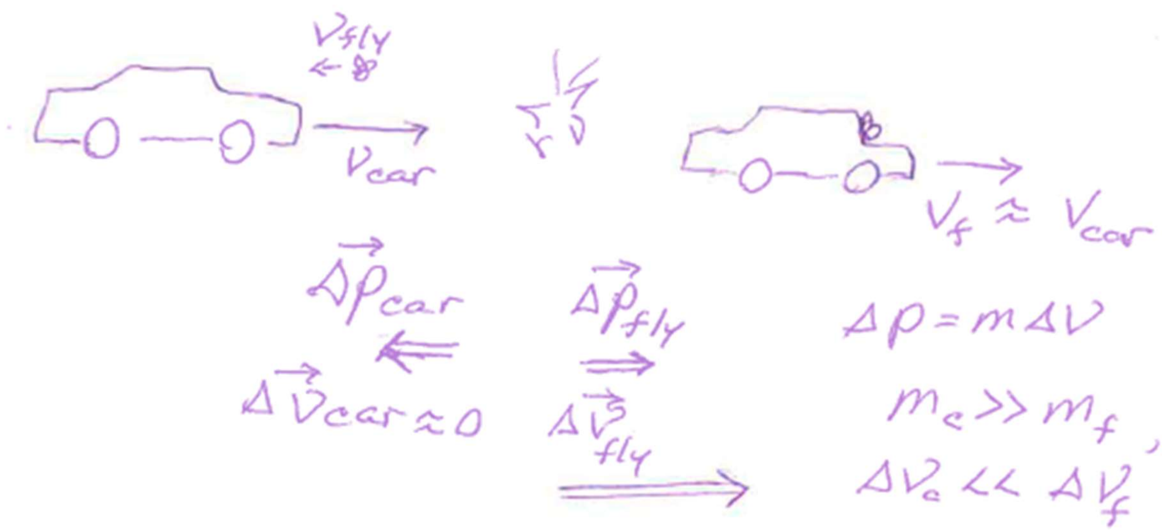
Problem Set #1, PHYS 121, Schwartz, Due the beginning of class, Monday, January 13.
***Please let me know if you find some mistake in the text (or a video), or if there is something that is confusing the way it is written. I appreciate any feedback that will improve the material for everyone*.

Please read text/work book sections 1.0 – 1.6. The link to the book is on the main class website. However, I will give you a hardcopy on the first day of class. While you are reading, please address the exercises. In particular, please do and hand in the following:

1. Exercise 1 in section 1.0, Describing your Problem-Solving Experience.
   Lots of interesting answers here. Many Folks expressed that they liked the expedience of just using a formula. Additionally, most people expressed greater appreciation and satisfaction when they used concepts.

2. Exercise 1 in section 1.1, fly and window collision
   This question and the "pushing off the boat" question (1.3 Ex.1) are essentially identical questions: pushing off something is like an inelastic collision in reverse, all the same laws hold. There is a force between the two objects, affecting each in opposite directions with same magnitude (because it's the same, single force). Because there are no outside forces, there is no change in the system's momentum, ($\Delta p = F*\Delta t$) so these two objects just exchange momentum. Each getting the same amount, but in opposite directions. This doesn't mean that the acceleration or change in velocity of the two bodies is the same because they can have different masses. The extreme example is the fly on the windshield: they both have the same impulse (change in momentum), but because $m_{fly} << m_{car}$ the <u>*effect*</u> *(on each is very different. The car's velocity changes imperceptibly, and the fly's velocity changes a lot. For the pushing off the boat, imagine the difference if you push off the side of an ocean liner versus the side of an inflatable kayak.*



3. Exercise 3 in section 1.2, Solar Panels
Using an energy lens because radiant energy from the sun is turned to thermal energy and electrical energy. In one case, all this energy is converted to thermal energy. In the other case, some is converted to electrical energy (to mechanical energy). If the energy can't go anywhere else, the solar panel connected to the motor produces less thermal energy and should therefore be cooler. In fact, solar companies use this technique in the solar fields to find out which solar panels are not working or not connected: they look at the field through an infrared camera. The broken solar panels appear brighter!

