**MCQ Practice Test 1**
**Answer Key and Solutions**

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## Answer Key

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

**Solutions are on the following pages**

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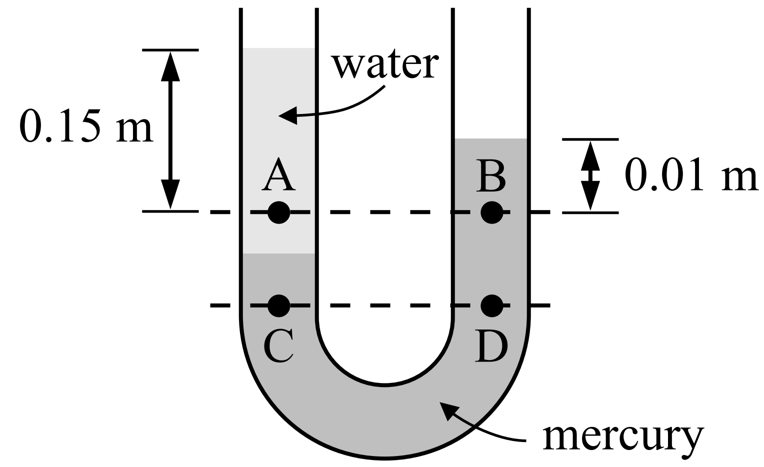



Note: Figure not drawn to scale.

1. A tube contains a volume of water and a volume of mercury as shown in the figure above. Both ends of the tube are open. Points A and B are at the same level and points C and D are at the same level. The distance between points A and B and the surface of the liquids are shown. Which of the following correctly relates the gauge pressures at the points shown? The density of the water is 1,000 kg/m³ and the density of the mercury is 13,600 kg/m³.

(A)

| $P_A$ and $P_B$ | $P_C$ and $P_D$ |
|---|---|
| $P_A > P_B$ | $P_C > P_D$ |

(B)

| $P_A$ and $P_B$ | $P_C$ and $P_D$ |
|---|---|
| $P_A > P_B$ | $P_C = P_D$ |

(C)

| $P_A$ and $P_B$ | $P_C$ and $P_D$ |
|---|---|
| $P_A = P_B$ | $P_C = P_D$ |

(D)

| $P_A$ and $P_B$ | $P_C$ and $P_D$ |
|---|---|
| $P_A = P_B$ | $P_C > P_D$ |

A Incorrect

**B Correct**

The pressure at two points that are at the same level in the same fluid are at the same pressure. Points C and D are both in the mercury at the same level so they are at the same pressure. Points A and B are in different fluids so they are not necessarily at the same pressure. We are given the depth of each point below the surfaces of the fluids which are exposed to the atmosphere, so we can calculate the gauge pressure of points A and B and compare them.

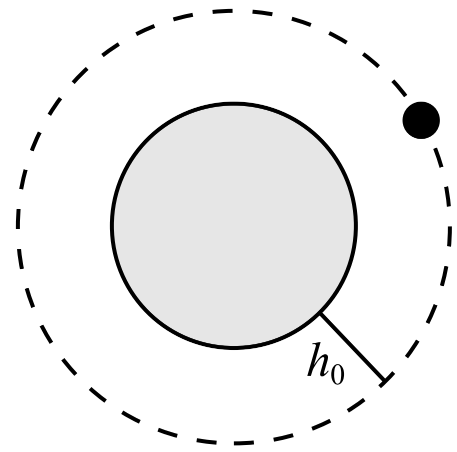
$P_A = \rho g h = (1{,}000 \text{ kg/m}^3) g (0.15 \text{ m}) = 1{,}500 \text{ Pa}$

$P_B = \rho g h = (13{,}600 \text{ kg/m}^3) g (0.01 \text{ m}) = 1{,}360 \text{ Pa}$

C Incorrect

D Incorrect

Related course pages: *8 - Pressure*




2. A satellite is in a circular orbit around the earth and moves at a constant speed. If the height of the orbit above the surface of the earth increased (and the orbit remained circular) the kinetic energy of the satellite would

(A) decrease

(B) increase

(C) not change

(D) a change in the kinetic energy cannot be determined

**A Correct**

The satellite is in uniform circular motion around the earth and the gravitational force is acting as the centripetal force. The kinetic energy of the satellite is inversely proportional to the orbital radius.

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

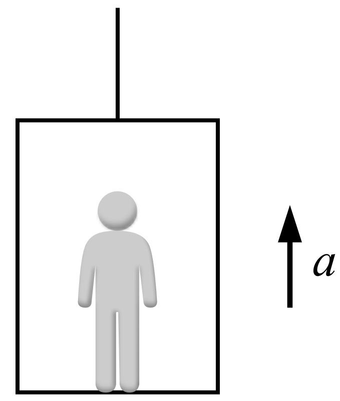
$$K = \frac{1}{2}mv^2 = \frac{GMm}{2r}$$

B Incorrect

C Incorrect

D Incorrect

Related course pages: *2 - Centripetal Acceleration and Force, 2 - Orbital Motion, 6 - Orbital Motion Energy*




3. A person is standing in an elevator which is accelerating upwards. Which of the following is true of the person's apparent weight?

(A) The person's apparent weight is zero

(B) The person's apparent weight is equal to the person's weight

(C) The person's apparent weight is less than the person's weight, but is not zero

(D) The person's apparent weight is greater than the person's weight

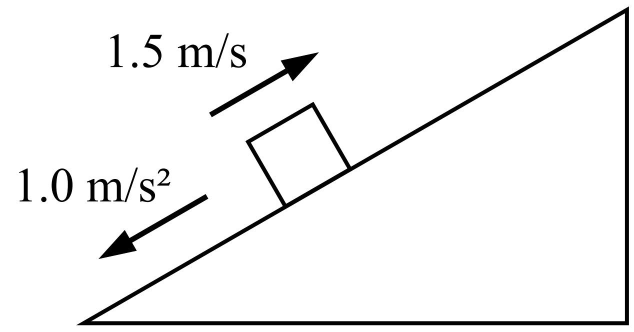
A Incorrect
The person's apparent weight would be zero if the elevator and the person were in free fall and accelerating downwards at 10 $m/s^2$, when the normal force on the person would be zero.

B Incorrect
The person's apparent weight would be equal to their true weight if they were not accelerating.

C Incorrect
The person's apparent weight would be less than the true weight, but not zero, if the elevator and the person were accelerating downwards at a rate less than 10 $m/s^2$.

**D Correct**
There is a downwards weight force (gravitational force) and an upwards normal force acting on the person. The person is accelerating upwards so the net force on the person is upwards (Newton's 2nd law) and the upwards normal force must be greater than the downwards weight force. The person's apparent weight is the magnitude of the normal force acting on them, which is greater than the weight force.

Related course pages: *2 - Gravity & Weight*




4. A block is sliding on an incline with negligible friction as shown in the figure above. At time $t = 0$ s the block is moving up the incline with a speed of 1.5 m/s. The magnitude of the acceleration of the block is a constant 1.0 m/s² down the incline. At $t = 3$ s, what is the direction of the block's motion and is the speed increasing or decreasing?

(A)

| Direction of motion | Speed |
|---|---|
| Down the incline | Decreasing |

(B)

| Direction of motion | Speed |
|---|---|
| Up the incline | Decreasing |

(C)

| Direction of motion | Speed |
|---|---|
| Down the incline | Increasing |

(D)

| Direction of motion | Speed |
|---|---|
| Up the incline | Increasing |

A Incorrect

B Incorrect

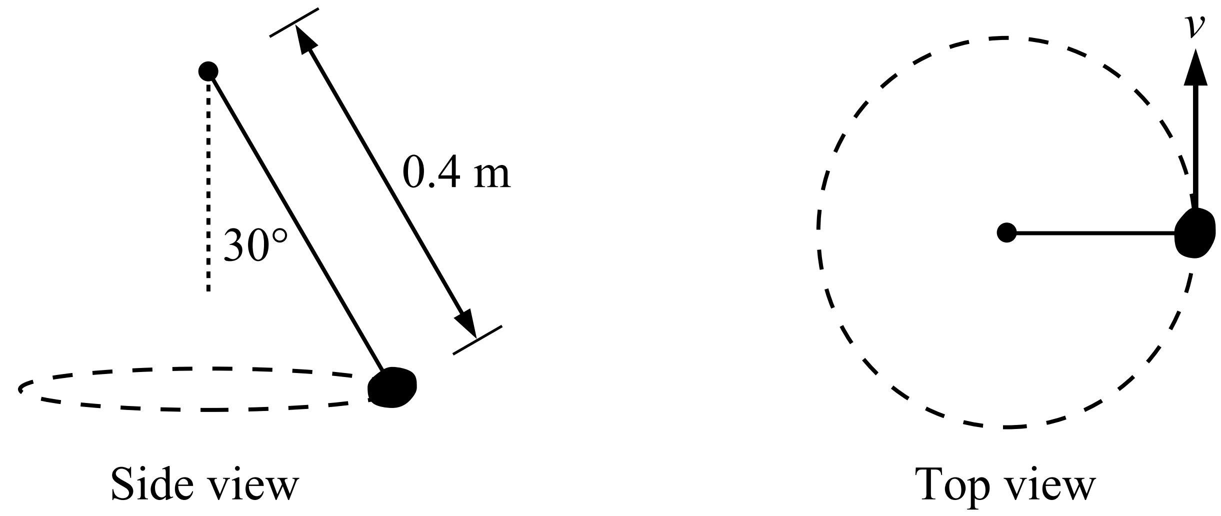
C **Correct**

The motion of the block can be analyzed using 1D kinematics in the direction of the incline (along an axis parallel to the incline). If we choose up the incline to be the positive direction, the initial velocity is positive, the acceleration is negative, and the velocity at 3 s can be found using the equation below. The final velocity is negative so the block is moving down the incline, and the final velocity is in the same direction as the acceleration so the speed (the magnitude of velocity) is increasing.

$v_f = v_i + at = (1.5 \text{ m/s}) + (-1.0 \text{ m/s}^2)(3 \text{ s}) = -1.5 \text{ m/s}$

D Incorrect

Related course pages: *1 - 1D Motion*




5. A rock is attached to a 0.4 m long string and is swung through the air so that the path of the rock follows a horizontal circle as shown in the top view figure above. The string makes a 30° angle with the vertical as shown in the side view figure. The rock completes one revolution per second. The speed of the rock is most nearly

(A) 0.6 m/s
(B) 1.3 m/s
(C) 2.2 m/s
(D) 2.5 m/s

A Incorrect
This answer incorrectly uses 0.2 m as the diameter of the circular path instead of the radius.

**B Correct**
The radius of the circular path is the horizontal component of the string length. The rock travels a distance of 1 circumference per second.

