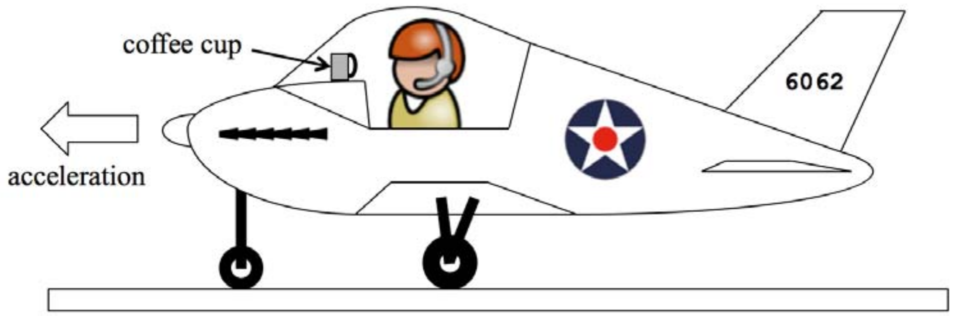
The next two questions pertain to the situation described below.

A careless pilot leaves an empty coffee cup on top of his instrument panel as he accelerates along a horizontal runway. There is friction between the instrument panel and the coffee cup, but it is insufficient to hold the cup in place. The cup slides off the instrument panel and bangs into the pilot as he accelerates down the runway.



1) As it slides along the instrument panel toward the pilot, the work done by friction on the cup is

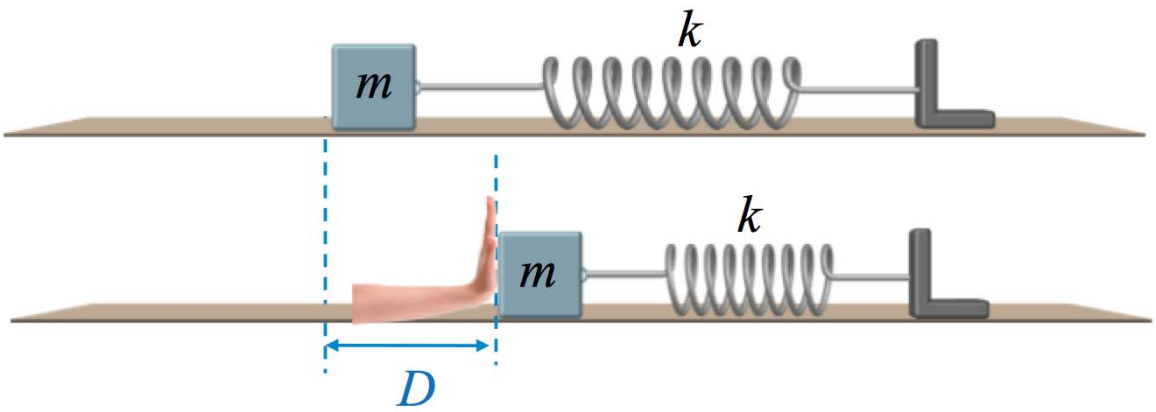
a. zero.
b. positive.
c. negative.

2) The direction of the frictional force acting on the cup is

a. towards the front of the plane.
b. towards the back of the plane.
c. undefined, since friction does no work in this case.

The next three questions pertain to the situation described below.

A box of mass m is initially at rest at $x = 0$ on a horizontal frictionless surface. It is attached to an unstretched spring with spring constant k, aligned with the x axis, whose other end is attached to a wall as shown. A hand applies a force on the box in the positive x direction so that it moves to the right with a constant velocity until it reaches $x = D$, where it stops moving.



