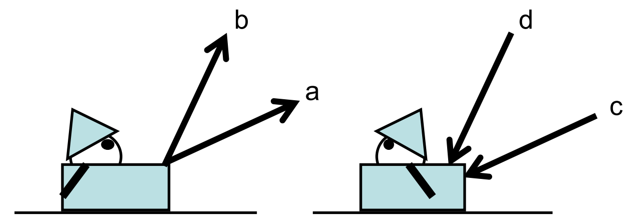
Problem Set #4 due beginning of class, Monday, Feb. 8. Remember to start each questions with a description of what concept is central to your strategy and *why*. Don't forget your 4 lenses

1. MT #1. Hand in a perfect copy of your midterm, with your original MT stapled to it. If you got a question completely correct on MT#1, you don't need to do that problem again. If you got part of the question wrong, or left out a lens analysis, please do a thorough job on the question.

2. My daughter is sledding (total mass = 20 kg), and I am applying a force of 120 N to her sled. I have 4 different options (pushing and pulling at two different angles) and I try all of them.



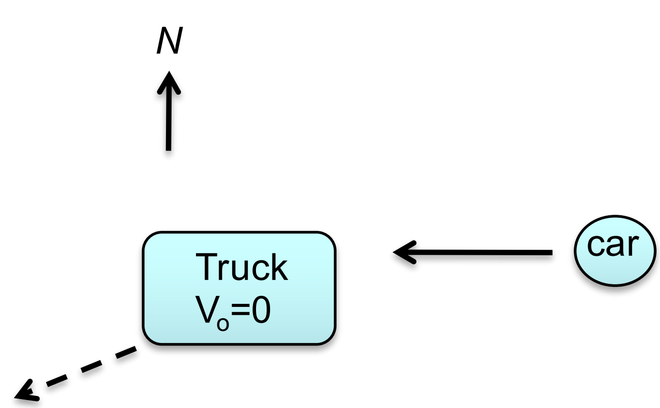
   a) For each scenario, estimate both the acceleration of the sled and the normal force between the sled and the frictionless snow.
   b) Now, please rank the different force scenarios in order of least acceleration to greatest acceleration. If some accelerations are the same, please indicate that.
   c) Now, let's say that the coefficient of friction of the snow is *actually* 0.2. How does this change things? Please rank again the different force scenarios in order of least acceleration to greatest acceleration.
   d) Have you ever pushed a lawn mower (or watched someone do it)… you are using force scenario d, pushing along the handle. When you run into some thick grass the "coefficient of friction" might be high enough to stop you cold. What scenario can you change to, and why does this work?

3. Consider pushing the sled above in scenario "c" on the 0.2 frictional snow for a total of four meters, please find the amount of work I do, the amount of heat produced and the final speed of the sled. Carefully lay out your lens discussion.

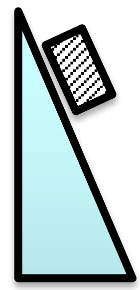
4. Consider throwing a rock from the edge of a 60 m high cliff at a speed of 30 m/s in the direction indicated by force vector "b" above.
   a) Please make a drawing showing the rock at each second until it hits the ground. You may not use a calculator, as we are making simple approximations here. For each second elapsed, estimate where the rock is and its velocity. Draw the velocity vector at that point.
   b) Use an energy lens to judge if your final speed is reasonably close to what you would expect.

5. On a surface of frictionless ice, a 1000 kg car driving 20 m/s eastward collides and sticks to a 5000 kg truck driving 15 m/s northward. The vehicles stick together and slide off:
   a) Please draw and indicate the final velocity of the vehicles.
   b) Please calculate the amount of energy turned to heat in the collision.

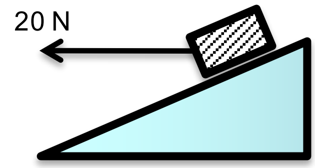
6. On a surface of frictionless ice, a 1000 kg car driving 30 m/s westward collides with a 4000 kg truck at rest. The truck subsequently takes off at 10 m/s in the direction indicated. North is indicated
   a) Without using a calculator, please determine as best you can the subsequent velocity of the car.
   b) Was mechanical energy conserved in this collision? Estimate the change in mechanical energy.



