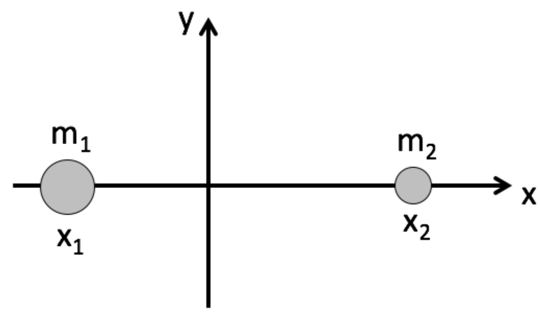
The next two questions pertain to the situation described below.

Two objects are located on the x-axis as shown in the diagram.
Object 1 has mass $m_1 = 4\ kg$ and is placed at $x_1 = -2\ m$.
Object 2 has mass $m_2 = 2\ kg$ and is placed at $x_2 = 4\ m$.



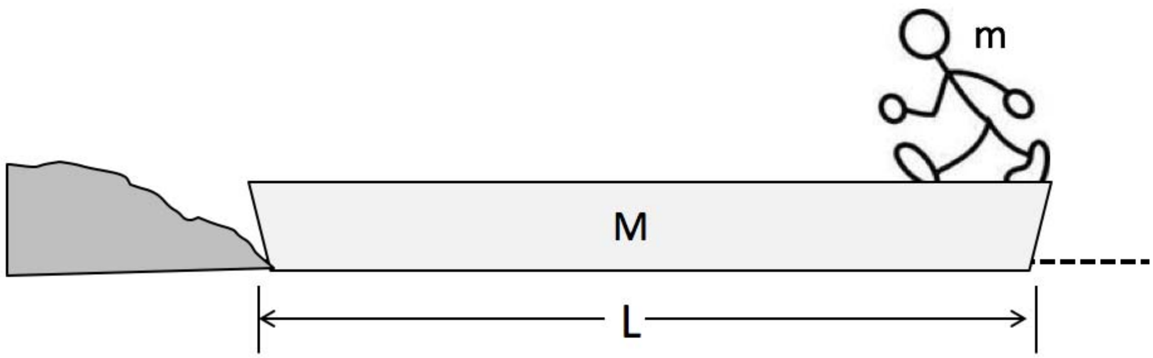
1) Suppose a third object has mass $m_3 = 1\ kg$ and that you want to place Object 3 on the (x, y) plane in such a way that the center of mass of the system of all three objects is located at $(x_{CM}, y_{CM}) = (1\ m, 2\ m)$. Where do you need to put Object 3?

a. $(x_3 = 7\ m, y_3 = 14\ m)$
b. $(x_3 = 3\ m, y_3 = 6\ m)$
c. $(x_3 = 1\ m, y_3 = 2\ m)$
d. $(x_3 = 6\ m, y_3 = 12\ m)$
e. $(x_3 = -6\ m, y_3 = -12\ m)$

2) Now suppose you apply a force of $F_1 = 4\ N$ to Object 1 in the $+x$ direction and a force of $F_2 = 2\ N$ to Object 2 in the $-x$ direction. In which direction is the center of mass of the system accelerating ?

a. The center of mass is accelerating to the right.
b. The center of mass is accelerating to the left.
c. The center of mass is not accelerating .

The next three questions pertain to the situation described below.



A boat with mass $M = 160\ kg$ and length $L = 14\ m$ is initially floating at rest with its left end next to the shore and its right end a distance L away from the shore. A man with mass $m = 50\ kg$ initially stands at rest at the right end of the boat. Assume there is no friction between the boat and water.

3) Suppose the man walks to the left end of the boat. As he is walking, what happens to the location of the center of mass of the man-boat system?

a. It does not move.
b. It moves to the left.
c. It moves to the right.

4) When the man reaches the left end of the boat, how far is he from the shore ?

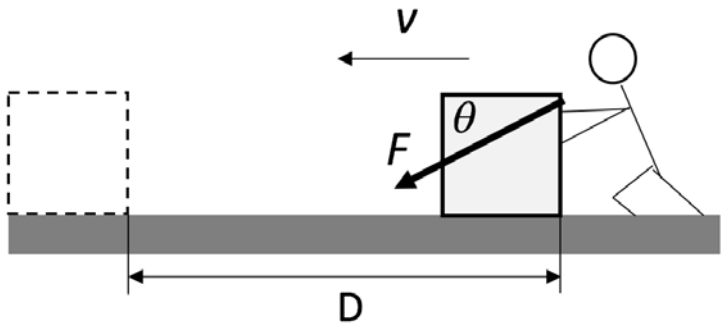
a. 0 m
b. 7 m
c. 8.67 m
d. 3.33 m
e. 4.38 m

5) If the man was carrying some heavy object as he walked from the right end of the boat to the left end, how would his new final distance from the shore change ?

a. It would increase.
b. It would not change.
c. It would decrease.

