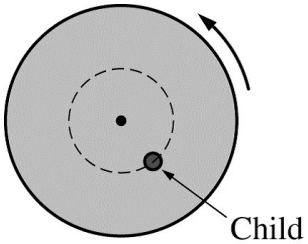
chapter7part b

1.



Top View

The diagram above shows a top view of a child of mass *M* on a circular platform of mass 5*M* that is rotating counterclockwise. Assume the platform rotates without friction. Which of the following describes an action by the child that will result in an increase in the total angular momentum of the child-platform system?

(A) The child moves toward the center of the platform.

(B) The child moves away from the center of the platform.

(C) The child moves along a circle concentric with the platform (dashed line shown) opposite the direction of the platform's rotation.

(D) None of the actions described will change the total angular momentum of the child-platform system.

2. A disk of known radius and rotational inertia can rotate without friction in a horizontal plane around its fixed central axis. The disk has a cord of negligible mass wrapped around its edge. The disk is initially at rest, and the cord can be pulled to make the disk rotate. Which of the following procedures would best determine the relationship between applied torque and the resulting change in angular momentum of the disk?

(A) Pulling on the cord, exerting a force of 15 N for 2 s and then 25 N for 3 s, and measuring the final angular velocity of the disk

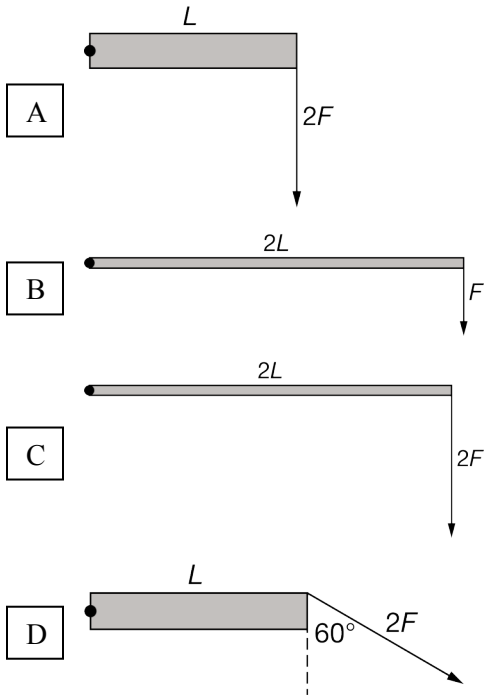
(B) For five different time intervals, pulling on the cord, exerting a force of 15 N, and then measuring the angle through which the disk rotates in each case

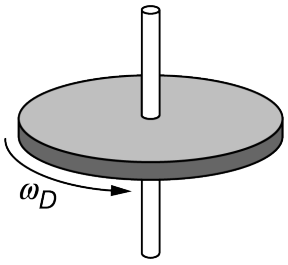
(C) For five different time intervals, pulling on the cord, exerting a force of 15 N, and then measuring the final angular velocity of the disk

(D) For five forces of different magnitude, pulling on the cord for 5 s, and then measuring the final angular velocity of the disk

3. Four rods, each of mass M, are pinned at the left end to the horizontal surface of a table and are shown from above in the following figures. Each rod is free to rotate about a pivot at its left end with negligible friction. In each case, forces are exerted on the rod with different magnitudes and in different directions as shown. The rotational inertia of a rod of mass M and length L about the end of the rod is $(1/3)ML^2$. In which cases do the rods experience equal initial angular accelerations? Select two answers.

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A disk-shaped platform has a known rotational inertia I_D. The platform is mounted on a fixed axle and rotates in a horizontal plane with an initial angular velocity of ω_D in the counterclockwise direction, as shown. After an unknown time interval, the disk comes to rest. A single point on the disk revolves around the center axle hundreds of times before the disk comes to rest. Frictional forces are considered to be constant.

4. A student must determine the angular impulse that frictional forces exert on the disk from the moment it rotates with angular velocity in the counterclockwise direction until it stops. What additional data, if any, should a student collect to determine the angular impulse on the disk? Justify your selection.

(A) The time interval in which the net torque is applied, because a net torque is not exerted on the disk at a single instant in time.

(B) The net torque exerted on the disk, because a net torque is responsible for an angular impulse.

(C) The force of friction exerted on the disk, because a force component perpendicular to the line connecting the axis of rotation and the point of application of the force results in a torque about that axis.

(D) No additional data are necessary, because the rotational inertia of the disk and its initial angular velocity are known.

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5. A student must determine the angular impulse that frictional forces exert on the disk from the moment it rotates with angular velocity ω_D in the counterclockwise direction until it stops. Which of the following could the student have used in order to approximate the initial angular velocity of the rotating disk?

(A) A motion sensor to collect data about the disk's linear position as a function of time after the disk was set into motion

(B) A motion sensor to collect data about the disk's angular position as a function of time after the disk was set into motion

(C) A slow-motion camera that filmed the disk to determine the amount of time it took a particular point on the disk to make its first revolution after the disk was set into motion

(D) A stopwatch to determine the amount of time it took a particular point on the disk to make all of its revolutions from the instant in time when the disk was set into motion to the instant in time when the disk came to rest

6. In a different experiment, the original disk is replaced with a disk for which frictional forces are considered to be negligible. The disk is set into motion such that it rotates with a constant angular speed. As the disk spins, a small sphere of clay is dropped onto the disk, and the sphere sticks to the disk. Which of the following claims is correct about the angular momentum and the total kinetic energy of the disk-sphere system immediately before and immediately after the collision?

(A)

Angular Momentum	Kinetic Energy
Greater before the collision	Greater before the collision

(B)

Angular Momentum	Kinetic Energy
Greater before the collision	The same before and after the collision

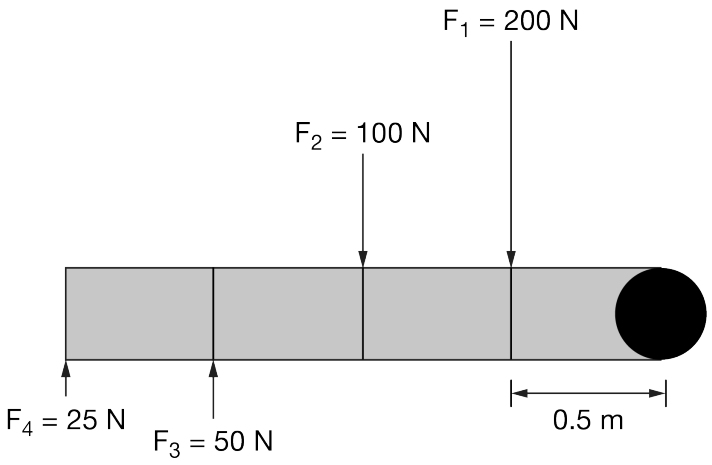
(C)

Angular Momentum	Kinetic Energy
The same before and after the collision	Greater before the collision

(D)

Angular Momentum	Kinetic Energy
The same before and after the collision	The same before and after the collision

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The figure above represents a stick of uniform density that is attached to a pivot at the right end and has equally spaced marks along its length. Any one or a combination of the four forces shown can be exerted on the stick as indicated.

7. All four forces are exerted on the stick that is initially at rest. What is the angular momentum of the stick after 2.0 s ?

(A) $150\ \frac{\text{kg}\cdot\text{m}^2}{\text{s}}$

(B) $450\ \frac{\text{kg}\cdot\text{m}^2}{\text{s}}$

(C) $650\ \frac{\text{kg}\cdot\text{m}^2}{\text{s}}$

(D) $750\ \frac{\text{kg}\cdot\text{m}^2}{\text{s}}$

8. Which of the four forces, when exerted in the absence of the other three forces, will change the angular momentum of the stick at the smallest rate?

(A) F_1

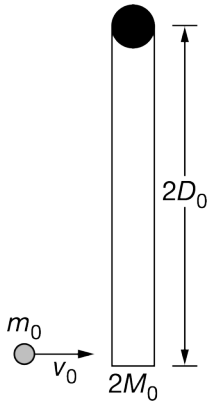
(B) F_2

(C) F_3

(D) F_4

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9.



A rod of length $2D_0$ and mass $2M_0$ is at rest on a flat, horizontal surface. One end of the rod is connected to a pivot that the rod will rotate around if acted upon by a net torque. A sphere of mass m_0 is launched horizontally toward the free end of the rod with velocity v_0, as shown in the figure. After the sphere collides with the rod, the sphere sticks to the rod and both objects rotate around the pivot with a common angular velocity. Which of the following predictions is correct about angular momentum and rotational kinetic energy of the sphere-rod system immediately before the collision and immediately after the collision?

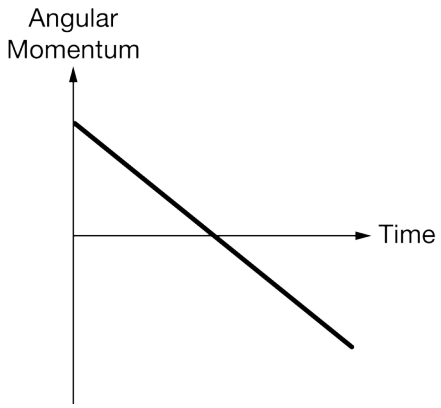
(A) The angular momentum immediately before the collision is greater than the angular momentum immediately after the collision. The rotational kinetic energy immediately before the collision is greater than the rotational kinetic energy immediately after the collision.

(B) The angular momentum immediately before the collision is greater than the angular momentum immediately after the collision. The rotational kinetic energy immediately before the collision is equal to the rotational kinetic energy immediately after the collision.

