Problem Set #4 due beginning of class, Monday Oct. 9. Please state the lens you are using and why. Remember that you will be graded on your ***communication*** of physics understanding.

1. Exercise 1 in 3.0
   This is a kinematics question because we are looking at explicit descriptions of motion. We did this in class. Hopefully you can see that the velocity of the tree and other car are to the right (East, +x direction) at 20 m/s and 50 m/s, respectively.

2. Dragsters have a mass of about 1000 kg and the best dragsters get to 44 m/s in about 0.8 s.
   a) What's the acceleration?
      This is straight kinematics because we have explicit descriptions about motion. The acceleration is 55 m/s^2, outrageously large… 5.5 gravities!!
   b) Estimate the coefficient of friction necessary to make this happen if you were in a regular car on flat ground.
      This is a forces (dynamics) problem because we have a force (friction) causing acceleration. The acceleration is outrageous, so the friction coefficient must be as well. First use a dynamics analysis in the y direction with a nice drawing where the acceleration is zero to find that the normal force = the force of gravity. You need a frictional coefficient of 5.5… impossible? Maybe. We'll see below that it really doesn't have to be that large.
   c) What's the average power output during this 0.8 s?
      This is an energy lens because we are looking at how the energy changes as a function of time, and the energy conversion is mechanical work (from the engine) to kinetic energy in the motion of the dragster. This is about 1.2 MW, or about 1600 HP… and outrageous amount of horsepower….. like 10 times as much as an average car. But again, dragsters aren't average. It was brought to my attention that this wasn't an adequate estimation: We calculated that this is the power the car received from the engine. However, the mechanical output of the engine was also turned into heat released from the spinning tires on the ground. We didn't include that. So, the engine must certainly be putting significantly more power than the 1600 HP we calculated. It's worth noting that if you don't spin your tires, there is little kinetic energy converted to heat, so you don't need to include this consideration.
   d) Dragsters have their exhaust pipes pointed *upwards*, which ejects a huge amount of exhaust straight up into the air at very high velocity. What effect does this thrust have on the ability of the car to accelerate? *Why? Please start with clarification of reasons, drawings, lenses.*
      We use a dynamics lens looking at the forces in the y direction. Force is the rate of change of momentum of the heated exhaust upward, there is an equal downward force on the dragster because the force is between the dragster and the air. We can then examine the forces in the y direction on the dragster and realize that now the normal force must be equal to the force of gravity *and* this down force combined.

   According to my calculations, the engines kick out about 18 kg of exhaust every second at about 230 m/s. This corresponds to a momentum change of 4400 kg m/s every second, exerting a force of 4400 N.
   e) What is the momentum of this amount of gas?
   f) How much force should this put on the vehicle? In which direction?
   g) With this extra "downforce", what coefficient of friction is necessary in order to accelerate the dragster? Now, the normal force must be 14100 N, requiring a friction force of only 3.9, which is still very large, but more attainable.

3. How fast was the ball thrown Thursday in Class?
   We realize the need to use two lenses here: the energy lens (because kinetic energy of the ball is converted to kinetic energy of the pendulum (and heat) which is converted to gravitational potential energy of the pendulum at the end. Because we don't know how much of the ball's kinetic energy is converted to heat, we can't rely on energy for the inelastic collision and need to use a momentum lens. Momentum is conserved because during the collision, the ball and pendulum are pretty much a closed system with negligible outside forces. We used geometry to show that the rise in the pendulum

is about 1 cm. Conserving energy, we see that the pendulum must have been moving at about 0.45 m/s. The ratio of the masses was about 1800g/41g, so the pendulum and ball together have about 46 times the mass of the ball alone, so, conserving momentum the ball must have about 46 times the velocity of the pendulum, or about 21 m/s. That's what?... 46 mph so that's a pretty good toss!

4. Exercise 2, in 3.1, What are the final velocities in this elastic collision?

   This is hard to define a lens. For sure, we need to conserve energy and momentum because in all collisions, the outside force is negligible compared to the force between the bodies, so we need to conserve momentum. Kinetic energy is also conserved because it is an elastic collision. We solved it with picture drawing as in the video and the textbook section 3.1. Conserving momentum in an inelastic collision, the resulting velocity would be $v_o/2$ to the right. Moving into this reference frame, the velocities would be $v_o/2$, and $-3v_o/2$ for the m_o and $3m_o$ masses, respectively if we take to the right as a positive direction. Verify that in this reference frame the total momentum is zero. After an elastic collision, the only way to have the total momentum zero and the same kinetic energy is for both masses to have the same speeds in the opposite direction. Lastly, and most importantly, we have to recognize that these observations are made in a reference frame that is moving to the right at $v_o/2$. In order to step off back into the lab frame, we need to add this velocity onto each body and we see that the $3m_o$ mass is at rest and the m_o mass has a speed of $2v_o$ to the right. Find the kinetic energy before and after the collision to show it is conserved. Do the same with total momentum. Remember that energy is a scalar and momentum is a vector.

5. From Big Exam! #3:

There is a 2 kg rubber block resting on the level ground. The coefficients of friction between the block and wooden floor are 0.7 and 0.5 for static and dynamic, respectively.

a) You want to slide the block horizontally, so you push on it with a force of 12 N westward. What is the acceleration of the block (include direction).

   This is a dynamics lens because forces are causing acceleration, although the acceleration in the y direction is zero, so the forces in the y direction must add to zero, finding that the force of gravity must be equal to the normal force. 12 N isn't as large as the static frictional force, so it is never able to break the static friction, and the block doesn't move.

b) Then you push the block westward with a force of 16 N. What is the acceleration of the block (include direction).

   Use same lens description as above. Same y direction discussion. Because 16 N > than the 14 N static friction maximum, the block moves, and we have a dynamic friction of only 10 N. The vector sum of the forces is 6N, causing an acceleration of 3 m/s^2.

c) If you push the block westward for with a force of 16 N for 2 meters, find the amount of work you do and the heat liberated in the process.

   I use an energy lens because my work is converted to kinetic energy and heat. The work I do is the force I apply times the distance I move the body… comes to be 32 J. Thermal energy is the work done by the frictional force, converting kinetic energy to thermal energy. This = the force of friction times the distance that the surface move past each other. We get 20 J

d) If you push the block westward for with a force of 16 N for 2 meters, find the final speed of the block.

   Again, because the work I do is converted to kinetic energy and heat, we see the kinetic energy of the block is the difference between my work and the energy "lost" to thermal energy = 12 J, corresponding to a speed for a 2 kg mass of about 2.5 m/s.