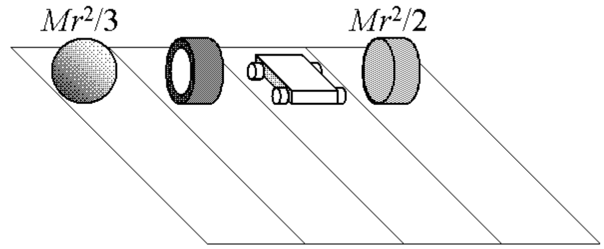
Due On: ________________ Name: ___________________________

AP Physics 1: Review Packet 09

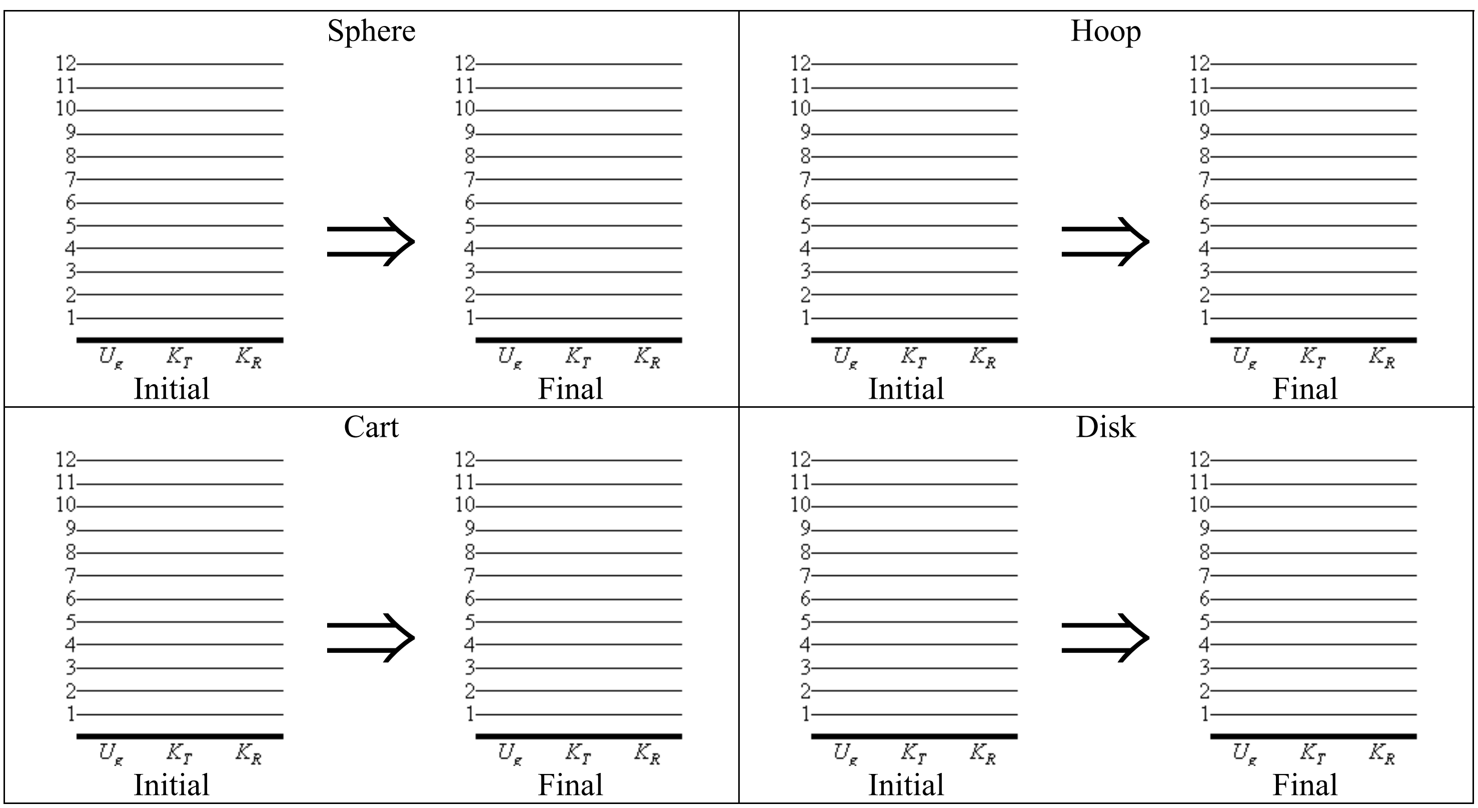
Problem 1: Four objects (in order: hollow sphere, thin hoop, cart with light wheels, and solid disk) each of mass 0.4 kg are released from rest at the top of identical inclines each with a height of 3 m. The objects move toward the bottom and each reach the bottom with a different final speed. The sphere, disk, and hoop have the same radius and do not slip as they roll. Two of the objects have their rotational inertias indicated in terms of their mass *m* and radius *r*.



