MCQ Practice Test 2
Answer Key and Solutions

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Answer Key

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

Solutions are on the following pages

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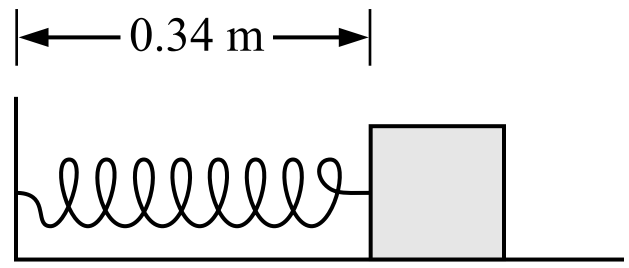
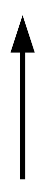


1. A block is attached to a spring which has an original unstretched length of 0.28 m. The other end of the spring is attached to a wall. The block is pulled away from the wall and released, and the block oscillates left and right. Which of the following shows the direction of the spring force acting on the block when it is in the position shown in the figure above?

(A) 

(B) 

(C) 

(D) The magnitude of the spring force is zero

A Incorrect

B Incorrect

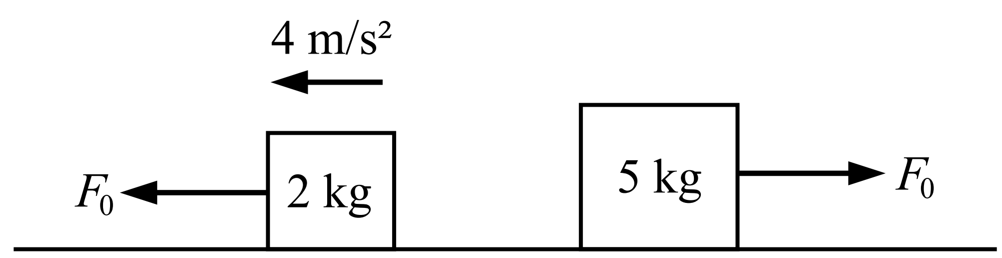
C **Correct**

The magnitude of the spring force is equal to the spring constant multiplied by the change in length from the original unstretched length (see the equation below). The spring is stretched longer than the original length so the spring applies a pulling force (not a pushing force) on the block, which acts in the left direction.

$F_{sp} = k\Delta x$

D Incorrect

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



2. Two blocks are on a surface with negligible friction. A force with a magnitude of F_0 is applied to the 2 kg block and it accelerates at 4 m/s². A force with the same magnitude of F_0 is applied to the 5 kg block. If the block starts at rest, what is the speed of the 5 kg block after 2 seconds?

(A) 1.6 m/s

(B) 3.2 m/s

(C) 4.0 m/s

(D) 8.0 m/s

A **Incorrect**

This answer is the acceleration of the 5 kg block (1.6 m/s²) with the unit of m/s.

B **Correct**

The magnitude of F_0 can be found by applying Newton's 2nd law to the 2 kg block. Then that same force can be used to find the acceleration of the 5 kg block using Newton's 2nd law. Then the speed of the 5 kg block can be found using kinematics.

2 kg block: $\Sigma F = ma$ $\quad F_0 = (2\text{ kg})(4\text{ m/s}^2) = 8\text{ N}$

5 kg block: $\Sigma F = ma$ $\quad 8\text{ N} = (5\text{ kg})a \quad a = 1.6\text{ m/s}^2$

$v_f = v_0 + at = (0\text{ m/s}) + (1.6\text{ m/s}^2)(2\text{ s}) = 3.2\text{ m/s}$

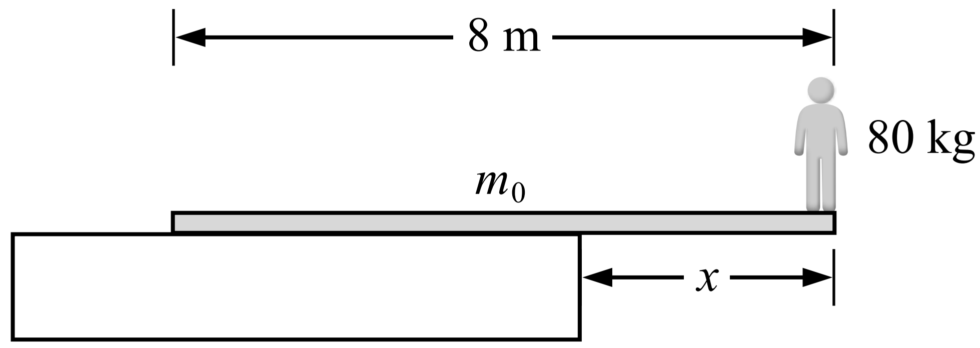
C **Incorrect**

This answer is the acceleration of the 2 kg block (4 m/s²) with the unit of m/s.

D **Incorrect**

This answer incorrectly uses 4 m/s² for the acceleration of the 5 kg block.

Related course pages: *1 - 1D Motion, 2 - Newton's 2nd Law*



3. An 80 kg person stands at the end of an 8 m long beam with a mass of m_0. The beam remains at rest on top of a large block as shown in the figure above. What is the maximum distance x that the beam can extend from the block without the beam rotating?

(A) 0 m
(B) 1 m
(C) 4 m
(D) Cannot be determined

A Incorrect

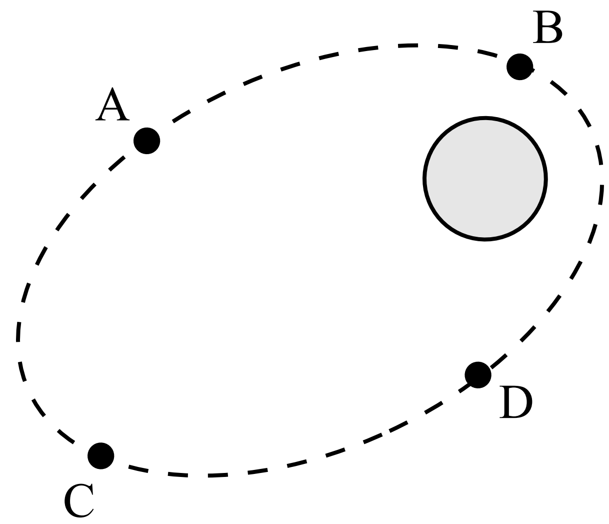
B Incorrect

C Incorrect

D Correct

The maximum length that the beam can extend from the block is when the net torque on the beam about the pivot point (the right end of the block) is zero. The net torque is the sum of the counterclockwise torque produced by the weight force acting on the center of the beam minus the clockwise torque produced by the weight force acting on the person. The mass of the beam must be given in order to find the torque produced by the weight force on the beam.

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



4. A satellite is orbiting a planet as shown in the figure above. At which of the points shown does the satellite have the greatest speed?

   (A) Point A
   (B) Point B
   (C) Point C
   (D) Point D

A Incorrect

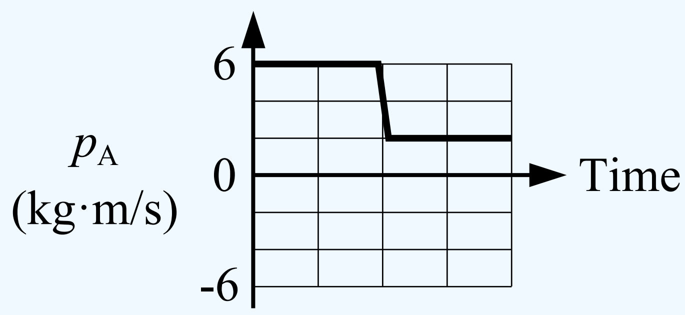
B Correct
The speed of a satellite in orbit is greater when the satellite is closer to the planet that it's orbiting because the total amount of energy in the satellite-planet system is conserved. The satellite has kinetic energy and the system has gravitational potential energy. As the satellite moves closer to the planet the gravitational potential energy decreases so the kinetic energy increases and the speed of the satellite increases.

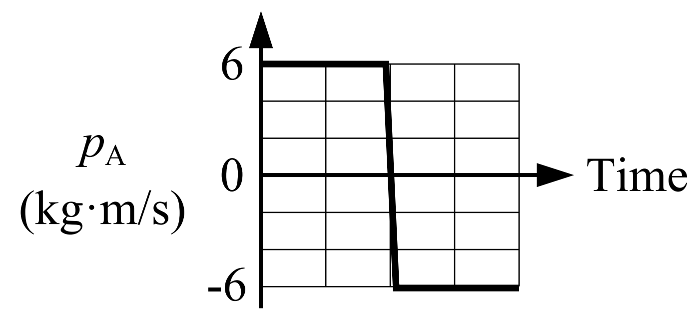
C Incorrect

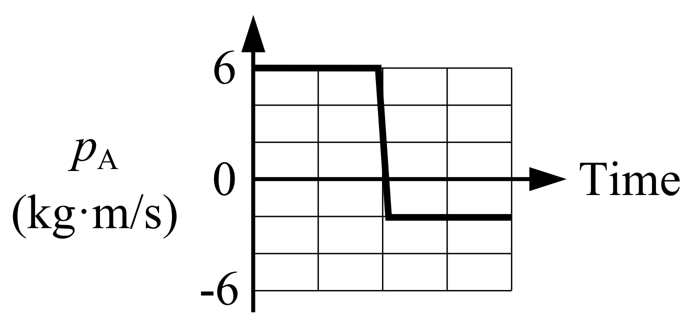
D Incorrect

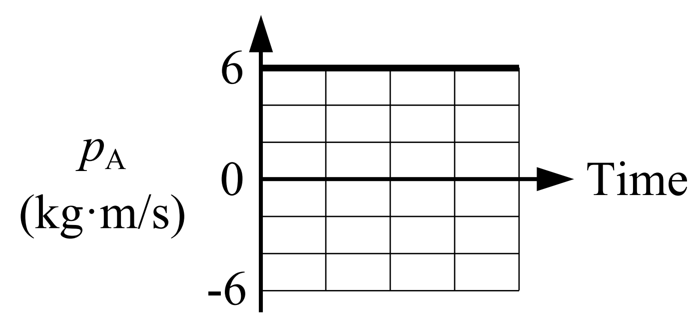
Related course pages: *3 - Conservation of Energy, Work & Power, 6 - Orbital Motion Energy*

5. Block A is sliding on a surface with negligible friction when it collides with block B which is initially at rest. After the collision block B moves to the right at 1 m/s. Which of the following could show the momentum of block A before and after the collision?

(A)


(B)


(C)


(D)


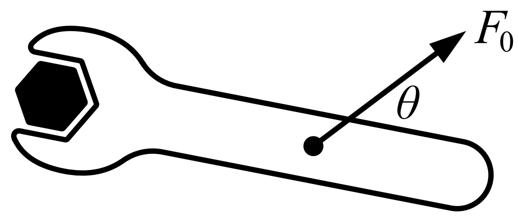
A Correct
The total momentum of the system of the two blocks is conserved (it doesn't change over time). Block B has zero momentum before the collision and 4 kg·m/s of momentum after the collision, so its momentum increases 4 kg·m/s. The momentum of block A must decrease by 4 kg·m/s if the total momentum stays the same.
$\Sigma p_i = \Sigma p_f$ $\quad p_{Ai} + p_{Bi} = p_{Af} + p_{Bf}$ $\quad (6\text{ kg·m/s}) + (0\text{ kg·m/s}) = p_{Af} + (4\text{ kg·m/s})$ $\quad p_{Af} = 2\text{ kg·m/s}$

B Incorrect

C Incorrect

D Incorrect

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



6. A force is exerted on a wrench in order to turn the bolt at the left end of the wrench as shown in the figure above. Which of the following changes would not increase the torque produced by the force about the center of the bolt?

