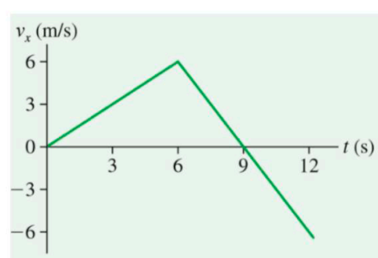
Problem Set #3 due beginning of class, Monday Jan. 28. Please state the lens you are using and why. Remember that you are graded on your ***communication*** of physics understanding.

1. Imagine that you are traveling downward in an elevator at a rate of about 10 m/s, but you are slowing down at a rate of 2 m/s every second. The mass of the elevator is 1000 kg (with you in it). I want to find the tension in the cable holding the elevator.
   a) I bet you already made a drawing and are considering everything involved.
   b) Please consider all the lenses quickly. Choose one and provide the motivation.
   c) If you chose dynamics, why would you do this? I mean, what is your motivation?
   d) What is the complete *mathematical* relationship between forces and acceleration that define dynamics?
   e) If you haven't done it, identify these forces with a free body diagram!
   f) Why is it very (very very) important to identify the direction of acceleration in a FBD?
   g) Between the tension and the force of gravity, which force is larger or are they the same? Why can you be sure?
   h) With a forces diagram, show how you add the forces on the elevator to find the resultant force.
   i) Find the tension of the cable from which the elevator is suspended.

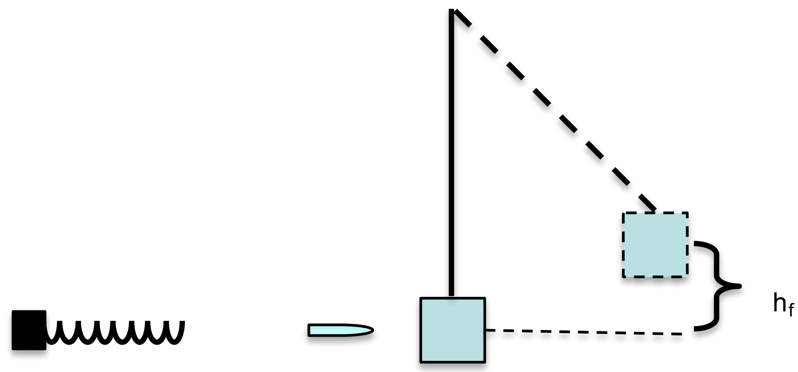
2. *From an old midterm. Even if you've never heard of fusion, you have the basic skills to draw a picture and analyze this problem.* Fusion is the process that powers the sun and hydrogen bombs: small nuclei are fused into larger nuclei. One fusion process involves a triton (two neutrons and a proton – recall that neutrons and protons have about the same mass) and a deuteron (one neutron and a proton) fusing to form a supercharged 5-nucleon nucleus, which gives off its energy by blasting apart into a single neutron and a helium nucleus (or alpha particle) at high speeds. I want to know which of the particles gets more of the energy. Let's simplify the problem to just the explosive breakup: Protons and neutrons have the same mass, so we can think of this process as **a 5-ball cluster (in space, at rest) breaking up through an energetic explosion into one ball and a 4-ball cluster. Do the two pieces equally share the kinetic energy or does one get all or more kinetic energy?** You will be graded not on your answer, but on your reasons, drawings, and lens descriptions.
   a) Make a good drawing of this process… maybe two drawings (before and after).
   b) One of your friends announces, "the energies must be equal because energy is conserved!" Please help this person out. What does conservation mean (and doesn't mean)? You can always refer them to section 1.8 in our text.
   c) Now, do your best to consider the process and what might be conserved and why. Consider what changes and how this will affect the ratio of speeds and energy.

3. Please see the velocity time graph at right for an object that starts at $x = -10$ m. Please:
   a) Write a narrative – what is happening in the graph.
   b) Make an acceleration vs time graph.
   c) Make a position vs time graph.



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.

5. A loaded gun is cocked by compressing a spring of $k = 10^4$ N/m. and then releasing it behind a 20 g bullet. The bullet strikes and sticks inside of a 0.5 kg ballistics pendulum and swings upward to a final height of 50 cm. Presume the spring is massless and there is no friction in the system. We want to find everything: The bullet's speed; how far the spring was originally compressed; The maximum acceleration of the bullet in the gun.



a) Your friend announces, "I'm using an energy lens to find *everything* because energy is always conserved!" Please explain to this friend that while energy is always conserved, it does convert in sneaky ways, and thus may not be universally usable… In particular, what happens here that may render the energy lens ineffective?
b) In fact, you will need to use two different lenses to solve this problem… maybe more depending on how you solve this, but two in particular are effective. Please describe the process from the moment I let go of the spring to the moment the pendulum swings to its highest point. In your description, for each event, identify a lens and state why you are using that lens.
c) Please calculate the speed of the bullet before it hits the pendulum.
d) Please calculate how far the spring was compressed.
e) Does the bullet have constant acceleration in the gun, or does the acceleration change over time? Please explain your answer… identify a lens.
f) Please find the maximum acceleration of the bullet in the gun.

6. Using an energy lens, please show that if you drop a 5 kg box from 60 m, it hits the ground at ~35 m/s. Then we *throw* the box *downward* from 60 meters height with an *initial speed* of 35 m/s.
a) Dropping a box from 60 m, find the speed when it hits the ground.
b) Throwing the box *downward* at 35m/s from a 60 m cliff, find the speed that it has when it hits the ground.
c) What if I throw the box *upwards* at 35 m/s, what is the speed when it hits the ground?
d) What if I throw it straight off the cliff at 35 m/s horizontally, what speed does it have when it hits the ground now?
e) *Can* I throw a 5 kg box at 35 m/s? Please back up your answer.

7. According to the hydrodynamic flow equations you'll learn in PHYS-122, the speed of water coming from a 200 PSI fire house is about 45 m/s (~100 mph!). Wikipedia claims these hoses are 25 mm in diameter. Imagine if you were hit with water by one of these hoses, like if you were protesting the Dakota Access Pipeline, and the fire department was called to clear the area (please see some drama: https://www.youtube.com/watch?v=K3Iv9okL4QU). I'd like to know the force that this water puts on someone's body. Let's model the water as a moving column that hits you and disperses all directions perpendicular to its original direction of travel, as in the figure of the demonstrator at right.

a) In order to solve this problem, I suggest you use a force/momentum lens. Please describe what happens with momentum in this problem, and how this consideration would lead to a calculation of force on her body.
b) Imagine a section of water headed toward her, 25 mm in diameter and 1 meter long. Calculate the volume of this column, the mass of water contained, and the column's momentum before hitting her.
c) What is the total momentum of water *after* it hits her body according to our model above?
d) How long did it take the water to change momentum?
e) Find the force that this water puts on her body. Estimate a reasonable acceleration with this force. Could it knock her over?

8. We clocked Harrison's throwing speed with our ballistics pendulum. The mass of the ball was 41 g, the mass of the cooler that he threw the ball into was 2.0 kg. The cooler swung back gaining about 1 cm of elevation.

a) Set out a plan for calculating the throwing speed.
b) Calculate the throwing speed.
c) Find out how much kinetic energy was changed to heat in the collision when the ball hit the cooler.