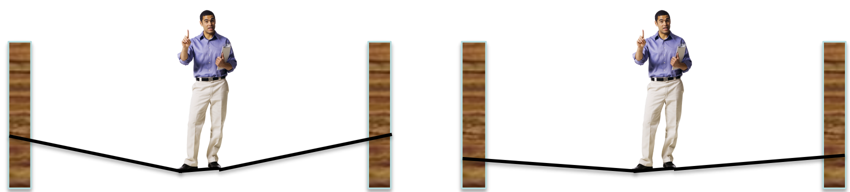
7. At right, you have an inclined plane. Make your drawing as realistic as possible, so you can solve the problem without measuring the angles. If you want to, you may assume the mass of the block is 10 kg, but if you allow it to be m_o you may find that mass doesn't matter.
   a) If the block is frictionless, calculate the anticipated acceleration.
   b) If the block slides down with an acceleration of 1 m/s^2, estimate the coefficient of friction.
   c) Why did or didn't mass matter?



8. At right, you see that I pull a 5 kg mass down a 2 m long incline with a 20 N, horizontal force. With good communication and without a calculator or angle measuring, please calculate:
   a) For a frictionless surface, please calculate the acceleration of the block, and the normal force of the surface on the block.
   b) For a frictionless surface, please calculate the total work I do, and the block's final speed.
   c) If the coefficient of friction is 0.25, please calculate the acceleration of the block.
   d) If the coefficient of friction is 0.25, please calculate the amount of heat produced (in Joules), and please calculate the final speed of the block.



9. Slacklining is pretty fun, but you have to run some webbing between two trees first. At right, you see two pictures of me at 70 kg, slack lining.
   a) In which drawing is the line tighter? Please prove how you know this with a good force drawing and discussion.
   b) Using your force drawing, please estimate the tension on the slack line at right.
   c) In a classic physics problem, a car is stuck in the mud, so you tie a rope to a tree on the other side of the road as tight as you can and then push the rope – do you pull it along the rope, or push it perpendicular? Would it be a good idea to slack line on it? If you were slack lining on it, would it be a good idea to jump on it?



10. You need to build a massive slingshot that propels a 100 kg object (you in a capsule) at 13 km/s so you can go into space (infinity)! For ***<u>each question</u>***, start with a statement of which of the 4 mechanics concepts is central to this problem and why.
a) How fast will you be going when you get to deep space?
b) How fast will you be going when you are one earth radius above the earth's surface.
c) If you passed near the moon, what effect would this have on your speed? I'm just looking for *speed* here. Direction is not what I'm asking about. Support your answer with a concept.
d) As you attain the moon's orbital distance from the earth what would be your acceleration from the pull of the earth's gravity? The moon is not nearby.
e) If your slingshot is a massive spring that compresses 10 m, please find the spring constant that gives you this speed.
f) What would be the maximum acceleration of your body at launch? How would this work for you?
g) We learned from the video that the escape velocity from the earth is about 11 km/s. Please look up the appropriate dimension of the moon and find the escape velocity from the moon's surface.

11. In 1930, it was discovered that a beta decay:

$n \Rightarrow p^+ + e^-$

didn't conserve energy, momentum or *angular momentum*. Wolfgang Pauli postulated the creation of a new particle, the *neutrino.* We now estimate that 65 billion neutrinos from the sun pass through each square centimeter on earth, *per second*. How fast does the sun produce neutrinos? How many pass through you during this class? How about if you were on Venus?

12. There are two planets with centers 10^6 m apart: Planet A, and Planet B. The radius of Planet A is twice that of planet B, or $r_A=2r_B$. Both planets are made of the same rocks, and therefore have the same density. There are no other objects, so we are only looking at the force of gravity acting between the two planets. *Provide reasons for your answers before showing the work, before showing the answer.*

a) What is the ratio of the masses of the planets? m_A=__m_B .
b) What is the ratio of the force of gravity acting on each of the two planets? F_A=__F_B .
c) What is the ratio of the acceleration of each object due to gravity between them? a_A=__a_B .
d) I want to put myself between the two planets so that there is no force acting on me. That is, the force of gravity from each planet should be equal and opposite. What should be the ratio of these distances (from the center of the planets)? x_A=__x_B
e) I want to put myself between the two planets such that my gravitational potential energy due to each planet is the same. What should be the ratio of these distances (from the center of the planets)? x_A=__x_B
f) Find x_A (my distance from the center of planet A) in meters for question d) and for question e)
g) Starting from rest, I let the planets fall together. When they hit, what is the ratio of the two speeds? v_A=__v_B be careful to identify which of the 4 concepts is at play here, what must be the same for them?