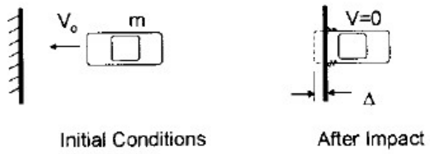
1. Describe the differences among size, shape and topology optimization in terms of three key elements to formulate the design optimization problem. (10 pts)

2. A 1000kg car impacts a rigid barrier at V_0 = 48 km/h. It is desired that the maximum deceleration level be a_{max} = 20g. The anticipated crush efficiency is η = 0.8. Assume fully plastic behavior. [40]



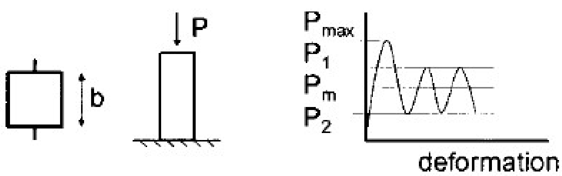
(1) What is the required crushable space Δ? (5 pts)

(2) What is the mean crush force which must be generated by the vehicle F_{avg}? (5 pts)

Assume that two midrails will provide 50% of the average crumpling force F_{avg} required. The body will be tested statically for this force level.

P_m : mean crush force (N)
P_{max} : maximum crush force (N)
t : material thickness (mm)
b : section width and height (mm)
σ_Y : material yield stress (N/mm^2)

$$\rightarrow \begin{cases} P_m = 386 t^{1.86} b^{0.14} \sigma_Y^{0.57} \\ P_{max} = 2.87 P_m \\ P_1 = 1.42 P_m \\ P_2 = 0.57 P_m \end{cases}$$



(3) Determine the maximum load for the square section P_{max}. (5 pts)

(4) What moment is needed at the toe pan to react the load in (3)? (5 pts)

(5) Determine the required section thickness at the toe pan so the load of part can be reacted if σ_{max} = 220 N/mm^2. The section is rectangular with height = 70 mm, width = 40 mm. (10 pts)

(6) Crush initiators are added to the front part of the crumple zone which lowers the maximum load(P_{max}) to P_1, the accordion buckling load. Recalculate your answer to (4) with this load. (5 pts)

(7) Determine the required section thickness as in (5) using the reduced moment from (6). (5 pts)

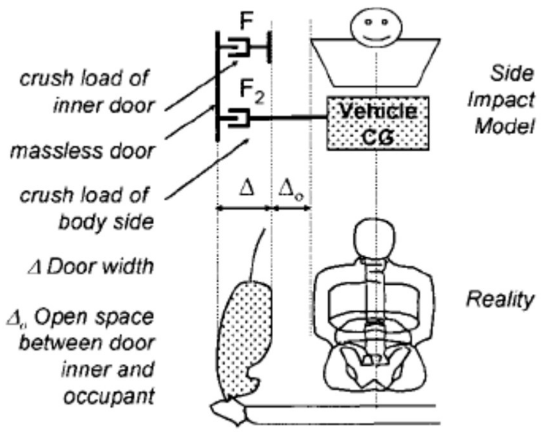
3. A change to the underbody structure is proposed to reduce injury in the standard side impact test. The current underbody crush capacity is $F_2 = 150,000N$. It is proposed to reinforce this structure to achieve a capacity of $F_2 = 200,000N$. For both design proposals, use velocity-time histories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

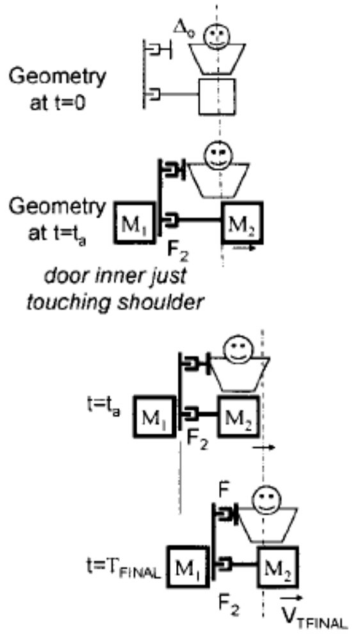
$$\begin{cases} M_1 = 1365kg \ (\text{Barrier mass}) \\ M_2 = 1590kg \ (\text{Vehicle mass}) \\ V_0 = 13.25\, m/\sec \ (\text{Lateral impact speed}) \\ \Delta = 175mm \ (\text{Crushable space within door}) \\ \Delta_0 = 125mm \ (\text{Space between door inner panel and occupant shoulder}) \end{cases}$$

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

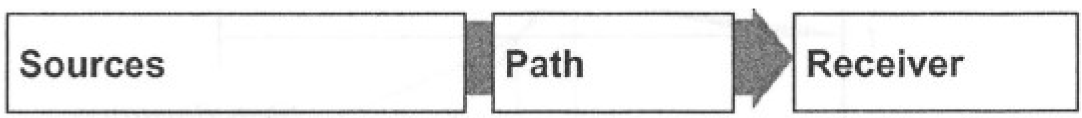
(2) Assuming injury is directly proportional to the change in occupant velocity during the impact, V_{TFINAL}, compute the percent reduction in injury with this change. (10 pts)

(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)





4. Describe the source-path-receiver model for the following vibration system.



(1) Powertrain-driven vibration (5 pts)

(2) Suspension-driven vibration (10 pts)