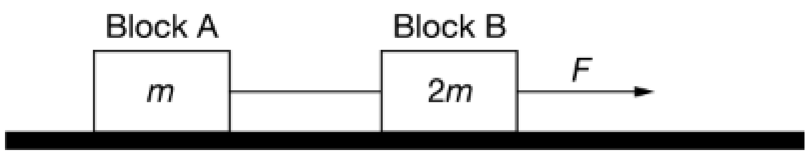
Physics C 2.5 Solutions

Newton's 2nd Law

1. Three blocks are in contact with each other, and they are at rest on a horizontal surface with negligible friction. The masses of the blocks are 2 kg, 4 kg, and 1 kg, as shown in the figure. While a force of 35 N pushes the 2 kg block to the right, what is the magnitude of the force that the 2 kg block exerts on the 4 kg block?

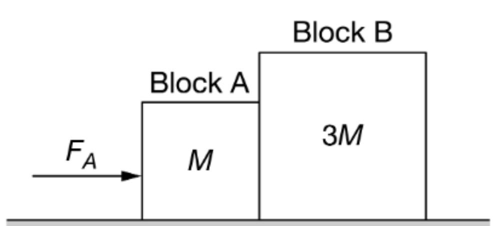
The 35 N force is applied to a total of 7 kg, which means all three blocks accelerate at $a = \frac{35}{7} = 5\ \frac{m}{s^2}$. The 2 kg is block is in direct contact with the 4 kg block, but it's pushing both the 4 kg and 1 kg block. Since this force accelerates both blocks at $5\ \frac{m}{s^2}$, the force is $F = ma = (5)(5) =$ **25 N**



2. Blocks A and B of masses m and $2m$, respectively, are connected by a light string and are pulled along a horizontal surface of negligible friction by a horizontal force of magnitude F, as shown in the figure. The tension in the string is T. If the masses of the blocks are doubled, and the magnitude of the horizontal force remains the same, the tension in the string will be:

None of the forces involved depend on mass (like normal force or friction). Doubling the masses only means the acceleration will be halved, but all the applied forces, including tension, remain the same.

Tension = *T*



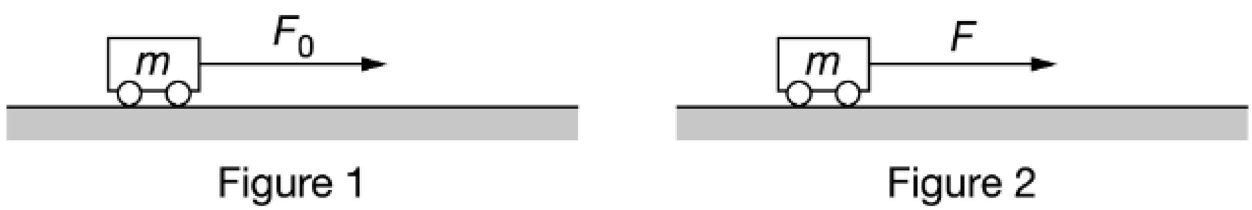
3. Blocks A and B of masses M and $3M$, respectively, are on a horizontal surface of negligible friction. A horizontal force F_A is exerted on block A, as shown. If the force exerted by block B on block A has a magnitude F, the magnitude of F_A, in terms of F, is:

The blocks share the same acceleration, and F_A must push both of them. Because Block B has three times the mass, it's being pushed with three times as much force, in order to have the same acceleration.

Therefore, Block B has $\frac{3}{4}$ of F_A applied to it. Due to Newton's 3rd Law, Block B is also pushing back on Block A with a force of $\frac{3}{4}F_A$, which in this problem, is equal to F.

$\frac{3}{4}F_A = F$

$\boldsymbol{F_A = \frac{4}{3}F}$



4. In experiment 1, a cart of mass m, initially at rest, is pulled by a force of magnitude F_0, as shown in Figure 1, for a time t_0 to give the cart a speed v. In experiment 2, a cart of mass m, initially at rest, is pulled by a force F, as shown in Figure 2, for a time $2t_0$ to give the cart speed v. Which of the following gives a correct equation for the magnitude of F and explains the equation based on experimental evidence?

