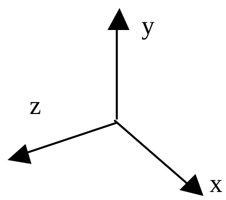
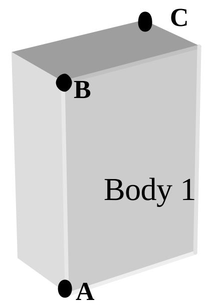
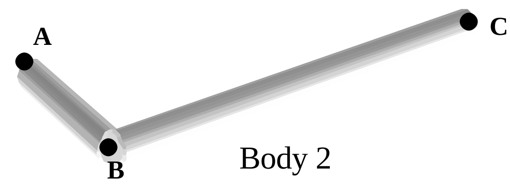
24-261 Statics August 28, 2001
Problem Set #1 Due: September 4, 2001

For problems 1 through 6, use the x-y-z axes shown below. Bodies and forces that appear to be aligned with these axes are, in fact, aligned with these axes.



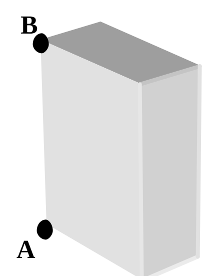




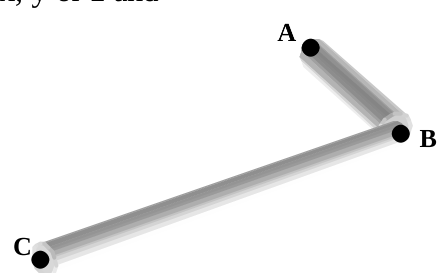
1. <u>Clearly</u> draw Body 1 rotated by 90° about the negative x-axis. Label new positions of points A, B and C. Repeat for 90° about the positive z-axis.

2. <u>Clearly</u> draw Body 2 rotated by 90° about the negative y-axis. Label new positions of points A, B and C. Repeat for 90° about the negative z-axis.

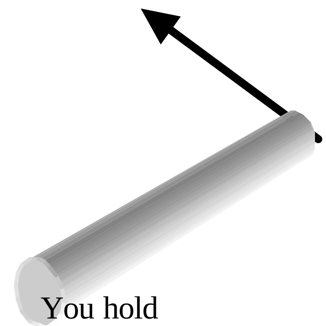
3. About which axis has Body 1 been rotated to be in the configuration to the right? (Indicate x, y or z and positive or negative.)



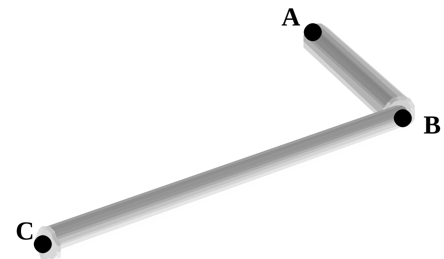
4. About which axis has Body 2 been rotated to be in the configuration below? (Indicate x, y or z and positive or negative.)



5. You hold the body at the indicated end. What force is being applied? (Indicate F_x, F_y or F_z and indicate > 0 or < 0.) What moment(s) must you exert at the end you are holding to maintain the body in equilibrium? (Indicate M_x, M_y or M_z and indicate > 0 or < 0.) Draw the configuration shown, and draw in the balancing moment vector(s) in the correct direction.



6. A force $F_y < 0$ is applied to point A. You are gripping at end C. What moment(s) must you exert at the end you are holding to maintain the body in equilibrium? (Indicate M_x, M_y or M_z and indicate > 0 or < 0.) Draw the configuration shown, and draw in the balancing moment vector(s) in the correct direction.

