PHYSICS

BOOKS - RESNICK AND HALLIDAY PHYSICS (HINGLISH)

RIGID BODY DYNAMICS - I

Sample Problem

1. The disk in Fig. 10-5a is rotating about its central axis like a merry-go-round. The angular position $\theta(t)$ of a reference line on the disk is given by

$\theta = -1.00 - 0.600t + 0.250t^2$,

with t in seconds, θ radians, and the zero angular position as indicated in the figure.

(a) Graph the angular position of the disk verus time from t = -3.0 s to t = 5.4 s. Sketch the disk and its angular position reference line at t = -2.0 s, 0 s, and 4.0 s, and when the curve crosses the t axis.

(b) At what time $t_{\min}$ does $\theta(t)$ reach the minimum value shown in Fig.

10-5b? What is that minimum value?

(c) Graph the angular velocity ω of the disk versus time from t = -3.0 s to t = 6.0 s. Sketch the disk and indicate the direction of turning and the sign of ω at t = -2.0 s, 4.0 s, and $t_{\min}$.

(d) Use the results in parts (a) through (c) to describe the motion of the disk from t = -3.0 s to t = 6.0 s.

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2. A child's top is spun with angular acceleration

$\alpha = 5t^3 - 4t$,

with t in seconds and α in radians per second-squared. At t = 0, the top has angular velocity 5 rad/s, and a reference line on it is at angular position $\theta = 2$ rad.

(a) Obtain an expression for the angular velocity $\omega(t)$ of the top. That is, find an expression that explicitly indicates how the angular velocity depends on time.

(b) Obtain an expression for the angular position $\theta(t)$ of the top.

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3. A grindstone rotates at constant angular acceleration $\alpha = 0.35 rad/s^2$. At time t = 0, it has an angular velocity of $\omega_0 = -4.6 rad/s$ and a reference line on it is horizontal, at the angular position $\theta_0 = 0$.

(a) At what time after t = 0 is the reference line at the angular position $\theta = 5.0$ rev ?

(b) Describe the grindstone's rotation between t = 0 and t = 32 s.

(c) At what time t does the grindstone momentarily stop?

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4. While you are operating a Rotor (a large, vertical, rotating cylinder found in amusement parks), you spot a passenger in acute distress and decrease the angular velocity of the cylinder from 3.40 rad/s to 2.00 rad/s in 20.0 rev, at constant angular acceleration. (The passender is obviously more of a "translation person" than a "rotation person.")

(a) What is the constant angular acceleration during this decrease in angular speed?

How much time did the speed decrease take?

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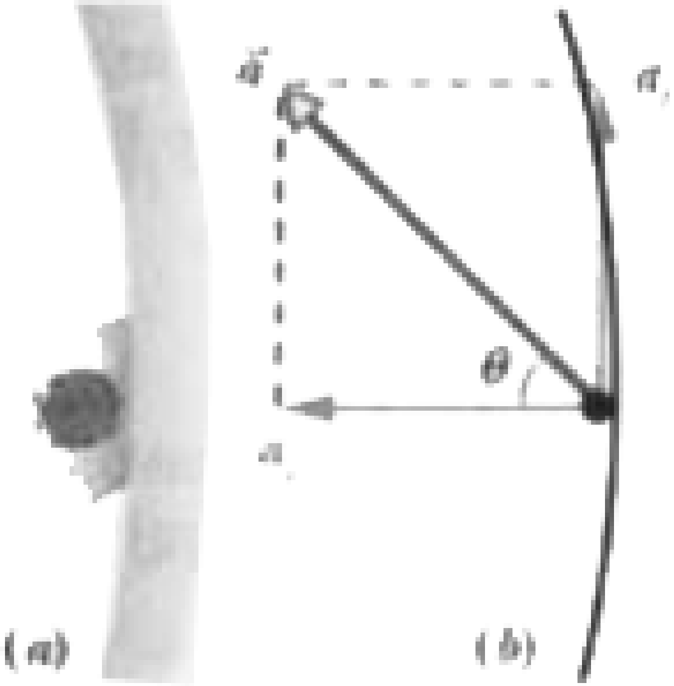
5. We are given the job of designing a large horizontal ring that will rotate around a vertical axis and that will have a radius of r = 33.1 m. Passengers will enter through a door in the outer wall of the ring and then stand next to that wall. We decide that for the time interval t = 0 to t = 2.30 s, the angular position $\theta(t)$ of a reference line on the ring will be given by

$\theta = ct^3,$



with $c = 6.39 \times 10^{-2} rad/s^3$. After t = 2.30 s, the angular speed will be held constant until the end of the ride. Once the ring begins to rotate, the floor of the ring will drop away from the riders but the riders will not fall - indeed, they feel as though they are pinned to the wall. For the time t = 2.20 s, let's determine a rider's angular speed ω, linear speed ν, angular acceleration α, tangential acceleration a_t, radial acceleration a_r, and acceleration $\vec{a}$.

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6. Figure a rigid body consisting of two particles of mass m connected by a rod of length L and negligible mass.

(a) What is the rotational inertia I_{com} about an axis through the center of mass, perpendicular to the rod as shown?

(b) What is the rotational inertia I of the body about an axis through the left end of the rod and parallel to the first axis.

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7. Figure shows a thin, uniform rod of mass M and length L, on an x axis with the origin at the rod's center.

(a) What is the rotational inertia of the rod about the perpendicular rotation axis through the center?

(b) What is the rod's rotational inertia I about a new rotation axis that is perpendicular to the rod and through the left end?

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8. Large machine components that undergo prolonged, high-speed rotation are first examined for the possibility of failure in a spin test system. In this system, a component is spun up while inside a cylindrical arrangement of lead bricks and containment liner, all within a steel shell that is closed by a lid clamped into place. If the rotation causes the component to shatter, the soft lead bricks are supposed to catch the pieces for later analysis.

In 1985, Test Devices, Inc. was spin testing a sample of a solid steel rotor of mass M = 272 kg and radius R = 38.0 cm. When the sample reached an angular speed ω of 14000 rev/min, the test engineers heard a dull thump from the test system, which was located one floor down and one room over from them. Investigating, they found that lead bricks had been thrown out in the hallway leading to the test room, a door to the room had been hurled into the adjacent parking lot, one lead brick had shot from the test site through the wall of a neighbor's kitchen, the structural beams of the test building had been damaged, the concrete floor beneath the spin chamber had been shoved downward by about 0.5 cm, and the 900 kg lid had been blown upward through the ceiling and had then crashed back onto the test equipment. The exploding pieces had not penetrated the room of the test engineers only by luck. How much energy was released in the explosion of the rotor?

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9. Find the moment of inertia of a uniform rign of mass M and radius R about a diameter.

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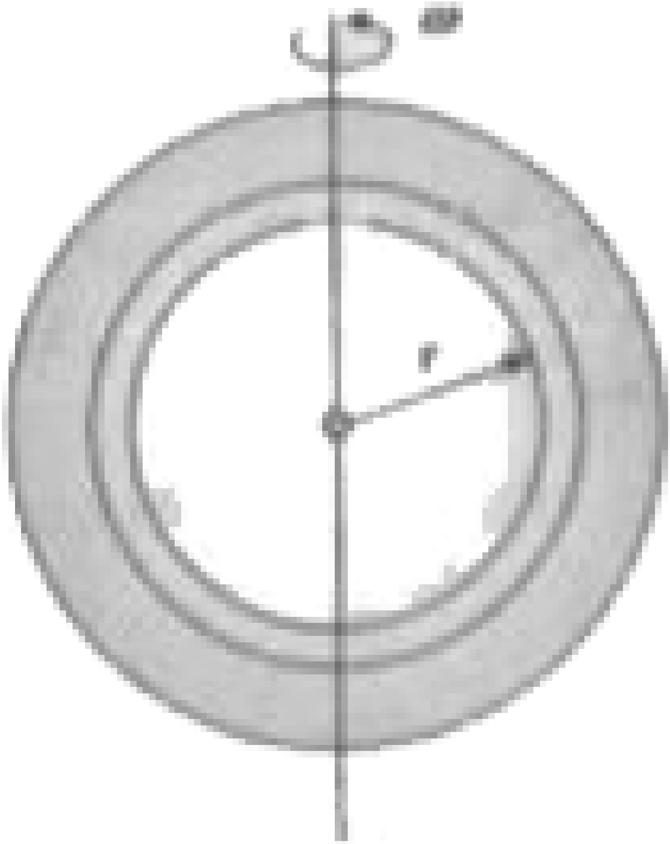
10. Find the moment of inertia of solid sphere of mass M about a diameter as shown in Fig.



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11. The moment of inertia of a ring about its geometrical axis is I, then its moment of inertia about its diameter will be

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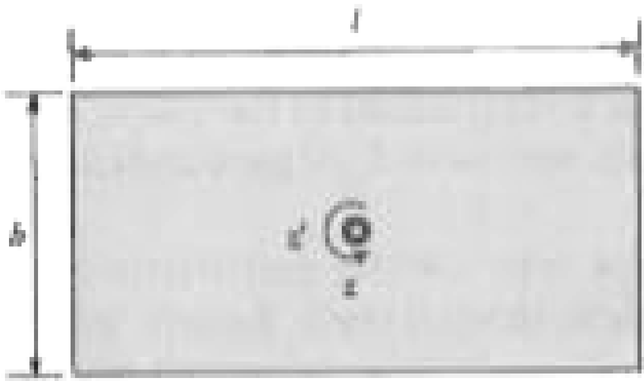
12. Find moment of inertia of a uniform rectangular plate about axis zz' passing through center and perpendicular to the plane of plate, as shown in Fig.



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13. In Fig., three forces, each of magnitude 2.0 N, act on a particle. The particle is in the xz' plane at point A given by position vector $\overrightarrow{r}$, where r = 3.0 m and $\theta = 30^\circ$. What is the torque, about the origin O, due to each force?

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14. To throw an 80 kg opponent with a basic judo hip throw, you intend to pull his uniform with a force $\vec{F}$ and a moment arm d_1 = 0.30 m from a pivot point on your right hip. You wish to rotate him about the pivot point with an angular acceleration α of $-6.0 rad/s^2$ - that is, with an angular acceleration that is clockwise in the figure. Assume that his rotational inertia I relative to the pivot point is $15 kg \cdot m^2$.

(a) What must the magnitude of $\vec{F}$ be if, before you throw him, you benf your opponent forward to bring his center of mass to your hip?

(b) What must the magnitude of $\vec{F}$ be if your opponent remains upright before you throw him, so that $\vec{F}_g$ has a moment arm $d_2 = 0.12m$?

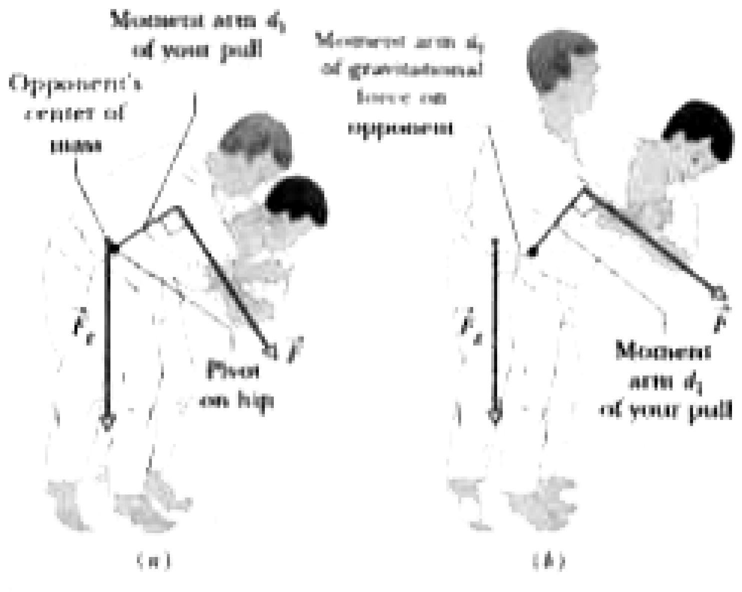

Figure 10-31 A judo hip throw (a) correctly executed and (b) incorrectly executed

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15. Figure shows a uniform disk, with mass M = 2.5 kg and radius R = 20 cm, mounted on a fixed horizontal axle. A block with mass m = 1.2 kg hangs from a massless cord that is wrapped around the rim of the disk. Find the acceleration of the falling block, the angular acceleration of the disk, and the tension in the cord. The cord does not slip, and there is no friction at the axle.

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16. Let the disk of mass 2.5kg start from rest at time t = 0 and also let the tension in the massless cord be 6.0 N and the angular acceleration of the disk be $-24 rad/s^2$. What is its rotational kinetic energy K at t = 2.5 s?

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17. A tall, cylindrical chimney starts falling over as shown in Fig. Treat the chimney as a thin rigid rod of length L = 55.0 m. At the instant it makes as angle of $\theta = 60.0^\circ$ m with the vertical, what is its angular speed ω_f?

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18. A uniform rod of length l and mass M pivoted about its end as shown in Fig. and is free to rotate in the vertical plane about the pivot. The rod is released from rest in the horizontal position.

(a) What is the initial angular acceleration of the rod?

(a)

(b) Find the initial acceleration of the right end of the rod?

(c) Find normal contact force due to hinge when rod has rotated through angle θ as shown in Fig.

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19. Figure shows an overhead view of two particles moving at constant momentum along horizontal paths.

Particle 1, with momentum magnitude $p_1 = 5.0 kg \cdot m / s$, has position vector $\vec{r}_1$ and will pass 2.0 m from point O.

Particle 2, with momentum magnitude $p_2 = 2.0 kg \cdot m / s$, has position vector $\vec{r}_2$ and will pass 4.0 m from point O. What are the magnitude and direction of the net angular momentum $\vec{L}$ about point O of the two particle system?

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20. Figure shows a freeze-frame of a 0.500 kg particle moving along a straight line with a position vector given by

$\vec{r} = (-2.00t^2 - t)\hat{i} + 5.00\hat{j},$

With $\vec{r}$ in meters and t in seconds, starting at t = 0. The position vector points from the origin to the particle. In unit-vector notation, find expressions for the angular momentum $\vec{l}$ of the particle and the torque

$\vec{\tau}$ acting on the particle, both algebraic signs in terms of the particle's motion.

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21. The original Ferris wheel was built in 1893 by George Washington Gale Ferris, Jr., a civil engineering. The wheel, an amazing engineering construction at the time, carried 36 wooden cars, each holding as many as 60 passengers, around a circle of radius R = 38 m. The mass of each car was about $1.1 \times 10^4 kg$. The mass of the wheel's structure was about $6.0 \times 10^5 kg$, which was mostly in the circular grid from which the cars were suspended. The wheel made a complete rotation at an angular speed ω_F in about 2 min.

(a) Estimate the magnitude L of the angular momentum of the wheel and its passengers while the wheel rotated at ω_F.

(b) If the fully loaded wheel is rotated from rest to ω_F in a time period $\Delta t_1 = 5.0 s$, what is the magnitude t_{avg} of the avergae net external torque acting on it?

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22. The conical pendulum is in steady circular motion with constant angular velocity ω as shown in Fig. Mass of the particle is M and string makes angle α with vertical.

(a) Find angular momentum of the particle about the center C of the circle and the hinge O about which the string is attached.

(b) Also check whether L is changing or is constant.

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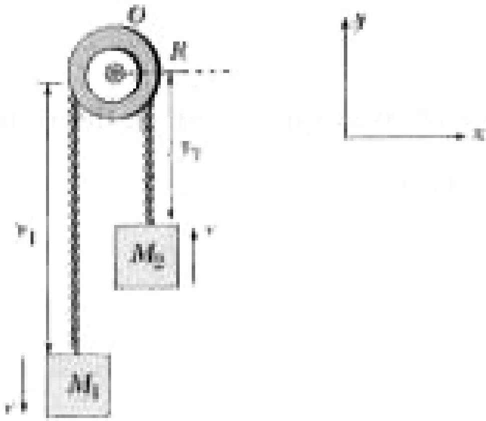
23. A block of mass M_1 and a block of mass M_2 are connected by a string that passes over a pulley as shown in Fig. The pulley is a uniform disk of radius R and mass M. Find the acceleration of the two object, using the concepts of angular momentum and torque.



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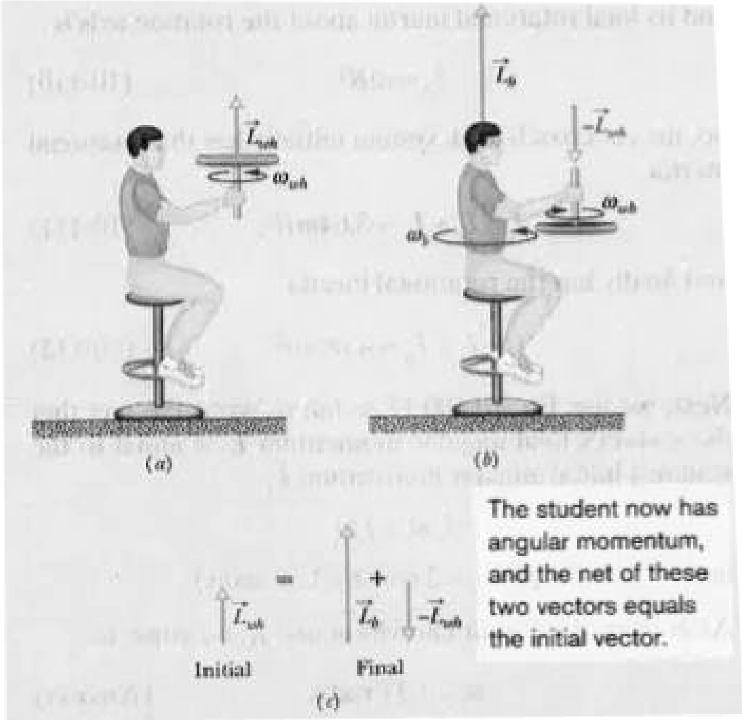
24. Figure shows a student, again sitting on a stool that can rotate freely about a vertical axis. The student, initially at rest, is holding a bicycle wheel whose rim is loaded with lead and whose rotational inertia I_{wh} about its central axis is $1.2 kg \cdot m^2$.

The wheel is rotating at an angular speed ω_{wh} of 3.9 rev/s, as seen from overhead, the rotation is counterclockwise. The axis of the wheel is vertical, and the angular Momentum $\overrightarrow{L}_{wh}$ of the wheel points vertically upward.



The student now inverts the wheel so that, as seen from overhead, it is rotating clockwise. Its angular momentum is now $-\vec{L}_{wh}$. The inversion results in the student, the stool, and the wheel's center rotating together as a composite rigid body about the stool's rotation axis, with rotational inertia $I_b = 6.8 kg \cdot m^2$. With what angular speed ω_b and in what direction does the composite body rotate after the inversion of the wheel?

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25. In Fig. a cockroach with mass m rides on a disk of mass 6.00 m and radius R. The disk rotates like a merry-go-round around its central axis at angular speed $\omega_i = 1.50 rad / s$. The cockroach is initially at radius r = 0.800R, but then it crawls out to the rim of the disk. Treat the cockroach as a particle. What then is the angular speed?