(a) What is the rotational inertia of the hoop in terms of *m* and *r*? Give a reason for your answer.

(b) What potential energy does each object start with?

(c) Fill in the four energy bar graphs below for each object, drawing a bar for the initial potential energy before the object is released and drawing bars for the final kinetic energies of the objects once they reach the bottom.



(d) Rank the objects (“sphere”, “hoop”, “cart”, “disk”) in order based on which one reaches the bottom first.

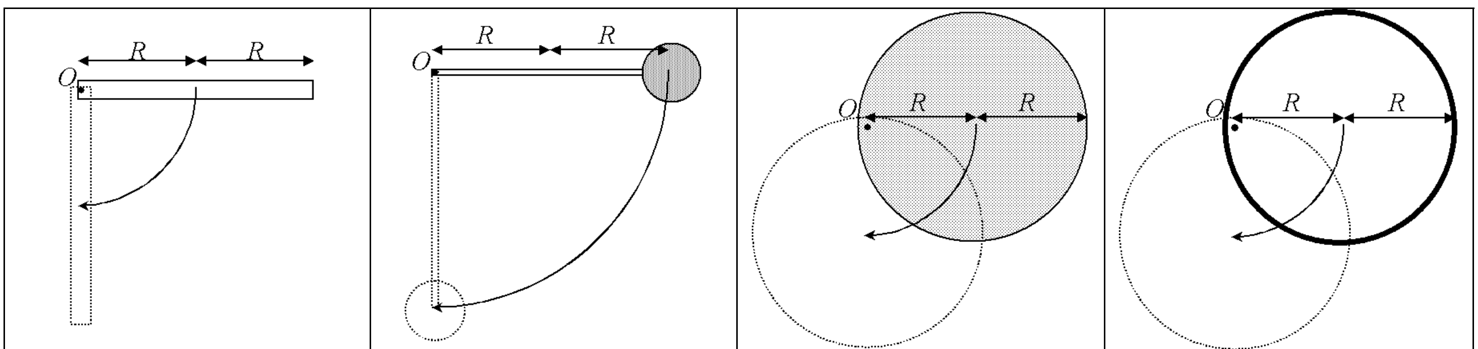
____________ ____________ ____________ ____________

First Place Last Place

Explain your ranking by referring to your energy bar graphs.

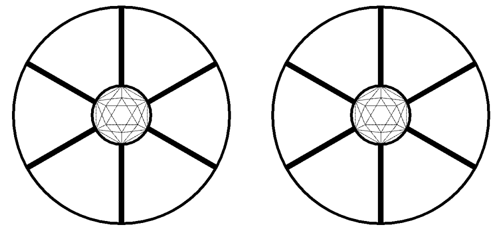
Problem 2: Write a well-organized paragraph response to each of the following questions. A full-credit response will state a clear answer to the question and connect that answer to specific physical laws and principles.

(a) The four objects shown below all have the same mass. Each one is pivoted about the point *O* shown and held horizontally at rest. Each is released from rest and swings through the vertical position shown by the dots. Three of the objects all have the same kinetic energy upon reaching the vertical position, and the other one has greater kinetic energy than that. Which object has the greater kinetic energy upon passing through the vertical position? Explain your reasoning.



