Physics 7A- Section 1, Fall 2004 (Lanzara)

FINAL EXAM

Monday December 15, 2004 6:00-8.00 pm CLOSED BOOK

GOOD LUCK!

Print your name, student ID number, GSI name, and your discussion section number on the front of your blue book. This exam contains 6 questions, and will be graded out of a total of 120 points. You should answer all the questions to the best of your ability. You are allowed both sides of three sheets of handwritten notes, and the use of a calculator, but no QWERTY keyboards are allowed. Express all numerical results to 3 significant figures. The following are useful constants: The acceleration due to Earth's gravity in the Bay Area is $g = 9.80\ m/s^2$. The Earths's radius is $r_E = 6.38\times10^3$ km. The mass of the Earth is $M_E = 5.97\times10^{24}$ kg. Newton's constant for universal gravitation is $G = 6.67 \times 10^{-11}$ Nm^2kg^2.

Please show all your work in your blue book. Explain the steps in your reasoning in coherent, English sentences. Define all symbols that you use. If you do not show relevant work for any part of the problem, you will not be awarded any credit, even if the answer is correct. 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.) For full credit, explain your reasoning carefully, show all steps neatly, and box your answers. Cross out any work you decide is incorrect, with an explanation in the margin.

Do the easiest problems first. You may answer the questions in any order you wish, but please clearly label each problem by number to ensure that it is properly graded.

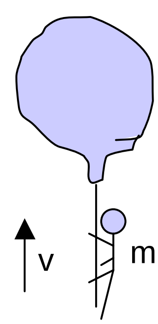
DO NOT OPEN THIS EXAM UNTIL YOU ARE TOLD TO DO SO. STOP ALL WORK WHEN TOLD TO SO AT THE END OF THE EXAM. GOOD LUCK!

Problem 1- [15 points]

A man of mass m=60kg clings to a rope ladder suspended below a hot-air balloon of mass M=400kg. The balloon is stationary with respect to the ground.

a) [10 points] If the man begins to climb the ladder at speed v (with respect to the ladder), in what direction and with what speed (with respect to the ground) will the balloon move?

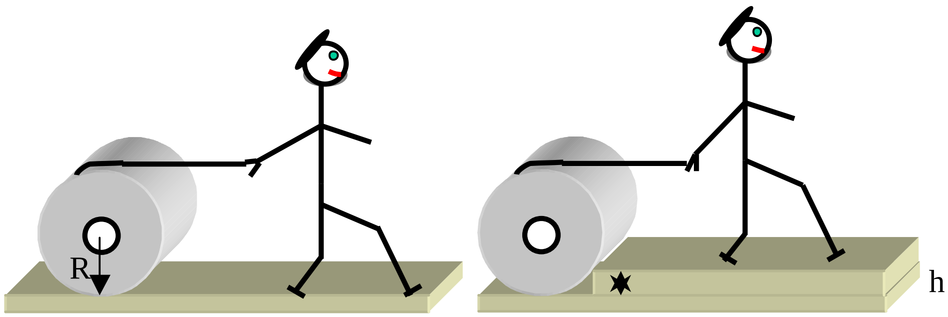
b) [5 points] What is the state of motion of the balloon after the man stops climbing?



Problem 2- [20 points]

A large spool of rope of mass M stands on the ground with the end of the rope lying on the top edge of the spool. The radius of the spool is R. A person grabs the end of the rope and starts to walk a distance L (see panel a).

1) (5 points) What length of the rope unwinds form the spool?
2) (5 points) How far does the spool's center of mass move?
3) (10 points) At one point the spool will hit a step of height h, against which the spool rests (see panel b). What force should the person apply in order for the spool to climb the step?



(a) (b)

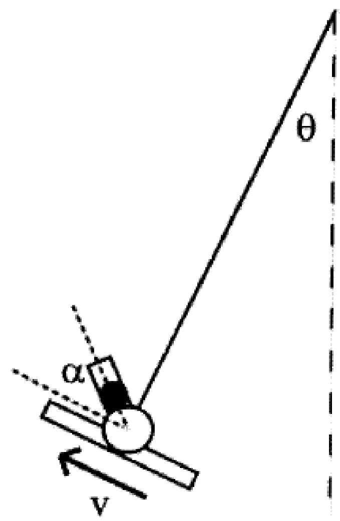
Problem 3- [25 points]

A spaceship is traveling in a circular path about the Earth. This trajectory is due to the force of gravity and a force produced by the spaceship's engines. The engines produce a force with a constant magnitude F_0 and which is always directed at the center of the Earth. Assume the mass of the spaceship is a constant m. The mass of the Earth is M_E. The radius of the circular path is R.

1) (5 points) Find the time that it takes to go around once. Your answer should be expressed in terms of G, M_E, m, R and F_0.
2) (5 points) How much work do the engines do on the spaceship each time it goes around the Earth? Explain.
3) (10 points) A large cloud of dust appears and creates a drag force with a magnitude F_D. Because the spaceship is slowing down, the astronauts' must reduce the force due to the engines (which continues to point at the center of the Earth) as a function of time, in order to maintain the radius of the circular path. Find F(t), the magnitude of the engines' force as a function of time, with $F(0)=F_0$. Assume that F_D is independent of the speed of the spaceship. Your answer for F(t) should go to zero for a certain finite value of t. You do not have to calculated F(t) for times after this.
4) (5 points) Suppose that at one point the spaceship come out of its circular orbit and struck the Earth at the equator with a velocity v. By what factor would this affect the rotational frequency of the Earth?

