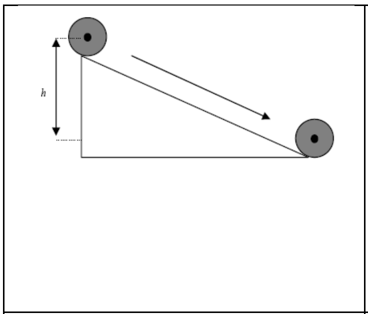
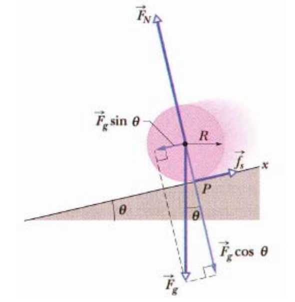
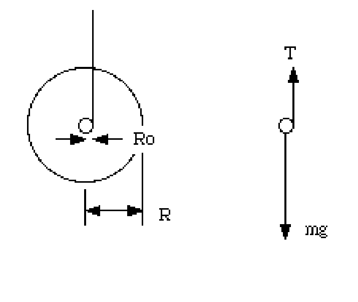
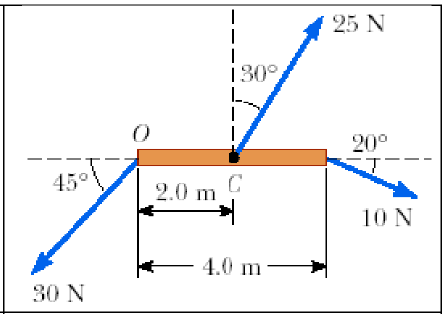
Ayman Ghannam **Chapter 11** **Rolling, Torque & Angular Momentum**	

Q.1 A bowling ball has a mass of $M = 4.0\ \text{kg}$, a M.I. $I_{cm} = 1.6\times10^{-2}\ \text{kg}\cdot\text{m}^2$ and a radius $R = 0.10\ \text{m}$. If it rolls straight in +x-direction without slipping with a linear speed of $v_{cm} = 4.0\ \text{m/s}$, what is its total energy? 44.8 J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Q.2 Consider a solid cylinder of radius *R* that rolls without slipping down an incline from some initial height *h*. Calculate the linear velocity, v_{cm}, of the cylinder at the bottom of the incline and the angular velocity ω. $v_{cm} = \sqrt{\frac{4}{3}gh}$

Q.3 The figure shows a round uniform body of mass *M* and radius *R* rolling smoothly down a ramp at angle θ, along an *x* axis. What is its linear acceleration? $a_{com,x} = -\dfrac{g\sin\theta}{1 + I_{com}/MR^2}$.

Note that the pull by the gravitational force causes the body to come down the ramp, but it is the frictional force that causes the body to rotate and thus roll. If you eliminate the friction (by, say, making the ramp slick with ice or grease) or arrange for $Mg\sin\theta$ to exceed $f_{s,max}$, then you eliminate the smooth rolling and the body slides down the ramp.

$$a = g\frac{1}{1 + \frac{I}{mR_0^2}}$$

Q.4 **THE YO-YO**

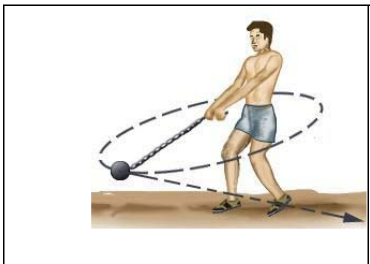
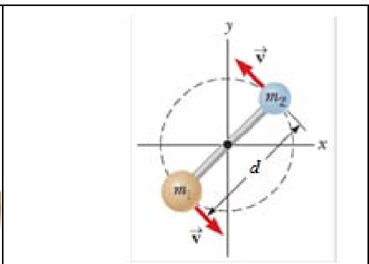
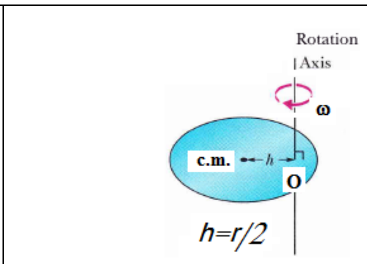
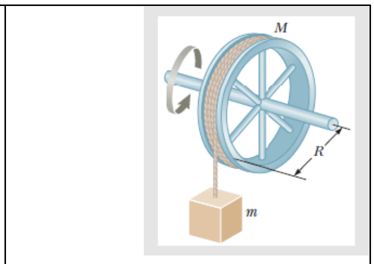
A yo-yo, which travels vertically up or down a string, can be treated as a wheel rolling along an inclined plane at angle $\theta = 90^\circ$ and R=Ro