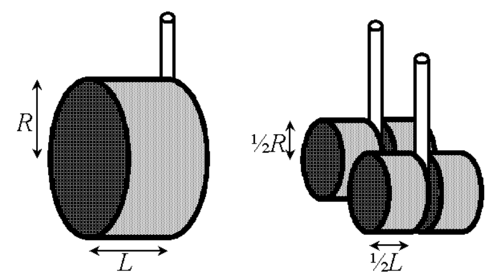
Uniform bar | Pendulum bob on string | Uniform Disk | Hoop

(b) Indiana Jones is searching an underground tomb for the Eye of Klaatu. He comes across two seemingly identical potential artifacts: a jewel in the center of a heavy steel framework. One is the Eye of Klaatu; it has a diamond in the center. The other is a fake and has a cubic zirconia in the center. Cubic zirconia is twice as dense as diamond, but the steel frame is so heavy that Indy can't tell by holding which one is heaver and he can only carry one out. Indy finds a fallen wooden beam that can act as a straight ramp, so he rolls both artifacts down the ramp from rest at the same time and object *A* reaches the bottom first. Which one is the true Eye of Klaatu? Explain your reasoning.



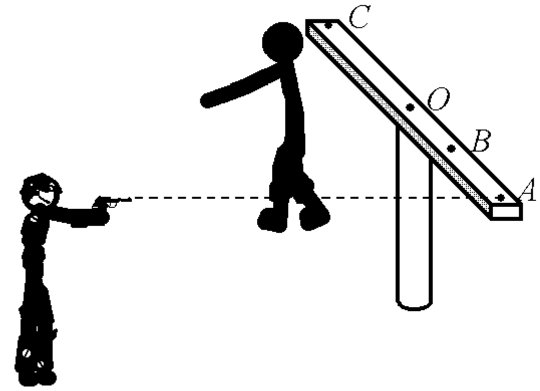
Object A Object B

(c) The B-36 Peacemaker was a strategic bomber airplane built for the US Air Force from 1949 to 1959. The first prototypes had a landing gear that consisted of a single large wheel as shown in the diagram. Later models replaced the single large wheel with four smaller wheels. The large wheel (a cylinder) has radius *R* and height *L*. Each of the four smaller wheels has radius ½*R* and height ½*L*. The big and small wheels all have the same density. When the big wheels were replaced with the smaller wheels, it was found that the bomber reached its take-off speed in much less time. Explain why this would be the case. Include specific calculations.



Big Wheel Four Small Wheels

Problem 3: James Bond is trying to enter a mansion by sneaking in through the back yard. There, he encounters a guard that is standing in front of a clothesline that consists of a horizontal wooden plank that can pivot and rotate freely on a vertical post at point *O*. In order to take down the guard non-lethally and without making much noise, James Bond shoots a bullet from his silenced Walther PPK pistol at point *A* on the clothesline. The bullet embeds itself in the wood and the wood rotates, causing point *C* to strike the back of the guard's head. The guard is hit just hard enough to knock him unconscious. Answer the following in brief paragraphs that cite specific physical principles.



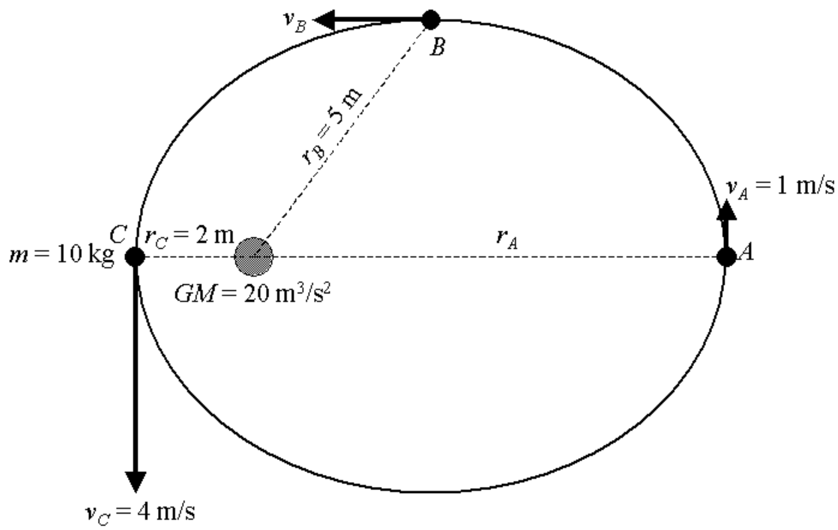
(a) Explain what would happen if the same bullet was fired at the same speed but at point *B* on the post.

