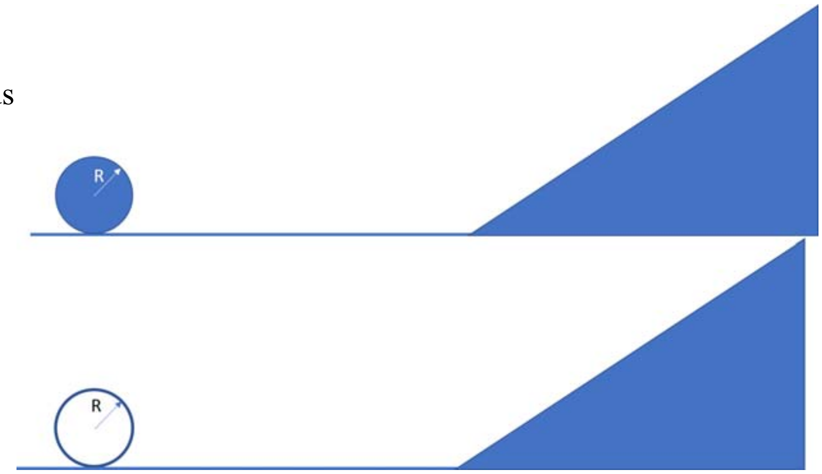
The next four questions pertain to the situation described below.

A hollow cylinder and a solid cylinder have the same outer radius $R = 0.6$ m and mass $m = 4$ kg and roll without slipping on a flat surface towards a ramp.



1) If the two cylinders initially have the same speed with respect to the flat surface and continue to roll without slipping up the ramp, which one goes further up?

a. They both go the same distance
b. The hollow cylinder
c. The solid cylinder

2) If the two cylinders initially have the same speed and roll without slipping with respect to the flat surface but there is no friction on the ramp, then which cylinder goes further up?

a. The solid cylinder
b. The hollow cylinder
c. They both go the same distance

3) The initial angular momentum of the solid cylinder is $L = 9$ kg m^2 rad/sec as it rolls without slipping along the horizontal surface. What is its total kinetic energy?

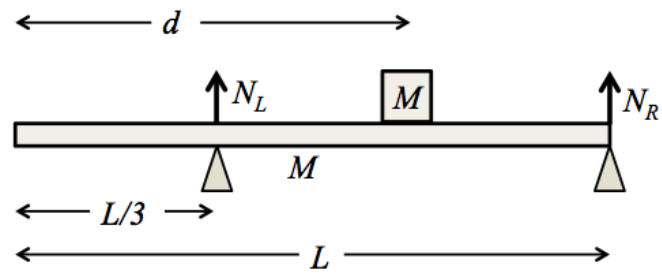
a. $K_{total} = 225$ J
b. $K_{total} = 9$ J
c. $K_{total} = 169$ J
d. $K_{total} = 112$ J
e. $K_{total} = 56.2$ J

4) If the two cylinders initially have the same angular momentum about an axis through their center and continue to roll without slipping up the ramp, which one goes further up?

a. The solid cylinder
b. They both go the same distance
c. The hollow cylinder

The next two questions pertain to the situation described below.

A beam of mass $M = 3.5\ kg$ and length $L = 3.62\ m$ rests on two supports as shown. The support on the left exerts an upward normal force N_L and is located a distance $L/3$ from the left end of the beam. The support on the right exerts an upward normal force N_R and is located at the right end of the beam. A box that has the same mass M as the beam is located a distance d from the left end of the beam.



5) If the box were located at the right side of the beam (i.e. $d = L$), how would N_L compare to N_R ?

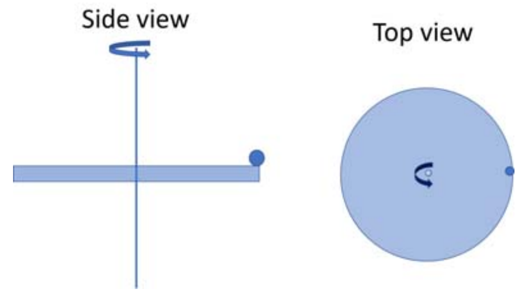
a. $N_L < N_R$
b. $N_L = N_R$
c. $N_L > N_R$

6) What is the value of d for which N_R is zero?

a. $d = 0.9\ m$
b. $d = 0.8\ m$
c. $d = 0.72\ m$
d. $d = 0.6\ m$
e. $d = 0.67\ m$

The next four questions pertain to the situation described below.

