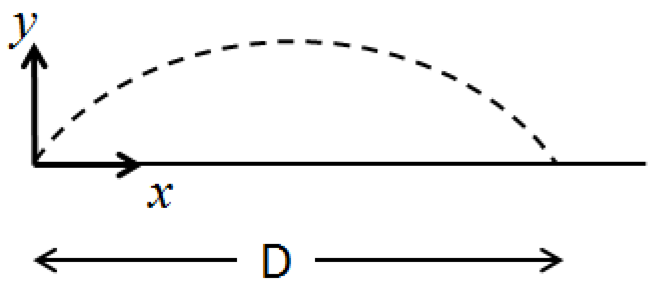
The next three questions pertain to the situation described below.



A ball is launched from ground level and hits the ground again after an elapsed time of 4 seconds and after traveling a horizontal distance of 56 m. The only force acting on the ball is gravity.

1) Which of the following statements best describes the magnitude of the horizontal component of the velocity of the ball?

a. It is constant the whole time the ball is in free-fall.
b. It is smallest when the height of the ball is maximum.
c. It is smallest just before the ball hits the ground.

2) What is the initial x-component of the ball's velocity?

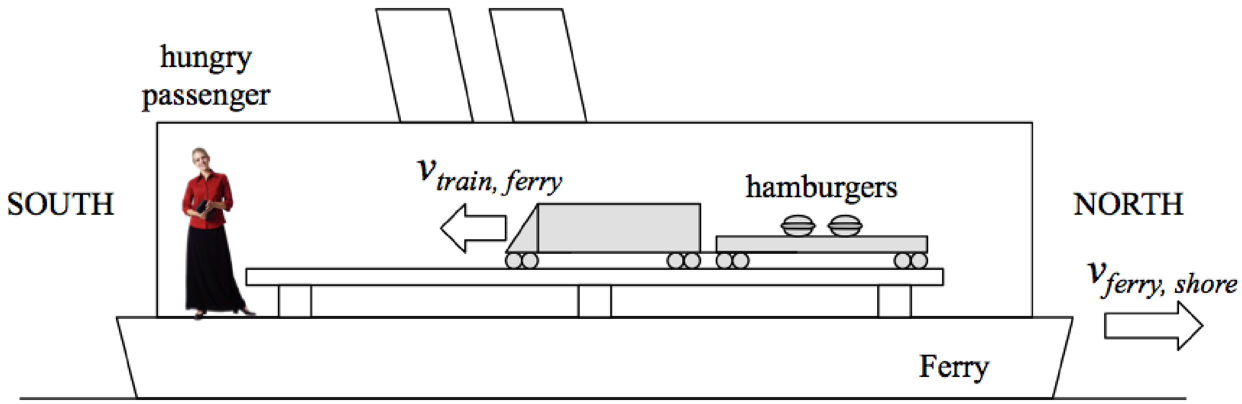
a. $V_{x,initial}$ = 17.1 m/s
b. $V_{x,initial}$ = 14 m/s
c. $V_{x,initial}$ = 20.2 m/s
d. $V_{x,initial}$ = 10.8 m/s
e. $V_{x,initial}$ = 23.2 m/s

3) What is the initial y-component of the ball's velocity?

a. $V_{y,initial}$ = 32.6 m/s
b. $V_{y,initial}$ = 26.1 m/s
c. $V_{y,initial}$ = 78.5 m/s
d. $V_{y,initial}$ = 39.2 m/s
e. $V_{y,initial}$ = 19.6 m/s

The next two questions pertain to the situation described below.

An entrepreneur installs a toy train on a ferry boat to carry food from the ferry's kitchen to hungry passengers. The ferry travels through still water at 12 m/s. Assume that the water through which the ferry travels is stationary with respect to the shore. As the ferry travels north, the kitchen sends a plate of hamburgers to a passenger standing at the back, as shown in the picture. Assume that the toy train carrying the hamburgers travels 4 m/s with respect to the ferry.