Problem 4 [20 points]

A pendulum consisting of a loaded spring gun and a gun support is attached to a pivot point by a massless, rigid rod of length L. The gun is loaded with a single bullet of mass m_2. The mass of the support and the gun (without the bullet) is m_1, where $m_2 << m_1$. The gun can be tilted at an angle α with respect to the support, as shown in the figure ($0 < \alpha < 180^o$).



Initially, the pendulum swings freely without friction, reaching a maximum height (with respect to the bottom of its trajectory) of H_0. At some point, the gun is fired and the bullet is shot away from the pendulum. The bullet leaves the gun with a velocity *u* relative to the gun, at an angle α with respect to the pendulum's direction of motion, as shown in the diagram.
You may assume that the small oscillation approximation is valid both before and after the gun is fired. Ignore friction and air resistance.
Find the velocity v_f of the pendulum after the gun is shot as a function of m_1, m_2, *u*, α and the velocity v_0 of the pendulum right before the gunshot.

1) (5 points) What is the maximum height that the pendulum can reach after the gun is triggered if the ball is shot along the attachment rod (α=90) and why?
2) (10 points) In general shooting of the gun will result in a change of the oscillation amplitude of the pendulum. Find the angle α, and the position on the pendulum's trajectory where the gunshot will result in the largest increase of the amplitude.
3) (5 points) What is the maximum height that can be reached by the pendulum after the gun is shot?

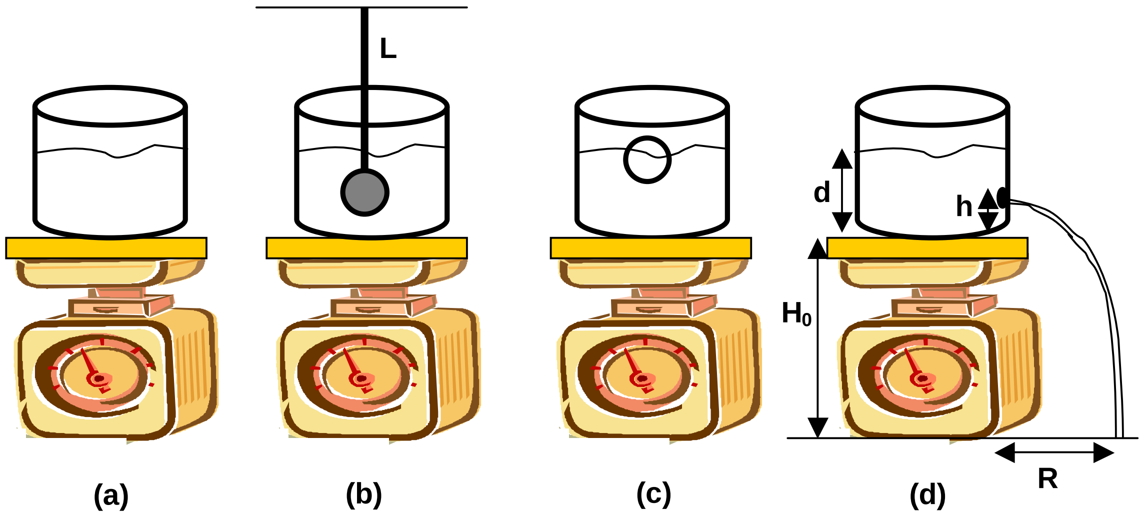
Problem 5 [20 points]

A bucket filled up with a fluid of density ρ_L is sitting on a scale as shown in figure 1. The total reading of the balance is A (panel a).
First a steel block of mass M_s is lowered into the water, suspended by a bar of negligible mass and length L (panel b):
1) (5 points) Does the weight registered by the scale go up, down or stay the same? (5 points).

Next, the block is removed and a cork of mass M_c ($Mc=1/10\ M_s$) is floated in the water (panel c):
2) (5 points) Is the weight registered now higher, lower or the same than in the original case (just the bucket of water)? The water never overflows the bucket. (5)

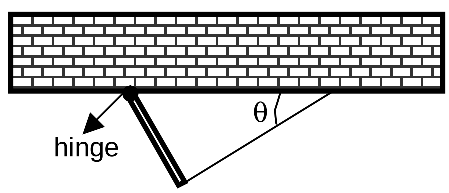
Suppose now to drill a hole into the side of the bucket at a height *h* from the bottom of the bucket (panel d). The level of the fluid inside the tank is *d*.
3) (10 points) Determine *h* such that the water stream exiting the hole lands on the ground as far away from the base of the balance as possible, i.e. calculate the *h* that maximizes

the horizontal range R of the water stream. Neglect viscosity of the water. Assume the water is uniformly distributed in the bucket.



Problem 6 [20 points]

A uniform rod of mass M and length L is supported by a hinge attached to the ceiling on one end and by a rope of very small mass on the other end (i.e. you can neglect the mass of the rope for this part). The rope makes an angle of 90 degrees with the rod and θ with the ceiling. The system doesn't move.



1) (5 points) Draw a free body diagram for the rod.
2) (5 points) Find the horizontal and vertical components of the force exerted by the hinge on the rod. Give both magnitude and direction (left/right; up/down) of each.
3) (10 points) Now assume that the mass of the rod M=2.00 Kg, the length L of the rod (not the rope!) is 1.0 m, the angle θ=30.0 degrees and the mass of the rope is 5 grams. This rope mass is so small that you may use any relevant results from part A to calculate the tension. I put a standing wave on the rope with a frequency of 47.6 Hz. How many nodes does this standing wave have (not counting the ends)?