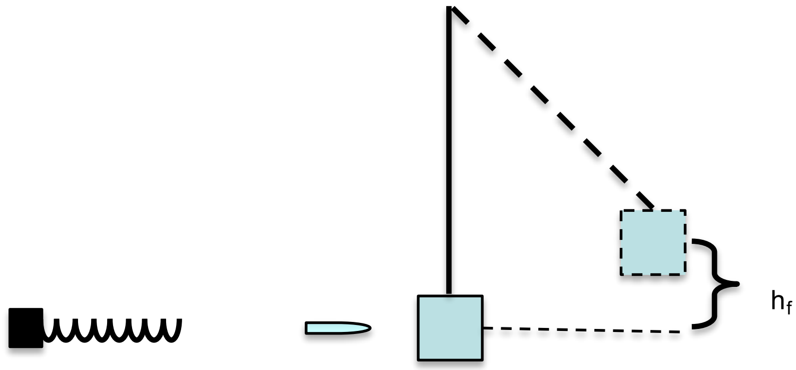
Problem Set #3 due beginning of class, Monday Oct 12. Remember to start each questions with a description of what concept is central to your strategy and *why*. Don't forget your 4 lenses

1. A spring 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 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. Please find:

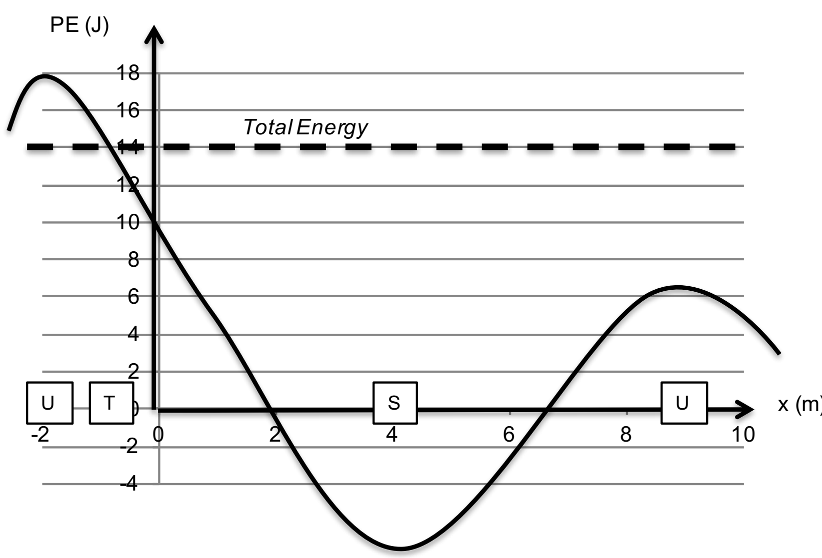


a) how fast the bullet was going. Energy lens because after it is hit with the bullet, the kinetic energy of the pendulum is transformed to gravitational potential energy. However, this is not enough because this isn't = to the initial kinetic energy of the bullet… the bullet has much more kinetic energy, some of which is transformed to heat in the *inelastic* collision. $v_{bullet} \sim 80$ m/s.

b) how far the spring was compressed. Conservation of energy because spring potential is changed to kinetic energy of the bullet. dx = 12 cm.

c) the maximum acceleration of the bullet in the gun. This is a dynamics problem because the force of the compressed spring accelerates the bullet. $a \sim 60{,}000$ m/s^2. OK, this is high, but thus is the life of a bullet. Consider exploding gunpowder.

