

MASSACHUSETTS INSTITUTE OF TECHNOLOGY  
Experimental Study Group

Physics 8.012, Fall 2010

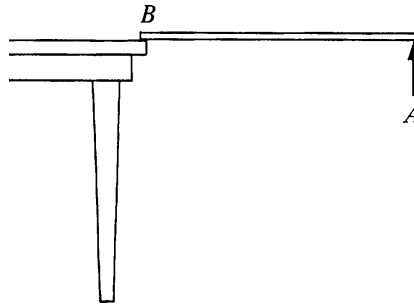
Problem Set 9

Due: Friday, November 19

Reading: Kleppner and Kolenkow, *An Introduction to Mechanics*, Chapter Six

Problem 1: K&K 6.14

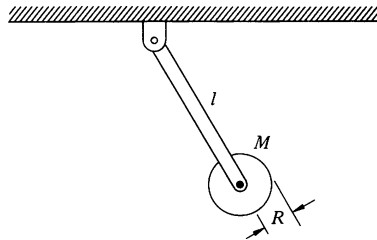
A uniform stick of mass  $m$  and length  $l$  is suspended horizontally with end  $B$  at the edge of a table and the other end  $A$  is held by hand. Point  $A$  is suddenly released. At the instant after release:



- What is the torque about the end  $B$  on the table?
- What is the angular acceleration about the end  $B$  on the table?
- What is the vertical acceleration of the center of mass?
- What is the vertical component of the hinge force at  $B$ ? Does the hinge force have a horizontal component at the instant after release?

Problem 2: K&K 6.18

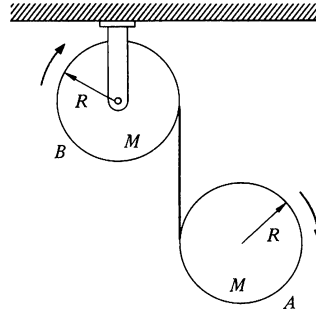
A physical pendulum consists of a disc of radius  $R$  and mass  $m_d$  fixed at the end of a rod of mass  $m_r$  and length  $l$ .



- Find the period of the pendulum.
- How does the period change if the disk is mounted to the rod by a frictionless bearing so that it is perfectly free to spin?

### Problem 3: K&K 6.24

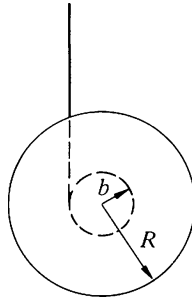
A drum  $A$  of mass  $m$  and radius  $R$  is suspended from a drum  $B$  also of mass  $m$  and radius  $R$ , which is free to rotate about its axis. The suspension is in the form of a massless metal tape wound around the outside of each drum, and free to unwind. Gravity is directed downwards. Both drums are initially at rest. Find the initial acceleration of drum  $A$ , assuming that it moves straight down.



### Problem 4: K&K 6.29

A Yo-Yo of mass  $m$  has an axle of radius  $b$  and a spool of radius  $R$ . Its moment of inertia can be taken to be  $I = (1/2)mR^2$  and the thickness of the string can be neglected.

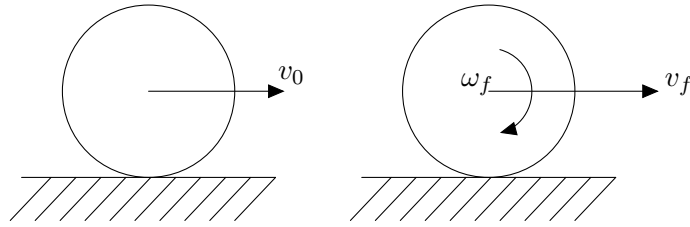
The Yo-Yo is released from rest.



- What is the tension in the cord as the Yo-Yo descends and as it ascends?
- The center of the Yo-Yo descends a distance  $h$  before the string is fully unwound. Use conservation of energy to find the angular velocity of the Yo-Yo when it reaches its lowest point.
- What happens to the Yo-Yo at the bottom of the string?
- Assuming it reverses direction with uniform angular velocity, find the average force on the string while the Yo-Yo turns around.

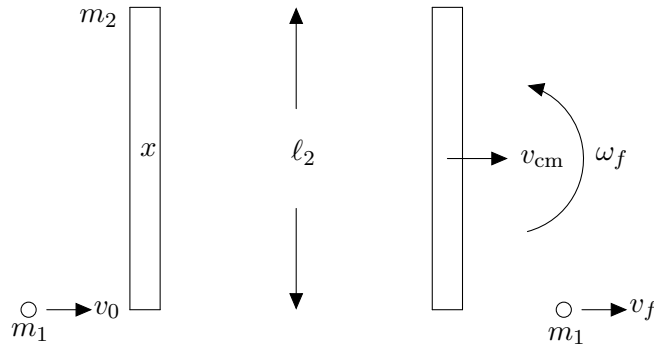
### Problem 5: K&K 6.30

A bowling ball of mass  $m$  and radius  $R$  is initially thrown down an alley with an initial velocity  $v_0$  and it slides without rolling but due to friction it begins to roll. The moment of inertia of the ball about its center of mass is  $I_{\text{cm}} = (2/5)mR^2$ . What is the velocity of the bowling ball when it just start to roll without slipping.



### Problem 6: K&K 6.37

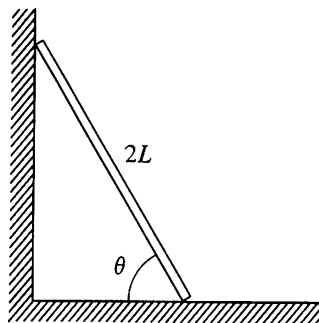
A hockey puck of mass  $m_1$  slides along ice with a velocity  $v_0$  and strikes one end of a stick lying on the ice of length  $l_2$  and mass  $m_2$ . The center of mass of the stick moves with an unknown magnitude  $v_{cm}$ . The stick also rotates about the center of mass with unknown angular velocity  $\omega_f$ . The puck continues to move in the same straight line as before it hit the stick with velocity  $v_f$ . Assume the ice is frictionless and there is no loss of mechanical energy during the collision.



- Write down the equation for conservation of momentum.
- Write down the equation for conservation of energy.
- Is there any external torques acting on the system consisting of the puck and the stick? Write down the equation for conservation of angular momentum about a convenient point.
- Find the velocity of the center of mass of the stick.
- Find the velocity of the puck after the collision.
- Find the angular velocity of the stick after the collision.

### Problem 7: K&K 6.41

A plank of length  $2l$  leans against a wall. The mass of the plank is  $m$  which is uniformly distributed. The plank is initially inclined at an angle  $\theta$  with respect to the horizontal. It starts to slip downward without friction.



- (a) Draw a force diagrams showing all the forces acting on the plank. What is the condition that the plank just starts to slip from the wall.
- (b) Is the mechanical energy of the plank conserved as it slips down the wall?
- (c) What equations arise from the conditions for static equilibrium for both forces and torque? Think about which point to compute the torque about.
- (d) Show that the top of the plank loses contact with the wall when it is two-thirds of its initial height against the wall. Hint: only a single variable and its derivatives are needed to describe the motion of the system. Consider the motion of the center of mass of the plank.