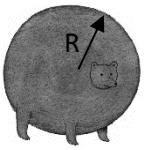
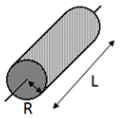
AP Physics C: Mechanics
Unit 5&6: Rotation

1. (10 pts) A bear is spinning (at time t = 0) at an angular velocity of 60 rad/s and an angular acceleration given by $\alpha(t) = -12t$. The bear has a radius of R = 2.0 m. Assume spherical bear.

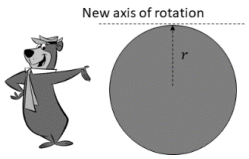


a) Calculate the linear velocity of a point on the outer surface of the bear at t = 2 s.
b) Find the displacement of the bear in number of revolutions at time t = 2 s.

2. (14 pts) A solid cylinder has a radius R = 2.0 m, mass of M = 20 kg, and length of L = 15.0 m.



a) Using integral calculus, calculate the moment of the cylinder about an axis through its center.
b) Yogi is smarter than the average bear, and knows that the cylinder will have a greater moment of inertia if he pivots it about along the lateral surface of the cylinder as shown.



i. Without using any calculations, briefly state why the moment of inertia will increase in this case.
ii. Calculate the new moment of inertia.

3. (14 pts) A hiker protects the food at his backcountry campsite using a balance as shown in **Figure 1**. He attaches a pole of mass ***M*** that has length ***D*** as shown to the top of a log and allows it to be perfectly horizontal by hanging picnic baskets, each of mass ***M***, on each end. The rod is free to rotate at point P, which is the exact center of the rod and frictionless. The system is perfectly horizontal when the bear Boo Boo, who has a mass of $5\boldsymbol{M}$, is placed into the right picnic basket as shown, which causes the system to rotate clockwise.

Figure 1

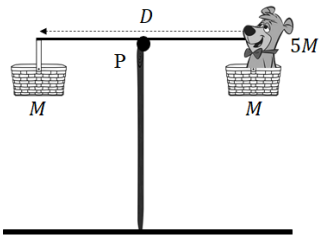


Figure 2

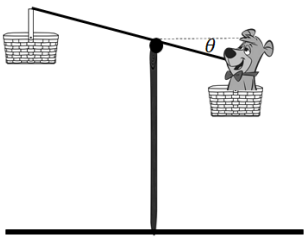
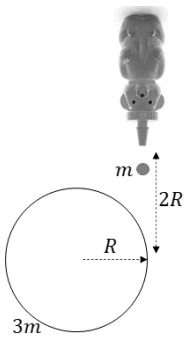


Figure 3

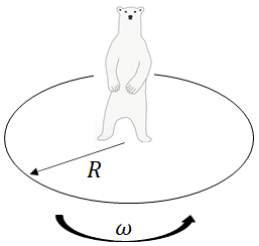
a) Determine an expression for the moment of inertia of the rod-baskets-bear system. The moment of inertia of a rod pivoted about its center is $I = \frac{1}{12}mL^2$. You'll need this result for parts b) and c).
b) At one point, the system is rotating, with the right half of the rod making an angle of $\theta = 60°$ below the horizontal as shown in **Figure 2**. Determine the angular acceleration of the system at this point.
c) Later, the system is in a vertical position as shown in **Figure 3**. Determine the angular velocity of the rod at this point.

4. (13 pts) A hollow ring with a mass of $3m$ and radius R is free to rotate about an axis through its center as shown. The ring is initially at rest. A drop of honey of mass m is dropped from a height of 2R above the center of ring and are dropped such that it lands at the exact outer edge of the ring after falling straight down, and sticks to the ring. ($I_{ring} = mr^2$)



a) Determine an expression for the initial angular velocity of the drop of honey about the center of the ring when it lands on it.
b) Determine an expression for the angular velocity of the wheel after the honey sticks to it.
c) Suppose the honey were elastic and bounced off the ring instead of sticking to it. Would the resulting angular velocity of the wheel increase, decrease or remain the same?