   (A) Increase θ to 90°

   (B) Move the force closer to the bolt

   (C) Double the magnitude of the force

   (D) All of the above would increase the torque

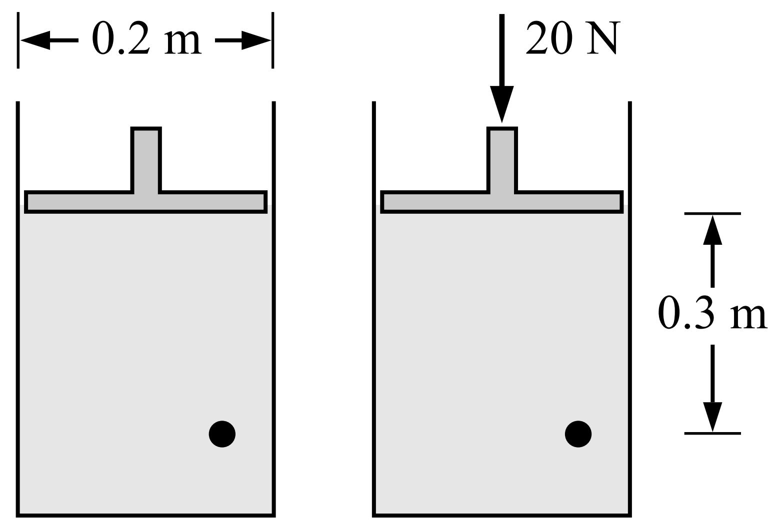
A Incorrect
This answer is a change that would increase the torque produced by the force about the center of the bolt.

B **Correct**
The magnitude of the torque produced by the force about the center of the bolt is equal to the distance between the center of the bolt and the point where the force is applied multiplied by the component of the force which is perpendicular to the wrench handle (the radial line). Moving the force closer to the bolt would decrease the torque produced by the force about the center of the bolt.

C Incorrect
This answer is a change that would increase the torque produced by the force about the center of the bolt.

D Incorrect

Related course pages: *5 - Torque*



7. A volume of water is contained in a cylinder below a piston as shown in the figure above. The diameter of the circular piston is 0.2 m. A force of 20 N is then applied to the piston. What is the change in pressure at the point shown, 0.3 m below the piston, when the 20 N force is applied? The density of the water is 1,000 kg/m³.

(A) 159 Pa

(B) 3,000 Pa

(C) 637 Pa

(D) 3,637 Pa

A Incorrect
This answer incorrectly uses 0.2 m for the radius of the piston.

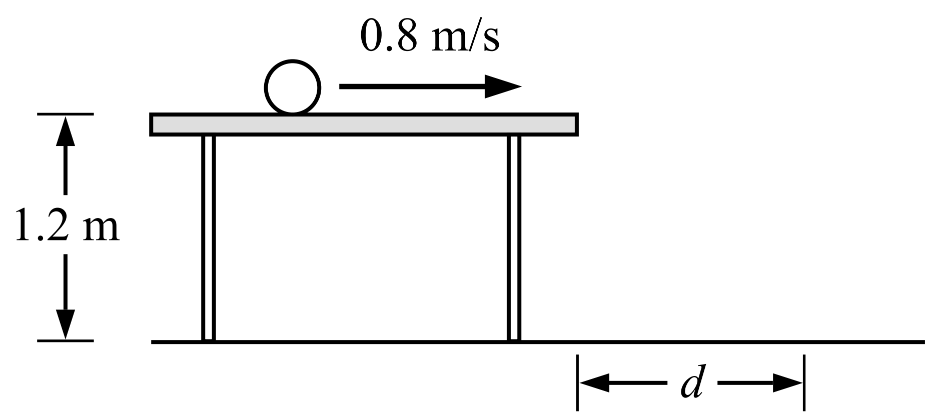
B Incorrect
This is the pressure at the point shown only due to its depth (due to the weight of the water above it). It is not the change in pressure at that point when the piston force is applied.

C **Correct**
When the force is applied to the piston the pressure at every point in the water changes by the same amount (Pascal's principle) including at the point shown. The change in pressure caused by the force on the piston is equal to the piston force divided by the piston area.

$$\Delta P = P_{\text{piston}} = \frac{F}{A} = \frac{F}{\pi r^2} = \frac{(20\text{ N})}{\pi(0.1\text{ m})^2} = 637\text{ Pa}$$

D Incorrect
This is the total gauge pressure at the point shown (the sum of the pressure due to its depth and the pressure applied by the piston). It is not the change in pressure at that point when the piston force is applied.

Related course pages: *8 - Pressure*



Note: Figure not drawn to scale.

8. A ball is rolling on a table with a constant speed as shown in the figure above. The ball rolls off the table and lands on the ground. What distance d from the edge of the table does the ball first hit the ground?

(A) 0.4 m

(B) 0.5 m

(C) 0.8 m

(D) 1.2 m

A Correct

The amount of time the ball takes to hit the ground depends on the vertical motion:

$y_f = y_i + v_{yi}t + \frac{1}{2}a_y t^2 \qquad (0\text{ m}) = (1.2\text{ m}) + (0\text{ m/s})t + \frac{1}{2}(-10\text{ m/s}^2)t^2 \qquad t = 0.49\text{ s}$

The horizontal velocity is constant so the horizontal displacement is:

$v_x = \frac{\Delta x}{\Delta t} \qquad \Delta x = v_x\,\Delta t = (0.8\text{ m/s})(0.49\text{ s}) = 0.4\text{ m}$

B Incorrect

This answer incorrectly switches the values for the table height and the velocity.

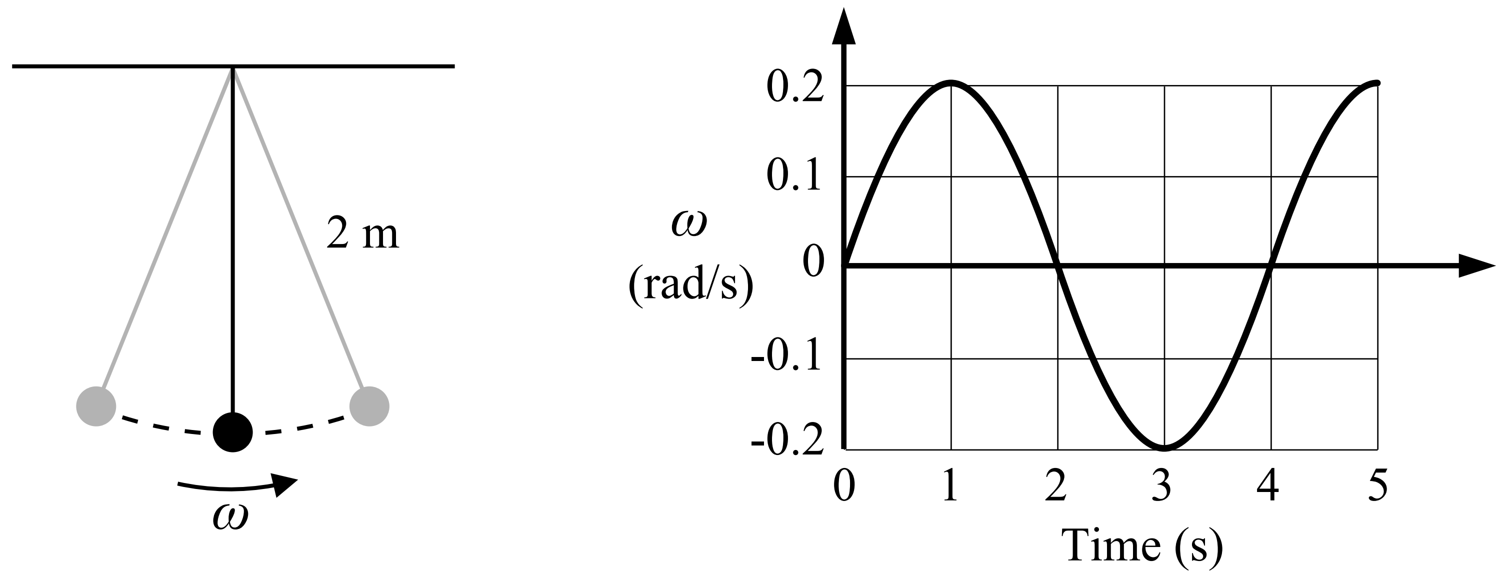
C Incorrect

This answer incorrectly assumes the ball takes 1 second to fall.

D Incorrect

This answer incorrectly assumes the ball will travel the same distance as the height.

Related course pages: *1 - Projectile Motion*



9. A 2 m long string is attached to the ceiling and a small sphere is attached to the bottom of the string. The sphere swings back and forth and a graph of the angular velocity of the sphere is shown in the figure above. The speed of the sphere at 1 second is most nearly

(A) 0.4 m/s

(B) 0.8 m/s

(C) 0.1 m/s

(D) 0.2 m/s

A Correct

As the sphere swings back and forth it follows a segment of a circular path which has a radius of 2 m (the length of the string). At 1 second the angular speed is 0.2 rad/s and the linear or tangential speed is equal to the radius of the circular path multiplied by the angular speed.

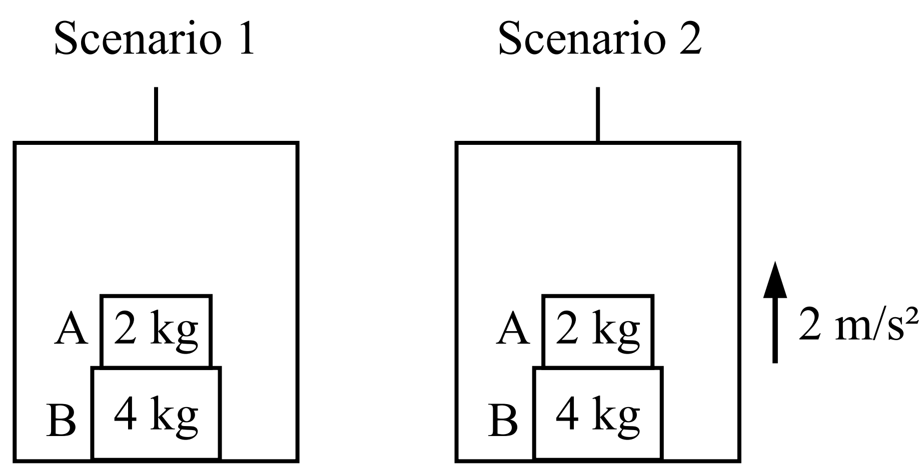
$v = r\omega = (2 \text{ m})(0.2 \text{ rad/s}) = 0.4 \text{ m/s}$

B Incorrect

C Incorrect

D Incorrect

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



10. Two blocks with different masses are stacked on the floor of an elevator as shown in the figure above. In scenario 1 the elevator is at rest and in scenario 2 the elevator is accelerating upwards. Which of the following statements is true?

(A) The weight of block A in scenario 1 is greater than the weight of block B in scenario 2

(B) The weight of block B in scenario 1 is greater than the weight of block A in scenario 2

(C) The weight of block B in scenario 1 is equal to the weight of block A in scenario 2

(D) The weight of block A in scenario 1 is equal to the weight of block B in scenario 1

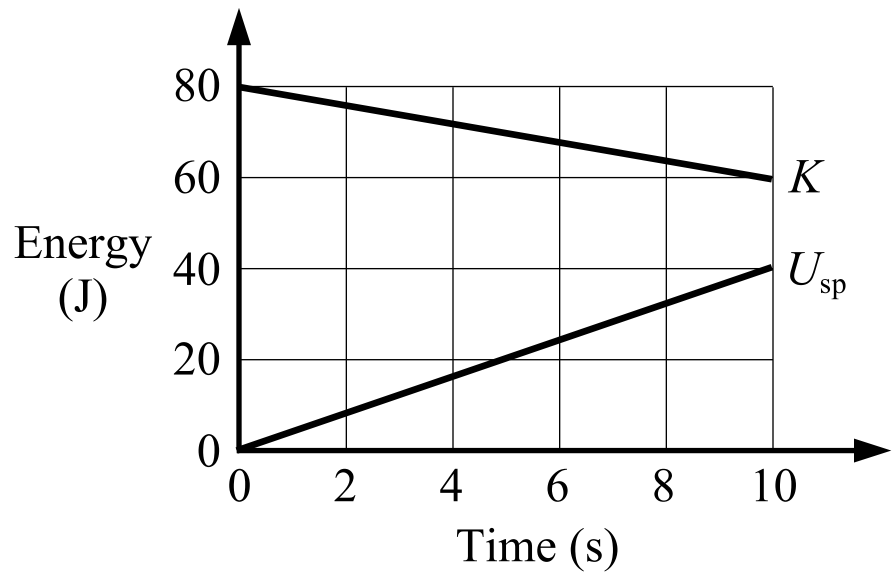
A Incorrect
The weight of block A in scenario 1 is 20 N and the weight of block B in scenario 2 is 40 N.