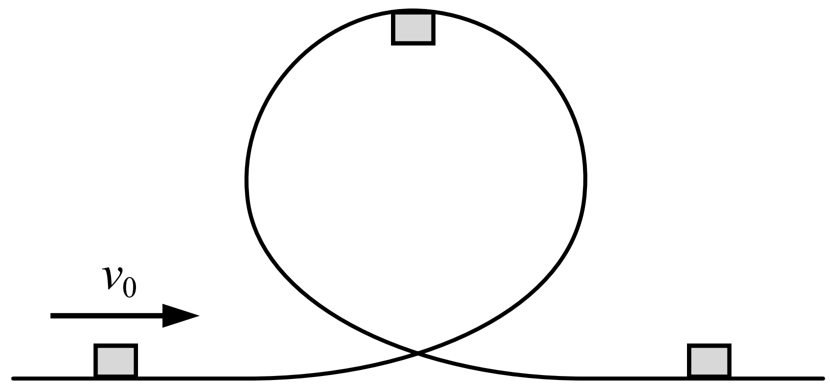
$r = (0.4 \text{ m})\sin(30°) = 0.2 \text{ m}$

$$v = \frac{d}{t} = \frac{2\pi r}{T} = \frac{2\pi(0.2 \text{ m})}{1 \text{ s}} = 1.3 \text{ m/s}$$

C Incorrect
This answer incorrectly uses $\cos(30°)$ instead of $\sin(30°)$ to find the radius.

D Incorrect
This answer incorrectly uses 0.4 m as the radius of the circular path.

Related course pages: *2 - Circular Motion*




6. A small block slides along a frictionless track with a vertical loop as shown in the figure above. The block is not attached to the track in any way, but its initial velocity is great enough that it moves through the loop without losing contact with the track. What is the direction of the force exerted on the block by the track when the block is at the top of the loop?

(A) 

(B) 

(C) 

(D) 

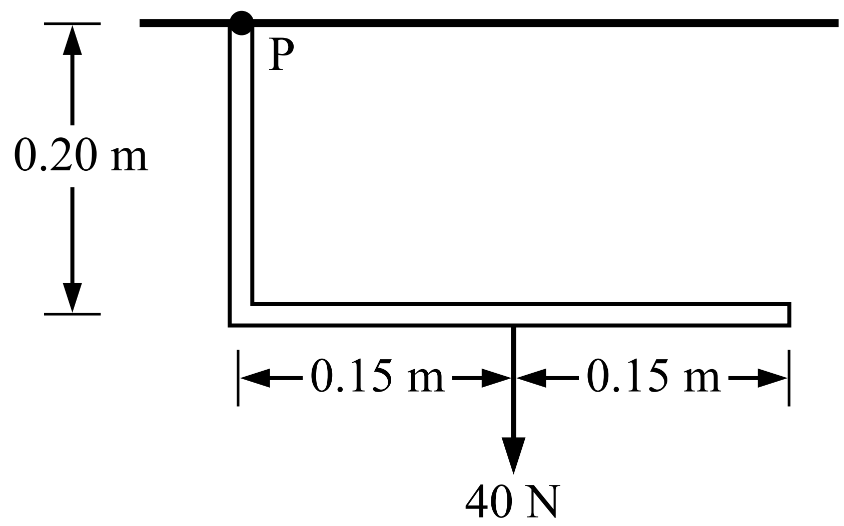
**A Correct**
The track is frictionless and the block is not attached to the track so the only force exerted by the track on the block is the normal force, which acts downwards when the block is below the track at the top of the loop.

B Incorrect
This is the direction of the block's velocity when it's at the top of the loop. The track does not apply a force on the block in this direction.

C Incorrect
This is the direction of the force exerted on the track from the block. The block is not attached to the track so the track can't apply an upwards force on the block at this point.

D Incorrect
This would be the direction of the friction force acting on the block by the track, but there is no friction.

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




7. A thin pipe with negligible mass is attached to the ceiling at point P as shown in the figure above. The torque generated at point P by the 40 N force is

(A) 14 N·m
(B) 12 N·m
(C) 8 N·m
(D) 6 N·m

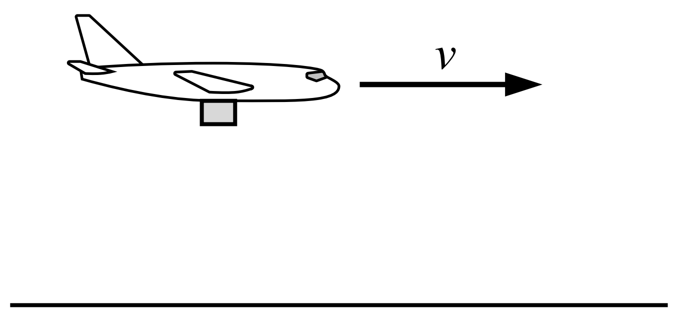
A Incorrect
This answer incorrectly calculates the torque as $\tau = (0.35\text{ m})(40\text{ N})$

B Incorrect
This answer incorrectly calculates the torque as $\tau = (0.30\text{ m})(40\text{ N})$

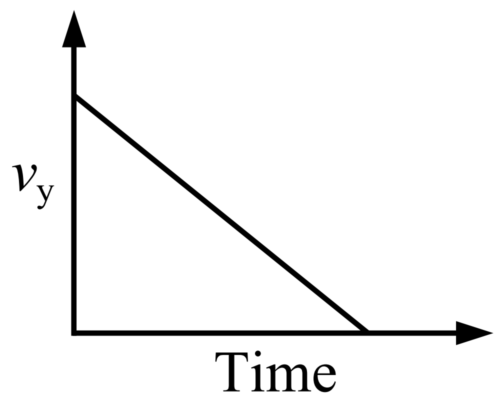
C Incorrect
This answer incorrectly calculates the torque as $\tau = (0.20\text{ m})(40\text{ N})$

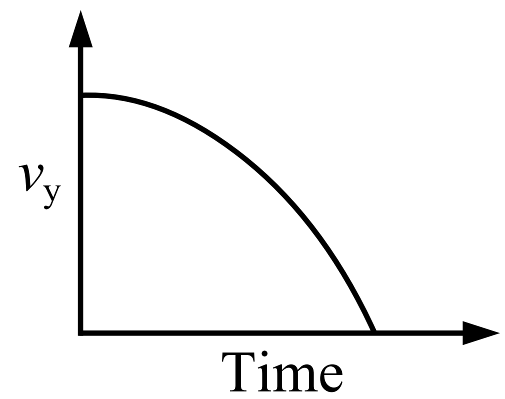
**D Correct**
The torque generated by the 40 N force about point P can be calculated as $\tau = rF_{\perp}$, the straight-line distance between point P and the point where the 40 N force acts (which would have to be found using geometry) multiplied by the component of the 40 N force that is perpendicular to that distance line (the angle between them would have to be found using geometry). The torque can also be calculated as $\tau = r_{\perp}F$, the distance between point P and a line passing through the 40 N force vector (which is 0.15 m) multiplied by the full 40 N force: $\tau = r_{\perp}F = (0.15\text{ m})(40\text{ N}) = 6\text{ N·m}$

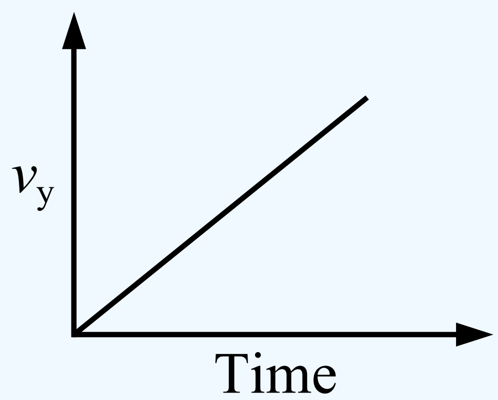
Related course pages: *5 - Torque*

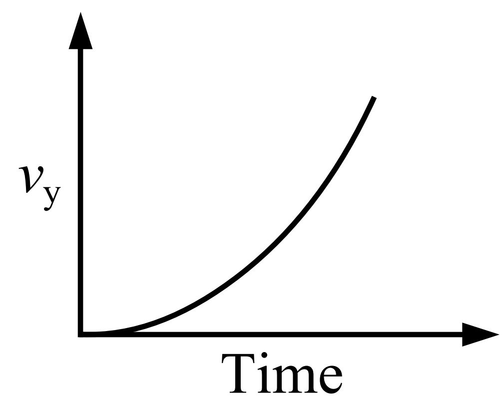



8. A plane is flying at a constant horizontal speed and is carrying a box as shown in the figure above. It then releases the box which falls through the air and lands on the ground. Ignoring air resistance, which of the following graphs shows the magnitude of the vertical velocity of the box before it lands on the ground?

(A)



(B)



(C)



(D)


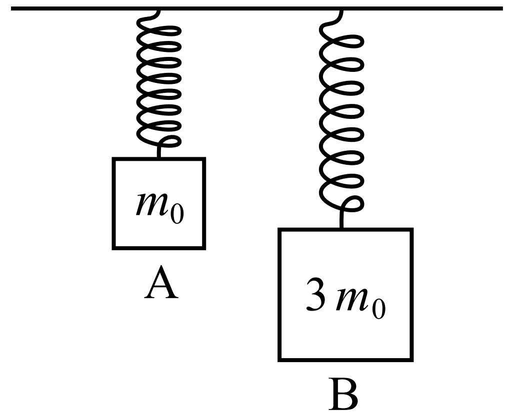

A Incorrect
This is a graph for an object with a positive initial vertical velocity which slows down over time with a constant acceleration.

B Incorrect
This is a graph for an object with a positive initial vertical velocity which slows down over time with a changing acceleration. This curve shows the height of the box over time if the vertical axis represented height.

C **Correct**
Before being released the box has the same velocity as the plane which is horizontal, so the initial vertical velocity of the box is zero. The box accelerates as it falls due to gravity, so the magnitude of the vertical velocity increases linearly with a constant slope (which is the acceleration).

D Incorrect
This is similar to the correct graph but the slope increases over time which represents an increasing acceleration, but the acceleration due to gravity is constant and air resistance is ignored.

Related course pages: *1 - Projectile Motion*




9. Two identical springs are suspended from the ceiling and then two blocks with different masses are attached to the bottom of the springs. How does the spring potential energy of the spring-block A system, $U_{\text{sp A}}$ , compare to the spring potential energy of the spring-block B system, $U_{\text{sp B}}$ ?

