Physics 7A (Prof. Hallatschek)

Final, Fall 2018, Berkeley, CA

Rules: *This exam is closed book and closed notes. You are allowed three sides of one-half sheet of 8.5" x 11" of paper on which you can whatever note you wish.* ***You are not allowed to use scientific calculators.*** *Cell phones must be turned off during the exam, and placed in your backpacks.* ***In particular, cell-phone-based calculators cannot be used.***

Please make sure that you do the following during the midterm:

- *Write your name, discussion number, ID number on all documents you hand in.*
- *Make sure that the grader knows what s/he should grade by circling your final answer.*
- *Answer all questions that require a numerical answer to three significant figures.*

We will give partial credit on this exam*, so if you are not altogether sure how to do a problem, or if you do not have time to complete a problem, be sure to write down as much information as you can on the problem. This includes any or all of the following: Drawing a clear diagram of the problem, telling us how you would do the problem if you had the time, telling us why you believe (in terms of physics) the answer you got to a problem is incorrect, and telling us how you would mathematically solve an equation or set of equations once the physics is given and the equations have been derived. Don't get too bogged down in the mathematics; we are looking to see how much physics you know, not how well you can solve math problems.*

If at any point in the exam you have any problems, just raise your hand, and we will see if we are able to answer it.

Name: ______________________________ *Disc Sec Number:* ________________________

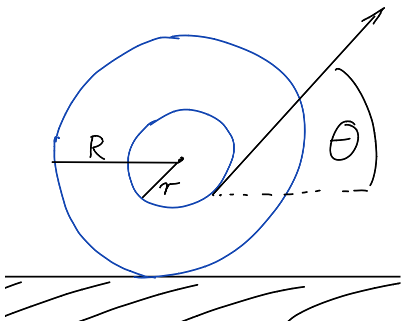
Signature: ____________________________ *Disc Sec GSI:* ___________________________

Student ID Number: ____________________

NOTE: Unless otherwise stated, your answers may contain any symbols defined in the problem statement and any physical constants such as the acceleration due to gravity g.

Problem 1 - Rolling Yo-Yo:

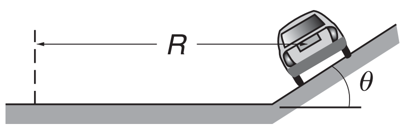
A Yo-Yo, seen here in cross-section, rests on a horizontal table and is free to roll without slipping. If the string is pulled at an angle $\theta < \theta_c$, the Yo-Yo rolls to the right. If the string is pulled at an angle $\theta > \theta_c$, the Yo-Yo rolls to the left. Find the angle $\theta = \theta_c$ for which the Yo-yo is in mechanical equilibrium.



End of Problem 1 workspace.

Problem 2 – Turning car
A car enters a turn whose radius is R. The road is banked at angle θ, and the static coefficient of friction between the wheels and the road is μ.

(a) Find the speed for which no friction force is required to keep the car on the road without skidding sideways.
(b) Find the maximum and minimum speeds for the car to stay on the road without skidding sideways.



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Problem 3 – *Scale spring constant* (20 points)
A mass of m falls a height h onto the platform of a spring scale, and sticks. The platform eventually comes to rest Δy below its initial position. The mass of the platform is M.

(a) Find the spring constant.
(b) It is desired to put in a damping system so that the scale comes to rest in minimum time without overshoot. This means that the scale must be critically damped. Find the necessary damping constant b. (Recall that the damping constant b occurs in the damping force $-b\ dy/dt$ acting on a damped spring oscillating in the y-direction.)

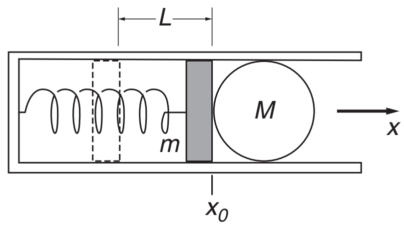
You may continue your work of Problem 3 on next page.

End of Problem 3 workspace.