Q.5 Calculate the net torque (magnitude and direction) on the beam in the figure about the O- and C- axes.

a) About the O-axis. 29.6N.m **counterclockwise**
b) About the C-axis. -35.6N.m **counterclockwise**

Q.6 A force $\vec{F} = (2.0\,\hat{i} + 3.0\,\hat{j})$ N is applied to an object that is pivoted about a fixed axis aligned along the *z*-axis. If the force is applied at the point of coordinates (4.0, 5.0, 0.0) m, what is the applied torque (in N.m) about the z axis? 2k N.m

Q.7 At an instant, a particle of mass 2.0 kg has a position of $\vec{r} = (9.0\,\hat{i} + 15.0\,\hat{j})$ m and acceleration of $\vec{a} = (-3.0\,\hat{i} + 3.0\,\hat{j})$ m/s^2. What is the net torque on the particle at this instant about the point having the position vector: $\vec{r}_o = (9.0\,\hat{i})$ m? 90k N.m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Q.8 A stone attached to a string is whirled at 3.0 rev/s around a horizontal circle of radius 0.75 m. The mass of the stone is 0.15 kg. The magnitude of the angular momentum of the stone relative to the center of the circle is: 1.6kg.m2/s

Q9. A light, rigid rod of length *d* = 1.00 m joins two particles, with masses m_1 = 4.00 kg and m_2 = 3.00 kg, at its ends. The combination rotates in the xy plane about a pivot through the center of the rod (see figure). Determine the angular momentum of the system about the origin when the speed of each particle is 2.00 m/s. 7kg.m^2/s

Q10. A uniform solid disk of mass m = 2.94 kg and radius *r* = 0.200 m rotates about a fixed axis perpendicular to its face with angular frequency 6.02 rad/s. $\left[I_{CM} = \frac{1}{2}mr^2\right]$

(a) Calculate the magnitude of the angular momentum of the disk when the axis of rotation passes through its center of mass. 0.354kg.m^2/s

(b) What is the magnitude of the angular momentum when the axis of rotation passes through a point midway between the center and the rim? 0.531kg.m2/s

(c) What is the magnitude of the angular momentum when the axis of rotation passes through a point at the rim? 1.06kg.m^2/s

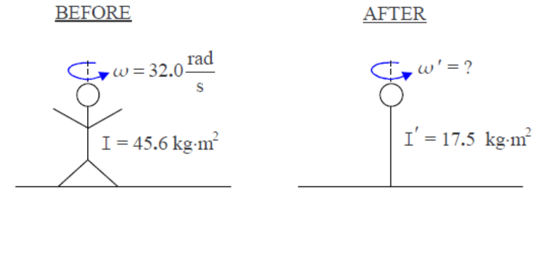
Q.11 At time *t*, the vector $\vec{r}(t) = 4.0\,t^2\,\hat{\mathrm{i}} - \left(2.0\,t\ + 6.0\,t^2\right)\hat{\mathrm{j}}$ gives the position of a 2.0 kg relative to the origin of an *xy* coordinate system ($\vec{r}$ is in meters and *t* is in seconds). Find an expression for the torque acting on the particle relative to the origin.32.0t k N.m

Q.12 A counterweight of mass *m* = 4.40 kg is attached to a light cord that is wound around a pulley as shown in the figure below. The pulley is a thin hoop of radius *R* = 9.00 cm and mass *M* = 2.50 kg. The spokes have negligible mass.

a) What is the net torque on the system about the axle of the pulley?3.88 k

b) When the counterweight has a speed *v*, the pulley has an angular speed = v/R. Determine the magnitude of the total angular momentum of the system about the axle of the pulley.0.621kg.m

c) Using your result from (b) and $\vec{\tau}_{net} = d\vec{L}/dt$, calculate the acceleration of the counterweight. (the magnitude of the acceleration.)6.25m/s2



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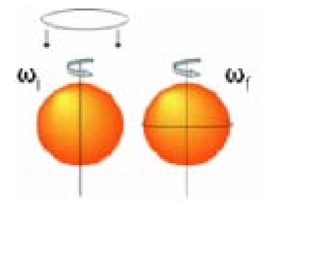

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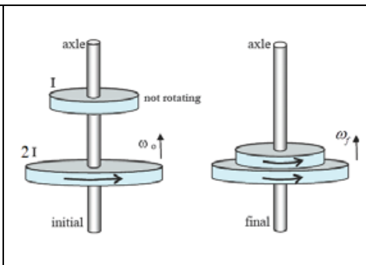