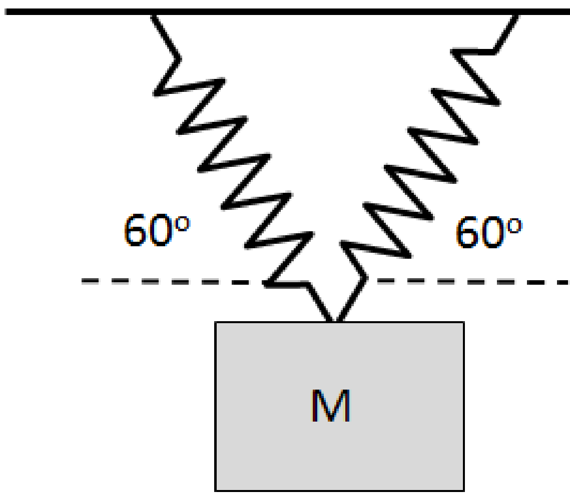
4) What is the speed of the plate of hamburgers with respect to the passenger?

a. 8 m/s
b. 4 m/s
c. 16 m/s
d. 12 m/s
e. 0 m/s

5) What is the speed of the plate of hamburgers with respect to a stationary observer on land?

a. 4 m/s
b. 12 m/s
c. 8 m/s

The next two questions pertain to the situation described below.



A mass, $M = 3.2$ kg, hangs motionless from the ceiling from two identical ideal, massless, springs with spring constants $k = 507$ N/M. Each spring makes an angle of $\theta = 60^o$ with respect to horizontal as shown.

6) How much is each spring stretched from its equilibrium position?

a. 0.071 m
b. 0.124 m
c. 0.062 m
d. 0.036 m
e. 0.031 m

7) If the angles were both changed to $\theta = 45^o$, the springs would?

a. Stretch more than before.
b. Stretch the same as before.
c. Stretch less than before.

The next three questions pertain to the situation described below.

Satellite A has mass M_A = 1517 kg and moves in a circular orbit of radius R_A = 10.4×10^6 m around a planet. The mass of the planet is M = 5.2×10^{24} kg and the universal gravitational constant is $G = 6.67 \times 10^{-11}$ Nm^2/kg^2. The speed of the satellite in this orbit is V_A.

8) How long does it take the satellite to make one complete orbit around the planet?

a. T_{orbit} = 154.6 minutes
b. T_{orbit} = 230.1 minutes
c. T_{orbit} = 188.6 minutes
d. T_{orbit} = 397.9 minutes
e. T_{orbit} = 271.6 minutes

9) Satellite B has twice the mass of Satellite A and moves in an orbit with the same radius. Which of the following best describes V_B, the speed of satellite B.

a. $V_B < V_A$
b. $V_B > V_A$
c. $V_B = V_A$

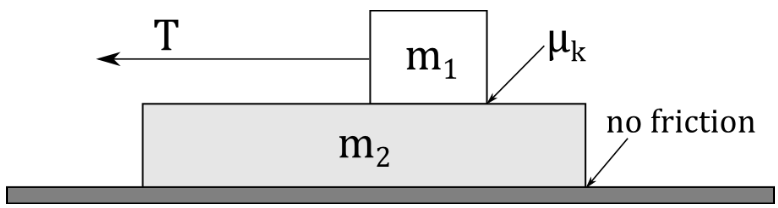
10) Satellite C has the same mass as Satellite A and moves in an orbit with twice the radius. Which of the following best describes V_C, the speed of satellite C.

a. $V_C = V_A$
b. $V_C > V_A$
c. $V_C < V_A$

11) A vehicle of mass m = 1100 kg is traveling at a speed of 37 m/s when the driver notices a deer on the road directly ahead of her. She slams on the brakes and the vehicle skids to a stop with constant acceleration. If the coefficient of kinetic friction between the tires and the road is μ_k = 0.32 and the deer doesn't move, what is the minimum distance between the vehicle and the deer when the brakes are applied in order to avoid a collision?

a. 436.1 m
b. 69.8 m
c. 218 m
d. 174.4 m
e. 261.7 m

The next three questions pertain to the situation described below.



A box of mass m_1 = 2.1 kg is being pulled by a horizontal string with tension T as shown. It moves to the left with a constant velocity across the top of a second box having a mass of m_2 = 5.1 kg. The kinetic coefficient of friction between the upper box and the lower box is μ_k = 0.6. There is no friction between the lower box and the horizontal floor, and the lower box accelerates to the left. Assume that the upper box is moving faster that the lower box.

12) Which of the following statements best describes the net force acting on the upper box?

a. It points to the left.
b. It points to the right.
c. It is zero.