(C) The angular momentum immediately before the collision is equal to the angular momentum immediately after the collision. The rotational kinetic energy immediately before the collision is greater than the rotational kinetic energy immediately after the collision.

(D) The angular momentum immediately before the collision is equal to the angular momentum immediately after the collision. The rotational kinetic energy immediately before the collision is equal to the rotational kinetic energy immediately after the collision.

10.



The angular momentum of a rigid body rotating around a fixed point as a function of time is shown in the graph. Which of the following statements are true? Select two answers.

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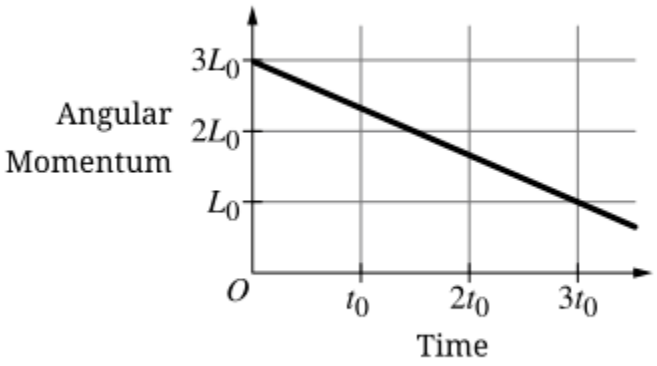
A The angular speed of the object is constant.

B The angular acceleration of the object is constant.

C The angular position of the object is constant.

D The net torque applied to the object is constant.

11.



The graph shows the angular momentum L of a wheel about its axle as a function of time t. What is the magnitude of the net torque on the wheel?

(A) $\frac{2L_0}{3t_0}$

(B) $\frac{L_0}{t_0}$

(C) $3L_0t_0$

(D) $6L_0t_0$

12. A satellite that is a spinning cylinder has initial rotational inertia I_0 and angular velocity w_0. Solar panels unfold from the satellite and are extended outward. The satellite then has rotational inertia $I_f = aI_0$ and angular velocity $w_f = bw_0$, where a and b are constants. Which of the following is true about the constants a and b?

(A) $a = 1$ and $b = 1$

(B) $a > 1$ and $b < 1$

(C) $a > 1$ and $b = 1$

(D) $a < 1$ and $b < 1$

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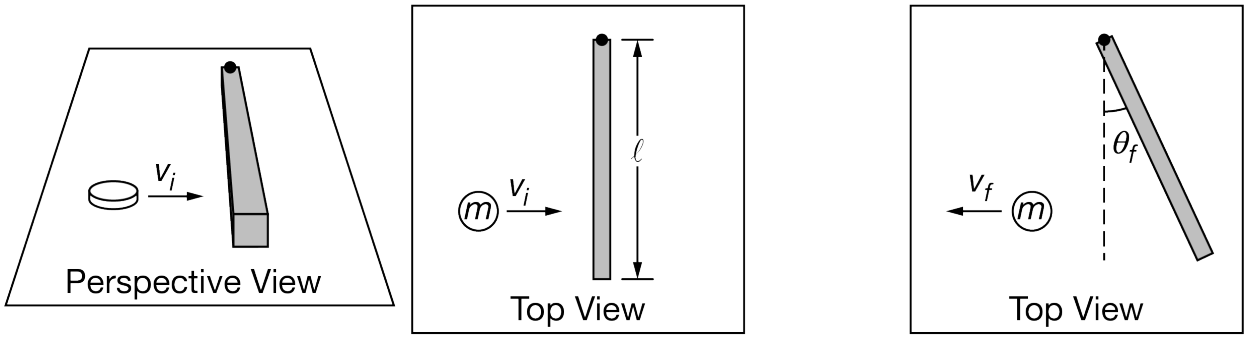


Figure 1

Figure 2

A disk of mass m slides with negligible friction to the right with speed v_i on a horizontal table. The disk collides elastically with a uniform rod of length ℓ that is at rest and free to pivot about one end, as shown in Figure 1 above. The disk rebounds to the left with speed v_f, and the rod rotates with friction and stops at a final angle θ_f from its initial position, as shown in Figure 2.

13. Immediately after the collision, the rod has angular speed ω, and the rod comes to rest a time Δt after the collision. If the rotational inertia of the rod about the pivot is I, the average torque exerted on the rod by friction while the rod is coming to rest is

(A) $\frac{I\omega}{\Delta t}$

(B) $\frac{2I\omega}{\Delta t}$

(C) $\frac{I\omega}{\ell\Delta t}$

(D) $\frac{2I\omega}{\ell\Delta t}$

14. What happens to the magnitude of the angular momentum of the disk-rod system with respect to the pivot during the time interval between Figure 1 and Figure 2, and why?

(A) It decreases because the disk reverses its direction of motion.

(B) It decreases because an external torque is exerted by friction.

(C) It does not change because there was no angular momentum before the collision.

(D) It does not change because angular momentum was conserved during the collision.

15. A wheel with radius $0.33\ \text{m}$ and rotational inertia $2.0\ \text{kg} \cdot \text{m}^2$ spins on an axle with an initial angular speed of $3.0\ \text{rad/s}$. Friction in the axle exerts a torque on the wheel, causing the wheel to stop after $6.0\ \text{s}$. The average torque exerted on the wheel as it slows down has magnitude

(A) $0.50\ \text{N} \cdot \text{m}$

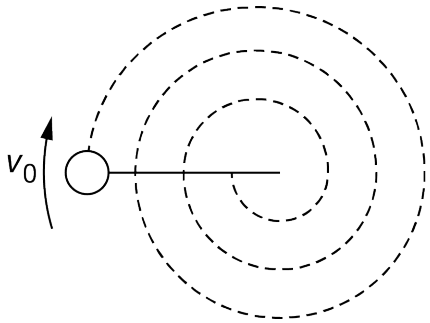
(B) $1.0\ \text{N} \cdot \text{m}$

(C) $2.0\ \text{N} \cdot \text{m}$

(D) $3.0\ \text{N} \cdot \text{m}$

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16.



A ball of mass M swings in a horizontal circle at the end of a string of radius R at an initial tangential speed v_0 as it undergoes uniform centripetal motion. A student gradually pulls the string inward such that the radius of the circle decreases, as shown in the figure. Which of the following predictions is correct regarding the angular momentum and rotational inertia of the ball about the axis of revolution as the ball is pulled inward?

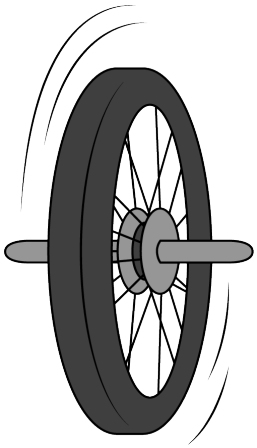
(A) The angular momentum of the ball increases. The rotational inertia of the ball about the axis of revolution decreases.

(B) The angular momentum of the ball increases. The rotational inertia of the ball about the axis of revolution stays the same.

(C) The angular momentum of the ball remains constant. The rotational inertia of the ball about the axis of revolution decreases.

(D) The angular momentum of the ball remains constant. The rotational inertia of the ball about the axis of revolution stays the same.

17.



A bicycle wheel of known rotational inertia is free to rotate about its central axis. With the wheel initially at rest, a student wraps a string around the wheel and pulls the string with a spring scale, causing the wheel to rotate. The student records the tension in the string and the time for which the string was pulled. Without measuring the wheel's final angular speed, can the student find the magnitude of the wheel's final angular momentum, and what is a correct explanation?

(A) Yes. The student has sufficient information already.

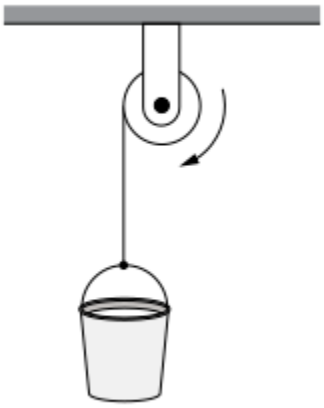
(B) Yes. The student also needs to measure the wheel's radius to calculate the torque exerted on the wheel.

(C) No. Angular momentum can only be found by measuring rotational inertia and angular speed.

(D) No. Measuring the radius would allow the student to calculate the torque, not the angular momentum.

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18.



A bucket is attached to a long, lightweight string that is wrapped around a pulley that has nonnegligible mass, as shown. The pulley is given an initial clockwise rotation and then rotates with negligible friction. The angular momentum of the pulley about the pulley's center has magnitude L, and the torque exerted by the string on the pulley about the pulley's center has magnitude τ . Which of the following correctly describes the changes, if any, in τ and L while the pulley is rotating clockwise?

	τ	L
A	Stays constant	Stays constant
B	Stays constant	Decreases
C	Decreases	Stays constant
D	Decreases	Decreases

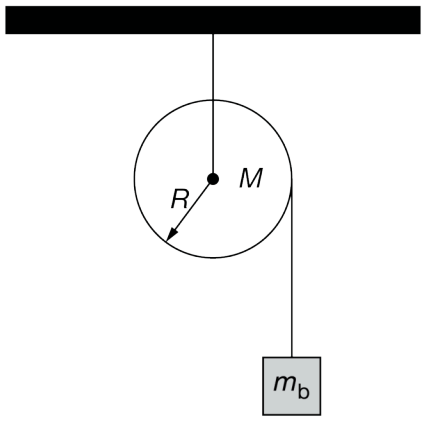
(A) A

(B) B

(C) C

(D) D

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Side View

An axle passes through a pulley. Each end of the axle has a string that is tied to a support. A third string is looped many times around the edge of the pulley and the free end attached to a block of mass m_b , which is held at rest. When the block is released, the block falls downward. Consider clockwise to be the positive direction of rotation, frictional effects from the axle are negligible, and the string wrapped around the disk never fully unwinds. The rotational inertia of the pulley is $\frac{1}{2}MR^2$ about its center of mass.