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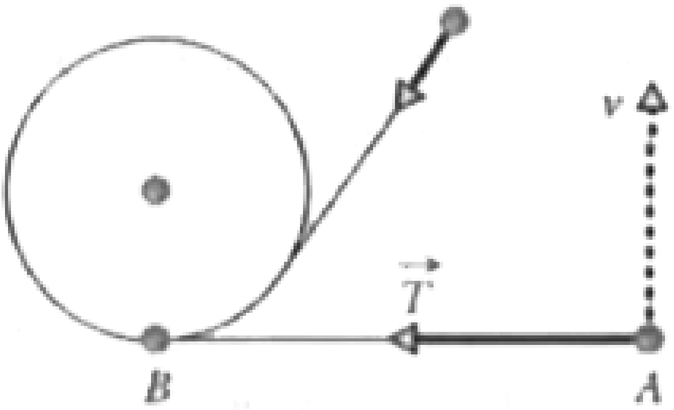
26. On a horizontal smooth plane there is a fixed vertical cylinder and a particle A connected to the cylinder by a thread AB. The particle is set in motion with the initial velocity v as shown in the figure. Is there any fixed point relative to which the angular



momentum of the particle is constant in the process of motion?

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27. Disk 1 rotates about a smooth vertical axis with the angular velocity ω_1. Disk 2 rotating with the angular velocity ω_2 is kept on disk 1 while rotating in the same direction. Find the change in the rotational kinetic energy of the system given that the moments of inertia of the disks relative to the rotation axis are equal to I_1 and I_2, respectively. The constant surface of the disks are rough.

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28. A smooth rod of length l rotates freely in a horizontal plane with the angular velocity about a stationary vertical axis O as shown in Fig. The moment of inertia of the rod is equal to I relative to the axis. A small ring of mass m is located on the rod close to the rotation axis and is tied to it by a thread. When the thread is burned, the ring starts sliding radially outwards along the rod. Find the velocity v of the ring relative to the rod as a function of its distance r from the rotation axis.

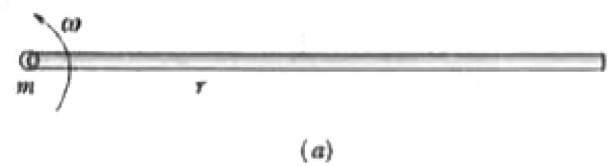

Figure 10-50 (a) Smooth rod rotating freely.

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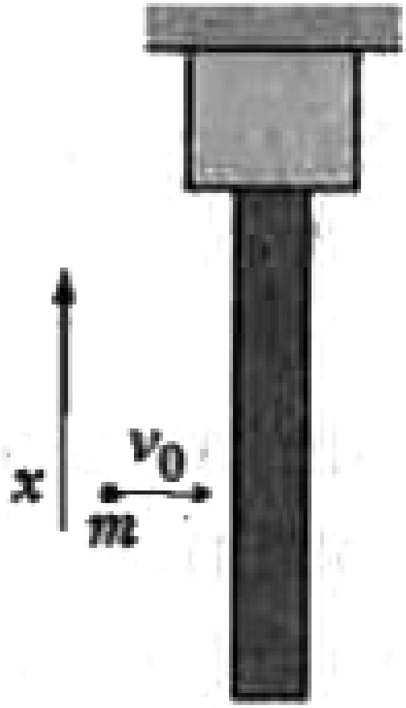
29. A uniform rod of mass m and length l is hinged about one of its end. The hinge is smooth and rod lies on a smooth horizontal surface as shown in Fig. A particle of mass m is coming towards the rod at speed v_0 perpendicular to the length of rod.

(a) Find angular velocity of the rod just after impact.



(b) Also find impulse due to hinge on rod during collision.

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30. A horizontal, homogeneous cylinder of mass M and radius R is pivoted about its axis of symmetry. A string is wrapped several times around the cylinder and tied to a body of mass m resting on a support positioned so that the string has no slack. The body of mass m is then lifted vertically to a distance h, and then released.

(a) Evaluate the angular velocity ω_0 of the cylinder, the speed v_0 of the falling body of mass m, and the kinetic energy K_0 of the system, just before the string becomes taut.

(b) Evaluate the corresponding quantities, $\omega_1, v_1,$ and K_1, for the instant just after the string becomes taut.

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Checkpoint

1. A disk can rotate about its central axis like a merry-go-round. Which of the following pairs of values for its initial and final angular positions, respectively, give a negative angular displacement: (a) -3 rad, +5 rad, (b) -3 rad, -7 rad, (c) 7 rad, -3 rad?

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2. In four situations, a rotating body has angular position $\theta(t)$ given by (a) $\theta = 3t - 4$, (b) $\theta = -5t^3 + 4t^2 + 6$, (c) $\theta = 2/t^2 - 4/t$, and (d) $\theta = 5t^2 - 3$. To which situations do the angular equations of Table 10-1 apply?

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3. A cockroach rides the rim of a rotating merry-go-round. If the angular speed of this system (merry-go-round + cockroach) is constant, does the cockroach have (a) radial acceleration and (b) tangential acceleration? If ω is decreasing, does the cockroach have (c) radial acceleration and (d) tangential acceleration?

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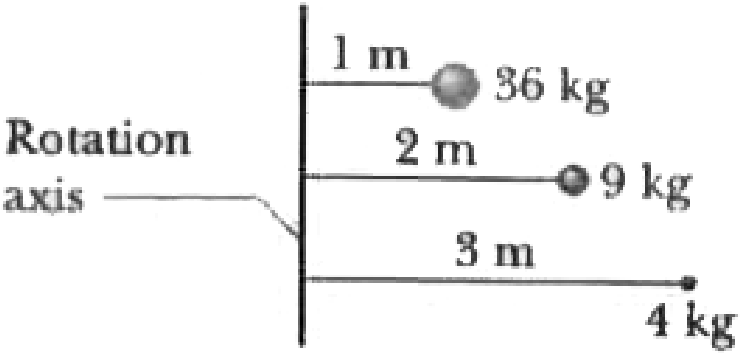
4. The figure shows three small spheres that rotate about a vertical axis. The perpendicular distance between the axis and the center of each sphere is given. Rank the three spheres according to their rotational inertia about that axis, greatest first.



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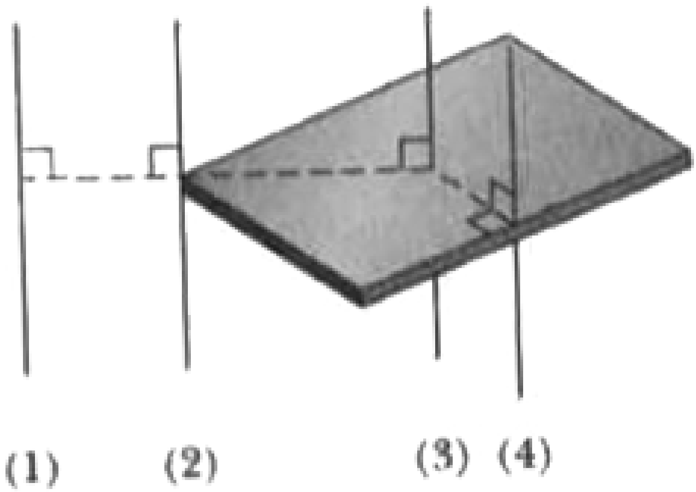
5. The figure shows a book-like object (one side is longer than the other) and four choices of rotation axes, all perpendicular to the face of the object. Rank the choices according to the rotational inertia of the object about the axis, greatest first.



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6. Find the moment of inertia of a half uniform ring (mass m, radius r) about its center.

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7. Find moment of inertia of a uniform solid sphere (mass m, radius r) about a tangent.

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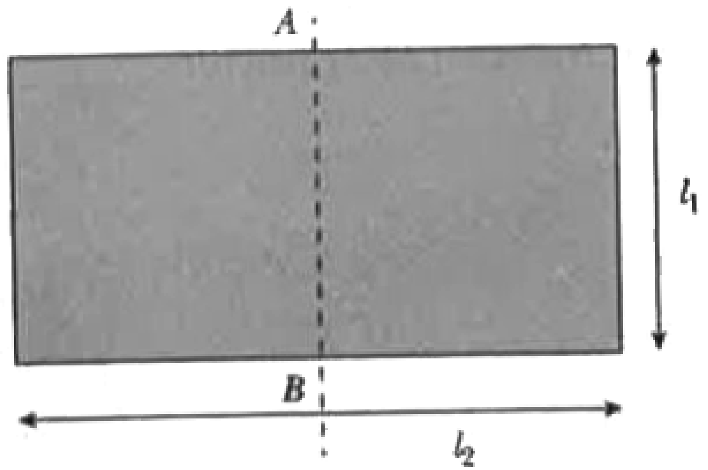
8. Find moment of inertia of a uniform rectangular plate (mass m) about axis AB lying in its plane and passing through center as shown in the figure.



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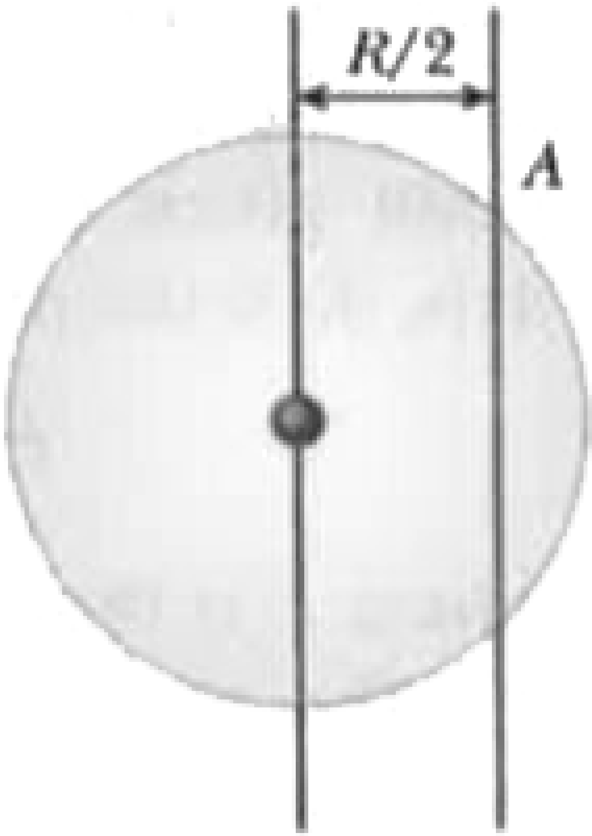
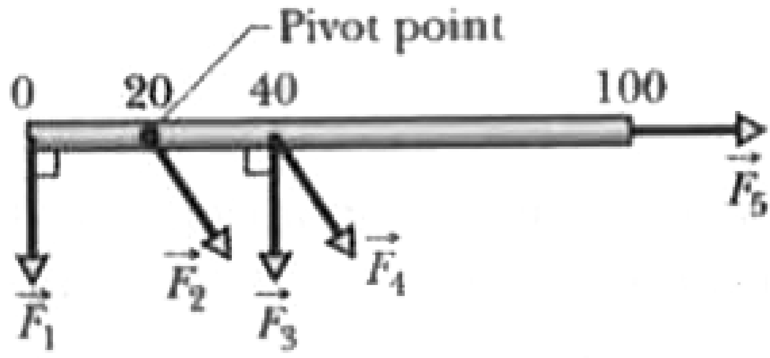
9. Find moment of inertia of a uniform ring (mass m, radius r) about chord AA' at distance R/2 from center.



10. The figure shows an overhead view of a meter stick that can pivot about the dot at the position marked 20 (for 20 cm). All five forces on the stick are horizontal and have the same magnitude. Rank the forces

according to the magnitude of the torque they produce, greatest first.



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11. The position vector $\vec{r}$ of a particle points along the positive direction of a z axis. If the torque on the particle is (a) zero, (b) in the negative direction of x, and (c) in the negative direction of y, in what direction is the force causing the torque?

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12. Find torque due to gravity at any time t about point of projection. If a body of mass m is projected at an angle θ with speed v_0 at t = 0.

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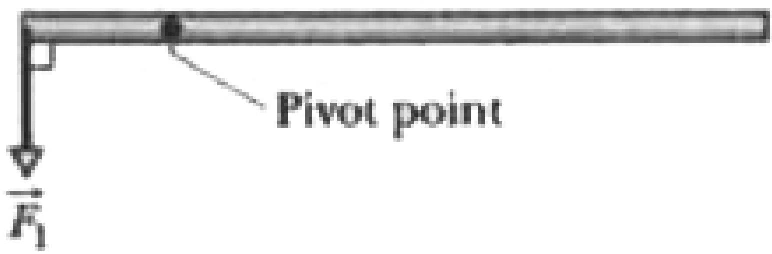
13. The figure shows an overhead view of a meter stick that can pivot about the point indicated, which is to the left of the stick's midpoint. Two horizontal forces, $\vec{F}_1$ and $\vec{F}_2$, are applied to the stick. Only $\vec{F}_1$ is shown. Force $\vec{F}_2$ is perpendicular to the stick and is applied at the right end. If the stick is not to turn, (a) what should be the direction of $\vec{F}_2$, and (b) should F_2 be greater than, less than, or equal to F_1?



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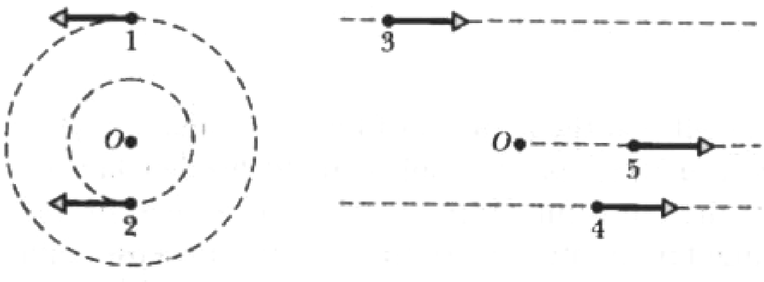
14. In part a of the figure, particles 1 and 2 move around point O in circles with radii 2 m and 4 m. In part b, particles 3 and 4 travel along straight lines at perpendicular distances of 4 m and 2 m from point O. Particle 5 moves directly away from O. All five particles have the same mass and the same constant speed. (a) Rank the particles according to the magnitudes of their angular momentum about point O, greatest first. (b) Which particles have neagtive angular momentum about point O?



(a) (b)

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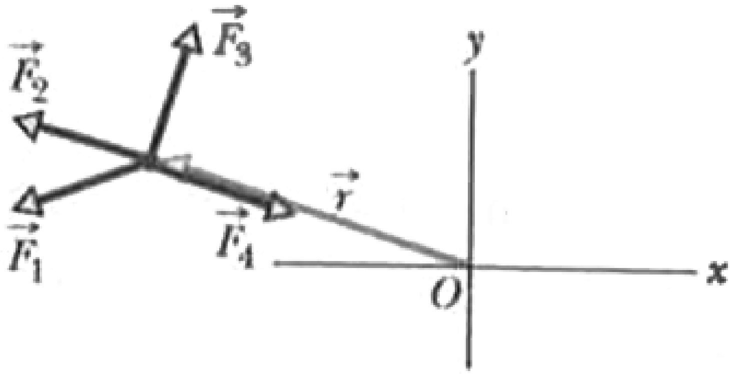
15. The figure shows the position vector $\vec{r}$ of a particle at a certain instant, and four choices for the direction of a force that is to accelerate the particle. All four choices lie in the xy plane. (a) Rank the choices according to the magnitude of the time rate of change (dl/dt) they produce in the angular momentum of the particle about point O, greatest first. (b) Which choice results in a negative rate of change about O?



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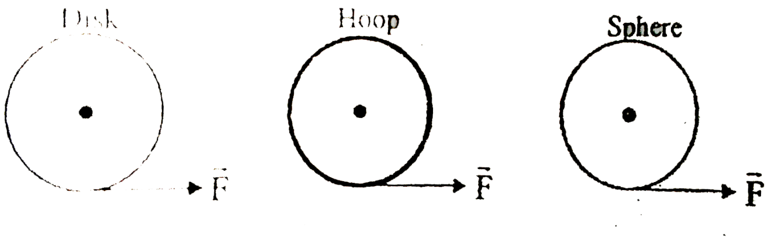
16. A uniform disk, a thin hoop (ring), and a uniform sphere, all with the same mass and same outer radius, are each free to rotate about a fixed axis through its center. Assume the hoop is connected to the rotation axis by light spokes. With the objects starting from rest, identical forces are simultaneously applied to the rims, as shown. Rank the objects according to their angular momentum after a given time t, least to greatest.



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17. A rhinoceros beetle rides the rim of a small disk that rotates like a merry-go-round. If the beetle crawls toward the center of the disk, do the following (each relative to the central axis) increase, decrease, or remain the same for the beetle-disk system: (a) rotational inertia, (b) angular momentum, and (c) angular speed?

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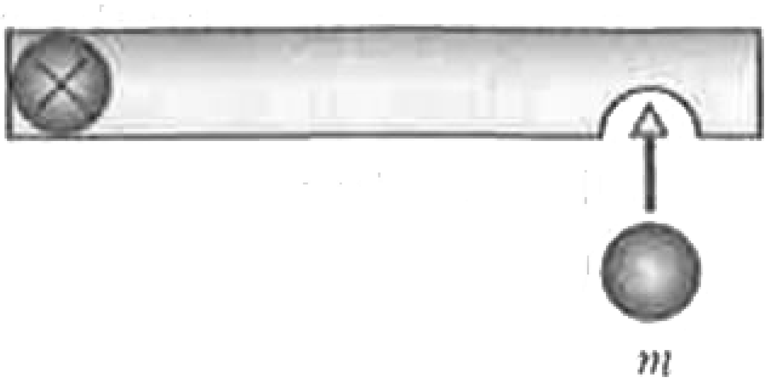
18. A rod of mass 12 m and length l lying on a smooth horizontal plane can rotate freely about a stationary, vertical axis passing through the rod's end. A particle of mass m moving along the plane with speed v_0 hits the rod's end perpendicularly and gets stuck there. Find the angular velocity of the system.



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Problems

1. A tractor has rear wheels with a radius of 1.00 m and front wheels with a radius of 0.250 m. The rear wheels are rotating at 100 rev/min. Find (a) the angular speed of the front wheels in revolutions per minute and (b) the distance covered by the tractor in 10.0 min.

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2. Just as a helicopter is landing, its blades are turning at 30.0 rev/s and slowing at a constant rate. In the 2.00 min required for them to stop, how many revolutions do they make?

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3. When a slice of buttered toast is accidentally pushed over the edge of a counter, it rotates as it falls. If the distance to the floor is 76 cm and for rotation less than 1 rev, what are the (a) smallest and (b) largest angular speeds that cause the toast to hit and then topple to be butter-side down?