A) $F = 2F_0$. Because it took the cart twice the time to reach the same speed, it has twice the acceleration and therefore twice the force.

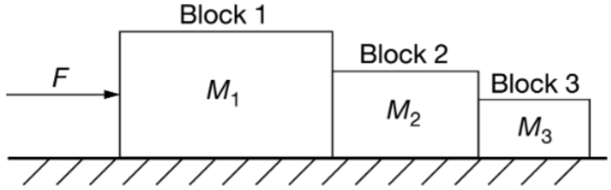
B) $F = 2F_0$. Because it took the cart twice the time to reach the same speed, it has half the acceleration and therefore twice the force.

C) $F = F_0$. Because the cart reaches the same speed, it has the same acceleration and therefore the same force.

D) $F = \frac{1}{2}F_0$. Because it took the cart twice the time to reach the same speed, it has twice the acceleration and therefore half the force.

E) $F = \frac{1}{2}F_0$. Because it took the cart twice the time to reach the same speed, it has half the acceleration and therefore half the force.

Velocity is acceleration multiplied by time. All other things being equal (like mass), it took twice as much time to reach the same velocity, so there must have been half as much acceleration. Because $F = ma$, there was also half as much force.



5. Blocks 1, 2, and 3 on a horizontal surface of negligible friction are pushed by a force of magnitude F. The blocks have the masses indicated in the figure with $M_1 > M_2 > M_3$. The accelerations of blocks 1, 2, and 3 are a_1, a_2, and a_3, respectively. F_{12} is the force block 1 exerts on block 2 and F_{23} is the force block 2 exerts on block 3. Which of the following indicates data that support the claim that $F_{12} > F_{23}$?

A) $a_1 = a_2 = a_3$; since $M_2 + M_3 > M_3$, then $F_{12} > F_{23}$.

B) $a_1 = a_2 = a_3$; since $M_1 + M_2 > M_3$, then $F_{12} > F_{23}$.

C) $a_1 = a_2 = a_3$; since $M_1 > M_3$, then $F_{12} > F_{23}$.

D) Since $a_1 > a_3$, then $F_{12} > F_{23}$.

E) Since $a_2 > a_3$, then $F_{12} > F_{23}$.

Because the blocks are all connected, they have the same acceleration.

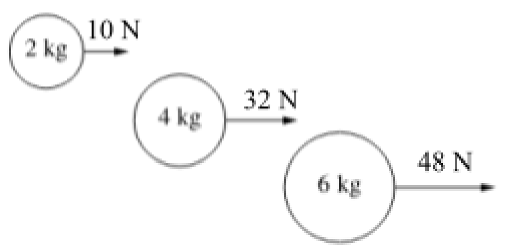
6. A large block of mass M is moving along a horizontal surface when it collides with a small block of mass m, which is initially at rest. Friction between the blocks and surface is negligible and $M > m$. Which of the following statements correctly compares the magnitude of the acceleration a_L of the large block to the magnitude of the acceleration a_S of the small block during the collision and provides a correct justification?

A) $a_L = a_S$ because Newton's third law states that every action has an equal and opposite reaction.

B) $a_L = a_S$ because the acceleration of the center of mass of the two-block system is zero as there is no external net force exerted on the system.

C) $a_L > a_S$ because the large block exerts a greater force on the small block than the small block exerts on the large block.

D) $a_L < a_S$ because the large block has more mass than the small block and the blocks exert forces of equal magnitude on each other.

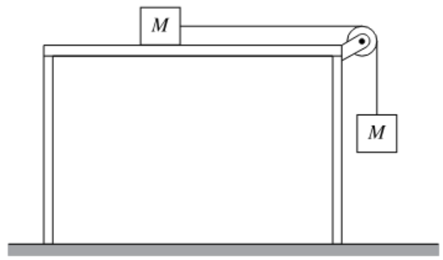


Note: Figure not drawn to scale.