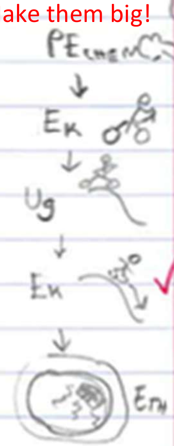
(3.) no motor   hooked to a motor   Energy lens?

$P_s \Rightarrow E_{th}$ $P_s \Rightarrow E_{th}$, E_{el}

the solar panel without the motor will be hotter because the power from the sun will only be converted to thermal energy. the solar panel with the motor converts the power from the sun into thermal energy and electrical energy and therefore will not get as hot. DI

4. Exercise 4 in section 1.2, Energy Bar Bicycling
The chemical potential energy (sugar in the bar) => kinetic (and thermal) energy in my body to the kinetic energy of the bicycle to the increase in gravitational potential energy climbing the hill, back to kinetic energy at the bottom of the hill to thermal energy in my breaks to the radiation of infrared light out into space. The chemical potential energy of the bar originated from solar energy through photosynthesis.

Drawings too tiny! Make them big!

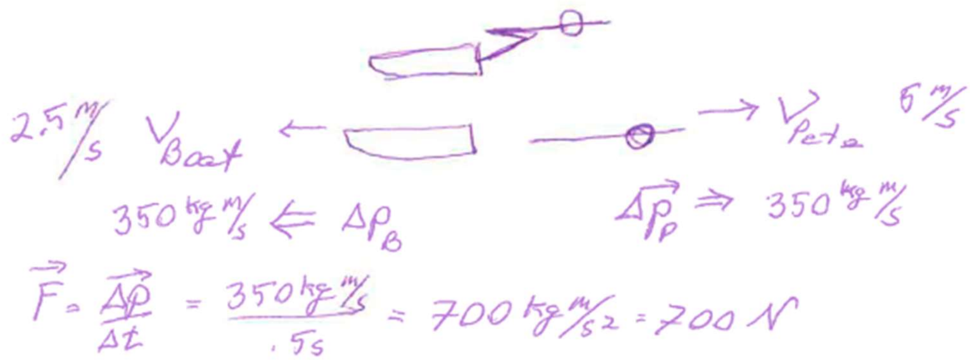


4 | 1.2 Exercise 4   Lens: energy. This involves analyzing energy transformations from PE to KE.

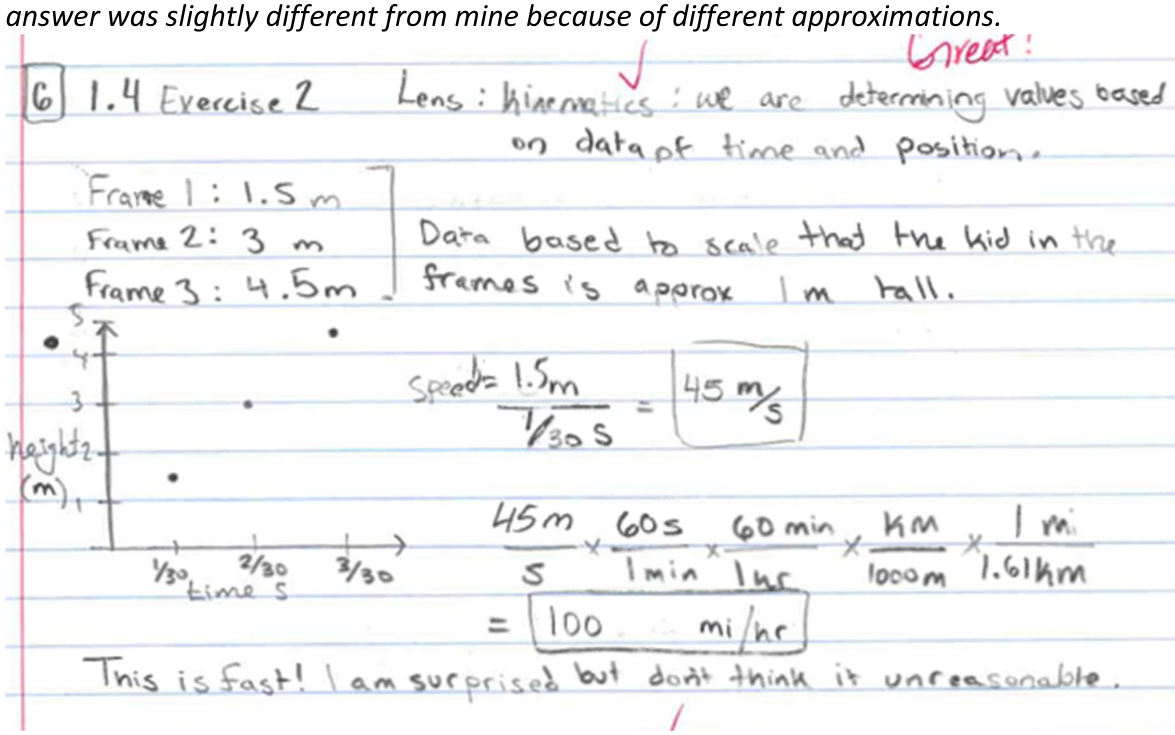
a] The energy bar has chemical potential energy, eaten and digested by me and transformed into ATP stored in my muscles, another form of chemical potential energy. I then transform my PE into kinetic energy by pedaling my bike, moving me up the hill. This kinetic energy is transformed to gravitational potential energy at the top of the hill. The U_g transfers to kinetic energy, pulling me down the hill. I hit my brakes, stopping me due to friction, and the kinetic energy transforms to thermal energy.