19. The block falls for a time t_0, but the string does not completely unwind. What is the change in angular momentum of the pulley-block system from the instant that the block is released from rest until time t_0?

(A) Zero

(B) Rm_bgt_0

(C) $RMgt_0$

(D) $R(m_b + M)gt_0$

20. The wheel on a vehicle has a rotational inertia of 2.0 kg·m^2. At the instant the wheel has a counterclockwise angular velocity of 6.0 rad/s, an average counterclockwise torque of 5.0 N·m is applied, and continues for 4.0 s. What is the change in angular momentum of the wheel?

(A) 12 kg·m^2/s

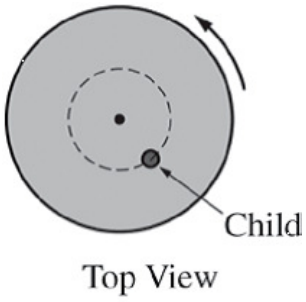
(B) 16 kg·m^2/s

(C) 20 kg·m^2/s

(D) 32 kg·m^2/s

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21.



The diagram above shows a top view of a child of mass M on a circular platform of mass $2M$ that is rotating counterclockwise. Assume the platform rotates without friction. Which of the following describes an action by the child that will increase the angular speed of the platform-child system and gives the correct reason why?

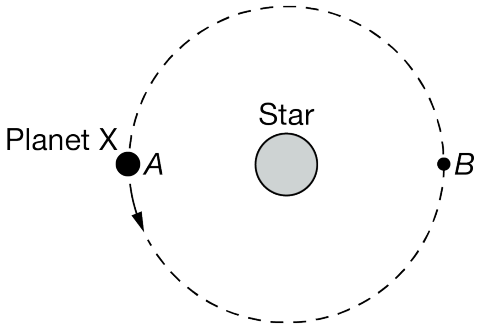
(A) The child moves toward the center of the platform, increasing the total angular momentum of the system.

(B) The child moves toward the center of the platform, decreasing the rotational inertia of the system.

(C) The child moves away from the center of the platform, increasing the total angular momentum of the system.

(D) The child moves away from the center of the platform, decreasing the rotational inertia of the system.

22.

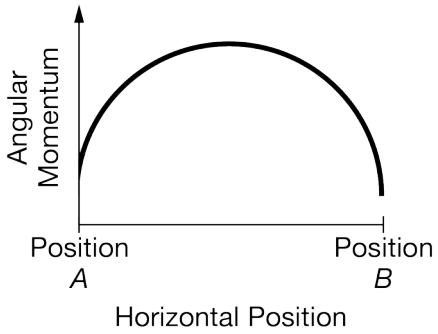


Note: Figure not drawn to scale.

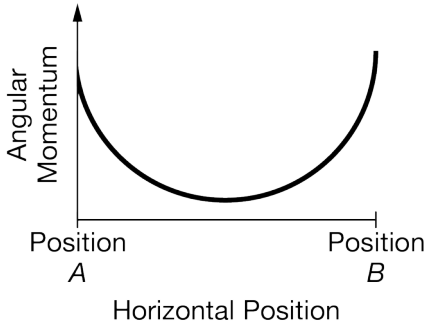
Planet X is in a stable circular orbit around a star, as shown in the figure. Which of the following graphs best predicts the angular momentum of the planet as a function of its horizontal position from point A to point B if the planet is moving counterclockwise as viewed in the figure above?

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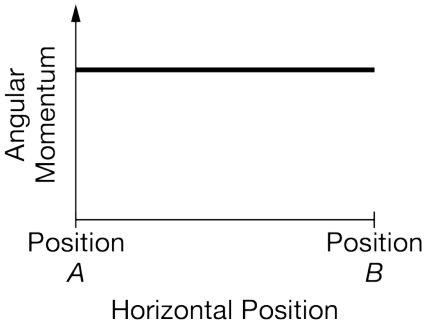
(A)



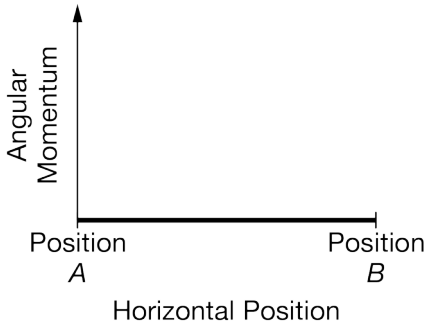
(B)



(C)

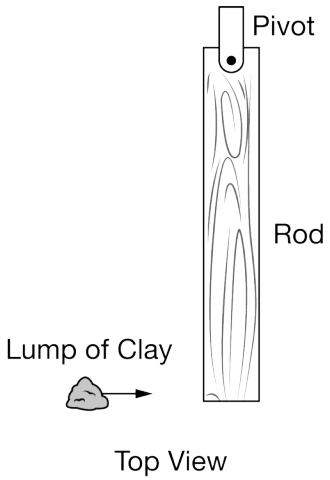


(D)



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23.



A rod of length $0.5\ \text{m}$ is placed on a horizontal surface. One end of the rod is connected to a pivot that will allow the rod to rotate around the pivot in the absence of frictional forces. A lump of clay is launched toward the free end of the rod at a known speed v_c. When the lump of clay strikes the free end of the rod, it sticks to the rod. The equation for the rotational inertia of the rod about the pivot is $I = \frac{1}{3}M\ell^2$. Which of the following quantities, when used together, could a student measure in order to determine the change in angular momentum of the rod from when it was initially at rest to the instant in time when the rod has rotated 90° in the counterclockwise direction? Select two answers.

A The mass of the lump of clay

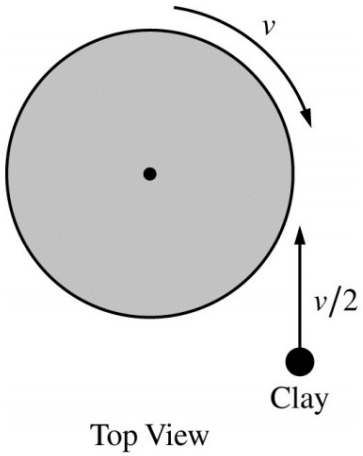
B The mass of the rod

C The tangential speed of the end of the rod after it has rotated 90° in the counterclockwise direction

D The time it takes the rod to rotate 90° in the counterclockwise direction

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24.



Top View

A system consists of a disk rotating on a frictionless axle and a piece of clay moving toward it, as shown in the figure above. The outside edge of the disk is moving at a linear speed v, and the clay is moving at speed *v*/2. The clay sticks to the outside edge of the disk. How does the angular momentum of the system after the clay sticks compare to the angular momentum of the system before the clay sticks, and what is an explanation for the comparison?

(A) It is the same because there is no external torque acting on the system.

(B) It is greater because the rotating mass increases, which increases the rotational inertia.

(C) It is less because the speed of the disk decreases when the clay sticks to it.

(D) It is less because the angular momentum of the clay opposes that of the disk.

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Two small objects of mass m_0 and a rotating platform of radius R and rotational inertia I_p about its center compose a single system. Students use the system to conduct two experiments. The objects are assumed to be point masses.

Experiment 1

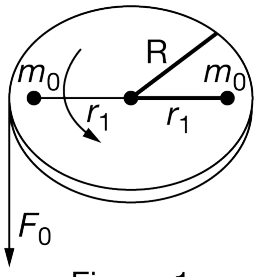


Figure 1

Each object of mass m_0 is placed a distance r_1 away from the center of the platform such that both masses are on opposite sides of the platform. A constant tangential force F_0 is applied to the edge of the platform for a time Δt_0, as shown in Figure 1. The system is initially at rest.

Experiment 2

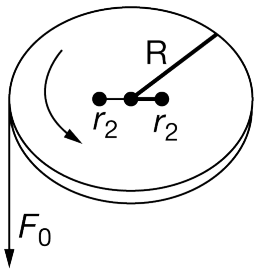


Figure 2

Each object of mass m_0 is placed a distance r_2 away from the center of the platform such that both masses are on opposite sides of the platform. Distance $r_2 < r_1$. A constant tangential force F_0 is applied to the edge of the platform for a time Δt_0 , as shown in Figure 2. The system is initially at rest.

25. Consider both experiments in Figure 1 and Figure 2. How do the angular momentum of each system, L_1 and L_2, and the angular speed of each system, ω_1 and ω_2, compare after a time Δt_0 ?

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(A)

L	ω
$L_1 = L_2$	$\omega_1 > \omega_2$

(B)

L	ω
$L_1 = L_2$	$\omega_1 < \omega_2$

(C)

L	ω
$L_1 < L_2$	$\omega_1 > \omega_2$

(D)

L	ω
$L_1 < L_2$	$\omega_1 < \omega_2$

26. For a given experiment, the students know how much the angular momentum of the system has changed after a specific time interval. The students create a series of graphs for each experiment. The students must determine if the change in angular momentum of a given system is equal to the angular impulse applied to the system. How should the students use data from a particular graph to make the determination by using only the graph?