3) What is the work done by the hand on the box?

a. 0
b. $-\int_0^D kx\,dx$
c. $+\int_0^D kx\,dx$
d. $+\int_0^D \frac{1}{2}kx^2\,dx$
e. $-\int_0^D \frac{1}{2}kx^2\,dx$

4) Suppose the answer to the above question is W_D. If the hand instead pushed the box twice the distance, the work done by the hand on the box is W_{2D}. How does W_{2D} compare with W_D?

a. $W_{2D} < 2W_D$
b. $W_{2D} = 2W_D$
c. $W_{2D} > 2W_D$

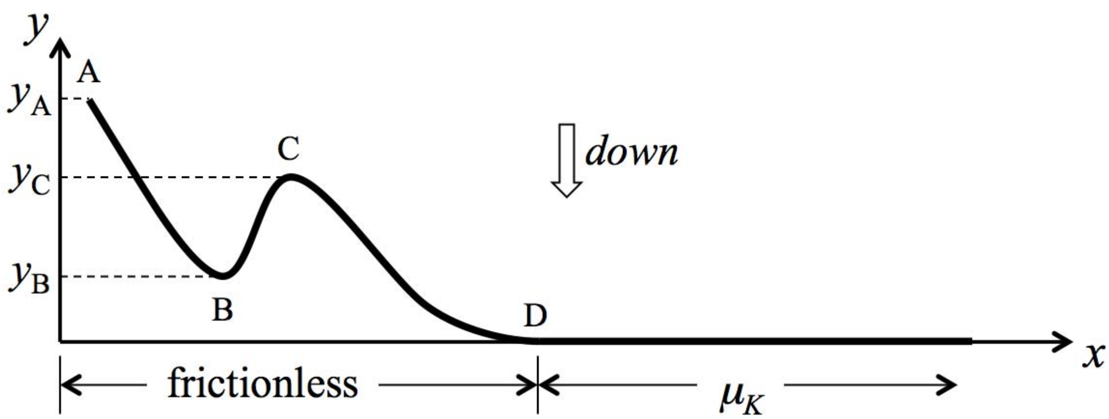
5) The total work done on the box by all forces during this motion is

a. positive.
b. negative.
c. zero.

The next three questions pertain to the situation described below.

A ski slope starts at point A, descends to point B, climbs to point C, then descends to point D. To the right of point D the surface is level and the coefficient of kinetic friction between the ground and the skier is μ_K. There is no friction anywhere to the left of point D. The elevations of points B, C, and D are y_B = 30 m, y_C = 90 m, and y_D = 0 m.

A skier starts from rest at point A and slides down the hill. She is observed to have a speed of 18 m/s at point C.



6) What is the starting elevation of the skier?

a. y_A = 136.5 m
b. y_A = 90 m
c. y_A = 106.5 m
d. y_A = 16.5 m
e. y_A = 46.5 m

7) If the skier slides a distance 440 m beyond point D before coming to rest, what is μ_K?

a. μ_K = 0.242
b. μ_K = 0.038
c. μ_K = 0.31
d. μ_K = 0.205
e. μ_K = 0.106

8) If y_A and μ_K were kept the same as above, but the elevation of point C were reduced to 15 m, the distance beyond point D that the skier would slide before stopping would be

a. equal to 440 m.
b. less than 440 m.
c. greater than 440 m.

The next three questions pertain to the situation described below.

A spherical planet has radius $R_P = 5 \times 10^3$ km and mass $M_P = 3 \times 10^{24}$ kg. The planet has a spherical moon of radius $R_M = 10^3$ km and mass $M_M = 4 \times 10^{22}$ kg. The distance between the center of the planet and the center of the moon is 1.5×10^5 km. The universal gravitational constant is $G = 6.67 \times 10^{-11} Nm^2/kg^2$.

9) How far from the center of the planet is the center of mass of the planet-moon system?

a. 1.5×10^5 km
b. 4947.4 km
c. 6907.9 km
d. 7.5×10^4 km
e. 1973.7 km

10) What is the escape velocity from the surface of the planet (i.e. the minimum initial velocity that an object launched from the surface needs to have in order to get infinitely far away) ? Ignore any effects due to the moon.