(b) Explain what would happen if the same bullet was fired at the same speed but at point *O* on the post.

(c) Explain what would happen if the same bullet was fired at the same speed but at point *C* on the post.

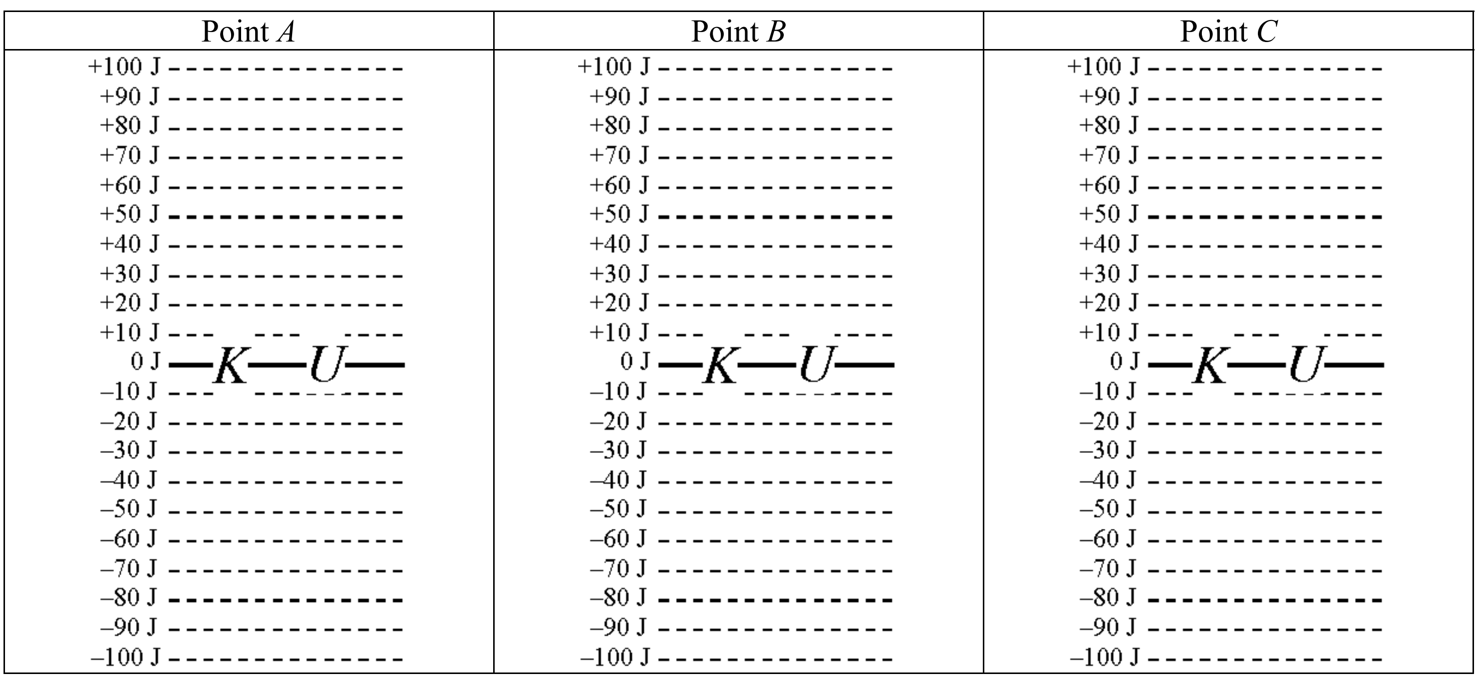
(d) Explain what would happen if a rubber bullet of the same mass is fired at the same speed at point *A* on the post. Assume the rubber bullet bounces elastically off of the post.

Problem 4: A rock of mass m = 10 kg makes an elliptical orbit around a dense asteroid that has a mass M such that GM = 20 m^3/s^2. Point A is at the rock's closest approach to the asteroid, and point C is at the rock's farthest distance from the asteroid. The table below shows some values of the orbital parameters at points A, B, and C. Fill in all other values for the data table.



