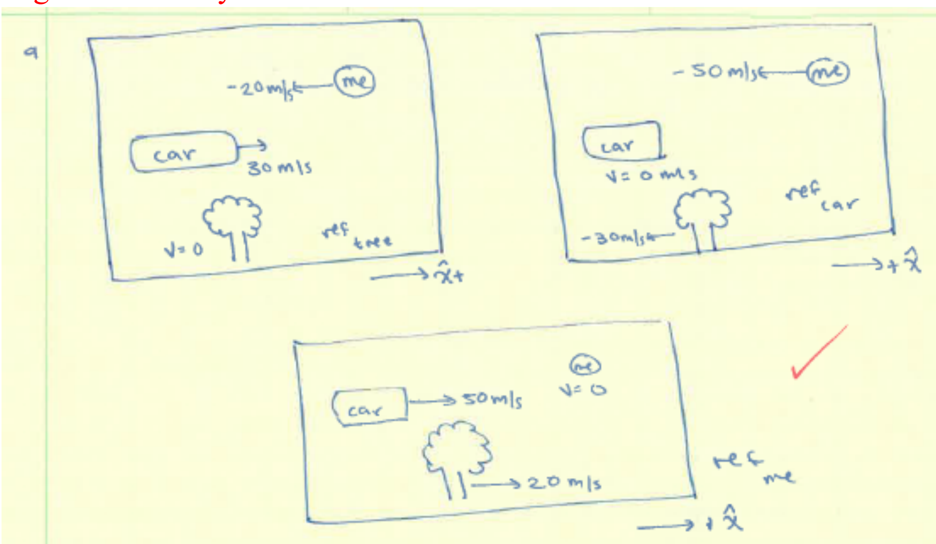
Problem Set #4 due beginning of class, Monday Feb. 4. Please state the lens you are using and why. Remember that you are graded on your ***communication*** of physics understanding.

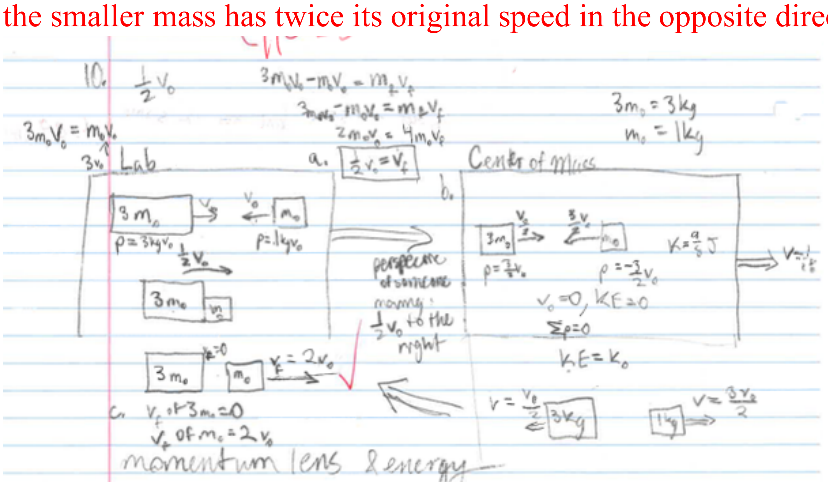
1. Exercise 1 in 3.0, changing reference frames

This is a simple kinematics lens because we are just looking at relative velocity. Each object sees itself at rest, but still sees the same relative velocity. For instance, in order to see itself moving at 0 m/s, the blue cart must add + 20 m/s to the velocity of each cart. Thus the tree has a velocity of + 20 m/s and the red bug has a velocity of + 50 m/s.



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

We did this in class. We find that the velocity of the center of mass is $v_o/2$. We remember that we want to be in this reference frame because this is where one would see the system as having zero momentum. Thus the final momentum must also be zero. We should find that the larger mass is at rest after the collision and the smaller mass has twice its original speed in the opposite direction.



3. 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.

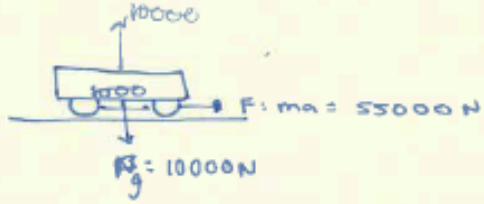
11. $m = 1000$ kg

best dragsters get to 44 m/s in .8s

$F_f = \mu N$

a) $a = \Delta v / \Delta t = 44\text{ m/s} / .8\text{s} = \boxed{55\text{ m/s}^2}$ ✓

Dynamics Lens ✓ because $\Sigma \vec{F} = m\vec{a}$



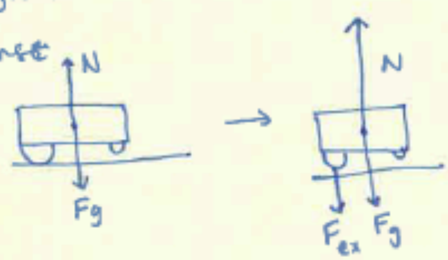
$55000 = (\mu)10000$

b) $\boxed{\mu = 5.5}$ ✓

c) ~~ΔE $\Delta W/\Delta t$ = 55000 / .8~~ $P = \frac{\frac{1}{2}(1000)(44)^2}{.8\text{s}} = \boxed{1210\text{ kW}}$ ✓

d) When the exhaust ~~exerts~~ ~~ejects~~ exerts force downwards on the wheel, the normal force increases significantly, consequently increasing the force of friction which allows for greater acceleration

Dynamics Lens



✓

e) $p = (18)(230) = \boxed{4140\text{ kg m/s}}$ ✓

f) $F = ma = (18)(230\text{ m/s}^2) = \boxed{4140\text{ N}}$ $\boxed{\text{downwards}}$

g) $55000 = (14140)\mu \Rightarrow \mu = \underline{3.89}$ ✓