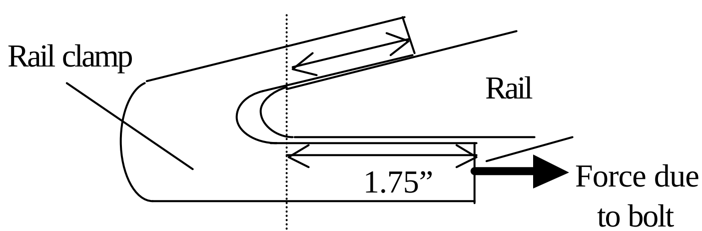
24-261 Statics September 18, 2001
Problem Set #4 Due: September 25, 2001

1. Rail clamps serve to attach electronic equipment to the rail. Each pair of opposing rail clamps is joined together with a bolt. When the bolts are tightened the clamps press against the rail. Pages from the patent, a mechanical drawing and an image of a rail clamp are shown in http://www.andrew.cmu.edu/~lkara/images/railclamp.html. The clamps are designed so as not to fail if the bolt is over-torqued; the bolt will fail first. Later in the semester, we will study the stresses in the clamp and the bolt.

In this problem we will consider the contact between the rail and the clamp. Say that the bolt is tightened to 30,000 lb. The rail presses against the two faces of the clamp. Say that the rail contacts the lower face up to 1.75" from the free end. The contact with the upper surface extends from its free end up to the same horizontal point (shown as the dashed line). For other dimensions, you should use the mechanical drawing mentioned above. Assume that friction is negligible.

(A) Isolate just the clamp (remove the rail) and use statics to determine the net force on the lower and upper faces of the clamp at which the rail makes contact.
(B) The force is actually distributed along each face. It is not easy to determine this distribution. We take a simple approach here of <u>assuming</u> that the force on the upper face is distributed uniformly along that face. Determine the point on the lower face through which the net force on that face acts. Indicate that force and its location in a drawing.
(C) Determine the average force per unit area acting on the lower and upper faces.



Hints:

- ?? The force due to the bolts acts in the center line of the hole.
- ?? Find the position of the point on the upper face at which the net force due to the uniform distribution acts. This is critical to doing part (B).

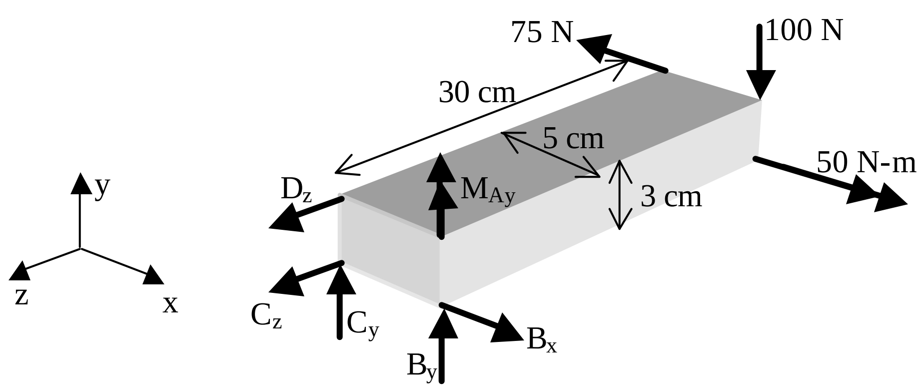
2. The SUV hatch system must be designed so that the hatch opens completely with no assistance once it has been opened a certain distance. (Conversely, if it is let go from a slightly lesser opening, it should close with enough force to latch. We will not deal with the latching problem here.) See the diagram from Problem Set #1. Say the hatch opens by itself, if x_G is larger than 50 cm. Let the mass of the hatch be 80 kg. Treat the hinge as a frictionless pin joint that can exert a force, but no moment, and continue to use the approximate planar geometry of Problem Set #1.

Determine the force (in Newtons) in the gas spring if the hatch is to be just balanced within 1? of this opening. Explain your calculations clearly.

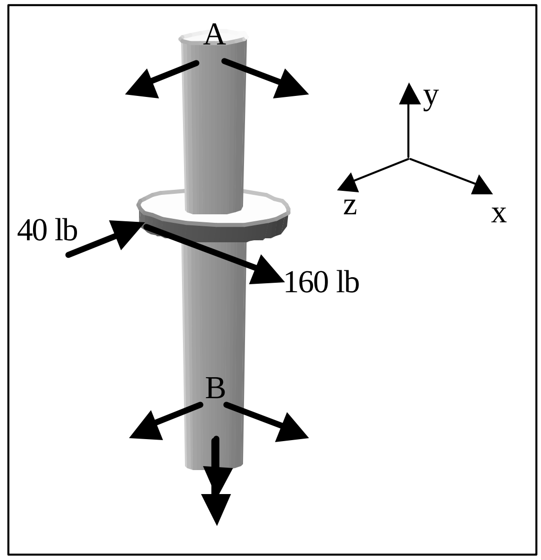
Show that the hatch will continue to open if it is let go from any more open position. Use a spreadsheet (you can adapt the previous one) to show that at each angle the tendency to open exceeds the tendency to close.

Determine the downward force that must be applied by hand at the end of the hatch to begin to close the hatch from the fully opened position (shown in the diagram of Problem Set #1). Take the end of the hatch to be located at 100 cm from the pivot point.

3. The bar is to be supported by a set of unknown forces and a moment at one end when subject to loads at the other end. Determine the unknown forces and moment. When you have determined them, redraw the member with all the forces and moments drawn in the correct senses at their points of application.



4. The vertical shaft is stabilized by bearings at A and B. Each bearing can exert a force acting perpendicular to the shaft running through the shaft center (components of the force are shown here). A gear is mounted on the shaft and the gear tooth forces are shown. (The 40 lb force is termed the gear separation force and it acts normal to the gear into the center of the shaft.) The shaft is connected to additional elements below, which supply a moment along the shaft axis. The gear is located 10" from the bearing at A and 15" from the bearing at B. The gear has a diameter of 6" (a radius of 3").



Give appropriate labels to the unknown forces and moments and then determine them using statics. (Statics is appropriately applied to a rotating shaft if the shaft spins at a constant speed.) Hint: You can solve for one unknown at a time if you first do the summation of moments about carefully selected axes and later deal with summation of forces.

Once you have solved for the unknowns, redraw the shaft with all loads acting in their correct senses.