Point	Distance r (m)	Speed v (m/s)	Angle bet. **r** & **v** (degrees)	Force F (N)	Accel. a (m/s^2)	Ang. Mom L (Js)	Kinetic Energy K (J)	Potential Energy U (J)	Total Energy E (J)
A		1							
B	5								
C	2	4							

As the rock travels from A to B to C, its energy changes. Draw energy bar graphs showing the kinetic and potential energies of the rock at each of the three points.



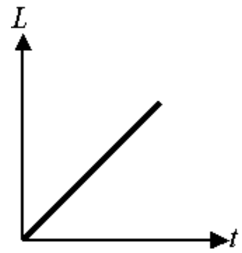
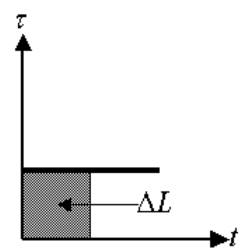
Rotational Energy and Momentum Review

IMPORTANT QUANTITIES

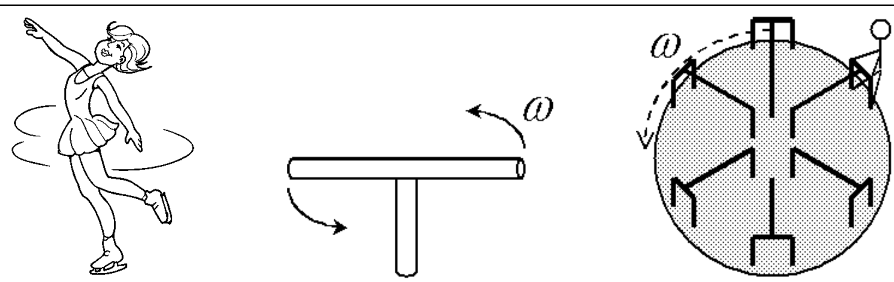
Name	Symbol	Units	Basic Equation
Translational Kin. Energy	K_T	Joules	$K_T = \frac{1}{2}mv^2$
Rotational Kin. Energy	K_R	Joules	$K_T = \frac{1}{2}I\omega^2$

Name	Symbol	Units	Basic Equation
Angular Momentum	L	kg•m²/s	$L = I\omega$ $L = r_\perp mv$ $L = rmv_\perp$ $L = mvr$

IMPORTANT GRAPHS

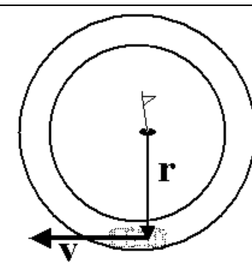
Name	Graph (Shape)	Notes
Angular Momentum vs. Time		**THE SLOPE OF ANGULAR MOMENTUM VS. TIME IS TORQUE.** This is just like the fact that the slope of a momentum vs. time graph is force.
Torque vs. Time		**THE AREA OF TORQUE VS. TIME IS CHANGE IN ANGULAR MOMENTUM.** This is just like the fact that the area of a force vs. time graph is change in momentum.

A ROTATING OBJECT HAS ANGULAR MOMENTUM. A MOVING OBJECT ALSO HAS ANGULAR MOMENTUM ABOUT A POINT THAT IS NOT ON THE OBJECT'S PATH.



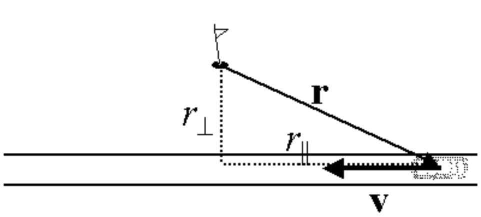
In all three of these cases, a rigid object rotates about its center. The object has a rotational inertia I, and makes ω radians of angle every second.

$L = I\omega$



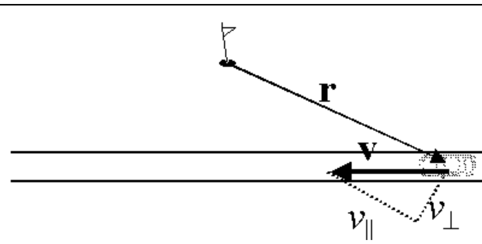
This car is in circular motion, so its radius & velocity are perpendicular.