B **Correct**
The question is asking about the weight of the blocks, not the apparent weight. The weight of an object is always the mass of the object multiplied by the gravitational acceleration (or the gravitational field strength), $w = F_g = mg$, regardless of the motion of the object.
Weight of block A in both scenarios: $F_g = mg = (2\text{ kg})(10\text{ m/s}^2) = 20\text{ N}$
Weight of block B in both scenarios: $F_g = mg = (4\text{ kg})(10\text{ m/s}^2) = 40\text{ N}$

C Incorrect
The weight of block B in scenario 1 is 40 N and the weight of block A in scenario 2 is 20 N.

D Incorrect
The weight of block A in scenario 1 is 20 N and the weight of block B in scenario 1 is 40 N.

Related course pages: *2 - Gravity & Weight*



11. A graph of the energy in a system, which only has kinetic energy and spring potential energy, is shown in the figure above. Which of the following is true about this system?

(A) There are no external forces acting on the system

(B) There must be at least one external force acting on the system

(C) There must be a friction force acting on the system

(D) It cannot be determined if there are any external forces acting on the system

A Incorrect

B **Correct**

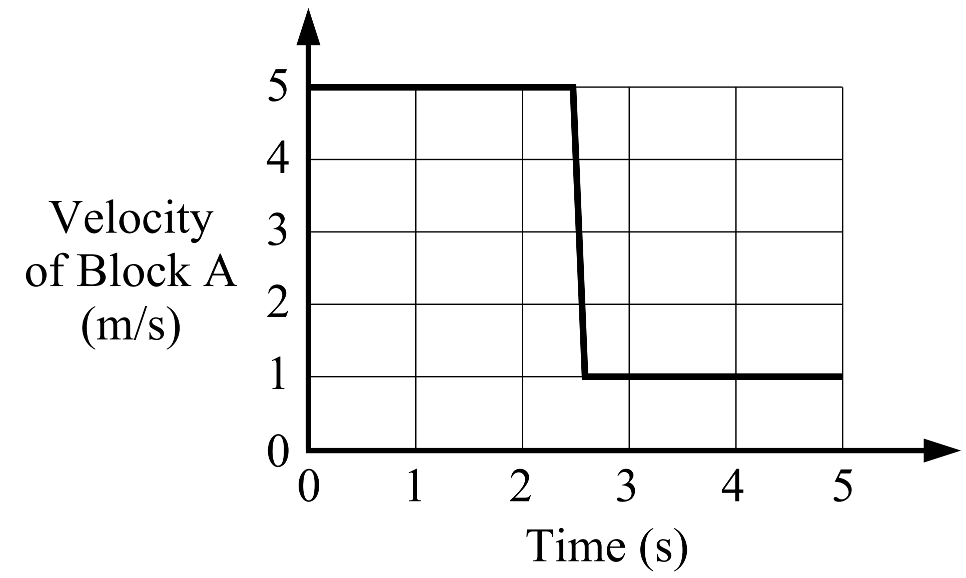
The total energy in the system increases over time from 80 J to 100 J so there must be a net external force doing work on the system. If there is a net external force there must be at least one external force.

C Incorrect

There must be a net external force acting on the system but it does not have to be a friction force.

D Incorrect

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



12. Block A is sliding on a surface with negligible friction towards block B which is initially at rest. The blocks collide and the collision is perfectly elastic. A graph of the velocity of block A is shown in the figure above. What is the speed of block B after the collision?

(A) 6 m/s

(B) 5 m/s

(C) 4 m/s

(D) 1 m/s

A **Correct**

The total momentum of the two block system is conserved during the collision.

$p_i = p_f \qquad m_A v_{Ai} + m_B v_{Bi} = m_A v_{Af} + m_B v_{Bf} \qquad (6\text{ kg})(5\text{ m/s}) + (4\text{ kg})(0\text{ m/s}) = (6\text{ kg})(1\text{ m/s}) + (4\text{ kg})v_{Bf}$

$v_{Bf} = 6\text{ m/s}$

B Incorrect

This answer is the initial speed of block A before the collision.

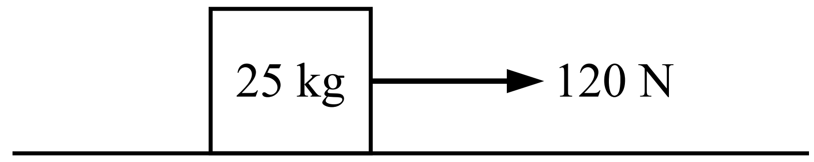
C Incorrect

This answer is the change in the speed of block A.

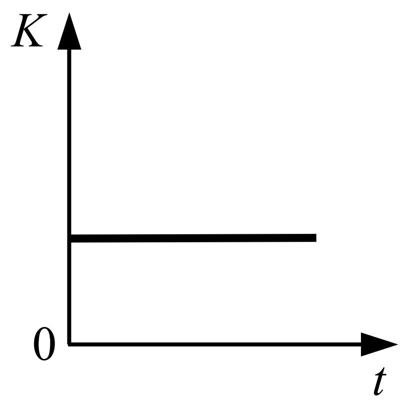
D Incorrect

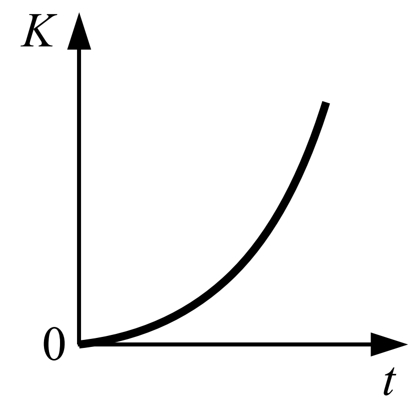
This answer is the final speed of block A after the collision.

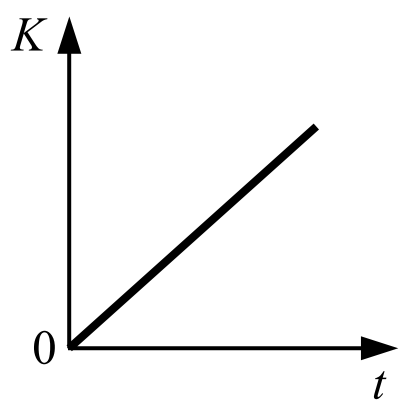
Related course pages: *4 - Conservation of Momentum & Collisions*

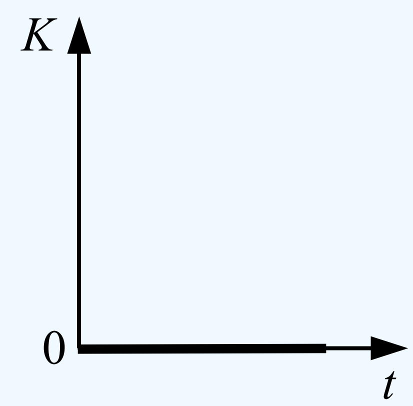


13. A block is sitting at rest on a floor when a 120 N force is exerted on the block. The coefficients of static friction and kinetic friction between the block and the floor are $\mu_s = 0.6$ and $\mu_k = 0.4$. Which of the following graphs shows the kinetic energy of the block after the 120 N force is applied?

(A)


(B)


(C)


(D)


A Incorrect

B Incorrect
This answer would be correct if the applied force was greater than the maximum static friction force. The block would accelerate and the kinetic energy is proportional to the square of the speed.

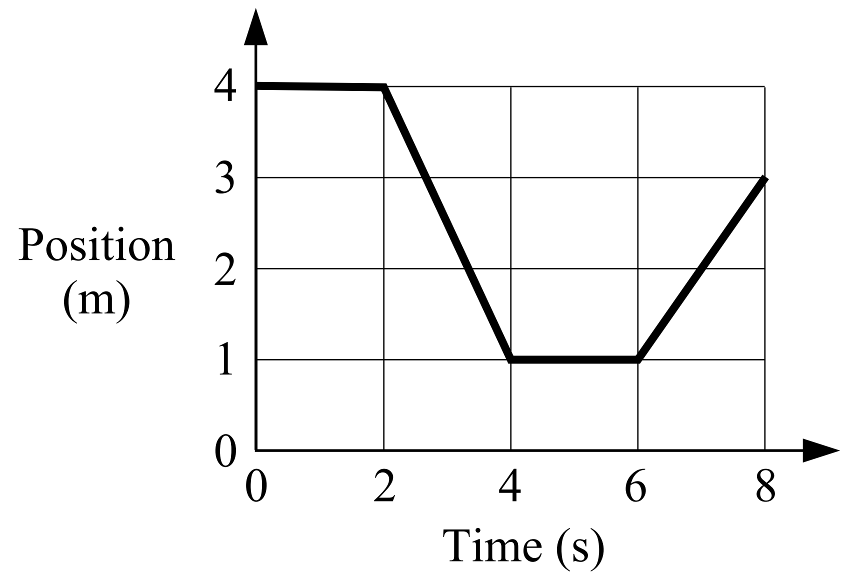
C Incorrect

D Correct
The maximum static friction force between the block and the floor is greater than the applied 120 N force so so the block remains at rest and has no kinetic energy.

$\Sigma F_y = F_n - mg = m(0\ \text{m/s}^2) \qquad F_n = mg$

$f_{s\,max} = \mu_s F_n = (0.6)(25\ \text{kg})g = 150\ \text{N}$

Related course pages: *2 - Friction, 3 - Types of Energy*



14. A cart moves on a horizontal track and its motion is shown in the graph above. Which of the following statements is true about the momentum of the cart?

(A) The magnitude of the momentum is decreasing from 2 seconds to 4 seconds

(B) The magnitude of the momentum from 0 seconds to 2 seconds is greater than it is from 4 seconds to 6 seconds

(C) The magnitude of the momentum from 2 seconds to 4 seconds is greater than it is from 6 seconds to 8 seconds

(D) The magnitude of the momentum is changing from 6 seconds to 8 seconds

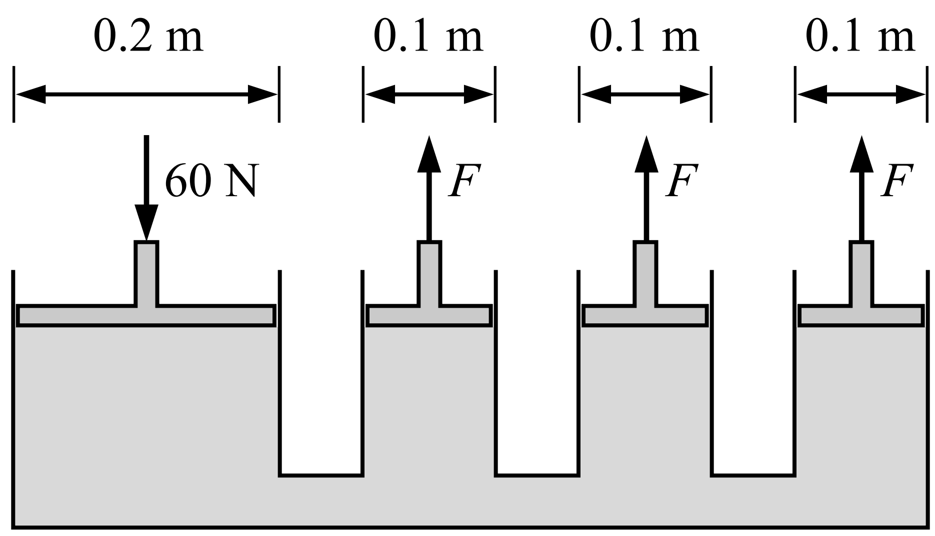
A Incorrect

B Incorrect

C **Correct**
The slope of the position-time graph is the velocity of the cart, and the momentum of the cart is the mass of the cart multiplied by the velocity. The magnitude of the slope of the graph from 2 seconds to 4 seconds is greater than the magnitude of the slope from 6 seconds to 8 seconds so the magnitude of the momentum is also greater.