The next three questions pertain to the situation described below.

A student is pushing a box of mass $M = 50\ kg$ across a level floor at a constant speed of $v = 1.5\ m/s$. The student pushes on the box with a downward force $F = 160\ N$ at an angle $\theta = 31°$ below the horizontal. The box moves a distance $D = 14\ m$ across the floor. The coefficient of kinetic friction between the box and the floor is μ_k.



6) The total work done by all forces on the box as it moves a distance D across the floor is:

a. Positive
b. Negative
c. Zero

7) What is the work done on the box by friction as it moves a distance D across the floor?

a. W_{fr} = -1154 J
b. W_{fr} = -6867 J
c. W_{fr} = -2240 J
d. W_{fr} = 0 J
e. W_{fr} = -1920 J

8) The work done by the box on the student during this motion is:

a. Zero
b. Positive
c. Negative

The next four questions pertain to the situation described below.

A 21 kg dog is initially at rest when he sees a squirrel. At $t_0 = 0$ he starts running toward the squirrel. At $t_1 = 1.5\ s$, when the velocity of the dog is $v_{dog} = 4.1\ m/s$, an elastic band that connects the dog to a stationary post starts to stretch and eventually stops the dog at $t_2 = 1.8\ s$.

9) What is the magnitude of the average force exerted on the dog between times t_1 and t_2?

a. $F_{ave} = 57\ N$
b. $F_{ave} = 287\ N$
c. $F_{ave} = 48\ N$
d. $F_{ave} = 687\ N$
e. $F_{ave} = 137\ N$

10) What is the magnitude of the total work done on the dog between times t_1 and t_2 ?

a. $W_{total} = 353\ J$
b. $W_{total} = 169\ J$
c. $W_{total} = 0\ J$
d. $W_{total} = 59\ J$
e. $W_{total} = 177\ J$

11) Suppose that the elastic band is replaced by a rope that does not stretch. The speed of the dog before being stopped by the rope is the same as above. How does the magnitude of the average force exerted on the dog as stops change?

a. It increases.
b. It decreases.
c. It stays the same.

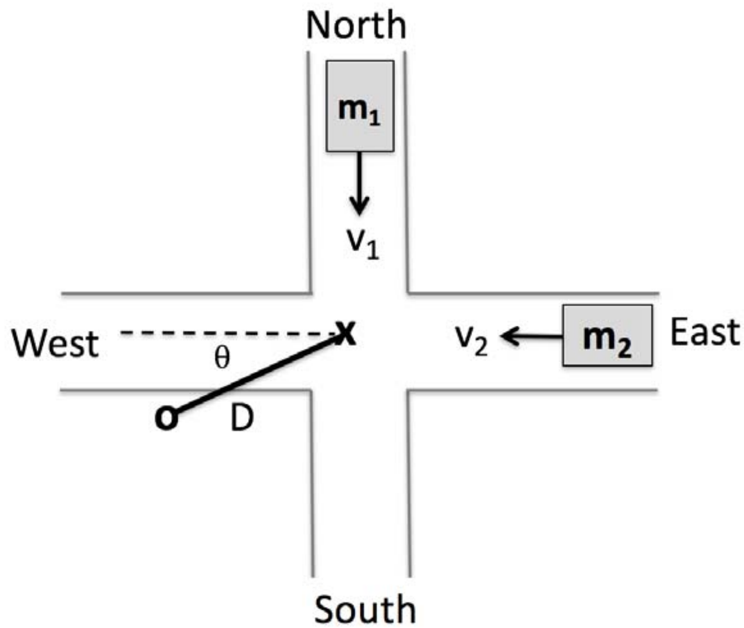
12) Suppose that the elastic band is replaced by a rope that does not stretch. The speed of the dog before being stopped by the rope is the same as above. How does the magnitude of the total work done on the dog as it stops change?

a. It stays the same.
b. It decreases.
c. It increases.

The next two questions pertain to the situation described below.

Two cars collide at an intersection. Just before the collision car 1 is moving from North to South with a constant speed of $v_1 = 21\ m/s$, and car 2 is moving from East to West with a constant speed of $v_2 = 35\ m/s$. After the cars collide, they stick together and slide in a straight line for a distance D until they stop completely.

The figure schematically shows the place of collision (as “x”) and the place where the two cars eventually stop (as “o”). The cars leave a mark on the pavement that makes an angle $\theta = 35^\circ$ below the West direction as shown. The coefficient of kinetic friction between the road and the sliding wreckage is μ_k.



