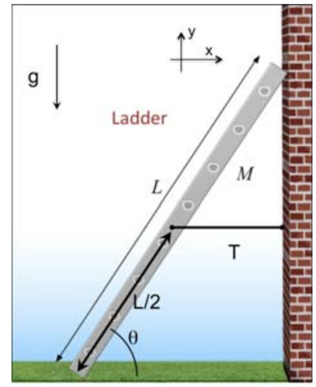
**The next four questions pertain to the situation described below.**

A ladder of length $L$ and mass $M$ leans against a wall, making an angle $\theta = 29$ degrees with the horizontal as shown in the figure. A horizontal cable with tension $T = 250$N is anchored to the wall, and attached to the center of the ladder. The bottom of the ladder rests on a frictionless surface; there is also no friction between the ladder and the wall. The system remains in equilibrium.




1) What is the $x$-component of the force applied by the ladder to the wall?

a. $F_{\text{ladder,wall-}x} = 125$ N
b. $F_{\text{ladder,wall-}x} = 121$ N
c. $F_{\text{ladder,wall-}x} = 286$ N
d. $F_{\text{ladder,wall-}x} = 219$ N
e. $F_{\text{ladder,wall-}x} = 250$ N

2) How does the magnitude of the torque produced by the weight of the ladder about the ladder-ground contact, $\tau_{\text{ladder,ground}}$, compare with the torque produced by the weight of the ladder about the ladder-wall contact, $\tau_{\text{ladder,wall}}$?

a. $|\tau_{\text{ladder,ground}}| > |\tau_{\text{ladder,wall}}|$
b. $|\tau_{\text{ladder,ground}}| < |\tau_{\text{ladder,wall}}|$
c. $|\tau_{\text{ladder,ground}}| = |\tau_{\text{ladder,wall}}|$

3) What is the mass of the ladder?

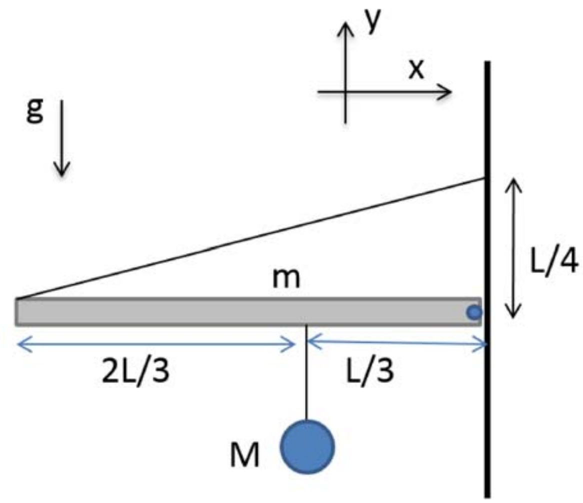
a. $M = 14$ kg
b. $M = 26$ kg
c. $M = 29$ kg
d. $M = 46$ kg
e. $M = 53$ kg

4) A person is now climbing the ladder. Compare the tension in the cable when the person is on the bottom step of the ladder, with the tension in the cable when the person is on the top step of the ladder.

a. $T_{\text{bottom}} = T_{\text{top}}$
b. $T_{\text{bottom}} < T_{\text{top}}$
c. $T_{\text{bottom}} > T_{\text{top}}$

**The next three questions pertain to the situation described below.**

A beam of mass $m$ = 24 kg and length L is hinged and extends outward perpendicular to a wall, as shown. A string is attached to the end of the beam with its other end attached to the wall a distance $L/4$ above the hinge. The tension in that string is $T$ = 710 N. A mass $M$ hangs a distance $L/3$ from the hinged end of the beam.




5) What is the $x$-component of the force exerted by the hinge on the beam?

a. $F_x$ = 172 N
b. $F_x$ = 689 N
c. $F_x$ = 532 N

6) Determine the mass $M$ hanging from the beam.