(A) $U_{\text{sp B}} = 9\,U_{\text{sp A}}$

(B) $U_{\text{sp B}} = 3\,U_{\text{sp A}}$

(C) $U_{\text{sp B}} = U_{\text{sp A}}$

(D) $U_{\text{sp B}} = U_{\text{sp A}}\,/\,3$

**A Correct**

The spring potential energy depends on the spring constant (which is the same for each spring) and the displacement of the spring which depends on the force exerted on the spring. The blocks are assumed to be at rest so the net vertical force on each block is zero and the spring force is equal to the weight force. Block B has 3 times the mass of block A so the spring potential energy is 9 times greater.

$$\Sigma F_y = F_{\text{sp}} - mg = m(0\text{ m/s}^2) \qquad F_{\text{sp}} = mg \qquad k\Delta x = mg \qquad \Delta x = \frac{mg}{k}$$

$$U_{\text{sp}} = \frac{1}{2}k\Delta x^2 = \frac{1}{2}k\left(\frac{mg}{k}\right)^2$$

B Incorrect

C Incorrect

D Incorrect

Related course pages: *2 - Spring Force & Hooke's Law, 3 - Types of Energy*


10. Two blocks are on a surface with negligible friction. Block A is sliding towards block B which is at rest. The blocks stick together and move to the right. During the collision the speed of the center of mass of the two-block system

(A) increases

(B) does not change

(C) decreases

(D) the change in the speed of the center of mass of the system cannot be determined

A Incorrect

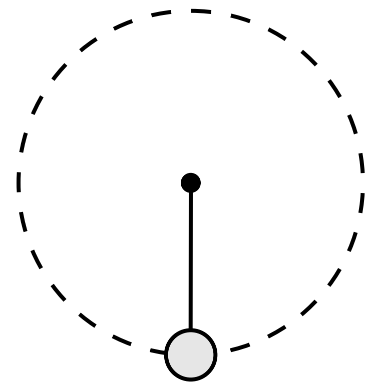
B **Correct**

There are no external forces acting on the two-block system in the horizontal direction (the forces between the blocks are internal forces) so the acceleration of the system's center of mass is zero and the velocity of the center of mass does not change (Newton's 1st law of motion).

C Incorrect

D Incorrect

Related course pages: *2 - Newton's 1st Law & Forces, 2 - Center of Mass, 4 - Conservation of Momentum & Collisions*



11. A sphere is attached to a string and swings around in a vertical circle at a constant speed. Which of the following shows the direction of the net force acting on the sphere when it is at the position shown in the figure above?

(A) 

(B) 

(C) 

(D) 

A Incorrect

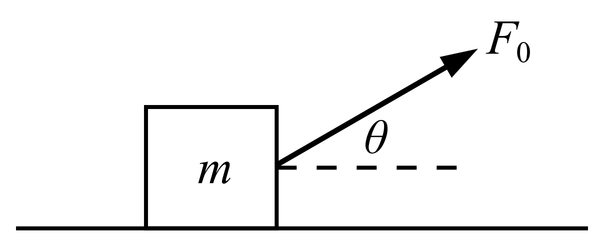
B Incorrect

C Incorrect

**D Correct**

There is an upwards tension force and a downwards weight force acting on the sphere when it's at the bottom of the circular path. The sphere is in uniform circular motion so the net force acting on the sphere always points towards the center of the circle, which is upwards at that position.

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




12. A force is exerted on a block as shown in the figure above. The block accelerates horizontally along the floor and the coefficient of kinetic friction between the block and the floor is $\mu_k$. Which of the following is a correct expression for the acceleration of the block?

(A) $\dfrac{F_0\cos(\theta) - \mu_k(mg - F_0\sin(\theta))}{m}$

(B) $\dfrac{F_0\cos(\theta) - \mu_k mg}{m}$

(C) $\dfrac{F_0\sin(\theta) - \mu_k(F_0\sin(\theta) - mg)}{m}$

(D) $\dfrac{F_0\sin(\theta) - \mu_k mg}{m}$

**A Correct**

The block accelerates in the horizontal direction so the acceleration and the net force in the vertical direction is zero (Newton's 1st law). The friction force on the block acts to the left and depends on the magnitude of the normal force acting on the block from the floor. The normal force can be found by applying Newton's 2nd law in the vertical direction, then the acceleration can be found by applying Newton's 2nd law to the horizontal direction.

$\Sigma F_y = m a_y \qquad F_0\sin(\theta) + F_n - F_g = m(0) \qquad F_n = F_g - F_0\sin(\theta) = mg - F_0\sin(\theta)$

$f_k = \mu_k F_n = \mu_k(mg - F_0\sin(\theta))$

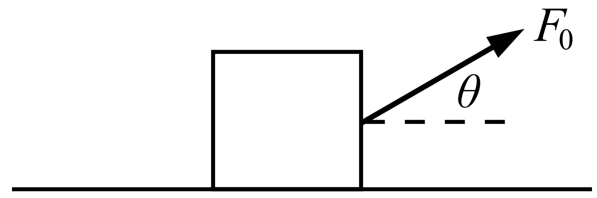
$\Sigma F_x = m a_x \qquad F_0\cos(\theta) - f_k = m a_x \qquad a_x = \dfrac{F_0\cos(\theta) - \mu_k(mg - F_0\sin(\theta))}{m}$

B Incorrect

C Incorrect

D Incorrect

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




13. A force with a magnitude of $F_0$ is exerted on a block as shown in the figure above. There is a friction force between the block and the floor with a magnitude of $f$. If the block remains in contact with the floor, the net force acting on block is

(A) $F_0 \cos(\theta) + f$

(B) $F_0 \sin(\theta) - mg$

(C) $F_0 - f$

(D) $F_0 \cos(\theta) - f$

A Incorrect
This is close to the correct answer but the forces are added instead of subtracted. The forces are acting in opposite directions so one force must be negative.

B Incorrect
This answer includes two of the forces in the vertical direction but does not include the normal force. The block remains in contact with the floor (it does not accelerate in the vertical direction) so the net force in the vertical direction is zero (Newton's 2nd law).

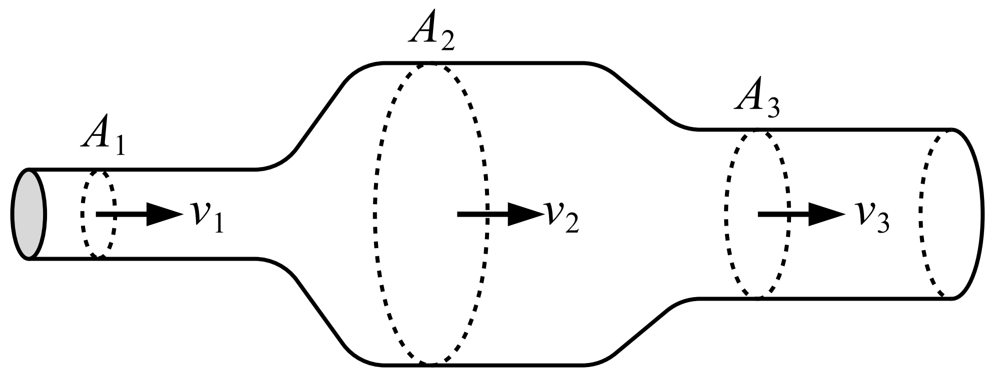
C Incorrect
This answer includes the full magnitude of the applied force $F_0$, but the horizontal and vertical components should be used to determine the net force in the horizontal and vertical directions (and the net force in the vertical direction is zero).

**D Correct**
The block remains in contact with the floor which means the block does not move (and does not accelerate) in the vertical direction, so the net force in the vertical direction is zero (Newton's 1st law). The net force on the block is equal to just the net horizontal force, which is the horizontal component of $F_0$ minus the friction force $f$ (the two forces act in opposite directions so they must have opposite signs).

$\Sigma F_y = m a_y = m(0) = 0$

$\Sigma F_x = F_0 \cos(\theta) - f$

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




14. An ideal fluid is flowing through the tube shown in the figure above. Which of the following correctly ranks the speed of the fluid through the three areas shown above?

(A) $v_1 < v_3 < v_2$

(B) $v_1 = v_2 = v_3$

(C) $v_2 < (v_1 = v_3)$

(D) $v_2 < v_3 < v_1$

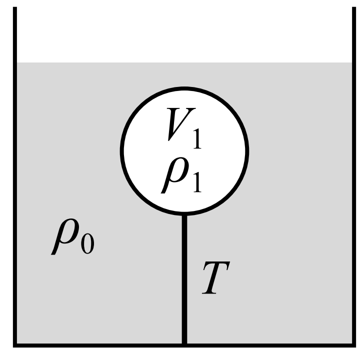
A Incorrect
This answer is the reverse ranking of the correct answer.

B Incorrect
The flow rate is the same through each area but the speed is not the same.

C Incorrect

**D Correct**
An ideal fluid is incompressible so the flow rate is the same everywhere in the tube. The flow rate is equal to the cross sectional area multiplied by the speed through that area as given below. The speed will be slower through a larger area and faster through a smaller area.
$A_1 v_1 = A_2 v_2 = A_3 v_3$

Related course pages: *8 - Flow*




15. A ball is submerged and floating at rest in a liquid as shown in the figure above. The ball is attached to the bottom of the container by a string. The density of the liquid is $\rho_0$ , the density of the ball is $\rho_1$ and the volume of the ball is $V_1$ . Which of the following is a correct expression for the tension in the string $T$ ?

(A) $\rho_1 V_1 g + \rho_0 V_1 g$

(B) $\rho_1 V_1 g - \rho_0 V_1 g$

(C) $\rho_0 V_1 g - \rho_1 V_1 g$

(D) $\rho_0 V_1 g$

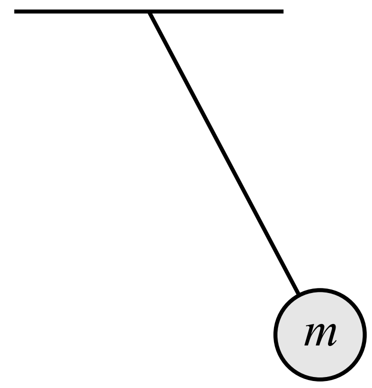
A Incorrect

B Incorrect
This answer incorrectly assumes the tension force on the ball is acting upwards instead of downwards.

C **Correct**
The ball is at rest so the net force on the ball is zero (Newton's 1st law). There is an upwards buoyant force, a downwards tension force and a downwards weight force acting on the ball. We can replace the mass of the ball with its density multiplied by its volume.
$\Sigma F_y = F_B - F_g - T = 0 \qquad T = F_B - F_g = \rho_f V_f g - mg = \rho_0 V_1 g - \rho_1 V_1 g$

D Incorrect
This is the upwards buoyant force acting on the ball.

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




16. A pendulum consists of a sphere of mass $m$ attached to a string with negligible mass. As the pendulum swings back and forth, which of the following statements is true?