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4. The angular position of a point on a rotating wheel is given by $\theta = 2.0 + 4.0t^2 + 2.0t^3$, where θ is in radians and t is in seconds. At t = 0, what are (a) the point's angular position and (b) its angular velocity? (c) What is its angular velocity at t = 3.0 s? (d) Calculate its angular acceleration at t = 4.0 s. (e) Is its angular acceleration constant?

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5. At time t = 0, a rotating bicylce wheel is thrown horizontally from a rooftop with a speed of 49 m/s. By the time its vertical speed is also 49 m/s, it has completed 40 revolutions. What has been its average angular speed to that point in the fall?

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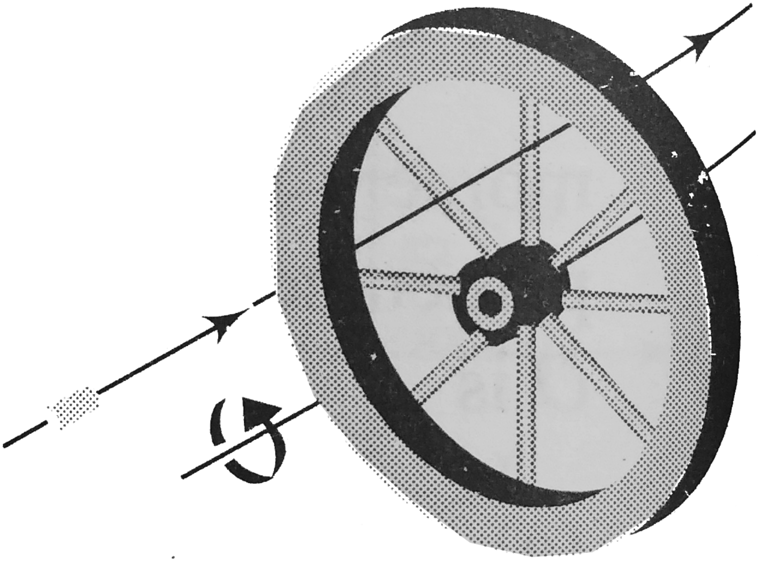
6. The wheel in figure has eight equally spaced spokes and of $30cm$. It is mounted on a fixed axle and is spinning at $2.5rev/s$. You want to shoot a $20-cm-long$ arrow parallel to this axle and through the wheel without hitting any of the spokes. Assume that the arrow and the spokes are very thin. What minimum speed must the arrow have ?



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7. The angular acceleration of a wheel is $\alpha = 6.0t^4 - 4.0t^2$, with α in radians per second-squared and t in seconds. At time t = 0, the wheel has an angular velocity of +2.5 rad/s and an angular position of +1.5 rad. Write expressions for (a) the angular velocity (rad/s) and (b) the angular position (rad) as functions of time (s).

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8. In 5.00 s, a 2.00 kg stone moves in a horizontal circle of radius 2.00 m from rest to an angular speed of 4.00 rev/s. What are the stone's (a) average angular acceleration and (b) rotational inertia around the circle's center?

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9. Starting from rest, a disk rotates about its central axis with constant angular acceleration. In 5.0 s, it rotates 20 rad. During that time, what are the magnitudes of (a) the angular acceleration and (b) the average angular velocity? (c) What is the instantaneous angular velocity of the disk at the end of the 5.0 s? (d) With the angular acceleration unchanged, through what additional angle will the disk turn during the next 5.0 s?

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10. Two identical disks A and B can spin around vertical axes. Disk A is spinning with an initial angular speed of 40 rev/s when its rim touches initially stationary disk B, causing that disk to begin to spin. The rubbing at the contact point slows A while speeding up B. The rate at which both disks change their angular speeds is $2.0 rev / s^2$. Find the time required for the two disks to reach the same angular speed.

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11. The angular speed of an automobile engine is increased at a constant rate from 1200 rev/min to 3200 rev/min in 12 s. (a) What is its angular acceleration in revolutions per minute-squared? (b) How many revolutions does the engine make during this 12 s interval?

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12. A flywheel turns through 40 rev as it slows from an angular speed of 1.5 rad/s to a stop. (a) Assuming a constant angular acceleration, find the time for it to come to rest. (b) What is its angular acceleration? (c) How much time is required for it to complete the first 20 of the 40 revolutions?

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13. A disc rotates about the central axis starting from rest and accelerates with constant angular acceleration. At one time, it is rotating at $10 rps$, 60 revolution later, its angular speed is $15 rps$. Calculate (i) angular acceleration (ii) time required to complete 60 revolutions (iii) the time required to reach $10 rev/\sec$ angular speed and (iv) number of revolutions from rest until the time the disc reaches $10 rps$ angular speed.

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14. Starting from rest, a wheel has constant $\alpha = 3.0 rad/s^2$. During a certain 4.0 s interval, it turns through 120 rad. How much time did it take to reach that 4.0 s interval?

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15. At t = 0, a flywheel has an angular velocity of 4.7 rad/s, a constant angular acceleration of $-0.25 rad/s^2$, and a reference line at $\theta_0 = 0$ (a) Through what maximum angle $\theta_{\max}$ will the reference line turn in the positive direction? What are the (b) first and (c) second times the reference line will be at $\theta = 1/2\theta_{\max}$? At what (d) negative time and (e) positive time will the reference line be at θ = 10.5 rad ? (f) Graph θ versus t, and indicate your answers.

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16. An open jar of water moves in a vertical circle of radius 0.50 m with a frequency that is small enough to put the water on the verge of falling out of the jar at the top of the circle. If the same demonstration is only $3.7 m/s^2$, what is the change in the circling frequency to again put the water on the verge of falling out at the top point?

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17. An object rotates about a fixed axis, and the angular position of a reference line on the object is given by $\theta = 0.40e^{2t}$, where θ is in radians and t is in seconds. Consider a point on the object that is 6.0 cm from the axis of rotation. At t = 0, what are the magnitudes of the point's (a) tangential component of acceleration and (b) radial component of acceleration?

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18. Between 1911 and 1990, the top of the leaning bell tower at Pisa, Italy, moved toward the south at an average rate of 1.2 mm/y. The tower is 55 m tall. In radians per second, what is the average angular speed of the tower's top about its base?

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19. Starting from rest at time t = 0, a circus stunt man drives a motorbike on a horizontal circular track of radius 10.0 m. His speed is given by $v = ct^2$, where $c = 1.00m / s^3$. At t = 2.00 s, what is the angle between his (total) acceleration vector and his radial acceleration vector?

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20. A flywheel with a diameter of 1.20 m is rotating at an angular speed of 200 rev/min. (a) What is the angular speed of the flywheel in radians per second? (b) What is the linear speed of a point on the rim of the flywheel? (c) What constant angular acceleration (in revolutions per minute-squared) will increase the wheel's angular speed to 1000 rev/min in 60.0 s? (d) How many revolutions does the wheel make during that 60.0 s?

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21. (a) What is the angular speed ω about the polar axis of a point on Earth's surface at latitude $40^\circ N$? (Earth rotates about that axis.) (b)

What is the linear speed v of the point? What are (c) ω and (d) v for a point at the equator?

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22. The flywheel of a steam engine runs with a constant angular velocity of 160 rev/min. When steam is shut off, the friction of the bearings and of the air stops the wheel in 2.2 h. (a) What is the constant angular acceleration, in revolutions per minute-squared, of the wheel during the slowdown? (b) How many revolutions does the wheel make before stopping? (c) At the instant the flywheel is turning at 75 rev/min, what is the tangential component of the linear acceleration of a flywheel particle that is 50 cm from the axis of rotation? (d) What is the magnitude of the net linear acceleration of the particle in (c) ?

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23. A seed is on a turntable rotating at 331/3 rev/min, 6.0 cm from the rotation axis. What are (a) the seed's acceleration and (b) the least coefficient of static friction to avoid slippage? (c) If the turntable has undergone constant angular acceleration from rest in 0.25 s, what is the least coefficient to avoid slippage?

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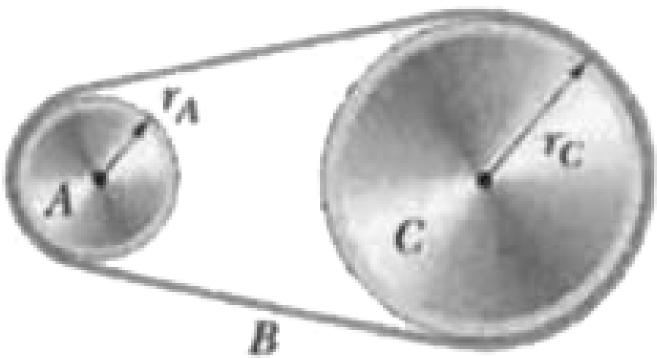
24. In Fig. 10-54, wheel A of radius $r_A = 10cm$ is coupled by belt B to wheel C of radius $r_C = 25cm$. The angular speed of wheel A is increased from rest at a constant rate of $2.0 rad / s^2$. Find the time needed for wheel C to reach an angular speed of 100 rev/min, assuming the belt does not slip.



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25. Figure 10-55 shows an early method of measuring the speed of light that makes use of a rotating slotted wheel. A beam of light passes through one of the slots at the outside edge of the wheel, travels to a distant mirror, and returns to the wheel just in time to pass through the next slot in the wheel. One such slotted wheel has a radius of 5.0 cm and 500 slots around its edge. Measurements taken when the mirror is L = 500 m from the wheel indicate a speed of light of $3.0 \times 10^5 km/s$. (a) What is the (constant) angular speed of the wheel? (b) What is the linear speed of a point on the edge of the wheel?

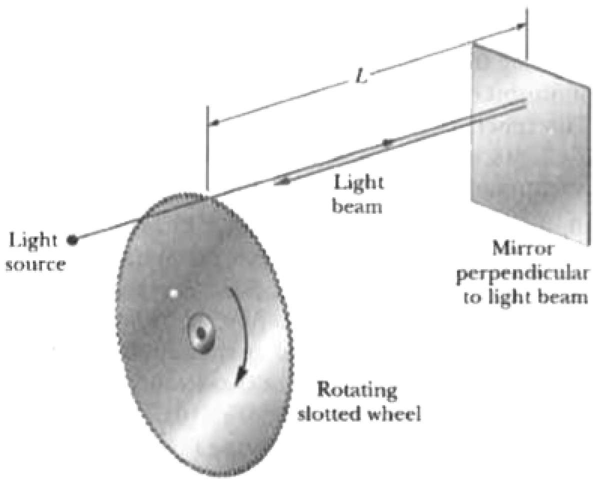

Figure 10-55 Problem 25.

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26. A disk, with a radius of 0.25 m, is to be rotated like a merry-go-round through 800 rad, starting from rest, gaining angular speed at the constant rate α_1 through the first 400 rad and then losing angular speed at the constant rate - α_1 until it is again at rest. The magnitude of the centripetal acceleration of any portion of the disk is not to exceed $400m / s^2$. (a) What is the least time required for the rotation? (b) What is the corresponding value of α_1?

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27. A car starts from rest and moves around a circular track of radius 32.0 m. Its speed increases at the constant rate of $0.600m / s^2$. (a) What is the magnitude of its net linear acceleration 15.0 s later? (b) What angle does this net acceleration vector make with the car's velocity at this time?

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28. (a) A uniform 2.00 kg disk of radius 0.300 m can rotate around its central axis like a merry-go-round. Beginning from rest at time t = 0, it undergoes a constant angular acceleration of $30.0 rad/s^2$. When is the rotational kinetic energy equal to 2000 J? (b) Repeat the calculation but substitute a ring of the same mass and radius and assume that the spokes have negligible mass.

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29. Figure 10-56 gives angular speed versus time for a thin rod that rotates around one end. The scale on the ω axis is set by $\omega_s = 60 rad/s$. (a) What is the magnitude of the rod's angular acceleration? (b) At t = 4.0 s, the rod has a rotational kinetic energy of 1.60 J. What is its kinetic energy at t = 0?

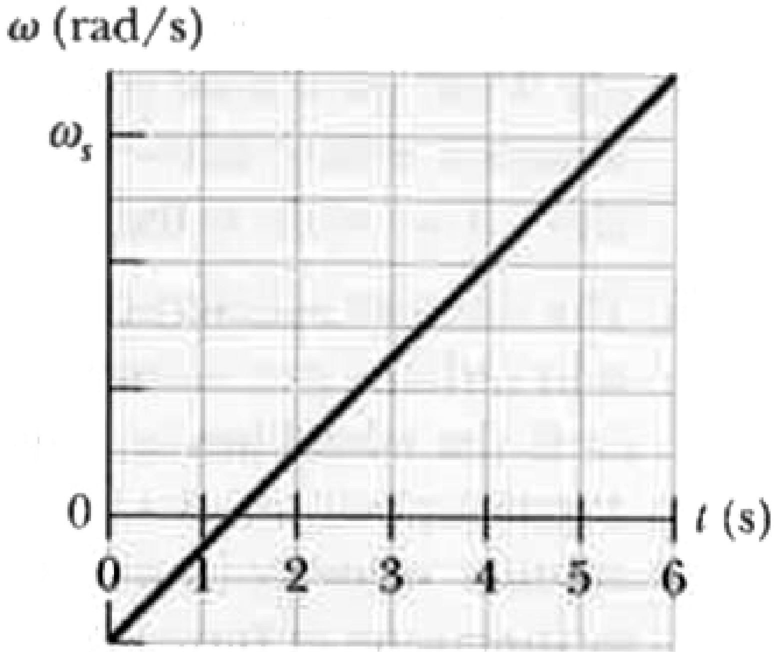

Figure 10-56 Problem 29.

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30. A meter stick of negligible mass can rotate about a vertical axis through a point at distant x from the point marked "0". A small block of mass 0.100 kg is glued at the mark of "0" and a small block of mass 0.500 kg is glued at the opposite end, at the mark of "1." The stick and blocks are to rotate with an angular speed of 5.00 rad/min. (a) For what choice of x is the associated rotational kinetic energy least and (b) what is that least erergy?

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31. Figure 10-57 a shows a disk that can rotate about an axis at a radial distance h from the center of the disk. Figure 10-57b gives the rotational inertia I of the disk about the axis as a function of that distance h, from the center out to the edge of the disk. The scale on the I axis is set by $I_A = 0.050 kg \cdot m^2$ and $I_B = 0.150 kg \cdot m^2$. What is the mass of the disk?

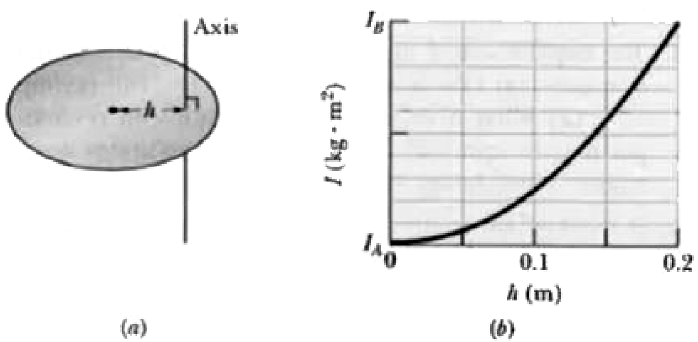

Figure 10-57 **Problem 31.**

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32. A 0.50 kg meter stick can rotate around an axis perpendicular to the stick. Find the difference in the stick's rotational inertia about the rotation axis if that axis is initially at the point marked "40cm" and then at the point marked "10cm".

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33. Figure 10-58 shows three 0.0100 kg particles that have been glued to a rod of length L = 8.00 cm and negligible mass. The assembly can rotate around a perpendicular axis through point O at the left end. If we remove one particle (that is, 33% of the mass), by what percentage does the rotational inertia of the assembly around the rotation axis decrease when that removed particle is (a) the inner-most one and (b) the outermost one?

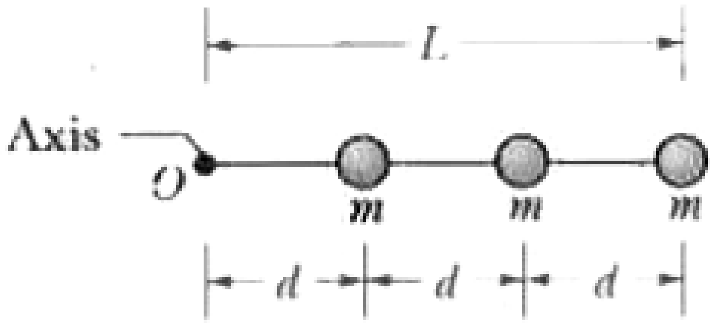

Figure 10-58 Problems 33

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34. A wheel with a rotational inertia of $0.50 kg \cdot m^2$ about its central axis is initially rotating at an angular speed of 15 rad/s. At time t = 0, a man begins to slow it at a uniform rate until it stops at t = 5.0 s. (a) By time t = 3.0 s, how much work had the man done? (b) For the full 5.0 s, at what average rate did the man do work?

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35. Figure 10-59 shows an arrangement of 15 identical disks that have been glued together in a rod-like shape of length L = 1.0000 m and (total) mass M = 100.0 mg. The disks are uniform, and the disk arrangement can rotate about a perpendicular axis through its central disk at point O. (a) What is the rotational inertia of the arrangement about that axis? (b) If we approximated the arrangement as being a uniform rod of mass M and length L, what percentage error would we make in using the formula in Table 10-2e to calculate the rotational inertia?

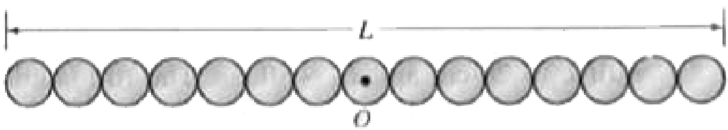

Figure 10-59 Problem 35.

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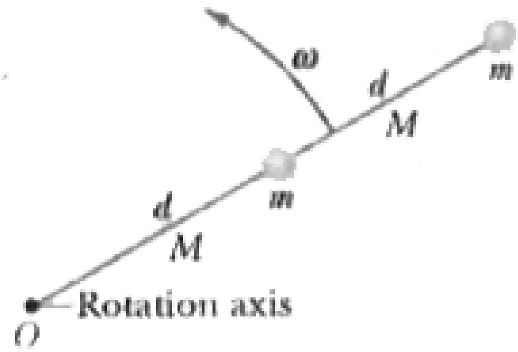
36. In Fig. 10-60, two particles, each with mass m = 0.85 kg, are fastened to each other, and to a rotation axis at O, by two thin rods, each with length d = 5.6 cm and mass M = 1.2 kg. The combination rotates around the rotation axis with the angular speed $\omega = 0.30 rad/s$. Measured about O, what are the combination's (a) rotational inertia and (b) kinetic energy?