A solid disk with mass $M = 18$ kg and radius $R = 1.3$ m spins around a vertical axis through the disk's center. A device of negligible mass is mounted at the disk's edge for catching, holding, moving, or releasing a ball. The mass of the ball $m = 1.4$ kg, and can be treated as a point mass.



7) If the disk is initially spinning with the ball held in place, and then the ball is simply released, what happens to the spinning disk?

a. The disk continues to spin at the same speed.
b. The disk spins slower.
c. The disk spins faster.

8) The disk is initially spinning with the ball held in place at the edge of the disk, with total angular momentum for the disk and ball $L = 90$ kg m^2 rad/sec, then the device moves the ball to the center of the disk. What is the minimum amount of work that the device does during this process?

a. $W = -19.2$ J
b. $W = 19.2$ J
c. $W = 35.8$ J
d. $W = -41.4$ J
e. $W = 41.4$ J

9) Now the disk is initially spinning without the ball with the angular speed $\omega_0 = 1.3$ rad/s in the counterclockwise direction, as seen from above. A ball is thrown at $v_0 = 3$ m/s (relative to the ground) and is caught at the edge of the disk on the side that is moving exactly in the same direction as the ball as shown in the figure. What is the final angular speed of the system?

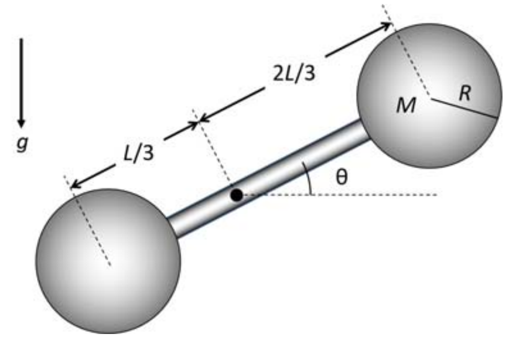
a. $\omega_f = 1.44$ rad/s
b. $\omega_f = 0.814$ rad/s
c. $\omega_f = 1.13$ rad/s
d. $\omega_f = 0.721$ rad/s
e. $\omega_f = 1.37$ rad/s

10) Compare the total mechanical energy of the disk and ball before the ball is caught by the disk with the total mechanical energy of the disk and ball after the ball is caught by the disk.

a. $KE_{before} = KE_{after}$
b. $KE_{before} < KE_{after}$
c. $KE_{before} > KE_{after}$

The next three questions pertain to the situation described below.

Two identical solid spheres of mass $M = 1.8$ kg and radius $R = 0.8$ m are connected by a massless rod of length $L = 3.6$ m. The system can rotate about a pivot axis directed into the page located $L/3$ from the center of the left mass. The system is tilted relative to the horizontal by an angle $\theta = 20°$. Gravity acts down as shown in the figure.



11) What is the moment of inertia I of the system about the rotation axis?

a. $I = 13$ kg m^2
b. $I = 13.9$ kg m^2
c. $I = 6.75$ kg m^2

12) What is the direction of the torque due to gravity on the system about the axis of rotation at the instant shown?

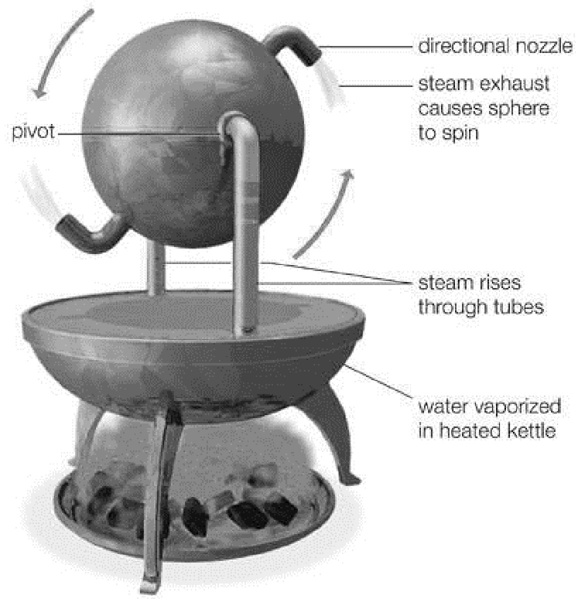
a. Out of the page
b. To the right
c. Down
d. To the left
e. Into the page

13) What is the magnitude of the torque due to gravity on the system about the axis of rotation at the instant shown?

a. $|\tau| = 21.7$ N m
b. $|\tau| = 7.25$ N m
c. $|\tau| = 19.9$ N m
d. $|\tau| = 59.7$ N m
e. $|\tau| = 21.2$ N m

The next two questions pertain to the situation described below.

