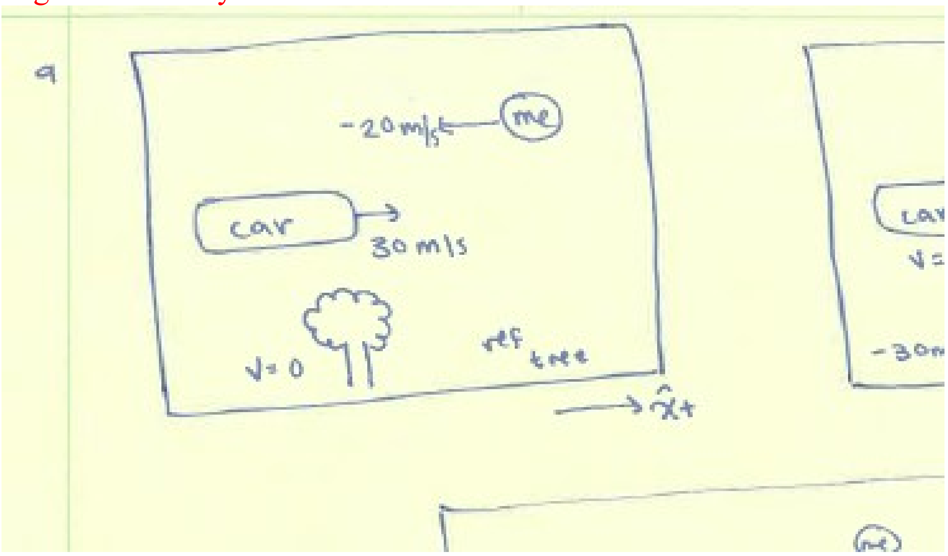
Problem Set #4 due beginning of class, Monday Feb. 4. Please state the lens you are using and why. Remember that you are graded on your ***communication*** of physics understanding.

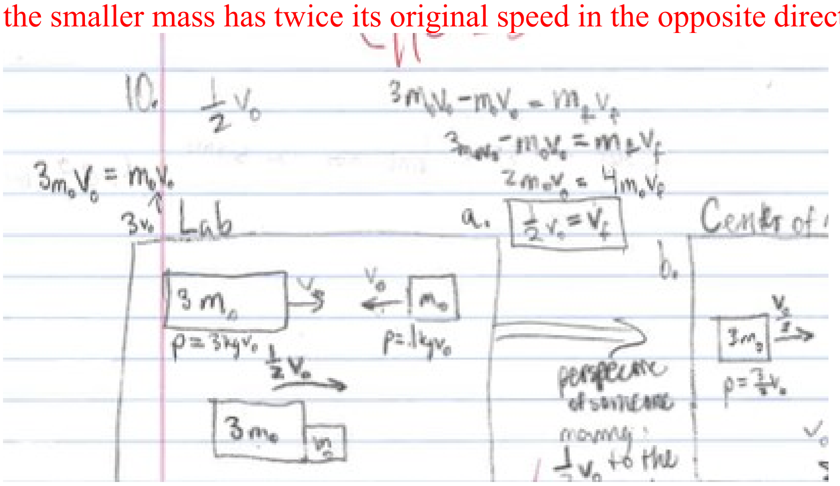
1. Exercise 1 in 3.0, changing reference frames. We did this in class. Please do it in good form.

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 also did this in class… please do this in lovely form.

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 average 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.

