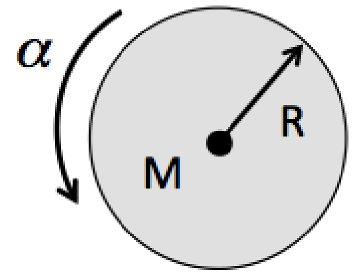
The next three questions pertain to the situation described below.

A wheel is made from a solid cylinder of mass M = 3.5 kg and radius R = 1.3 m. It can rotate without friction around a central axis (out of the page). The wheel is initially at rest and at $t = 0$ a constant torque τ is applied around the axis, causing the wheel to rotate with an angular acceleration α = 3.5 rad/s^2.



1) What is the magnitude of the applied torque?

a. τ = 1.69 N-m
b. τ = 1.18 N-m
c. τ = 0.59 N-m
d. τ = 10.35 N-m
e. τ = 20.7 N-m

2) How many revolutions N has the wheel made after 25 seconds?

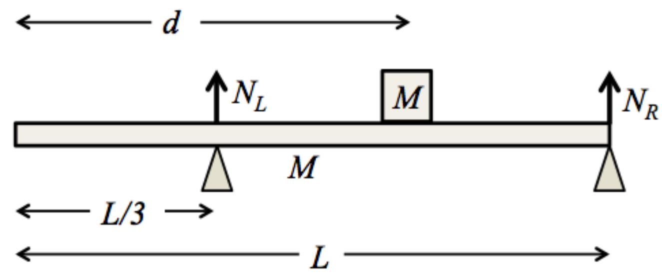
a. $N = 348.2$
b. $N = 174.1$
c. $N = 696.3$
d. $N = 1093.8$
e. $N = 2187.5$

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

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

The next three questions pertain to the situation described below.

A beam of mass $M = 5.4\ kg$ and length $L = 3.72\ m$ 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.



4) 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. $N_L > N_R$

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

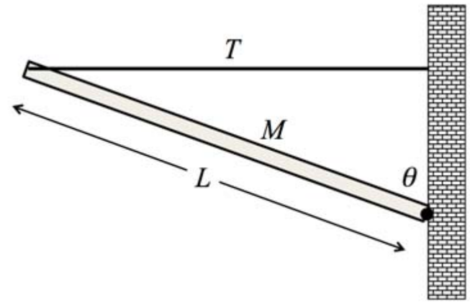
a. $d = 0.93\ m$
b. $d = 0.83\ m$
c. $d = 0.74\ m$
d. $d = 0.62\ m$
e. $d = 0.69\ m$

6) If the box is located halfway between the supports (i.e. $d = 2L/3$), what is the value of N_R?

a. $N_R = 26.49\ N$
b. $N_R = 39.73\ N$
c. $N_R = 52.97\ N$
d. $N_R = 17.66\ N$
e. $N_R = 35.32\ N$

The next four questions pertain to the situation described below.

A beam of mass $M = 2.5$ kg and length $L = 3.2$ m is attached to a vertical wall by a hinge at its lower end and a horizontal massless wire at its top end, as shown in the diagram. The angle between the wall and the beam is $\theta = 61$.



7) What is the tension in the wire ?

a. $T = 13.6$ N
b. $T = 11.89$ N
c. $T = 6.8$ N
d. $T = 22.1$ N
e. $T = 44.2$ N

8) If the attachment point of the wire on the wall were moved upward by half a meter, but M, L and θ were the same as in the above question, how would the tension in the wire change? (Note that a longer wire is required to move the attachment point this way.)

a. It would decrease.
b. It would stay the same.
c. It would increase.

9) Now suppose the wire breaks and the beam starts to rotate around the hinge. What is α_0, the magnitude of the angular acceleration of the beam about the hinge immediately after the wire breaks?

