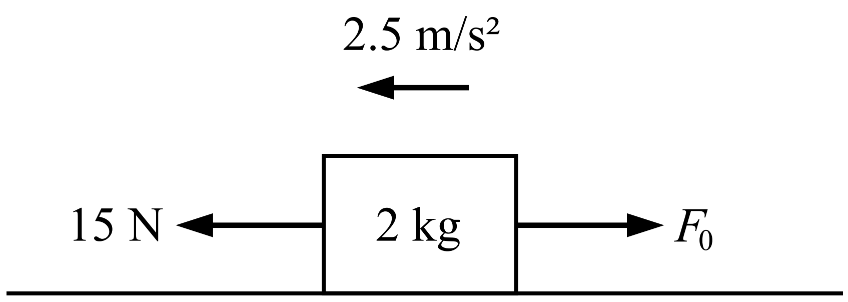
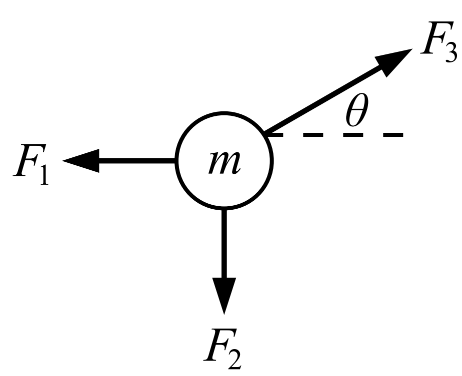
NEWTON'S 2ND LAW OF MOTION



Note: Figure not drawn to scale.

1. A 2 kg block slides along a frictionless surface as shown in the figure above with an acceleration of 2.5 m/s². Two horizontal forces are acting on the block. What is the magnitude of force F_0 ?

   (A) 20 N
   (B) 10 N
   (C) 15 N
   (D) 5 N



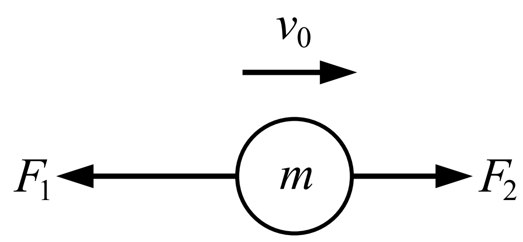
2. Three forces of magnitudes F_1 , F_2 and F_3 are acting on an object of mass m as shown in the figure above. Which of the following represents the magnitude of the object's acceleration?

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

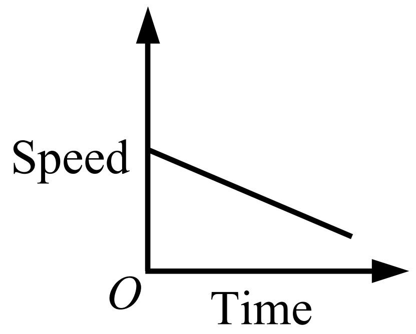
   (C) $\sqrt{\left(\frac{F_3\cos\theta - F_1}{m}\right)^2 + \left(\frac{F_3\sin\theta - F_2}{m}\right)^2}$

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

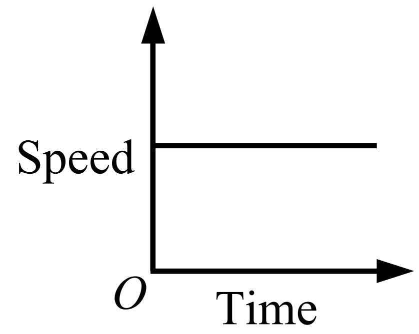


3. An object of mass m is moving with an initial speed v_0 when two forces are applied as shown in the figure above. If $F_1 > F_2$ in magnitude, which of the following graphs show the speed of the object over time?