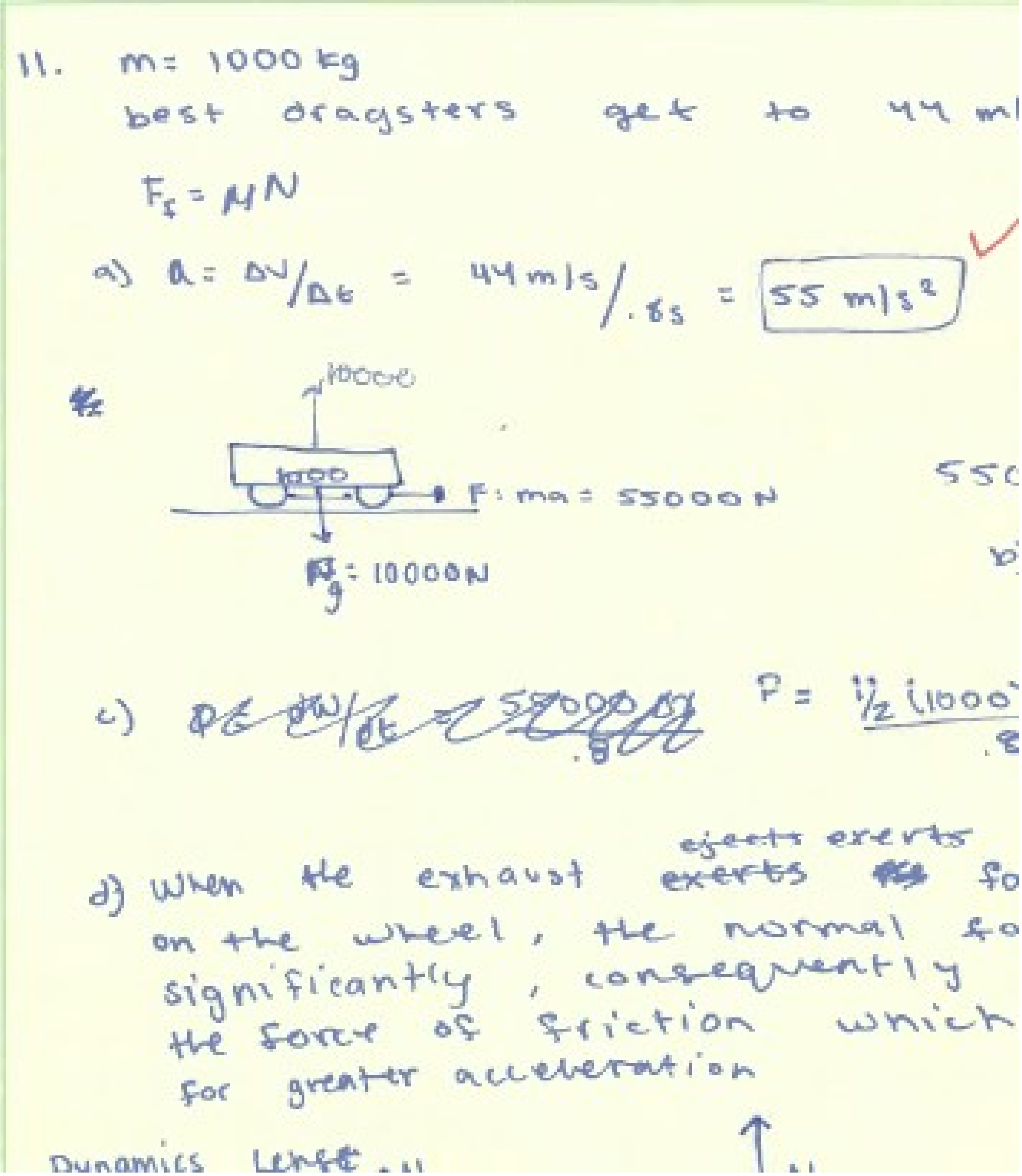
c) What's the average power output during this 0.8 s
This is an energy lens because we are looking at how the energy changes as a function of time, and the energy conversion is mechanical work (from the engine) to kinetic energy in the motion of the dragster. This is about 1.2 MW, or about 1600 HP… and 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) According to my calculations, the engines kick out about 18 kg of exhaust every second at about 230 m/s. What is the momentum that this gas gained from the engine?
This is a straight forward calculation, $p = mv = 18\ kg * 230\ m/s = 4140\ kgm/s$

e) Dragsters have their exhaust pipes pointed *upwards*. What effect does this thrust put on the vehicle? In which direction? What does this do to the normal force between the road and the wheels.
I'm using a force/momentum lens. Forces cause a change in momentum. The exhaust doesn't have that momentum before it enters the engine, it gets that momentum change every second so if Force is rate of change of momentum, then the force exerted on the gas = $\Delta p/\Delta t = 4140\ kgm/s/s = 4140\ N$. A force is a single interaction between two bodies… the repulsive force pushing the gas out of the engine, also pushes the engine downward. Looking through the dynamics lens, we see that there are forces in the vertical direction causing an acceleration (of zero). In order to keep the vehicle in equilibrium in the y direction, the normal force must be equal to the force of gravity AND the down force on the vehicle. So, when the engine starts revving, the normal force increases from 10,000 N to ~ 14,000 N.

f) What effect does this *downforce* have on the ability of the car to accelerate? *Why?* The 40% increase in normal force provides a 40% increase in frictional force.

g) With this extra "downforce", what coefficient of friction is necessary in order to accelerate the dragster? Because the normal force has increased by 40%, the coefficient of friction can be smaller by a factor of 1/1.4, or now, only needs to be 3.9.



