Problem Set #9 Discussed on the last day of classes!

1. * * (more difficult problem) The classic "infamous ladder problem": why does a ladder not slip when you stand on it at the bottom, but then it slips as you go higher? A 30 kg 5 m ladder leans up against a frictionless wall at an angle of 53° with respect to the ground. You are 50 kg, and the coefficient of static friction with the floor is a dangerous 0.50. At first, you are standing at the base of the ladder on the bottom rung, essentially 0 meters from the bottom.

a) I hope you already drew a great diagram! … and labeled all the forces? And thought about all the torques?

b) How much force can we depend on the friction to provide for us? Is this the actual force friction is providing, or don't we know? The actual amount of frictional force is going to depend on how hard we push on it. This will be equal to the normal force provided by the wall… as long as this normal force is less than the maximum force we calculate. Also remember that the frictional force increases when I get on the ladder.

c) Let's see if we need more than this… what force is pushing against the frictional force? Normal force of the wall – we don't know this force, but it is the amount of force that is necessary to keep the ladder from rotating into the building.

d) This is a statics problem… There are forces in the x direction, in the y direction, and there are torques. Three equations, three unknowns: The normal force, the required frictional force, and the actual frictional force. Set up the equilibrium equations for forces in the x and y direction, and consider what each tells us.

e) Please set up the torques. Which point to you use to be the center of rotation? Why do you choose that point? Can you use this equation to find the normal force of the wall on the ladder.

f) Can you use this information to show that the ladder does not slip? Can you show that you can "test" the ladder by bouncing up and down on it and it won't slip?

g) Now that you are confident about the security of the ladder, you start walking up the ladder. Which of the equations does this change? How does it change them? How does the situation become more dangerous?

h) Will I make it to the top of the ladder? Find out by doing an analysis with me at the top of the ladder, and see if the ladder will slide.

i) Please find my location when the ladder slides. Is it bad for me?

j) If we were to do this problem again, and we changed the inclination angle of the ladder to 60°, would this make the situation safer, or more dangerous? How do you know?

2. A bicycle is a beautiful thing to me! Imagine that I can put a constant force (perpendicular to the radius of rotation) of 200 N onto the pedal that is 20 cm long, and am able to maintain that force for some time as I pedal along. Let's say that I am rotating the pedals at 60 rotations per minute. Imagine that I am riding up at constant speed against wind friction.

A) Find the torque my legs put on the pedals and the omega of the pedals.
B) Find the power I'm putting out.
C) I'm in my highest gear, so the diameter of the pedal gear is 20 cm, and the diameter of the gear driving the rear wheel is 4 cm. Please find the tension in the chain, and the torque the chain produces on the rear wheel.
D) Given the speed of the chain and the tension in the chain, what is the power I deliver to the chain?
E) What is omega of the rear wheel? What is the power the torque of the chain delivers to the rear wheel?
F) If the diameter of the rear wheel is 700 mm, what is the force that the torque on the rear wheel delivers to the road (assume that there is no slipping). This is equal to the force of the air friction if I am not accelerating.
G) What must be the speed of the surface of the rear tire surface (which is equal to the speed of the bike)? And what is the power that this surface delivers to the bicycle?
H) At some time, I change gears, putting the chain on a rear gear cluster on a gear that is 8 cm in diameter (doubling the diameter of the rear gear), and I am able to continue putting the same amount of force on the pedals. What change to I experience? What do I notice in my pedaling? what would be the new:
i) The torque on the rear wheel?
ii)   The power to the rear wheel?
iii)   The speed of the chain?
iv)   Omega of my legs?
v)   What will happen to the motion of my bike?
vi)   What will happen to the feeling in my body? (will I relax or get more tired?)

3. *(more difficult problem) Remember the flywheel from PS#8, question 5? It's rolling down two rails inclined at 30° as shown at right. The flywheel is a 3 kg flat disk of uniform thickness and has a radius of 30 cm. The hub is of radius = 10 cm.
The flywheel starts from rest and rolls without slipping along 4 m of rail.
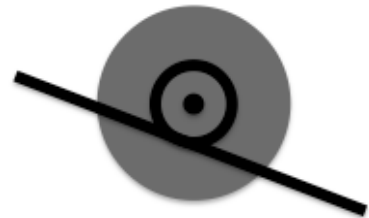
a) You already solved this by using energy considerations. Please see the solutions so you understand how this worked.
b) Now, please solve for the angular acceleration and acceleration by using three equations: rotational dynamics, linear dynamics, and the relationship between acceleration and angular acceleration. See if this gives you the same answer as using energy.
c) Now, please solve for angular acceleration using the parallel axis theorem, by recognizing that at this instant, the wheel is actually rotating about the point of contact. Please verify that this gives you the same answer as a)

4. *(more difficult problem) A disk of uniform mass and radius, R is secured to a wall with a frictionless pivot that allows rotation as shown at right. It is started in the higher position where the center of the circle is at the same height as the pivot and allowed to drop and swing. When the disk is at the bottom of the swing (dotted line), please find:
a) Omega, the angular velocity of the disk about the pivot.
b) The angular momentum of the disk about the pivot.
c) The force that the pivot is providing to the disk. Include direction.