Physics 1135: Homework for Recitation #22: Statics

1. A uniform beam of mass $m = 5.0 \text{ kg}$ and length $L = 2.0 \text{ m}$ can rotate about an axle through its center. Four forces are acting on it as shown in the figure. Their magnitudes are $F_1 = 4.0 \text{ N}$, $F_2 = 6.0 \text{ N}$, $F_3 = 3.5 \text{ N}$ and $F_4 = 7.0 \text{ N}$. $F_2$ acts a distance $d = 0.5 \text{ m}$ from the center of mass.

Calculate the torques exerted by each of the forces on the beam. Calculate the net torque. In which direction will the beam rotate?

2. You are trying to tip over a uniform rectangular box of mass 100 kg, height 1.0 m and length 2.0 m by pulling on a rope that is attached to the box as shown in the figure. The rope makes an angle of $40^\circ$ with the vertical. The floor is rough and the box does not slip on the floor.

   a) Find the magnitude of the pulling force needed to just get the box to tip.
   
   b) In that situation, what is the minimum coefficient of static friction that will prevent the box from sliding?

3. A physics professor of mass 58 kg and height 1.68 m is rappelling down a vertical cliff when she pauses for a moment. Her feet are touching the cliff, and she is leaning back so that her body makes an angle $\theta = 40^\circ$ with the vertical. She is tied into a harness that is connected to a rope that makes an angle of $\beta = 20^\circ$ with the cliff face. The tension in the rope has a line of action that goes through her center of mass which is 1.0 m from her feet. Her hands are not exerting a force on the rope (it is fed through a figure eight shaped braking device that exerts the necessary tension).

   a) Find the minimum coefficient of static friction between her feet and the cliff so that her feet do not slip on the cliff wall. (Hint: begin with the sum of torques about the center of mass).

   b) Find the tension in the rope if her feet are about to slip and the coefficient of static friction has the value you obtained in part a).
4. A stationary ladder of length $L$ and mass $M$ leans against a smooth vertical wall, while its bottom legs rest on a rough horizontal floor. The coefficient of static friction between floor and ladder is $\mu$. The ladder makes an angle $\theta$ with respect to the floor. A painter of mass $\frac{1}{2}M$ stands on the ladder a distance $d$ from its base.

Find an expression for the largest value of $d$ for which the ladder does not slip.