D Incorrect

Related course pages: *1 - 1D Motion, 4 - Linear Momentum & Impulse*



Note: Figure not drawn to scale.

15. A series of square tubes are connected and filled with liquid as shown in the figure above. The area of each piston is a square and the side lengths of the pistons are shown. When a 60 N force is applied to the left piston, what is the magnitude of the force exerted on each of the three right pistons, F?

(A) 30 N
(B) 20 N
(C) 60 N
(D) 15 N

A Incorrect
This answer may have been found by incorrectly assuming the force on a small piston is half of the force on the large piston because the width of the small piston is half of the width of the large piston. However the forces are related by the piston areas, not the widths.

B Incorrect
This answer may have been found by incorrectly assuming the 60 N force is evenly divided among the three other pistons.

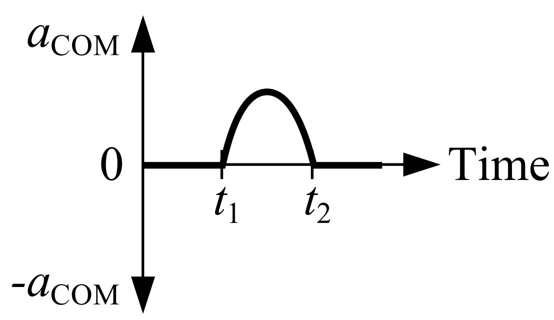
C Incorrect
This answer may have been found by incorrectly assuming the forces on each piston are the same. The pressures on each piston are the same but the forces are not the same because the piston areas are different.

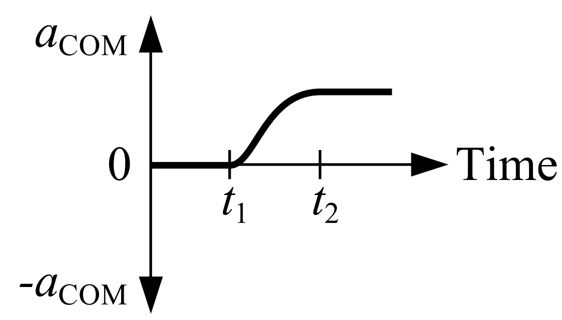
D Correct
We assume the pistons are at the same height and that the pressure exerted on each piston by the liquid is the same. The pressure acting on the left piston is equal to the pressure acting on one of the right pistons.

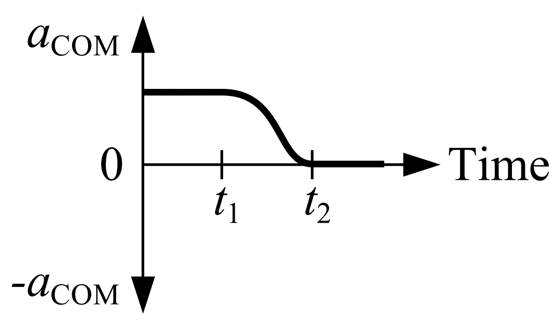
$$P_1 = P_2 \qquad \frac{F_1}{A_1} = \frac{F_2}{A_2} \qquad \frac{(60\text{ N})}{(0.2\text{ m})^2} = \frac{F}{(0.1\text{ m})^2} \qquad F = 15\text{ N}$$

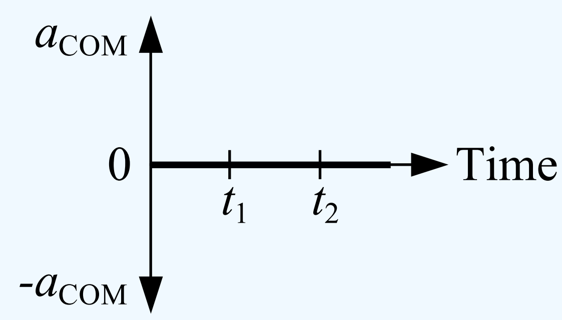
Related course pages: *8 - Pressure*

16. Two blocks are separated by a compressed spring with negligible mass and are held at rest on a frictionless surface. The blocks are released at time t_1. The spring expands and the 2 kg block loses contact with the spring at time t_2 and the spring remains attached to the 10 kg block. Which of the following shows the acceleration of the center of mass of the system of the two blocks and the spring?

(A)


(B)


(C)


(D)


A Incorrect

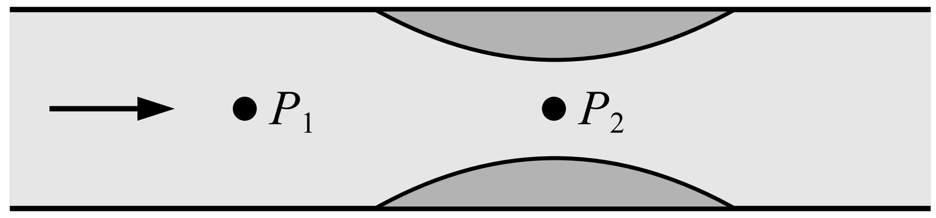
B Incorrect

C Incorrect

D Correct

The system is defined to include both blocks and the spring so the spring force that acts on each block is an internal force and not an external force. Only a net external force will cause a system's center of mass to accelerate (Newton's 1st law of motion) so this system's center of mass does not accelerate, and it remains in the same position because the system is initially at rest.

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



17. Water is flowing through a pipe as shown in the figure above. Some material has collected inside the pipe which has created a narrower opening for the fluid to flow through. How do the pressures at the two points shown compare?

(A) $P_1 = P_2$
(B) $P_1 > P_2$
(C) $P_1 < P_2$
(D) Cannot be determined

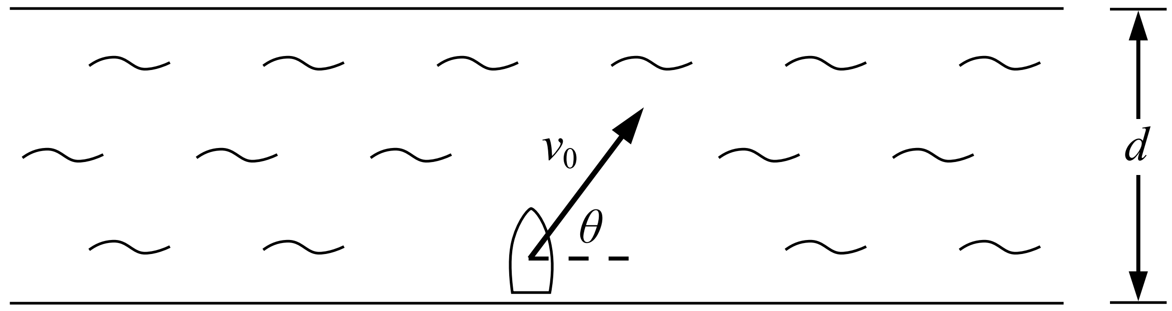
A Incorrect
This answer may have been found by incorrectly assuming the pressures are equal because they are at the same level, but this is only true if the fluid is not moving (static).

B **Correct**
The cross-sectional area of the flow is smaller at point 2 (where the blockage is) than it is at point 1. The flow rate is the same at each point (and everywhere in the pipe) so the speed of the flow must be greater at point 2.
$A_1 v_1 = A_2 v_2 \qquad A_2 < A_1 \text{ so } v_2 > v_1$
We can use Bernoulli's equation to compare the pressures at the two points. The points are at the same height so $y_1 = y_2$. If $v_1 < v_2$ then $P_1 > P_2$.
$P_1 + \rho g y_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g y_2 + \frac{1}{2}\rho v_2^2 \qquad P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$

C Incorrect

D Incorrect

Related course pages: *8 - Flow*



18. A boat crosses a river with a width of d. The boat points straight across the river and the river is flowing to the right. The resultant velocity of the boat is a constant v_0 as shown in the figure above. When the boat reaches the other side of the river, the distance that the boat moves downstream (to the right) is

(A) $\dfrac{d\sin(\theta)}{\cos(\theta)}$

(B) $\dfrac{d}{v_0\sin(\theta)}$

(C) $\dfrac{d\cos(\theta)}{\sin(\theta)}$

(D) $\dfrac{d}{v_0\cos(\theta)}$

A **Incorrect**
This answer switches the vertical and horizontal components of the velocity.

B **Incorrect**
This answer is the amount of time it takes the boat to cross the river.

C **Correct**
Using kinematics, the amount of time the boat takes to cross the river depends on the vertical component of the velocity and the width of the river. The distance the boat travels to the right depends on the time and the horizontal component of the velocity:

$$v_y = \frac{\Delta y}{\Delta t} = \frac{d}{\Delta t} \qquad \Delta t = \frac{d}{v_y} = \frac{d}{v_0\sin(\theta)}$$

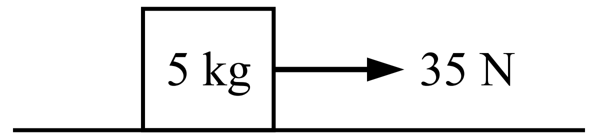
$$v_x = \frac{\Delta x}{\Delta t} \qquad \Delta x = v_x\Delta t = v_0\cos(\theta)\frac{d}{v_0\sin(\theta)} = \frac{d\cos(\theta)}{\sin(\theta)}$$

Using only trigonometry, the boat follows a straight path across the river in the direction of the velocity. The horizontal component of the displacement vector is the distance the boat travels to the right, and the vertical component is the width of the river:

$$\tan(\theta) = \frac{\Delta y}{\Delta x} = \frac{d}{\Delta x} \qquad \Delta x = d\,\frac{1}{\tan(\theta)} = d\,\frac{\cos(\theta)}{\sin(\theta)}$$

D **Incorrect**
This answer would be the amount of time it takes the boat to cross the river but incorrectly uses the horizontal component of the velocity.

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



19. A block with a mass of 5 kg is sitting at rest. The coefficient of static friction between the block and the floor is 0.5 and the coefficient of kinetic friction is 0.4. A force with a magnitude of 35 N is then applied to the block. After the force is applied, the acceleration of the block is most nearly

(A) 0 m/s²

(B) 3 m/s²

(C) 7 m/s²

(D) 2 m/s²

A Incorrect

This answer incorrectly assumes that 35 N is less than the maximum static friction force, so the friction force is static and equal to 35 N, which would mean the net horizontal force is 0 N and the acceleration is 0.

B Correct

There is a 35 N force acting on the block to the right and a friction force acting on the block to the left which opposes the direction of motion. The magnitude of the friction force needs to be found first. If 35 N is less than the maximum static friction force then the friction force is static friction and is equal to 35 N, so the net horizontal force would be 0 N and the block would remain at rest (Newton's 1st law). If 35 N is greater than the maximum static friction force then the friction force transitions to kinetic friction and the block will slide. The friction force depends on the normal force between the block and the floor, which is equal in magnitude to the weight of the block because the vertical acceleration of the block is 0 (Newton's 1st law).

$\Sigma F_y = F_n - F_g = m a_y \qquad F_n - mg = m(0) \qquad F_n = mg$

Maximum static friction force: $f_{s\,max} = \mu_s F_n = \mu_s mg = (0.5)(5\text{ kg})g = 25\text{ N}$

Kinetic friction force: $f_k = \mu_k F_n = \mu_k mg = (0.4)(5\text{ kg})g = 20\text{ N}$

The 35 N force is greater than the maximum static friction force (25 N) so the friction force is kinetic (20 N):

$\Sigma F_x = (35\text{ N}) - f_k = m a_x \qquad (35\text{ N}) - (20\text{ N}) = (5\text{ kg})a_x \qquad a_x = 3\text{ m/s}^2$

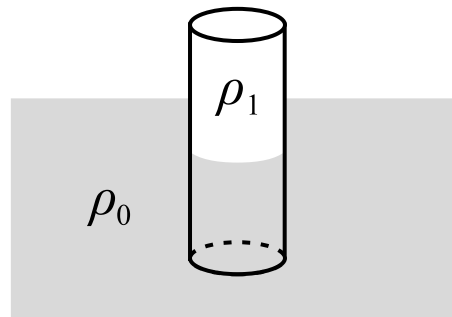
C Incorrect

This answer incorrectly assumes there is no friction force acting on the block so the net horizontal force is 35 N.