5. (15 pts) A polar bear has a mass of 400 kg and stands at the center of a circular disc of ice of mass 200 kg and radius $R = 3.0\ m$ that is rotating with an angular speed of $\omega = 10.0\frac{1}{s}$ as shown. ($I_{disc} = \frac{1}{2}mr^2$). The polar walks from the center of the disk to the very edge of the disc in a span of 2.0 s.

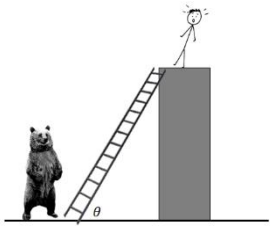


a) Calculate the angular speed of the disc when the bear reaches the edge of the disc.

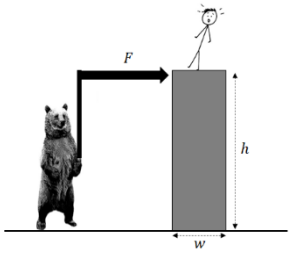
b) Calculate the average torque the bear exerts on the disc.

c) Does the bear do positive, negative, or zero work on the disc? Briefly justify your answer.

6. (14 pts) A grizzly goes to pick up Thanksgiving dinner for his family, but the dinner is up on a ledge as shown.



a) The bear attempts to climb up to his dinner with a ladder. The ladder has a length of 8 m and a mass of 20 kg, while the bear has a mass of 100 kg. The bear places the ladder at angle of $\theta = 60$ with the ground. What minimum coefficient of friction must exist between the ladder and ground for the bear to climb all the way to the lop of the ladder without it slipping?

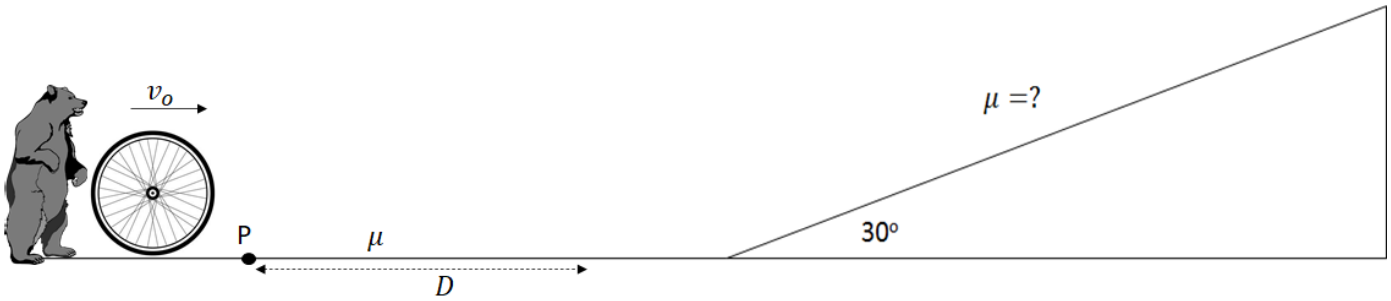


b) The ladder idea didn't work, so the bear simply decides to tip over the box his dinner is standing. He grab and bends a pole and pushes the very top of the box with a force F. The box has a height of h = 5 m, a width of w = 2 m, and a mass of 40 kg. The dinner has a mass of 80 kg.

i. Draw a free-body diagram of the box. Draw each force where it acts.

ii. What minimum coefficient of static friction must exist between the box and the ground for it to tip?

7. (22 pts) A bear pushes a wheel with an initial velocity of $v_0 = 20\ m/s$ on frictionless surface. The wheel encounters friction at point P, with $\mu = 0.25$. The wheel initially slides, then rolls and slips for a distance D before eventually rolling without slipping. Once the wheel is rolling without slipping, it enters a rough incline that is inclined 30° above the horizontal. The wheel rolls without slipping up the incline. Due to the wheel's shape, it has a moment of inertia given by $I = \frac{3}{5}mr^2$. The wheel has a mass of 2.0 kg and radius of 0.5 m.



a) Calculate the distance D, which is the distance for which the wheel rolls and slips.

b) Calculate the maximum height up the incline the wheel travels.

c) Calculate the force of friction on the incline.

d) Would a wheel with the same mass but a higher moment of inertia traveling at the same initial speed go further up the incline, not as far, or the same distance up the incline as the original wheel? Briefly justify your answer.