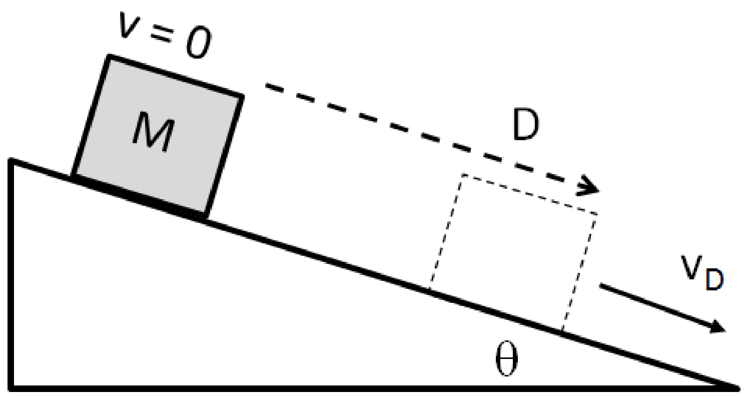
13) Which of the following statements best describes the force of friction acting on the lower box?

a. It is zero.
b. It points to the right.
c. It points to the left.

14) What is the magnitude of the acceleration of the lower box ?

a. a = 1.7 m/s^2
b. a = 2.4 m/s^2
c. a = 1.2 m/s^2
d. a = 14.3 m/s^2
e. a = 5.9 m/s^2

The next three questions pertain to the situation described below.



A box of mass M = 3 kg is initially held at rest near the top of a frictionless ramp that makes an angle of θ = 20 degrees with respect to the horizontal. When the box is released it accelerates down the ramp.

15) The total work done by all forces on the box as it moves a distance D down the ramp is:

a. Zero
b. Negative
c. Positive

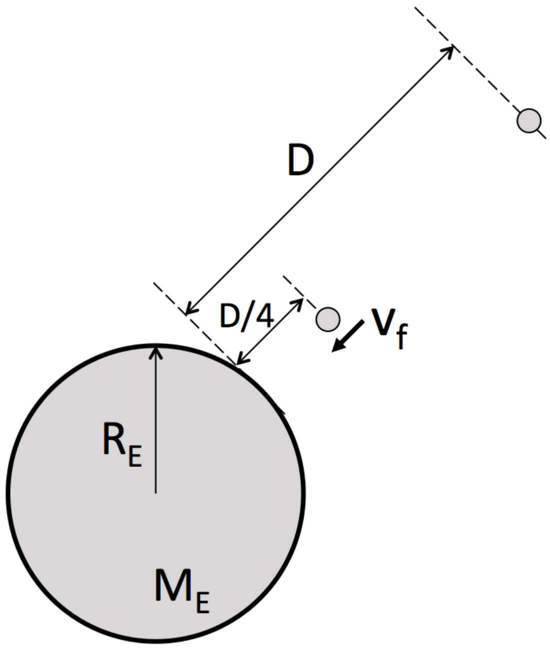
16) After the box has moved a distance D = 1.1 m down the ramp from its starting point, what is its speed?

a. V_D = 4.65 m/s
b. V_D = 2.72 m/s
c. V_D = 2.48 m/s
d. V_D = 5.19 m/s
e. V_D = 4.5 m/s

17) Now suppose that there is friction between the box and the ramp, but that the box still accelerates down the ramp. The kinetic coefficient of friction is μ_K. As the box moves a distance D down the ramp, the total work done on it by friction is

a. $-\mu_K MgDsin\theta$
b. $-\mu_K MgD$
c. $-\mu_K MgDcos\theta$

The next two questions pertain to the situation described below.



A rock is released from rest at a distance D = 3 × 10^7 m above the surface of the Earth as shown in the figure. Useful constants for this problem are the universal gravitational constant G = 6.67 × 10^{-11} Nm^2/kg^2, the mass of the Earth M_e = 5.97 × 10^{24} kg, and the radius of the Earth R_e = 6.38 × 10^6 m.

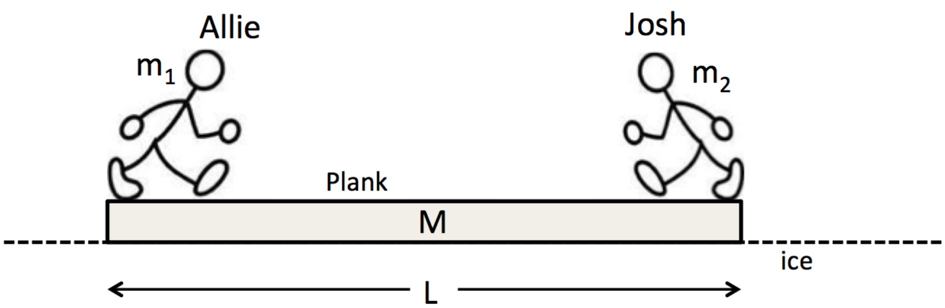
18) What is the speed of the rock, v_f, when it has fallen to a distance D/4 above the surface of the Earth?

a. v_f = 4212 m/s
b. v_f = 5957 m/s
c. v_f = 21011 m/s
d. v_f = 11173 m/s
e. v_f = 8924 m/s

19) Planet Hondo has the same radius as the earth but has a smaller mass. Suppose the same rock were released from the same height D above Hondo. How would be speed of the rock a distance D/4 above the surface compare to the answer you found above?

a. It would be bigger.
b. It would be the same.
c. It would be smaller.