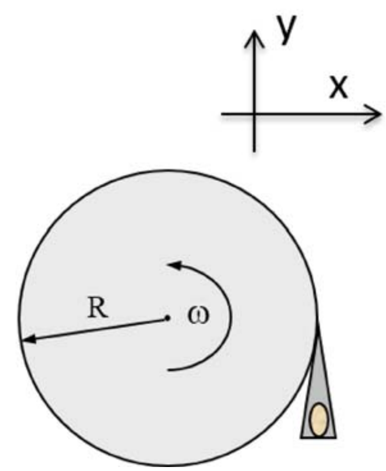
a. $M$ = 29 kg
b. $M$ can not be determined unless a value for $L$ is provided.
c. $M$ = 11 kg
d. $M$ = 170 kg
e. $M$ = 17 kg

7) If the mass $M$ is moved to the left so that it hangs from the beam at a distance $L/2$ from the hinge, the **horizontal** component of the force exerted by the **hinge** on the beam will be

a. larger than when the mass was at $L/3$
b. the same as when the mass was at $L/3$
c. smaller than when the mass was at $L/3$

**The next three questions pertain to the situation described below.**

A cylindrical grindstone of mass $m$ = 18 kg and radius $R$ = 0.6 m is initially rotating freely at 29π radians/s. An axe is brought into contact with the grindstone which brings it to a stop after 30 revolutions.




8) What is the magnitude of the angular acceleration of the grindstone?

a. $\alpha$ = 0.154 radians/s$^2$
b. $\alpha$ = 14.5 radians/s$^2$
c. $\alpha$ = 22 radians/s$^2$
d. $\alpha$ = 0.967 radians/s$^2$
e. $\alpha$ = 3.04 radians/s$^2$

9) What is the magnitude of the frictional force of the axe on the grindstone?

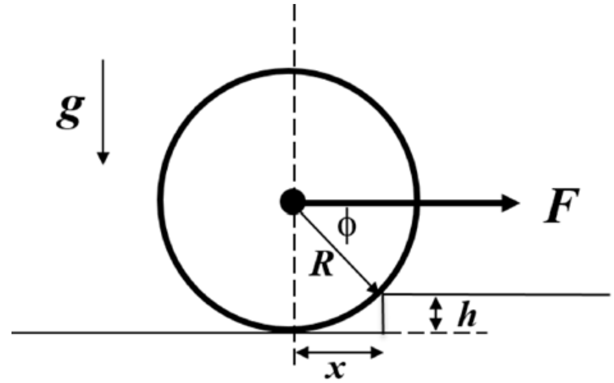
a. $f$ = 119 N
b. $f$ = 396 N
c. $f$ = 374 N
d. $f$ = 298 N
e. $f$ = 238 N

10) What is the direction of the <u>torque</u> due to the frictional force of the axe on the grindstone?

a. -$y$
b. -$z$ (into page)
c. -$x$

**The next two questions pertain to the situation described below.**

A wheel of mass $M = 2.1$ kg and radius $R$ rests on a horizontal surface against a vertical step of height $h$. A point below the center of the wheel is a distance $x$ from the vertical step. The wheel is to be raised over the step by a horizontal force $F$ applied to the axle of the wheel as shown in the figure. The angle between the horizontal force and a line connecting the center of the wheel and the point of contact with the step is $\varphi = 65$ degrees.




11) Which expression gives the magnitude of the torque that gravity exerts on the wheel about the point of contact between the wheel and the step?