2. You see below a potential energy diagram for a **2 kg mass**, as a function of displacement. (positive x is to the right). The mass **<u>starts out at $x = 0$ moving at 2 m/s</u>** to the left. *There may be more than one correct answer. In this case, list all correct answers.* These are mostly energy lens. The "accountant" comes out and asks for all the energy – potential and kinetic. HEY, do we get the "total energy line" provided? no this is part of your calculation. You can add KE+PE to get total energy, and this must be conserved! Then you can put in the "total energy" line. The object is going to turnaround when the total energy is zero and then go off to the right… slowing down somewhat between 4 and 9 meters, but then speeding up again. We don't know if it will every come back again… It will only come back if the potential gets above 14 J somewhere to the right.



a) Label stable equilibria with "S" Dynamics = equilibrium means there's no acceleration => no force

b) Label unstable equilibria with "U"

c) Label any turning points with "T"

d) what is its speed at $x = 6$m? This is an energy lens because loss of potential energy yields an increase in kinetic energy. v = 4 m/s

e) What is the approximate acceleration of the mass at $x = 6$m? (What two concepts are necessary for this?) Energy (force is the –gradient of energy), and dynamics. A = -2 m/s^2 to left.
Include direction in your answer, with a unit vector or an arrow.

f) In *reality* this is *not* a friction*less* track, just a low friction track. How does this change the energy considerations? In time the total mechanical energy will decrease because mechanical energy is being turned to heat as the 2 kg mass moves around on the chart.

g) Let's say the track-mass has a coefficient of friction of $\mu = 0.05$. If we started the cart as indicated above under *these* circumstances, estimate the speed at $x = 6$ m. To do this, recognize that the cart is not *moving* in the y direction. The movement is only in x. The y component on the graph is the energy, which could be the result of some electric field, magnets, rubber bands, etc. There is a force of friction on the cart of 1 N, so there is – 1 J of work being done on the cart for every meter it travels, or it loses 6 J by the time it gets to 6 meters, and therefore only has 8 J of total energy, or 10 J of kinetic energy at x = 6 m, and is therefore moving at about 3.1 m/s. What you also see is that in time, the "total energy" line drops because the friction turns the mechanical energy to heat, which leaves the system. So the line should really be called "total mechanical energy". As this line drops, you will see the turning points come closer together, and then meet… as the object comes to rest at the bottom of the potential. You see this as the mass moves a shorter distance each time.

3. A hockey puck is sliding along at 10 m/s when it hits a patch of rough ice, bringing it to rest in 20 m. You want to find the coefficient of friction between the puck and the rough ice.

a) Explain why using an energy lens is a great way to solve this problem, then find the coefficient of friction using this method. Energy lens because KE => heat through the *work* of friction. mu ~ ¼.

b) Explain why using dynamics and kinematics is also a great way to solve this problem, and then find the coefficient of friction using this method. Find average speed, find total time, find acceleration from the definition of acceleration.

4. Two masses approach each other head-on with equal speeds ($v_O = 10$ m/s). The one from the left has three times the mass as the one from the right. If you like, the one from the right can be 1 kg, and the one from the left be 3 kg, or just allow them to be m_o and $3m_o$. *For full credit, draw good pictures of before and after as seen in both reference frames. This is a clever trick that involves some kinematics to change reference frames. However, in the process, we also invoke rules that come from the need to conserve momentum and energy.*

a) Let's say they have a (totally) inelastic collision, sticking together. What's the final speed? 5 m/s

b) This speed is called the speed of the center of mass. Put yourself in this reference frame… pretend you're moving at this speed watching the collision. What do you see happen (Provide numbers and draw the picture? Big mass comes at 5 m/s, small mass at 15 m/s

c) For b) above, what is the momentum of the ball approaching from the left? From the right? What's the total momentum of the system? +/- 15 m_om/s. total p = 0

d) For c) above, now say that they have a perfectly elastic collision. What must be the speed of each ball after the collision in this CM reference frame in order to conserve momentum and energy?

e) What would the person in the laboratory frame (the earth's reference frame) see? What are the final speeds of each ball? Big mass is at rest, small mass v = 20 m/s

f) Find the total momentum of the system before and after the collision 20 m_o m/s, before and after!

g) Find the total energy of the system before and after the collision 200 J, before and after!

h) Was momentum and energy conserved in this elastic collision? Wonderfully, yes we can see above that the initial momentum and energy are equal to the final momentum and energy, respectively.