theta = \frac{49\pi/4\text{ rad}}{} \times \frac{1\text{ rev}}{2\pi\text{ rad}} = 6\ 1/8\text{ rev}$$

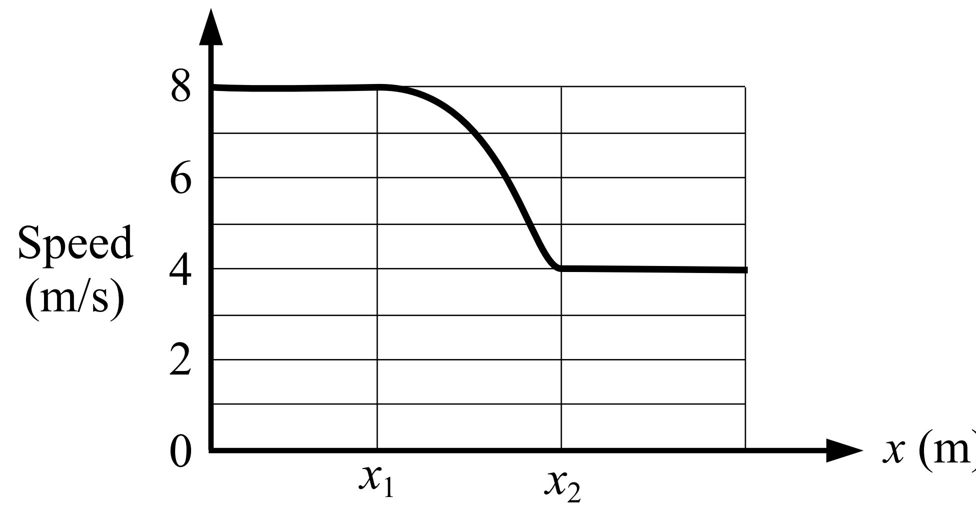
B Incorrect

C Incorrect

D Incorrect

Related course pages: *5 - Rotational Motion*





36. A block is sliding across a surface with negligible friction except for the length of surface between x_1 and x_2. A graph of the block's motion is shown in the figure above. The work done on the block by friction is most nearly

(A) -48 J
(B) -16 J
(C) -64 J
(D) Cannot be determined

A Correct
The work done on the block by friction is equal to the change in the kinetic energy of the block as it slides across the length of surface with friction.

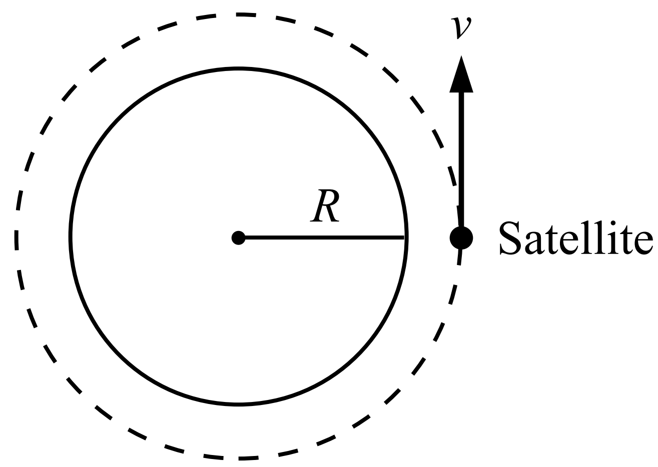
$$W = \Delta E = \Delta K = \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2 = \frac{1}{2}(2\text{ kg})(4\text{ m/s})^2 - \frac{1}{2}(2\text{ kg})(8\text{ m/s})^2 = -48\text{ J}$$

B Incorrect
This answer is the negative of the kinetic energy of the block after x_2.

C Incorrect
This answer is the negative of the initial kinetic energy of the block.