b] Energy from the sun comes to the earth in the form of light. Plants, through photosynthesis, absorb the light energy and convert it to chemical potential energy. The plant is harvested and added as an ingredient in the energy bar, still chemical potential energy.

5. Please just read exercise 1 in section 1.3, Pushing off a boat.
   please see the fly and windshield collision problem above… and drawings below. Using ($\Delta p = F*\Delta t$), we can see that the total momentum must be conserved because there is no outside force. So, the change in momenta of the two objects must add to zero (be equal and opposite). This is consistent with the fact that there is a single force between the body and the boat, affecting each in opposite directions.

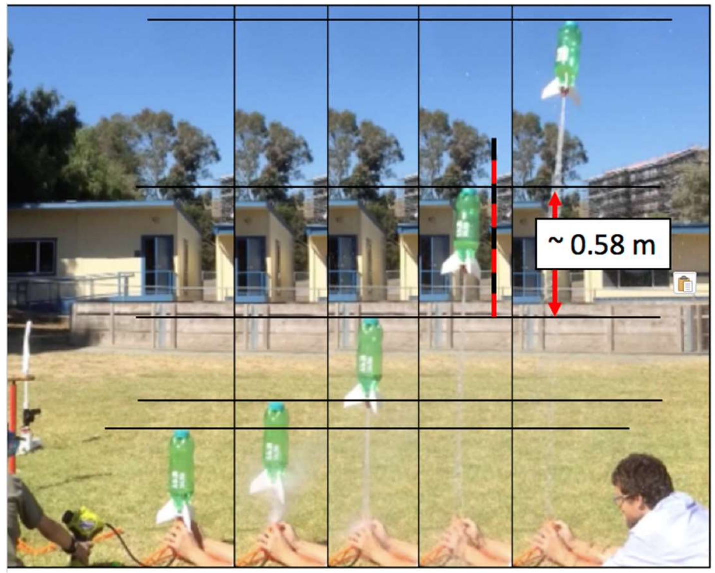


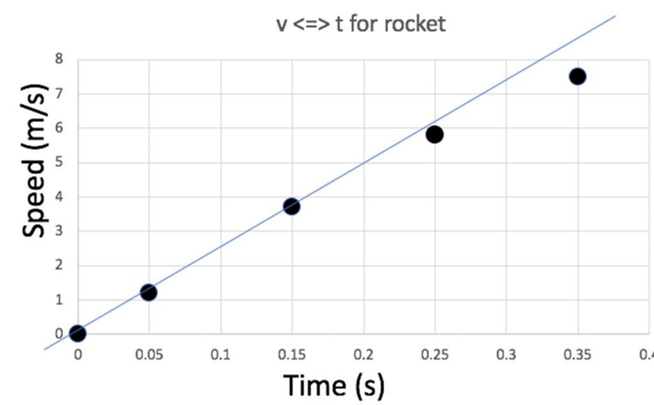
6. Exercise 2 in section 1.4, Rocket speed.
   We use a kinematics (not kinetics. Kinetics means energy) lens because the video frames give us perfect measurement of position as an explicit function of time. Knowing that the frames are taken every 1/30 s. If the white launch tube is 60 cm high (and the boy is about 1.5 m tall), then the distance between the rocket positions in the first and second frame is about 2.25 m. We can use the definition of velocity to find a speed of about 67 m/s or about 155 mph! The student below did a great job, finding the speed ($v = \Delta x/\Delta t$) by recognizing it is the slope of the x ⇔ t graph. Their answer was slightly different from mine because of different approximations.

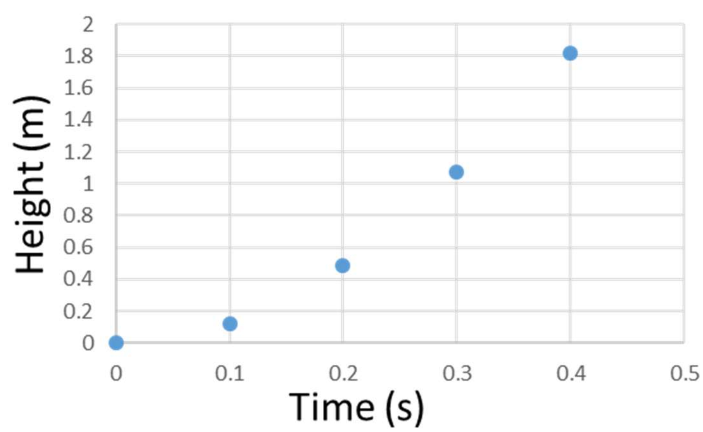


7. Exercise 3 in section 1.4, Car Collision solution is in the text.