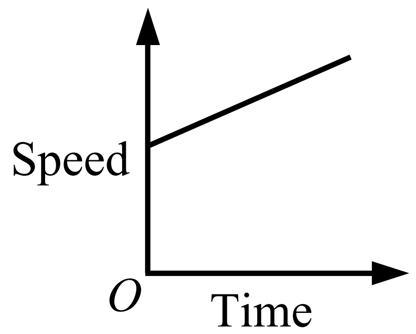
(A)



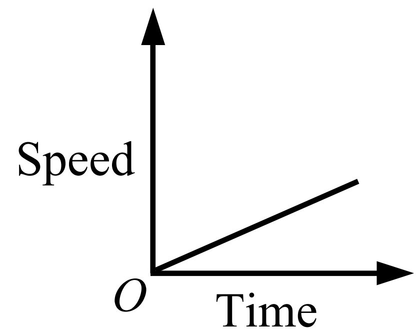
(B)

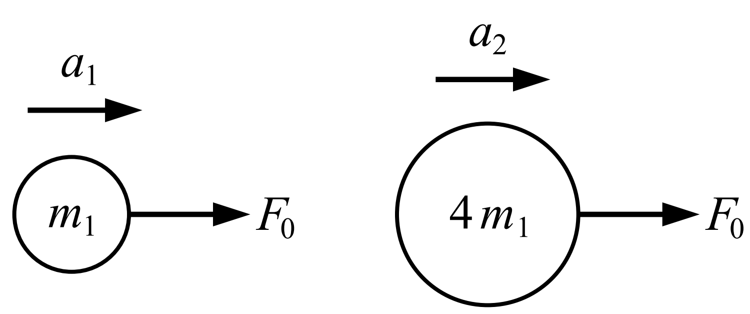


(C)



(D)





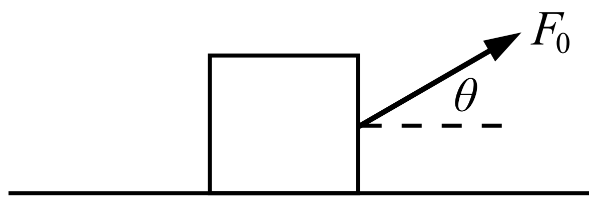
4. A force with a magnitude of F_0 acts on an object with a mass of m_1, causing it to move with an acceleration of a_1. The same force is applied to an object with a mass of $4m_1$, causing it to move with an acceleration of a_2. Which of the following is the correct expression for a_2 in terms of a_1?

(A) a_1

(B) $4a_1$

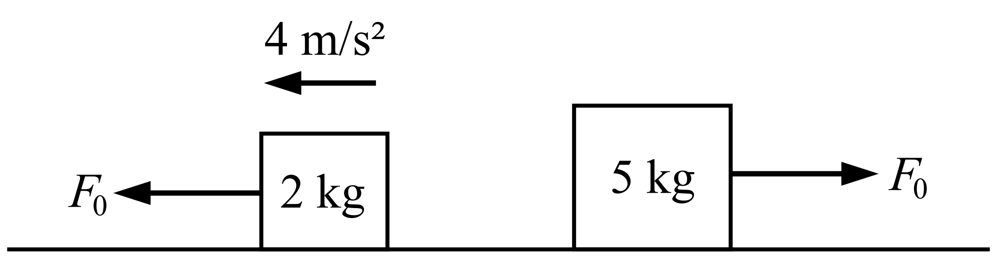
(C) $\frac{a_1}{16}$

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



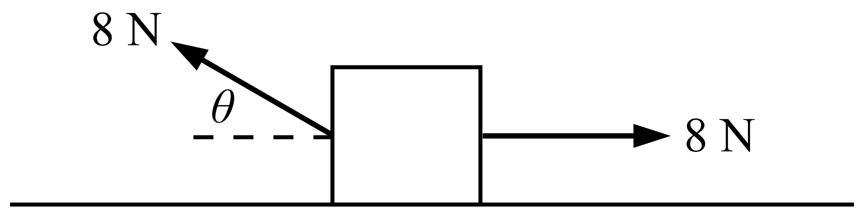
5. A force with a magnitude of F_0 is exerted on a block as shown in the figure above. There is a friction force between the block and the floor with a magnitude of f. If the block remains in contact with the floor, the net force acting on block is

