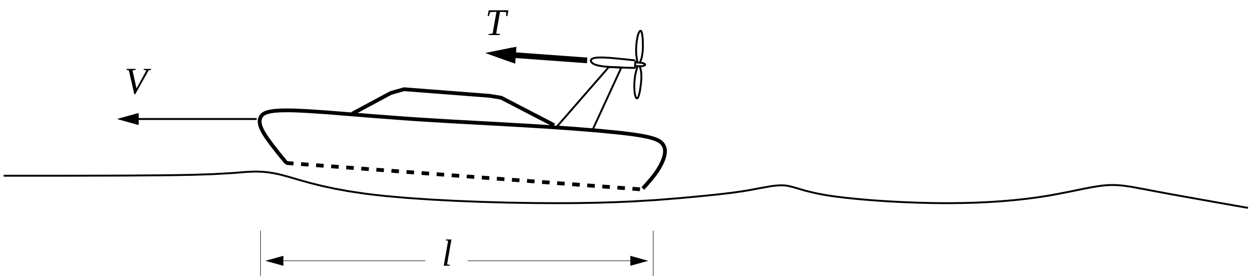
1. (40 %) A hovercraft of length $\ell$ and mass $m$ is flying along at a steady speed $V$ on its cushion of air. Some thrust $T$ is needed to overcome the direct air resistance, and also to drive the hovercraft "uphill" on the deformed sloping water surface underneath.




a) List all the physical parameters which will influence the required thrust $T$.

$$T = f(V, m, \ldots)$$

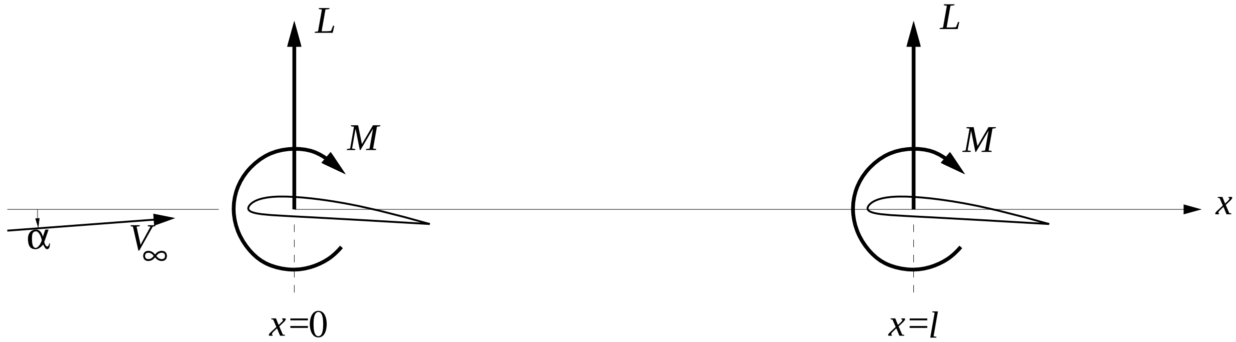
To reduce the complexity, you may assume that the speed of sound and viscosity of the air and water are not important.

b) Determine a set of nondimensional parameters (or Pi products) which fully describe this situation. The list must be complete and non-redundant (e.g. you cannot have $\Pi_1 = \Pi_2 \times \Pi_3$, etc.)

c) We wish to do tests on a 25% scale model having dynamic similarity with the actual hovercraft, so $\ell_{\text{model}}/\ell = 0.25$ . What must be the following ratios be?

$$\frac{V_{\text{model}}}{V} \qquad\qquad \frac{T_{\text{model}}}{T}$$

2. (30 %) A tandem aircraft has two identical wings as shown. Assuming no interaction between them, each wing will have the same lift $L$ and moment $M$ about its own quarter-chord location.




a) Determine the total lift $L_{\text{tot}}$ and moment $M_{\text{tot}}$ about the $x = 0$ location for the entire aircraft.

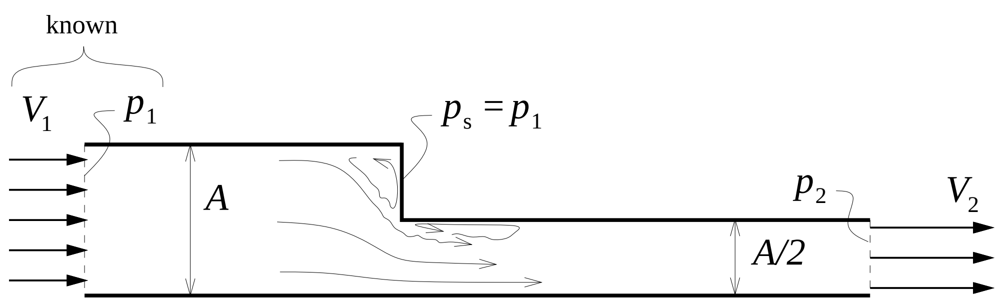
b) Determine the center of pressure location $x_{cp}$ for the entire aircraft.

c) The lift of each wing is expected to be proportional to the overall angle of attack $\alpha$, while the moment of each wing is expected to be nearly constant.

$$L = K\alpha \qquad\qquad M = \text{const}$$

Determine the aerodynamic center location $x_{\text{ac}}$.

3. (30 %) A low-speed flow channel with area $A$ has a step constriction down to area $A/2$ as shown. The flow approaches the step at some known uniform velocity $V_1$ and known pressure $p_1$. There is a great deal of flow mixing in front and behind the step, but the flow eventually becomes uniform again with some velocity $V_2$ and pressure $p_2$. The average pressure on the step face is $p_s$.




a) Determine velocity $V_2$.

b) The step face pressure is measured to be approximately $p_s = p_1$. Determine the exit pressure $p_2$.