Exercise 8.

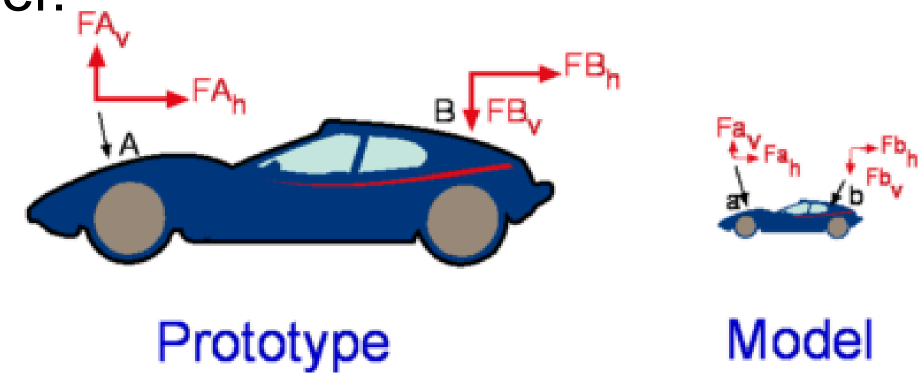
- Fluid problems depended on several variables $f(U, \mu, \rho, L \ldots)$
  - Use Buckingham Pi-theorem to form dimensionless numbers

- **Dimensionless numbers** reduce the complexity, e.g. $f(\mathrm{Re}),\ \mathrm{Re} = \frac{\rho U L}{\mu} = \frac{\text{Inertia}}{\text{Viscous}}$

- If the problem can be classified with dimensionless numbers, than the flow field should be similar at the same dimensionless number.

- Prototype = Large/full scale

- Model = Small scale (e.g. model train, plane…)



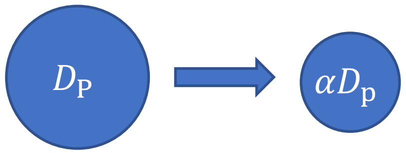
Exercise 8.

- Relation between measured force and characteristic force from flow.
  $C = \frac{F}{{}^1\!/_2 \rho U^2 A}$
- Drag coefficient is the most common:
  $C_\mathrm{D} = \frac{F_\mathrm{D}}{{}^1\!/_2 \rho U^2 \cdot A} = \frac{\text{True drag force}}{\text{Potential retarding force}}$
  - F_D, is the force by the flow direction
  - ${}^1\!/_2\, \rho U^2 \cdot A$, is the *kinematic pressure* times the *projected area in the flow direction*
  - C_D some times function of only Re → $\mathrm{C_D}(\mathrm{Re})$

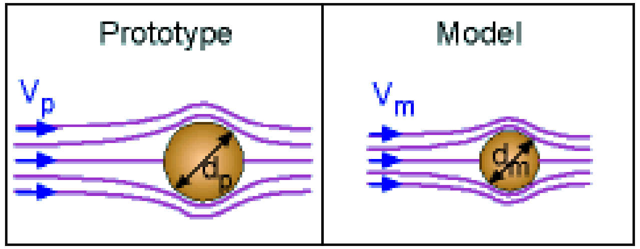
- Lift force → Change the drag force to the lift force (normal to the flow)

Model test similarity

- **Geometric similarity**:
  - Dimensions scaled with one parameter
  - $\alpha L_{\text{Prototype}} = L_{\text{Model}}$



- **Kinematic similarity**:
  - Require geometric similarity
  - Flow field scaled with one coefficient, e.g. Re-number
  - Flow field the same between prototype and model
  - $\text{Re}_{\text{Prototype}} = \text{Re}_{\text{Model}}$



- **Dynamic similarity:**
  - Require both geometric and kinematic similarity
  - All force vectors are scaled with one coefficient
  - If: incompressible flow, no free-surface → $\text{Re}_{\text{Prototype}} = \text{Re}_{\text{Model}}$