The next four questions pertain to the situation described below.



Newlyweds Allie (mass m_1 = 58.2 kg) and Josh (mass m_2 = 77.6 kg) are initially standing still at opposite ends of a plank of length L = 5.5 m and mass M = 15.9 kg, with Allie at the left end and Josh at the right end. The plank is initially at rest on smooth ice (a frictionless horizontal surface).

20) Suppose they walk toward each other and meet for a kiss at the exact center of the plank. What is the displacement of the plank from its initial position as they are kissing? (The +x direction is toward the right in the picture).

a. Δx = 0.43 m
b. Δx = 2.4 m
c. Δx = -0.35 m
d. Δx = -0.43 m
e. Δx = 0.35 m

21) Suppose the mass of the plank was smaller but everything else stayed the same. The distance moved by the plank would be:

a. The same
b. Smaller
c. Bigger

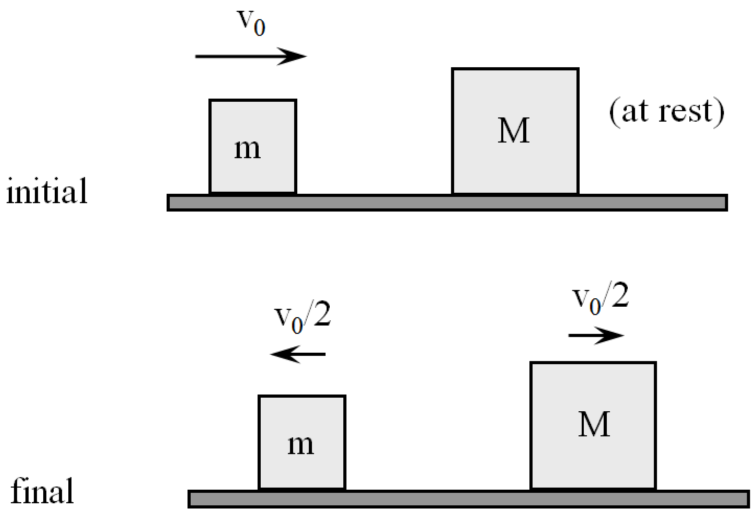
22) Suppose instead that Allie walked to the center of the plank first, and then Josh walked over to meet her after she got there. Which of the following statements best describes the movement of the plank?

a. The plank does not move.
b. The plank moves to the right a distance D_R and then to the left a distance D_L, where $D_R > D_L$
c. The plank moves to the left a distance D_L and then to the right a distance D_R, where $D_L < D_R$
d. The plank moves to the right a distance D_R and then to the left a distance D_L, where $D_R < D_L$
e. The plank moves to the left a distance D_L and then to the right a distance D_R, where $D_L > D_R$

23) During the activities described in the above problems, which of the following is true?

a. Neither the total kinetic energy nor the total horizontal momentum of the system is conserved.
b. The total kinetic energy of the system is conserved but the total horizontal momentum is not.
c. The total horizontal momentum of the system is conserved but the total kinetic energy is not.

The next two questions pertain to the situation described below.



A box of mass m slides on a frictionless horizontal air-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 boxes have the same speed, $V_0/2$, one moving to the left and the other to the right as shown.

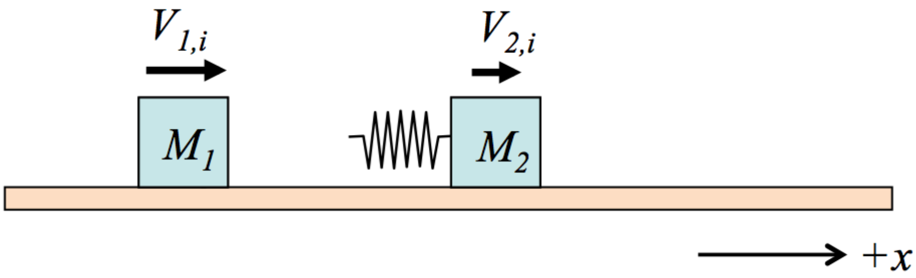
24) Which of the following statements is true?

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.

25) How are the masses of the two boxes related? (Hint: You only need to consider momentum conservation)

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

The next three questions pertain to the situation described below.