(A) The total kinetic energy of the sphere-earth system is constant

(B) The total energy of the sphere-earth system is constant

(C) The total gravitational potential energy of the sphere-earth system is constant

(D) All of the above

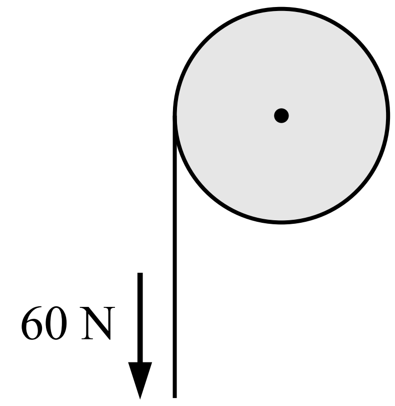
A Incorrect

B **Correct**
The total energy of the sphere-earth system is conserved but the kinetic energy and gravitational potential energy are transformed back and forth as the sphere moves, so the amount of kinetic energy and gravitational potential energy is not constant. The kinetic energy depends on the speed of the sphere and the gravitational potential energy depends on the height of the sphere.

C Incorrect

D Incorrect

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




17. A string with negligible mass is wrapped around the outside of a pulley which has a radius of 0.1 m. The pulley is initially at rest when a constant 60 N force is applied to the string. The angular momentum of the pulley after a period of 2 s is most nearly

(A) 0

(B) 12 kg·m²/s

(C) 6 kg·m²/s

(D) Cannot be determined

A Incorrect

**B Correct**

The change in angular momentum of the pulley is equal to the net torque exerted on the pulley multiplied by the period of time that the torque is applied. The net torque on the pulley is due to the tension in the string which is 60 N. The force acts at the outer edge of the pulley, perpendicular to the radius, so the full force contributes to the torque. The pulley starts at rest with zero angular momentum.

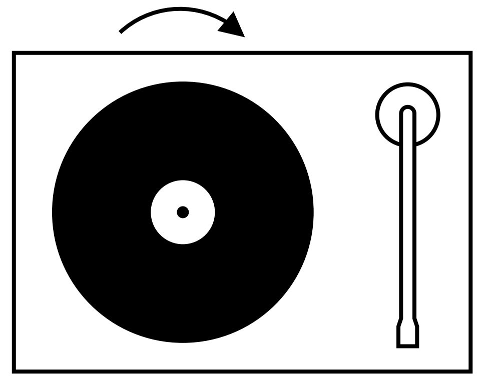
$\Delta L = \tau \Delta t = r F_{\perp} \Delta t = (0.1\ \text{m})(60\ \text{N})(2\ \text{s}) = 12\ \text{kg·m}^2/\text{s}$

C Incorrect

This answer is the torque exerted on the pulley by the tension force with the unit of angular momentum.

D Incorrect

Related course pages: *5 - Torque, 6 - Angular Momentum*




18. A vinyl record begins at rest and then experiences an angular acceleration of $\alpha$. What is the angular displacement of the record after a period of 3 seconds?

(A) $6\alpha$

(B) $9\alpha$

(C) $3\alpha$

(D) $9\alpha/2$

A Incorrect

B Incorrect

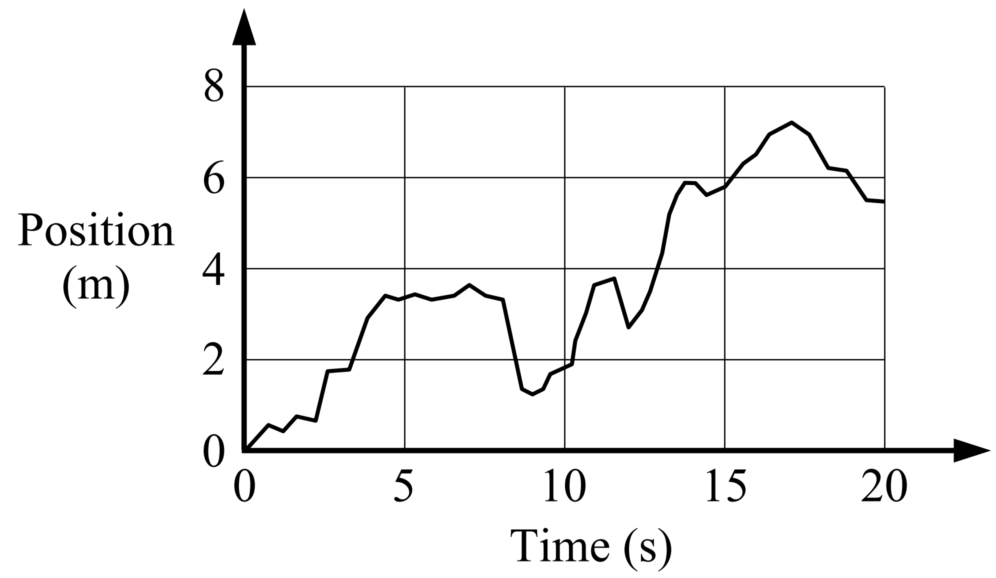
C Incorrect

D **Correct**

The angular displacement can be found using the kinematic equation below.

$$\Delta\theta = \omega_0 t + \frac{1}{2}\alpha t^2 = (0\text{ rad/s})(3\text{ s}) + \frac{1}{2}\alpha(3)^2 = 9\alpha/2$$

Related course pages: *5 - Rotational Motion*




19. A group of students want to make a graph that shows their position over time while walking. They set up a detector in a hallway which measures their position relative to the detector, and they take turns walking in the hallway. One student's motion is shown in the graph above. Which of the following is the best approximation of the student's average velocity for the period of time between 10 seconds and 15 seconds?

(A) 0.8 m/s
(B) 0.4 m/s
(C) 1.2 m/s
(D) 1.4 m/s

**A Correct**

The average velocity can be found by dividing the displacement by the period of time, and approximating the position at 10 seconds (2 m) and 15 seconds (6 m). This is the average slope during that time.

$$v = \frac{\Delta x}{\Delta t} = \frac{6\text{ m} - 2\text{ m}}{15\text{ s} - 10\text{ s}} = 0.8\text{ m/s}$$

B Incorrect

This answer incorrectly uses 6 m as the displacement and 15 seconds as the duration, or 2 m as the displacement and 5 seconds as the duration.

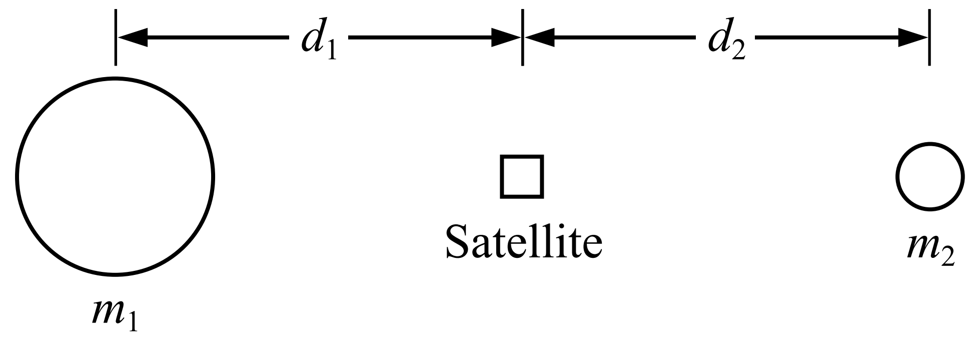
C Incorrect

This answer incorrectly uses 6 m as the displacement during that period.

D Incorrect

This answer incorrectly uses 7 m as the displacement during that period.

Related course pages: *1 - 1D Motion*




<u>Note</u>: Figure not drawn to scale.

20. A satellite is in line with a planet of mass $m_1$ and a moon with a mass of $m_2$ as shown in the figure above, and $m_1$ is greater than $m_2$. The net force on the satellite is zero at this position. How does the distance between the satellite and the center of the planet, $d_1$, compare to the distance between the satellite and the center of the moon, $d_2$?

(A) $d_1 > d_2$
(B) $d_1 < d_2$
(C) $d_1 = d_2$
(D) Cannot be determined

**A Correct**

The only forces acting on the satellite are the two gravitational forces exerted by the planet and the moon. The forces act in opposite directions and the net force on the satellite is zero, so the gravitational forces from the planet and the moon are equal in magnitude.

$$\Sigma F = F_{g2} - F_{g1} = 0 \qquad F_{g1} = F_{g2} \qquad \frac{G m_1 m_s}{d_1^2} = \frac{G m_2 m_s}{d_2^2}$$

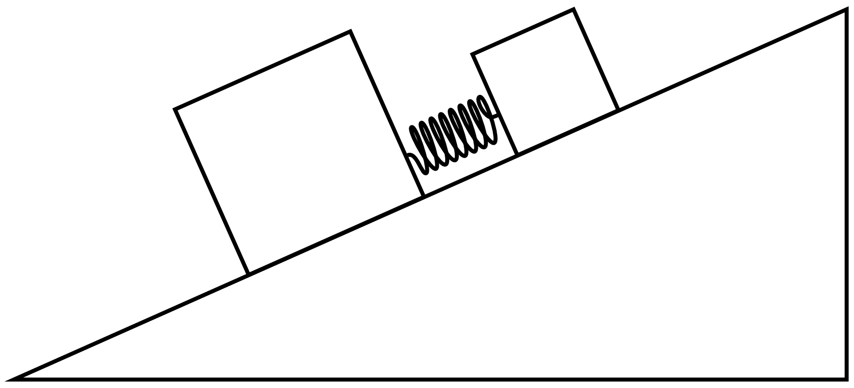
If $m_1$ is greater than $m_2$ then $d_1$ must be greater than $d_2$ for the forces to be equal in magnitude.

B Incorrect

C Incorrect

D Incorrect

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



21. Two blocks are connected by a spring and placed on an incline with negligible friction. The blocks are held so that the spring is initially compressed. The blocks are then released from rest and they move apart from each other due to the spring. How does the total momentum of the blocks-spring system change after the blocks are released?

(A) The total momentum decreases

(B) The total momentum increases

(C) The total momentum does not change

(D) Cannot be determined

A Incorrect

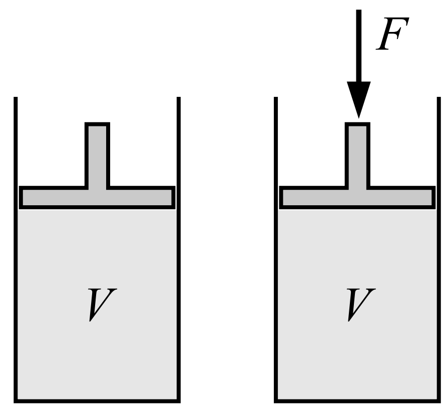
B **Correct**

The blocks-spring system is not isolated because there is an external weight force acting on each block which has a component parallel to the incline (parallel to the block's motion). There is an impulse exerted by the weight forces which changes the momentum of the blocks-spring system (the center of mass of the system will accelerate down the incline due to the weight force). The total momentum of the system does not increase because of the spring force, which is an internal force. If the blocks were on a horizontal surface the weight forces would be perpendicular to the motion and the total momentum of the system would not change.