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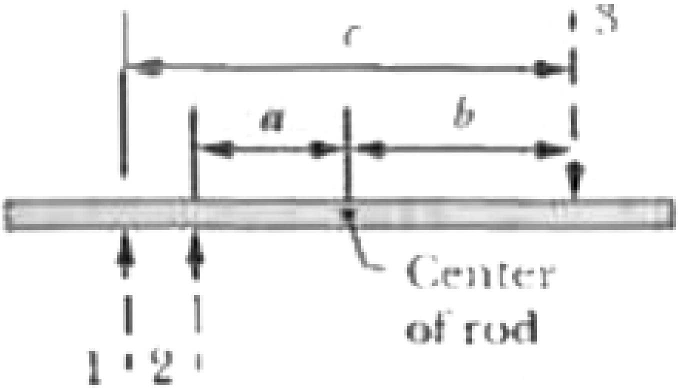
37. Figure 10-61 is an overhead view of a rod of length 1.0 m and mass 1.0 kg that is lying stationary on a frictionless surface when three bullets hit it simultaneously. The bullets move along paths that are in the plane of the rod and per-pendicular to the rod. Bullet 1 has mass 10 g and speed 2.0 m/s. Bullet 2 has mass 20 g and speed 3.0 m/s. Bullet 3 has mass 30 g and speed 5.0 m/s. The labelled distance are $\alpha = 10cm$, b = 60 cm, and c = 80 cm. As a result of the impacts, the rod-bullets system rotates around its center of mass while the center of mass moves in a straight line over the frictionless surface. (a) What is the linear speed of the system's center of mass? (b) What is the distance between the rod's center and the system's center of mass ? (c) What is the rotational inertia of the system about the system's center of mass?



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38. The uniform solid block in Fig. 10-62 has mass 0.172 kg and edge lengths a = 3.5 cm, b = 8.4 cm, and c = 1.4 cm. Calculate its rotational inertia about an axis through one corner and perpendicular to the large faces.

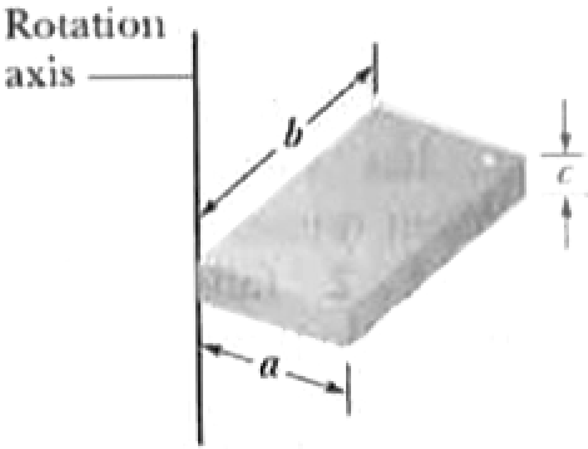

Figure 10-62 Problem 38.

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39. Four identical particles of mass 0.75 kg each are placed at the vertices of a $2.0m \times 2.0m$ square and held there by four massless rods, which form the sides of the square. What is the rotational inertia of this rigid body about an axis that (a) passes through the midpoints of opposite sides and lies in the plane of the square, (b) passes through the midpoint of one of the sides and is perpendicular to the plane of the square, and (

c) lies in the plane of the square and passes through two diagonally opposite particles?

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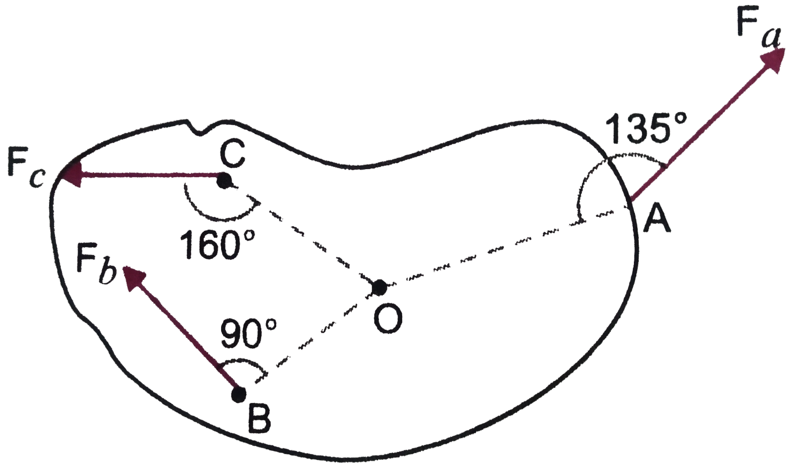
40. The body shown in Fig. is pivoted at point O. Three forces act on it $F_a = 10N$ at point A, $8.0m$ from O, $F_b = 16N$ at B, $4.0m$ from O, and $F_c = 19N$ at C, $3.0m$ from O. What is the net torque about O.



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41. A 60 kg father and 20 kg child sit on opposite ends of a seesaw consisting of a board of length 4.0 m and negligible mass. The pivot can be placed anywhere between the father and the child. At what distance from the child should it be placed so that the seesaw is balanced when the father and child are stationary?

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42. A 100 kg cubical box lies on a floor. A child pushes horizontally at a top edge. What force magnitude puts the box on the verge of tipping over if there is sufficient friction between it and the floor to prevent sliding?

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43. A cord with negligible mass is wrapped around a pulley that is a uniform disk of mass 5.00 kg and radius 0.300 m and that can rotate without friction about its central axis. A 1.0 kg bucket is attached at the free end of the cord hanging down from the pulley and then released at time t = 0. The cord begins to unwrap from the pulley as the bucket descends. At t = 5.00 s, through how many rotations has the pulley turned (the bucket is still descending)?

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44. If a $42.0N \cdot m$ torque on a wheel causes angular acceleration $25.0rad/s^2$, what is the wheel's rotational inertia?

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45. In Fig. 10-64, block 1 has mass $m_1 = 460g$, block 2 has mass $m_2 = 500g$, and the pulley, which is mounted on a horizontal axle with negligible friction, has radius R = 5.00 cm. When released from rest, block 2 falls 75.0 cm in 5.00 s without the cord slipping on the pulley. (a) What is the magnitude of the acceleration of the blocks? What are (b) tension T_2 and (c) tension T_1? (d) What is the magnitude of the pulley's angular acceleration? (e) What is its rotational inertia?

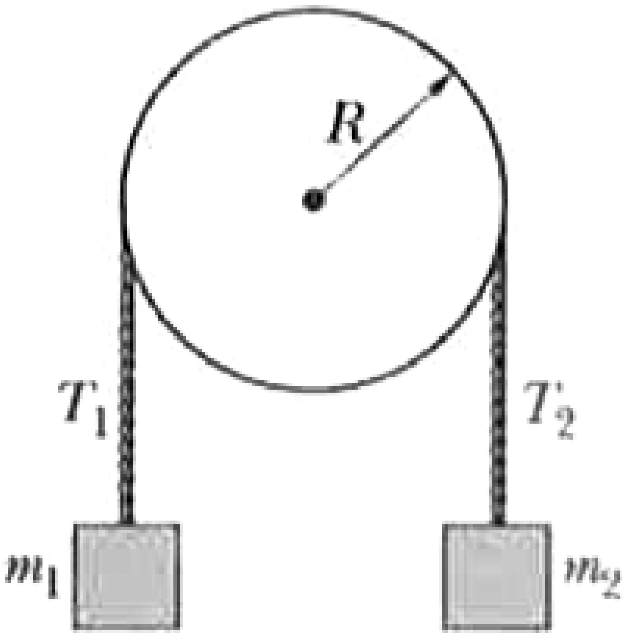

Figure 10-64 Problem 45.

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46. In Fig. 10-65, a cylinder having a mass of 3.0 kg can rotate about its central axis through point O. Forces are applied as shown: $F_1 = 6.0N$, $F_2 = 4.0N$, $F_3 = 2.0N$ and $F_4 = 5.0N$. Also, r = 5.0 cm and R = 12 cm. Find the (a) magnitude and (b) direction of the angular acceleration of the cylinder. (During the rotation, the forces maintain their same angles relative to the cylinder.)

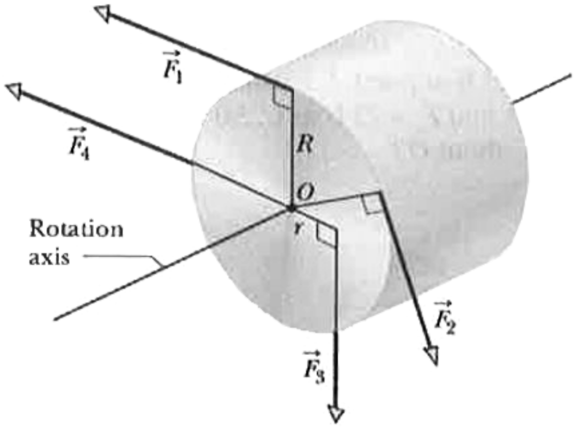

Figure 10-65 Problem 46.

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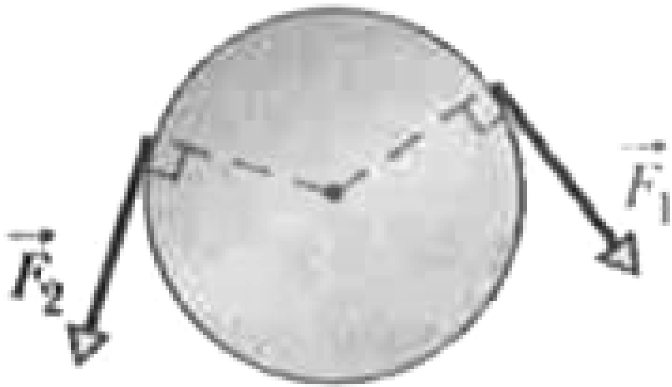
47. Figure shows a uniform disk that can rotate around its center like a merry-go-round. The disk has a radius of 2.00 cm and a mass of 20.0 grams and is initially at rest. Starting at time t = 0, two forces are to be applied tangentially to the rim as indicated, so that at time t = 1.25 s the disk has an angular velocity of 250 rad/s counterclockwise. Force $\overrightarrow{F}_1$ has a magnitude of 0.100 N. What is magnitude F_2 ?



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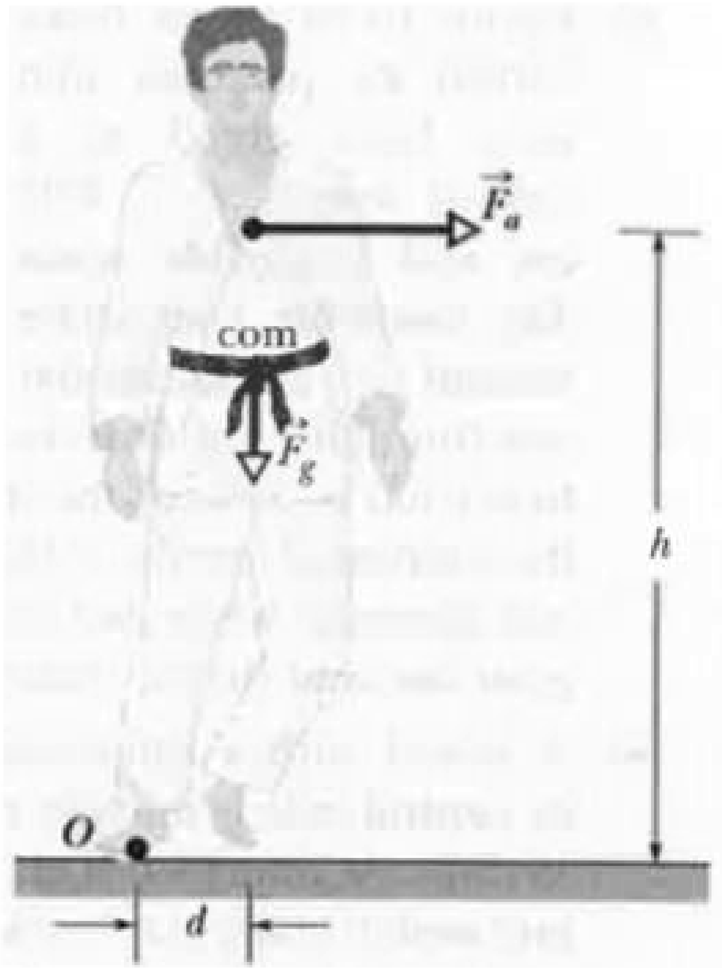
48. In a judo foot-sweep move, you sweep your opponent's left foot out from under him while pulling on his gi (uniform) toward that side. As a result, your opponent rotates around his right foot and onto the mat. Figure 10-67 shows a simplified diagram of your opponent as you face him, with his left foot swept out. The rotational axis is through point O. The gravitational force $\overrightarrow{F}_g$ on him effectively acts at his center of mass, which is a horizontal distance d = 28 cm from point O. His mass is 75 kg, and his rotational inertia about point O is $65 kgm^2$. What is the magnitude of his initial angular acceleration about point O if your pull

$\vec{F}_a$ on his gi is (a) negligible and (b) horizontal with a magnitude of 300 N and applied at height h = 1.4 m?



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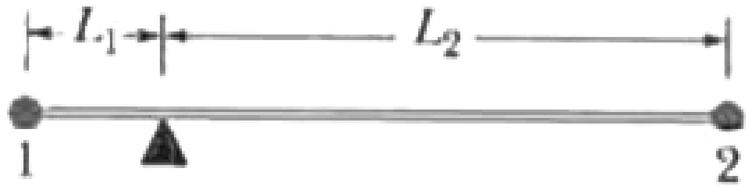
49. Figure shows particles 1 and 2, each of mass m, fixed to the ends of a rigid massless rod of length $L_1 + L_2$, with $L_1 = 20cm$ and $L_2 = 80cm$. The rod is held horizontally on the fulcrum and then released. What are the magnitudes of the initial accelerations of (a) particle 1 and (b) particle 2?



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50. A pulley, with a rotational inertia of $1.0 \times 10^{-3} kg \cdot m^2$ about its axle and a radius of 10 cm, is acted on by a force applied tangentially at its rim. The force magnitude varies in time as $F = 0.50t + 0.30t^2$, with F in newtons and t in seconds. The pulley is initially at rest. At t = 3.0 s what are its (a) angular acceleration and (b) angular speed?

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51. (a) If R = 15 cm, M = 350 g, and m = 50 g in Fig. 10-19, find the speed of the block after it has descended 50 cm starting from rest. Solve the problem using energy conservation principles. (b) Repeat (a) with R = 5.0 cm.

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52. A uniform metal pole of height 30.0 m and mass 100 kg is initially standing upright but then falls over to one side without its lower end sliding or losing contact with the ground. What is the linear speed of the pole's upper end just before impact?

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53. A thin rod of length 0.75 m and mass 0.42 kg is suspended freely from one end. It is pulled to one side and then allowed to swing like a pendulum, passing through its lowest position with angular speed 3.5

rad/s. Neglecting friction and air resistance, find (a) the rod's kinetic energy at its lowest position and (b) how far above that position the center of mass rises.

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54. A metre stick is held vertically with one end on the floor and is then allowed to fall . Find the speed of the other end when it hits the floor , assuming that the end of the floor does not slip . Take g = 10 m/s^2.

$\left[\sqrt{30}m / s\right]$

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55. A uniform cylinder of radius 12 cm and mass 25 kg is mounted so as to rotate freely about a horizontal axis that is parallel to and 5.0 cm from the central longitudinal axis of the cylinder. (a) What is the rotational inertia of the cylinder about the axis of rotation? (b) If the cyliner is released from rest with its central longitudinal axis at the same height as the axis about which the cylinder rotates, what is the angular speed of the cylinder as it passes through its lowest position?

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56. A tall, cylindrical chimney falls over when its base is ruptured. Treat the chimney as a thin rod of length 55.0 m. At the instant it makes an angle of 35.0° with the vertical as it falls, what are (a) the radial acceleration of the top, and (b) the tangential acceleration of the top. (c) At what angle θ is the tangential acceleration equal to g?

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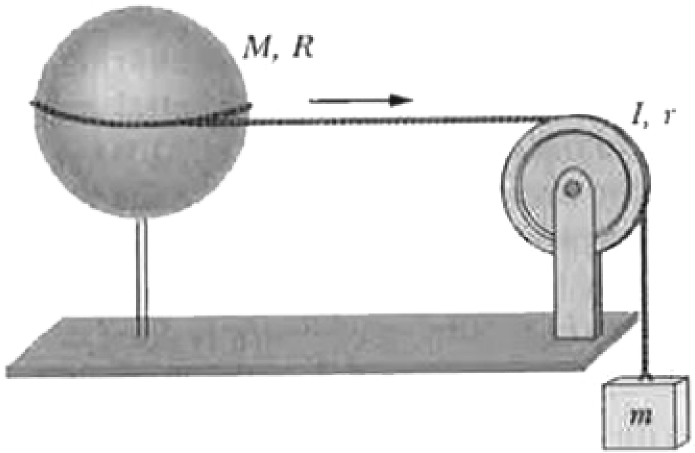
57. A uniform spherical shell of mass M = 4.5 kg and radius R = 8.5 cm can rotate about a vertical axis on frictionless bearings (Fig. 10-69). A massless cord passes around the equator of the shell, over a pulley of rotational inertia $I = 3.0 \times 10^{-3} kg \cdot m^2$ and radius r = 5.0 cm, and is attached to a small object of mass m = 0.60 kg. There is no friction on the pulley's axle, the cord does not slip on the pulley. What is the speed of the object when it has fallen 82 cm after being released from rest? Use energy considerations.



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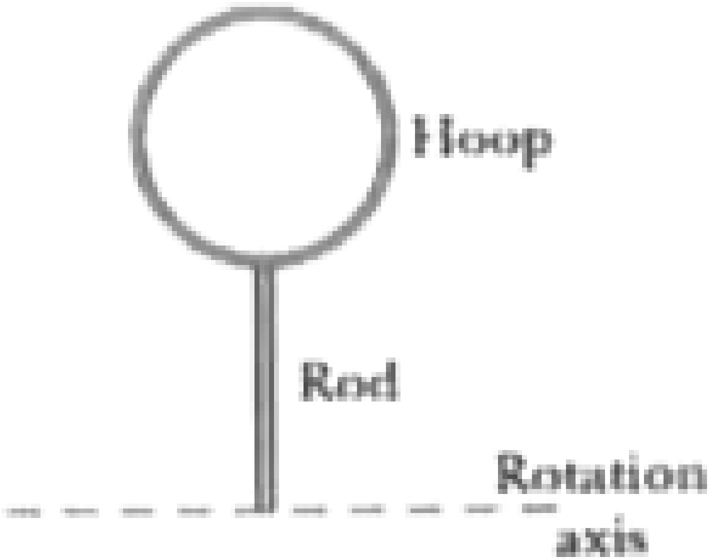
58. Figure shows a rigid assembly of a thin hoop (of mass m and radius R = 0.150 m) and a thin radial rod (of mass m and length L = 2.00R). The assembly is upright, but if we give it a slight nudge, it will rotate around a horizontal axis in the plane of the rod and hoop, through the lower end of the rod. Assuming that the energy given to the assembly in such a nudge is negligible, what would be the assembly's angular speed about the rotation axis when it passes through the upside-down (inverted) orientation?