(A) $F_0 \cos(\theta) + f$
(B) $F_0 \sin(\theta) - mg$
(C) $F_0 - f$
(D) $F_0 \cos(\theta) - f$

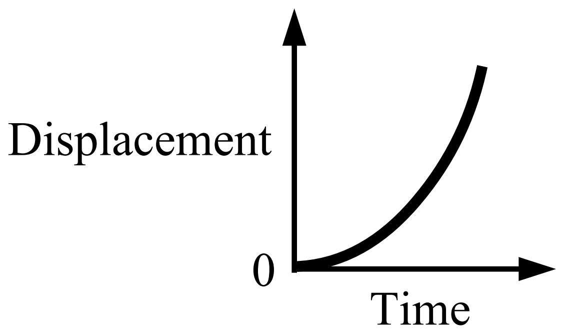


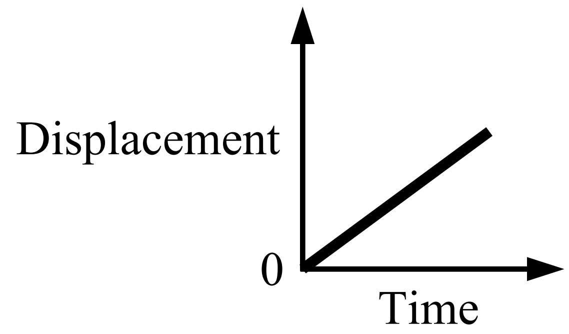
6. Two blocks are on a surface with negligible friction. A force with a magnitude of F_0 is applied to the 2 kg block and it accelerates at 4 m/s². A force with the same magnitude of F_0 is applied to the 5 kg block. If the block starts at rest, what is the speed of the 5 kg block after 2 seconds?

(A) 1.6 m/s
(B) 3.2 m/s
(C) 4.0 m/s
(D) 8.0 m/s



7. A block is sitting at rest on a surface with negligible friction when two forces are applied to the block as shown in the figure above. If the block remains in contact with the surface, which of the following graphs shows the motion of the block starting when the forces are applied?

(A)


(B)


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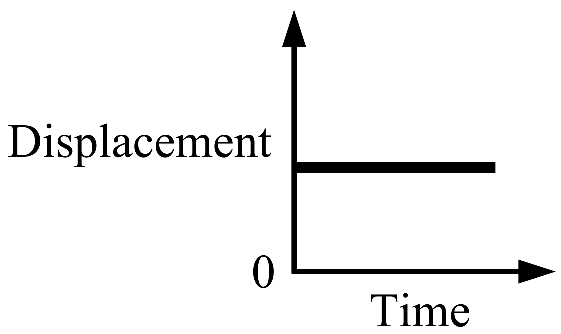
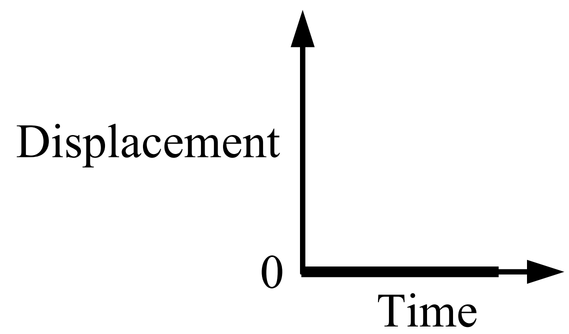
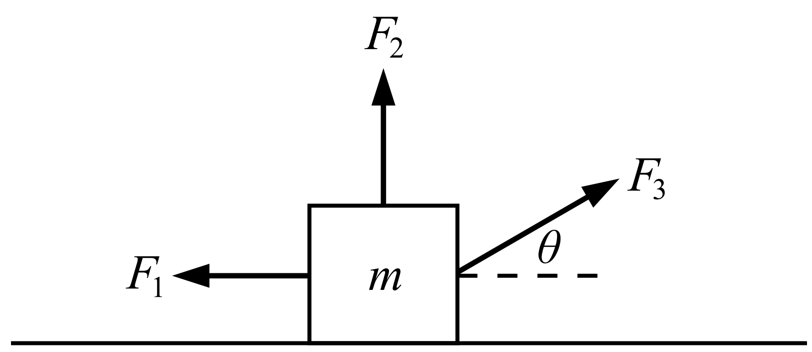