Problem 4 – Spring gun (20 points)

A spring gun fires a marble of mass *M* by means of a spring and piston in a barrel, as shown.
The piston has mass *m* and is attached to the end of a spring having spring constant *k*. The piston and marble are pulled back a distance *L* from equilibrium and released. Gravity and friction are neglected.

(a) Find the speed of the marble just as it loses contact with the piston, assuming the piston has negligible mass, m=0.
(b) Suppose the marble is glued to the piston. At t=0 the spring is released. Find the motion of piston & marble as a function of time. (Do not ignore the mass of the piston)
(c) Back to the original problem: Find the speed of the marble just as it loses contact with the piston.



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Problem 5 (20 points)
An ant walks on top of a long rope of line density μ under tension T. Suppose one end of the rope is wiggled in Simple Harmonic Motion with displacement A sin $(-\omega t)$, such that a sinusoidal wave travels down the rope.

(a) Give a mathematical representation of the transverse displacement $D(x,t)$ of the rope as a function of time and position for the traveling wave (in terms of A, ω, T, μ).

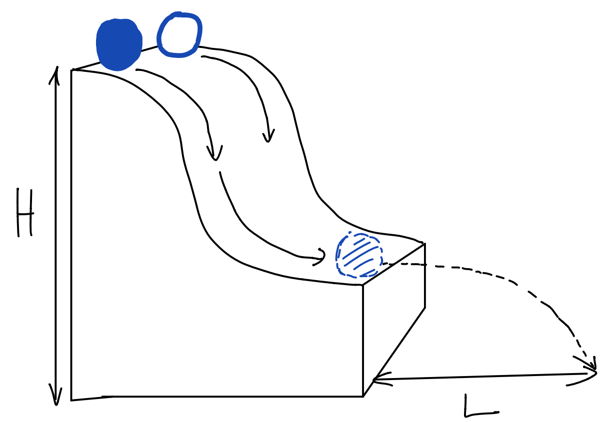
(b) Under what condition will the ant be lifted off the cord as the wave is traveling by? Assume the ant does not stick or actively hold on to the rope.

You may continue your work of Problem 5 on next page.

End of Problem 5 workspace.

Problem 6 – disc vs ring

A solid disc and a thin ring of the same mass *m* and radius *R* are released from rest at height *H* and roll down a ramp without slipping. The ramp has a complicated form, but each object is moving horizontally as it leaves the ramp. When the solid disc hits the ground, you find that it lands a distance *L* from the base of the ramp. Predict the distance that the thin ring lands from the base of the ramp in terms of *L* and any other necessary parameters. (The moment of inertia of a ring and a solid disc are given by $m\,R^2$ and $m\,R^2/2$, respectively.)



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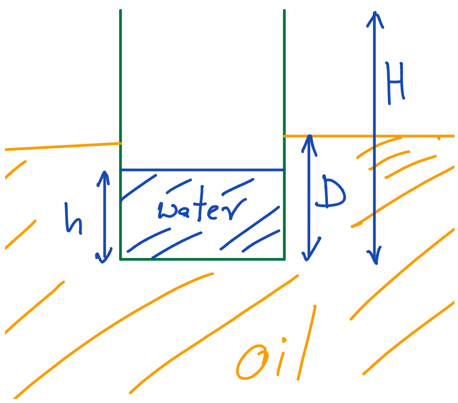
Problem 7 -- *Cup of water in oil*.
A cup filled with water up to height h is gently placed onto the surface of a body of oil (see figure). Although the density ρ_o of oil is smaller than the density ρ_w of water, the cup will float if it does not contain too much water. The cup has mass m and height H, and its bottom has a surface area A

(a) Find the maximum height h_* for which the water-filled cup can float on the oil surface.
(b) Assuming $h < h_*$, how far does the cup sink into water (find D)?

Now suppose a small hole suddenly forms at the bottom of the cup.
(c) Will water flow outside the cup or oil into the cup? Why?
(d) Use Bernoulli's equation to determine the flow speed through the opening (ignoring any effects due to the viscosity of the fluids).



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