An early example of a steam engine (called "Hero's engine") consists of a spherical shell filled with steam as shown in the figure. Two nozzles direct steam exhaust in opposite directions, causing the shell to rotate about an axis through its center. The spherical shell has mass $M = 0.7$ kg and radius $R = 0.13$ m. Assume for simplicity that the nozzles have negligible mass.



14) If each nozzle generates a thrust force $F = 4.3$ N, how long does the engine take to make one rotation when started from rest?

a. $t = 0.365$ s
b. $t = 0.119$ s
c. $t = 0.399$ s
d. $t = 0.298$ s
e. $t = 0.107$ s

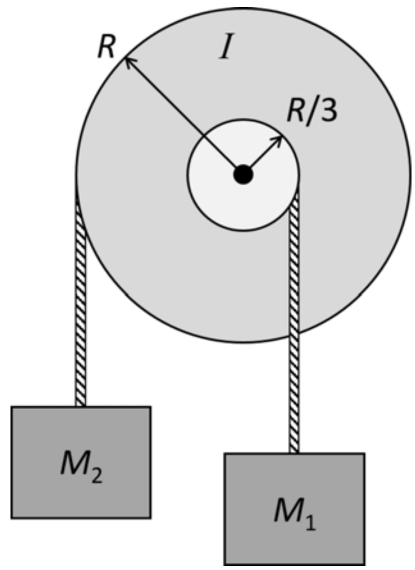
15) Now suppose the nozzle masses are no longer negligible. How would the time above change?

a. t would increase
b. t would decrease
c. t would remain the same.

The next two questions pertain to the situation described below.

A pulley system is made up of two rigidly connected, concentric solid cylinders of radius $R = 0.8$ m and $R/3$. The moment of inertia for the pulley system is $I = 5.2$ kg m^2.

A mass M_2 is attached to a massless string wrapped around the outer cylinder, while mass $M_1 = 5.8$ kg is attached to a massless string wrapped around the inner cylinder, as shown in the figure.



16) What must the mass M_2 be for the system to remain at rest?

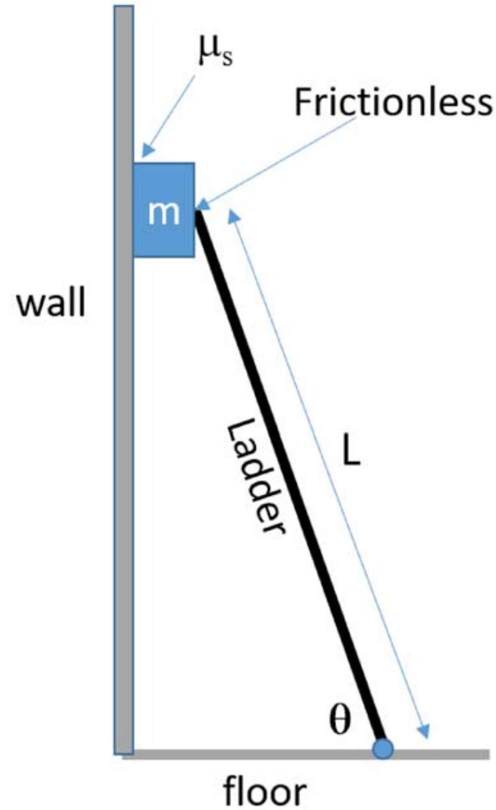
a. $M_2 = 0.644$ kg
b. $M_2 = 17.4$ kg
c. $M_2 = 3.35$ kg
d. $M_2 = 1.93$ kg
e. $M_2 = 10$ kg

17) Now the string attached to mass M_2 is cut. What is the acceleration a of mass M_1?

a. $a = 8.5$ m/s^2
b. $a = 1.9$ m/s^2
c. $a = 4.1$ m/s^2
d. $a = 0.78$ m/s^2
e. $a = 0.72$ m/s^2

The next two questions pertain to the situation described below.