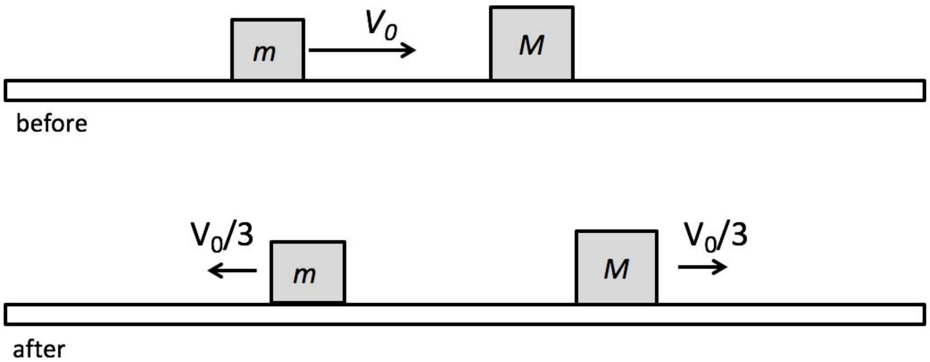
13) If the mass of car 1 is $m_1 = 800\ kg$, what is the mass of car 2 ?

a. $m_2 = 837\ kg$
b. $m_2 = 560\ kg$
c. $m_2 = 400\ kg$
d. $m_2 = 586\ kg$
e. $m_2 = 686\ kg$

14) Which of the following expressions is correct?

a. $\mu_k(m_1 + m_2)gD < \frac{1}{2}m_1 v_1^2 + \frac{1}{2}m_2 v_2^2$
b. $\mu_k(m_1 + m_2)gD = \frac{1}{2}m_1 v_1^2 + \frac{1}{2}m_2 v_2^2$
c. $\mu_k(m_1 + m_2)gD > \frac{1}{2}m_1 v_1^2 + \frac{1}{2}m_2 v_2^2$

The next two questions pertain to the situation described below.



A box of mass m slides on a straight frictionless horizontal track with an initial speed V_0. It collides and bounces off a box of mass M which is initially at rest. After the collision the box having mass m is moving to the left with speed, $V_0/3$ and the box having mass M is moving to the right with the same speed, $V_0/3$.

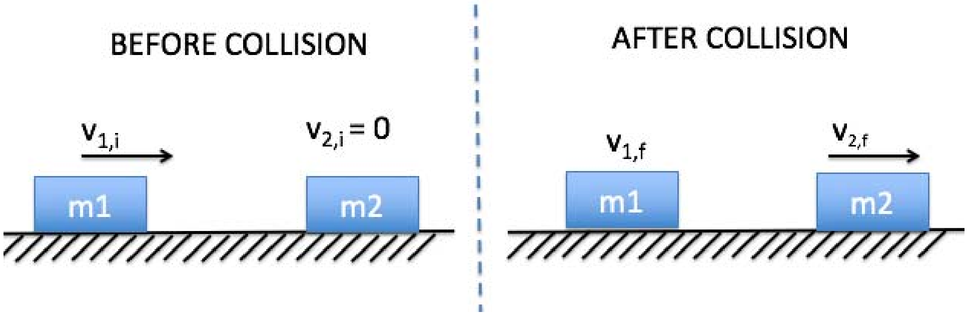
15) How are the masses of the two boxes, M and m, related?

a. $M = 3m/2$
b. $M = 4m$
c. $M = 2m$
d. $M = 2m/3$
e. $M = 3m$

16) Which of the following statements is true?

a. We need to know the masses of the boxes in order to determine whether or not the collision is elastic.
b. The collision is elastic, and this can be determined without knowing the masses of the boxes.
c. The collision is not elastic, and this can be determined without knowing the masses of the boxes.

The next three questions pertain to the situation described below.



A cart of mass $m_1 = 2\ kg$ is moving along a straight horizontal frictionless track with a constant velocity of $v_{1,i} = 3.1\ m/s$ relative to the track when it hits a second cart that is initially at rest on the same track. The mass of the second cart $m_2 = 3\ kg$. The positive direction is to the right.

