Physics 7A, Section 1 (Prof. Speliotopoulos)
Second Midterm, Fall 2008
Berkeley, CA

Rules: *This midterm is closed book and closed notes. You are allowed two sides of one-half sheet of 8.5" x 11" of paper on which you can write whatever notes you wish for the exam. You are also allowed to use scientific calculators in general, but not ones that can communicate with other calculators through any means.* ***Anyone who does use a wireless-capable calculator will automatically receive a zero for this midterm.*** *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 midterm*, 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.*

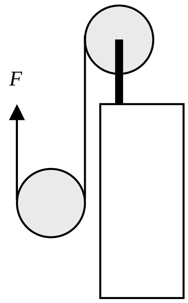
If at any point in the exam you have any problems, just raise your hand, and we will see if we are able to answer it.

Please be sure the write the following information on the front of your bluebook, and remember to sign your name! There are five questions, and the point total for the exam is 100 pts.

Name: ______________________________ *Disc Sec Number:* _______________________

Signature: ___________________________ *Disc Sec GSI:* __________________________

Student ID Number: ____________________



1. A string is wound around a hollow, cylindrical drum with a mass of *2 kg*. It is then threaded through a solid pulley with the same mass and radius as the drum, and is pulled upward with a force *F* (see figure). What must *F* be so that the center of mass of the pulley does not move? You may assume that the string's mass is negligible, that the length of string on the drum is so long that the person pulling up with force *F* never runs out of string, and that the drum can rotate without friction. **(worth 20 points)**

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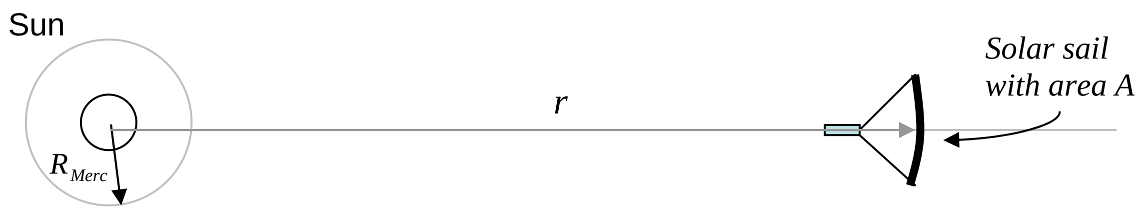
2. Over four hundred years ago, Johannes Kepler speculated on using solar sails to propel spacecraft, and research on solar sails is even now being done by NASA. Spacecraft with solar sails would use these sails to reflect light from the Sun to propel themselves instead of traditional rocket engines. **(worth 20 points)**

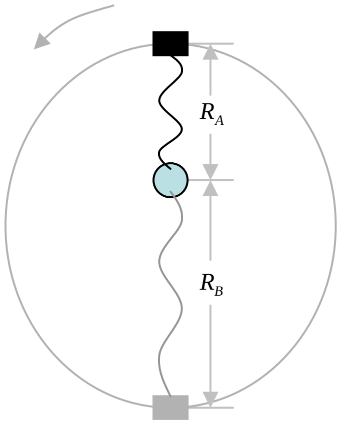


a. Treat the light from the Sun as though it is collection of photons, each with a momentum, *p*. Show that the net force on the spacecraft is the following:

$$m\frac{d\vec{v}}{dt} = \left(2pAn_{Merc}R_{Merc}^2 - GmM_{Sun}\right)\frac{\hat{r}}{r^2},$$

where *m* is the mass of the spacecraft with mass, $\vec{r}$ is the distance of the spacecraft from the Sun, M_{Sun} is a unit vector pointing from the Sun to the spacecraft, M_{Sun} is the mass of the Sun, n_{Merc} is the total number of photons per square meter per second at Mercury's orbit, and R_{Merc} is the radius of Mercury's orbit. The sail is a perfect reflector, and you should know that the momentum transferred to the sail by a photon is the same *no matter what the speed of the spacecraft is*. You should also know that the total number of photons per second that passes through the surface of any sphere centered on the Sun is the same.

b. Suppose that the spacecraft is in orbit about the Sun at $r = R_{Merc}$ with sails closed. The craft suddenly opens its sails so that they face the Sun, and it begins accelerating away from the Sun. What is the maximum speed that the spacecraft can attain?



3. A mass, *m*, is connected by a spring to a pivot point. The spring has spring constant *k*, and an equilibrium length of zero. Suppose that the mass rotates vertically about the pivot point as shown in the figure. What is the difference, $R_B - R_A$, in the amount the spring is stretch at point B versus point A? You may assume that the spring can rotate without friction about the pivot point. **(worth 15 points)**

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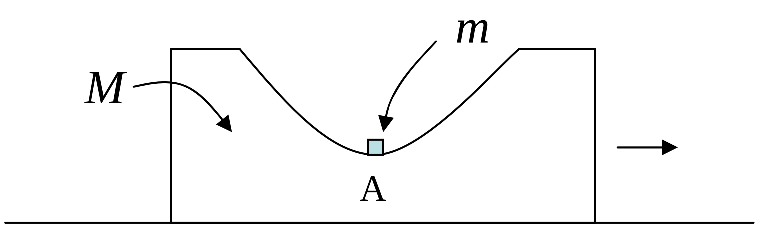
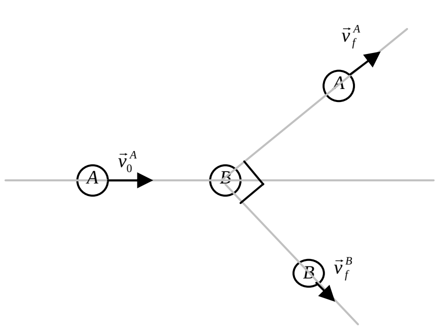
4. A hole is cut out of a large block with mass *M* that slides across the table with a speed V_0. A small block with mass *m* is gently placed within the hole (see figure) at point A on the large block so that its initial velocity relative to the table is zero. You may assume that the friction on all surfaces is negligible, that the size of the small block is negligible, and that the small block will never fly off the large block. **(worth 25 points)**



a. What is the maximum height, *h*, that the small block rises as measured from the bottom of the hole?

b. What is the maximum velocity of the small block in the horizontal direction? Use physical reasons (as opposed to mathematical ones) to explain why you think that this is the maximum velocity. (Do not try to find the maximum by taking the derivative of something, say.)

c. Suppose that *N* is the number of times the small block passes point A on the big block. Periodically, the system will return to its initial state of having the large block move with a speed of V_0 and the small block being instantaneously at rest. For which values of *N* will this happen? Take $N = 1$ when you first place the small block into the hole.



5. Particle A with mass m_A and initial velocity $\vec{v}_0^{\,A}$ collides *elastically* with particle B with mass m_B and which is initially at rest. After the collision, the two particles move off with velocities $\vec{v}_f^{\,A}$ and $\vec{v}_f^{\,B}$, respectively. Show that if the two particles have the same mass, then the angle between $\vec{v}_f^{\,A}$ and $\vec{v}_f^{\,B}$ is 90° (see figure). (HINT: Use the scalar/dot product!) **(worth 20 points)**