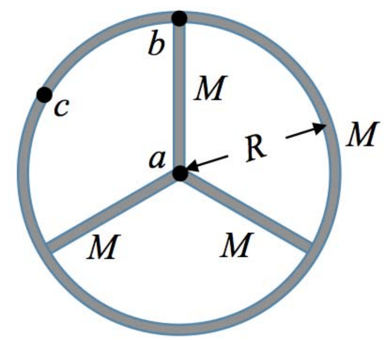
a. $\alpha_0 = 2.68$ rad/s^2
b. $\alpha_0 = 1.79$ rad/s^2
c. $\alpha_0 = 1.53$ rad/s^2
d. $\alpha_0 = 3.07$ rad/s^2
e. $\alpha_0 = 4.02$ rad/s^2

10) If the beam were shorter, but M and θ were the same as above, how would the answer to the above question change ?

a. The magnitude of α_0 would be bigger.
b. The magnitude of α_0 would be smaller.
c. The magnitude of α_0 would be the same.

The next three questions pertain to the situation described below.

A wheel is made by combining a hoop of radius R and mass M with three spokes, each a thin rod of length R and mass M.



11) What is the moment of inertia of the wheel for rotations around an axis through its center and perpendicular to the page, labeled a in the diagram?

a. $I_a = 4MR^2$
b. $I_a = 2MR^2$
c. $I_a = 3MR^2$
d. $I_a = 6MR^2$
e. $I_a = MR^2$

12) Suppose the answer to the above question is I_a. What is the moment of inertia of the wheel for rotations around the axis labeled b in the diagram? (The b axis is perpendicular to the page and passes through the rim of the wheel at the end of one of the spokes).

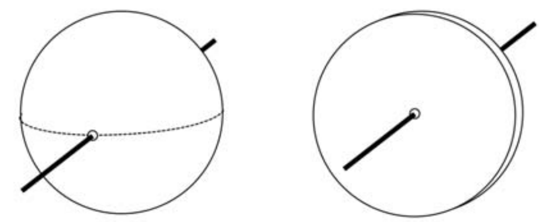
a. $I_b = I_a + 3MR^2$
b. $I_b = I_a + MR^2$
c. $I_b = I_a + 4MR^2$

13) The c axis is perpendicular to the page and passes through the rim of the wheel halfway between two spokes, as shown in the diagram. The moment of inertia for rotations around the c axis is I_c. How does I_c compare to I_b?

a. $I_c = I_b$
b. $I_c > I_b$
c. $I_c < I_b$

The next four questions pertain to the situation described below.

A solid sphere of mass m and radius r is mounted on an axle that passes through the center of the sphere. A solid disk, also of mass m and radius r, is mounted on a second axle which passes through the center of the disk and is perpendicular to the face of the disk.



14) If both objects are spinning around their axles with the same angular velocity ω_0, what is the ratio of their angular momentum L_{sphere}/L_{disk}?

a. L_{sphere}/L_{disk} = 2/5
b. L_{sphere}/L_{disk} = 3/5
c. L_{sphere}/L_{disk} = 3/4
d. L_{sphere}/L_{disk} = 5/3
e. L_{sphere}/L_{disk} = 4/5

15) How does the ratio of the kinetic energy of the objects compare to the ratio of the angular momentum of the objects ?

a. $K_{sphere}/K_{disk} = L_{sphere}/L_{disk}$
b. $K_{sphere}/K_{disk} > L_{sphere}/L_{disk}$
c. $K_{sphere}/K_{disk} < L_{sphere}/L_{disk}$

16) Now suppose the solid sphere is released so that it rolls without slipping along a horizontal floor. What is the ratio of its translational kinetic energy to its total kinetic energy?

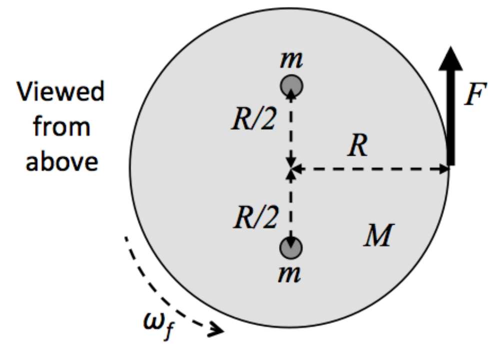
a. K_{trans}/K_{total} = 3/5
b. K_{trans}/K_{total} = 1/5
c. K_{trans}/K_{total} = 2/5
d. K_{trans}/K_{total} = 3/4
e. K_{trans}/K_{total} = 5/7

17) Now suppose that both objects roll without slipping along a horizontal floor. If they move with the same speed, which one has the bigger total kinetic energy?

a. The disk and the solid sphere have the same total kinetic energy.
b. The disk has the bigger total kinetic energy.
c. The solid sphere has the bigger total kinetic energy.