C Incorrect

D Incorrect

Related course pages: *2 - Newton's 1st Law & Forces, 4 - Linear Momentum & Impulse*




22. A volume of an unknown fluid is contained in a cylinder below a piston as shown in the figure above. A downwards force is then applied to the piston. If the unknown fluid is a liquid or a gas, which of the following correctly describes how the volume of the fluid changes when the force is applied?

(A)

| Liquid volume | Gas volume |
|---|---|
| Decreases | Does not change |

(B)

| Liquid volume | Gas volume |
|---|---|
| Does not change | Does not change |

(C)

| Liquid volume | Gas volume |
|---|---|
| Decreases | Decreases |

(D)

| Liquid volume | Gas volume |
|---|---|
| Does not change | Decreases |

A Incorrect

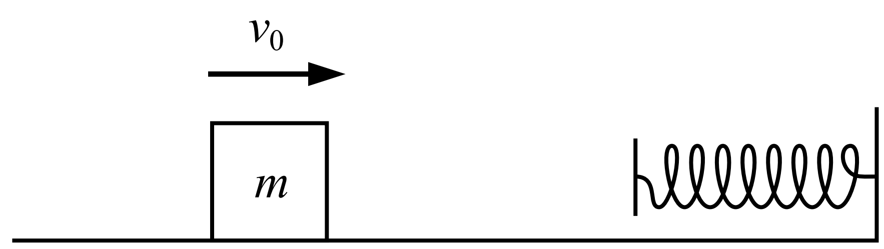
B Incorrect

C Incorrect

**D Correct**

A liquid is nearly incompressible (and an ideal fluid is defined as completely incompressible) so the volume would not change if the fluid was a liquid. A gas is very compressible so the volume would decrease if the fluid was a gas.

Related course pages: *8 - Fluids & Density*




23. A block is sliding across a surface where the friction is not negligible. The block has an initial speed of $v_0$ at time $t_0$. The block then collides with a spring and momentarily comes to a stop at time $t_1$. Which of the following is true about the block-spring system from time $t_0$ to time $t_1$?

(A) The spring does positive work on the system

(B) The total energy of the system is constant

(C) The spring does negative work on the system

(D) The total energy of the system decreases

A Incorrect

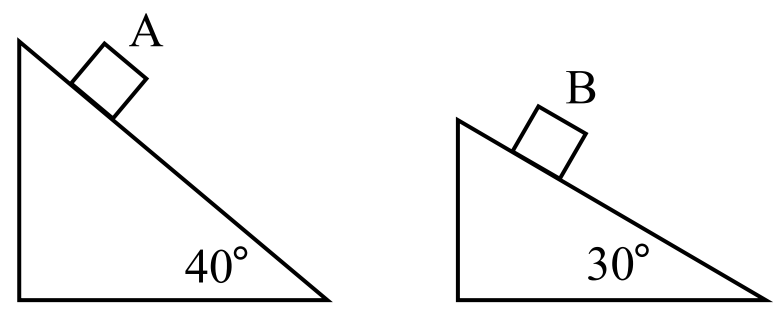
B Incorrect

C Incorrect

D **Correct**

The system is defined as the block and the spring so the forces between the block and the spring are internal and do not do work on the system (they only transform the kinetic energy into spring potential energy). The friction force acting on the block is an external force that does negative work on the system and some of the kinetic energy in the system is lost to the environment as heat energy, so the total energy of the block-spring system decreases.

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




24. Two identical blocks are sliding down two inclines as shown in the figure above. The coefficient of kinetic friction is the same for both inclines. Which block experiences a friction force with a greater magnitude?

(A) Block A

(B) Block B

(C) The blocks experience friction forces with equal magnitudes

(D) Cannot be determined

A Incorrect

B **Correct**

The friction force on an object is proportional to the normal force between the object and the surface. For each block, the normal force is equal to the component of the weight force that is perpendicular to the incline surface because the block does not accelerate in the direction perpendicular to the incline (Newton's 1st law). The normal force is greater for block B so the friction force is greater for block B.

$\Sigma F_{\perp} = m a_{\perp} \qquad F_n - F_g \cos(\theta) = m(0) \qquad F_n = F_g \cos(\theta) = m g \cos(\theta)$

$f_k = \mu_k F_n = \mu_k m g \cos(\theta)$

C Incorrect

D Incorrect

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


25. Two systems consist of identical rods and identical spheres which are free to rotate about the left end of the rod. The sphere in system A is located at the center of the rod, and the sphere in system B is located at the end of the rod. If torques are applied to the systems so that both systems rotate with the same angular speed, which system will have a greater rotational kinetic energy?

(A) The systems will have the same rotational kinetic energy

(B) System A

(C) System B

(D) Cannot be determined

A Incorrect

B Incorrect

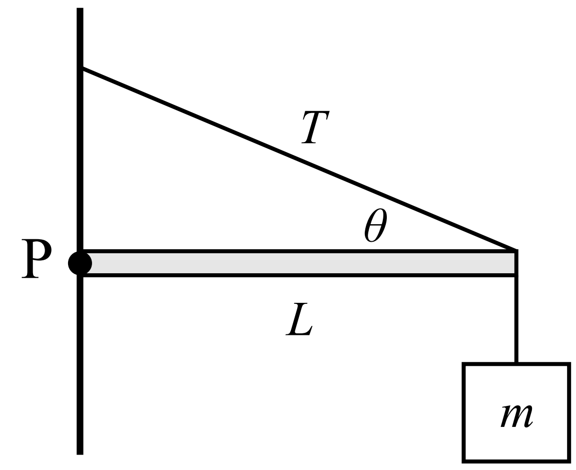
C **Correct**

The rotational kinetic energy of an object or system is proportional to the rotational inertia and the square of the angular speed. System B has a greater rotational inertia because mass is located farther from the point of rotation, so system B will have the grater rotational kinetic energy if the systems have the same angular speed.

$K_{rot} = \frac{1}{2} I\omega^2$

D Incorrect

Related course pages: *5 - Rotational Dynamics*, *6 - Rotational Kinetic Energy*




26. A horizontal pole with a length of $L$ and negligible mass is attached to a wall at point P where it is free to rotate. At the other end of the pole, a block of mass $m$ is suspended by a string with negligible mass and a rope with a tension of $T$ and negligible mass connects the pole and the wall at an angle as shown in the figure above. The magnitude of the net torque acting on the pole about point P is

(A) $LT\sin(\theta) + Lmg$

(B) $LT\cos(\theta) - Lmg$

(C) $LT\sin(\theta) - Lmg$

(D) $T\sin(\theta) - mg$

A Incorrect
This answer incorrectly adds the two torques, but they are in opposite directions so one must be negative.

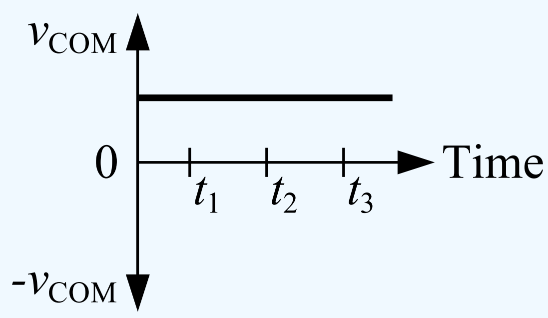
B Incorrect
This answer incorrectly uses the horizontal component of the tension force and switches $\sin(\theta)$ and $\cos(\theta)$.

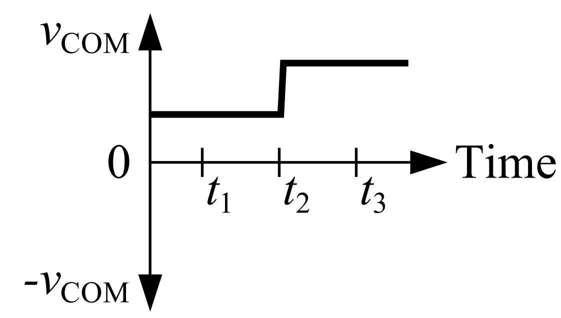
C **Correct**
There is a torque produced by the tension force from the upper rope and a torque produced by the weight force from the suspended block. The net torque about point P is the sum of those two torques which are in opposite directions, so one torque must be positive and the other must be negative (conventionally counterclockwise torques are positive).
$\Sigma\tau = \tau_{\text{rope}} - \tau_{\text{block}} = rF_{\text{rope}\perp} - rF_{\text{block}\perp} = LT\sin(\theta) - Lmg$

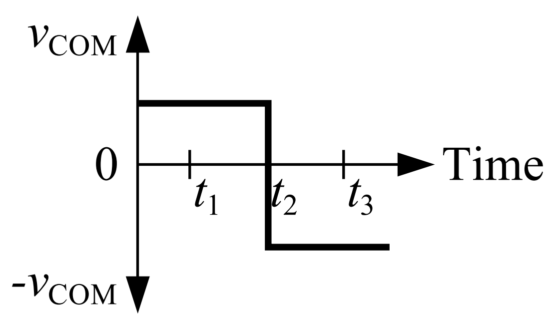
D Incorrect
This answer includes the forces but not the torques, which must be multiplied by the distance between the point of rotation and the point where the force is applied ($L$).

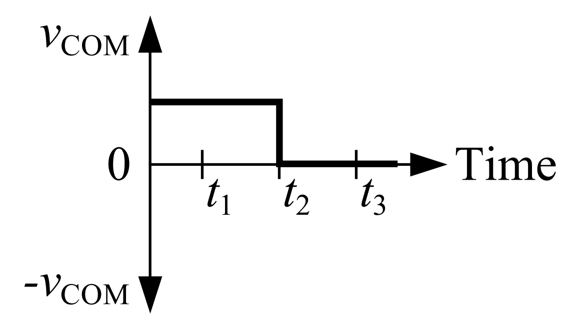
Related course pages: *5 - Torque, 5 - Rotational Dynamics*


27. Two blocks are connected by a compressed spring and are sliding together to the right on a surface with negligible friction at time $t_1$. Some time later at time $t_2$ the spring expands and pushes the blocks apart. Some time later at time $t_3$ the blocks are moving in opposite directions. Which of the following could be a graph of the velocity of the center of mass of the blocks-spring system if right is considered the positive direction?