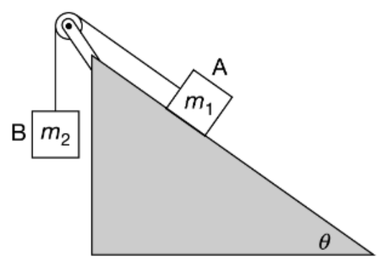
7. A system consists of three discrete masses, and a different rightward force is exerted on each mass. A 10 N force is exerted on the 2 kg mass, a 32 N force is exerted on the 4 kg mass, and a 48 N force is exerted on the 6 kg mass as shown in the figure. What is the magnitude of the acceleration of the center of mass of the system?

Acceleration of center of mass is found by dividing $\frac{total\ force}{total\ mass}$.

$\frac{\Sigma F}{\Sigma m} = \frac{10 + 32 + 48}{2 + 4 + 6} = \frac{90}{12} =$ **7.5 m/s²**



8. A hanging block of mass M is connected to an identical block of mass M on a horizontal surface with negligible friction by a light cord over an ideal pulley, as shown. When the blocks are released, the magnitude of the acceleration of each block is a. If the block on the surface is replaced with a block of mass $3M$, what will be the magnitude of the acceleration of each block after the blocks are released?
The amount of gravitational force remains constant (Mg), but the total mass of the system has doubled from $2M$ to $4M$. As a result, the acceleration is halved: $\boldsymbol{\frac{1}{2}a}$



9. Blocks A and B of unknown masses m_1 and m_2, respectively, are set up on an inclined plane as shown. Block A is attached to block B by a light string that passes over an ideal pulley. Block A is on a surface of negligible friction. The blocks are released from rest, block A accelerates up the incline, and its acceleration a is measured. Which of the following uses the data for the magnitude of the acceleration to support a correct claim about the masses of the blocks?
A) If $a > g\sin\theta$, then $m_1 > m_2$.
B) If $a < g\sin\theta$, then $m_1 > m_2$.
C) If $a > g\sin\theta$, then $m_1 < m_2$.
D) If $a < g\sin\theta$, then $m_1 < m_2$.
E) It cannot be determined which block has more mass from the information provided.
a and $g\sin\theta$ are in the same direction (down the ramp), so it makes no sense to compare them.

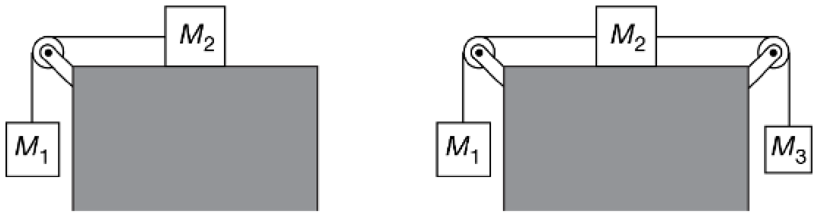


Figure 1　　Figure 2

10. Two blocks are connected by a light string, as shown in Figure 1. There is friction between the blocks and the table. The system is released from rest, and the blocks accelerate. The tension in the string is T_1. Then the setup is returned to its starting position, and a third block is attached as shown in Figure 2. The masses of the blocks are related as follows: $M_1 > M_2 > M_3$. The system is again released from rest and allowed to accelerate. The tension in the string on the left is T_2. Which of the following gives a correct relationship between the tensions in the string on the left in the two situations?

A) $T_1 < T_2$

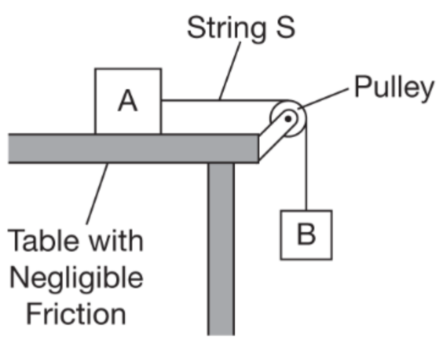
B) $T_1 = T_2$

C) $T_1 > T_2$

D) The relationship cannot be determined without knowing the actual masses of the blocks.

E) The relationship cannot be determined without knowing the coefficient of friction between the blocks and the table.

In both situations, the system will accelerate counter-clockwise, because $M_1 > M_3$. M_1 pulls on M_2 with the same force in both scenarios, but in scenario 2, an additional force (gravity on M_3) is introduced, which pulls back on M_2 in the opposite direction. This increases the tension in the left string, since tension is essentially the sum of forces working in opposite directions.