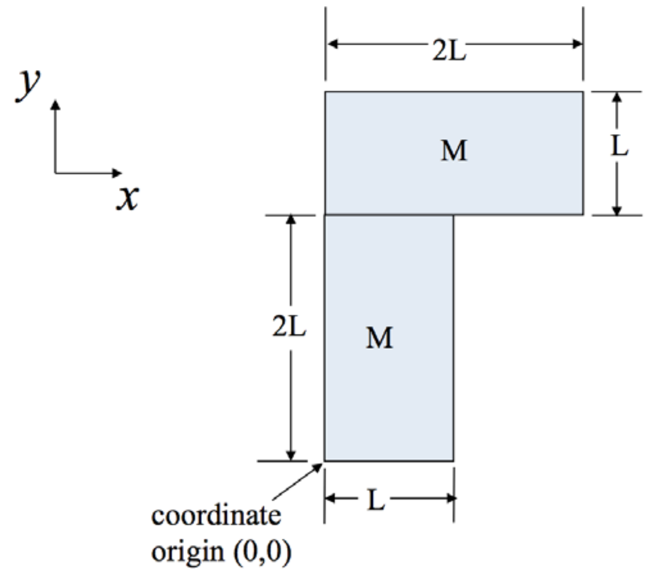
a. V_i = 4 m/s
b. V_i = 12652.3 m/s
c. V_i = 8946.5 m/s
d. V_i = 4473.3 m/s
e. V_i = 6326.1 m/s

11) If the planet was compressed so that it had the same mass but one quarter the radius, how would the escape velocity change?

a. It would stay the same.
b. It would double.
c. It would quadruple.

The next two questions pertain to the situation described below.

Two rectangular blocks each have mass M, length 2L, and width L. They are arranged as shown in the figure. In the following questions, use the lower left-hand corner of the system as the origin.



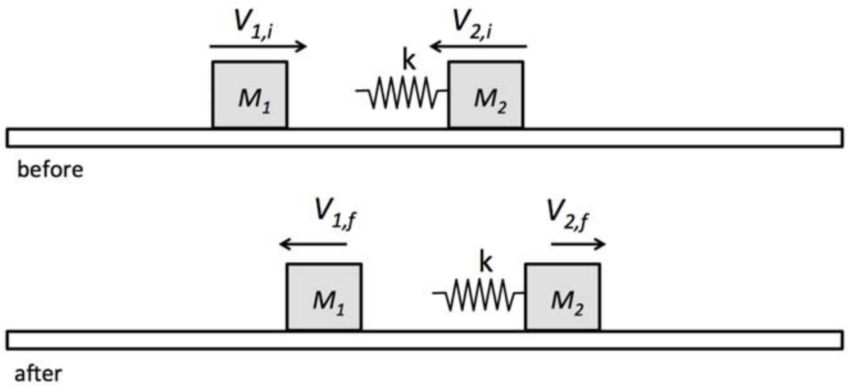
12) What are the (x,y) coordinates of the center of mass of the system?

a. (5L/4, 9L/4)
b. (2L/3, 4L/3)
c. (3L/5, 7L/5)
d. (3L/2, 5L/4)
e. (3L/4, 7L/4)

13) If the mass of the top block were decreased but its size were to remain the same, what would happen to the location of the center of mass of the system?

a. It will move to the right and up.
b. It will move to the left and up.
c. It will move to the left and down.

The next two questions pertain to the situation described below.



Two carts move toward each other on a one-dimensional horizontal frictionless track. Cart 1 has mass M_1 = 21 kg and initial velocity $V_{1,i}$ = 12.143 m/s. Cart 2 has mass M_2 = 32 kg and initial velocity $V_{2,i}$ = -0.469 m/s. A spring between them makes the collision between the carts elastic.

14) Before the collision, what is the velocity of cart 1 as viewed by someone in the center of mass reference frame?