A ladder is attached to a hinge on the floor and is leaning against a box pressing the box against a vertical wall. Friction between the wall and the box ($\mu_s = 0.43$) prevents the box from slipping. There is no friction between the ladder and the box. The ladder has length $L = 4.5$ m, mass $M = 7.5$ kg, and makes and angle $\theta = 50°$ with the horizontal floor as shown in the figure. The box has mass m.



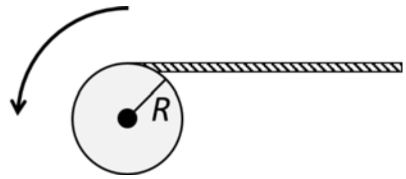
18) What is the magnitude of the torque about the hinge due to the weight of the ladder ?

a. $\tau = 106$ N m
b. $\tau = 166$ N m
c. $\tau = 127$ N m

19) What is the maximum mass the box can have before it starts sliding down the wall?

a. $m = 2.1$ kg
b. $m = 1.35$ kg
c. $m = 1.04$ kg
d. $m = 4.47$ kg
e. $m = 1.61$ kg

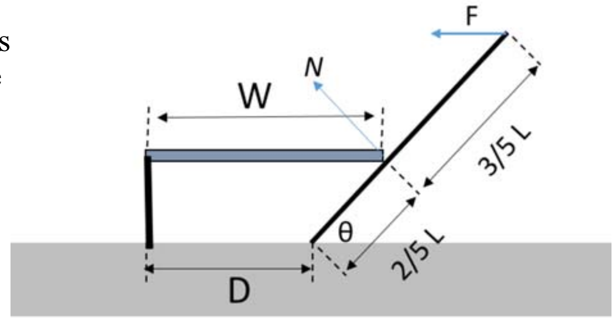
20) A winch of radius $R = 7$ cm is used to reel in a fishing line on a boat. The winch rotates, accelerating from rest for a time duration of 1 s with a constant angular acceleration α up to an angular velocity $\omega_{max} = 2.6$ rad/s. After 1 s, the angular velocity remains constant at 2.6 rad/s. How much of the fishing line is reeled in after 6 s?



a. 1.09 m
b. 1 m
c. 0.182 m
d. 1.18 m
e. 0.91 m

The next two questions pertain to the situation described below.

A clever physics student uses a massless lever of length L to support one side of a bench with width W and mass M so that it is parallel to the ground. The lever makes an angle $\theta = 18°$ with the horizontal ground. The distance between the lever-ground and the lever-plate contacts is 2/5 L as shown in the figure. There is no friction force acting at the plate-lever contact point, but the lever does provide a normal force of $N = 35$ N on the edge of the bench. (Note, the point of contact of the lever with the ground remains fixed).



21) What is the mass M of the bench? (Hint, use left support of bench as your axis of rotation.)

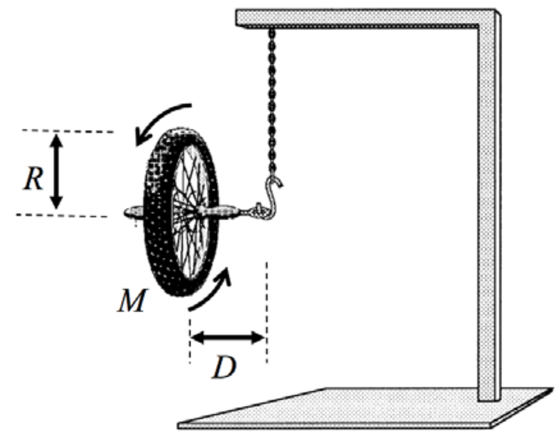
a. $M = 70$ kg
b. $M = 6.79$ kg
c. $M = 2.21$ kg

22) What is the magnitude of the horizontal force F that the student must apply to the end of the massless lever?

a. $F = 14.7$ N
b. $F = 33.3$ N
c. $F = 45.3$ N
d. $F = 43.1$ N
e. $F = 14$ N

The next two questions pertain to the situation described below.

A gyroscope made from a bike wheel hangs from a stationary rope as shown. The wheel spins around a horizontal axle through its center in such a way that the top of the wheel is moving out of the page and the bottom of the wheel is moving into the page. The rope is attached to one end of the axle at a distance D from the wheel.



23) At the instant shown, what is the direction of the torque on the wheel due to gravity? (Use the point where the axle connects to the hook as the axis of rotation.)

a. Out of page.
b. Into the page.

24) At the instant shown, which way is the center of the wheel moving?

a. Out of the page.
b. Into the page.