11. $m = 1000$ kg

best dragsters get to 44 m/

$F_f = \mu N$

a) $a = \Delta v / \Delta t = 44\,m/s / .8s = 55\,m/s^2$

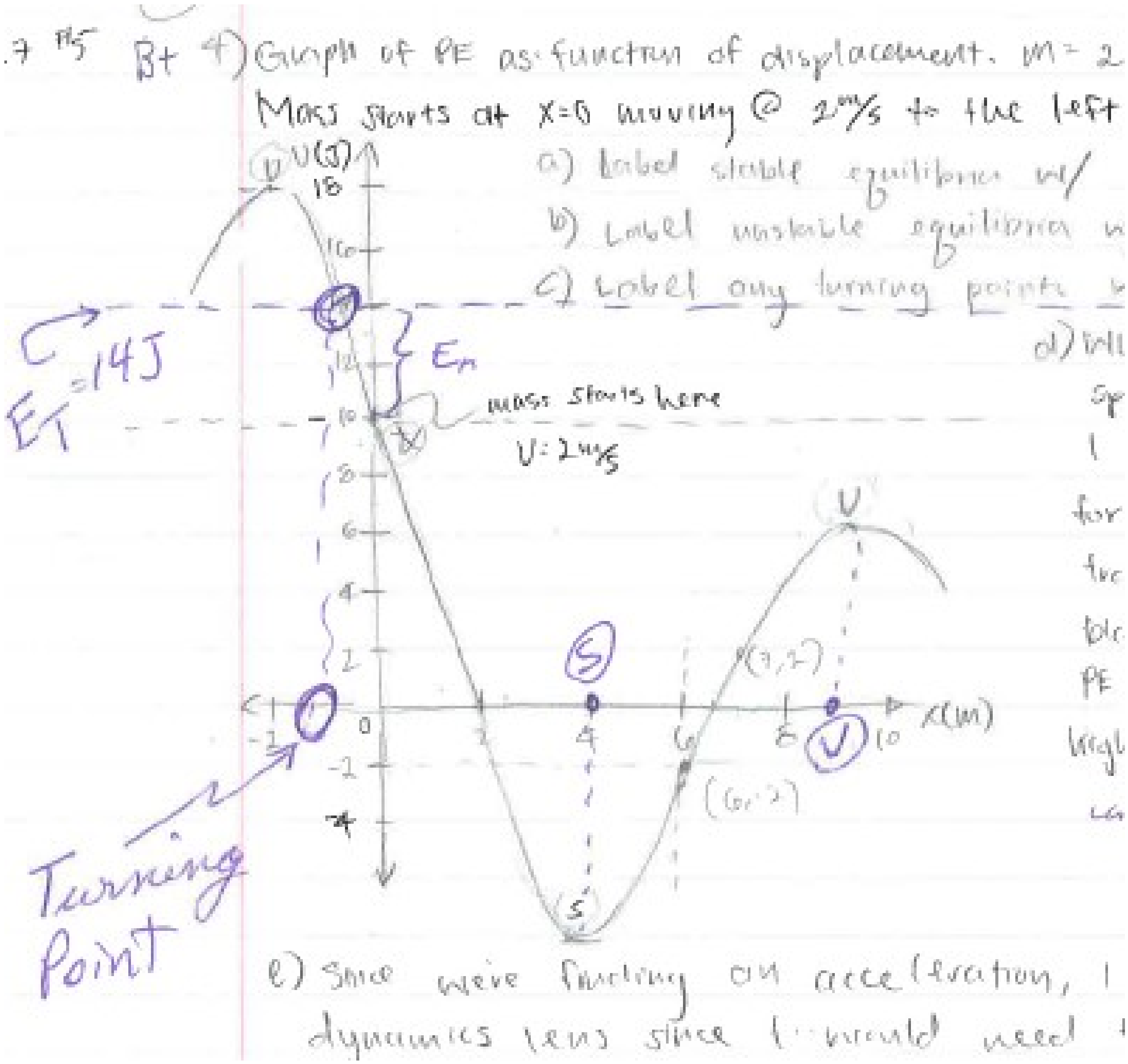
$F = ma = 55000$ N

$F_g = 10000$ N

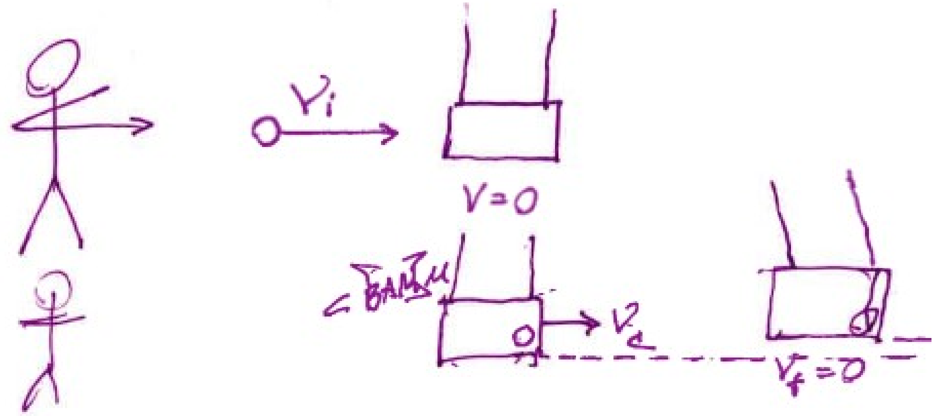
c) $P = \frac{1}{2}(1000$

d) When the exhaust exerts fo… on the wheel, the normal fo… significantly, consequently the force of friction which… for greater acceleration