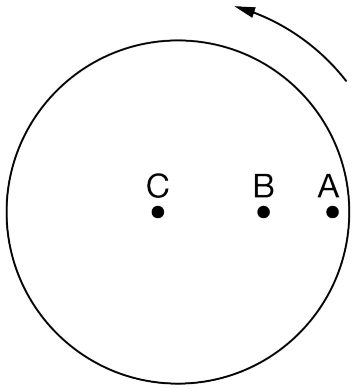
(A) Calculate the slope of an angular velocity versus time graph and see if it equals the angular acceleration.

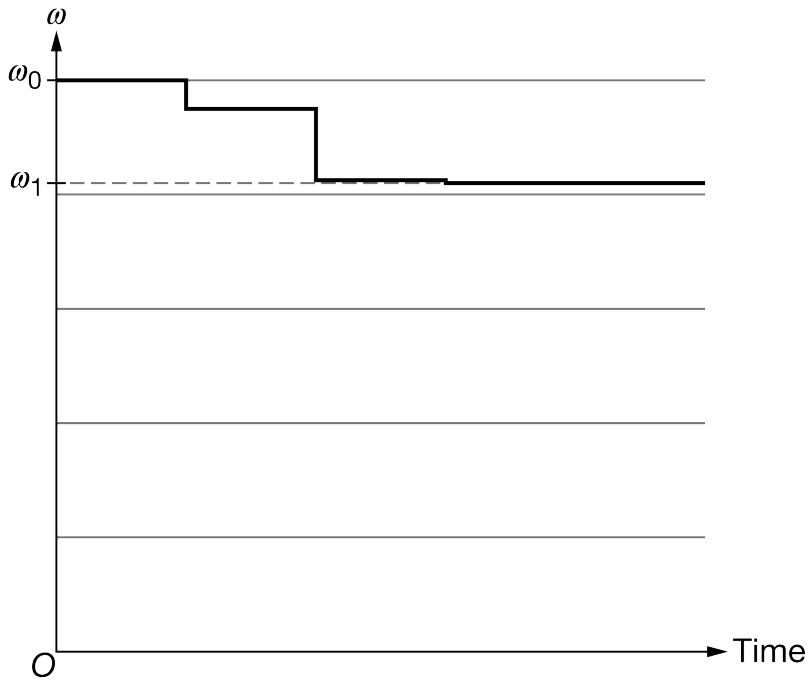
(B) Calculate the slope of an angular position versus time graph and see if it equals the average angular velocity.

(C) Calculate the slope of a graph of the change in angular momentum versus the product of the net torque and the time interval and determine if the slope is equal to one.

(D) Calculate the slope of an angular momentum versus time graph and see if it equals the net torque.

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A solid disk whose plane is parallel to the ground spins with an initial angular speed ω_0. Three identical blocks are dropped onto the disk at locations A, B, and C, one at a time, not necessarily in that order. Each block instantaneously sticks to the surface of the disk, slowing the disk's rotation. A graph of the angular speed of the disk as a function of time is shown.

27. The blocks are now dropped in the reverse order and the final angular speed of the disk is ω_2. How does ω_2 compare to ω_1, the final angular speed shown on the graph from the initial experiment?

(A) $\omega_2 < \omega_1$

(B) $\omega_2 = \omega_1$

(C) $\omega_2 > \omega_1$

(D) The final angular speed cannot be compared without knowing the distances from the disk's center to points A, B, and C.

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28. Based on the data presented in the graph, which of the following lists the points in the order in which the blocks are dropped onto the disk?

(A) A, B, C
(B) B, C, A
(C) C, A, B
(D) B, A, C

29.

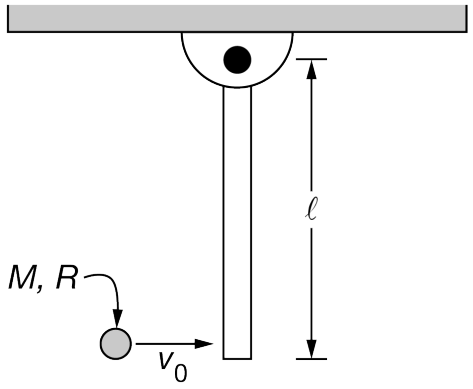


Figure 1. Before Collision

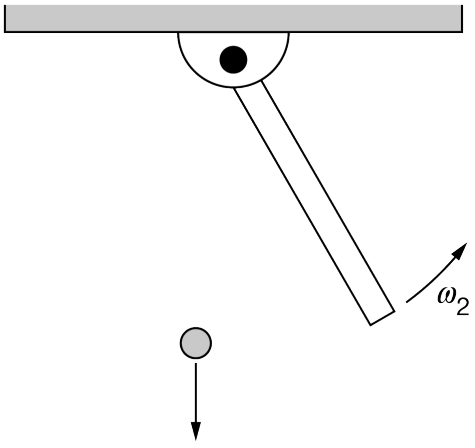


Figure 2. After Collision

A rod of length ℓ and rotational inertia I_r about one end may freely rotate about a pivot that is attached to the ceiling and upper end of the rod. A sphere of mass M and radius R is launched horizontally with velocity v_0 toward the rod. It collides with the bottom of the rod, as shown in Figure 1. After colliding with the rod, the sphere momentarily comes to rest before it falls vertically to the ground. The rod swings upward with an angular speed ω_2, as shown in Figure 2. The rotational inertia of the sphere is I_s. Which of the following mathematical procedures, if any, can a student use to determine ω_2 immediately after the sphere collides with the rod? Justify your selection.

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chapter7part b

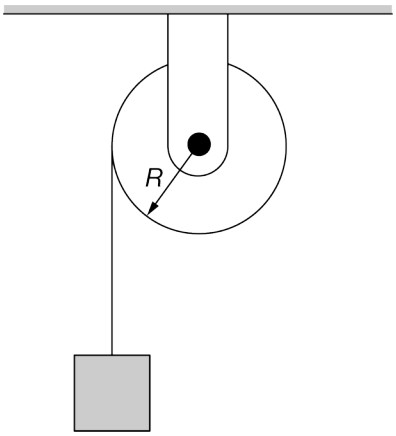
(A) Angular momentum is conserved, so calculate the initial angular momentum of the sphere as measured from the end of the rod, and set that equal to the angular momentum of the rod immediately after the collision.

(B) Angular momentum is conserved, so calculate the initial angular momentum of the sphere as measured from the pivot, and set that equal to the angular momentum of the rod immediately after the collision.

(C) Energy is conserved, so calculate the initial kinetic energy of the sphere immediately before the collision, and set that equal to the kinetic energy of the rod immediately after the collision.

(D) None of the procedures can be used to determine ω_2 immediately after the collision.

30.



A student hangs a block from a light string that is attached to a massive pulley of unknown radius R, as shown in the figure. The student allows the block to fall from rest to the floor. Which two of the following sets of data that could be measured or determined should the student use together to determine the final angular velocity of the pulley just before the block hits the floor? Select two answers. Justify your selections.

A The angular displacement of the pulley and the time the pulley rotates before coming to rest, because these quantities are related to the final angular velocity of the pulley.

B The mass of the block, the distance of the block above the floor, and the amount of time it takes the block to reach the floor, because these quantities can be used to determine the acceleration of the block.

C The radius and mass of the pulley, because these quantities can be used together to determine the rotational inertia of the pulley.

D The weight of the pulley, W_p, and the weight of the block, W_b, because the difference between these two forces, $W_p - W_b$, is equal to the tension in the string.

A meteoroid is in a circular orbit $600\ \text{km}$ above the surface of a distant planet. The planet has the same mass as Earth but has a radius that is $90\ \%$ of Earth's (where Earth's radius is approximately $6370\ \text{km}$).

31. Does the planet exert a torque on the meteoroid with respect to the center of mass of the planet? Why or why not?

(A) Yes, because the planet exerts a centripetal force on the meteoroid.

(B) Yes, because the meteoroid's direction of motion is constantly changing.

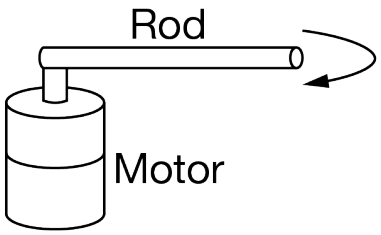
(C) No, because the force exerted by the planet on the meteoroid has a negligible magnitude.

(D) No, because the planet exerts a force on the meteoroid parallel to its position vector relative to the center of mass of the planet.

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32.



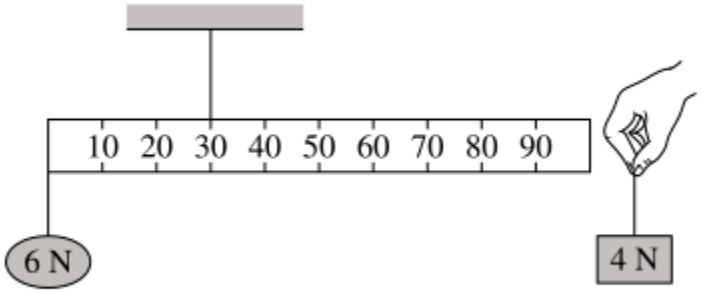
A motor rotates an axle that is connected to one end of a rod, as shown in the figure. Students may adjust the speed at which the motor causes the axle and rod to rotate. During an experiment, what essential quantity or quantities should be measured or determined in order for the students to determine the rod's change in angular momentum after 8 s? Justify your selection.

(A) The mass of the rod, because the mass is related to the net force that is exerted on the rod.