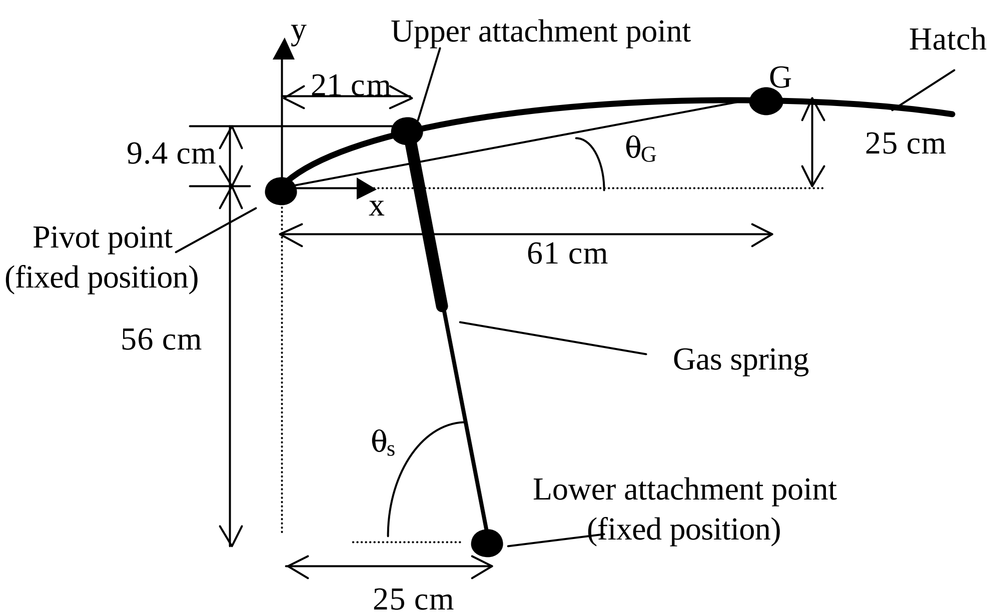


7. One element in designing the hatch system of a vehicle is to determine how to keep it propped open, but still allow it to be closed without undo difficulty. Some vehicles rely on a pair of gas springs each exerting a constant force along its length. In practice, one has to decide on the maximum and minimum extensions of the gas springs, the spring force, and the attachment points on the hatch and vehicle. One knows the properties of the hatch (its weight distribution), the hinge locations and the fully open and full closed positions.

   This problem deals with a single aspect of this design. Given proposed attachment points, how does the gas spring change length and orientation as the hatch is pivoted from its fully open to its fully closed position? Images of the hatch can be found in http://www.andrew.cmu.edu/~lkara/images/suv.html. To simplify, we have approximated the gas cylinder and the hinge (pivot point) as lying in the same plane. Relevant dimensions are given in the drawing below. For a series of intermediate positions between the fully open and fully closed, you should track: the horizontal (x_G) and vertical (y_G) coordinates of the hatch center of gravity G relative to the pivot point, the gas spring length (L_s), and the gas spring orientation (θ_s) relative to the horizontal. The upper attachment point is initially 9.4 cm above and 21.0 cm to the right of the pivot point. The hatch closes when the horizontal distance from the pivot point to G is 36 cm.

First neatly derive all the equations you need. This is an exercise in trigonometry. The change in the gas spring length and orientation can be tracked by following the triangle joining the lower attachment point, the pivot point and the upper attachment point. One side of the triangle is fixed and one side merely changes orientation. To track the change in position, you should vary the angle θ_G that the line from the pivot point to G makes with the x-axis. Remember that the upper attachment point is also on the hatch, so the line joining the pivot point and the upper attachment point rotates by the same angle as does the line joining the pivot point and G. You should do this using an Excel spreadsheet, changing θ_G by 1° increments. The first column should be the change in the angle θ_G from the initial (0, 1°, 2°,…) , and there will be columns for x_G and y_G, the angle θ_s, and length of the gas spring L_s. You will find it convenient to have additional columns for intermediate results, such as θ_G, etc. Continue the spreadsheet until the hatch closes.

(Here is one check on your results: when θ_G is –18.71°, the gas spring L_s should be 49.41 cm and its angle θ_s should be 86.53°.)



Initial configuration of hatch and gas spring