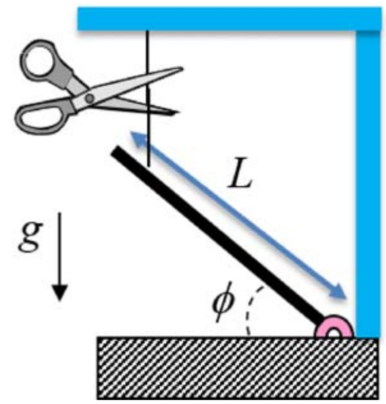
a. $\tau = M\,g\,R\sin(\varphi)$
b. $\tau = M\,g\,R$
c. $\tau = M\,g\,R\cos(\varphi)$

12) What is the minimum horizontal force $F$ needed to raise the wheel over the step?

a. $F = 9.6$ N
b. $F = 20.6$ N
c. $F = 8.7$ N
d. $F = 18.7$ N
e. $F = 44.1$ N

**The next two questions pertain to the situation described below.**

A uniform rod of mass $M = 2.1$ kg and length $L = 0.6$ m is attached to the floor with a frictionless pivot and is suspended by a string. The initial angle of the rod with respect to the ground $\varphi = 35$ degrees. The string is then cut.




13) What is the angular acceleration of the rod immediately after the string is cut?

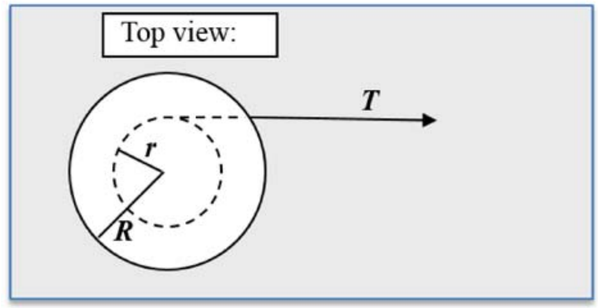
a. $\alpha = 20.1$ rad/s$^2$
b. $\alpha = 10$ rad/s$^2$
c. $\alpha = 49$ rad/s$^2$
d. $\alpha = 28.1$ rad/s$^2$
e. $\alpha = 14.1$ rad/s$^2$

14) What is the angular velocity of the rod just before it becomes horizontal and hits the ground?

a. $\omega = 5.3$ rad/s
b. $\omega = 2.6$ rad/s
c. $\omega = 7.5$ rad/s
d. $\omega = 10.6$ rad/s
e. $\omega = 8.96$ rad/s

**The next two questions pertain to the situation described below.**

A spool of mass $M = 0.23$ kg rests on its flat side on a frictionless horizontal table, as shown in the figure. A thread wound around the spool is pulled with a force $T = 0.16$ N to the right. The moment of inertia about the center of mass of the spool is $I = 4.6 \times 10^{-5}$ kg m$^2$, its outer radius $R = 0.024$ m and its inner radius $r = 0.016$ m. The spool is initially at rest.




15) What is the angular acceleration about the center of mass of the spool as the thread is pulled?

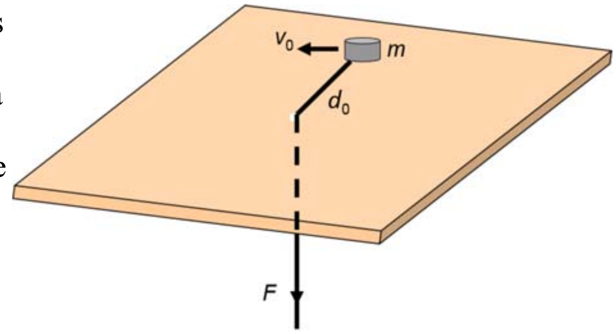
a. $\alpha = 83.5$ rad/s$^2$
b. $\alpha = 55.7$ rad/s$^2$
c. $\alpha = 61$ rad/s$^2$

16) What is the linear acceleration of the center of mass of the spool as the thread is pulled?

a. $a = 0.696$ m/s$^2$
b. $a = 0.891$ m/s$^2$
c. $a = 1.34$ m/s$^2$

**The next two questions pertain to the situation described below.**

A small disk of mass $m$ is on a horizontal, frictionless table. It is attached to a string, which passes through a hole on the table. The other end of the string is slowly pulled vertically down by a force of magnitude $F$. Initially, the disk is in circular motion about the hole, when the length of the string from the hole to the disk is $d_0$ and the orbital speed of the disk is $v_0$, as shown in the figure.