A block of mass M_1 = 2 kg is moving to the right with initial speed $V_{1,i}$ = 3.4 m/s. It collides with another block of mass M_2 = 3 kg that is initially moving to the right with $V_{2,i}$ = 1.7 m/s. There is a massless spring connected to the second block as shown, and the collision between the blocks is elastic. All motion is in one dimension and the +x direction is to the right in the picture.

26) What is the velocity of the center of mass of the system?

a. V_{cm} = 1.95 m/s
b. V_{cm} = 2.55 m/s
c. V_{cm} = 3.4 m/s
d. V_{cm} = 1.36 m/s
e. V_{cm} = 2.38 m/s

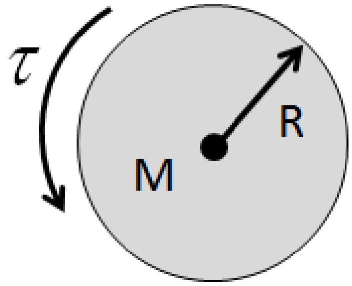
27) As measured by someone in the center of mass reference frame, in what direction is M_2 moving before the collision.

a. In the +x direction.
b. In the -x direction.
c. M_2 is at rest in the center of mass reference frame.

28) At the instant during the collision when the compression of the spring is maximum, both blocks move with the same velocity as the center of mass, V_{cm}. At this instant, which of the following correctly expresses the potential energy stored in the spring U_{spring} ?

a. $U_{spring} = \frac{1}{2}M_1V_{1,i}^2 + \frac{1}{2}M_2V_{2,i}^2 + \frac{1}{2}(M_1+M_2)V_{cm}^2$
b. $U_{spring} = \frac{1}{2}M_1V_{1,i}^2 + \frac{1}{2}M_2V_{2,i}^2$
c. $U_{spring} = \frac{1}{2}M_1V_{1,i}^2 - \frac{1}{2}M_2V_{2,i}^2$
d. $U_{spring} = \frac{1}{2}(M_1+M_2)V_{cm}^2$
e. $U_{spring} = \frac{1}{2}M_1V_{1,i}^2 + \frac{1}{2}M_2V_{2,i}^2 - \frac{1}{2}(M_1+M_2)V_{cm}^2$

The next two questions pertain to the situation described below.



A uniform solid cylinder having mass $M = 2.4\ kg$ and radius $R = 0.43\ m$ is free to rotate around a fixed frictionless axle through its center (out of the page in the figure). The cylinder is initially at rest and at $t = 0$ a constant torque with magnitude $|\tau| = 9.763\ Nm$ is applied around the axis causing the cylinder to rotate.

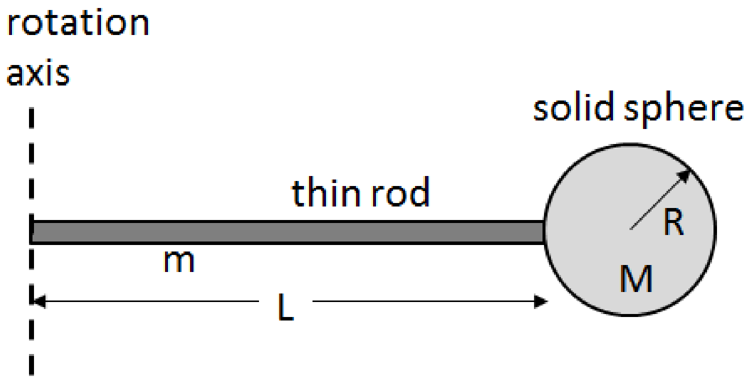
29) How many revolutions N has the cylinder made after 14.7 seconds?

a. $N = 1513$
b. $N = 378$
c. $N = 757$
d. $N = 1135$
e. $N = 504$

30) Suppose the answer to the above problem is N. If the same cylinder is restarted from rest and the magnitude of the applied torque is <u>doubled</u>, how many turns would the cylinder make in <u>half</u> the time?

a. $2N$
b. N
c. $N/2$

The next two questions pertain to the situation described below.



A uniform solid sphere having mass M and radius R is attached to the end of a uniform thin rod of length L and mass m. The moments of inertia of a rod and of a sphere are given in your formula sheet.