(A)



(B)



(C)



(D)


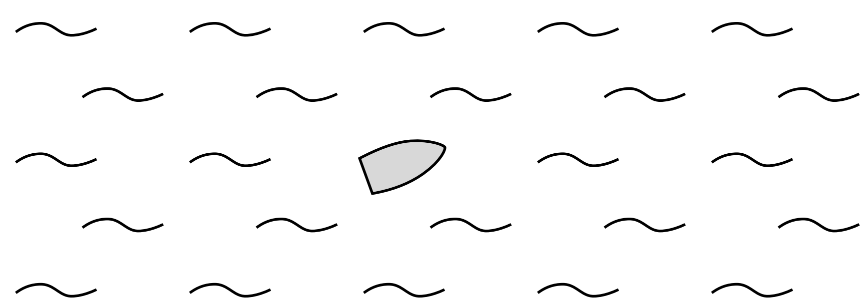

**A Correct**
The blocks are sliding on a frictionless surface. If the system is defined as the two blocks and the spring then there are no external forces acting on the system in the horizontal direction (the spring force is an internal force) so the acceleration of the system’s center of mass is zero and the velocity of the center of mass does not change (Newton's 1st law of motion). The center of mass will continue moving to the right at the same speed.

B Incorrect

C Incorrect

D Incorrect

Related course pages: *2 - Newton's 1st Law & Forces, 4 - Conservation of Momentum & Collisions*



28. A boat is in the middle of a lake as shown in the figure above. The boat moves 18 m in a straight line with an unknown direction, and then it moves 25 m in a straight line with an unknown direction. Which of the following cannot be the magnitude of the boat's total displacement?

(A) 43 m
(B) 18 m
(C) 25 m
(D) 5 m

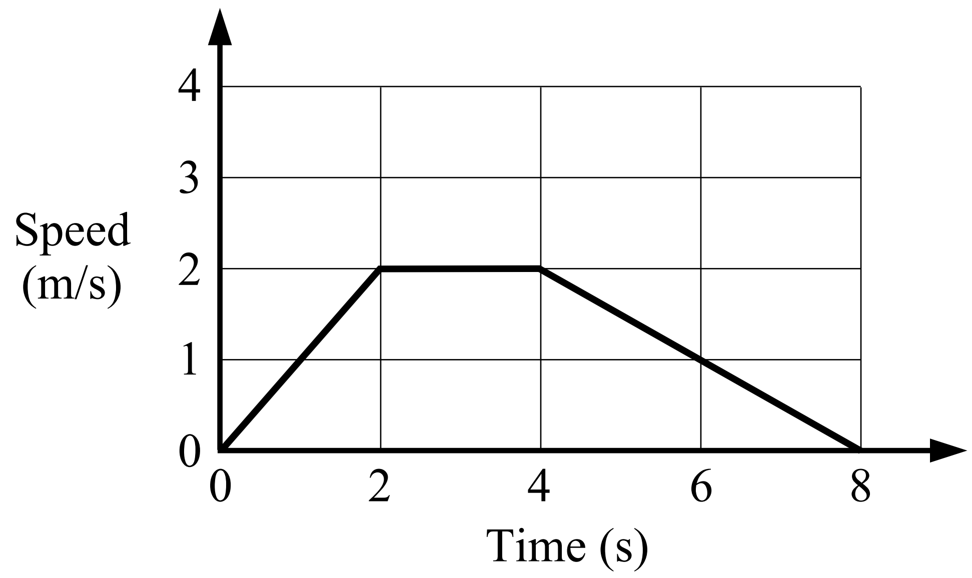
A Incorrect
This answer is within the range of possible magnitudes of the resultant displacement vector, and is the maximum possible magnitude when the two displacements are in the same direction.

B Incorrect
This answer is within the range of possible magnitudes of the resultant displacement vector.

C Incorrect
This answer is within the range of possible magnitudes of the resultant displacement vector.

**D Correct**
When two vectors are added, the maximum magnitude of the resultant vector is the sum of the individual vector magnitudes, which is when the vectors point in the same direction. The minimum magnitude of the resultant vector is the difference between the individual vector magnitudes, which is when the vectors point in opposite directions. For the boat's resultant displacement vector:
The minimum magnitude is: $(25 \text{ m}) - (18 \text{ m}) = 7 \text{ m}$
The maximum magnitude is: $(25 \text{ m}) + (18 \text{ m}) = 43 \text{ m}$
A magnitude of 5 m is not within this range.

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




29. A cart moves on a horizontal surface and its motion is shown in the above graph. Which of the following statements about the motion of the cart is most accurate?

(A) There must be no horizontal forces on the cart between 0 s and 2 s

(B) There must be no horizontal forces on the cart between 2 s and 4 s

(C) There may be horizontal forces on the cart between 2 s and 4 s

(D) None of the above

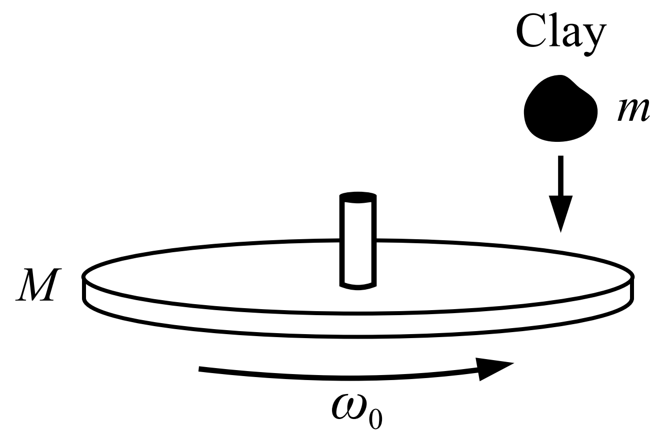
A Incorrect
The cart is accelerating between 0 s and 2 s so there must be a net force acting on the cart during that period.

B Incorrect
The cart is moving at a constant speed and not accelerating between 2 s and 4 s so there is no net force acting on the cart during that period. However, there may be multiple forces acting on the cart which are balanced in opposite directions.

C **Correct**
The cart is moving at a constant speed and not accelerating between 2 s and 4 s so there is no net force acting on the cart during that period. However, there may be multiple forces acting on the cart which are balanced in opposite directions.

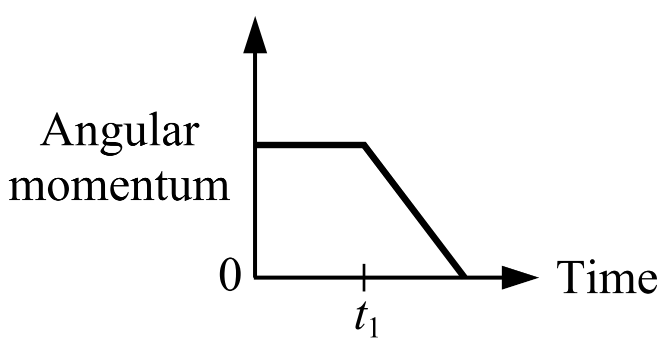
D Incorrect

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

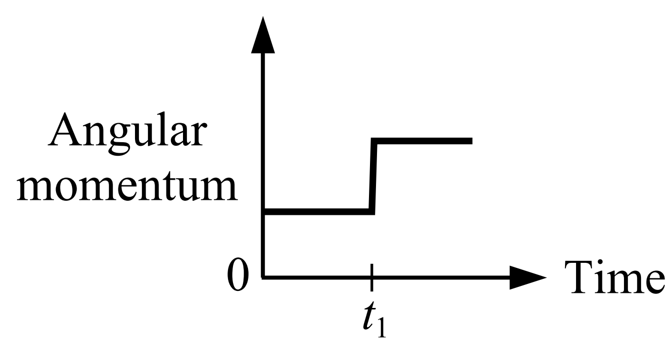



30. A large wheel is free to spin about an axle passing through its center without friction. The wheel is rotating with a constant angular speed of $\omega_0$ when a ball of clay is dropped from rest onto the wheel from above and the clay immediately sticks to the wheel at time $t_1$. Which of the following graphs show the angular momentum of the wheel-clay system about an axis passing through the axle?

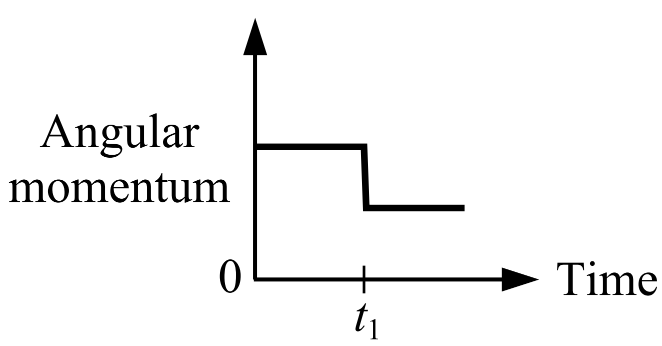
(A)



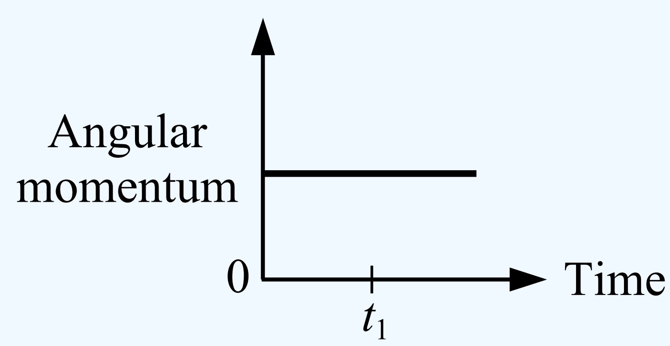

(B)




(C)




(D)




A Incorrect

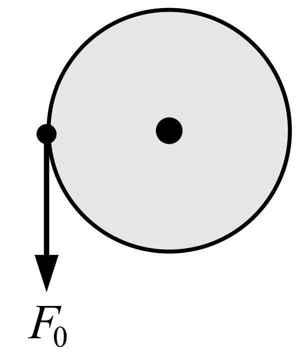
B Incorrect

C Incorrect

**D Correct**

There is no external torque acting on the wheel-clay system about the axis passing through the axle so the angular momentum about that axis is conserved (there is no change in angular momentum). The gravitational forces are parallel to that axis and do not produce a torque. There is no friction from the axle producing a torque. The forces between the wheel and the clay are internal so they do not change the angular momentum of the system.

Related course pages: *6 - Angular Momentum*




31. A wheel is initially spinning freely about its center in the clockwise direction with a constant angular speed. A force is then applied to the wheel as shown in the figure above. At the moment the force is applied, which of the following is true about the angular acceleration of the wheel?