(D)




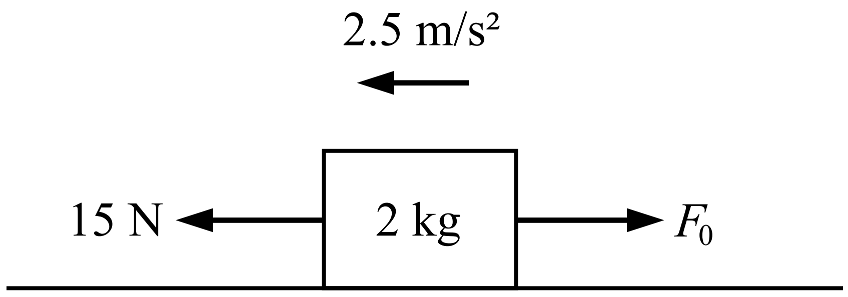
8. Three forces are exerted on a block of mass m which is sitting on a surface with negligible friction. The block accelerates but remains in contact with the surface. Which of the following is a correct expression for the acceleration of the block?

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



Note: Figure not drawn to scale.

1. A 2 kg block slides along a frictionless surface as shown in the figure above with an acceleration of 2.5 m/s². Two horizontal forces are acting on the block. What is the magnitude of force F_0 ?

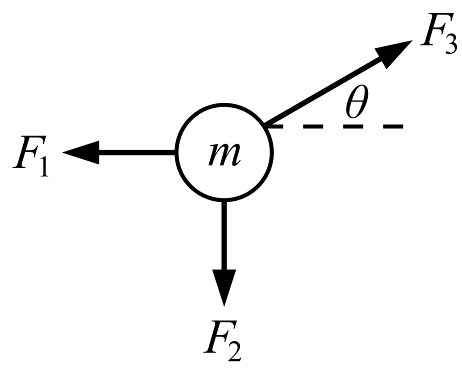
(A) 20 N
(B) 10 N
(C) 15 N
(D) 5 N

A Incorrect
This answer incorrectly switches some of the positive and negative values, such as treating the 15 N force as negative and the acceleration as positive:
$F_0 - 15\text{ N} = (2\text{ kg})(2.5\text{ m/s}^2)$ $\quad F_0 = 20\text{ N}$

B **Correct**
Newton's 2nd law of motion can be used to relate the forces, the mass and the acceleration in the horizontal direction to solve for F_0. If we say left is the positive direction:
$\Sigma F = ma$ $\quad 15\text{ N} - F_0 = (2\text{ kg})(2.5\text{ m/s}^2)$ $\quad F_0 = 10\text{ N}$

C Incorrect
This answer incorrectly assumes that F_0 has the same magnitude as the 15 N force.

D Incorrect
This answer incorrectly multiplies the mass and the acceleration and assumes that should be the magnitude of the force F_0:
$(2\text{ kg})(2.5\text{ m/s}^2) = 5\text{ N}$



2. 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.