8. YIKES! I failed to indicate in the text that I only showed every third frame in the video, so the frames are actually 1/10 s apart. Sorry… I've fixed the text. Anyway, here is the solutions to the correct version of the problem. Exercise 2 in chapter 1.5, rocket acceleration. This will be very important toward preparing you for project #1. Please make sure you understand how to do this. *As in the problem above, we recognize these pictures as explicit position vs time information. We can use a kinematics lens!* *a =* $\frac{\Delta v}{\Delta t}$ *or the slope of a v ⇔ t graph… rate of change of speed. You can graph height vs time for times 0, 0.1, 0.2 s, etc. You can calculate the speeds between each frame v =* $\frac{\Delta x}{\Delta t}$ *(corresponding to times t = 0.05s, 0.15s, 0.25s, and 0.35s, or midway between the two points in time) and also consider that at t = 0s, the rocket is not moving… v = 0. I copied the picture into PPT and made a little "ruler" out of a line that is the same length as the rocket, and cut it into 4 pieces using the "format" option. It's OK if you were not so precise. I loaded the distances into Excel to calculate the average speeds between each frame and made a v ⇔ t graph, which you see below. We immediately see that the velocity increases during the whole time, meaning that the acceleration is always positive. However, the* ***rate*** *of increase declines a little, which we discuss below. We see that the speed goes from v = 0 m/s to about 7.5 m/s in a time span of 0.35 seconds, corresponding to an acceleration of a =* $\frac{\Delta v}{\Delta t} = 21\frac{m}{s^2}$*. About two gravities. Does this seem reasonable? Watch the rocket video again, does it seem as though the rocket accelerates at about twice that of a dropped object? This amount of acceleration would not hurt you. We also see that the initial acceleration is a little*