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59. In unit vector notation, find the net torque about the origin on a particle located at $(2.0m, -2.0m, -6.0m)$ when the three forces $\overrightarrow{F}_1 = (6.0N)\hat{j}, \overrightarrow{F}_2 = (1.0N)\hat{i} - (2.0N)\hat{j}$, and $\overrightarrow{F}_3 = (4.0N)\hat{i} + (2.0N)\hat{j}$ act on the particle.

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60. In unit vector notation, find the torque about a point at coordinates (2.0 m, 1.0 m, 3.0 m) on a particle located at (3.0 m, 1.0 m, 2.0 m) when a force $\overrightarrow{F} = (1.0N)\hat{i} - (3.0N)\hat{k}$ acts on the particle.

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61. In unit vector notation, what is the torque about the origin on a particle located at coordinates (0, -4.0 m, 3.0 m) if that torque is due to (a) force $\overrightarrow{F}_1$ with components $F_{1x} = 2.0N$, $F_{1y} = F_{1z} = 0$, and (b) force $\overrightarrow{F}_2$ with components $F_{2x} = 0$, $F_{2y} = 2.0N$, $F_{2z} = 4.0N$?

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62. A particle moves through an xyz coordinate system while a force acts on the particle. When the particle has the position vector $\overrightarrow{r} = (2.00m)\hat{i} - (3.00m)\hat{j} + (2.00m)\hat{k}$, the force is given by $\overrightarrow{F} = F_x\hat{i} + (7.00N)\hat{j} - (6.00N)\hat{k}$ and the corresponding torque about the origin is $\overrightarrow{\tau} = (400N \cdot m)\hat{i} + (2.00N \cdot m)\hat{j} - (1.00N \cdot m)\hat{k}$.

Determine F_x.

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63. Force $\overrightarrow{F} = (2.0N)\hat{i} - (3.0N)\hat{k}$ acts on a pebble with position vector $\overrightarrow{r} = (0.50m)\hat{j} - (2.0m)\hat{k}$ relative to the origin. In unit-vector notation, what is the resulting torque on the pebble about the origin ?

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64. A force $\overrightarrow{F} = \left(6.00\hat{i} - 4.00\hat{j}\right)N$ acts on a particle with position vector $\overrightarrow{r} = \left(-3.00\hat{i} + 1.00\hat{j}\right)m$. Find (a) the torque about the origin acting on the particle and (b) the angle between $\overrightarrow{r}$ and $\overrightarrow{F}$.

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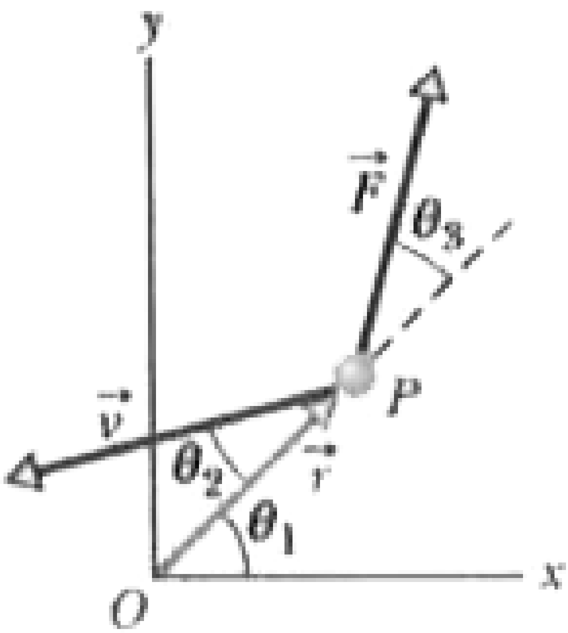
65. At the instant of Figure, a 2.0 kg particle P has a position vector $\vec{r}$ of magnitude 5.0 m and angle $\theta_1 = 45^\circ$ and a velocity vector $\vec{v}$ of magnitude 4.0 m/s and angle $\theta_2 = 30^\circ$, Force $\vec{F}$, of magnitude 2.0 N and angle $\theta_3 = 30^\circ$, acts on P. All three vectors lie in the xy plane. About the origin, what are the (a) magnitude and (b) direction of the angular momentum of P and the (c) magnitude and (d) direction of the torque acting on P?



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66. A particle of mass m is shot from ground level at initial speed u and initial angle θ relative to the horizontal. When it reaches its highest point in its flight over the level ground, what are the magnitudes of (a) the torque acting on it from the gravitational force and (b) its angular momentum, both measured about the launch point?

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67. A 3.0 kg particle-like object moves in a plane with velocity components $v_x = 30m/s$ and $v_y = 60m/s$ as is passes through the point with (x, y) coordinates of (3.0, -4.0) m. Just then, in unit vector notation, what is its angular momentum relative to (a) the origin and (b) the point located at (-2.0, -2.0) m?

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68. Two particles each of mass m and speed v, travel in opposite direction along parallel lines separated by a distance d. Show that the vector angular momentum of this system of particles is the same about any point taken as origin.

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69. At the instant the displacement of a 1.50 kg object relative to the origin is $\vec{d} = (2.00m)\hat{i} + (4.00m)\hat{j} - (3.00m/s)\hat{k}$, its velocity is $\vec{v} = -(6.00m/s)\hat{i} + (3.00m/s)\hat{j} + (3.00m)\hat{k}$ and it is subject to a force $\vec{F} = (6.00N)\hat{i} - (8.00N)\hat{j} + (4.00N)\hat{k}$. Find (a) the acceleration of the object, (b) the angular momentum of the object about the origin, (c) the torque about the origin acting on the object, and (d) the angle between the velocity of the object and the force acting on the object.

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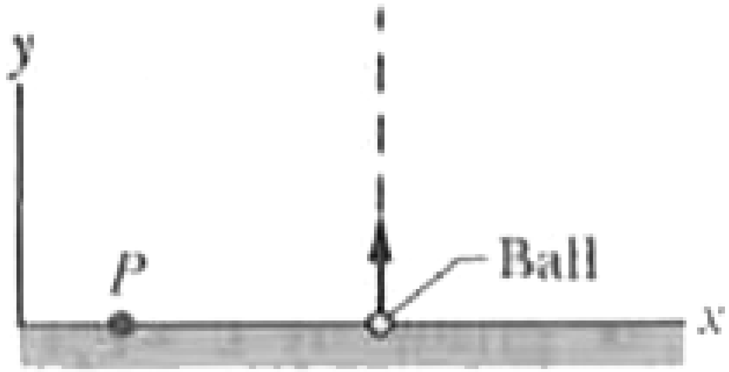
70. In Fig. 10-72, a 0.400 kg ball is shot directly upward at initial speed 40.0 m/s. What is its angular momentum about P, 2.00 m horizontally from the launch point, when the ball is (a) at maximum height and (b) halfway back to the ground? What is the torque on the ball about P due to the gravitational force when the ball is (c) at maximum height and (d) halfway back to the ground?



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71. A particle is acted on by two torques about the origin: $\vec{\tau}_1$ has a magnitude of $2.0N \cdot m$ and is directed in the positive direction of the x axis, and $\vec{\tau}_2$ has a magnitude of $3.0N \cdot m$ and is directed in the nagative direction of the y axis. In unit-vector notation, find $\vec{dl} / dt$, where $\vec{l}$ is the angular momentum of the particle about the origin.

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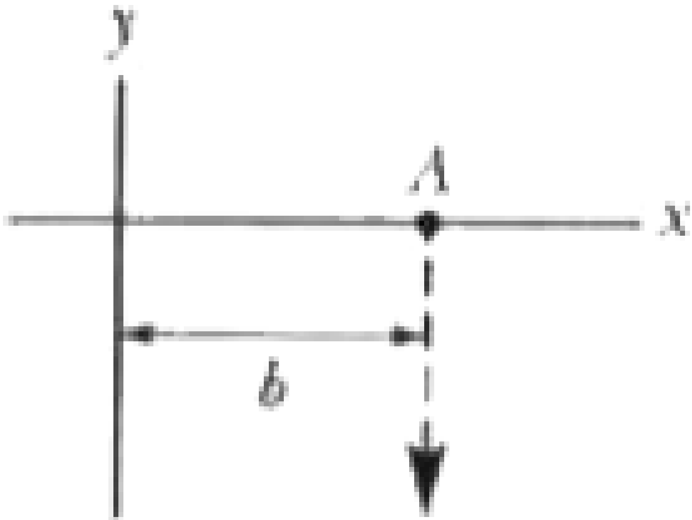
72. In Fig. 10-73, a particle of mass m is released from rest at point A, at distance b from the origin, and falls parallel to a vertical y axis. As a function of time t and with respect to the origin, find the magnitudes of (a) the torque τ on the particle due to the gravitational force and (b) the angular momentum L of the particle. (c) From those results, verify that $\tau = dL/dt$.



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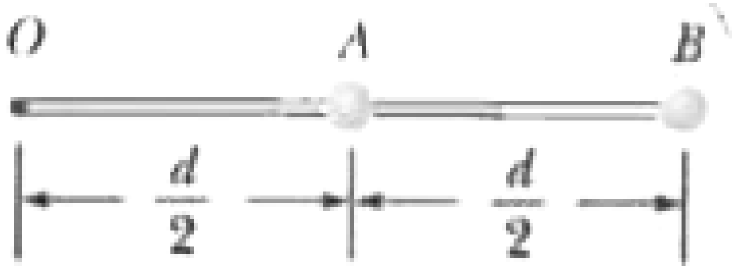
73. Figure 10-74 is an overhead view of a rod of length d and negligible mass that rotates at angular speed ω in the horizontal plane about a vertical axis through point O. Particle A of mass m is attached at the center point and an identical particle B is attached at the far end. Find the angular momentum of particle B with respect to particle A.



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74. A force $\left(2.00\hat{i} - 4.00\hat{j} + 2.00\hat{k}\right)N$ acts on a particle located at $\left(3.00\hat{i} + 2.00\hat{j} - 4.00\hat{k}\right)m$. What is the magnitude of the torque on the particle as measured about the origin?

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75. Figure 10-75 shows three rotating, uniform disks that are coupled by belts. One belt runs around the rims of disks A and C. Another belt runs around a central hub on disk A and the rim of disk B. The belts move smoothly without slip-page on the rims and hub. Disk A has radius R, its hub has radius 0.5000R, disk B has radius 0.2500R, and disk C has radius 2.000 R. Disks B and C have the same density (mass per unit volume) and thickness. What is the ratio of the magnitude of the angular momentum of disk C to that of disk B?

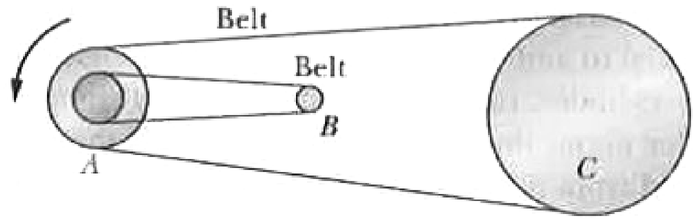

Figure 10-75 Problem 75.

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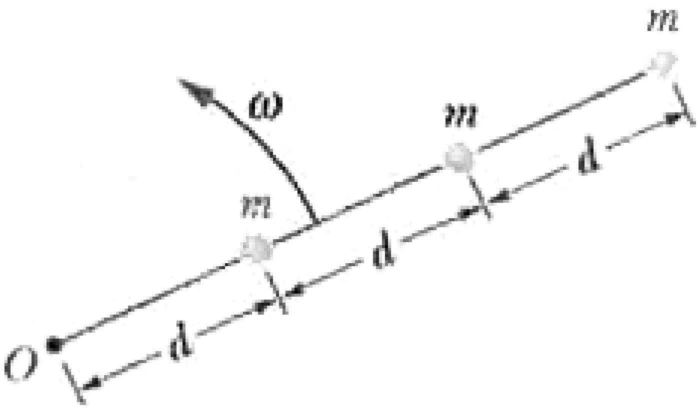
76. In Figure, three particles of mass m = 23 g are fastened to three rods of length d = 12 cm and negligible mass. The rigid assembly rotates around point O at the angular speed $\omega = 0.85 rad/s$. About O, what are (a) the rotational inertia of the assembly, (b) the magnitude of the angular momentum of the middle particle, and (c) the magnitude of the angular momentum of the assembly?



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77. A sanding disk with rotational inertia $8.6 \times 10^{-3} kg \cdot m^2$ is attached to an electric drill whose motor delivers a torque of magnitude $16 N \cdot m$ about the central axis of the initially stationary disk. About that axis and with the torque applied for 33 ms, what is the magnitude of the (a) angular momentum and (b) angular velocity of the disk?

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78. The angular momentum of a flywheel having a rotational inertia of $0.140 kg \cdot m^2$ about its central axis decreases from 3.00 to $0.800 kg \cdot m^2 / s$ in 1.50 s. (a) What is the magnitude of the average torque acting on the flywheel about its central axis during this period? (b) Assuming a constant angular acceleration, through what angle does the flywheel turn? (c) How much work is done on the wheel? (d) What is the average power of the flywheel?

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79. A disk with a rotational inertia of $7.00 kg \cdot m^2$ rotates like a merry-go-round while undergoing a variable torque given by $\tau = (5.00 + 2.00t) N \cdot m$. At time t = 1.00 s, its angular momentum is $5.00 kg \cdot m^2 / s$. What is its angular momentum at t = 5.00 s?

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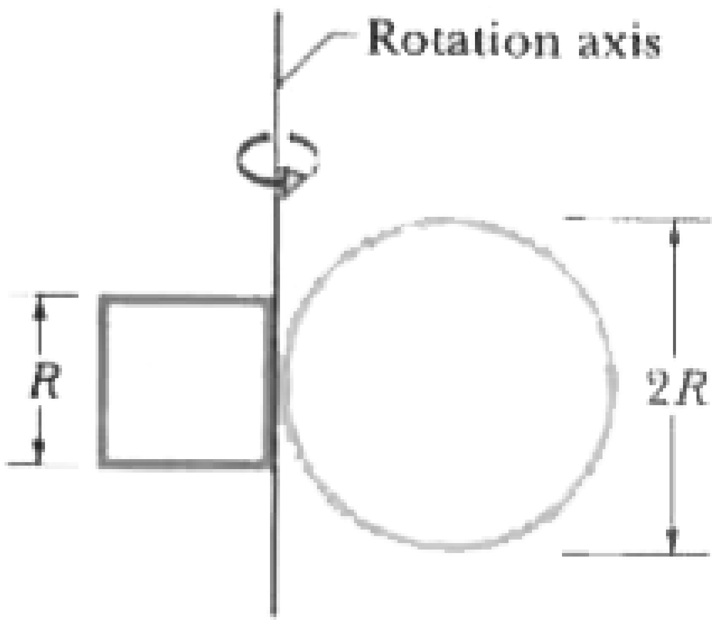
80. Figure 10-77 shows a rigid structure consisting of a circular hoop of radius R and mass m, and a square made of four thin bars, each of length R and mass m. The rigid structure rotates at a constant speed about a vertical axis, with a period of rotation of 2.5 s. Assuming R = 0.50 m and m = 2.0 kg, calculate (a) the structure's rotational inertia about the axis of rotation and (b) its angular momentum about that axis.



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81. In Fig. 10-78, two skaters, each of mass 50 kg, approach each other along parallel paths separated by 3.0 m. They have opposite velocities of 1.4 m/s each. One skater carries one end of a long pole of negligible mass, and the other skater grabs the other end as she passes. The skaters then rotate around the center of the pole. Assume that the friction between skates and ice is negligible. What are (a)the radius of the circle, (b) the angular speed of the skaters, and (c) the kinetic energy of the two skater system? Next, the skaters pull along the pole unyil they are separated by 1.0 m. What then are (d) their angular speed and (e) the kinetic energy of the system? (f) What provided the energy for the increased kinetic energy?

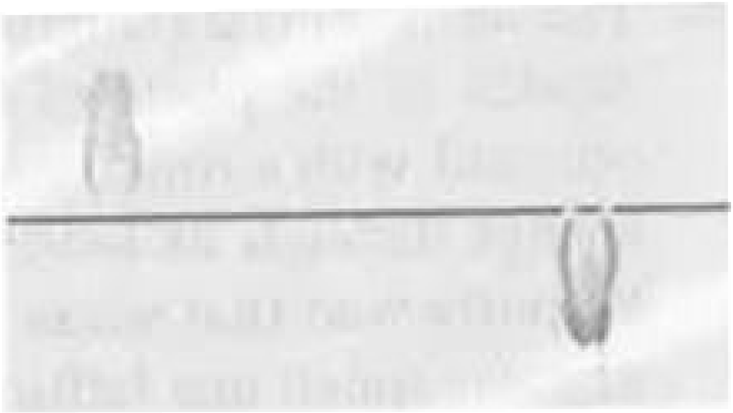

Figure 10-78 Problem 81.

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82. A cockroach of mass 0.20 kg runs counterclockwise around the rim of a lazy Susan (a circular disk mounted on a vertical axle) that has radius 18 cm, rotational inertia $5.0 \times 10^{-3} kg \cdot m^2$, and frictionless bearings. The cockroach's speed (relative to the ground) is 2.0 m/s, and the lazy Susan turns clockwise with angular speed $\omega_0 = 2.8 rad/s$. The cockroach finds a bread crumb on the rim and, of course, stops. (a) What is the angular speed of the lazy Susan after the cockroach stops? (b) Is mechanical energy conserved as it stops?

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83. A man stands holding a weight in each hand and with his arms outstretched on a frictionless platform which is rotating at a speed of 1 revolution per sec. In ths position the total rotational intertia of the man, the weights and the platform is $6kgm^2$. If by drawing in his arms, the man decreases the rotational inertia of the system by $2kgm^2$, calcualte the resulting speed of the platform and the increase in kinetic energy. How do you account for the increase of kinetic energy?

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84. The rotational inertia of a collapsing spinning star drops to $\frac{1}{4}$ its initial value. What is the ratio of the new rotational kinetic energy to the initial rotational kinetic energy?

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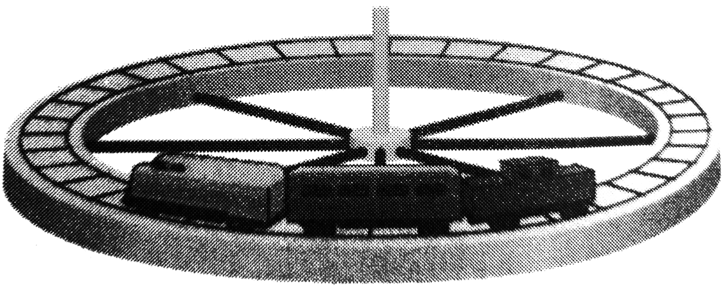
85. A track is mounted on a large wheel that is free to turn with neigligible friction about a vertical axis (Fig). A toy train of mass M is placed on the track and, with the system initially at rest, the train's electrical power is turned on. The train reaches speed v with respect to the track. What is the wheel's angular speed if its mass is m and its radius is r ? (Treat it as a hoop, and neglect the mass of the spokes and hub).