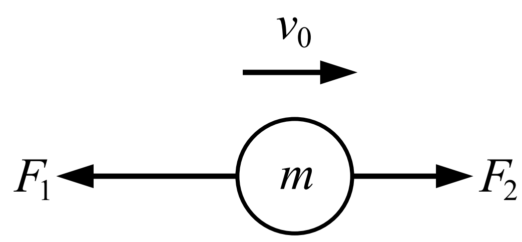
C **Correct**
The horizontal and vertical components of the acceleration vector can be found by applying Newton's 2nd law of motion to each direction. Then the magnitude of the acceleration vector can be found by using the Pythagorean theorem:

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

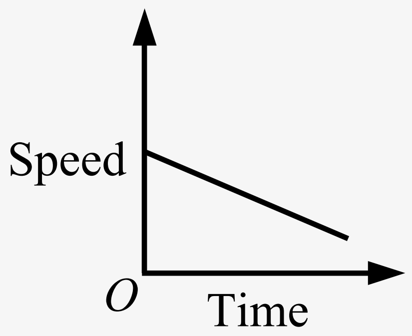
$$\Sigma F_y = m a_y \qquad F_3\sin\theta - F_2 = m a_y \qquad a_y = \frac{F_3\sin\theta - F_2}{m}$$

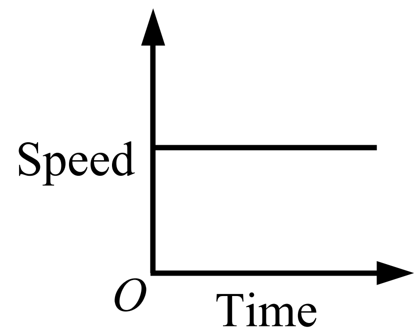
$$a = \sqrt{a_x^2 + a_y^2} = \sqrt{\left(\frac{F_3\cos\theta - F_1}{m}\right)^2 + \left(\frac{F_3\sin\theta - F_2}{m}\right)^2}$$

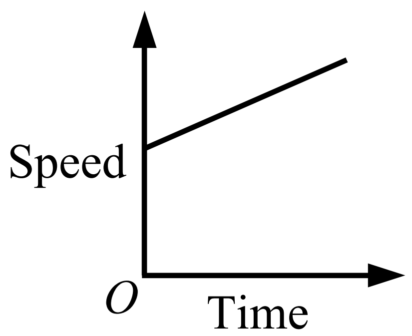
D Incorrect
This answer correctly finds the horizontal and vertical components of the acceleration vector but incorrectly adds their magnitudes instead of adding them as vector components using the Pythagorean theorem.

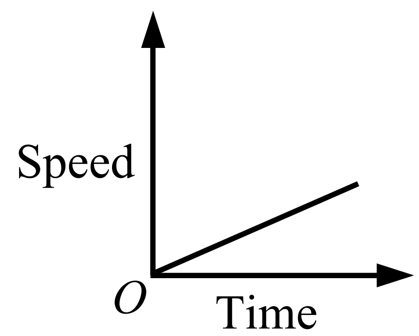


3. An object of mass m is moving with an initial speed v_0 when two forces are applied as shown in the figure above. If $F_1 > F_2$ in magnitude, which of the following graphs show the speed of the object over time?

(A)


(B)


(C)


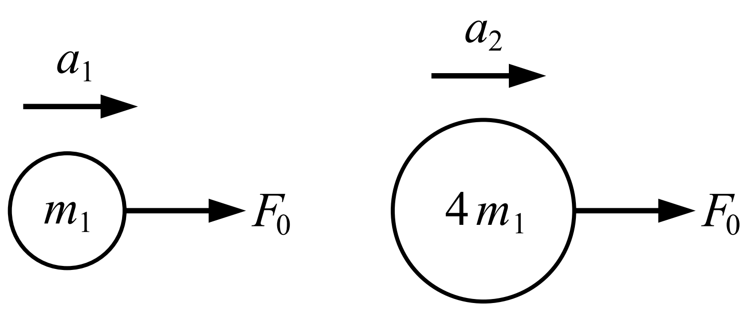
(D)


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.



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

(A) a_1

(B) $4a_1$

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

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

A Incorrect

This answer incorrectly assumes the acceleration is the same if the force is the same.

