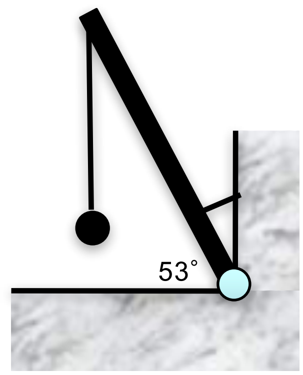
PS#9 Due Thursday, June 7 in class. Start each question with a description of the lens and method.

1. 7.5 Exercise 3, Precession of a bicycle wheel.
   - Predict what happens when the wheel is spinning in the opposite direction? Why?
   What happens if the wheel is spinning faster? Can you explain why?
   - How does the rate of precession change when you push harder on the axle? Why?
   - What changes if you switch sides and support the axle on the other side? Why?
   - What happens if you support the axle closer to the center of the wheel? Why?

2. 7.6 Exercise 3, Throwing a rock upwards off the edge of a cliff.

3. 7.6 Exercise 4, Catching the Bus.

4. 7.6 Exercises 5 – 7 (Pulling sled, Hitting a baseball, Torque on a wheel.
5. In the diagram at right, a post of some length supports a 100 kg ball. The length of the tilted rod is 10 m and the cable is attached 2.5 m from the pivot. From the drawing at right (make your own better drawing), estimate the tension on the cable and the force provided by the foundation at the pivot.



6. 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, 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?)

7. 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? Can you group all the horizontal forces and make a statement about them? Can you do the same with all the vertical forces?

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. What forces are competing with this frictional force to keep the ladder in equilibrium?

c) We may notice that there's a normal force provided by the wall the ladder is leaning against? Why is this force necessary? Does this normal force supply a necessary torque to keep the ladder in equilibrium?

d) 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?

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

f) 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?

g) 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.

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

i) 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?