Homework #6

due 10/25/05

1. Simplicio and Newton are in an elevator. The elevator begins to accelerate upward. Simplicio says that there must be an additional downward force on him, since he feels heavier. Newton says that the additional force on him must be upward, since it is the additional force required to accelerate them upward. Who is right? Explain Simplicio's observation that he feels 'heavier' using Newton's laws.

2. Suppose all the people on earth crowded together in one spot. This question is supposed to show that you know how much gravitational force they exert on the earth—even if you don't know that you know. If you don't like the question, blame the student in class who asked it in class!

(a) The people exert a gravitational force upward on the earth. Approximately how large is this force? Do not use any numbers that you have to look up to answer this. *Hint:* use your approximate knowledge of the number of people on earth (6 billion) and their average weight. Then use Newton's third law. It may also be useful to know that 1 kg weighs about 2.2 lb on the earth's surface.

(b) Suppose that all these people jumped into the air. While they are in the air, the earth is experiencing an acceleration *toward* the people due to the gravitational force the people exert on the earth. Approximately how large is this acceleration? Do you think it would be easily observable? *Hint:* To answer this question, you need to know the mass of the earth. Rather than looking it up, use the following simple estimate. Assume that the density of the earth is the same as that of water. By definition, this is almost exactly 1 gram/cm^3. Use the approximate radius of the earth 6000 km, and the formula for the volume of a sphere to arrive at the mass of the earth. After you have done this, compare your estimate for the mass of the earth to a more accurate answer that you look up (on the web for example). How close are they? Does it make a difference in answering the question we are interested in?

3. A chain of mass m_{chain} is being used to pull a box of mass 2.5 kg across a horizontal frictionless surface. Assume that the chain and the force exerted on the chain are horizontal. The force on the chain is 15 N. You are not given the mass of the chain, so all your answers will depend on m_{chain}.

(a) What is the horizontal acceleration of the box? What happens to the

acceleration as $m_{\text{chain}} \to 0$? What happens to the acceleration as $m_{\text{chain}} \to \infty$?

(b) What is the force that the chain exerts on the box? What happens to this force as $m_{\text{chain}} \to 0$? What happens to the acceleration as $m_{\text{chain}} \to \infty$?

4. A 50 kg man stands on a bathroom scale in an elevator that has a mass of 300 kg when empty. Suppose it is desired to make the scale read n kg.

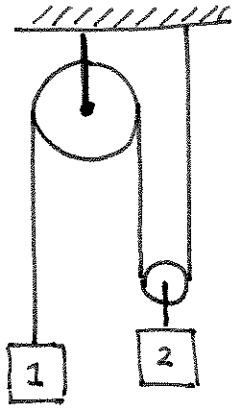
(a) Suppose the elevator is at rest, so that $n = 50$. What is the force that the man exerts on the scale? This force is what is measured by the scale. From this find the proportionality factor between the force on the scale (in Newtons) and n (in kg). Use this proportionality factor in the following.

(b) Suppose we want to make the scale read $n < 50$. What is the required acceleration of the elevator? Your answer will be a function of n. In what direction is the acceleration? What is the force that must be exerted on the elevator to attain this acceleration?

(c) Suppose we want the scale to read $n = 0$ ('weightlessness'). What is the required acceleration of the elevator? What is the force that must be exerted on the elevator to attain this acceleration?

5. A person of mass 50 kg is standing in a boat of mass 100 kg. The boat and the person are initially at rest. The person then runs toward the back of the boat and jumps off. Just after jumping off, the person has a horizontal velocity of 4 m/s. What is the recoil speed of the boat?

6. Consider the pulley arrangement shown below. The large pulley is attached to the ceiling, and the small pulley is attached to m_2. The right end of the string is attached to the ceiling. You may neglect the mass of the pulleys and assume that the tension T in the string is the same throughout the string.



$m_1 = 1$ kg
$m_2 = 1.5$ kg

(a) Consider the system consisting of m_1 alone. Write Newton's second law for this system.

(b) Consider the system consisting of m_2 and the pulley attached to it. Write Newton's second law for this system. Note that this system has *two* string forces acting on it. Be sure you include the effects of both of them.

(c) Argue that the displacements of m_1 and m_2 are related by $\Delta y_1 = -2\Delta y_2$. That is, if m_2 moves down by a certain amount, then m_1 moves up twice that amount. What is the relation between the velocities v_1 and v_2? What is the relation between the accelerations a_1 and a_2?

(d) Use your results above to find the acceleration a_1. What direction is it?