(B) The length of the rod, because the length of the rod is related to the rotational inertia of the rod.

(C) The average net torque applied to the rod, because the average net torque is related to the change in angular velocity of the rod.

(D) The average net force applied to the rod, because the average net force is related to the impulse of the rod.



A student suspends a uniform meterstick that weighs 3 N from the ceiling by a string attached at the 30 cm mark. While holding the meterstick horizontal, the student hangs an object that weighs 6 N from the left end of the meterstick. The student attaches a second object that weighs 4 N at a position x, measured from the left end of the meterstick, so that the meterstick remains horizontal and in static equilibrium.

33. The string that suspends the static two-object-meterstick system is suddenly cut. Which of the following best describes the resulting motion of the system?

(A) The system falls and rotates in the clockwise direction about the center of mass of the system.

(B) The system falls and rotates in the counterclockwise direction about the center of mass of the system.

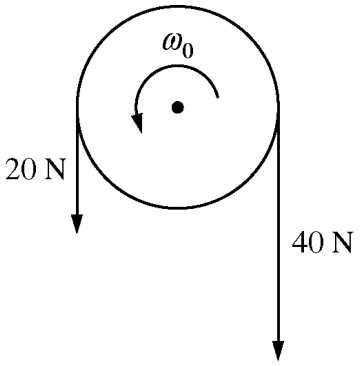
(C) The system falls and rotates in the counterclockwise direction about the center of the meterstick.

(D) The system falls without rotating.

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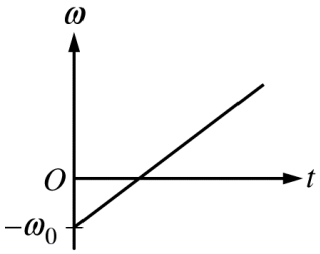
34.



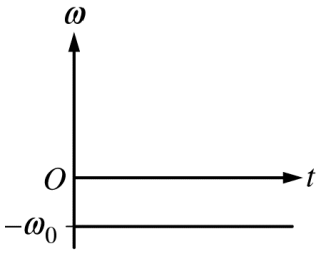
A disk is initially rotating counterclockwise around a fixed axis with angular speed w_0.

At time $t = 0$, the two forces shown in the figure above are exerted on the disk. If counterclockwise is positive, which of the following could show the angular velocity of the disk as a function of time?

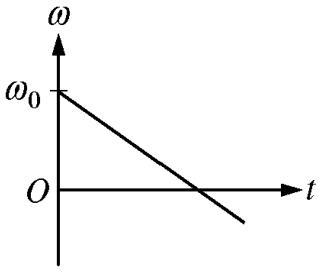
(A)



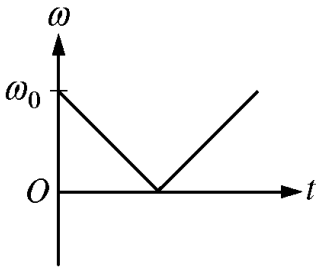
(B)



(C)

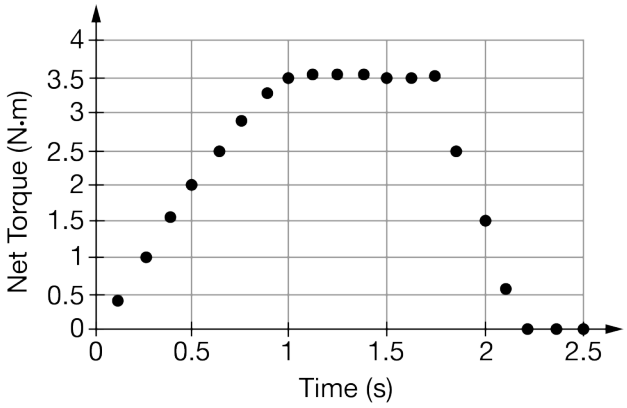


(D)



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35.



A horizontal disk of radius $0.2\ \text{m}$ and mass $0.3\ \text{kg}$ is mounted on a central vertical axle so that a student can study the relationship between net torque and change in angular momentum of the disk. In the experiment, the student uses a force probe to collect data pertaining to the net torque exerted on the edge of the disk as a function of time, as shown in the graph. The disk is initially at rest. At what instant in time does the disk have the greatest angular momentum?

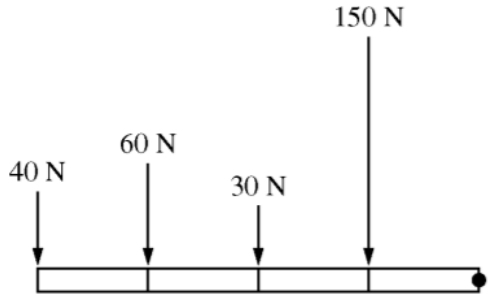
(A) $0.00\ \text{s}$

(B) $1.00\ \text{s}$

(C) $1.75\ \text{s}$

(D) $2.50\ \text{s}$

36.



The figure above represents a stick of uniform density that is attached to a pivot at the right end and has equally spaced marks along its length. Any one of the four forces shown can be exerted on the stick as indicated. Which force will create the largest rate of change in the stick's angular momentum?

(A) The 30 N force

(B) The 40 N force

(C) The 60 N force

(D) The 150 N force

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37.

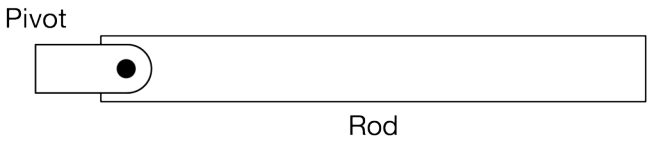


Figure 1

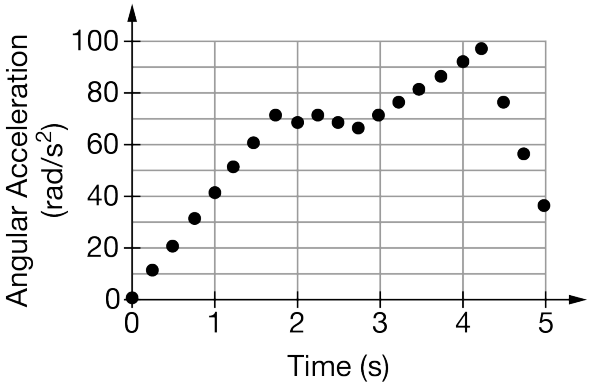


Figure 2

A rod is at rest on a flat, horizontal surface. One end of the rod is attached to a pivot, and the rod may freely rotate around the pivot if acted upon by a net external torque, as shown in Figure 1. In an experiment, the rod is initially at rest and student exerts a net torque on the rod. Data are collected to create a graph of the rod's angular acceleration as a function of time, as shown in Figure 2. Frictional forces are considered to be negligible. How can the student use the graph to determine the angular momentum of the rod at 5 s?

(A) Determine the average angular acceleration from 0 s to 5 s and multiply the result by the rotational inertia of the rod.

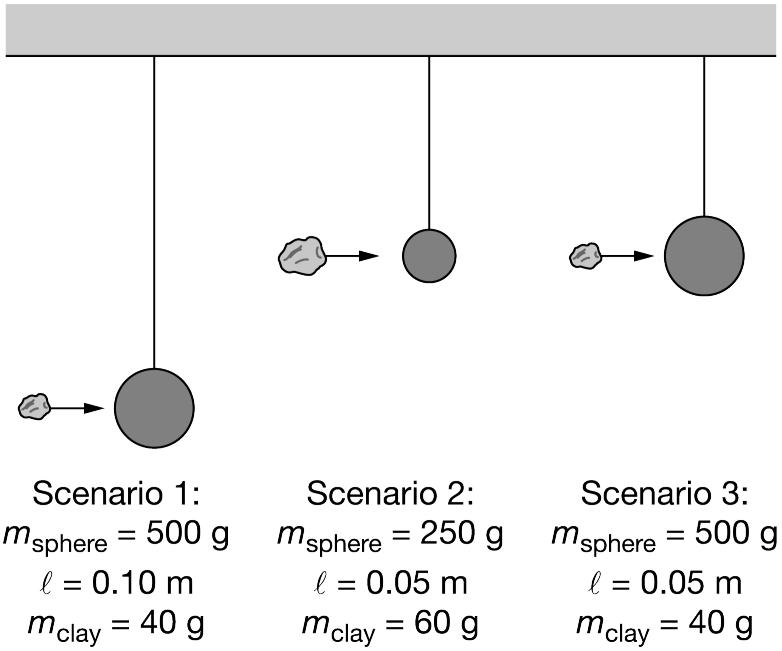
(B) Determine the area bound by the curve and the horizontal axis from 0 s to 5 s and multiply the result by the rotational inertia of the rod.

(C) Determine the average slope of the curve from 0 s to 5 s and multiply the result by the rotational inertia of the rod.

(D) Multiply the angular acceleration at 5 s by the rotational inertia of the rod.

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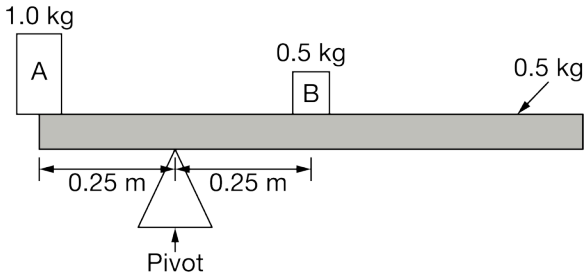
38.



