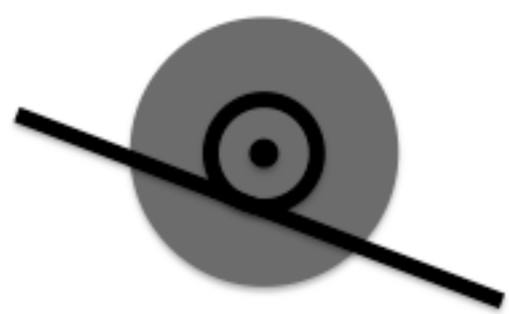
PS#10 Due Thursday Dec. 8 in class. Remember to start each question with a description of the lens and method.

1) 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).
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 do I have to work harder?)

2) Remember the flywheel from the first problem in PS #7?, now it has a hub on either side, 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) What is the loss of potential energy?
b) Find the final velocity and rotational velocity. *hint: you have two unknowns and only one equation! Poop! Ah, but there is a relationship between the speed of the disk and how fast it is spinning. Is this a helpful relationship?*
c) Use the above to find the average velocity, the time taken, and the angular and linear acceleration.

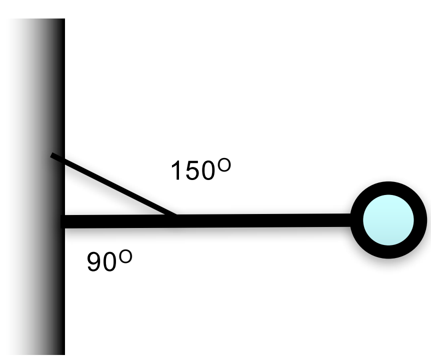
d) Use the above to find the torque on the wheel, and therefore find the frictional force that must have been applied by the rails.
e) Now that you know the frictional force on the wheel, and the force of gravity, can you find the acceleration the wheel should have and see if it matches your value for (c) above?

3) Cars. Folks in the physics department are making a fuss about the fastest, most expensive production car in the world, Bugatti Veyron. Here's the video: http://www.youtube.com/watch?v=LO0PgyPWE3o Then you will need to look up some facts about the car. Look up the maximum power output of the engine (please give answer in HP and Watts). This would be the output power of the engine in motive or kinetic energy.

a) Make an energy flow diagram that shows the conversion of energy all the way from the most fundamental energy source (radiant solar energy) to the most final energy form (dissipated IR radiation from the earth).
b) How fast does the Veyron consume gas (gallons per second, and kg per second) at max speed? How much energy is in a gallon of gas? At the above gasoline consumption rate, at what rate does the car consume the chemical potential energy? Please put answer in Watts. This is the input power.
c) What is the efficiency of the engine turning gasoline into kinetic energy? Where else could the energy have gone?
d) At what rate (in Watts) does the engine dissipate heat? How many 100W light bulbs would this be? Why would this car need 10 radiators?
e) Burning a gallon of gas releases close to 10 kg of CO_2. At what rate does the Veyron produce CO_2, a scientifically recognized climate change gas?
f) The Veyron costs ~$1.5 million. If you could save half your income, how long would it take you to buy one? How about the average USA citizen? The average Guatemalan? The average Zambian?
g) As you for forward to become engineers and policy makers and citizens, there will be many challenges involved with:
    a) how to create something like the Veyron and,
    b) If something like the Veyron should be created.

    Please consider which question is more important, or give your thoughts…. You might also inquire as to whether this last question is relevant to our course or a complete waste of time and distraction from physics.

4) Now that we've introduced Trigonometry, please solve this problem with the 100 kg sphere explicitly using the correct angles and trigonometry. The length of the pole is 10 m and the string is connected 3 m from the pivot point. Please the tension in the string and the reactive force at the pivot.



5) The classic "notorious ladder problem": why does a ladder not slip when you stand on it at the bottom, but then it slips as you go higher? *Please don't attempt this problem until you thoroughly understand the diving board problem from previous problem sets.* 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? Do you have a lens?

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… unless the normal force exceeds the maximum static frictional force.

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) What's your lens? How do you sent this up?… There are forces in the x direction, in the y direction, and there are torques. 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. How do you calculate the torque when the forces are not perpendicular to the radius?

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?