(A) The angular acceleration is in the clockwise direction
(B) The angular acceleration is in the counterclockwise direction
(C) The angular acceleration is zero
(D) None of the above can be determined

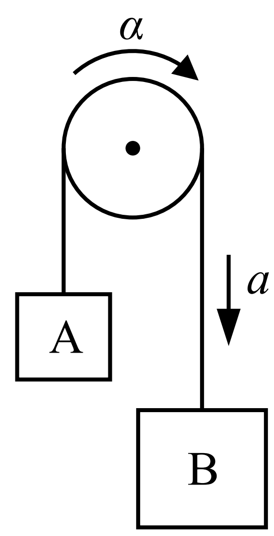
A Incorrect

**B Correct**
The angular acceleration of an object is in the same direction as the net torque acting on the object, regardless of the direction of the angular velocity: $\Sigma\tau = I\alpha$. The applied force produces a torque in the counterclockwise direction so the angular acceleration of the wheel is counterclockwise and the angular speed decreases.

C Incorrect

D Incorrect

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




32. Two blocks are connected by a cable that is wrapped around a pulley as shown in the figure above. Block B has a greater mass than block A so the blocks accelerate and the pulley experiences an angular acceleration (the cable turns the pulley without slipping). If the diameter of the pulley is 0.2 m and the angular acceleration of the pulley is 15 rad/s², the magnitude of the acceleration of the blocks is most nearly

(A) 0.75 m/s²

(B) 150 m/s²

(C) 1.5 m/s²

(D) 3.0 m/s²

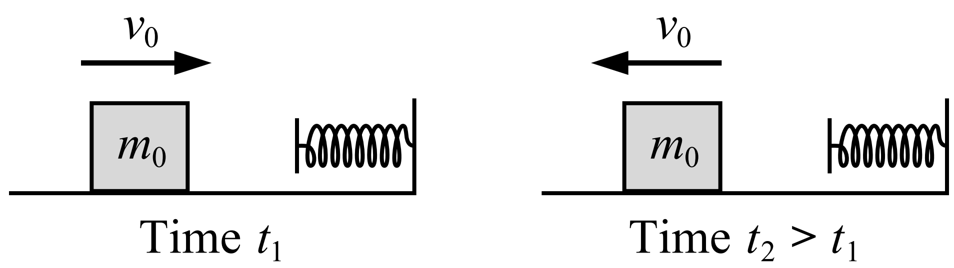
A Incorrect

B Incorrect
This answer incorrectly divides the angular acceleration by the radius instead of multiplying them.

C **Correct**
The cable is wrapped around the outer edge of the pulley so the linear or tangential acceleration of the cable and the blocks is equal to the radius of the pulley multiplied by the angular acceleration.
$a = r\alpha = (0.1 \text{ m})(15 \text{ rad/s}^2) = 1.5 \text{ m/s}^2$

D Incorrect
This answer incorrectly uses 0.2 m as the radius of the pulley instead of 0.1 m.

Related course pages: *5 - Connecting Circular & Rotational Motion*




33. A block is sliding to the right on a surface with negligible friction with a speed of $v_0$ at time $t_1$. The block then compresses a spring and reverses direction. The block is moving to the left with the same speed of $v_0$ at a later time $t_2$. The magnitude of the impulse exerted on the block by the spring is

(A) $2m_0v_0$
(B) $m_0v_0$
(C) $m_0v_0/2$
(D) 0

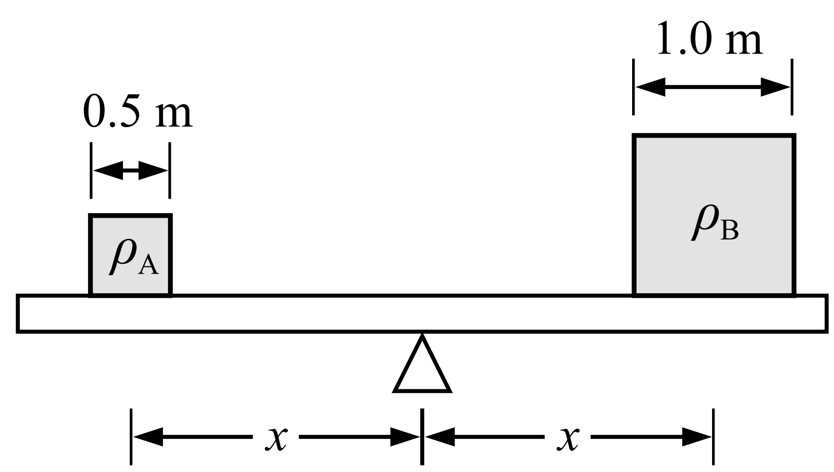
**A Correct**
The impulse exerted on the block is equal to the change in the block's momentum. Momentum is a vector so it has a direction. If we say right is the positive direction:
$J = \Delta p = p_f - p_i = m_0v_0 - m_0(-v_0) = 2m_0v_0$

B Incorrect
This would be the impulse exerted on the block if the spring only stopped the block and the final momentum of the block was zero.

C Incorrect

D Incorrect
This answer incorrectly treats momentum as a scalar without a direction, and assumes the change in momentum is zero because the magnitude of the momentum is the same at both times. The change in momentum cannot be zero because momentum is a vector and the momentum changes direction.

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




34. Two cubes are balanced on a beam which is at rest as shown in the figure above. The centers of mass of each cube are the same distance from the pivot point of the beam. Cube A has a side length of 0.5 m and cube B has a side length of 1.0 m. What is the ratio of the density of cube A to the density of cube B, $\rho_A/\rho_B$?

(A) 1/8

(B) 4

(C) 8

(D) 2

Ⓐ Incorrect
This answer may have been found by incorrectly dividing the volume of cube A by the volume of cube B.

Ⓑ Incorrect
This answer may have been found by incorrectly calculating the volume as the square of the side length.

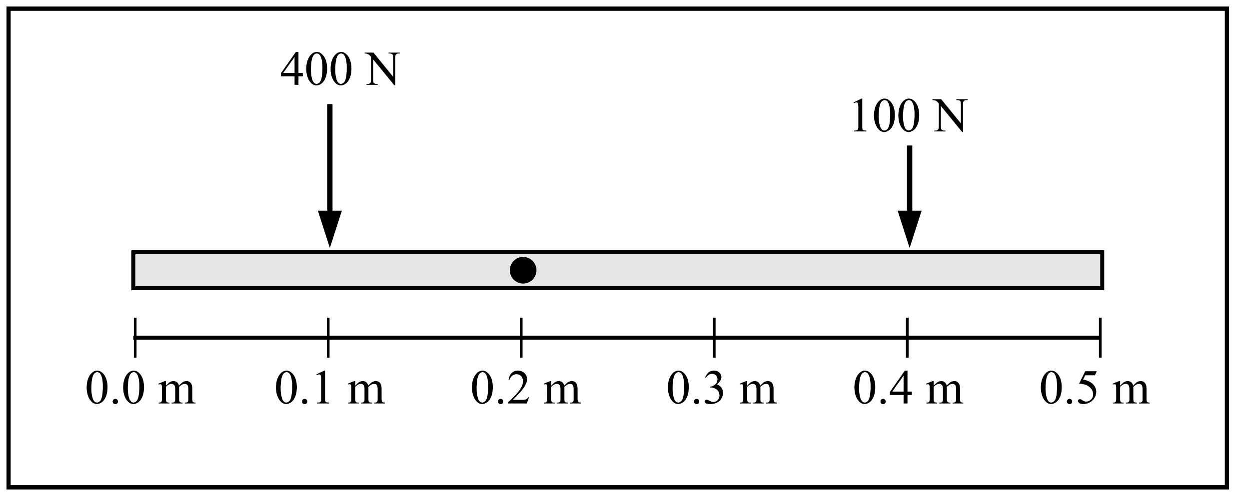
Ⓒ **Correct**
The beam is balanced at rest so the net torque on the beam is zero. The center of mass of each cube is the same distance away from the pivot point so the weight force of each cube must be the same and therefore the mass of each cube must be the same. The density of a cube is its mass divided by its volume.

$$\rho_A = \frac{m_A}{V_A} \qquad m_A = \rho_A V_A \qquad \rho_B = \frac{m_B}{V_B} \qquad m_B = \rho_B V_B$$

$$m_A = m_B \qquad \rho_A V_A = \rho_B V_B \qquad \rho_A(0.5\text{ m})^3 = \rho_B(1.0\text{ m})^3 \qquad \frac{\rho_A}{\rho_B} = \frac{(1.0\text{ m})^3}{(0.5\text{ m})^3} = 8$$

Ⓓ Incorrect
This answer may have been found by incorrectly assuming the density of the smaller cube is twice the density of the larger cube because it has half of the side length of the larger cube.

Related course pages: *5 - Torque, 5 - Rotational Dynamics, 8 - Fluids & Density*



Top view

35. A rod is resting on a table with negligible friction and is pinned so it is free to rotate about a point 0.2 m from the left end of the rod. Two horizontal forces are applied to the beam as shown in the figure above, which is a top-down view of the rod on the table. The rotational inertia of the beam is 20 kg·m². At the moment the two forces are applied, the magnitude of the angular acceleration of the beam is

(A) 0 rad/s²

(B) 3 rad/s²

(C) 1 rad/s²

(D) 20 rad/s²

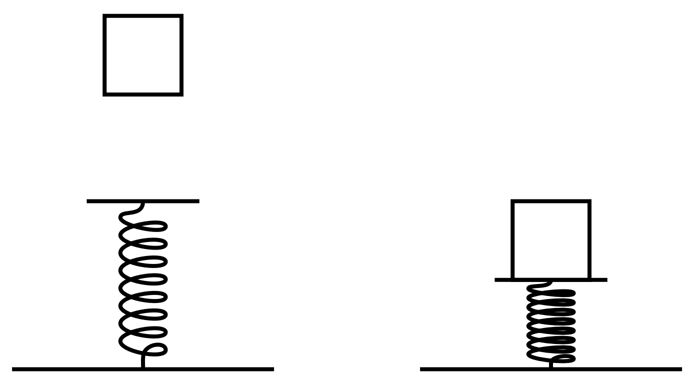
A Incorrect
This answer incorrectly uses 0.4 m as the distance between the 100 N force and the point of rotation.

B Incorrect
This answer incorrectly adds the torques produced by each force. The torques are in opposite directions so one torque must be negative.

C **Correct**
The net torque acting on the beam about the point of rotation is equal to the rotational inertia of the beam multiplied by the angular acceleration of the beam. The torques act in opposite directions.
$\Sigma\tau = \tau_{400\text{ N}} - \tau_{100\text{ N}} = I\alpha$ $\quad (0.1\text{ m})(400\text{ N}) - (0.2\text{ m})(100\text{ N}) = (20\text{ kg}\cdot\text{m}^2)\alpha$ $\quad \alpha = 1\text{ rad/s}^2$

D Incorrect
This answer is the value of the net torque (20 N·m) with the units for angular acceleration.