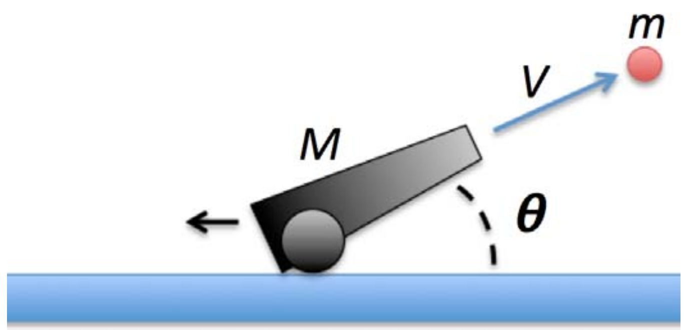
a. $V_{1,i}^{*}$ = 5 m/s
b. $V_{1,i}^{*}$ = -7.61 m/s
c. $V_{1,i}^{*}$ = -5 m/s
d. $V_{1,i}^{*}$ = 4.53 m/s
e. $V_{1,i}^{*}$ = 7.61 m/s

15) After the collision, what is the speed of cart 1 as viewed by someone in the reference frame of cart 2?

a. $V_{1,2}$ = 4.53 m/s
b. $V_{1,2}$ = 8.76 m/s
c. $V_{1,2}$ = 11.67 m/s
d. $V_{1,2}$ = 16.14 m/s
e. $V_{1,2}$ = 12.61 m/s

The next three questions pertain to the situation described below.

A cannon of mass M = 2100 kg is initially at rest on a horizontal frictionless surface of ice. It fires a cannonball of mass m = 55 kg (not included in M). An observer on the ice measures the initial angle of the cannonball as it exits the cannon's barrel to be θ = 25 degrees above horizontal, and its initial speed to be V = 290 m/s. The cannon recoils and slides to the left.



16) Considering the system made up of the cannon and the cannonball, which of the following quantities are the same just before and just after the cannonball is fired?

a. Both the horizontal and vertical components of momentum.
b. The horizontal component of momentum.
c. The vertical component of momentum.

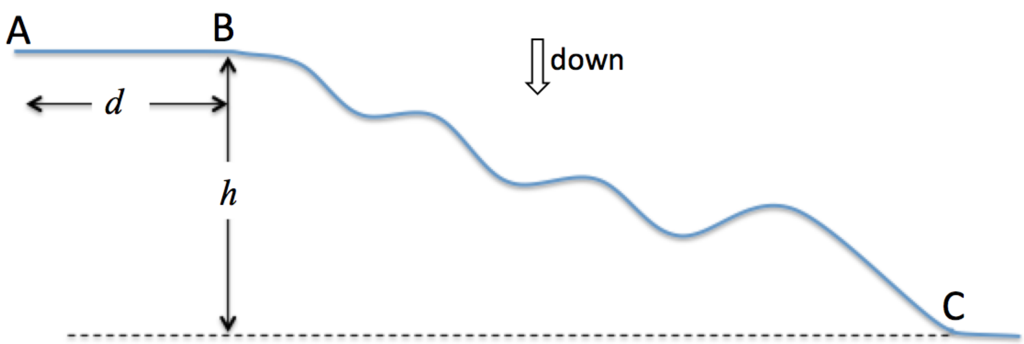
17) In the reference frame of the cannon, the initial angle of the cannonball relative to the surface of the ice is

a. greater than 25 degrees.
b. less than 25 degrees.
c. equal to 25 degrees.

18) At the instant the cannonball hits the ice, how far to the left of its initial position has the cannon moved? (You can neglect the height of the cannon's barrel above the ice in your calculation.)

a. 368.9 m
b. 86 m
c. 172 m
d. 80.2 m
e. 6567.2 m

The next three questions pertain to the situation described below.