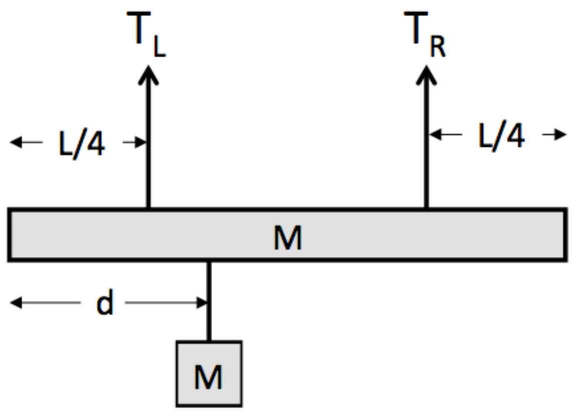
31) Which expression is correct for the moment if inertia I_{end} of the of the sphere-rod object about a perpendicular axis through the left end of the rod, as shown in the picture?

a. $I_{end} = \frac{1}{12}mL^2 + M((L+R)^2 + \frac{2}{5}R^2)$
b. $I_{end} = \frac{1}{3}mL^2 + M[(L^2 + \frac{2}{5}R^2]$
c. $I_{end} = \frac{1}{3}mL^2 + \frac{2}{5}MR^2$
d. $I_{end} = \frac{1}{12}mL^2 + M[(L^2 + \frac{2}{5}R^2]$
e. $I_{end} = \frac{1}{3}mL^2 + M((L+R)^2 + \frac{2}{5}R^2)$

32) Suppose the answer to the above problem is I_{end}. If the orientation of the rotation axis were kept the same but moved to the right so that it passed through the center of mass of the system, how would the new moment of inertia, I_{cm}, compare to I_{end}?

a. $I_{cm} > I_{end}$
b. $I_{cm} < I_{end}$
c. $I_{cm} = I_{end}$

The next three questions pertain to the situation described below.



A beam of mass M=4.3 kg and length L=5.1 m is suspended by two vertical ropes as shown. The rope on the left has tension T_L and is attached a distance $L/4$ from the left end of the beam. The rope on the right has tension T_R and is attached a distance $L/4$ from the right end of the beam. A box that has the same mass M as the beam is suspended by a short rope which it attached a distance d from the left end of the beam.

33) If the box is hung directly under the left rope (i.e. $d = L/4$), how would T_L compare to T_R?

a. $T_L = T_R$
b. $T_L > T_R$
c. $T_L < T_R$

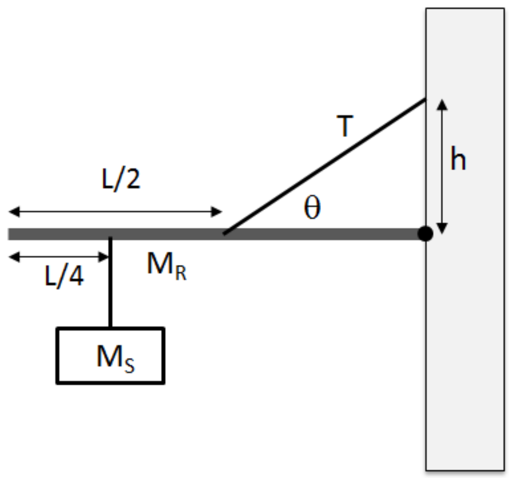
34) What is the value of d for which $T_L = \frac{3}{4}Mg$?

a. d = 3.19 m
b. d = 5.1 m
c. d = 1.7 m
d. d = 4.25 m
e. d = 1.27 m

35) If the box is hung at the right end of the beam (i.e. $d = L$), what is the value of T_R?

a. T_R = 56.24 N
b. T_R = 42.18 N
c. T_R = 84.37 N
d. T_R = 0 N
e. T_R = 63.27 N

The next three questions pertain to the situation described below.



A horizontal rod of length L and mass M_R = 1.8 kg is used to hang a sign on a wall. The right end of the rod is attached to the wall by a hinge. A wire having tension T runs from the center of the rod to a place on the wall a distance h above the hinge as shown. The wire makes an angle $\theta = 28^o$ with the rod. The sign has mass M_S = 0.6 kg and hangs distance L/4 from the end of the rod. The system is in equilibrium.