B Incorrect

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

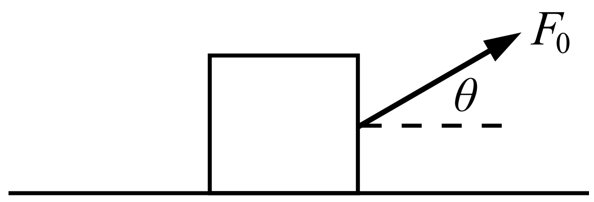
C Incorrect

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

D Correct

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

$F_0 = m_1 a_1$ and $F_0 = 4m_1 a_2$, so $m_1 a_1 = 4m_1 a_2$ and $a_1/4 = a_2$



5. 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

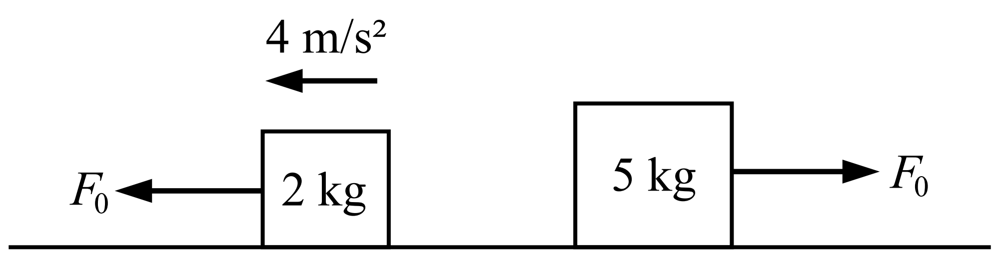
This answer includes the full magnitude of the applied force F_0, but the horizontal and vertical components should be used to determine the net force in the horizontal and vertical directions (and the net force in the vertical direction is zero).

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).

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

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



6. 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?

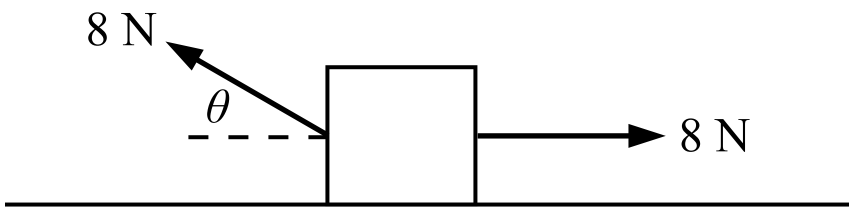
(A) 1.6 m/s
(B) 3.2 m/s
(C) 4.0 m/s
(D) 8.0 m/s

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: $\Sigma F = ma$ $\quad 8\text{ N} = (5\text{ kg})a \quad a = 1.6\text{ m/s}^2$
$v_f = v_0 + at = (0\text{ m/s}) + (1.6\text{ m/s}^2)(2\text{ s}) = 3.2\text{ m/s}$

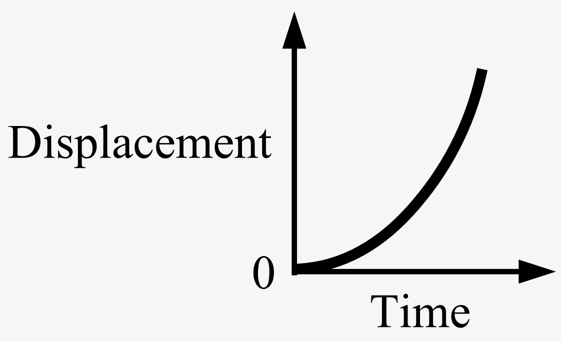
C Incorrect
This answer is the acceleration of the 2 kg block (4 m/s²) with the unit of m/s.