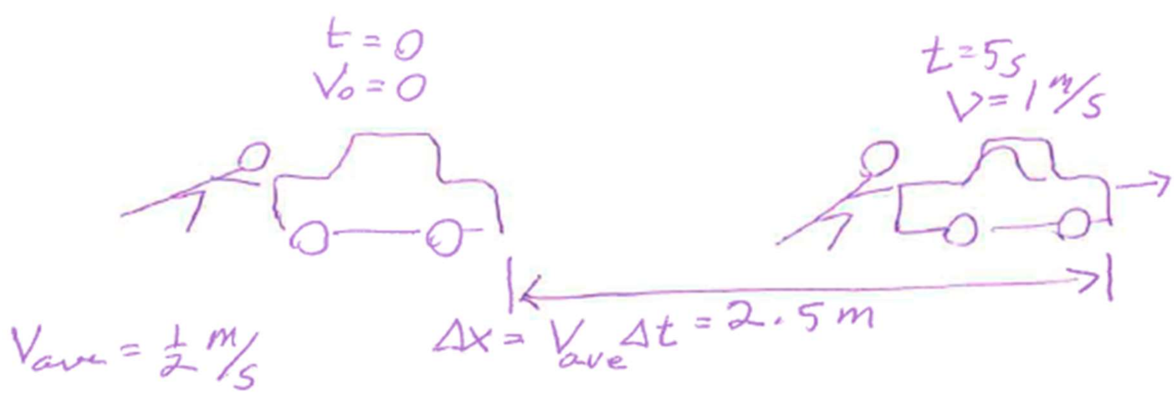
higher, ~ $25\frac{m}{s^2}$ *and decreases to about 17* $\frac{m}{s^2}$ *… Again, you don't have to be so precise, but you might notice how I did this. Please find the Excel worksheet on the main class website.*
So, why might the acceleration change? We use a dynamics lens because the force (of the thrust, pushing out the water) causes the acceleration of the rocket (and the water in the opposite direction). We write F = ma. Or the acceleration, a = F/m. As the water is pushed from the rocket, two things happen:

- The mass of the rocket decreases. This would have an affect to *increase* the acceleration.
- The pressure of the air pushing out the water decreases. This would *decrease the acceleration.*
- … also the force of gravity pull the rocket downward would decrease (with less mass).

These two changes in the dynamics equation largely (coincidentally) cancel out, yielding a rather constant acceleration. However, ultimately the acceleration does decrease (even before we run out of water) indicating that the decrease in pressure has more of an effect than the decrease in mass).

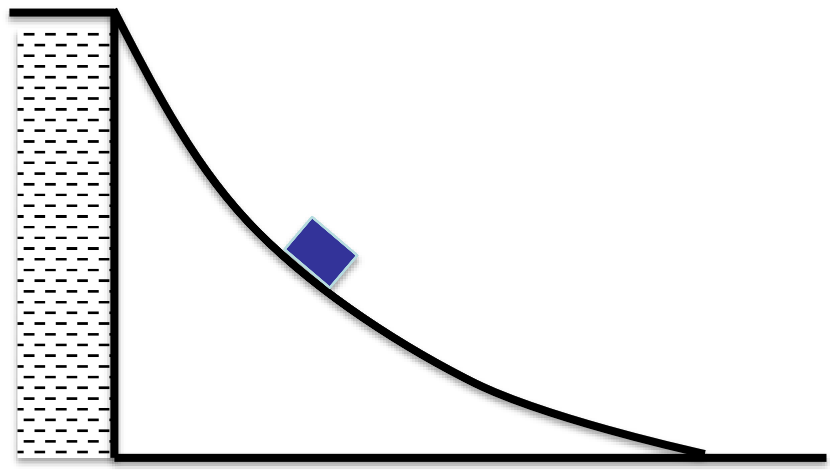
9. Taken from Exercise 4 in chapter 1.5. *Please be mindful <u>to identify</u> a lens for each step*:
   You push a 1000 kg car from rest on smooth level ground. It takes you 5 s to get the car to a speed of 1 m/s.

