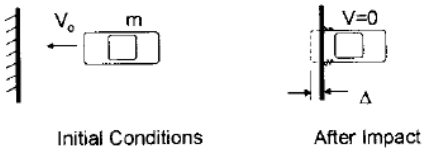
1. A manufacturer sells products A and B. Profit from A is \$10/kg and from B \$8/kg. Available raw materials for the products are: 100 kg of C and 80 kg of D. To produce 1 kg of A, 0.4 kg of C and 0.6 kg of D are needed. To produce 1 kg of B, 0.5 kg of C and 0.5 kg of D are needed. The markets for the products are 70 kg for A and 110 kg for B. How much of A and B should be produced to maximize profit? Formulate the design optimization problem. (Do not solve!) (20 pts)

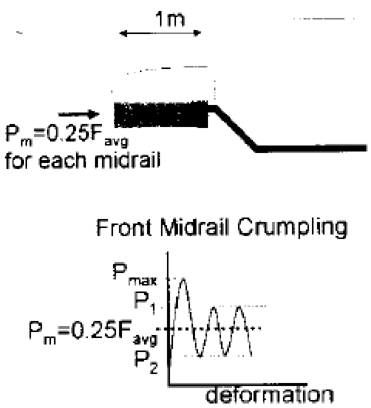
2. A 1000kg car impacts a rigid barrier at V_0 = 48 km/h. It is desired that the maximum deceleration level be a_{max} = 20g. The anticipated crush efficiency is η = 0.8. Assume fully plastic behavior.



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

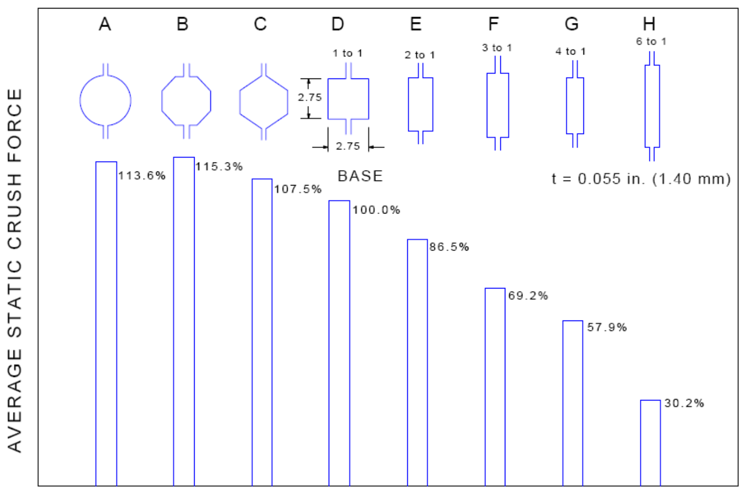
(2) What is the mean crush force which must be generated by the vehicle F_{avg}? (5 pts)

Assume that the two midrails will provide 25% of the average crumpling force F_{avg} required. The body will be tested statically for this force level. Material yield is σ_y = 207 N/mm^2.



$$P_m = 386 t^{1.86} b^{0.14} \sigma_Y^{\ 0.57}$$

For same perimeter and thickness



(3) Determine the size (b, t) of the square section required to generate 0.25 F_{avg} if the width to thickness ratio b/t = 60. What is the mass of the two rails(density = $7.83\times10^{-6}\ kg/mm^3$)? (10 pts)

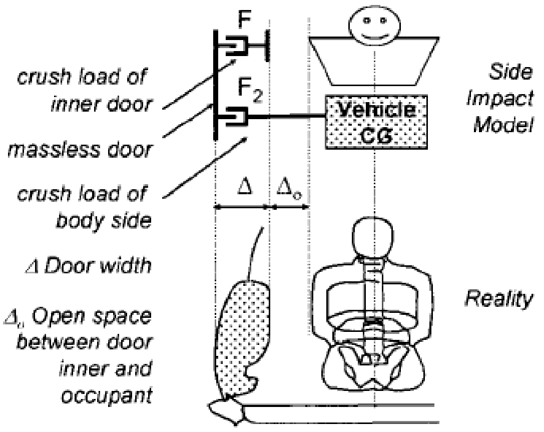
(4) A hexagonal section is being considered with the same b/t ratio. What is the resulting mass? (5 pts)

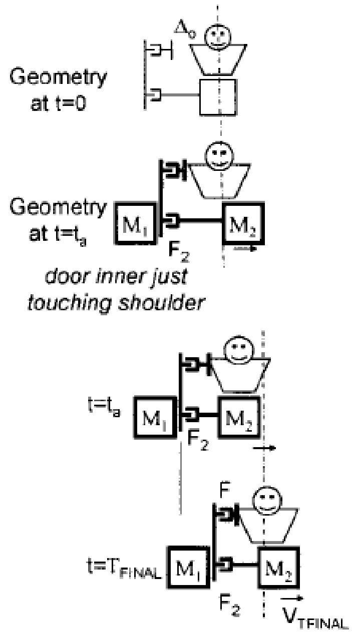
(5) Compare the two sections. What is preferred? (5 pts)

3. Consider the impact of the vehicle(M_2) by a moving barrier(M_1). We can model each as a point mass with the impact being perfectly plastic. In this linear model, we are looking at motions lateral to the vehicle and will consider the lateral component of the barrier velocity as the initial impact velocity.

(1) Sketch the velocity-time histories for the barrier, the vehicle and the occupant based on the following figures. Indicate t_a, t_{final} and t_f in the time axis and corresponding V_a, V_{final} and V_f in the velocity axis. (10 pts)

(2) Specify Δ_0, Δ and a_{occ} (acceleration of occupant) in the histories. (10 pts)





4. A powertrain is installed in the body as shown in the figure. To save cost, the powertrain is mounted directly to the body (no compliant engine mounts). Consider only the vertical motions of the powertrain and assume the powertrain has negligible mass compared to the body.

The four-cylinder engine generates a vertical unbalance force caused by the reciprocating pistons equal to: $f(t) = 4mr\omega^2 \dfrac{r}{L}\cos(2\omega t)$ where $\begin{cases} m = 1kg\,(\text{reciprocating mass}),\ r = 50mm\,(\text{crank radius}) \\ L = 120mm\,(\text{conneting rod length}),\ \omega = (\text{engine speed},\ rad/\text{sec}) \end{cases}$

(1) Plot the excitation force versus engine speed on log-log axes for $500rpm \le \omega \le 900rpm$. (10 pts)

(2) Plot the steering column mount acceleration amplitude Y_2 vs. engine rpm. (10 pts)

(3) For the range $500rpm \le \omega \le 900rpm$, are the vibration levels calculated in (2) acceptable? Use the human response to vertical vibration shown.. (10 pts)