D Incorrect

This answer incorrectly assumes the friction force on the block is the maximum static friction force (25 N).

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



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

20. A solid cylinder is floating partially submerged in a liquid as shown in the figure above. The density of the liquid ρ_0 is 1,100 kg/m³ and the density of the cylinder ρ_1 is 900 kg/m³. The percent of the cylinder's volume that is below the surface of the liquid is most nearly

(A) 22%
(B) 82%
(C) 18%
(D) 90%

A Incorrect

B **Correct**
We assume the cylinder is floating at rest so the net force on the cylinder is zero (Newton's 1st law), so the upwards buoyant force is equal to the downwards weight force on the cylinder. We can replace the mass of the cylinder with its density ρ_1 multiplied by its total volume V_1. Then we can calculate the percent of the cylinder's total volume V_1 that is below the surface, V_f (the volume of fluid displaced by the cylinder).

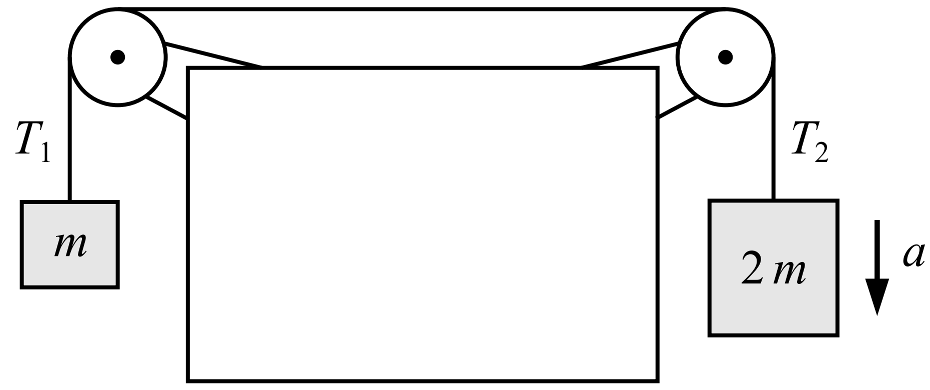
$$\Sigma F_y = F_B - F_g = 0 \qquad F_B = F_g \qquad \rho_f V_f g = mg \qquad \rho_0 V_f g = \rho_1 V_1 g$$

$$\frac{V_f}{V_1} = \frac{\rho_1}{\rho_0} = \frac{900 \text{ kg/m}^3}{1{,}100 \text{ kg/m}^3} = 0.82 = 82\%$$

C Incorrect

D Incorrect

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



21. Two blocks are connected by a string with negligible mass which passes over two pulleys with negligible mass and negligible friction as shown in the figure above. One block has twice the mass of the other block and accelerates downwards. Which of the following correctly relates the tensions in the two segments of the string?

(A) $T_1 < T_2$

(B) $T_1 > T_2$

(C) $T_1 = T_2$

(D) A comparison between the tensions cannot be determined

A Incorrect

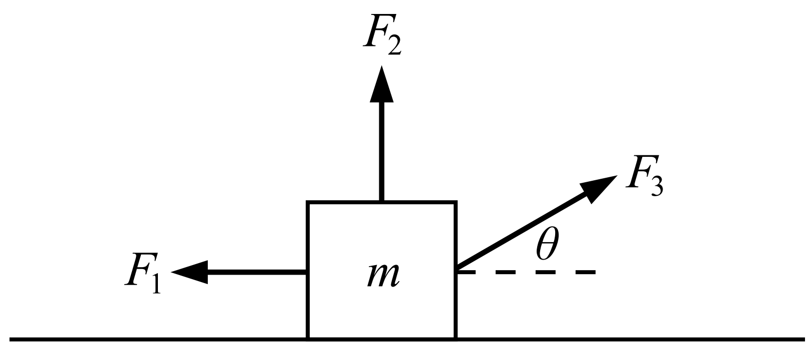
B Incorrect

C **Correct**

The pulleys have negligible mass and negligible friction so the tension is the same everywhere in the string.

D Incorrect

Related course pages: *2 - Tension & Pulley Systems*



22. Three forces are exerted on a block of mass m which is sitting on a surface with negligible friction. The block accelerates but remains in contact with the surface. Which of the following is a correct expression for the acceleration of the block?

(A) $\dfrac{F_2 + F_3 \sin(\theta) - F_1}{m}$

(B) $\dfrac{F_3 \cos(\theta) + F_1}{m}$

(C) $\dfrac{F_2 + F_3 \sin(\theta)}{m}$

(D) $\dfrac{F_3 \cos(\theta) - F_1}{m}$

A Incorrect

B Incorrect

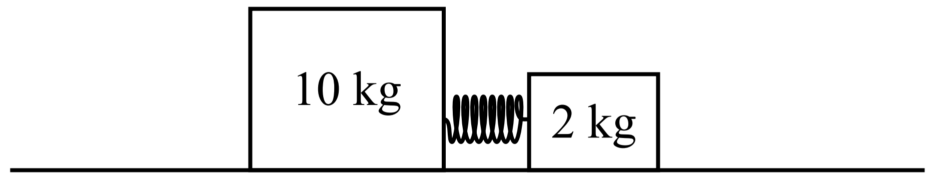
C Incorrect

D **Correct**

The block remains in contact with the surface so it does not accelerate in the vertical direction. The net force in the horizontal direction is the horizontal component of F_3 minus the force F_1. The acceleration can be found using Newton's 2nd law in the horizontal direction.

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

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



23. Two blocks are connected by a spring and are placed on a surface where the friction between the surface and the blocks is negligible. The blocks are held in place so that the spring is initially compressed. When the blocks are released, which block experiences an impulse with a greater magnitude?

(A) The 10 kg block

(B) The 2 kg block

(C) The blocks experience an impulse with the same magnitude

(D) Cannot be determined

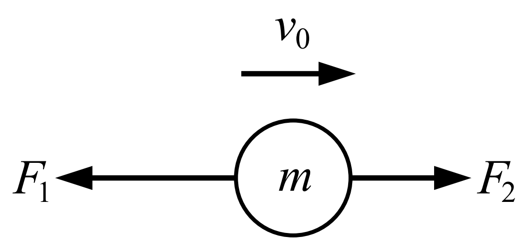
A Incorrect

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 spring force is applied to each block for the same period of time so the impulses have the same magnitude.

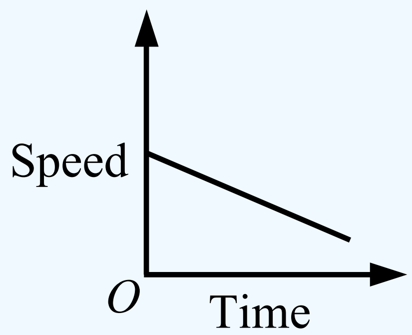
D Incorrect

Related course pages: *2 - Spring Force & Hooke's Law, 4 - Linear Momentum & Impulse*

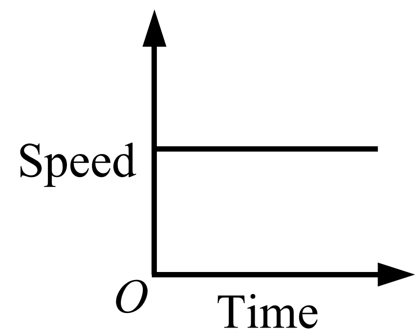


24. An object of mass m is moving with an initial speed v_0 when two forces are applied as shown in the figure above. If $F_1 > F_2$ in magnitude, which of the following graphs show the speed of the object over time?

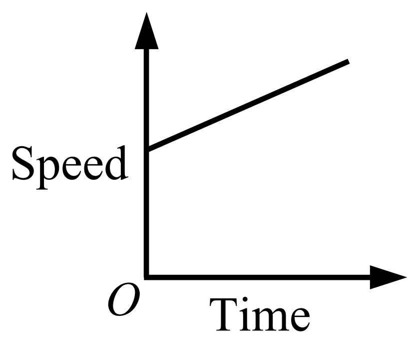
(A)



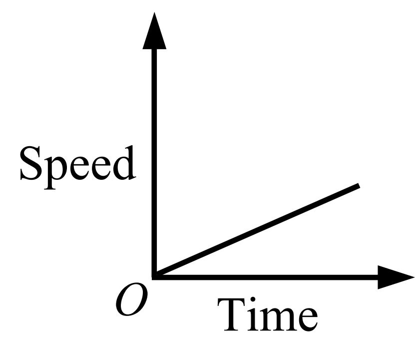
(B)



(C)



(D)



A Correct
The object has an initial speed so the graph starts at a value above the origin (above zero). If F_1 is greater than F_2 then the net force on the object is acting to the left, so the object accelerates to the left. Since the acceleration is in the opposite direction as the initial speed, the speed will decrease over time.

B Incorrect
This answer would be correct if the magnitude of F_1 and F_2 were the same and there was no acceleration.

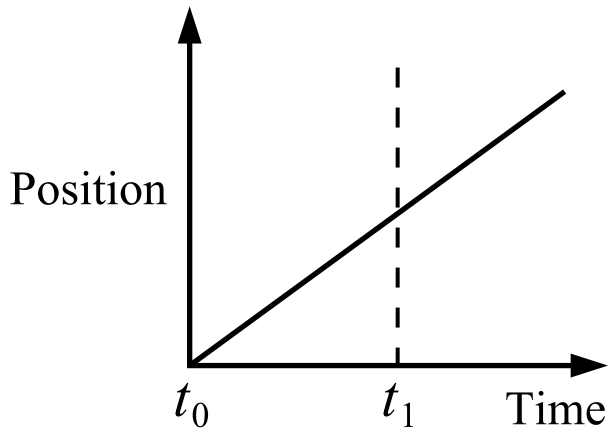
C Incorrect
This answer would be correct if the magnitude of F_2 was greater than F_1.

D Incorrect
This answer would be correct if the magnitude of F_2 was greater than F_1 and the initial speed was zero.

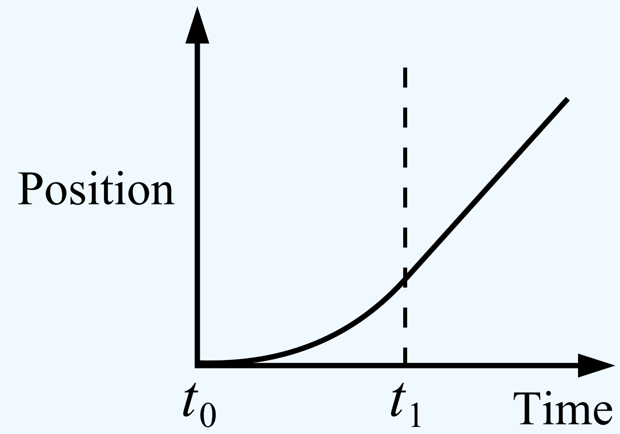
Related course pages: *1 - 1D Motion, 2 - Newton's 2nd Law*

25. A train is stopped at a station. From time t_0 to time t_1 the train accelerates and then after time t_1 the train moves at a constant speed. Which of the following graphs could represent the motion of the train?