   a) *What is the car's acceleration? This is a kinematics lens, because we are looking only at the car's motion as it evolves in time. We use the definition of acceleration to find the car's acceleration to be 0.2 m/s*^{2}.
   b) *What is the force you are exerting on the car? This is a dynamics lens because the force is causing the car to accelerate. Using F = ma, we can find a total force of 200 N.*
   c) *How does this force compare with the force of gravity on your body? Again, we can use a dynamics lens because gravity acting on my body would cause it to acceleration at 10 m/s*^{2}*. Thus, the force from gravity on my 70-kg body is about 700 N. So, I'm not pushing as hard on the car as gravity is pulling on me.*
   d) *Please imagine doing this in your mind. Does this sound reasonable? I personally imagine that I'd have to give the car a nudge of greater force to break the frictional force that keeps it from starting. However, if the 1000 kg car were instead a 1000 boat floating tranquilly at a dock, then this would make sense.*



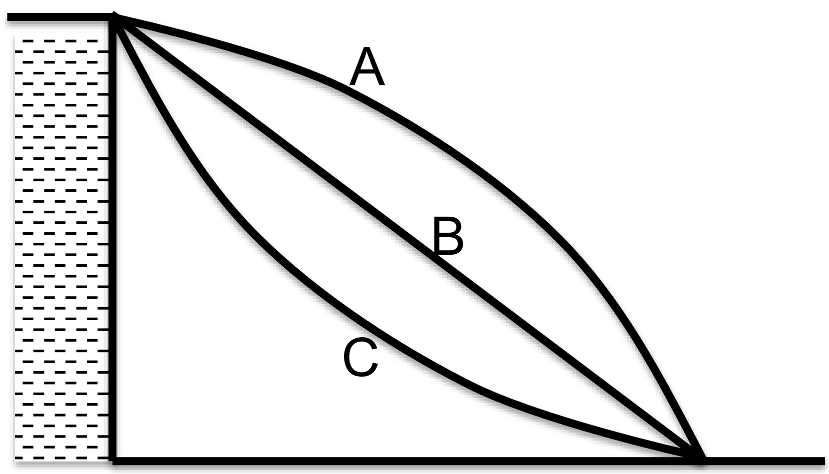
This is the first problem that requires the use of force units, the Newton, N. I haven't defined this unit, but we have defined and spoken about force already. Can you describe a Newton in terms of other more basic units to do this problem?

10. Please read through exercise 8 in 1.6. What does this tell you about conservation of energy versus conservation of <u>*kinetic*</u> energy in a collision?... *in a system we will conserve energy, but kinetic energy can turn to other kinds of energy,… in particular it can turn to thermal energy, which we can't see (through and inelastic collision, or the work of friction).*
11. No #11
12. Imagine a 5 kg box sliding down a frictionless curved track at the edge of a 60 m high cliff as shown at right. We would like to know how fast it's going at the bottom. Neglect air friction.



a) Describe using each of the four lenses, what is happening in this process.
b) Which lens is the most helpful to find the final speed of the block at the end?
c) Please find out the speed at the bottom of the track.

Now imagine that there are two other tracks that the box could use as shown at right, bottom.



d) Which track should we use for the fastest final speed, or would all three tracks yield the same final speed? Which lens do you look at this problem through? Please explain your answer.
e) How about if we wanted to know which was going the fastest *half way* down the total length of its path?
f) If three identical frictionless boxes were released at the top of each track, which would get to the bottom first, or would it be the same for all of them? Please explain your answer in terms of which lens you used.

The most useful lens is the energy lens because potential energy is being converted to kinetic energy as the box descends. Thus A, B, and C tracks all result in the same final speed because the same amount of potential energy is lost. Half way through, the box on C would have lost the most potential energy, so it would have the greatest amount of kinetic energy and thus the greatest speed. In fact, the box on C would have the greatest speed throughout the trip, so it would finish first, then the box on B, then A would finish last. The other interesting lens (in my opinion) is the momentum lens. The momentum of the box changes significantly… so there must be an outside force with who? The EARTH! So we recognize that the earth must have acquired the opposite change of momentum as the cart gained. We see this in the class demo when the track is a cart on wheels rather than connected to the earth… the cart recoils in the opposite direction as the cart.