$L = mvr$



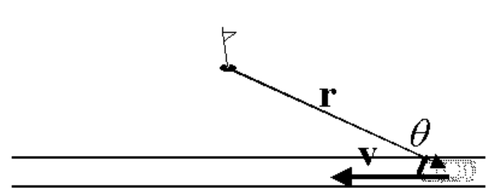
This car has constant angular momentum since it has constant v and $r_\perp$ is the same for the whole line.

$L = mvr_\perp$



You can also break the velocity into components parallel to r and perpendicular to r.

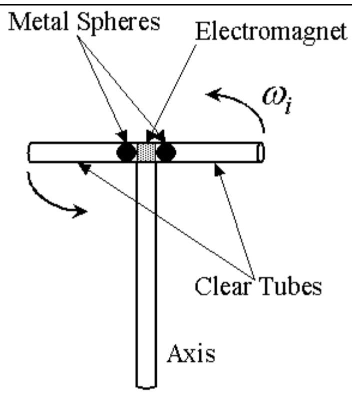
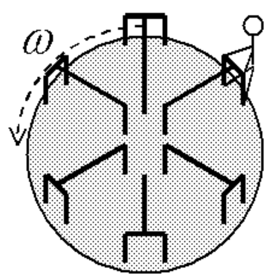
$L = mv_\perp r$



You can just skip making components either way and use the sine function to calculate L.

$L = mvr \sin\theta$

ANGULAR MOMENTUM IS CONSERVED IF NO EXTERNAL TORQUES ACT ON A SYSTEM.

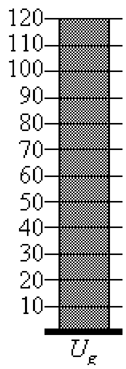
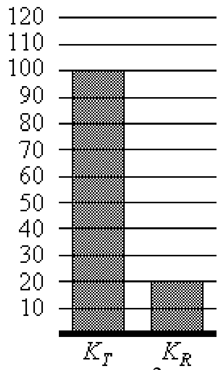
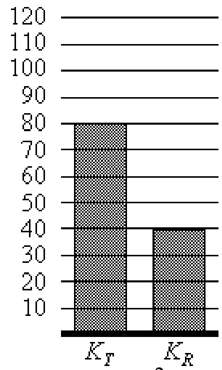
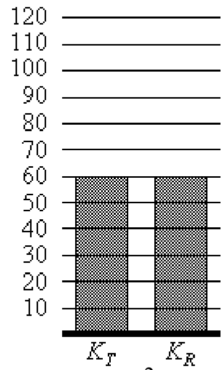
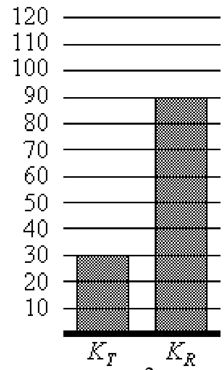
Situation	Does NOT change angular momentum!	DOES change angular momentum!
 Ice skater whirls in a circle.	Moving arms outward • Increases I by putting matter farther from the center. • $L = \overset{\uparrow}{I}\,\underset{\downarrow}{\omega}$, so she spins slower Moving arms inward • Decreases I by putting matter closer to the center. • $L = \underset{\downarrow}{I}\,\overset{\uparrow}{\omega}$, so she spins faster	Grab on to a pole and push to spin faster. • She pushes on pole, so pole pushes on her. • "Pole pushes on her" exerts a torque giving her more ang.mom. Grind skates into ice to decrease speed. • Friction exerts a torque to take away angular momentum
 Whirling apparatus has heavy spheres inside of it.	Spheres are attracted inward by magnets. • Decreases I by putting matter closer to the center. • $L = \underset{\downarrow}{I}\,\overset{\uparrow}{\omega}$, so it spins faster Spheres are allowed to roll to the outside. • Increases I by putting matter farther from the center. • $L = \overset{\uparrow}{I}\,\underset{\downarrow}{\omega}$, so it spins slower	Someone grabs on to the center post and spins the object faster. • The person's torque adds angular momentum to the apparatus. There is friction in the center post's bearings. • The torque due to friction takes away angular momentum.
 Kid rides on a merry-go-round	Kid moves toward the outside. • Increases I by putting matter farther from the center. • $L = \overset{\uparrow}{I}\,\underset{\downarrow}{\omega}$, so it spins slower Kid moves toward the inside. • Decreases I by putting matter closer to the center. • $L = \underset{\downarrow}{I}\,\overset{\uparrow}{\omega}$, so it spins faster	Stick out foot and drag the foot on the ground to decrease speed. • Friction exerts a torque that takes away angular momentum. Jump off and run while holding merry-go-round to make it go faster. • He pushes on ground, so ground pushes on him. • Ground exerts a torque giving M-G-R more angular momentum.