36) What is the tenstion T in the wire that runs between the wall and the rod?

a. T = 56.42 N
b. T = 18.81 N
c. T = 37.61 N
d. T = 10 N
e. T = 30 N

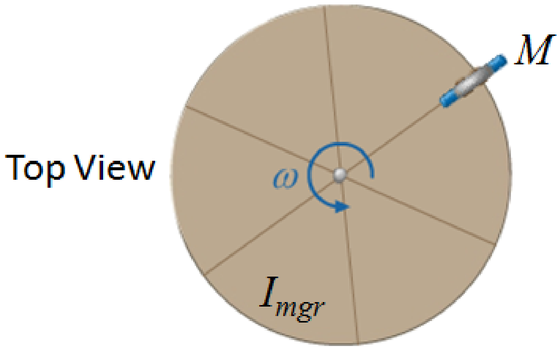
37) What is F_V, the vertical component of the force that the hinge exerts on the right end of the rod? A positive answer indicates an upward force and a negative answer indicates a downward force. Hint: Balance torques about an axis through the center of the rod.

a. F_V = -5.89 N
b. F_V = 2.94 N
c. F_V = -2.94 N
d. F_V = -4.41 N
e. F_V = 5.89 N

38) Suppose the answer to the first question on this page is T. If the wire is replaced by a longer one that runs from the **left end** of the rod to the same point on the wall a height h above the hinge, and if the rod is still horizontal, how would the new tension in the wire, T_{new}, compare to T?

a. $T_{new} < T$
b. $T_{new} > T$
c. $T_{new} = T$

The next two questions pertain to the situation described below.



A child of mass M = 40 kg is standing next to a merry-go-round having moment of inertia I_{mgr} = 834 kg-m^2 and radius R = 2.3 m. The merry-go-round is initially rotating with angular speed ω_0 = 6 rad/s. The child now jumps onto the outer edge of the merry-go-round and starts to rotate with it. You can treat the child as a point mass.

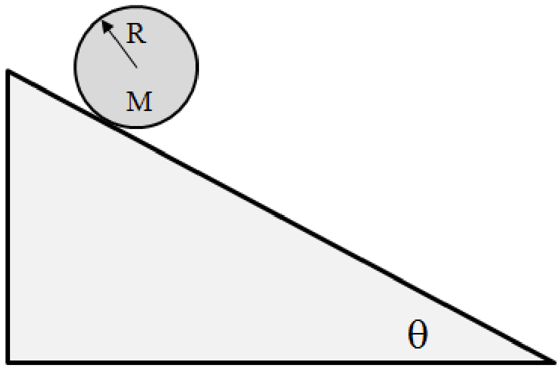
39) What is the angular speed ω of the merry-go-round after the child jumps on?

a. ω = 6.72 rad/s
b. ω = 5.36 rad/s
c. ω = 4.79 rad/s
d. ω = 6 rad/s
e. ω = 7.52 rad/s

40) Suppose the total kinetic energy of the system with the child standing on the edge of the merry go round is K_{edge}. The child now walks inward and stands at the center of the merry-go-round. How does K_{center}, the new kinetic energy of the system when the child is at the center, compare to K_{edge}?

a. $K_{center} > K_{edge}$
b. $K_{center} < K_{edge}$
c. $K_{center} = K_{edge}$

The next three questions pertain to the situation described below.



A hollow ball (spherical shell) having a mass M = 2.02 and a radius of R = 0.171 m is released from rest on a rough inclined plane which makes an angle $\theta = 30^{o}$ with the horizontal. The static frictional force causes the ball to roll without slipping as it moves down the incline.

41) What is the magnitude of the acceleration of the center of mass of the ball?

a. a = 2.94 m/s^2
b. a = 3.5 m/s^2
c. a = 1.96 m/s^2
d. a = 3.27 m/s^2
e. a = 4.9 m/s^2

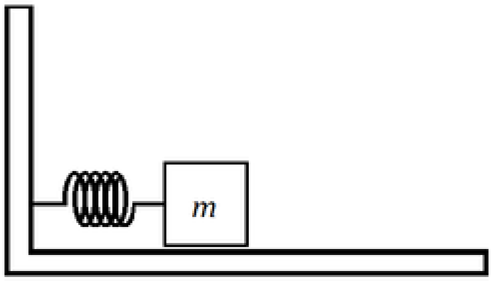
42) Suppose the magnitude of the acceleration of the ball is a. What is the magnitude of the static frictional force that the inclined plane exerts on the ball ?

a. $f > Ma$
b. $f < Ma$
c. $f = Ma$

43) Now suppose that three objects, a solid ball, a solid disk, and a hollow hoop, are simultaneously released from rest at the top of the inclined plane. The objects all roll down the plane without slipping. What is the order in which the objects arrive at the bottom of the incline?

a. The ball arrives first, then the disk, and finally the hoop.
b. The hoop arrives first, then the disk, and finally the ball.
c. The disk arrives first, then the hoop and finally the ball.

The next three questions pertain to the situation described below.