11. Block A of mass M is on a horizontal surface of negligible friction. An identical block B is attached to block A by a light string that passes over an ideal pulley. The tension force exerted on block A after the system is released from rest has magnitude T. Block B is then replaced by a block of mass $2M$ and the system again released from rest. In terms of T, what is the tension force now exerted on block A ?

Tension in both situations can be found with the zoom out/in method:

1st scenario: $\Sigma F = Mg$

$\Sigma a = \Sigma F/\Sigma M = (Mg)/(2M) = g/2$

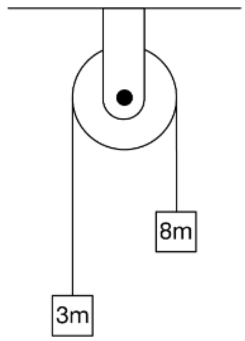
$F_A = M(g/2) = \frac{1}{2}Mg = T$

2nd scenario:

$\Sigma F = 2Mg$

$\Sigma a = \Sigma F/\Sigma M = (2Mg)/(3M) = \frac{2}{3}g$

$F_A = M(\frac{2}{3}g) = \frac{2}{3}Mg = \frac{4}{3}\boldsymbol{T}$



12. An Atwood's machine is set up as shown in the figure. The blocks have the masses indicated, and the pulley has negligible mass and friction. Which of the following claims best describes the motion of the block of mass $3m$ and provides appropriate reasoning?

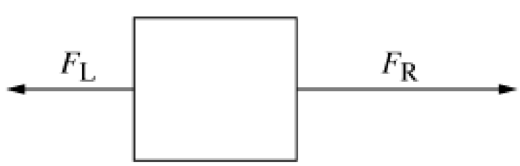
A) The block will accelerate downward with magnitude $a < g$, because the force of gravity on it will be greater than the tension in the string.

B) The block will accelerate downward with magnitude $a < g$, because the force of gravity on it will be less than the tension in the string.

C) The block will accelerate upward with magnitude $a < g$, because the force of gravity on it will be greater than the tension in the string.

D) The block will accelerate upward with magnitude $a > g$, because the force of gravity on the 8m block is greater than the force of gravity on the 3m block.

E) The block will accelerate upward with magnitude $a < g$, because the force of gravity on it will be less than the tension in the string.



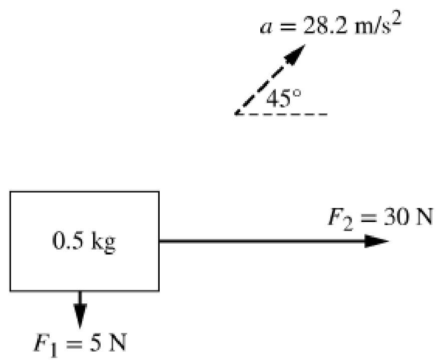
13. Two horizontal forces cause an object to move with an acceleration a to the right. The force F_L is exerted to the left, with magnitude F, and the force F_R is exerted to the right, with magnitude $3F$. What

would the magnitude of F_R need to be to cause the object to move with an acceleration of $3a$ to the right while F_L remains unchanged?

In the first scenario, the total force on the object is $(3F - F) = 2F$ to the right. In order to triple the acceleration, the total force must also be tripled, to $3(2F) = 6F$. Because F_L remains unchanged:

$(F_R - F) = 6F$

$\boldsymbol{F_R = 7F}$



14. A 0.5 kg object with three constant forces exerted on it has an acceleration $a = 28.2\ \text{m/s}^2$ at an angle of 45° above the horizontal as shown in the figure. Two of the forces are given as $F_1 = 5$ N and $F_2 = 30$ N with directions as shown. What is the magnitude of the third force?

