**Physics 7A- Spring 2006 (Lanzara)**

2nd MIDTERM

GOOD LUCK!

This exam is closed book, but you are allowed one 8.5" x 11" (double-sided) page of handwritten notes. You may use a calculator, however NO wireless calculators are allowed. **Anyone using a wireless calculator will forfeit their exam and automatically receive the score of zero.**

Don't forget: a) Remember to circle all of your final answers.

b) Express all numerical results to 3 significant figures. Cross out any work you decide is incorrect, with an explanation in the margin.

Read through the entire exam to start. Work to maximize your credit -- try to obtain at least partial credit on every part of every problem.

- For partial credits show all relevant drawings and explain clearly your reasoning.
- If you recognize that an answer does not make physical sense and you do not have time to find your error, write that you know that the answer cannot be correct and explain how you know this to be true. (We will award some credit for recognizing there is an error.).
- Do not get bogged down in algebra - if you have enough equations to solve for your unknowns, box the equations, state how you would finish, and move on (you can go back and complete the algebra later if you have time).

And if you have questions about the interpretation of a problem, *please ask!*

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***Problem 1- [30 points]***

A point-like mass m is pushed against a spring with spring constant k and held in place with a catch (see figure). The spring compresses an unknown distance x. When the catch is removed, the mass leaves the spring and slides along a frictionless circular loop of radius r. When the mass reaches the top of the loop, the force of the loop on the mass (the normal force) is equal to twice the weight of the mass. Neglect friction.

a) (5 pts) Using conservation of energy, find the kinetic energy at the top of the loop. Express your answer as a function of k, m, x, g and r.

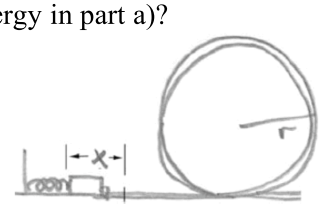
b) (5pts) Calculate the work done by the spring on the mass m. Explain how you get the sign right.

c) (5 pts) Using Newton's second law, find the velocity of the mass when it is at the top of the loop.

d) (5 pts) How far was the spring compressed?

e) (5 pts) If we consider only static friction between the mass and the loop, the force of friction points tangentially, how would you modify the equation of conservation of energy in part a)?

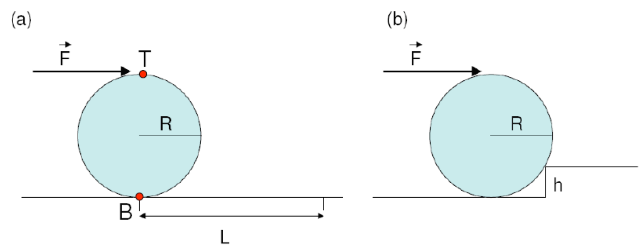
f) (5 pts) If the point-like mass is replaced with a rolling disk of radius R, how would you modify the equation of conservation of energy in part a)?



***Problem 2- [30 points]***

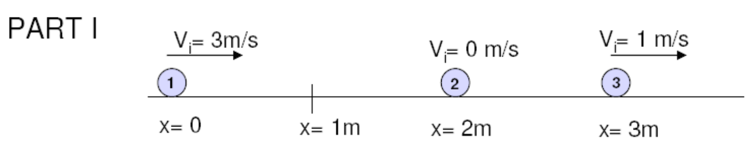
A spool of wire of mass M and radius R is unwound along a horizontal surface under a constant force **F**. Assume the spool is a uniform solid cylinder that does not slip. The coefficient of static friction is $\mu_s$. Assume that the radius of the spool does not decrease significantly while the spool is rolling. Give all your answers in terms of **F**, M, R, $\mu_s$, g and L. The moment of inertia of the spool about its center of mass is $I = MR^2/2$.

a) (5 pts) What is the acceleration of the center of mass (direction and magnitude)?
b) (5 pts) What is the angular acceleration (direction and magnitude) of the center of mass?
c) (5 pts) What is the force of friction **f** (magnitude and direction) acting on the spool? Show the direction of this force on the diagram.
d) (5 pts) What is the total kinetic energy of the spool when it has rolled through a distance L?
e) (10 pts) At one point the spool will hit a step of height h, against which the spool rests (see panel b). What should be the minimum force $\mathbf{F}_{\mathbf{min}}$ we need to apply in order for the spool to climb the step? (You can ignore inertia in this final part, i.e. the spool doesn't jump the curb simply because it's moving fast). (Hint: Make sure to identify correctly the new axis of rotation)




***Problem 3- [30 points]***

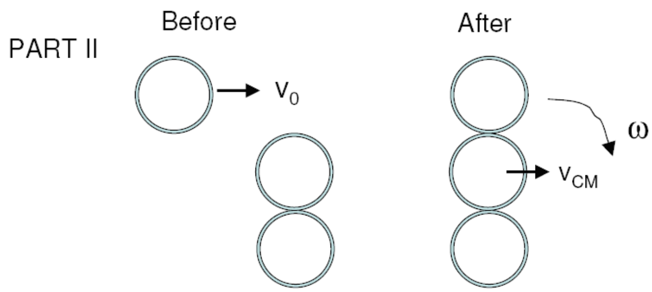
Consider a system of three identical 1 kg point-like masses always confined to the x-axis. At time t=0 the masses have initial positions and velocities as shown (see figure –part I).




a) (5 pts) Where is the center of mass of the system at t=0?
b) (5 pts) Assuming perfectly elastic collisions, determine the total kinetic energy of the system at times t=0sec, t= 1sec and t=3sec.
Assuming fully inelastic collisions (i.e. any masses that collide will stick together) determine:
c) (5 pts) The center of mass immediately after 1 and 2 stick together
d) (5 pts) Find the total kinetic energy of the system (e.g. 1+2+3) at times t=0sec, t=1 sec and t=3sec.

(*Prob 3 is continued on the next page*)

Assume now that the collision occurs between one ring of mass M, radius R and initial velocity $v_0$, with two other identical rings at rest attached one to the other (see figure- part II). The rings can be attached vertically, so when the first ring collides, it instantaneously attaches to the middle ring. Ignore gravity and friction and assume the rings have negligible thickness.




e) (5 pts) What is the center of mass of the 3-ring system after the collision?
f) (5 pts) What is the velocity of the center of mass after the collision?

## *Problem 4- [20 points]*

A cart of initial mass $M_0$, is collecting water shot from a fire hydrant as shown in the figure below. The water is shot from the hydrant with horizontal velocity $v_W$, with mass per unit length $\lambda = dm/dl$. The mass of the cart increases as it collects water from the hydrant. Assume that the water collides with the cart inelastically, so that the water sticks to the side of the cart and drips down. You may ignore gravity and friction in this problem.

a) (10 pts) Find the equation of motion for the cart, expressing the acceleration of the cart, dv/dt, in terms of v(t), $v_W$, M(t) and dm/dt.

b) (10 pts) Derive an expression for dm/dt relevant to the equation of motion in part a).
(Think carefully about the mass per unit time striking the cart). Express your answer in terms of $\lambda$, v(t) and $v_W$.