17) If the collision is elastic, what is the final velocity cart 2 in the reference frame of the track, $V_{2,f}$?

a. $V_{2,f}$ = 1.24 m/s
b. $V_{2,f}$ = 1.86 m/s
c. $V_{2,f}$ = 4.34 m/s
d. $V_{2,f}$ = 3.1 m/s
e. $V_{2,f}$ = 2.48 m/s

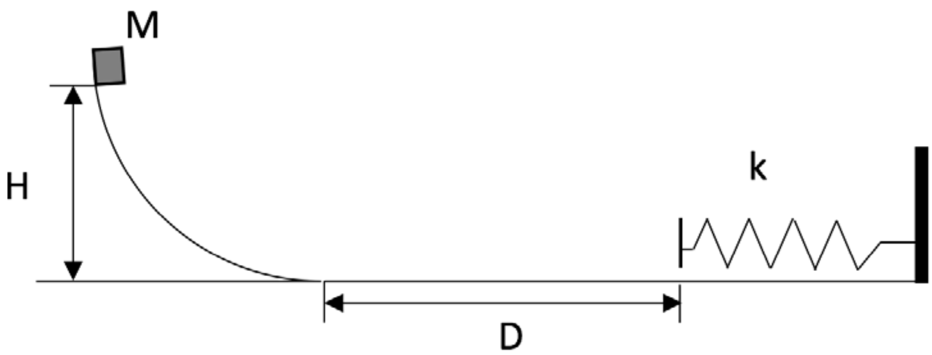
18) If the collision is elastic, what is the speed of card 2 relative to cart 1 after the collision?

a. 1.24 m/s
b. 3.1 m/s
c. 2.48 m/s

19) Instead of colliding elastically, suppose the carts stick together after they collide. In this case, what is the speed of the two carts after the collision?

a. 3.1 m/s
b. 1.86 m/s
c. 1.24 m/s

The next three questions pertain to the situation described below.



A block with mass $M = 3\ kg$ starts at rest and slides down a frictionless slope from a starting height $H = 2.1\ m$. After traveling across a horizontal surface for a distance of $D = 3.2\ m$, the block hits a horizontal spring with spring constant k = 2×10^3 N/m.

20) If the horizontal plane is also frictionless, what is the maximal distance d_{max} that the spring will be compressed.

a. d_{max} = 0.249 m
b. d_{max} = 0.176 m
c. d_{max} = 0.029 m
d. d_{max} = 0.124 m
e. d_{max} = 0.015 m

21) If the mass of the block was doubled and the spring constant was halved and the block was released from the same height, how would the new maximum compression of the spring $d_{max,new}$ compare to the original d_{max} in the above problem?

a. $d_{max,new} = 4d_{max}$
b. $d_{max,new} = 16d_{max}$
c. $d_{max,new} = 2d_{max}$

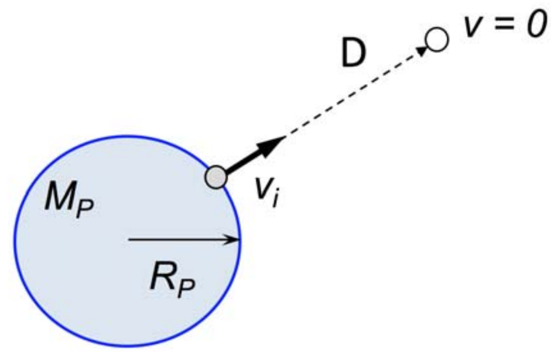
22) Now suppose there is friction present when the block is sliding on the horizontal surface, and that the coefficient of kinetic friction is $\mu_k = 0.15$. If the mass and starting height of the block are the same as in the first question, what is the speed V of the block just before it hits the spring?

a. The block stops before reaching the spring.
b. V = 5.64 m/s
c. V = 3.34 m/s
d. V = 6.04 m/s
e. V = 6.42 m/s

The next two questions pertain to the situation described below.

A cannon on the surface of the a planet fires a shell of mass $m = 50\ kg$ directly upward with initial speed V_i. The shell rises a distance of $D = 2.262 \times 10^6$ m above the surface of the planet before stopping and falling back down again.

The mass of the planet is $M_P = 7.35 \times 10^{22}\, kg$, the radius of the planet is $R_P = 1.74 \times 10^6\, m$ and the universal gravitational constant is $G = 6.67 \times 10^{-11}\, Nm^2/kg^2$. The planet has no atmosphere and is not rotating.



23) What was the shell's initial speed, V_i?

a. V_i = 1785 m/s.
b. V_i = 6662 m/s.
c. V_i = 1488 m/s.
d. V_i = 7994 m/s.
e. V_i = 1262 m/s.

24) What should the minimum value of the initial kinetic energy of the shell be if we wanted it to completely escape the gravity of the planet and never fall back down?

a. It would need an infinite amount of kinetic energy.
b. $K_i = 5.635 \times 10^6$ J.
c. $K_i = 2.8175 \times 10^8$ J.
d. K_i = 2817500 J.
e. $K_i = 1.40875 \times 10^8$ J.