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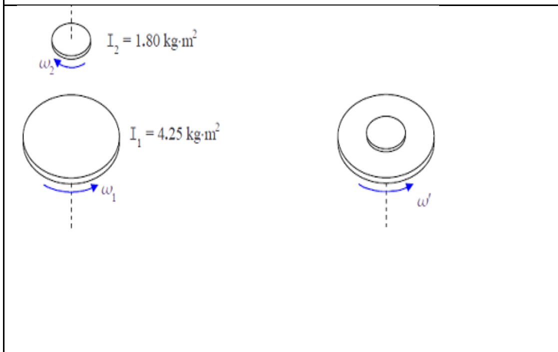

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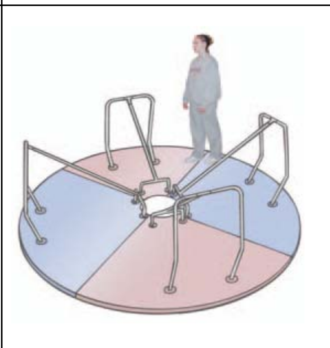

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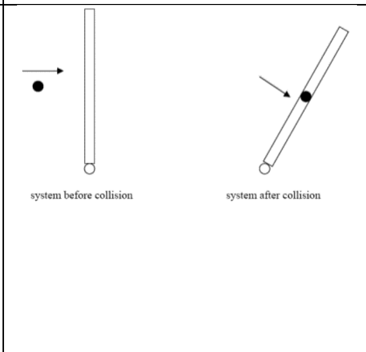

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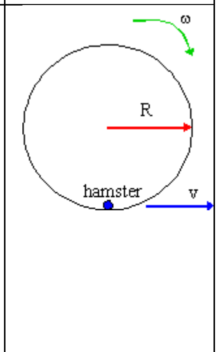

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Q.13 A skater is spinning at 32.0 rad/s with his arms and legs extended outward. In this position his moment of inertia with respect to the vertical axis about which he is spinning is 45.6 kg·m^2. He pulls her arms and legs in close to her body changing his moment of inertia to 17.5 kg·m^2. What is his new angular velocity?83.4rad/s

Q.14 A solid sphere of mass *M* =1.0 kg and radius *R* =10 cm rotates about a frictionless axis at 4.0 rad/s (see Figure). A hoop of mass m = 0.10 kg and radius *R* =10 cm falls onto the ball and sticks to it in the middle exactly. Calculate the angular speed of the whole system about the axis just after the hoop sticks to the sphere. 3.2rad/s

Q.15 A disk (rotational inertia = 2*I*) rotates with angular velocity ω_o about a vertical, frictionless axle. A second disk (rotational inertia = *I*) and initially not rotating, drops onto the first disk (see figure). The two disks stick together and rotate with an angular velocity ω_f . Find ω_f . $\omega_f = \underline{2\omega_o/3}$

Q.16 A horizontal disk of rotational inertia 4.25 kg.m^2 with respect to its axis of symmetry is spinning counterclockwise about its axis of symmetry, as viewed from above, at 15.5 rev/s on a frictionless massless bearing. A second disk, of rotational inertia 1.80 kg.m^2 with respect to its axis of symmetry, spinning clockwise as viewed from above about the same axis (which is also its axis of symmetry) at 14.2 rev/s, is dropped on top of the first disk. The two disks stick together and rotate as one about their common axis of symmetry at what new angular velocity (in units of radians per second)? 41.9rad/s

Q.17 A merry-go-round of radius R = 2.0 m is rotating about a frictionless pivot. It makes one revolution every 5.0 sec. The moment of inertia of the merry-go-round (about an axis through its center) is 500 kg·m^2. A child of mass m = 25 kg, originally standing at the rim, walks radially in to the exact center. The child can be considered as a point mass. What is the new angular velocity, in rad/sec, of the merry-go-round? 1.51rad/s

Q.18 A bullet, mass = 10 grams, is fired into the center of a door, of mass = 15 kg and width W = 1.0 meter, with a velocity of 400 m/s. The door is mounted on frictionless hinges. Find the angular speed of the door after the impact. 0.4rad/s [$I_{door} = \frac{1}{3}M\,\mathrm{W}^2$]

Is energy conserved?

$K_i = \frac{1}{2}mv^2 = \frac{1}{2}(0.01)(400)^2(0.5) = 800\ \mathrm{J}$’

$K_f = \frac{1}{2}I_{f,system}\omega_f^2 = 0.4\ \mathrm{J}$, it is 1/2000 of the initial value!

Q.19 A hamster of mass 300 g is running in an exercise wheel with a speed of 3.2 m/s. A typical exercise wheel has a moment of inertia about its center of 0.250 kg-m^2. How fast is the wheel rotating? The radius of the wheel is 12.0 cm. Treat the hamster as a point mass. 0.461rad/s