IMPORTANT ANGULAR MOMENTUM CONCEPTS:

- If a translating object strikes an object and causes it to rotate, then angular momentum is conserved. This might look like $mv_i r = mv_f r + I\omega$ assuming the rotating object is initially at rest and the translating object doesn't change direction when it hits the rotating object. (If the direction of motion changes, then the final angular momentum of the translating object is negative).
- Angular momentum is conserved in an elliptical orbit. Rotational energy is also conserved in an elliptical orbit.

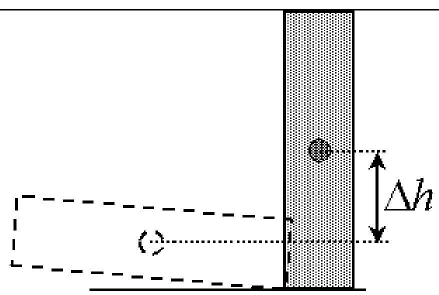
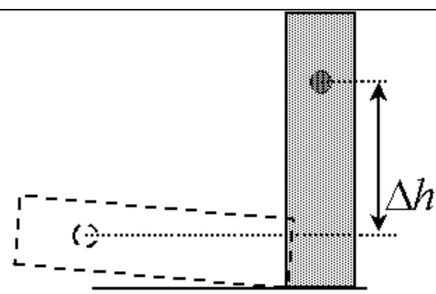
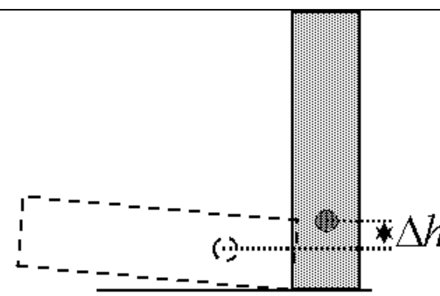
ROLLING OBJECTS: When an object rolls without slipping, it has both translational and rotational kinetic energy. If an object has rotational inertia kmr^2, then the rotational kinetic energy is k times the translational kinetic energy. For example, an object whose rotational inertia is ¼mr^2 has K_R = ¼K_T at all times while it rolls without slipping.

Consider four objects with the same mass and that start at rest at the top of the same ramp. Suppose that they start with 120 J of potential energy. Now the objects roll down the ramp to the bottom. Here is what each object's final energy bar graph looks like. Note that their rotational inertia is given at the top.

Initial Energy	$I = 0.2MR^2$	$I = 0.5MR^2$	$I = 1MR^2$	$I = 3MR^2$
				
All the objects start with MgH = 120 J	$I = 0.2MR^2$, so rotational KE is 0.2 times translational. Total energy=120 J.	$I = 0.5MR^2$, so rotational KE is 0.5 times translational. Total energy=120 J.	$I = 1MR^2$, so rotational KE is same as translat. Total energy=120 J.	$I = 3MR^2$, so rotational KE is 3 times translational. Total energy=120 J.

POTENTIAL ENERGY IS ALWAYS MEASURED FROM THE OBJECT'S CENTER OF MASS.

Suppose a bookcase falls over. The bookcase starts with gravitational potential energy and ends with rotational kinetic energy. The height for gravitational potential energy is measured using the center of mass.

		
A bookcase with no books has a center of mass in the center of the bookcase. The bookcase's *mgh* is found by measuring the height of the center of mass.	Suppose there are books on the top shelf. These books put the center of mass high, so the bookcase has more potential energy to start with and more KE when it falls over.	Suppose there are books on the bottom shelf. These books put the center of mass low, so the bookcase has less potential energy to start with and less KE when it falls over.