The next three questions pertain to the situation described below.

A playground ride consists of a uniform disk of mass M = 35 kg and radius R = 1.3 m that can rotate in the horizontal plane around a frictionless axle through its center. Two children, each having mass m, are sitting on opposite sides of the disk, halfway between the center and the edge. The combined moment of inertia of the ride and the children in this configuration is $I_{initial}$ = 50.7 kg-m^2. Treat the children as point masses.



18) What is the mass of each child?

a. m = 50 kg
b. m = 25 kg
c. m = 60 kg
d. m = 12.5 kg
e. m = 6.25 kg

19) Once the disk reaches its final angular velocity the parent stops pushing and steps away from the ride. One child now crawls to the center of the disk, and the other child crawls out to the edge of the disk. The final combined moment of inertia of the disk and the children in this new configuration is I_{final}. How does I_{final} compare to $I_{initial}$?

a. $I_{final} = I_{initial}$
b. $I_{final} < I_{initial}$
c. $I_{final} > I_{initial}$

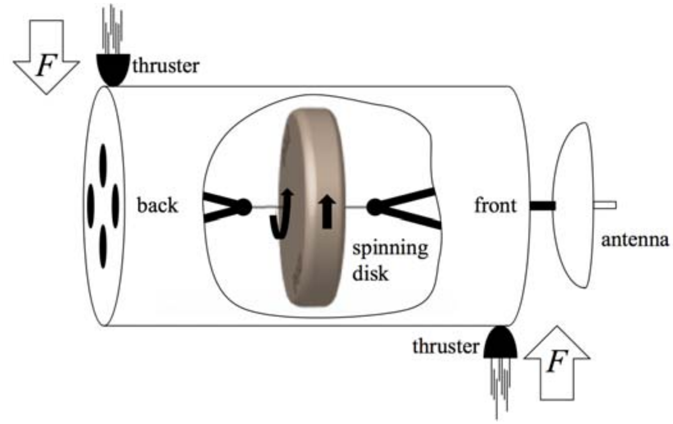
20) As the children crawl to their new positions on the disk, which of the following statements best describes the system composed of the disk and the children ?

a. Both the kinetic energy and the angular momentum of the system are conserved.
b. The angular momentum of the system is conserved but the kinetic energy is not.
c. The kinetic energy of the system is conserved but the angular momentum is not.

The next three questions pertain to the situation described below.

A space probe is motionless in interstellar space. It contains a massive disk rotating rapidly around the central axis of the probe. The direction of rotation of the disk, as indicated by the black arrows in the diagram, is counter-clockwise as viewed from the back of the probe.

At time t = 0 a pair of small identical thrusters begin firing, pushing down on the back side of the probe and up on the front side of the probe. The forces provided by the two thrusters are always equal in magnitude and opposite in direction.



21) While the thrusters are firing, at the instant shown in the diagram, which of the following statements is true?

a. The net force on the space probe *is not zero*, and the net torque on the space probe about an axis perpendicular to the page through the center of the disk *is also not zero*.
b. The net force on the space probe *is not zero*, but the net torque on the space probe about an axis perpendicular to the page through the center of the disk *is zero*.
c. The net force on the space probe *is zero*, but the net torque on the space probe about an axis perpendicular to the page through the center of the disk *is not zero*.

22) After the thrusters have been firing for several minutes, the probe has rotated by approximately 90 degrees. As a result, the antenna at the front of the probe (which was initially pointing towards the right side of the page) is now pointing

a. towards the bottom of the page.
b. into the page.
c. out of the page.
d. towards the left side of the page.
e. towards the top of the page.

23) If the angular velocity of the disk had been increased by a factor of 4 before the thrusters began firing, the time required to achieve a 90 degree rotation would have

a. increased by a factor of 16.
b. increased by a factor of 2.
c. increased by a factor of 4.