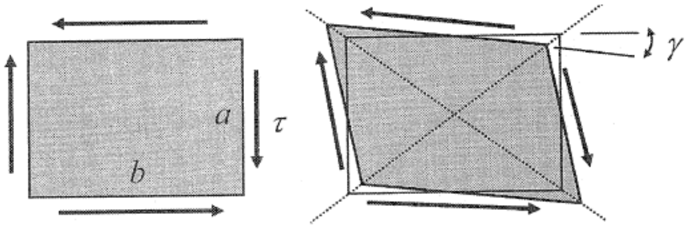
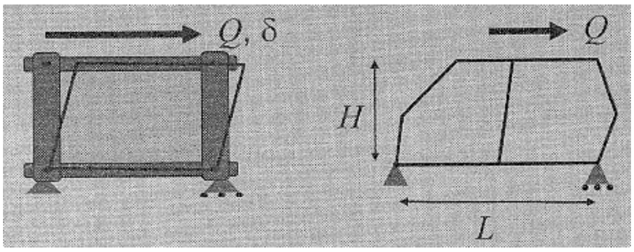
1. In the calculation procedure for the torsional stiffness of a realistic cabin structure when a torque T is applied,

(1) Determine the shear stain energy for a surface in uniform shear (panel dimensions: a, b, t, material shear modulus: G, shear flow: q). (10 pts)



(2) Determine the effective shear rigidity $(Gt)_{eff}$ in terms of $Q,\ \delta,\ H$ and L. (10 pts)



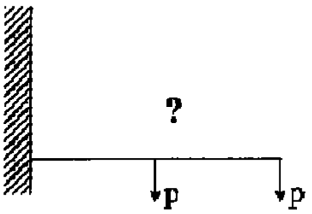
(3) From the energy balance, show that the torsional stiffness can be found by (15 pts)

$$K = \frac{1}{\left(\frac{q}{T}\right)^2 \sum_{\text{all surfaces}} \left[\frac{\text{area of surface}}{(Gt)_{eff}}\right]_i}$$

2. [Design Optimization]

(1) Describe three key elements to formulate the design optimization problem. (10 pts)

(2) Describe each for the following truss weight minimization problem. (10 pts)



$$\delta \le \delta_{allow}$$
$$\sigma \le \sigma_{allow}$$

(3) Describe the differences among size, shape and topology optimization. (10 pts)

3. A change to the underbody structure is proposed to reduce injury in the standard side impact test. The current underbody crush capacity is $F_2 = 150,000N$. It is proposed to reinforce this structure to achieve a capacity of $F_2 = 200,000N$. For both design proposals, use velocity-time histories for the struck vehicle, the moving barrier, and the occupant. The parameters are:

$$\begin{cases} M_1 = 1365kg \ (\text{Barrier mass}) \\ M_2 = 1590kg \ (\text{Vehicle mass}) \\ V_0 = 13.25\,m/\text{sec} \ (\text{Lateral impact speed}) \\ \Delta = 175mm \ (\text{Crushable space within door}) \\ \Delta_0 = 125mm \ (\text{Space between door inner panel and occupant shoulder}) \end{cases}$$

(1) Sketch the velocity-time histories for the barrier, the vehicle and the occupant based on the current structure. (15 pts)

(2) Assuming injury is directly proportional to the change in occupant velocity during the impact, V_{TFINAL}, compute the percent reduction in injury with this change. (10 pts)

(3) Assuming injury is directly proportional to the occupant acceleration during the impact, a_{occ}, compute the percent reduction in injury with this change. (10 pts)