PS #1 cont'd

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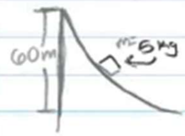


a.) Momentum: The force of gravity changes the velocity and therefore momentum of the box, so the box has momentum moving down the slope.
Energy: The box has gravitational Potential E at the top, which is converted to Kinetic E, moving it down the slope.
Forces: The force of gravity is causing acceleration and moving the box
Kinematics: The object's speed will become faster as a fn of time.

b) Energy is the most useful lens: potential energy transforms to kinetic and energy is conserved. Nice!

c) $V_g = mgh$ $E_k = \frac{1}{2}mv^2$

$$mgh = \frac{1}{2}mv^2$$
$$(\cancel{5kg})(10\,m/s^2)(60\,m) = \frac{1}{2}(\cancel{5kg})(v)^2$$
$$1200\,\frac{m^2}{s^2} = v^2$$
$$v = \sqrt{1200\,\frac{m^2}{s^2}} = \boxed{34.64\,m/s}$$

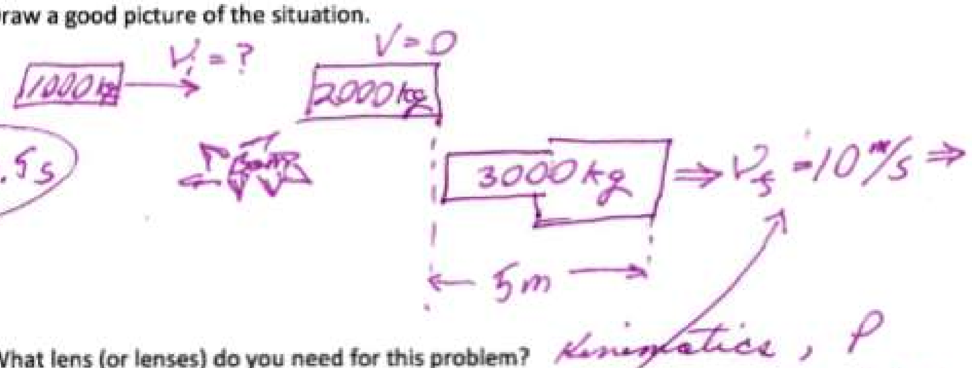
d) Each track would yield same final speed, since masses are the same, height is same, and force of gravity is the same. I looked at this again through the energy lens as energy is conserved and transferred from gravitational potential to kinetic.

13. Please do Assessment #1 in fine fashion. It is on the next page.

Assessment #1 121 Schwartz

You are taking a video of Sarah sitting in her 2000 kg car and BAM! she's hit by Michael driving a 1000 kg car. The two vehicles stick together. You catch on your video that Sarah is surprised (but unhurt) and the wreckage of the two cars moves 5 meters in the 0.5 s that you record. Michael swears he was driving only 15 m/s (~30 mph) before the collision. I'm not sure. Please estimate his speed from what you are sure of.

a) Draw a good picture of the situation.



b) What lens (or lenses) do you need for this problem? kinematics, P

c) What is the motivation for the lens you picked?

1) The video provides position as an explicit function of time, so I can calculate x, v, a .... if needed.
2) $F \Rightarrow \Delta p$. Because $F_{outside} = 0$, $P_i = P_f$ of the system.

d) Set up equation(s) to solve the problem

$$V_f = \frac{\Delta x}{\Delta t} = \frac{5m}{.5s} = 10 \ m/s$$

$\Sigma P_i = \Sigma P_f$ for system

$$P_f = m_f V_f = 3000 kg (10 m/s) = 3 \times 10^4 kg \ m/s$$

e) Estimate the speed of Michael's car.

Because $F_{system} = 0$, $P_i = P_f = 30{,}000 \ kg \ m/s$

But before the collision, $V_{Sarah} = 0$, so $P_i = P_f = P_{Michael}$

$P_{Mich} = m_{Mich} V_{mich}$ $\quad V = \frac{P}{m} = \frac{3 \times 10^4 \cancel{kg} \ m/s}{1000 \cancel{kg}} = 30 m/s$

f) Reflect on your answer (does this value make sense to you?) and make sure you carried your units throughout your work

in the collision the mass of the moving body increased by a factor of 3 so $V_m = 3V_f$. 30 m/s is ~ 66 mph. Michael is a liar and was driving fast irresponsibly.

- What's your name? ~~[illegible]~~ ______