Problem Set #5 due beginning of class, Monday, Feb. 9
Please Remember: It's not the numerical answer, but the identification of the concept and support for this concept and drawing that you will get credit for on a test.
Level of Challenge:
No marks indicate basic knowledge. You should expect very similar problems in a 121 exam
* (one asterisk) somewhat more challenging. You should expect very similar problems on a 141 exam, and challenging 121 problems (who are preparing to get an "A".
** (Two asterisks) more challenging. More challenging problems for 141 students, who are preparing to get an "A".

#1 You need to build a massive slingshot that propels a 100 kg object (you in a capsule) at 12 km/s so you can go into space (infinity)! For *each question*, 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 got to deep space?
b) * How fast will you be going as you attain the moon's orbital distance from the earth? The moon is not nearby.
c) * If the moon *was* nearby when you passed the moon's orbital distance, 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.

#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 **starts out at $x = 0$ moving at 2 m/s** to the left. *There may be more than one correct answer. In this case, list all correct answers.*
a) Label stable equilibria with "S"
b) Label unstable equilibria at with "U"
c) Label any turning points with "T"
d) what is its speed at $x = 6$m?
e) * What is the approximate acceleration of the mass at $x = 6$m? (What two concepts are necessary for this?)
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. It has a low 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.
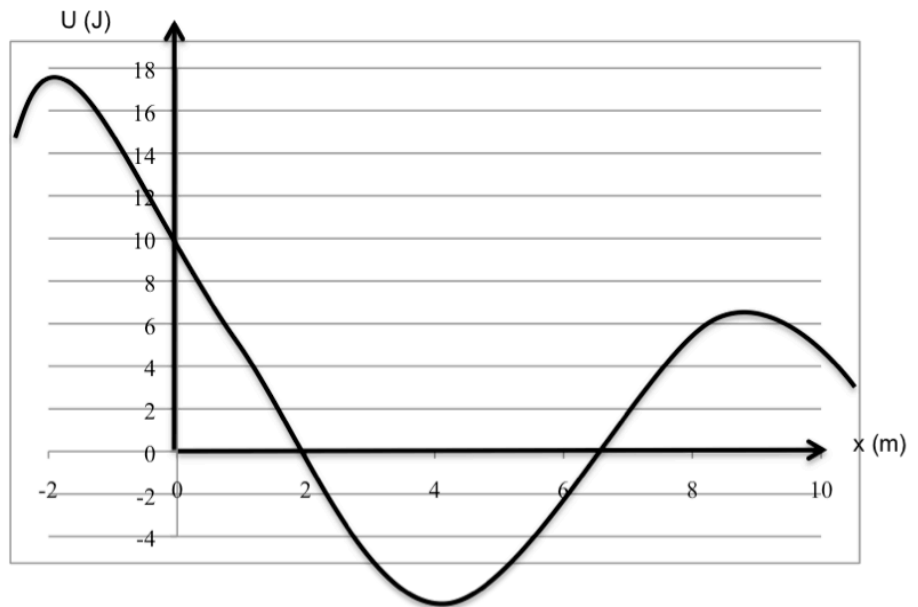
#3. There are two planets with centers 10^6 m apart: Planet A, and Planet B. The radius of Planet A is twice that of planet B, or $r_A=2r_B$. Both planets are made of the same rocks, and therefore have the same density. There are no other objects, so we are only looking at the force of gravity acting 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?

#4 The classic lawn mower problem: Imagine that you need to cut the grass with a 20 kg push lawn mower with a force of 200 N via the 2 m handle that makes a 40° angle with the horizon and the grass is very high, so it presents a significant amount of friction and we can think of it as having a high coefficient of friction. I am considering which would be better: to push the lawn mower or to turn it around and pull the lawn mower along the handle at a 40° angle above the horizon. Please fully explain to me why one way would be better than the other, or why both ways are equally good. Keep in mind that like pulling a string, the force you exert on the handle is oriented parallel to the handle – unlike a string, you can push via a handle.
a) Explain why you know this is a dynamics problem. And explain why you should draw a really good picture of each scenario and they should be big (I won't ask you to do this on a test, but it is important).
b) With explicit use of the protocol, please solve this problem and answer the question – which way minimizes the force I need to push and why?
c) *Imagine you are *pushing* the lawn mower with a force of 200 N along and enter an area of long grass with the coefficient of friction of 1.2. What is the resulting acceleration?
d) *You then decide to turn the mower around and *pull* the lawn mower. What is the resulting acceleration?
e) *Let's say starting from a speed of 3 m/s, I *pull* the lawn mower for a distance of 2 m. Find the work I do on the mower and the work that friction does on the mower. Using the work/energy theorem, find the final speed of the mower.
f) *Let's say starting from a speed of 3 m/s, I *push* the lawn mower for a distance of 2 m. Find the work I do on the mower and the work that friction does on the mower. Using the work/energy theorem, find the final speed of the mower.

#5 I slide boxes down from a height of 2 m down an inclined plane making a 30° angle with the horizon. There is a coefficient of (kinetic) friction of 0.8 between the cardboard boxes and the smooth wood.
a) * Please find the work of friction as the block slides down the incline. If the box starts from rest, please find the kinetic energy it has at the bottom. What's curious about your answer? Does this mean that the box never makes it to the bottom? Mass can be m_o, or if you like, pick 10 kg or whatever. Do you find that mass cancels out of the equation? Should mass matter?
b) * Using conservation of energy, please find the initial speed that I would have to give the boxes in order for them to make it to the bottom of the inclined plane.
c) Using the dynamics protocol – find the acceleration
d) * Check answer b and c against each other. Using b) find the average speed, the time, and the acceleration.

#6 In class today, I lifted the incline until the block moved. This happened when the incline was 22°.
a) Please calculate the static coefficient of friction.
b) Then the block accelerated uniformly (or so we are assuming), covering 0.5 m in 0.8 s. first find the acceleration, and then find the kinetic coefficient of friction. Again, indicate the lens you use.

#7 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.

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.