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

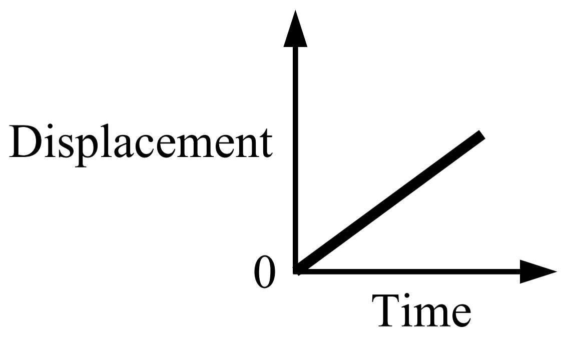


7. A block is sitting at rest on a surface with negligible friction when two forces are applied to the block as shown in the figure above. If the block remains in contact with the surface, which of the following graphs shows the motion of the block starting when the forces are applied?

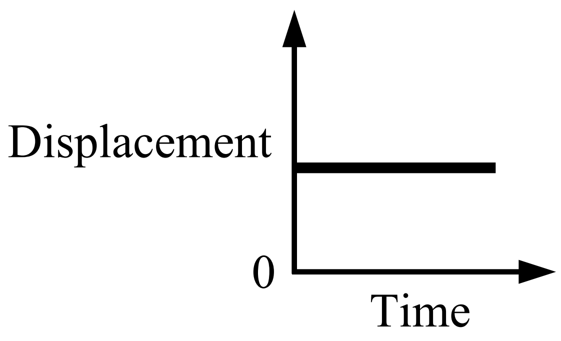
(A)



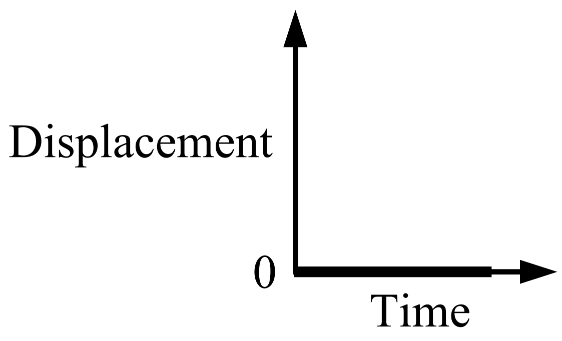
(B)



(C)



(D)



A Correct

The block remains in contact with the surface (it does not accelerate in the vertical direction) so the net force in the vertical direction is zero (Newton’s 1st law). The net force in the horizontal direction is the 8 N force to the right minus the horizontal component of the 8 N force to the left. The left force acts at an angle so the horizontal component (the leftwards force) must be less than 8 N, so there is a net horizontal force to the right. If a net force acts on an object, the object will accelerate (Newton's 1st law) and the position-time graph or the displacement-time graph is a curved line (the slope is changing because the velocity is changing).

$\Sigma F_x = m a_x \qquad (8\text{ N}) - (8\text{ N})\cos(\theta) = m a_x$

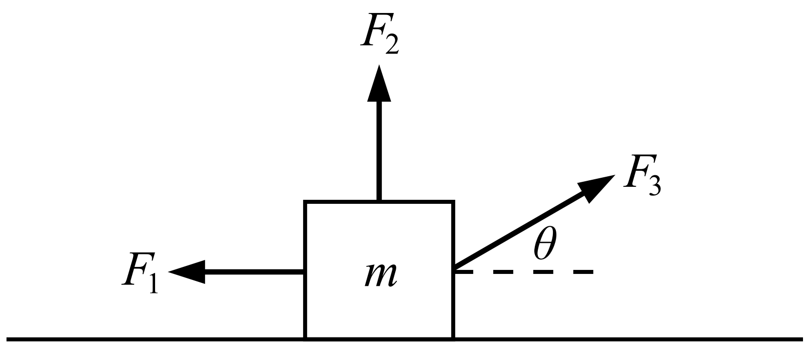
B Incorrect

This graph would be correct if the net force on the block was zero and the block started with an initial speed.

C Incorrect

D Incorrect

This graph would be correct if the net force on the block was zero.



8. 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.

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