4. Exercise 5 in 2.7, potential energy graph. Traditionally, students have a hard time with this. Please consider reading through 2.7 while you do this example and/or watching the associated video. …. In particular, students have a hard time with turning point. The turning point is where the body turns around… it stops… there's no kinetic energy. But if it's not clear, please read the section again, OK? The first thing you want to do with potential energy graphs is find the total energy = $E_P + E_K$. Draw this line in (as you see the student below did). This will give you the kinetic energy at all points (the difference between the total energy and the potential energy) and allow you to find the turning points (where $E_k = 0$).



5. Ballistics Pendulum: Please calculate the speed of the ball that was thrown by Drew. The mass of the cooler is 2.0 kg, the mass of the ball is 41 g, the length of the string that the cooler was hanging from is 60 cm, and the cooker swung back ~ 7 cm. First, use some Pythagorean Theorem to find that the cooler gained 4.1 mm of elevation in the process. Hannah used a video (and a kinematics lens) to calculate the speed at about 16 m/s… is this about what you got?




I can't use only an energy len[s]
for energy:

$E_{k_{ball}} \Rightarrow E_{k_{cooler}}$
$\quad + E_{therm[al]}$

much of the energy of
the ball is converted
to $E_{th}$ .... and we don't know how
in this collision we know $F_{..} = 0$

Now, we solve the problem i[n]
find the speed of the cooler!
the energy lens, Theres no
on the system after the coll[ision]

$E_{k_{C+B}} \Rightarrow E_{g_{C+B}}$ , $\frac{1}{2} m_{C+B} v_{CB}^2$

$v_{CB} = (2$

$= (2$

$= 0.$

This is a pretty low speed but

6. Skidding to a stop. Please do exercises 2 and 3 in section 3.2.

*Below, I explain exercise 2, although the answers are provided in the text.*

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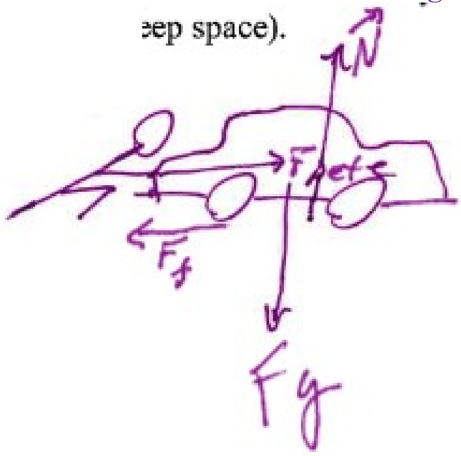



I'm going to use because forces acceleration....

$$\sum \vec{F}_y = ma_y = 0$$

$$\sum F_x = ma_x = ?$$

$$F_g = mg = -10{,}000\,N\hat{y}, \text{ so } \vec{N} = N_y$$

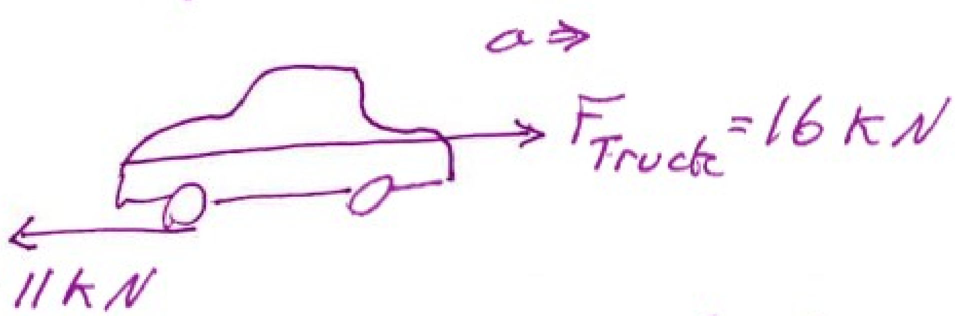
$$F_{s\,max} = \mu_s N = 1.4N = 14\,kN$$

$$F_{d\,max} = \mu_d N = 1.1N = 11\,kN$$

d) Now it gets interesting!

$16\,kN > F_s = 13\,kN$, so the ca

the $F_f$ drops to $F_d = 11\,kN$



Exercise 3, the answer is given in the text, and we discussed it in class. You need to find the frictional force that causes the acceleration of the car to slow down. You can use a dynamics lens, but it is a little complicated to find the amount of time it takes before the collision because we don't know the final speed (and thus the average speed). It is best to use an energy lens because the final kinetic energy of the car is the initial kinetic energy minus the work of friction (dynamic friction * skidding distance) that is turned into thermal energy and lost from the mechanical system.