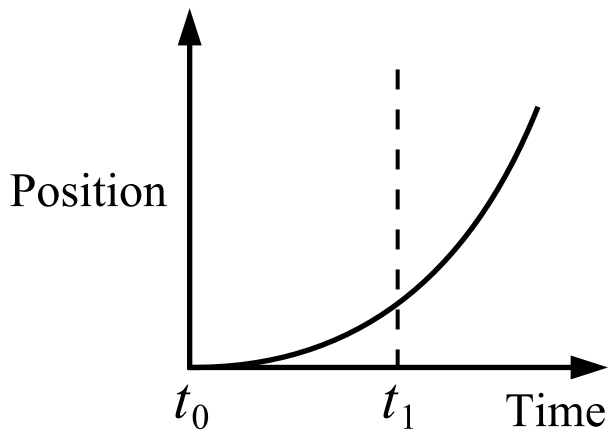
(A)



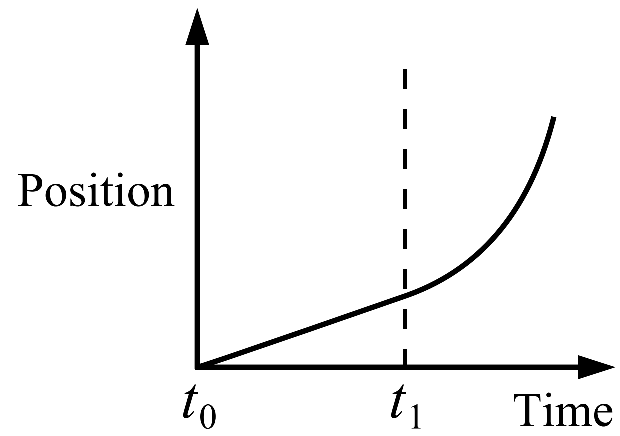
(B)



(C)



(D)



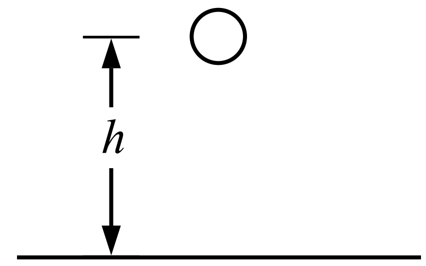
A Incorrect
This graph is a straight line with a constant slope and would represent a train that is moving at a constant speed for the entire period.

B Correct
The slope of the position-time graph represents the speed of the train. The train starts from rest so it begins with a speed of zero and the graph starts with a slope of zero. During the first period the train accelerates which is shown as a curved line with an increasing slope. During the second period the train maintains a constant speed so the line is straight and has a constant, positive slope.

C Incorrect
This graph is a curved line with an increasing slope and would represent a train that is accelerating for the entire period.

D Incorrect
This graph is a straight line with a constant slope during the first period, and a curved line with an increasing slope during the second period. This would represent a train that is moving at a constant speed during the first period and then accelerating during the second period.

Related course pages: *1 - 1D Motion*



26. A ball with a mass of m is at a height of h above the ground on a planet with a mass of M and a radius of R. Which of the following is a correct expression for the acceleration of the ball the moment it is released from that height?

(A) $\frac{GM}{R^2}$

(B) $\frac{GMm}{(R+h)^2}$

(C) $\frac{GM}{(R+h)^2}$

(D) $\frac{GMm}{R^2}$

A Incorrect
This answer incorrectly uses the radius of the planet R as the distance between the center of the ball and the center of the planet.

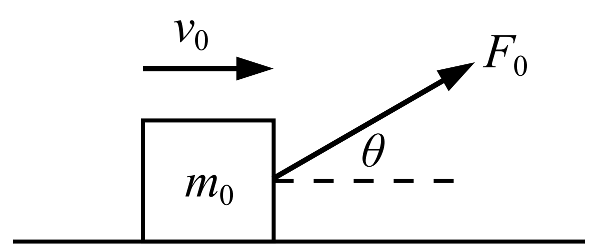
B Incorrect
This answer is the expression for the gravitational force acting on the ball from the planet.

C Correct
The ball is in projectile motion or free fall and its downwards acceleration is the acceleration due to gravity at that point, which is the same as the gravitational field stength at that point. The distance between the center of the ball and the center of the planet is the radius of the planet plus the height above the surface (ground).

$$a = g = \frac{GM}{r^2} = \frac{GM}{(R+h)^2}$$

D Incorrect
This answer would be the expression for the gravitational force acting on the ball, and it also incorrectly uses the radius of the planet R as the distance between the center of the ball and the center of the planet.

Related course pages: *2 - Gravity & Weight*



27. A block is sliding on a surface with negligible friction with a speed of v_0 when a force is applied to the block as shown in the figure above. When the block has moved a distance of d_0 it has kinetic energy K_0. If the motion was repeated with a greater value of θ and no other changes, the kinetic energy of the block after moving a distance of d_0 would be

(A) less than K_0
(B) greater than K_0
(C) equal to K_0
(D) Cannot be determined

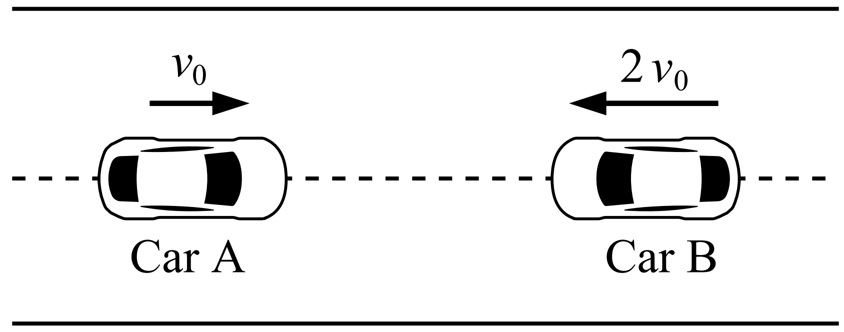
A Correct
The change in the kinetic energy of the block is equal to the work done by the applied force, which is equal to the horizontal component of the force multiplied by the distance that the block moves. If the angle is increased then the horizontal component of the applied force decreases and the work done (and the change in kinetic energy) is less than before.
$W = \Delta E = \Delta K \qquad F_0 \cos(\theta) d_0 = \Delta K$

B Incorrect

C Incorrect

D Incorrect

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



28. During a crash test, cars A and B are driven into each other head on as show in the figure above. Car A is moving at a speed of v_0 and car B is moving at a speed of $2\,v_0$. Which of the following is true during the crash?

(A) The force exerted by car A on car B has twice the magnitude as the force exerted by car B on car A

(B) The force exerted by car B on car A has twice the magnitude as the force exerted by car A on car B

(C) The force exerted by car A on car B has the same magnitude as the force exerted by car B on car A

(D) The relationship of the forces between car A and car B cannot be determined without knowing the masses

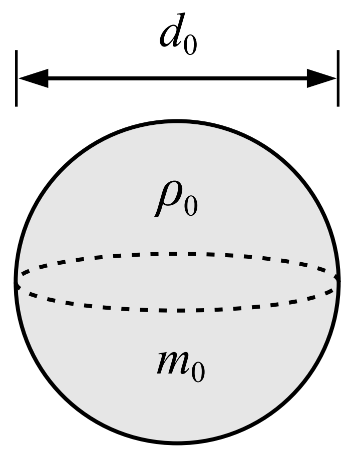
A Incorrect

B Incorrect

C **Correct**
The force exerted by object A on object B is equal in magnitude and opposite in direction to the force exerted by object B on object A according to Newton’s 3rd law of motion, regardless of the velocities and masses.

D Incorrect

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



29. A solid sphere with a diameter of d_0, a mass of m_0 and a density of ρ_0 is shown in the figure above. A second sphere with the same density and twice the diameter would have a mass of

(A) $4\,m_0$

(B) $16\,m_0$

(C) $2\,m_0$

(D) $8\,m_0$

A Incorrect

B Incorrect

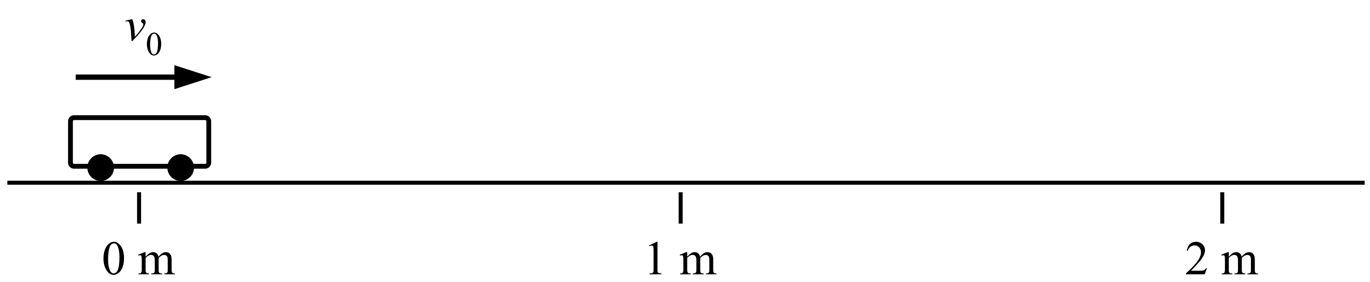
C Incorrect

D **Correct**

The equation for density and the volume of a sphere are given below. We can simplify the equation to find that the mass of the sphere is directly proportional to its diameter cubed. If the diameter of the sphere is mutliplied by 2 then the mass will be multiplied by 8.

$$\rho = \frac{m}{V} = \frac{m}{(4/3)\pi(d/2)^3} \qquad m = \rho\frac{4}{3}\pi\left(\frac{d}{2}\right)^3 \qquad m \propto d^3 \qquad 8\,m_0 \propto (2\,d_0)^3$$

Related course pages: *8 - Fluids & Density*



30. A car is placed on a track as shown in the figure above and given an initial velocity. The car passes the 1 m mark with a speed of 2 m/s and it passes the 2 m mark with a speed of 1 m/s. The acceleration of the car is most nearly

(A) 0.75 m/s²
(B) -0.75 m/s²
(C) 1.5 m/s²
(D) -1.5 m/s²

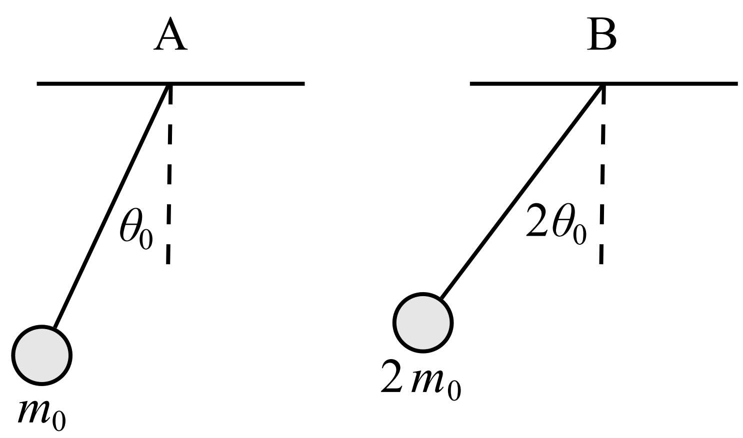
A Incorrect
This answer incorrectly uses 2 m for the displacement instead of 1 m. It also has the incorrect sign, which may result from switching the initial and final velocities.

B Incorrect
This answer incorrectly uses 2 m for the displacement instead of 1 m.

C Incorrect
This answer has the correct magnitude but the incorrect sign which may result from switching the initial and final velocities.

D Correct
The acceleration of the car between the 1 m and 2 m mark can be found using the kinematic equation below.
$v^2 = v_0^2 + 2a\Delta x \qquad (1\text{ m/s})^2 = (2\text{ m/s})^2 + 2a(2\text{ m} - 1\text{ m}) \qquad a = -1.5\text{ m/s}^2$

Related course pages: *1 - 1D Motion*



Note: Figure not drawn to scale.

31. Two spheres are attached to identical strings and released from rest at the angles shown in the figure above. Which of the following correctly relates the periods of pendulum A and pendulum B?

(A) $T_B = 4T_A$
(B) $T_B = 2T_A$
(C) $T_B = T_A$
(D) $T_B = T_A/2$

A Incorrect

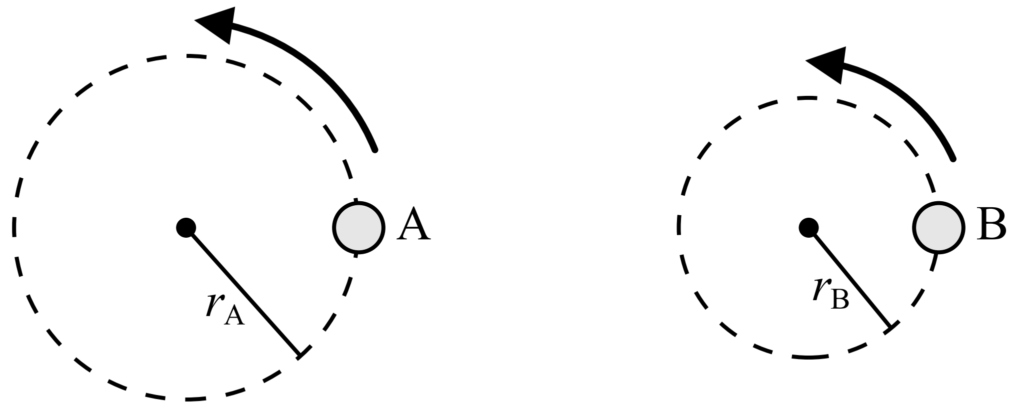
B Incorrect

C **Correct**
The period of a pendulum depends on the length of the pendulum and the acceleration due to gravity g. The pendulums have identical strings with the same length so the pendulums have the same period. The period does not depend on the mass or the amplitude (maximum height or angle).