17) As the string is pulled down which statement best describes the conserved quantities?

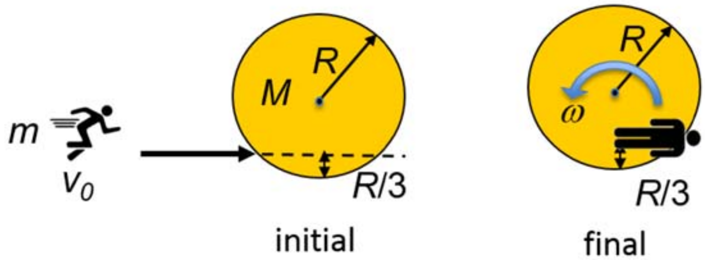
a. Both, the kinetic energy and the angular momentum of the disk are conserved.
b. The angular momentum of the disk is conserved.
c. The kinetic energy of the disk is conserved.

18) When the length of the string from the hole to the disk has decreased by a factor of 2, the speed $v_f$ of the disk is equal to:

a. $v_f = v_0 + (gd_0)^2$
b. $v_f = 4v_0$
c. $v_f = 2v_0$

**The next three questions pertain to the situation described below.**

A person of mass $m$ = 65 kg is running with speed $v_0$ = 5 m/s towards a merry-go-round with mass $M$, radius $R$ and moment of inertial $I$ that is at rest. The person jumps and lands a distance $R/3$ from the edge of the merry-go-round. The person and merry-go-round spin with angular velocity $\omega$ = 1.37 rad/s as shown in the figure. The total moment of inertia for the person and merry-go-round is $I_{total}$ = 300 kg m$^2$




19) What is the radius $R$ of the merry-go-round?

a. $R$ = 0.43 m
b. $R$ = 1.9 m
c. $R$ = 1.3 m

20) How much mechanical energy is dissipated by friction when the person lands on the merry-go-round?

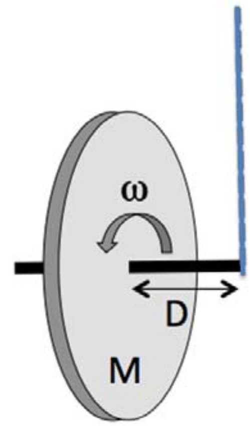
a. $W_f$ = 626.2 J
b. $W_f$ = 531 J
c. $W_f$ = 281.5 J

21) If the process is repeated by a person with twice the mass, the resulting angular velocity $\omega$ of the person and merry-go-round will be

a. more than twice as fast.
b. twice as fast.
c. less than twice as fast.

**The next three questions pertain to the situation described below.**

A gyroscope made from a solid disk of mass $M = 2.63$ kg and radius $R$ hangs from a vertical rope attached to the ceiling. The disk spins with angular velociy $\omega =$ 15.2 rad/s around a horizontal axle through its center in the direction shown by the arrow, and the rope is attached to one end of this axle at a distance $D$ from the center of mass of the disk.




The angular momentum of the spinning disk is $L = 64.9$ kg-m$^2$/s. The time it takes the gyroscope to make one complete revolution in the horizontal plane (its precession period) is 11.4 seconds.

22) What is the moment of inertia of the spinning disk?

a. $I = 2.63$ kg-m$^2$
b. $I = 1.46$ kg-m$^2$
c. $I = 4.27$ kg-m$^2$

23) What is the distance $D$ between the gyroscope and the rope?

a. $D = 2.91$ m
b. $D = 3.65$ m
c. $D = 1.39$ m
d. $D = 0.44$ m
e. $D = 0.69$ m

24) Suppose the same gyroscope is moved to the surface of a new planet where the acceleration of gravity on the surface is smaller than it is on the Earth. How does the precession period change?

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