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86. Two disks are mounted (like a merry-go-round) on low-friction bearings on the same axle and can be brought together so that they couple and rotate as one unit. The first disk, with rotational inertia

$3.30 kg \cdot m^2$ about its central axis, is set spinning counterclockwise at 450 rev/min. The second disk, with rotational inertia $6.60 kg \cdot m^2$ about its central axis, is set spinning counterclockwise at 900 rev/min. They then couple together. (a) What is their angular speed after coupling? If instead the second disk is set spinning clockwise at 900 rev/min, what are their (b) angular speed and (c) direction of rotation after they couple together?

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87. The rotor of an electric motor has rotational inertia $I_m = 2.0 \times 10^{-3} kg \cdot m^2$ about its central axis. The motor is used to change the orientation of the space probe in which it is mounted. The motor axis is mounted along the central axis of the probe, the probe has rotational inertia $I_p = 10 kg \cdot m^2$ about this axis. Calculate the number of revolutions of the rotor required to turn the probe through 30° about its central axis.

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88. A wheel of moment of inertia $0.10kg - m^2$ is rotating about a shaft at an angular speed o 160 rev/minute. A second wheel is set into rotation at 300 rev/minute and is coupled to the same shaft so that both the wheels finally rotate with as common angular speed of 200 rev/minute. Find the moment of inertia o the second wheel.

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89. A cockroach of mass m lies on the rim of a uniform disk of mass 4.00 m that can rotate freely about its center like a merry-goround. Initially the cockroach and disk rotate together with an angular velocity of 0.320 rad/s. Then the cockroach walks halfway to the center of the disk. (a) What then is the angular velocity of the cockroach-disk system? (b) What is the ratio K / K_0 of the new kinetic energy of the system to its initial kinetic energy? (c) What accounts for the change in the kinetic energy?

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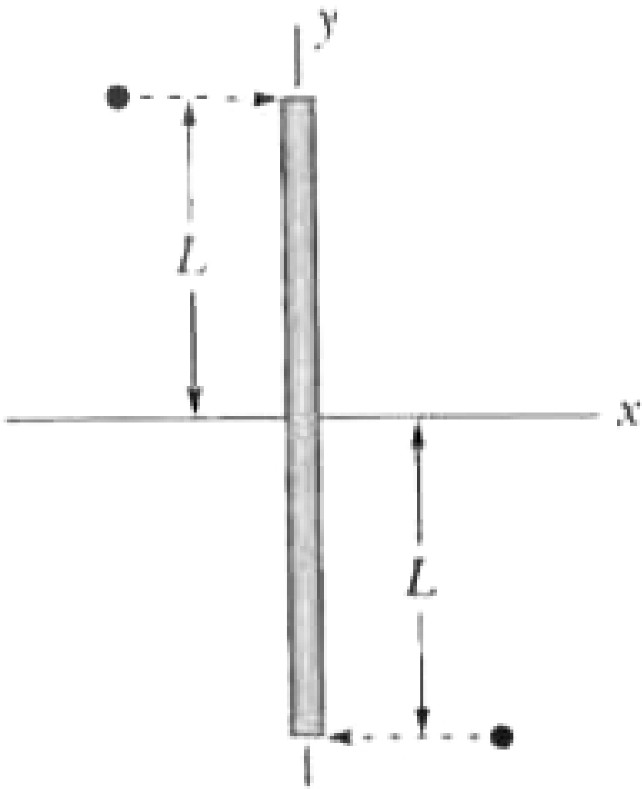
90. Figure 10-80 is an overhead view of a rod with length 2L and negligible mass and which lies on a frictionless surface. Two bullets, each with mass m and speed v and traveling parallel to the x axis, hit the ends of the rod simultaneously and are buried in the rod. After the collision, what are (a) the angular speed of the system and (b) the speed of the system's center of mass? (c) What is the change in the total kinetic energy because of the collisions?



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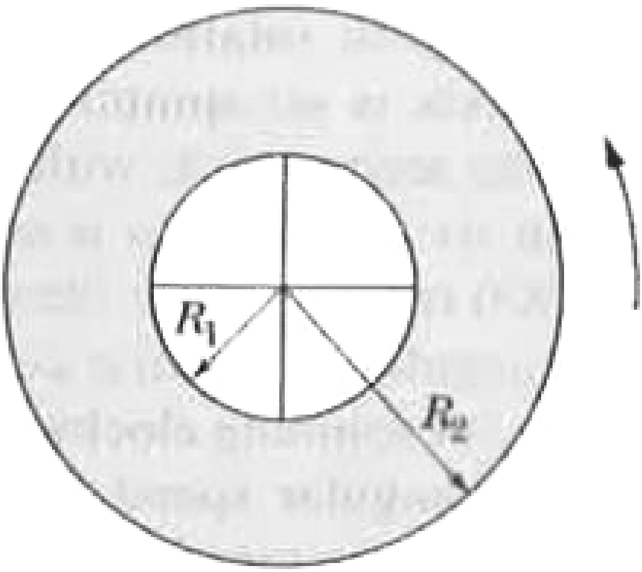
91. Figure 10-81 shows an overhead view of a ring that can rotate about its center like a merry-go-round. Its outer radius R_2 is 0.800 m, its inner radius R_1 is $R_2 / 2.00$, its mass M is 6.00 kg, and the mass of the crossbars at its center is negligible. It initially rotates at an angular speed of 8.00 rad/s with a cat of mass m = M/4.00 on its outer edge, at radius R_2. By how much does the cat increase the kinetic energy of the cat-ring system if the cat crawls to the inner edge, at radius R_1?



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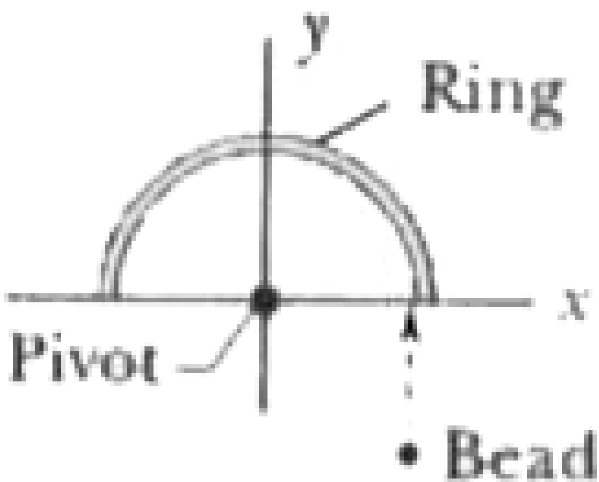
92. Figure 10-82 is an overhead view of semicircular ring of mass m and radius R that lies on a frictionless surface. The ring is connected by elevated spokes (not shown) to a pivot at the center of the semicircle. The ring can rotate around that pivot but is initially stationary. A bead of mass m and speed v is shot into the ring, entering under the spokes and tangentially to the ring and then sliding along the ring. The ring and bead then rotate together around the pivot. Find their angular speed.



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93. A horizontal platform in the shape of a circular disk rotates on a frictionless bearing about a vertical axle through the centre of the disk. The platform has a mass of $150kg$, a radius of $2.0m$, and a rotational inertia of$300kgm^2$ about the axis of rotation. A $60kg$ student walks slowly from the rim of the platform toward the centre. If the angular speed of the system is $1.5rad/s$ when the student starts at the rim, what is the angular speed when she is $0.50m$ from the centre ?

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94. Figure 10-83 is an overhead view of a spring lying on a frictionless surface and attached to a pivot at its right end. The spring has a relaxed length of $l_0 = 1.00$ and negligible mass. A small 0.100 kg disk is attached to the free end at the left. That disk is then given a velocity $\overrightarrow{v}_0$ of magnitude 11.0 m/s perpendicular to the spring's length. The disk and spring then move around the pivot. (a) When the stretching of the spring reaches its maximum value of $0.100l_0$, what is the speed of the disk? (b)

What is the spring constant?

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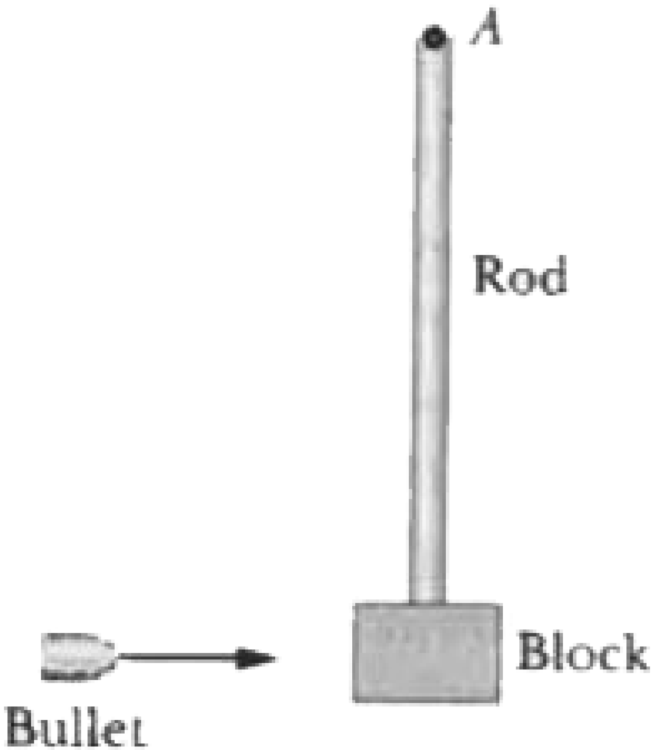
95. In Fig. 10-84, a 1.0 g bullet is fired into a 0.60 kg block attached to the end of a 0.75 m nonuniform rod of mass 0.50 kg. The block-rod-bullet system then rotates in the plane of the figure, about a fixed axis at A. The rotational inertia of the rod alone about that axis at A is $0.060 kg \cdot m^2$. Treat the block as a particle. (a) What then is the rotational inertia of the block-rod-bullet system about point A? (b) If the angular speed of the system about A just after impact is 4.5 rad/s, what is the bullet's speed just before impact?



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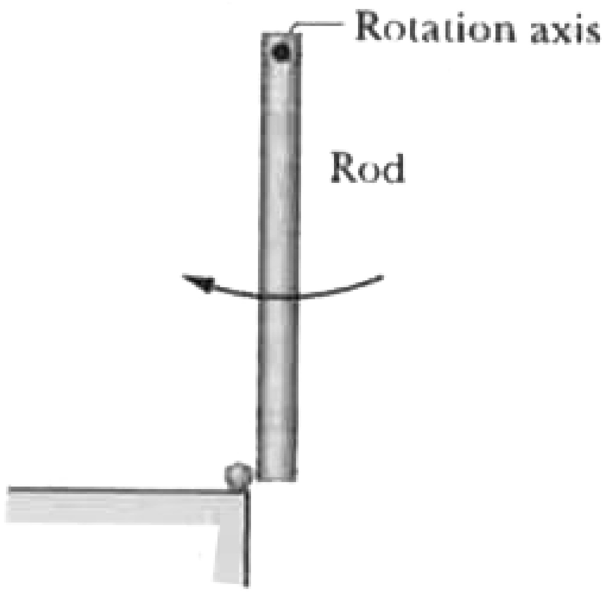
96. The uniform rod (length 0.60 m, mass 1.0 kg) in Fig. 10-85 rotates in the plane of the figure about an axis through one end, with a rotational inertia of $0.12 kg \cdot m^2$. As the rod swings through its lowest position, it collides with a 0.20 kg putty wad that sticks to the end of the rod. If the rod's angular speed just before collision is 2.4 rad/s, what is the angular speed of the rod-putty system immediately after collision?



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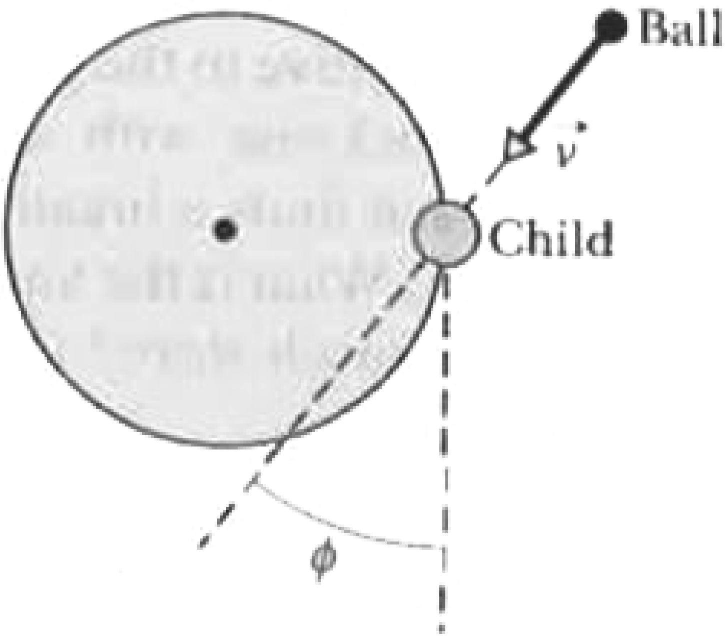
97. In Fig. 10-86, a 30 kg child stands on the edge of a stationary merry-go-round of radius 2.0 m. The rotational inertia of the merry-go-round about its rotation axis is $150 kg \cdot m^2$. The child catches a ball of mass 1.0 kg thrown by a friend. Just before the ball is caught, it has a horizontal velocity $\vec{v}$ of magnitude 12 m/s, at angle $\phi = 37^\circ$ with a line tangent to the outer edge of the merry-go-round, as shown. What is the angular speed of the merry-go-round just after the ball is caught?



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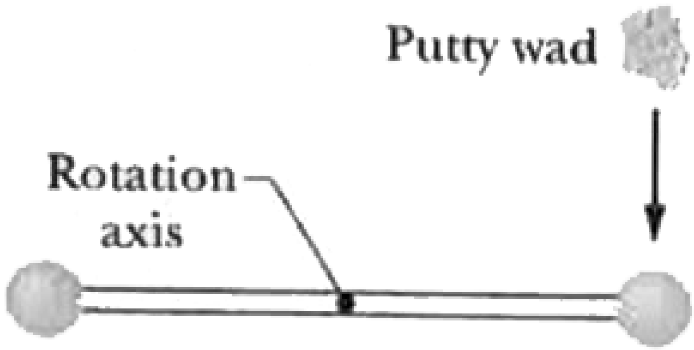
98. Two 2.00 kg balls are attached to the ends of a thin rod of length 50.0 cm and negligible mass. The rod is free to rotate in a vertical plane without friction about a horizontal axis through its center. With the rod initially horizontal (Fig. 10-87), a 50.0 g wad of wet putty drops onto one of the balls, hitting it with a speed of 3.00 m/s and then sticking to it. (a)

What is the angular speed of the system just after the putty wad hits? (b) What is the ratio of the kinetic energy of the system after the collision to that of the putty wad just before? (c) Through what angle will the system rotate before it momentarily stops?



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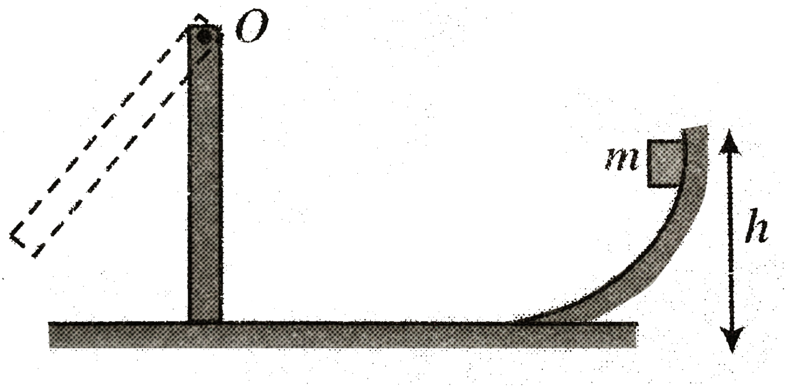
99. In the shown figure a mass m slides down the frictionless surface from height h and collides with the uniform vertical rod of length L and mass M after collision the mass m sticks to the rod. The rod is face to rotate in a vertical plane about fixed axis through O. Find the maximum angular deflection of the rod from its initial position.



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100. A top spins at 25 rev/s about an axis that makes an angle of 30° with the vertical. The mass of the top is 0.50 kg, its rotational inertia about its central axis is $5.0 \times 10^{-4} kg \cdot m^2$, and its center of mass is 4.2 cm from the pivot point. If the spin is clockwise from an overhead view, what are the (a) precession rate and (b) direction of the precession as viewed from overhead?

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Practice Questions Single Correct Choice Type

1. A hoop of radius r mass m rotating with an angular velocity ω_0 is placed on a rough horizontal surface. The initial velocity of the centre of the hoop is zero. What will be the velocity of the centre of the hoop when it cases to slip ?

A. $v = 0.5\omega_0 r$

B. $v = 1.5\omega_0 r$

C. $v = 2.0\omega_0 r$

D. $v = 3.5\omega_0 r$

Answer: A

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2. The Earth takes slightly less than one day to complete one rotation about the axis passing through its poles. The actual time is 8.616×10^4s.

With this given information, what is the angular speed of the Earth about its axis?

A. 7.292×10^{-5} rad/s

B. 9.951×10^{-5} rad/s

C. 2.321×10^{-6} rad/s

D. 6.334×10^{-4} rad/s

Answer: A

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3. A marble and a cube are placed at the top of a ramp. Starting from rest at the same height, the marble rolls and the cube slides (no kinetic friction) down the ramp. Determine the ratio of the center-of-mass speed of the cube to the center-of-mass speed of the marble at the bottom of the ramp.

A. 1.14

B. 1.20

C. 0.707

D. 1.18

Answer: D

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4. A wheel with a 0.10 m radius is rotating at 35 rev/s. It then slows uniformly to 15 rev/s over a 3.0 s interval. What is the angular acceleration of a point on the wheel?

A. $-2.0rev/s^2$

B. $-6.7rev/s^2$

C. $-17rev/s^2$

D. $0.67rev/s^2$

Answer: B

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5. A body is rotating uniformly about a vertical axis fixed in an inertial frame. The resultant force on a particle of the body not on the axis is

A. vertical

B. horizontal and skew with the axis.

C. horizontal and intersecting the axis

D. none of the above.

Answer: B

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6. During the spin-dry cycle of a washing machine, the motor slows from 95 rad/s to 30 rad/s while the turning the drum through an angle of 402 rad. What is the magnitude of the angular acceleration of the motor?

A. $64 rad / s^2$

B. $10 rad / s^2$

C. $32 rad / s^2$

D. $20 rad / s^2$

Answer: B

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7. Two people start at the same place and walk around a circular lake in opposite directions. One has an angular speed of 1.7×10^{-3} rad/s while the other has an angular speed of 3.4×10^{-3} rad/s. How long will it be before they meet?

A. 600 s

B. 2400 s

C. 1231 s

D. 1800 s

Answer: C

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8. A fan rotating with an initial angular velocity of 1000 rev/min is switched off. In 2s, the angular velocity decreases to 200 rev/min. Assuming the angular acceleration is constant, how many revolutions does the blade undergo during this time?