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

D Incorrect

Related course pages: *7 - Simple Harmonic Motion*



32. Two objects are in uniform circular motion. Object A follows a circular path with radius r_A and object B follows a circular path with a radius of $r_B < r_A$. If the period of each object's circular motion is the same, the magnitude of the acceleration of object B is

(A) less than the magnitude of the acceleration of object A

(B) greater than the magnitude of the acceleration of object A

(C) equal to the magnitude of the acceleration of object A

(D) a comparison between the acceleration of object A and object B cannot be determined

A **Correct**

The objects are in uniform circular motion so they move with a constant speed. The acceleration of each object is the centripetal acceleration which points towards the center of the circle. The centripetal acceleration is related to the radius, speed and period using the equations below (the variable for speed can be replaced with a term that includes the period). The objects have the same period and object B moves in a circle with a smaller radius so object B has a smaller centripetal acceleration than object A.

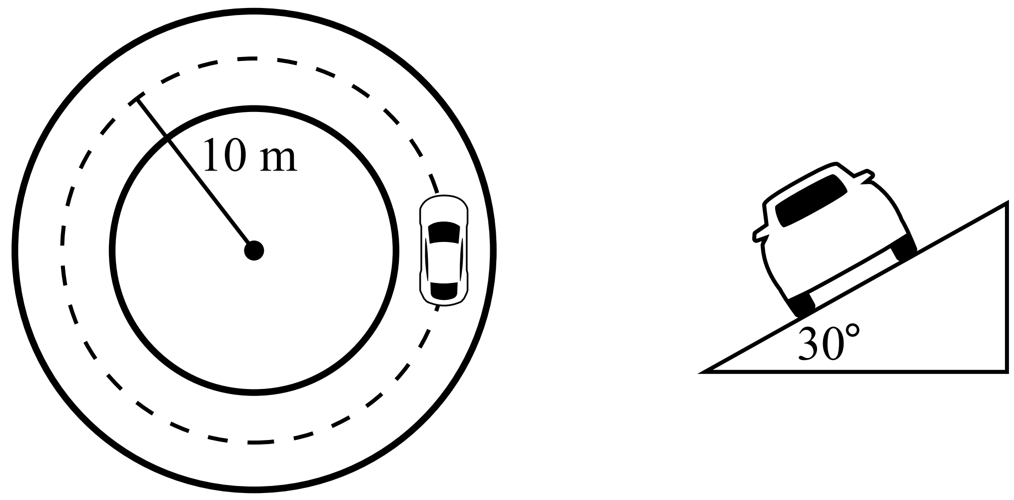
$$a_c = \frac{v^2}{r} = \left(\frac{2\pi}{T}\right)^2 r$$

B Incorrect

C Incorrect

D Incorrect

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



Top view Side view

33. A car is driving around a banked circular track at a constant speed as shown in the figure above. The track is inclined at an angle of 30° with the ground and the radius of the circular path of the car is 10 m. The track is covered in ice and the friction between the tires and the inclined track is negligible, but the car does not slide up or down the incline. The speed of the car is most nearly

(A) 10.0 m/s

(B) 13.2 m/s

(C) 7.6 m/s

(D) 7.1 m/s

A **Incorrect**

This answer incorrectly uses $\sin(30°)$ or $\cos(30°)$ for both components of the normal force.

B **Incorrect**

This answer incorrectly uses $\sin(30°)$ for the vertical component of the normal force and $\cos(30°)$ for the horizontal component of the normal force.

C **Correct**

There is a weight force on the car which acts vertically downwards and a normal force on the car which acts perpendicular to the surface of the incline. The car is moving in uniform circular motion so the net force acting on the car (the centripetal force) always points towards the center of the circle. From the side view, this centripetal force acts horizontally to the left. The weight force only acts in the vertical direction, so the centripetal force is the horizontal component of the normal force on the car. The car does not move or accelerate vertically so the net force in the vertical direction is zero.

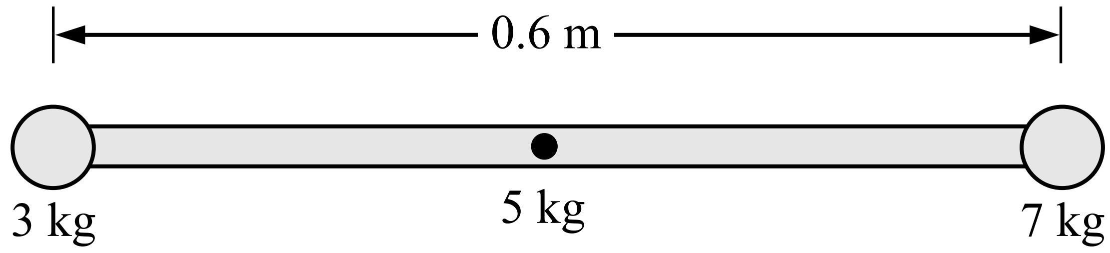
$$\Sigma F_y = F_n \cos(30°) - mg = m(0\text{ m/s}^2) \qquad F_n = \frac{mg}{\cos(30°)}$$

$$\Sigma F_x = F_n \sin(30°) = \frac{mv^2}{r} \qquad \frac{mg}{\cos(30°)}\sin(30°) = \frac{mv^2}{r} \qquad \frac{g\ \sin(30°)}{\cos(30°)} = \frac{v^2}{(10\text{ m})} \qquad v = 7.6\text{ m/s}$$

D **Incorrect**

This answer incorrectly assumes the centripetal force is equal to the component of the weight force which acts parallel to the incline, $mg\sin(30°)$.

Related course pages: *2 - Newton's 2nd Law, 2 - Centripetal Acceleration and Force*



34. A 3 kg sphere and a 7 kg sphere are attached to the ends of a 5 kg rod which is free to rotate about an axle passing through its center. When the rod is horizontal as shown in the figure above, the magnitude of the net torque on the rod about the axle is most nearly

(A) 60 N·m
(B) 12 N·m
(C) 30 N·m
(D) 90 N·m

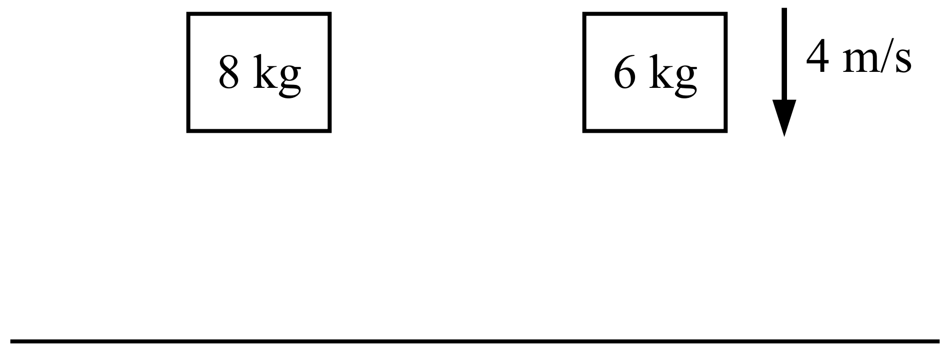
A Incorrect
This answer incorrectly adds each torque and includes a torque from the rod as $\tau = (0.6\ \text{m})(5\ \text{kg})g$.

B Correct
The net torque acting on the rod about the axle is the sum of the torques produced by the weight forces on the spheres and the rod. Each weight force acts vertically downwards at the center of mass of each object. The torque produced by the rod's weight force is zero because the force acts directly at the point of rotation. The torques produced by each sphere act in opposite directions. Using counterclockwise as positive:
$\Sigma\tau = \tau_3 + \tau_5 - \tau_7 = (0.3\ \text{m})(3\ \text{kg})g + (0\ \text{m})(5\ \text{kg})g - (0.3\ \text{m})(7\ \text{kg})g = \text{-}12\ \text{N}\cdot\text{m}$ (magnitude is positive)

C Incorrect
This answer incorrectly adds the torques from each sphere. The torques act in opposite directions so one must be negative.

D Incorrect
This answer incorrectly adds the torques as $\Sigma\tau = (0.6\ \text{m})(3\ \text{kg} + 5\ \text{kg} + 7\ \text{kg})g$.

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



35. An 8 kg block is dropped from rest at the same time that a 6 kg block is falling at a speed of 4 m/s. Which of the two blocks has a greater momentum 2 seconds later (assuming the blocks are still falling)?

(A) The 6 kg block
(B) The 8 kg block
(C) The blocks will have the same momentum
(D) Cannot be determined

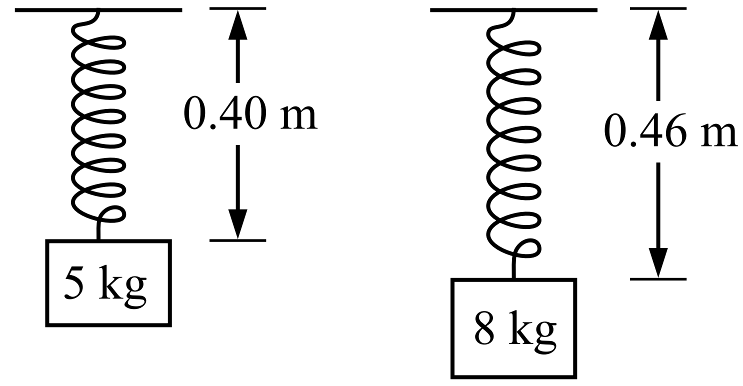
A Incorrect

B **Correct**
The momentum of each block is equal to its mass multiplied by its velocity. The velocity of each block 2 seconds later can be found using kinematics:
8 kg block: $v_f = v_i + a\Delta t = (0 \text{ m/s}) + g(2 \text{ s}) = 20 \text{ m/s}$ $\quad p = mv = (8 \text{ kg})(20 \text{ m/s}) = 160 \text{ kg·m/s}$
6 kg block: $v_f = v_i + a\Delta t = (4 \text{ m/s}) + g(2 \text{ s}) = 24 \text{ m/s}$ $\quad p = mv = (6 \text{ kg})(24 \text{ m/s}) = 144 \text{ kg·m/s}$
We can also find the change in momentum (impulse) of each block during the 2 second period due to the gravitational force and add that to the initial momentum:
8 kg block: $\Delta p = F\Delta t \quad p_f - p_i = mg\Delta t \quad p_f - (8 \text{ kg})(0 \text{ m/s}) = (8 \text{ kg})g(2 \text{ s}) \quad p_f = 160 \text{ kg·m/s}$
6 kg block: $\Delta p = F\Delta t \quad p_f - p_i = mg\Delta t \quad p_f - (6 \text{ kg})(4 \text{ m/s}) = (6 \text{ kg})g(2 \text{ s}) \quad p_f = 144 \text{ kg·m/s}$

C Incorrect

D Incorrect

Related course pages: *1 - 1D Motion, 4 - Linear Momentum & Impulse*



36. A 5 kg block is suspended from a spring attached to the ceiling. When the block is at rest the spring is 0.40 m long. The 5 kg block is removed and replaced with an 8 kg block. When the new block is at rest the spring is 0.46 m long. The spring constant of the spring is most nearly

(A) 125 N/m

(B) 1333 N/m

(C) 174 N/m

(D) 500 N/m

A **Incorrect**

This answer incorrectly solves for the spring constant using only the 5 kg block and 0.40 m for Δx.