A lump of clay of mass m_{clay} with speed $v_{clay} = 8\ \mathrm{m/s}$ travels toward various spheres that are suspended from the ceiling by lightweight strings of different lengths, as shown in the figure. For the three scenarios, the clay collides with the suspended sphere and sticks to it. Which of the following correctly relates the angular momentum L of the clay-bob system immediately after the collision for each scenario, where the angular momentum is taken about the point where the string is attached to the ceiling?

(A) $L_2 > L_1 = L_3$
(B) $L_1 = L_2 = L_3$
(C) $L_1 > L_2 = L_3$
(D) $L_1 > L_2 > L_3$

39.



A meterstick with a uniformly distributed mass of $0.5\ \mathrm{kg}$ is supported by a pivot placed at the $0.25\ \mathrm{m}$ mark from the left, as shown. At the left end, a small object of mass $1.0\ \mathrm{kg}$ is placed at the zero mark, and a second small object of mass $0.5\ \mathrm{kg}$ is placed at the $0.5\ \mathrm{m}$ mark. The meterstick is supported so that it remains horizontal, and then it is released from rest. One second after it is released, what is the change in the angular momentum of the meterstick?

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(A) 0

(B) $500\ \mathrm{kg \cdot m^2/s}$

(C) $1000\ \mathrm{kg \cdot m^2/s}$

(D) The change in angular momentum of the meterstick cannot be determined from this information.

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40.

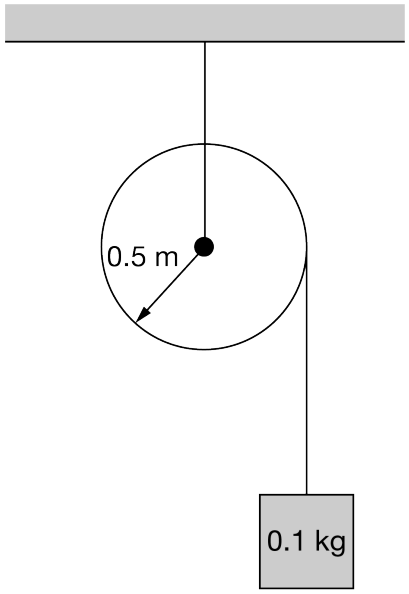


Figure 1

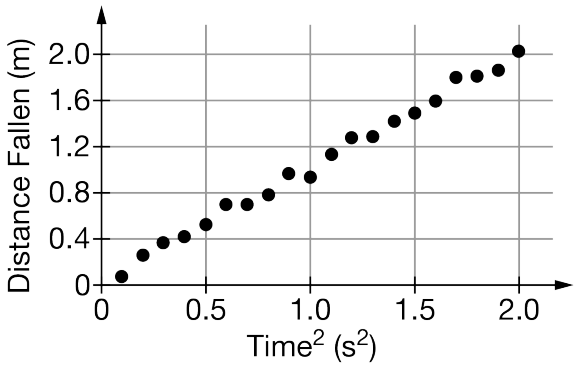


Figure 2

One end of a string is attached to a $0.1\ \text{kg}$ object. The string is wrapped around a pulley of known rotational inertia and radius $0.5\ \text{m}$ that may rotate about its central axis. The central axis is supported by strings that are connected to the ceiling, as shown in Figure 1. In an experiment, the $0.1\ \text{kg}$ object is released from rest, and the necessary data are collected to graph the distance fallen by the object as a function of the square of the time fallen, as shown in Figure 2. A student makes the following claim.

"Figure 1 and Figure 2 can be used to determine the magnitude and direction of the net torque exerted on the pulley."

Which of the following statements is correct about the student's evaluation of the data from the graph? Justify your selection.

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(A) The student is correct, because the linear acceleration of the 0.1 kg object can be determined from the graph. The angular acceleration of the pulley can then be determined. The direction of the net torque will be in the direction of the angular acceleration.

(B) The student is correct, because the average linear velocity of the 0.1 kg object can be determined from the graph. The average angular velocity of the pulley can then be determined. The direction of the net torque will be in the direction of the average angular velocity.

(C) The student is incorrect, because the linear acceleration of the 0.1 kg object can be determined from the graph. However, there is no relationship between the linear acceleration of the 0.1 kg object and the net torque exerted on the pulley.

(D) The student is incorrect, because the average linear velocity of the 0.1 kg object can be determined from the graph. However, there is no relationship between the average linear velocity of the 0.1 kg object and the net torque exerted on the pulley.

41.



Figure 1

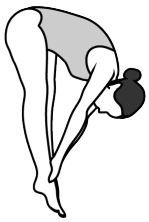


Figure 2

A person diving into a pool is initially rotating in a position with her legs pulled inward, as shown above in Figure 1. The person then stretches out her legs, as shown in Figure 2. Which of the following correctly describes the person's rotational inertia and angular momentum about an axis though her center of mass in the two figures?

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(A)

Rotational Inertia	Angular Momentum
Greater in Figure 1	Greater in Figure 2

(B)

Rotational Inertia	Angular Momentum
Greater in Figure 2	Greater in Figure 2

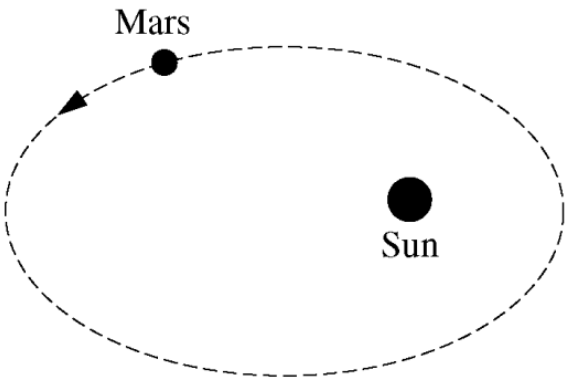
(C)

Rotational Inertia	Angular Momentum
Greater in Figure 1	The same in both figures

(D)

Rotational Inertia	Angular Momentum
Greater in Figure 2	The same in both figures

42.



Note: Figure not drawn to scale.

Mars moves in an elliptical orbit around the Sun, and the mass of Mars is much less than the mass of the Sun. At the instant shown above, Mars is getting farther away from the Sun. How does this affect the potential energy of the Mars-Sun system and the magnitude of Mars's angular momentum with respect to the Sun?

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(A)

System Potential Energy	Mars's Angular Momentum
Increases	Increases

(B)

System Potential Energy	Mars's Angular Momentum
Increases	Remains the same

(C)

System Potential Energy	Mars's Angular Momentum
Decreases	Decreases

(D)

System Potential Energy	Mars's Angular Momentum
Decreases	Remains the same

43. Disk Y of rotational inertia $I_{\mathrm{Y}} = \frac{1}{2} M_{\mathrm{Y}} R_{\mathrm{Y}}^2$ about its center is held at rest above disk X of rotational inertia $I_{\mathrm{X}} = \frac{1}{2} M_{\mathrm{X}} R_{\mathrm{Y}}^2$ about its center. Disk X initially rotates about its center with an angular velocity of $+\omega_0$. Disk Y is then slowly lowered onto disk X until both disks are in contact and rotate together with a common angular velocity. Which two of the following predictions are correct about the angular momentum of disk X and disk Y immediately before and after the rotational collision? Select two answers.

A The angular momentum of disk X immediately after the collision is greater than the angular momentum of disk X immediately before the collision.

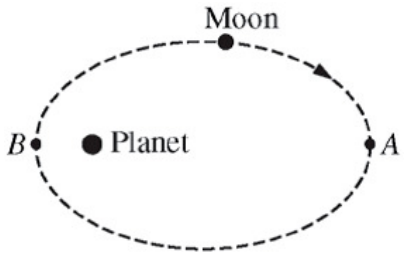
B The angular momentum of disk Y immediately after the collision is greater than the angular momentum of disk Y immediately before the collision.

C The angular momentum of disk Y immediately after the collision is greater than the angular momentum of the disk X–disk Y system immediately before the collision.

D The angular momentum of the disk X–disk Y system immediately after the collision is equal to the angular momentum of the system immediately before the collision.

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44.



A moon is in an elliptical orbit about a planet as shown above. At point A the moon has speed μ_A and is at distance R_A from the planet. At point B the moon has speed μ_B. Which of the following explains a correct method for determining the distance of the moon from the planet at point B in terms of the given quantities?

(A) Conservation of angular momentum, because the gravitational force exerted by the moon on the planet is the same as that exerted by the planet on the moon

(B) Conservation of angular momentum, because the gravitational force exerted on the moon is always directed toward the planet

(C) Conservation of energy, because the gravitational force exerted on the moon is always directed toward the planet

(D) Conservation of energy, because the gravitational force exerted by the moon on the planet is the same as that exerted by the planet on the moon

45. In an experiment, a solid, uniform sphere is at rest on a horizontal surface. A net force is applied tangentially to the edge of the sphere that is the greatest horizontal distance away from the central axis of the sphere. The sphere begins to rotate from rest until the force is no longer applied after 3 s. Frictional forces between the sphere and the horizontal surface are considered to be negligible. Which two of the following quantities, when used together, could a student measure to determine the change in angular momentum of the sphere from 0 s to 3 s? Select two answers.

A Radius of the sphere

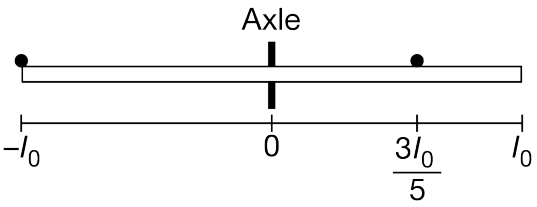
B Volume of the sphere

C Average angular acceleration of the sphere from 0 s to 3 s

D Average net force exerted on the sphere from 0 s to 3 s

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46.



