4^{th} Homework
Due: 31 October 2008

1. At lift-off, the Saturn V rocket used for the Apollo missions has a mass of $2.45 \times 10^6\ kg$.

   (a) What is the minimum thrust that the rocket engines must develop to achieve lift-off?

   (b) The actual thrust that the engines develop is $3.3 \times 10^7\ N$. What is the vertical acceleration of the rocket at lift-off?

   (c) At burn out, the rocket has spent its fuel and its remaining mass is $0.75 \times 10^6\ kg$. What is the acceleration just before burn out? Assume that the motion is still vertical and that the strength of of gravity is the same as when the rocket is on the ground.

   (H. C. Ohanian, "Physics," Pr. 6.5)

2. A spherical ball hanging on a string on a smooth, frictionless wall. The mass of the ball is m, its radius is R, and the length of the string is l. Draw a "free-body" diagram with all the forces acting on the ball. Find the normal force between the ball and the wall. Show that $N \to 0$ as $l \to \infty$. (H. C. Ohanian, "Physics"' Pr. 6.13)

3. A woman pushes horizontally on a cardboard box of 60 kg sitting on a frictionless ramp inclined at an angle of 30°.

   (a) Draw the "free-body" diagram for the box

   (b) Calculate the magnitudes of all the forces acting on the box under the assumption that the box is at rest or in uniform motion along the ramp.

   (H. C. Ohanian, "Physics," Pr. 6.15)

4. A string passes over a frictionless, massless pulley attached to the ceiling. A mass m_1 hangs from one end of this string, and a second massless, frictionless pulley hangs from the other end. A second string passes over the second pulley, and a mass m_2 hangs from one end of this string, whereas the other end is attached firmly to the ground. Draw separate "free-body" diagrams for the mass m_1, the second pulley, and the mass

m_2. Find the accelerations of the mass m_1, the second pulley, and the mass m_2. (H. C. Onahian, "Physics", Pr. 6.18, see also the figure in the book)

5. A block of mass m_1 sits on top of a larger block of mass m_2 which sits on a flat surface. The coefficient of kinetic friction between the upper and lower blocks is μ_1, and that between the lower block and the flat surface is μ_2. A horizontal force $\vec{F}$ pushes against the upper block, causing it to slide; the friction force between the blocks then causes the lower block to slide also. Find the acceleration of the upper block and the acceleration of the lower block. (H. C. Onahian, "Physics", Pr. 6.42, see also the figure in the book)

6. Show that if two springs are attached end-to-end, the spring constant of the combined system k will be given by

$$\frac{1}{k} = \frac{1}{k_1} + \frac{1}{k_2} \tag{1}$$

where k_1 and the k_2 are the string constants of the individual springs. (*Hint:* Note that the total elongation of the spring is equal to the sum of individual elongations)

7. A mass is attached to the lower end of a string of length l; the upper end of the string is held fixed. Suppose that the string initially makes and angle θ with the vertical. With what horizontal velocity must we launch the mass so that it continues to travel at a constant speed along a horizontal circular path under the influence of the combined force of the tension and gravity? This device is called a conical pendulum. (H. C. Ohanian, "Physics," Pr. 6.68)

8. A horse pulls a sled along a snow-covered curved ramp. Seen from the side, the surface of the ramp follows an arc of a circle of radius R. The pull of the horse is always parallel to this surface. The mass of the sled is m and the coefficient of sliding friction between the sled and the surface is μ_k. How much work must the horse do on the sled to pull it to a height $(1 - \sqrt{2}/2)R$ corresponding to an angle of 45° along the circle? How does this compare with the amount of work required to pull the sled from the same starting point to the same height along a straight ramp inclined at 22.5°? (H. C. Ohanian, "Physics," Pr. 7.20)

9. The electron in a hydrogen atom has a speed of $2.2 \times 10^6\ m/s$. What is the kinetic energy of this electron? (H. C. Ohanian, "Physics," Pr. 7.23)

10. the Skyplab satellite disintegrated when it reentered the atmosphere. Among the pieces that crashed down on the surface of the Earth, one of the heaviest was a lead-lined film vault of 1770 kg which had an estimated impact speed of 120 m/s on the surface. What was its kinetic energy? How many kilotons of TNT would we have to explode to release the same amount of energy? (One kilogram of TNT releases $4.6 \times 10^6\ J$.) (H.C. Ohanian, "Physics," Pr. 7.25)