In order for a 0.5 kg object to have an acceleration equal to $28.2\ \text{m/s}^2$, the total force exerted must be:

$\Sigma F = ma = (0.5)(28.2) = 14.1$ N

Because this force is exerted at a 45° angle, we can break it into components:

$\Sigma F_x = \Sigma F\cos(\theta) = 14.1\cos(45°) = 9.970$ N

$\Sigma F_y = \Sigma F\sin(\theta) = 14.1\sin(45°) = 9.970$ N

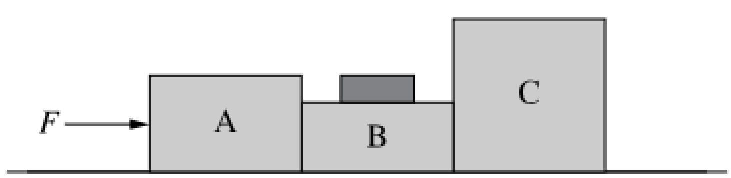
This is the *total* force, or in other words, the force which results from adding the pictured forces and the third force (the one we're solving for). Therefore:

$F_{3x} = \Sigma F_x - 30 = -20.030$ N

$F_{3y} = \Sigma F_x - -5 = 14.970$

Add the vector components using the Pythagorean Theorem:

$F_3 = \sqrt{(-20.030)^2 + (14.970)^2} = \mathbf{25.006\ N}$



15. Three large blocks, A, B, and C, and a small block attached to Block B slide across a horizontal surface as a constant force F is exerted on Block A, as shown in the figure. There is negligible friction between the blocks and the horizontal surface. Block A pushes Block B with a force F_{AB}. The small block is then removed from Block B and attached to Block C and the same force F is exerted on Block A. How does F_{AB} compare in the second situation to the first situation and why?

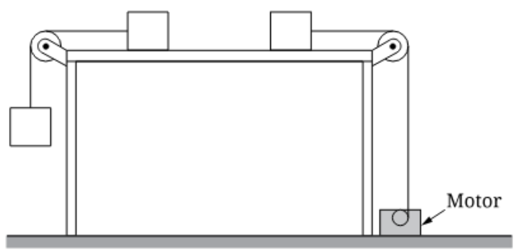
A) F_{AB} is not the same as the first situation because Block B now has the same acceleration but a different mass.

B) F_{AB} is not the same as the first situation because Block B now has a different acceleration.

C) F_{AB} is the same as the first situation because Block B is also being pushed by Block C by the same amount in both situations.

D) F_{AB} is the same as the first situation because the net force on Block A is the same in both situations.

Moving the small block from Block B to Block C doesn't change the amount of mass "downstream" from Block A, which means Block A still has to push on Block B with the same amount of force.



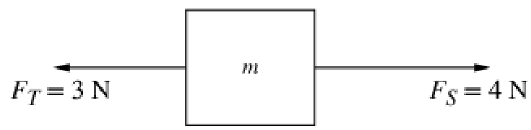
16. Two identical blocks are placed on a table as shown in the figure. The block on the left is attached to another identical block hanging over the edge of the table. The block on the right is attached to a motor pulling downward with a constant tension equal to the weight of one block. The mass of the strings and friction between the blocks and table are negligible and the pulleys are ideal. How do the magnitudes of the acceleration of the blocks compare and why?

A) The block on the right has a greater acceleration. The net force on the system with the motor is greater than the net force on the two-block system.

B) The block on the right has a greater acceleration. Each system has the same net force exerted on it, but the system on the right has less total mass.

C) Each block has the same acceleration. The tension in the string pulling on the blocks is the same in each case.

D) Each block has the same acceleration. The system of blocks on the left has twice the mass and also twice the weight compared to the block on the right.



17. Two forces, $F_T = 3$ N and $F_S = 4$ N, exerted in opposite directions as shown in the figure, cause an object to move with an acceleration of magnitude a_0. If these forces are instead exerted perpendicular to each other, what is the new magnitude of the acceleration of the object?
Vectors are added tip-to-tail, and if they're perpendicular, you can use the Pythagorean Theorem to find the total force. This is a 3-4-5 triangle, so it's easy: $\Sigma F = 5$ N
In the original scenario, the total force was (4 - 3) = 1 N, which resulted in an acceleration of a_0. With a total force of 5 N, the acceleration is $\boldsymbol{5a_0}$

1. 25 N
2. T
3. $F_A = \frac{4}{3}F$
4. E
5. A
6. D
7. 7.5 m/s^2
8. $\frac{1}{2}a$
9. E
10. A
11. $\frac{4}{3}T$
12. E
13. $7F$
14. 25.006 N
15. D
16. B
17. $5a_0$