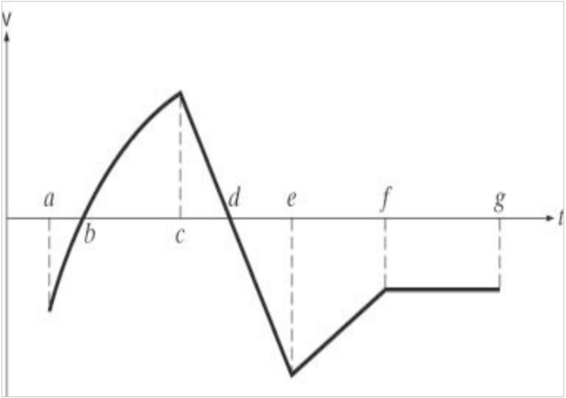
- worksheet: `positron.hep.upenn.edu/p8/files/ws10.pdf`
- 5 required problems, 1 optional/XC **hands-on activity**,
  1 more optional/XC problem,
  + Monday's activity repeat if you didn't get to it Monday
- Before Monday's class meeting, either skim Mazur ch10 or watch my ch10/part1 ("day11") video
- Email me **in advance** & file a CAR if you need to miss class.

$$U^{\text{spring}} = \frac{1}{2} k \, (x - x0)^2 \qquad U^{\text{gravity}} = mgh$$

$$W = \int F_{x,\text{external}} \, \mathrm{d}x \quad = \quad F_{x,\text{external}} \, \Delta x \quad \text{(if constant force)}$$

$$\text{power} \; = \; \frac{\mathrm{d}(\text{energy})}{\mathrm{d}t} \; = \; F_x \, v_x$$

1*. The velocity of an object as a function of time is shown in the figure below. Assume that the changes in the object's velocity are caused by a single (external) force acting on the object. Over what intervals is the work done on the object (a) positive, (b) negative, (c) zero? (Hint: make a table showing sign of acceleration (hence sign of (net) force), sign of displacement, and sign of their product, for each segment.)



2*. One day I get the foolish idea to jump off a bridge with an elastic bungee cord tied to my waist. The bridge deck is 150 m above the water, and the spring constant of the bungee cord is 40 N/m. Since I must fall the length of the unstretched cord before it begins to stretch, I realize that the unstretched length, which is adjustable, has to be adjusted based on my inertia (mass). What must the maximum unstretched length of the cord be if I am to stop falling (ie reach zero velocity for an instant) just above the water surface? Take my inertia (mass) to be 70 kg and treat my body like a particle (i.e. a mass that is concentrated at a single point). Note that the bungee cord is slack, hence stores no elastic potential energy, until I stretch it beyond its relaxed length. To solve this problem, consider both gravitational and elastic potential energy (and possibly kinetic energy?) at various points in my descent.

3*. A motor must lift a 1000 kg elevator cab. The cab's maximum occupant capacity is 400 kg, and its constant "cruising" speed is 21.5 m/s. The design criterion is that the cab must achieve this speed within 2.0 s at constant acceleration beginning from rest.
(a) When the cab is carrying its maximum capacity, what power must the motor deliver to get the cab up to cruising speed? (b) What constant power must the motor supply as the fully loaded cab rises after attaining cruising speed?

4. An object is said to be in *stable equilibrium* if a displacement in either direction requires positive work to be done on the object by an external force. What is **(i.e. draw)** the shape of the potential energy curve (as a function of position) in the region of stable equilibrium? (Hint: think of a spring at its relaxed length.)

5. A 50 kg woman climbs a 10 m rope in 25 s. What is her average power output during the climb?

6. Optional/XC hands-on activity. Do this if you have time and tend to enjoy the hands-on actitivies. Otherwise, feel free to skip it. We have only 4 copies of this set of materials, vs our usual 6 copies, so plan your time accordingly.
Materials: two newton scales, one 1 kg mass, one 0.5 kg mass, two S-hooks (for interconnections), one ringstand (to hold things up, if you like). If you like, you can take a blank sheet of paper from the front of the room for your results.

(a) Use one scale to determine the weight in newtons of the other scale, just so that you are aware of the effect (just over 1 N) the scale's presence may have on your later results.

(6b) Holding the top of one scale in your hand, suspend the 1 kg mass from the bottom of that scale. Draw a FBD for the 1 kg mass and check that your scale reading makes sense.

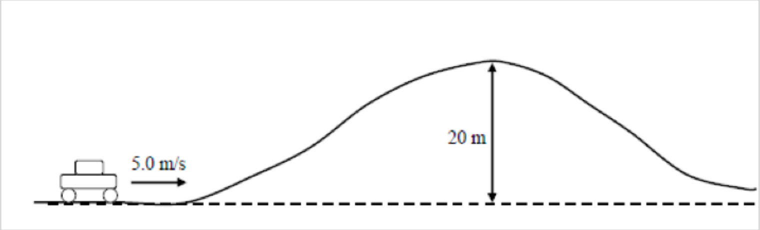
(c) Use your hand to accelerate the scale and 1 kg mass upward. Draw a FBD for the 1 kg mass while it is accelerating upward. Does the change in scale reading during this acceleration make sense? Note that your hand is only able to accelerate upward for a short time, so you want to notice which way the scale deflects when you first start to move your hand upward.

(d) Use your hand to accelerate the scale and 1 kg mass downward. Draw a FBD for the 1 kg mass while it is accelerating downward. Does the change in scale reading (when you first start to move your hand downward) make sense?

(6e) Using the ringstand, both scales, both masses, and an S-hook, connect, from top to bottom, ringstand (or your hand if you prefer), scale, 1 kg mass, S-hook, scale, 0.5 kg mass. Draw a FBD for the lower (0.5 kg) mass and draw a FBD for the upper (1 kg) mass. Check that the scale readings are consistent with your diagrams. (The upper scale's reading will include the weight of the lower scale. You may want to subtract that (just over 1 N) offset for simplicity.)

(f) Repeat part (e) with the 1 kg and 0.5 kg masses swapped. So from top to bottom you have ringstand, scale, 0.5 kg mass, S-hook, 1 kg mass. Draw a FBD for the lower (1 kg) mass and draw a FBD for the upper (0.5 kg) mass. Check that the scale readings are consistent with your diagrams (after correcting for the effect that the weight of the lower scale has on the upper scale's reading).

7*. Optional/XC. (From Chapter 9.) A 1000 kg car starting at the bottom of a 20 m hill at 5.0 m/s almost comes to a complete stop as it crests the hill, barely making it over the top. (See figure below.) The power rating of the engine is 67 kW. (a) Assuming the engine's delivery of power just accounts for the change in the car's potential and kinetic energies as it moves from the bottom of the hill to the top, how long does it take the car to make it up the hill under full power? (b) Does your answer to (a) seem reasonable? (c) If not, what do you think is going on?



Rubric: 4 points per problem: 2 for effort, 2 for correctness.

- 4 points = correct or very nearly correct
- 3 points = minor mistake
- 2 points = major mistake
- 1 point = you haven't convinced us that you put in much effort to try to solve the problem
- 0 points = nothing or very little of substance written down
- For some problems (such as today's hands-on bridge model), it may be unreasonable for us to look for "correctness," so instead all 4 points will be for effort.
- 4 additional overall points for presenting your work clearly, with adequate reasoning. So if n is the number of problems, the total points will usually be $4n + 4$.