A. 10

B. 100

C. 20

D. 125

Answer: C

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9. A basketball player is balancing a spinning basketball on the tip of his finger. The angular velocity of the ball slows down from 18.5 to 14.1 rad/s. During the slow-down, the angular displacement is 85.1 rad. Determine the time it takes for the ball to slow down.

A. 4.50 s

B. 5.22 s

C. 3.11 s

D. 4.76 s

Answer: B

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10. An airplane engine starts from rest, and 2 s later, it is rotating with an angular speed of 300 rev/min. If the angular acceleration is constant, how many revolutions does the propeller undergo during this time?

A. 5

B. 50

C. 10

D. 300

Answer: A

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11. In 9.5 s a fisherman winds 2.6 m of fishing line onto a reel whose radius is 3.0 cm (assumed to be constant as an approximation). The line is being reeled in at a constant speed. Determine the angular speed of the reel.

A. 9.1 rad/s

B. 5.0 rad/s

C. 3.7 rad/s

D. 7.4 rad/s

Answer: A

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12. During the time a CD accelerates from rest to a constant rotational speed of 477 rev/min, it rotates through an angular displacement of 0.250 rev. What is the angular acceleration of the CD?

A. $358 rad / s^2$

B. $901 rad / s^2$

C. $794 rad / s^2$

D. $866 rad / s^2$

Answer: C

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13. A person is riding a bicycle, and its wheels have an angular velocity of +20.0 rad/s Then, the brakes are applied, and the bike is brought to a uniform stop. During braking, the angular displacement of each wheel is +15.92 rev. How much time does it take for the bike to come to rest?

A. 5.00 s

B. 10.0 s

C. 3.18 s

D. 6.36 s

Answer: B

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14. A grindstone, initially at rest, is given a constant angular acceleration so that it makes 20.0 rev in the first 8.00 s. What is its angular acceleration?

A. $0.313 rad / s^2$

B. $2.50 rad / s^2$

C. $3.93 rad / s^2$

D. $1.97 rad / s^2$

Answer: C

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15. A thin circular ring of mass M and radius R is rotating about its axis with constant angular velocity ω. The objects each of mass m are attached gently to the ring. The wheel now rotates with an angular velocity.

A. $\frac{\omega M}{(m+M)}$

B. $\frac{\omega(M-2m)}{(M+2m)}$

C. $\frac{\omega M}{(M+2m)}$

D. $\frac{\omega(M+2m)}{M}$

Answer: C

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16. A wheel turns through an angle of 188 rad in 8.0 s, and its angular speed at the end of the period is 40 rad/s. If the angular acceleration is constant, what was the angular speed of the wheel at the beginning of the 8.0 s interval?

A. 4.8 rad/s

B. 9.1 rad/s

C. 7.0 rad/s

D. 23.5 rad/s

Answer: C

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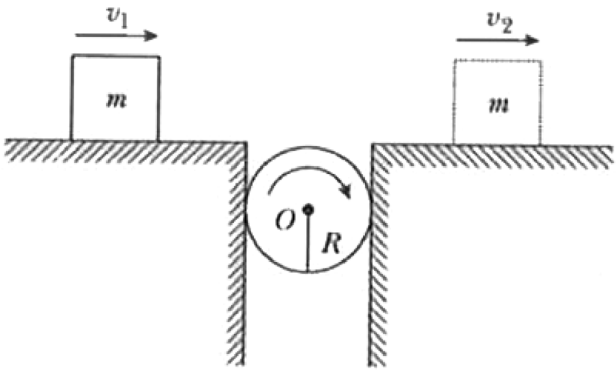
17. A uniform disc of mass M and radius R is initially at rest. Its axis is fixed through O. A block of mass m is moving with speed v_1 on a frictionless surface passes over the disc to the dotted position. On coming in contact with the disc, it slips on it. The slipping ceases before the block loses contact with the disc, due to the high friction. Now, the velocity of mass m is



A. $v_2 = \dfrac{v_1}{1 + (M/2m)}$

B. $v_2 = \dfrac{v_1}{2M}$

C. $v_2 = \dfrac{v_1}{1 + (M/m)}$

D. $v_2 = 2v_1$

Answer: A

18. A 1.0 m roulette wheel reaches a maximum angular speed of 18 rad/s before it begins decelerating. After reaching this maximum angular speed, it turns through 35 rev (220 rad) before it stops. How long did it take the wheel to stop after reaching its maximum angular speed?

A. 12 s

B. 24 s

C. 48 s

D. 88 s

Answer: B

19. A ody is in pure rotation. The linear speed v of a particle, the distance r of the particle from the axis and the angular velocity ω of the body are related as $\omega = \frac{v}{r}$. Thus

A. $\omega \propto \frac{1}{r}$

B. $\omega \propto r$

C. $\omega = r_0$

D. ω is independent of r

Answer: D

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20. A circular disk of radius 0.010 m rotates with a constant angular speed of 5.0 rev/s. What is the acceleration of a point on the edge of the disk?

A. $0.31 m / s^2$

B. $9.9 m / s^2$

C. zero m / s^2

D. $1.6 m / s^2$

Answer: B

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21. After 10.0 s, a spinning roulette wheel at a casino has slowed down to an angular velocity of +1.88 rad/s. During this time, the wheel has an angular acceleration of $-5.04 rad / s^2$. Determine the angular displacement of the wheel.

A. $+440$ rad

B. $+252$ rad

C. $+271$ rad

D. $+188$ rad

Answer: C

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22. A circular disk of radius 2.0 m rotates, starting from rest, with a constant angular acceleration of $20.0 rad / s^2$. What is the tangential acceleration of a point on the edge of the disk at the instant that its angular speed is 1.0 rev/s?

A. $40 m / s^2$

B. $110 m / s^2$

C. $79 m / s^2$

D. $120 m / s^2$

Answer: C

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23. At the local swimming hole, a favorite trick is to run horizontally off a cliff that is 8.3 m above the water. One diver runs off the edge of the cliff, tucks into a ball, and rotates on the way down with an average angular speed of 1.6 rev/s. Ignore air resistance and determine the number of revolutions she makes while on the way down.

A. 1.6 rev

B. 2.4 rev

C. 0.81 rev

D. 2.1 rev

Answer: D

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24. The original Ferris wheel has a radius of 38 m and completed a full revolution (2π rad) every two minutes when operating at its maximum speed. If the wheel were uniformly slowed from its maximum speed to a stop in 35 s, what would be the magnitude of the tangential acceleration at the outer rim of the wheel during its deceleration?

A. $0.0015m/s^2$

B. $0.54m / s^2$

C. $0.057m / s^2$

D. 1.6 m/s

Answer: C

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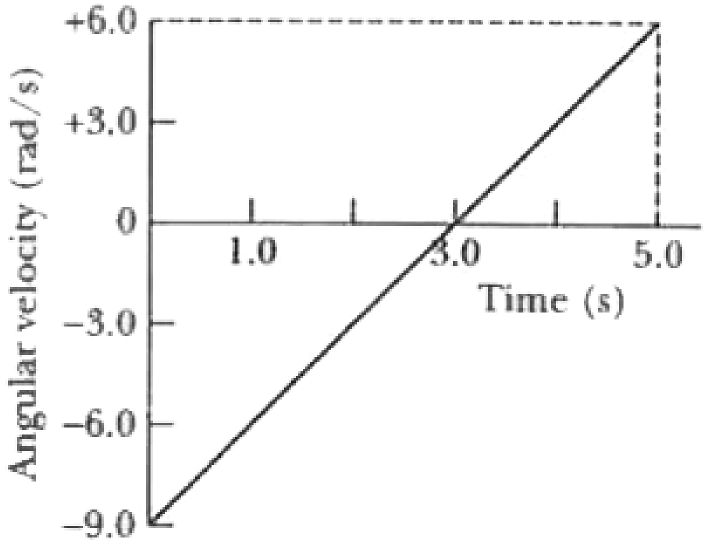
25. The figure shows a graph of the angular velocity of a rotating wheel as a function of time. Although not shown in the graph, the angular velocity continues to increase at the same rate until t = 8.0 s. What is the angular displacement of the wheel from 0 to 8.0 s?



A. 36 rad

B. 60 rad

C. 24 rad

D. 48 rad

Answer: C

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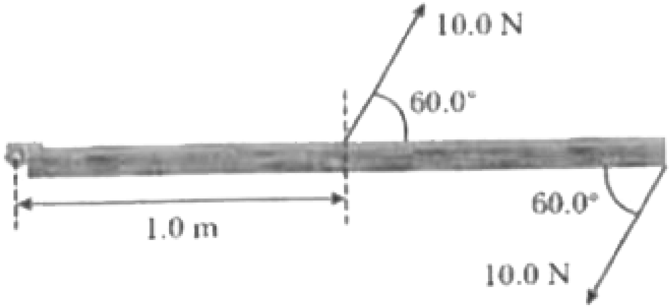
26. The figure shows the top view of a door that is 2 m wide. Two forces are applied to the door as indicated. What is the magnitude of the net torque on the door with respect to the hinge?



A. $0 N \cdot m$

B. $10.0 N \cdot m$

C. $5.0 N \cdot m$

D. $8.7 N \cdot m$

Answer: D

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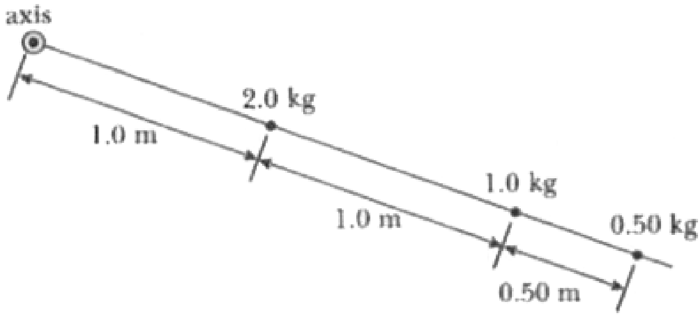
27. Three objects are attached to a massless rigid rod that has an axis of rotation an shown. Assuming all of the mass of each object is located at the point shown for each, calculate the moment of inertia of this system.



A. $5.3 kg \cdot m^2$

B. $9.1 kg \cdot m^2$

C. $3.1 kg \cdot m^2$

D. $7.2 kg \cdot m^2$

Answer: B

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28. A solid circular disk has a mass of 1.2 kg and a radius of 0.16 m. Each of three identical thin rods has a mass of 0.15 kg. The rods are attached perpendicularly to the plane of the disk at its outer edge to form a three-legged stool. Find the moment of inertia of the stool with respect to an axis that is perpendicular to the plane of the disk at its center.

A. $0.027 kg \cdot m^2$

B. $0.096 kg \cdot m^2$

C. $0.185 kg \cdot m^2$

D. $0.072 kg \cdot m^2$

Answer: A

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29. A 50 kg rider on a moped of mass 75 kg is traveling with a speed of 20 m/s. Each of the two wheels of the moped has a radius of 0.2 m and a moment of inertia of $0.2 kg \cdot m^2$. What is the total rotational kinetic energy of the wheels?

A. 500 J

B. 4000 J

C. 100 J

D. 2000 J

Answer: D

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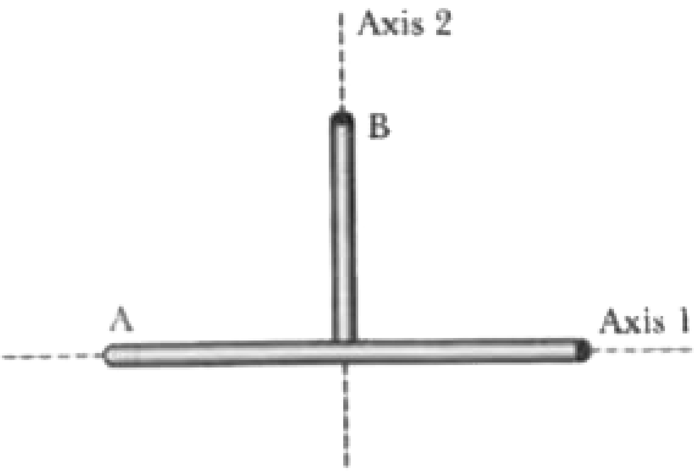
30. A long thin rod is cut into two pieces, one being twice as long as the other. To the midpoint of piece A (the longer piece), piece B is attached perpendicularly, in order to form the inverted "T" as shown in the figure. The application of a net external torque causes this object to rotate about axis 1 with an angular acceleration of $4.6 \text{rad} / s^2$. When the same net external torque is used to cause the object to rotate about axis 2, what is the angular acceleration?



A. $1.2 \text{rad} / s^2$

B. $2.3 \text{rad} / s^2$

C. $3.5\text{rad} / s^2$

D. $4.6\text{rad} / s^2$

Answer: B

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31. A 50 N m torque acts on a wheel with a moment of inertia $150 kg \cdot m^2$. If the wheel starts from rest, how long will it take the wheel to make 1 rev?

A. 2.4 s

B. 10 s

C. 0.66 s

D. 6.1 s

Answer: D

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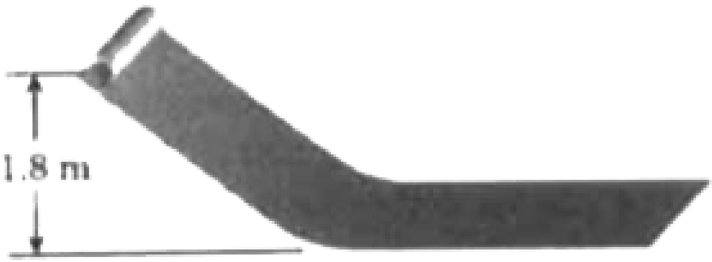
32. A solid cylinder of radius 0.35 m is released from rest from a height of 1.8 m and rolls down the incline as shown in the figure. What is the angular speed of the cylinder when it reaches the horizontal surface?



A. 8.2 rad/s

B. 34 rad/s

C. 14 rad/s

D. 67 rad/s

Answer: B

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33. One end of a thin rod is attached to a pivot, about which it can rotate without friction. Air resistance is absent. The rod has a length of 0.80 m and is uniform. It is hanging vertically straight downward. The end of the rod nearest the floor is given a linear speed v_0, so that the rod begins to rotate upward about the pivot. What must be the value of v_0, such that the rod comes to a momentary halt in a straight-up orientation, exactly opposite to its initial orientation?

A. 6.9 m/s

B. 5.6 m/s

C. 4.7 m/s

D. 8.1 m/s

Answer: A

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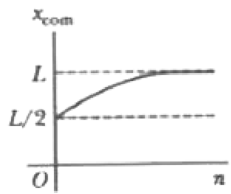
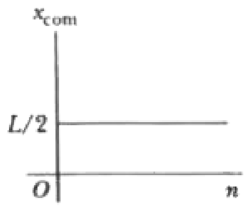
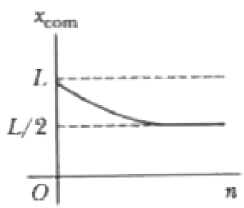
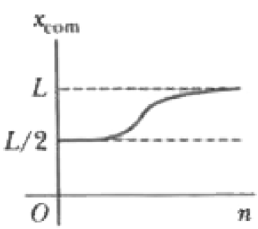
34. A thin rod of length L is lying along the x-axis with its ends at x = 0 and x = L. Its linear density (mass/length) varies with x as $k\left(\frac{x}{L}\right)^n$ where n can be zero or any positive number. If the position X_{CM} of the centre of mass of the rod is plotted against n, which of the following graphs best approximates the dependence of X_{CM} on n?

A. 

B. 

C. 

D. 

Answer: A

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35. A solid cylinder with a mass m and radius r is mounted so that it can be rotated about an axis that passes through the center of both ends. At what angular speed, ω must the cylinder rotate to have the same total kinetic energy that it would have if it were moving horizontally with a speed v without rotation?

A. $\omega = \frac{v}{r}$

B. $\omega = \frac{v}{2r}$

C. $\omega = \frac{v^2}{r^2}$

D. $\omega = \frac{v}{r}\sqrt{2}$

Answer: D

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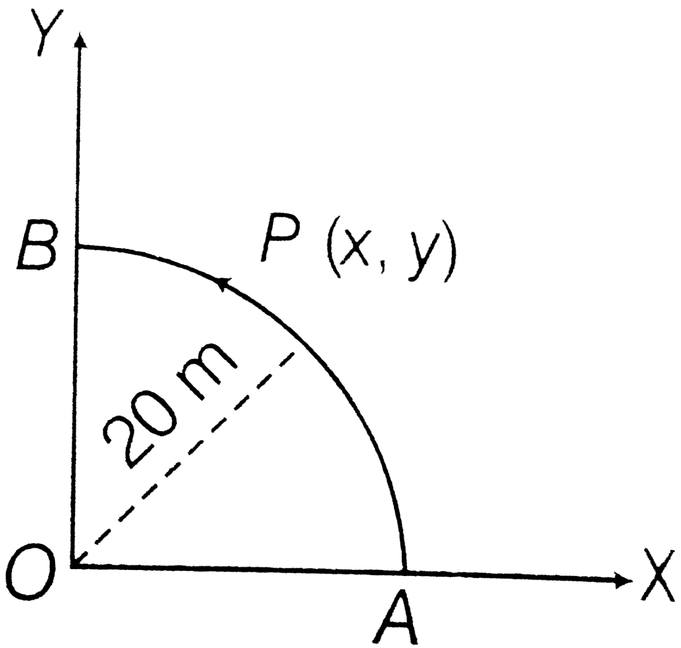
36. A point P moves in counter-clockwise direction on figure. The movement of P is such that it sweeps out a length $s = t^3 + 5$, where s is in metre and t is in second. The radius of the pathh is 20 m. the acceleration of P when t=2s is nearly



A. $14m / s^2$

B. $13m / s^2$

C. $12m / s^2$

D. $7.2m / s^2$

Answer: A

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37. A certain merry-go-round is accelerated uniformly from rest and attains an angular speed of 0.4 rad/s in the first 10 s. If the net applied torque is 2000 $N \cdot m$, what is the moment of inertia of the merry-go-round?

A. $400kg \cdot m^2$

B. $800kg \cdot m^2$

C. $50000kg \cdot m^2$

D. $5000kg \cdot m^2$

Answer: C

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38. A body is rotating around a fixed axis with angular velocity 3 rad/s with constant angular acceleration of $1 rad/s^2$ at some time. Find the magnitude of acceleration of a particle 5 m away from the axis after the body has turned by 90°.

A. $5\sqrt{1+(9+\pi)^2} m/s^2$

B. $5(9+\pi) m/s^2$

C. $5 m/s^2$

D. $5\sqrt{82} ms^{-2}$

Answer: A

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39. A 1.0 kg wheel in the form of a solid disk rolls along a horizontal surface with a speed of 6.0 m/s. What is the total kinetic energy of the wheel?