B **Incorrect**

This answer incorrectly solves for the spring constant using the 8 kg block and 0.06 m for Δx.

C **Incorrect**

This answer incorrectly solves for the spring constant using only the 8 kg block and 0.46 m for Δx.

D **Correct**

When the blocks are at rest the net vertical force on each block is zero (Newton's 1st law) so the upwards spring force is equal in magnitude to the downwards weight force on the block. The spring force is equal to the spring constant multiplied by the change in length of the spring from its original unstretched length (which is not known). A system of two equations and two unknowns (the spring constant k and the original length of the spring L_0) can be set up and solved using substitution.

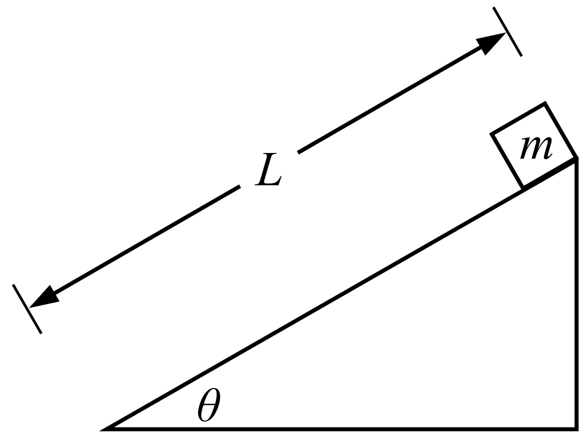
Each block: $\Sigma F_y = m a_y \qquad F_{sp} - F_g = m(0) \qquad F_{sp} = F_g \qquad k\Delta x = mg$

5 kg block: $k\Delta x = (5\text{ kg})g \qquad k(0.40\text{ m} - L_0) = (5\text{ kg})g \qquad L_0 = 0.40\text{ m} - \dfrac{(5\text{ kg})g}{k}$

8 kg block: $k\Delta x = (8\text{ kg})g \qquad k(0.46\text{ m} - L_0) = (8\text{ kg})g \qquad k\left(0.46\text{ m} - \left(0.40\text{ m} - \dfrac{(5\text{ kg})g}{k}\right)\right) = (8\text{ kg})g$

$k = 500\text{ N/m}$

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



37. A small block of mass m starts at rest at the top of an incline with a length of L. The block slides down the incline and the coefficient of kinetic friction between the block and the incline is μ_k. Which of the following is a correct expression for the speed of the block at the bottom of the incline?

(A) $\sqrt{2gL\sin(\theta) - 2gL\mu_k\cos(\theta)}$

(B) $mgL\sin(\theta) - mgL\mu_k\cos(\theta)$

(C) $\sqrt{2gL\sin(\theta)}$

(D) $mgL\sin(\theta)$

A Correct

The change in the total energy of the block-earth system between the times when the block is at the top and the bottom of the incline is equal to the work done on the block by the friction force from the incline. The block has no kinetic energy at the top of the incline and we can establish the reference height for zero gravitational potential energy at the bottom of the incline. The work done by the friction force is negative.

$E_f - E_i = W \qquad K_f - U_{gi} = -f_k L \qquad \frac{1}{2}mv_f^2 - mgL\sin(\theta)(\mu_k mg\cos(\theta))L$

$v_f = \sqrt{2gL\sin(\theta) - 2gL\mu_k\cos(\theta)}$

B Incorrect

This answer is the kinetic energy of the block at the bottom of the incline.

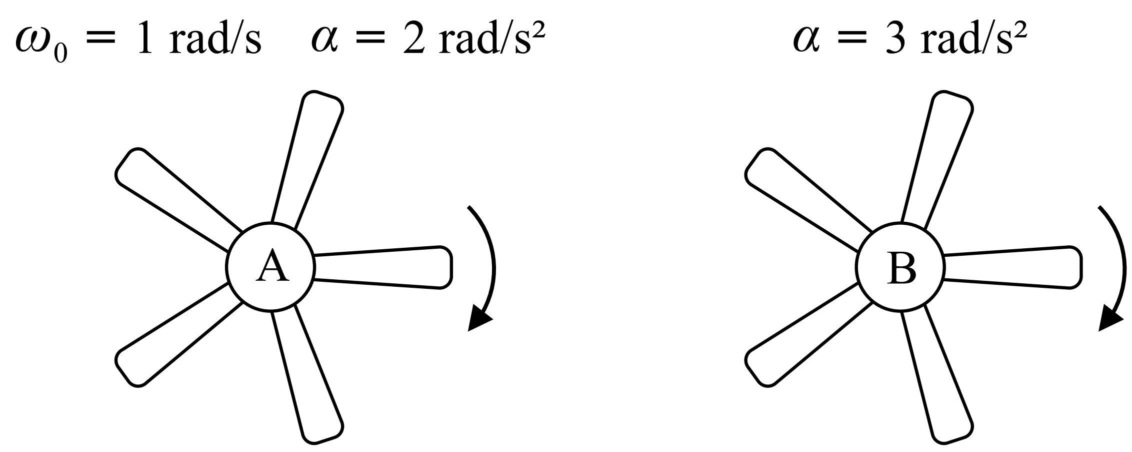
C Incorrect

This answer would be the final speed of the block if there was no friction force doing work on the block.

D Incorrect

This answer is the gravitational potential energy of the block-earth system when the block is at the top of the incline.

Related course pages: *2 - Friction, 3 - Conservation of Energy, Work & Power*



38. Two ceiling fans are shown in the figure above. At time t_0, fan A is spinning at 1 rad/s and begins accelerating at 2 rad/s², while fan B starts from rest and accelerates at 3 rad/s². What is the relationship between the angular speed of the fans after a period of 5 seconds?

(A) $\omega_A < \omega_B$

(B) $\omega_A > \omega_B$

(C) $\omega_A = \omega_B$

(D) Cannot be determined

A Correct

Fan A: $\omega = \omega_0 + \alpha t = (1 \text{ rad/s}) + (2 \text{ rad/s}^2)(5 \text{ s}) = 11 \text{ rad/s}$

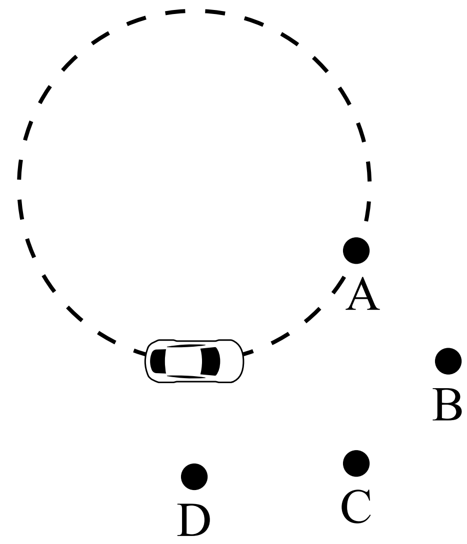
Fan B: $\omega = \omega_0 + \alpha t = (0 \text{ rad/s}) + (3 \text{ rad/s}^2)(5 \text{ s}) = 15 \text{ rad/s}$

B Incorrect

C Incorrect

D Incorrect

Related course pages: *5 - Rotational Motion*



39. A car is driving around in a counterclockwise circle at a constant speed as shown in the figure above. The car is driving on ice but the friction between the tires and the ice is great enough for the car to drive in the circle. When the car is in the position shown the tires slip. If the friction force on the tires is assumed to be zero after that moment, which of the points shows the position of the car a period of time later?

(A) Point A

(B) Point B

(C) Point C

(D) Point D

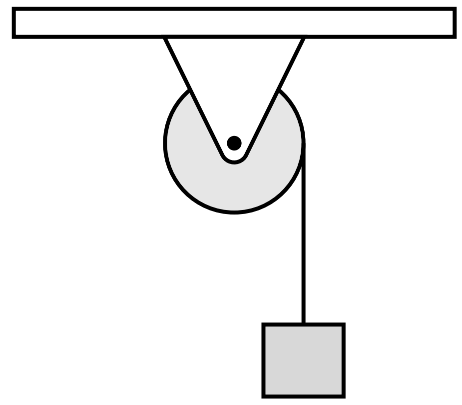
A Incorrect

B **Correct**
The car is in uniform circular motion and the velocity of the car is always tangent to the circular path. When the friction force is removed, there are no horizontal forces acting on the car (parallel to the ground) so the car will move with a constant velocity (Newton's 1st law of motion). At the position shown, the velocity of the car is tangent to the circle and points directly to the right, so the car will move in a straight line that passes through point B.

C Incorrect

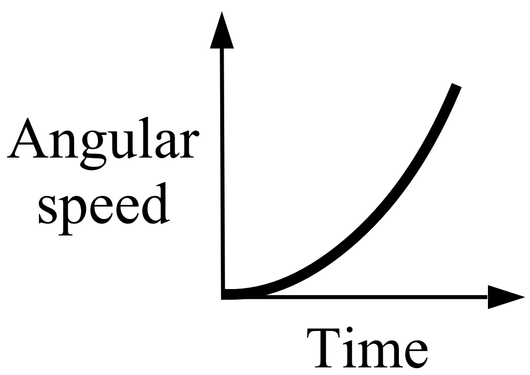
D Incorrect

Related course pages: *2 - Newton's 1st Law & Forces, 2 - Centripetal Acceleration and Force*

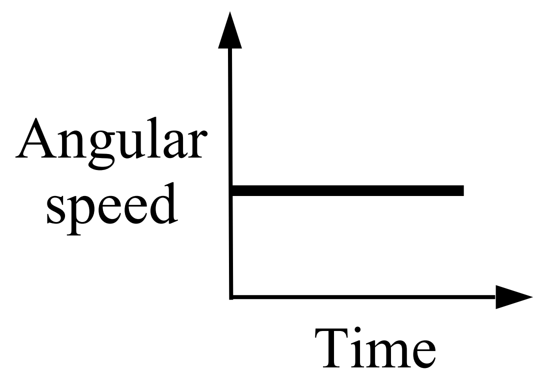


40. A block is hanging from a string which is wrapped around the outside of a pulley as shown in the figure above. The mass of the pulley and the block is not negligible, but the friction on the pulley's axle is negligible. The pulley and block are released from rest. Which of the following graphs shows the motion of the pulley?

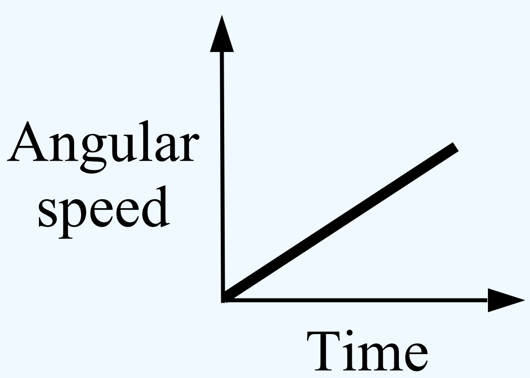
(A)



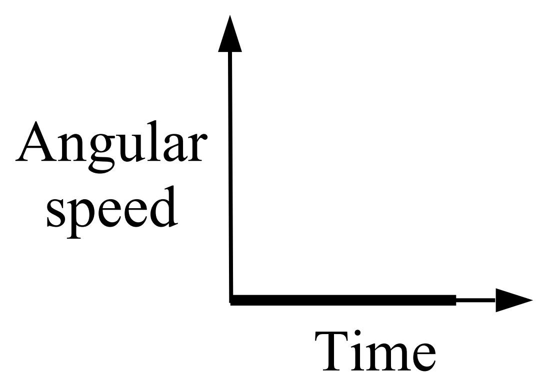
(B)



(C)



(D)



A **Incorrect**
This would be a graph of the angular position or displacement of the wheel vs time.

B **Incorrect**

C **Correct**
The tension in the string from the weight of the block produces a constant torque on the pulley about its center. A net torque causes an object to rotate with a constant angular acceleration, $\tau_{net} = I\alpha$. Angular acceleration is the change in angular velocity divided by time, $\alpha = \Delta\omega/\Delta t$, so a graph of the angular speed is a straight line with a constant positive slope (which is the angular acceleration).

D **Incorrect**

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