A system consists of a horizontal rod and two small objects, as shown. The horizontal rod has a total length 2 $_0$ and mass M, with rotational inertia $I_R = \frac{Ml^2}{3}$. Each object has a mass m_0 and a rotational inertia $I_O = m_0 r^2$ where r is the distance from the object to the axle. The objects are fixed to the rod at the positions shown in the figure. The system is initially at rest, and a net torque is exerted on the system until it rotates with an angular speed, ω_0 about the vertical axis shown, which is through the center of the rod. What is the change in the angular momentum of the system from when the system was at rest to the instant when the net torque is no longer applied to the system?

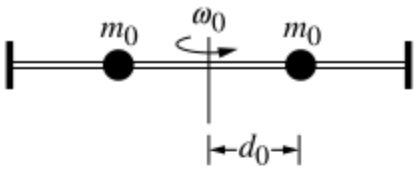
(A) $\left(\frac{M \; ^2_0}{3} + m_0 \; ^2_0\right)\omega_0$

(B) $\left(\frac{M \; ^2_0}{3} + 2m_0 \; ^2_0\right)\omega_0$

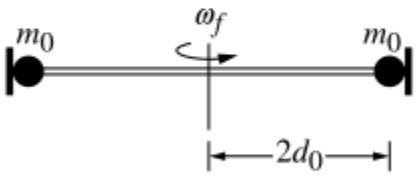
(C) $\left(\frac{M \; ^2_0}{3} - m_0\left(\frac{16 \; ^2_0}{25}\right)\right)\omega_0$

(D) $\left(\frac{M \; ^2_0}{3} + m_0\left(\frac{34 \; ^2_0}{25}\right)\right)\omega_0$

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Initial State



Final State

Note: Figures not drawn to scale.

Consider a system that consists of two beads and a thin rod of negligible mass. In the initial state, the beads, each of mass m_0, are attached with their centers a distance d_0 from the center of the rod. The rod is freely rotating with angular speed ω_0 about a fixed vertical axis through the center of the rod, as shown. Then, an internal mechanism releases the beads and they slide with negligible friction outward until the beads hit the end stops. In the final state, the centers of the beads are a distance $2d_0$ from the center of the rod, which is rotating with an angular speed ω_f, as shown. The curved arrows in the figures indicate the directions only, not the magnitudes, of the angular speeds.

47. The rotational inertia I of the beads-rod system is $2m_0r^2$, where m_0 is the mass of each bead and r is the distance of each bead from the vertical axis. Which of the following is equal to the rotational speed of the rod in the final state, ω_f ?

(A) $4\omega_0$

(B) $2\omega_0$

(C) $\omega_0/2$

(D) $\omega_0/4$

48. Which of the following statements about a satellite in an elliptical orbit around Earth are correct? Select two answers.

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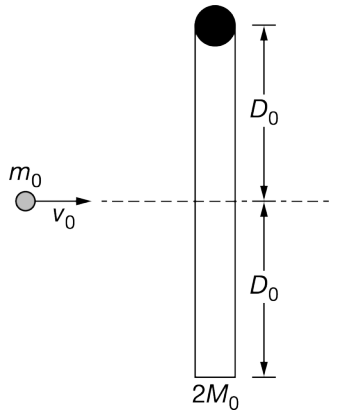
A The satellite's kinetic energy is constant throughout the orbit.

B The satellite's angular momentum about the center of mass of the satellite-Earth system is constant throughout the orbit.

C The magnitude of the satellite's linear momentum is constant throughout the orbit.

D The gravitational potential energy of the Earth-satellite system is greatest at the satellite's farthest point from Earth.

49.



A rod of length $2D_0$ and mass $2M_0$ is at rest on a flat, horizontal surface. One end of the rod is connected to a pivot that the rod will rotate around if acted upon by a net torque. A lump of clay of mass m_0 is launched horizontally toward the center of the rod with velocity v_0, as shown in the figure. After the clay collides with the rod, the clay sticks to the rod and both objects rotate around the pivot with the common angular velocity ω_f. The rotational inertia of the clay-rod system is I_s. Which of the following equations could a student use to solve for the common angular velocity ω_f immediately after the collision? Justify your selection.

(A) $m_0 v_0 D_0 = I_s \omega_f$, because the clay hits the rod a distance D_0 from the pivot.

(B) $2m_0 v_0 D_0 = I_s \omega_f$, because the length of the rod is $2D_0$.

(C) $2M_0 v_0 D_0 = I_s \omega_f$, because the rod's mass is $2M_0$ and the clay hits the rod a distance D_0 from the pivot.

(D) $4M_0 v_0 D_0 = I_s \omega_f$, because the rod's mass is $2M_0$ and its length is $2D_0$.

50. Disk Y of rotational inertia $I_\mathrm{Y} = \frac{1}{2} M_\mathrm{Y} {R_\mathrm{Y}}^2$ is held at rest above disk X of rotational inertia $I_\mathrm{X} = \frac{1}{2} M_\mathrm{X} {R_\mathrm{X}}^2$ that rotates about its center with an angular velocity of $+\omega_0$. Disk Y is slowly lowered onto disk X until both disks are in contact and travel together with a common angular velocity ω_f. Which of the following equations could a student use to correctly solve for the final angular velocity of the two-disk system immediately after the collision? Justify your selection.

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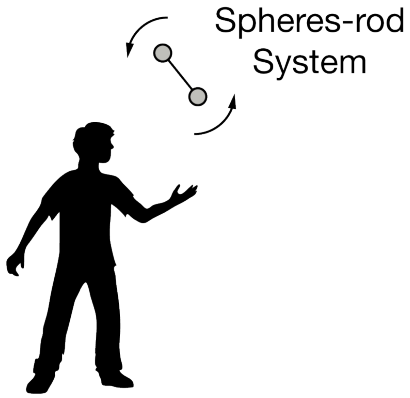
(A) $\frac{1}{2}M_{\mathrm{X}}{R_{\mathrm{X}}}^2\omega_0 = (\frac{1}{2}M_{\mathrm{X}}{R_{\mathrm{X}}}^2 + \frac{1}{2}M_{\mathrm{Y}}{R_{\mathrm{Y}}}^2)\omega_f$, because the initial momentum of disk X is equal to the sum of the final momentum of disk X and the final momentum of disk Y.

(B) $\frac{1}{2}M_{\mathrm{Y}}{R_{\mathrm{Y}}}^2\omega_0 = (\frac{1}{2}M_{\mathrm{X}}{R_{\mathrm{X}}}^2 + \frac{1}{2}M_{\mathrm{Y}}{R_{\mathrm{Y}}}^2)\omega_f$, because the initial momentum of disk Y is equal to the sum of the final momentum of disk X and the final momentum of disk Y.

(C) $(\frac{1}{2}M_{\mathrm{X}}{R_{\mathrm{X}}}^2 + \frac{1}{2}M_{\mathrm{Y}}{R_{\mathrm{Y}}}^2)\omega_0 = (\frac{1}{2}M_{\mathrm{X}}{R_{\mathrm{X}}}^2 + \frac{1}{2}M_{\mathrm{Y}}{R_{\mathrm{Y}}}^2)\omega_f$, because the initial momentum of the sum of disk X and disk Y is equal to the sum of the final momentum of disk X and the final momentum of disk Y.

(D) $\frac{1}{2}M_{\mathrm{X}}{R_{\mathrm{X}}}^2\omega_0 = \frac{1}{2}M_{\mathrm{Y}}{R_{\mathrm{Y}}}^2\omega_f$, because the initial momentum of disk X is equal to the final momentum of disk Y.

51.



Two identical spheres are attached to opposite ends of a thin rod of negligible mass, as shown in the figure. The spheres-rod system is thrown straight upward and is rotating counterclockwise as it moves through the air. Which of the following is correct about the angular momentum of the spheres-rod system while it is in the air? What is a valid justification?

(A) The angular momentum remains constant because there is never a net torque acting on the system.

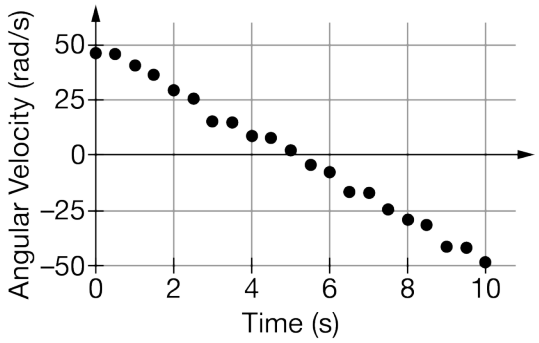
(B) The angular momentum remains constant because there is a changing net torque acting on the system that averages to zero over time.

(C) The angular momentum constantly decreases because there is a constant net torque acting on the system.

(D) The angular momentum constantly increases because there is a constant net torque acting on the system.

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52.



A student conducts an experiment in which the angular velocity of a rotating object about a central axis of rotation changes as a function of time, as shown by the graph. The student makes the following claim.

"The net torque responsible for the rotation of the object changes direction at approximately 5.0 s."

Which of the following statements is correct about the student's evaluation of the data from the graph? Justify your selection.

(A) The student is correct, because the angular velocity cannot change direction unless the net torque also changes direction.