A bobsled having mass M = 210 kg is initially at rest at point A at the top of the track shown in the figure. The distance from point A to point B is d = 15 m and is horizontal. From point B to point C the track twists and turns as it moves down the hill. The vertical distance from point B to point C is h = 70 m. The track is **not** frictionless.

19) Four men, each having the same mass m = 85 kg, start pushing the sled from point A toward point B. Each one pushes with the same force 65.6 N for the whole distance d. When the bobsled reaches point B its speed is 5 m/s. What was the total work done by all forces on the bobsled as it moved from point A to point B?

a. 7875 J
b. 3936 J
c. 2625 J
d. 1750 J
e. 5250 J

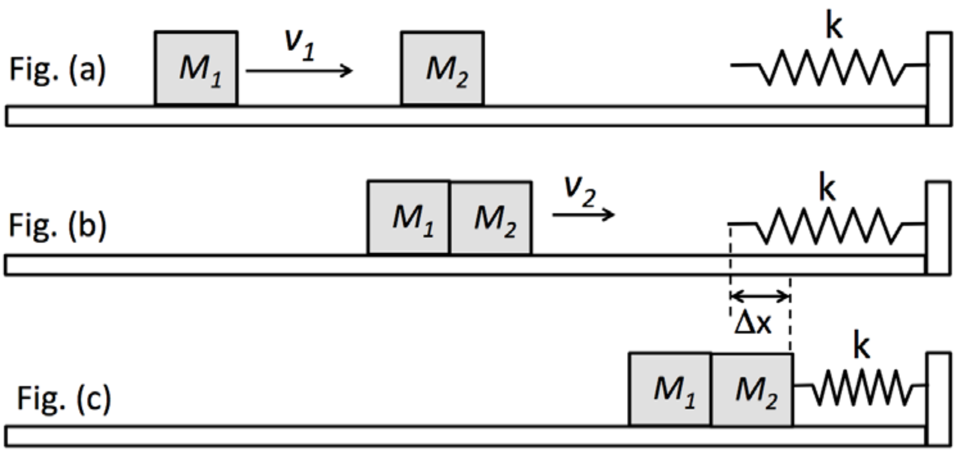
20) The four men jump on the bobsled at Point B and slide down the hill. As they pass point C at the bottom of the hill their speed is 25 m/s. What was the work done on the bobsled and the men by nonconservative forces as they moved from point B to point C?

a. -212685 J
b. -377685 J
c. -81207 J
d. 377685 J
e. 1.65×10^5 J

21) The total work done on the bobsled by all forces between point A and point C is

a. zero.
b. positive.
c. negative.

The next three questions pertain to the situation described below.



A box of mass M_1 slides on a horizontal frictionless surface with speed V_1, as in Fig. (a). It collides with, and sticks to, an initially stationary box of mass M_2, as in Fig. (b). The speed of the boxes moving together after the collision is V_2.

22) Which of the following is a correct expression for M_1 in terms of other variables?

a. $M_1 = M_2 V_2 / V_1$
b. $M_1 = M_2 (V_1 - V_2) / V_2$
c. $M_1 = M_2 V_2 / (V_1 - V_2)$

23) If $M_1 = 2$ kg and $M_2 = 5$ kg, what is the ratio of the final kinetic energy of the blocks just after the collision, K_F, to the initial kinetic energy of the blocks just before the collision, K_I?

a. $K_F / K_I = 5/2$
b. $K_F / K_I = 5/7$
c. $K_F / K_I = 2/5$
d. $K_F / K_I = 3/5$
e. $K_F / K_I = 2/7$

24) The boxes now slide into the free end of a spring whose other end is fixed as shown in Fig. (c). If the spring constant is k, which of the following is a correct expression for the maximum compression of the spring ΔX in terms of other variables?

a. $\Delta X = V_2 \sqrt{(M_1 + M_2)/2k}$
b. $\Delta X = V_1 \sqrt{M_1 / 2k}$
c. $\Delta X = V_2 \sqrt{(M_1 + M_2)/k}$