Spring 2018 Physics 7A Lec 001 (Yildiz) Midterm II

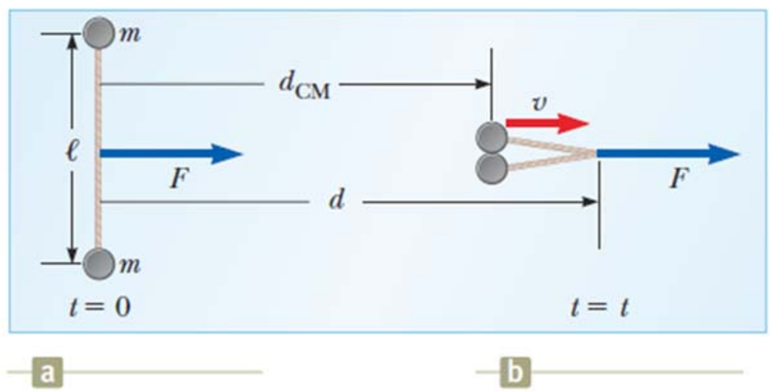
(Use g = 10 m/s^2 if you need to do any numeric calculations)

1. (15 points) The fastest possible rotation of a planet is that for which the gravitational force on material at the equator just barely provides the centripetal force needed for the rotation.

a) Why can a planet not rotate faster?

b) Calculate the period of rotation under this condition in terms of the gravitational constant G and the uniform mass density ρ of the planet.

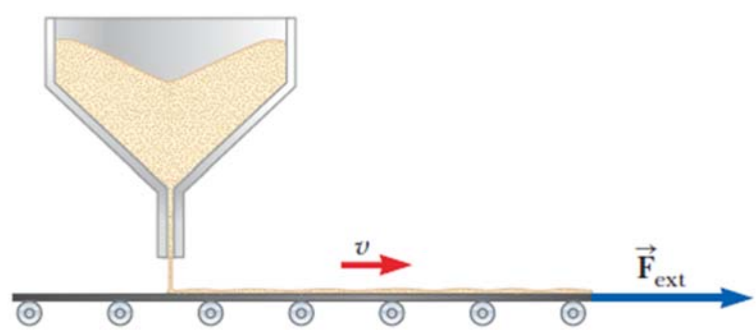
2. (20 points) The left half of the figure shows an overhead view of the initial configuration of two pucks of mass m on frictionless ice. The pucks are tied together with a string of length ℓ and negligible mass. At time t = 0, a constant force of magnitude F begins to pull to the right on the center point of the string. At time t, the moving pucks strike each other and stick together. Just after this collision, the point where the force is applied has moved through a distance d, and the pucks move with speed v. You may assume the string is much longer than the diameter of the pucks. The time t and distance d_{CM} traveled by the center of mass are shown for clarity but should not appear in your answers.



a) What is v in terms of F, d, ℓ, and m?

b) What fraction of the work done by the force has been transformed to kinetic energy? Your answer may contain F, d, ℓ, and/or m.

3. (20 points) Sand from a stationary hopper falls onto a moving conveyor belt at the rate of 5.00 kg/s as shown in figure on the right. The conveyor belt is supported by frictionless rollers and moves at a constant speed of v = 1 m/s under the action of a constant horizontal external force F_{ext} supplied by the motor that drives the belt. Find



a) the sand's rate of change of momentum in the horizontal direction,

b) the force of friction exerted by the belt on the sand,

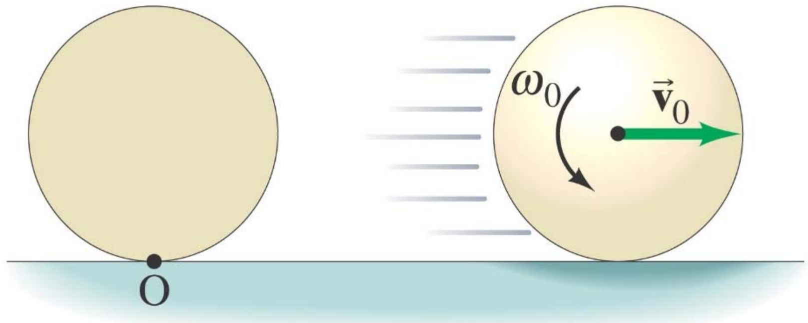
c) the external force F_{ext}

d) the work done by F_{ext} in 1 s

e) the kinetic energy acquired by the falling sand each second due to the change in its horizontal motion.

f) Why are the answers to parts (d) and (e) different?

4. (25 points) On a level billiards table, a cue ball of uniform density and radius R, initially at rest at point O on the table, is struck so that it leaves the cue stick with a center of mass speed v_0 and a "reverse" spin of angular speed ω_0 at time t = 0. The coefficient of kinetic friction between the ball and the table is μ_k.

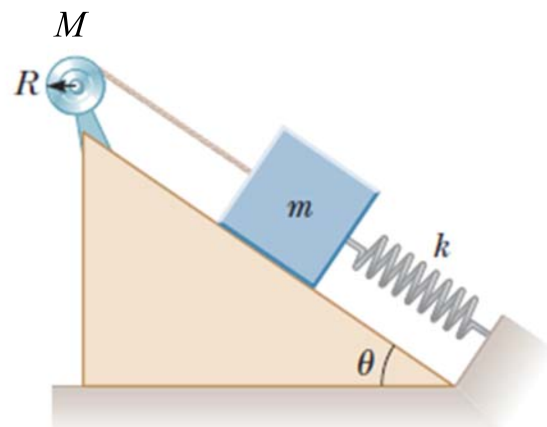


a) Find the critical speed $\omega_0 = \omega_c$ such that kinetic friction will bring the ball to a complete stop.

b) If $\omega_0 = 0.5\ \omega_c$ determine the ball's center of mass velocity when it starts to roll without slipping. How long does the ball slip before it starts rolling without slipping?

c) If $\omega_0 = 2\ \omega_c$ determine the ball's center of mass velocity when it starts to roll without slipping. How long does the ball slip before it starts rolling without slipping?

5. (20 points) The reel shown in the figure is a uniform solid cylinder with a radius R and mass M. One end of the block of mass m is connected to a spring of force constant k, and the other end is fastened to a cord wrapped around the reel. The reel is wound counterclockwise so that the spring stretches a distance d from its unstretched position and the reel is then released from rest.



a) Find the angular speed of the reel when the spring is again unstretched assuming that the surface of the incline and the axle of the reel are frictionless.

b) Find the angular speed of the reel when the spring is unstretched for the first time after the reel is released, assuming that the coefficient of kinetic friction of the incline is μ_k and the frictional torque on the axle of the reel is τ_{fr}. [Hint: Find the work done by this torque using the analogy between linear and rotational motion.]

c) Find the total distance the mass m travels before the mass comes to a complete stop in the presence of friction on the incline and axle. [Hint: Find the equilibrium position d_{eq} of the block when the system comes to a rest. Assume that the frictional force on the block and frictional torque on the reel are negligible at rest and that there is always tension in the cord.]