A. 9.0 J

B. 27 J

C. 18 J

D. 36 J

Answer: B

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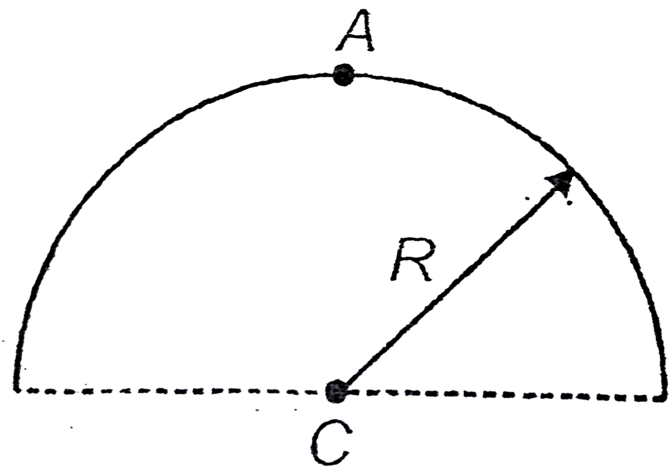
40. Moment of inertia of a half ring of mass m and radius R about an axis passing through point A perpendicular to the plane of the paper is I_A. If I_C is the moment of inertia of the ring about an axis perpendicular to the plane of paper and passing through point C, then



A. $\frac{3}{2}MR^2$

B. $2MR^2$

C. $2MR^2\left(1-\frac{2}{\pi}\right)$

D. $2MR^2\left(1+\frac{2}{\pi}\right)$

Answer: C

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41. Which one of the following statements concerning the moment of inertia I is false?

A. Moment of inertia I may be expressed in units of $kg \cdot m^2$.

B. Moment of inertia I depends on the angular acceleration of the object as it rotates.

C. Moment of inertia I depends on the location of the rotation axis relative to the particles that make up the object.

D. Moment of inertia I depends on the orientation of the rotation axis relative to the particles that make up the object

Answer: B

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42. Consider the following four objects:

(i) a hoop

(ii) a flat disk

(iii) a solid sphere

(iv) a hollow sphere

Each of the objects has mass M and radius R. The axis of rotation passes through the center of each object and is perpendicular to the plane of the hoop and the plane of the flat disk. Which object requires the largest torque to give it the same angular acceleration?

A. The solid sphere

B. The hollow sphere

C. The hoop

D. The flat disk

Answer: C

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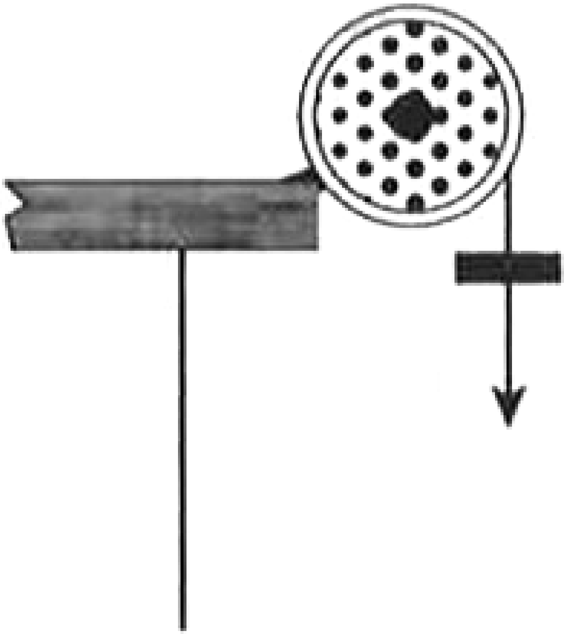
43. A 45 N brick is suspended by a light string from a 2.0 kg pulley. The brick is released from rest and falls to the floor below as the pulley rotates through 5.0 rad. The pulley may be considered a solid disk of radius 1.5 m. What is the angular speed of the pulley?



A. 17 rad/s

B. 8.1 rad/s

C. 15 rad/s

D. 7.3 rad/s

Answer: A

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Practice Questions More Than One Correct Choice Type

1. A rigid body is in pure rotation, that is, undergoing fixed axis rotation. Then which of the following statement(s) are true?

A. You can find two points in the body in a plane perpendicular to the axis of rotation having same velocity.

B. You can find two points in the body in a plane perpendicular to the axis of rotation having same acceleration.

C. Speed of all the particles lying on the curved surface of a cylinder whose axis coincides with the axis of rotation is same.

D. Angular speed of the body is same as seen from any point in the body.

Answer: C::D

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2. The axis of rotation of a purely rotating body

A. must pass through the center of mass

B. may pass through the center of mass

C. must pass through a particle of the body

D. may pass through a particle of the body

Answer: B::D

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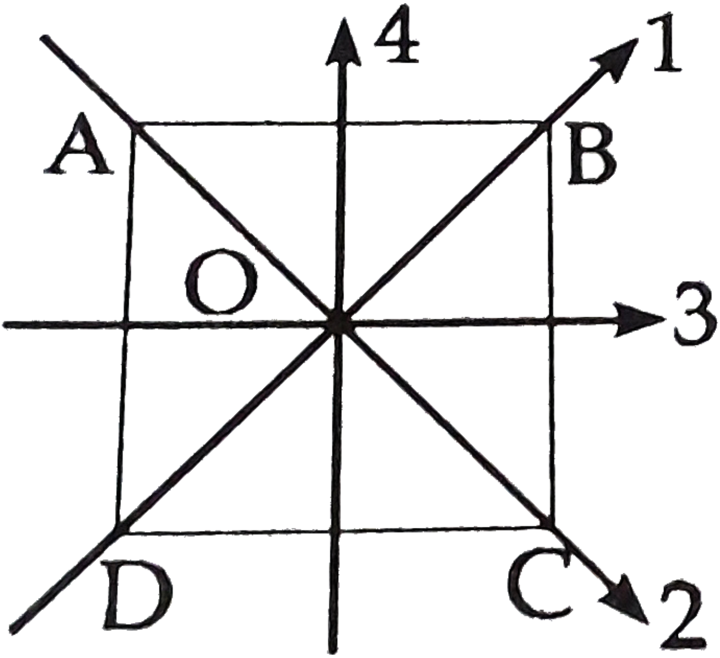
3. The moment of inertia of a thin square plate ABCD of uniform thickness about an axis passing through its center and perpendicular to its plane will



A. $I_1 + I_2$

B. $I_3 + I_4$

C. $I_1 + I_3$

D. $I_1 + I_2 + I_3 + I_4$

Answer: A::B::C

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4. When toque is acting on a system, then the

A. system may be in translational equilibrium but not in rotational equilibrium

B. system is neither in translation equilibrium nor in rotational equilibrium

C. angular momentum of the system remains conserved

D. angular momentum of the system is not conserved

Answer: A::D

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5. If no external force acts on a system

A. the center of mass remains stationary

B. the center of mass accelerates

C. the momentum of the center of mass of the system remains conserved

D. the position of the center of mass of the system shifts

Answer: A::C

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6. A particle moves on a straight line with a uniform velocity. The angular momentum of the particle is

A. is zero about a point on the straight line

B. remains constant about any given point

C. is always zero

D. is not zero about a point away from the straight line

Answer: A::B::C

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7. A sphere is rolled on a rough horizontal surface. It gradually slows down and stops. The force of friction tries to

A. decrease the angular velocity of the sphere

B. increase the angular velocity of the sphere

C. decrease the linear velocity of the sphere

D. increase the linear momentum of the sphere

Answer: B::C

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Practice Questions Linked Comprehension

1. A grindstone of radius 4.0 m is initially spinning with an angular speed of 8.0 rad/s. The angular speed is then increased to 10 rad/s over the next

4.0 s. Assume that the angular acceleration is constant.

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

A. $0.50 rad / s^2$

B. $4.5 rad / s^2$

C. $18 rad / s^2$

D. $2.0 rad / s^2$

Answer: A

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2. A grindstone of radius 4.0 m is initially spinning with an angular speed of 8.0 rad/s. The angular speed is then increased to 10 rad/s over the next 4.0 s. Assume that the angular acceleration is constant.

Through how many revolutions does the grindstone turn during the 4.0 s interval?

A. 0.64

B. 4.0

C. 3.8

D. 5.7

Answer: D

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3. A wheel of radius 0.5 m rotates with a constant angular speed about an axis perpendicular to its center. A point on the wheel that is 0.2 m from the center has a tangential speed of 2 m/s.

Determine the tangential speed of a point 0.4 m from the center of the wheel.

A. 0.4 m/s

B. 4 m/s

C. 2 m/s

D. 10 m/s

Answer: B

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4. A wheel of radius 0.5 m rotates with a constant angular speed about an axis perpendicular to its center. A point on the wheel that is 0.2 m from the center has a tangential speed of 2 m/s.

Determine the tangential acceleration of the point that is 0.2 m from the center.

A. $0.4m/s^2$

B. $4.0m/s^2$

C. $\text{zero} \quad m/s^2$

D. $2.0m/s^2$

Answer: C

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5. A long thin rod of length 2L rotates with a constant angular acceleration of $10 rad / s^2$ about an axis that is perpendicular to the rod and passes through its center.

What is the ratio of the tangential acceleration of a point on the end of the rod to that of a point a distance L/2 from the end of the rod?

A. $1:1$

B. $2:1$

C. $1:4$

D. $1:2$

Answer: B

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6. A long thin rod of length 2L rotates with a constant angular acceleration of $10 rad / s^2$ about an axis that is perpendicular to the rod and passes through its center.

What is the ratio of the centripetal acceleration of a point on the end of the rod to that of a point a distance L/2 from the end of the rod?

A. $1:1$

B. $2:1$

C. $1:4$

D. $1:2$

Answer: B

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7. A long thin rod of length 2L rotates with a constant angular acceleration of $10 rad / s^2$ about an axis that is perpendicular to the rod and passes through its center.

What is the ratio of the tangential speed (at any instant) of a point on the end of the rod to that of a point a distance L/2 from the end of the rod?

A. $1:1$

B. $1:4$

C. $2:1$

D. $1:2$

Answer: C

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Practice Questions Matrix Match

1. Match the statement in Column I with the statements in Column II. One or more than one choice from Column II can match with a statement from Column I.

Column I	Column II
(a) When a sphere is in pure rolling on a fixed horizontal surface	(p) upward direction
(b) When a cylinder is in pure roiling on a fixed inclined plane in upward direction then friction force acts in	(q) $v_{com} > r\omega$

Column I	Column II
(c) When a cylinder is in pure rolling down a fixed incline plane, friction force acts in	(r) $v_{com} < r\omega$
(d) When a sphere of radius R is rolling with slipping on a fixed horizontal surface, the relation between v_{com} and ω is	(s) no frictional force acts.
	(t) no frictional force acts.

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2. In each question, there is a table having 3 columns and 4 rows. Based on the table, there are 3 questions. Each question has 4 options (a), (b), (c) and (d), ONLY ONE of these four options is correct.

In the given table, Column I gives masses of rigid bodies, Column II their length and Column III gives their acceleration.

Column I	Column II	Column III
(I) Mass = 12.5 kg	(i) Length = 10 m	(J) Acceleration = 11.3 m/s^2
(II) Mass = 18.8 kg	(ii) Length = 12.2 m	(K) Acceleration = 13 m/s^2
(III) Mass = 24.3 kg	(iii) Length = 10.1 m	(L) Acceleration = 14.5 m/s^2
(IV) Mass = 16.7 kg	(iv) Length = 11.3 m	(M) Acceleration = 18.2 m/s^2

Which object has 2048.13 N as the net torque?

A. (I) (iv) (L)

B. (I) (iii) (L)

C. (II) (i) (M)

D. (I) (ii) (M)

Answer: A

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3. In each question, there is a table having 3 columns and 4 rows. Based on the table, there are 3 questions. Each question has 4 options (a), (b), (

c) and (d), ONLY ONE of these four options is correct.

In the given table, Column I gives masses of rigid bodies, Column II their length and Column III gives their acceleration.

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(III) Mass = 24.3 kg	(iii) Length = 10.1 m	(L) Acceleration = 14.5 m/s²
(IV) Mass = 16.7 kg	(iv) Length = 11.3 m	(M) Acceleration = 18.2 m/s²

Which object has 1887.1 N as the net torque?

A. (I) (iii) (K)

B. (IV) (iii) (L)

C. (II) (iii) (L)

D. (IV) (i) (J)

Answer: D

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4. In each question, there is a table having 3 columns and 4 rows. Based on the table, there are 3 questions. Each question has 4 options (a), (b), (c) and (d), ONLY ONE of these four options is correct.

In the given table, Column I gives masses of rigid bodies, Column II their length and Column III gives their acceleration.

Column I	Column II	Column III
(I) Mass = 12.5 kg	(i) Length = 10 m	(J) Acceleration = 11.3 m/s^2
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(III) Mass = 24.3 kg	(iii) Length = 10.1 m	(L) Acceleration = 14.5 m/s^2
(IV) Mass = 16.7 kg	(iv) Length = 11.3 m	(M) Acceleration = 18.2 m/s^2

Which object has 2981.7 N as the torque ?

A. (III) (i) (J)

B. (I) (i) (L)

C. (II) (ii) (K)

D. (II) (iii) (M)

Answer: C

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5. In each question, there is a table having 3 columns and 4 rows. Based on the table, there are 3 questions. Each question has 4 options (a), (b), (c) and (d), ONLY ONE of these four options is correct.

Column I		Column II		Column III	
(I)	Force = 120 N	(i)	Radius = 2.2 m	(J)	$\phi = 90^\circ$
(II)	Force = 112 N	(ii)	Radius = 3.6 m	(K)	$\phi = 30^\circ$
(III)	Force = 99 N	(iii)	Radius = 6.2 m	(L)	$\phi = 45^\circ$
(IV)	Force = 125 N	(iv)	Radius = 4 m	(M)	$\phi = 60^\circ$

Which object has $137.5 N \cdot m$ as the resulting torque (as a vector)?

A. (I) (iii) (L)

B. (IV) (i) (M)

C. (II) (iv) (K)

D. (IV) (i) (K)

Answer: D

6. In each question, there is a table having 3 columns and 4 rows. Based on the table, there are 3 questions. Each question has 4 options (a), (b), (c) and (d), ONLY ONE of these four options is correct.

Column I	Column II	Column III
(I) Force = 120 N	(i) Radius = 2.2 m	(J) $\phi = 90°$
(II) Force = 112 N	(ii) Radius = 3.6 m	(K) $\phi = 30°$
(III) Force = 99 N	(iii) Radius = 6.2 m	(L) $\phi = 45°$
(IV) Force = 125 N	(iv) Radius = 4 m	(M) $\phi = 60°$

Which object has $178.2\sqrt{3}N \cdot m$ as the resulting torque (as a vector)?

A. (III) (ii) (L)

B. (III) (ii) (K)

C. (II) (iii) (K)

D. (I) (i) (M)

Answer: B

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7. In each question, there is a table having 3 columns and 4 rows. Based on the table, there are 3 questions. Each question has 4 options (a), (b), (c) and (d), ONLY ONE of these four options is correct.

Column I		Column II		Column III	
(I)	Force = 120 N	(i)	Radius = 2.2 m	(J)	$\phi = 90^\circ$
(II)	Force = 112 N	(ii)	Radius = 3.6 m	(K)	$\phi = 30^\circ$
(III)	Force = 99 N	(iii)	Radius = 6.2 m	(L)	$\phi = 45^\circ$
(IV)	Force = 125 N	(iv)	Radius = 4 m	(M)	$\phi = 60^\circ$

Which object has $480N \cdot m$ as the resulting torque (as a vector)?

A. (I) (iv) (J)

B. (I) (i) (K)

C. (III) (iii) (L)

D. (I) (ii) (L)

Answer: A

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Practice Questions Integer Type

1. Four solid sphereas each of diameter $\sqrt{5}cm$ and mass $0.5kg$ are placed with their centres at the corners of a square of side $4cm$. The moment of inertia of the system about the diagonal of the square is $N \times 10^{-4}kg - m^2$, the N is -

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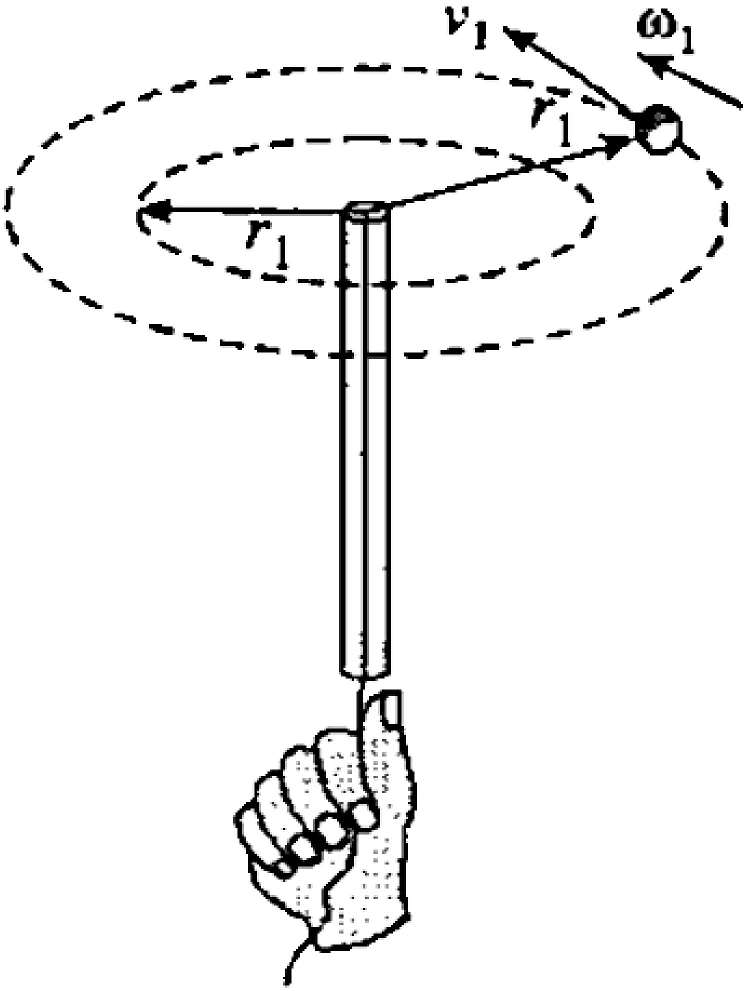
2. A point mass is tied to one end of a cord whose other end passes through a vertical hollow tube , caught in one hand. The point mass is being rotated in a horizontal circle ofradius 2 m with speed of 4m/sec.The cord is then pulled down so that the radius of the circle reduces to 1m . Compute the new linear and angular velocities of the point mass and compute the kinetic energies under the initial and final states.



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3. Two small bals A and B, each of mass m, are joined rigidlyl by a light horizontal rol of lengh L. The rod is clasmped at the centre in such a way that it c an rotate freely about a verticl axis through its centre. The systemis rotated with an angualr speed ω about the axis. A particle P of masss m kept at rest sticks to the ball A as the ball collides with it. Find the new angular speed of the rod.

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