D Incorrect

Related course pages: *3 - Conservation of Energy, Work & Power*



37. A satellite is in a circular orbit around the Earth at height of 2,000 km above the surface of the earth. The radius of the earth is 6,371 km. If the satellite completes one orbit every 2 hours, the speed of the satellite is most nearly

(A) 1.7 km/s
(B) 5.6 km/s
(C) 6.4 km/s
(D) 7.3 km/s

A Incorrect
This answer incorrectly uses 2,000 km for the radius of the orbit.

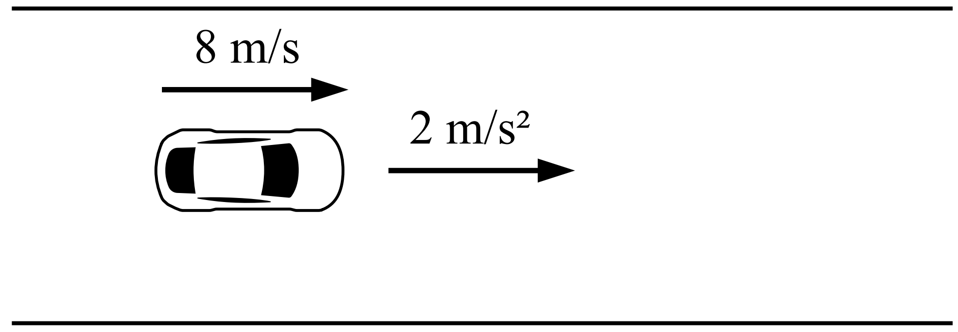
B Incorrect
This answer incorrectly uses 6,371 km for the radius of the orbit.

C Incorrect
This answer incorrectly uses 7,371 km for the radius of the orbit.

D **Correct**
The radius of the orbit is the radius of the earth plus the height of the satellite above the surface of the earth.

$$v = \frac{2\pi r}{t} = \frac{2\pi(6{,}371\text{ km} + 2{,}000\text{ km})}{2\text{ h}} = 26{,}299\text{ km/h} \qquad \frac{26{,}299\text{ km}}{\text{h}} \times \frac{1\text{ h}}{60\text{ min}} \times \frac{1\text{ min}}{60\text{ s}} = 7.3\text{ km/s}$$

Related course pages: *2 - Circular Motion*



38. A 1500 kg car is driving at a speed of 8 m/s. It then accelerates at 2 m/s^2 for a period of 3 seconds. The kinetic energy of the car after that period is most nearly

(A) 147 kJ
(B) 48 kJ
(C) 27 kJ
(D) 14 kJ

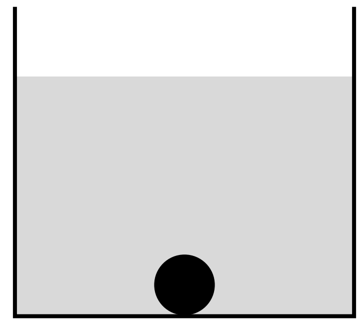
A **Correct**
The final speed of the car can be found using a kinematic equation, then the final speed can be used to calculate the final kinetic energy of the car.
$v_f = v_i + at = (8\text{ m/s}) + (2\text{ m/s}^2)(3\text{ s}) = 14\text{ m/s}$
$K = \frac{1}{2}mv^2 = \frac{1}{2}(1500\text{ kg})(14\text{ m/s})^2 = 147\text{ kJ}$

B Incorrect
This answer incorrectly uses 8 m/s for the final speed of the car.

C Incorrect
This answer incorrectly uses 6 m/s for the final speed of the car.

D Incorrect
This answer is the value of the final speed of the car (14 m/s) with the units of kJ.

Related course pages: *1 - 1D Motion, 3 - Types of Energy*



39. A ball is dropped into a container of liquid and it sinks to the bottom as shown in the figure above. Which of the following statements is true about the forces acting on the ball?