A mass m = 3 kg is placed on an ideal spring with spring constant k = 185 N/m and is free to oscillate on a horizontal surface with no friction. The mass is pulled 16 cm to the left of equilibrium and released at t = 0.

44) What is the maximum speed the mass attains as it oscillates on the spring?

a. 3.14 m/s
b. 1.78 m/s
c. 1.26 m/s
d. 0.89 m/s
e. 2.18 m/s

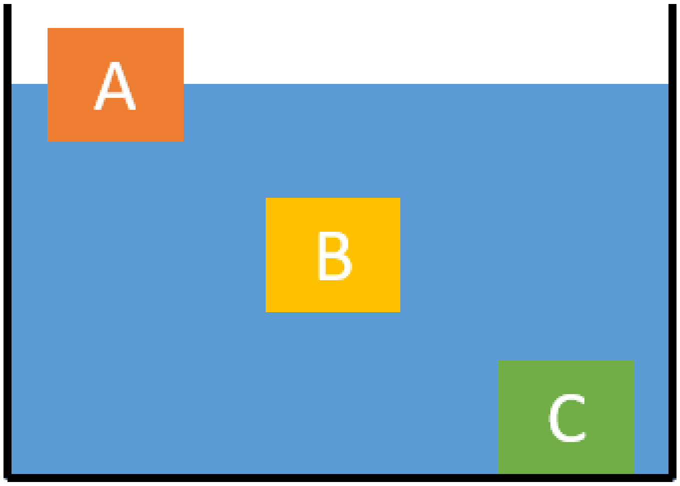
45) How much time does it take for the mass to return to equilibrium for the first time after being released at t = 0?

a. 0.2 s
b. 0.1 s
c. 0.4 s
d. 1.6 s
e. 0.8 s

46) What is the magnitude and direction of the spring force on the mass at the instant the mass is 11 cm to the right of equilibrium?

a. 0 N
b. 29.6 N to the right
c. 20.35 N to the right
d. 20.35 N to the left
e. 29.6 N to the left

The next two questions pertain to the situation described below.



Three masses are in a swimming pool filled with water (density 1000 kg/m^3). All three objects are identical in size (400 cm^3) but have different densities. Object A floats on the water (density 580 kg/m^3), Object B is completely submerged underwater but has a density equal to that of water, and Object C sinks to the bottom (density 3700 kg/m^3).

47) Compare the magnitude of the buoyant force on each block:

a. $F_A < F_B = F_C$
b. $F_A > F_B > F_C$
c. $F_A < F_B < F_C$
d. $F_A > F_B = F_C$
e. $F_A = F_B = F_C$

48) Calculate the magnitude of the normal force that acts on Object C due to the bottom of the pool:

a. 0 N
b. 18.44 N
c. 14.52 N
d. 10.59 N
e. 3.92 N

The next two questions pertain to the situation described below.

A wave has a displacement (units in meters) given by: $z = 0.25sin(0.7y - 2.3t)$

The wave travels on a string with mass density 0.056 kg/m.

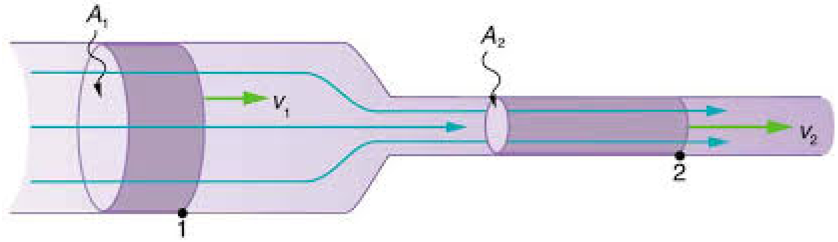
49) What direction is the wave moving?

a. -x direction
b. +y direction
c. +z direction

50) Calculate the tension in the string:

a. 0.6 N
b. 0.01 N
c. 192.78 N
d. 0.02 N
e. 0.18 N

The next two questions pertain to the situation described below.



An incompressible fluid (density 1000 kg/m^3) flows through a horizontal pipe with cross sectional area A_1 = 0.0045 m^2 and speed v_1 = 3.2 m/s. The pipe tapers down to a cross sectional area of A_2 = 0.0019 m^2.

51) As the pipe tapers down to a smaller cross sectional area the speed of the fluid:

a. increases
b. remains the same
c. decreases

52) Calculate the pressure differential of the fluid in the two areas of the pipe. (A positive answer means the pressure increases in region 2 and a negative answer means the pressure decreases in region 2.)

a. 23600 Pa
b. -2189 Pa
c. 2189 Pa
d. -23600 Pa
e. 0 Pa