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




36. A block is released from rest at a height above an uncompressed spring at time $t_1$. The block falls and compresses the spring, and momentarily comes to rest at time $t_2$. Which of the following correctly compares the total energy of the following systems at time $t_1$ and time $t_2$?

(A)

| Block System | Block-Earth System | Block-Spring System |
|---|---|---|
| $E_1 < E_2$ | $E_1 > E_2$ | $E_1 < E_2$ |

(B)

| Block System | Block-Earth System | Block-Spring System |
|---|---|---|
| $E_1 = E_2$ | $E_1 = E_2$ | $E_1 = E_2$ |

(C)

| Block System | Block-Earth System | Block-Spring System |
|---|---|---|
| $E_1 > E_2$ | $E_1 < E_2$ | $E_1 > E_2$ |

(D)

| Block System | Block-Earth System | Block-Spring System |
|---|---|---|
| $E_1 = E_2$ | $E_1 > E_2$ | $E_1 < E_2$ |

A Incorrect

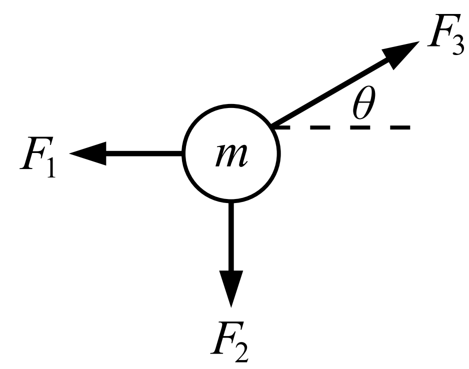
B Incorrect

C Incorrect

**D Correct**

The block system has zero kinetic energy at both times because it is not moving, and it cannot have gravitational potential energy or spring potential energy because the earth and the spring are not in the block system. The block-earth system has more gravitational potential energy when the block is at a greater height, and the block-earth system cannot have spring potential energy because the spring is not in the system. The block-spring system has zero spring potential energy at the initial time because the spring is not compressed, and it has some spring potential energy when the spring is compressed. The block-spring system cannot have gravitational potential energy because the earth is not in the system.

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




37. Three forces of magnitudes $F_1$ , $F_2$ and $F_3$ are acting on an object of mass $m$ as shown in the figure above. Which of the following represents the magnitude of the object's acceleration?

(A) $\sqrt{\left(\frac{F_3\sin\theta - F_1}{m}\right)^2 + \left(\frac{F_3\cos\theta - F_2}{m}\right)^2}$

(B) $\frac{F_1 + F_2 + F_3}{m}$

(C) $\sqrt{\left(\frac{F_3\cos\theta - F_1}{m}\right)^2 + \left(\frac{F_3\sin\theta - F_2}{m}\right)^2}$

(D) $\frac{F_3\cos\theta - F_1}{m} + \frac{F_3\sin\theta - F_2}{m}$

A Incorrect
This answer incorrectly switches the $\sin(\theta)$ and $\cos(\theta)$ terms (the horizontal and vertical components of $F_3$).

B Incorrect
This answer incorrectly adds the magnitudes of each force without treating them as vectors.

C **Correct**
The horizontal and vertical components of the acceleration vector can be found by applying Newton's 2nd law of motion to each direction. Then the magnitude of the acceleration vector can be found by using the Pythagorean theorem:

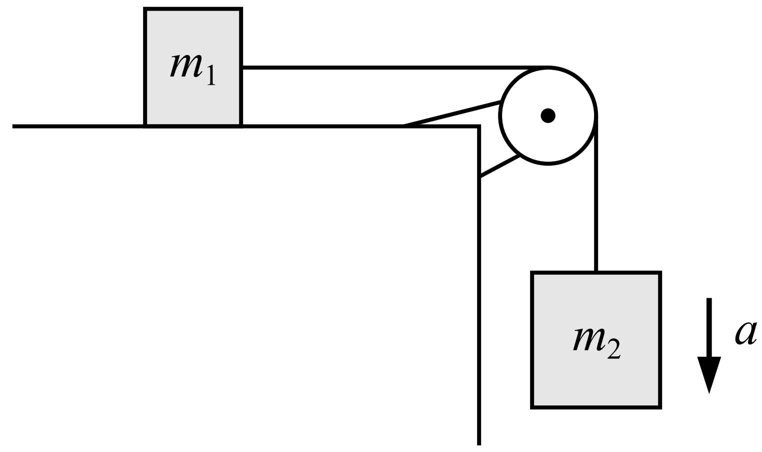
$$\Sigma F_x = m a_x \qquad F_3\cos\theta - F_1 = m a_x \qquad a_x = \frac{F_3\cos\theta - F_1}{m}$$

$$\Sigma F_y = m a_y \qquad F_3\sin\theta - F_2 = m a_y \qquad a_y = \frac{F_3\sin\theta - F_2}{m}$$

$$a = \sqrt{a_x^2 + a_y^2} = \sqrt{\left(\frac{F_3\cos\theta - F_1}{m}\right)^2 + \left(\frac{F_3\sin\theta - F_2}{m}\right)^2}$$

D Incorrect
This answer correctly finds the horizontal and vertical components of the acceleration vector but incorrectly adds their magnitudes instead of adding them as vector components using the Pythagorean theorem.

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




38. Two blocks are connected by a string with negligible mass which passes over a pulley with negligible mass and negligible friction as shown in the figure above. There is negligible friction between the block of mass $m_1$ and the surface. Which of the following is an expression for the magnitude of the acceleration of the lower block?

(A) $g$

(B) $\frac{m_2 g}{m_1}$

(C) $\frac{(m_1 + m_2)g}{m_1 + m_2}$

(D) $\frac{m_2 g}{m_1 + m_2}$

A Incorrect

B Incorrect

C Incorrect

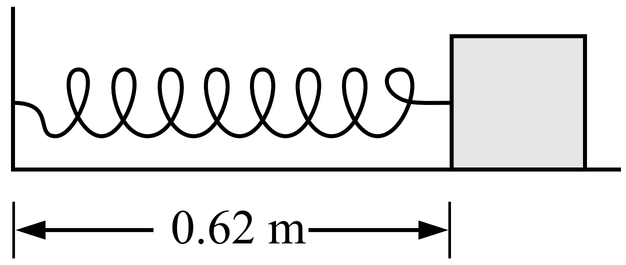
D **Correct**

Newton's 2nd law can be applied to each block to get a system of two equations. The magnitude of the tension forces ( $T$ ) and the accelerations of each block ( $a$ ) are the same. If right and down are positive:

Block 1: $\Sigma F_x = T = m_1 a$

Block 2: $\Sigma F_y = m_2 g - T = m_2 a \qquad m_2 g - (m_1 a) = m_2 a \qquad m_2 g = m_1 a + m_2 a \qquad a = \frac{m_2 g}{m_1 + m_2}$

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




39. A block is attached to a spring which has an unstretched length of 0.68 m. The block is held in the position shown in the figure above. If the block is moved 0.10 m to the right, the magnitude of the spring force on the block

(A) will be greater than the magnitude of the spring force at the position shown

(B) will be less than the magnitude of the spring force at the position shown

(C) will be the same as the magnitude of the spring force at the position shown

(D) cannot be compared to the magnitude of the spring force at the position shown

A Incorrect

B **Correct**

The magnitude of the spring force acting on the block depends on the change in length of the spring from its original length of 0.68 m.

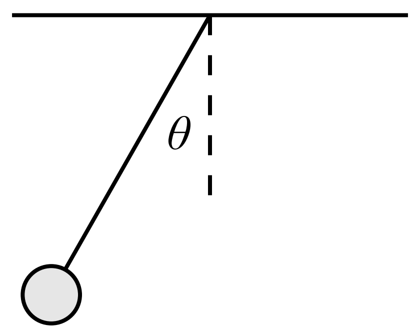
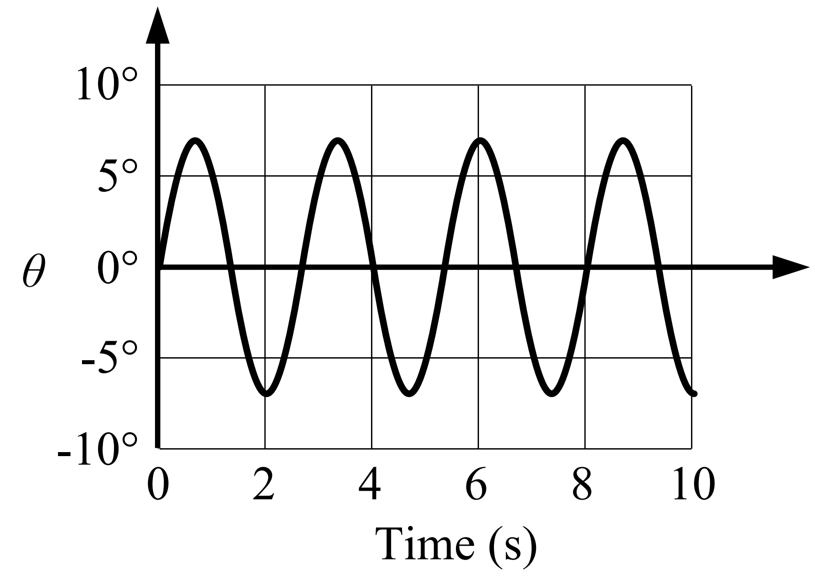
When the block is at the position shown: $F_{sp} = k\Delta x = k(0.68\text{ m} - 0.62\text{ m}) = k(0.06\text{ m})$ (to the right)

When the block is moved 0.10 m to the right: $F_{sp} = k\Delta x = k(0.72\text{ m} - 0.68\text{ m}) = k(0.04\text{ m})$ (to the left)

C Incorrect

D Incorrect

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


40. A graph of the angle between a pendulum and the vertical is shown in the figure above. The frequency of the pendulum is most nearly

(A) 0.25 Hz
(B) 0.38 Hz
(C) 1 Hz
(D) 2.67 Hz

A Incorrect

**B Correct**

The frequency of the pendulum is the number of oscillations per second, or the inverse of the period. There are 1.5 cycles (wavelengths) in 4 seconds or 3 cycles in 8 seconds.

$$f = \frac{3 \text{ cycles}}{8 \text{ s}} = 0.38 \text{ Hz}$$

C Incorrect

D Incorrect

This answer is the period (2.67 s) with the unit of Hz.

Related course pages: *7 - Simple Harmonic Motion*