(A) The magnitude of the buoyant force acting on the ball is less than the weight of the ball but not zero
(B) The magnitude of the buoyant force acting on the ball is equal to the weight of the ball
(C) The magnitude of the buoyant force acting on the ball is greater than the weight of the ball
(D) The magnitude of the buoyant force acting on the ball is zero

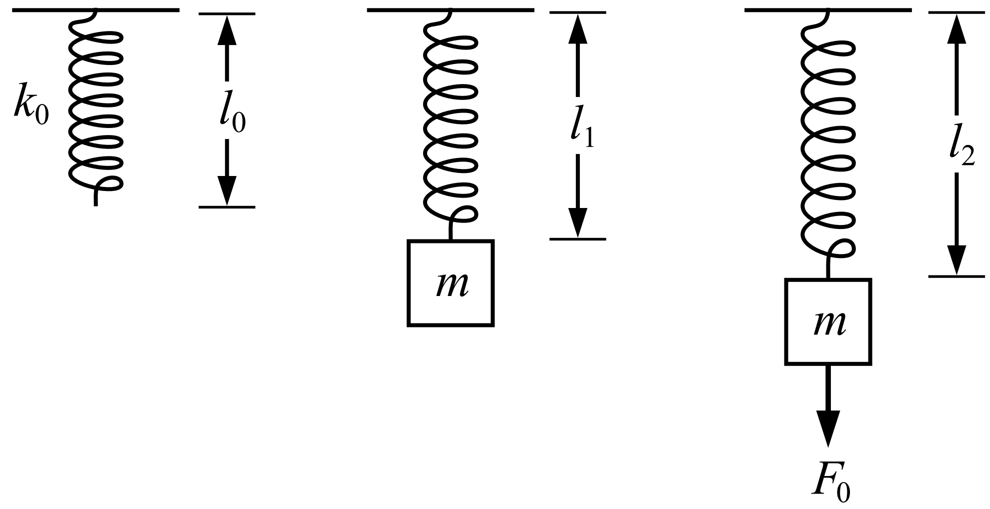
A **Correct**
The ball is submerged in a fluid so there is an upwards buoyant force acting on the ball due to the fluid, and there is a downwards weight force acting on the ball. The ball sank in the fluid so the weight force is greater than the buoyant force (if the buoyant force was equal to the weight force the ball would float). When the ball is at rest on the bottom of the container the weight force is equal to the buoyant force plus the normal force.

B Incorrect

C Incorrect

D Incorrect

Related course pages: *2 - Gravity & Weight, 8 - Buoyant Force*



40. A spring with a spring constant of k_0 and an unstretched length of l_0 is suspended from the ceiling as shown in the figure above. A block with a mass of m is then attached to the bottom end of the spring and the block is at rest when the spring has a length of l_1. A force with a magnitude of F_0 then pulls down on the block so that the spring has a length of l_2 and the block is at rest. The moment that the force F_0 is removed, the acceleration of the block is

(A) $k_0(l_2 - l_1)$

(B) $\dfrac{k_0(l_2 - l_1)}{m} - g$

(C) $\dfrac{k_0(l_2 - l_0)}{m} - g$

(D) $k_0(l_2 - l_0)$

A Incorrect
This answer would be the spring force acting on the block but it also incorrectly uses l_1 instead of l_0 for the change in length of the spring.

B Incorrect
This answer incorrectly uses l_1 instead of l_0 for the change in length of the spring.

C **Correct**
The moment that the force F_0 is removed, there is an upwards spring force and a downwards weight force acting on the block. The spring force depends on the change in length from the original unstretched length of the spring l_0, not from the equilibrium length when the block is attached l_2.
$F_{sp} = k\Delta x = k_0(l_2 - l_0)$

$$\Sigma F_y = F_{sp} - F_g = m a_y \qquad k_0(l_2 - l_0) - mg = m a_y \qquad a_y = \frac{k_0(l_2 - l_0)}{m} - g$$

D Incorrect
This answer is the spring force acting on the block.

Related course pages: *2 - Newton's 2nd Law, 2 - Spring Force & Hooke's Law*