(B) The student is correct, because the net torque and direction exerted on the object before $5.0\,\text{s}$ is different from the net torque and direction exerted on the object after $5.0\,\text{s}$.

(C) The student is incorrect, because the angular acceleration of the object remains constant.

(D) The student is incorrect, because the angular velocity is inversely related to the net torque exerted on the object.

53. A student is at rest on a stool that may freely spin about its central axis of rotation. As the stool spins, the student holds onto two dumbbells as the stool spins at an angular speed of $1.2\,\text{rad/s}$ with the student's arms completely stretched out from the student's body. At this instant, the student-dumbbell system has rotational inertia of $6\,\text{kg}\cdot\text{m}^2$. The student then brings their arms close to their body, and rotational inertia of the student-dumbbell system is changed to $2\,\text{kg}\cdot\text{m}^2$. What is the new angular speed of the student?

(A) $0.4\,\text{rad/s}$

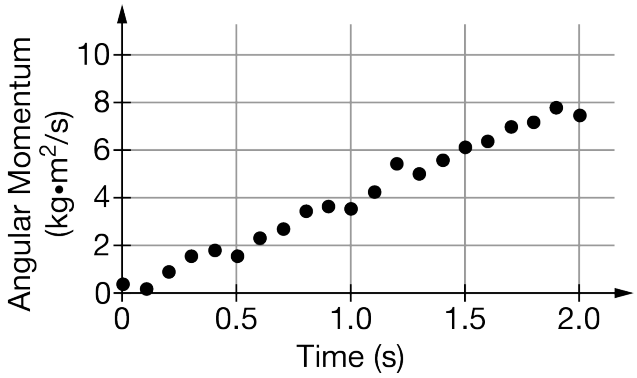
(B) $1.2\,\text{rad/s}$

(C) $3.6\,\text{rad/s}$

(D) $7.2\,\text{rad/s}$

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54.



A student conducts an experiment in which one end of a rod may freely rotate around a pivot that is attached to its other end. The student collects the necessary data to construct a graph of the rod's angular momentum as a function of time, as shown. The student makes the following claim.

"This graph shows that the magnitude of the net torque exerted on the rod increases as time increases."

Which of the following statements is correct about the student's evaluation of the data from the graph? Justify your selection.

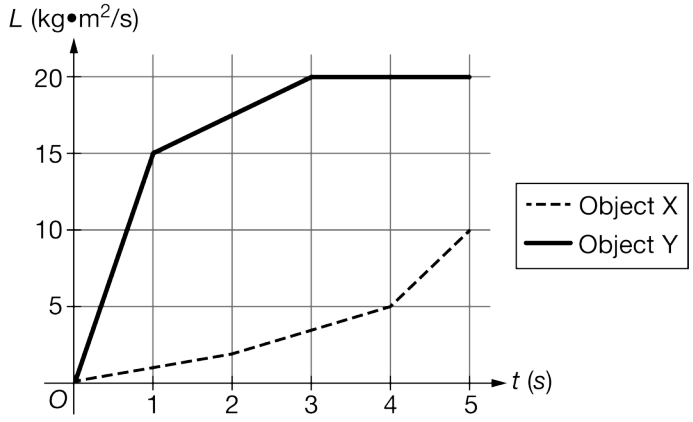
(A) The student is correct, because the angular momentum of the rod increases as time increases.

(B) The student is correct, because the area bound by the best-fit curve and the horizontal axis from $0\ \text{s}$ to $2\ \text{s}$ is positive.

(C) The student is incorrect, because the graph shows that the net torque exerted on the rod is constant as time increases.

(D) The student is incorrect, because this graph does not contain enough information to make a direct connection between the angular momentum of the rod and the net torque exerted on the rod.

55.

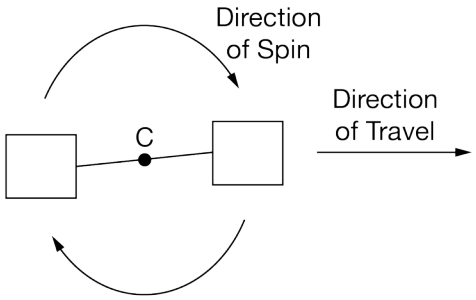


Two objects, X and Y, experience external net torques that vary over a period of 5 seconds. Object X has a moment of inertia I_0, and Object Y has a moment of inertia $2I_0$. The average value of the magnitude of the external net torque exerted on Object X from time $t = 0$ to $t = 5$ s is τ_X. Similarly, the average value for Object Y is τ_Y. The magnitudes of the angular momenta L of Objects X and Y versus t are shown in the graph. Which of the following expressions correctly relates τ_Y to τ_X ?

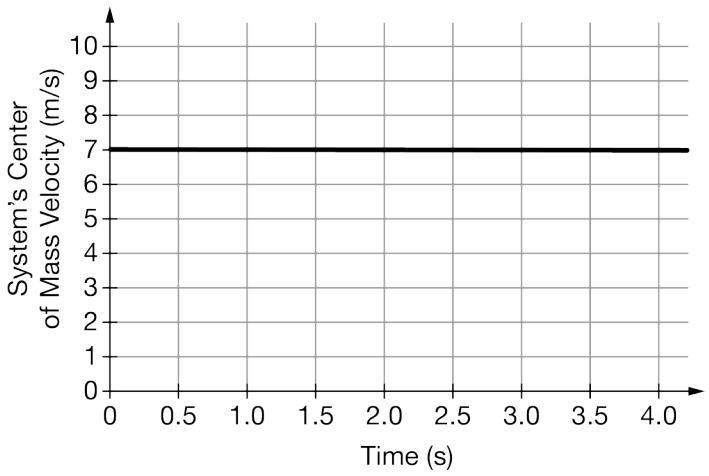
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(A) $\tau_Y = 4\tau_X$
(B) $\tau_Y = 2\tau_X$
(C) $2\tau_Y = \tau_X$
(D) $4\tau_Y = \tau_X$

56.



Top View

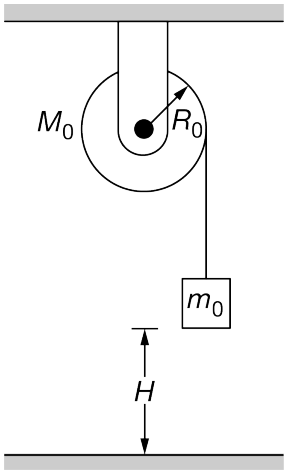


Two boxes are tied together with a string. They are thrown onto a layer of ice such that they spin around their center of mass C as they slide horizontally across the icy surface, as shown in the figure. The system has an angular momentum $\vec{L}_0$ and an angular velocity $\vec{\omega}_0$ at a time $t = 0$ s. A graph of the two-block system's center of mass velocity as a function of time is shown. Which of the following predictions are correct about the angular momentum $\vec{L}_4$ and angular velocity $\vec{\omega}_4$ at $t = 4$ s ?

(A) $L_0 = L_4$ and $\omega_0 = \omega_4$
(B) $L_0 > L_4$ and $\omega_0 > \omega_4$
(C) $L_0 < L_4$ and $\omega_0 < \omega_4$
(D) $L_0 > L_4$ and $\omega_0 < \omega_4$

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57.



In experiment 1, a disk of mass M_0 and radius R_0 rotates about a center axle, as shown in the figure. An object of mass m_0 hangs from a string that is wound around the disk. The object is released from rest and falls a vertical distance H before striking the ground. The string does not completely unwind. The disk's angular momentum is L_1 when the falling object strikes the ground. The rotational inertia of the disk is $I_d = \frac{MR^2}{2}$. In experiment 2, a thin circular hoop with mass M_0 and radius R_0 replaces the disk, and the experiment is repeated. The rotational inertia of the hoop is $I_h = MR^2$. How does the magnitude of the hoop's final angular momentum compare to the magnitude of the disk's final angular momentum?

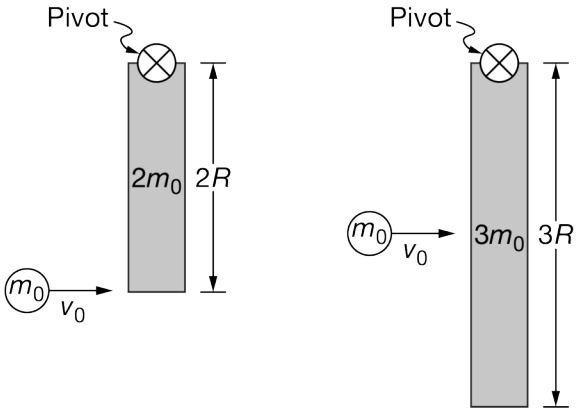
(A) The hoop's final angular momentum is less than the disk's final angular momentum.

(B) The hoop's final angular momentum is equal to the disk's final angular momentum.

(C) The hoop's final angular momentum is greater than the disk's final angular momentum.

(D) The comparison cannot be made without knowing the net torque exerted on the disk and the hoop.

58.



Two identical clay spheres of mass m_0 traveling with identical velocity v_0 collide with and stick to two different vertical rods. The shorter rod has length $2R$ and mass $2m_0$, while the longer rod has length $3R$ and mass $3m_0$, as shown in the figure. One sphere collides with the end of the short rod, which begins to rotate about its pivot with angular momentum L_1. The other sphere collides with the center of the long rod, which begins to rotate about its pivot with angular momentum L_2. What is the ratio of L_1 to L_2 ?

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(A) $\frac{4}{9}$

(B) $\frac{2}{3}$

(C) 1

(D) $\frac{4}{3}$