MAE 158 F2024

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Lectures tues/thurs 2-3:20pm
Discussions Fri 12, 1, 2 pm

- Weekly Recommended HWs posted Fri
Weekly canvas Quizzes begin
end of week 2
Based on lecture & HW problems

In - class participation : 70%

log onto pollev.com/maeaircraft
during lecture
to participate

-or- join by text : send "Maeaircraft"
to 22333
& enter answer

What is A/C performance

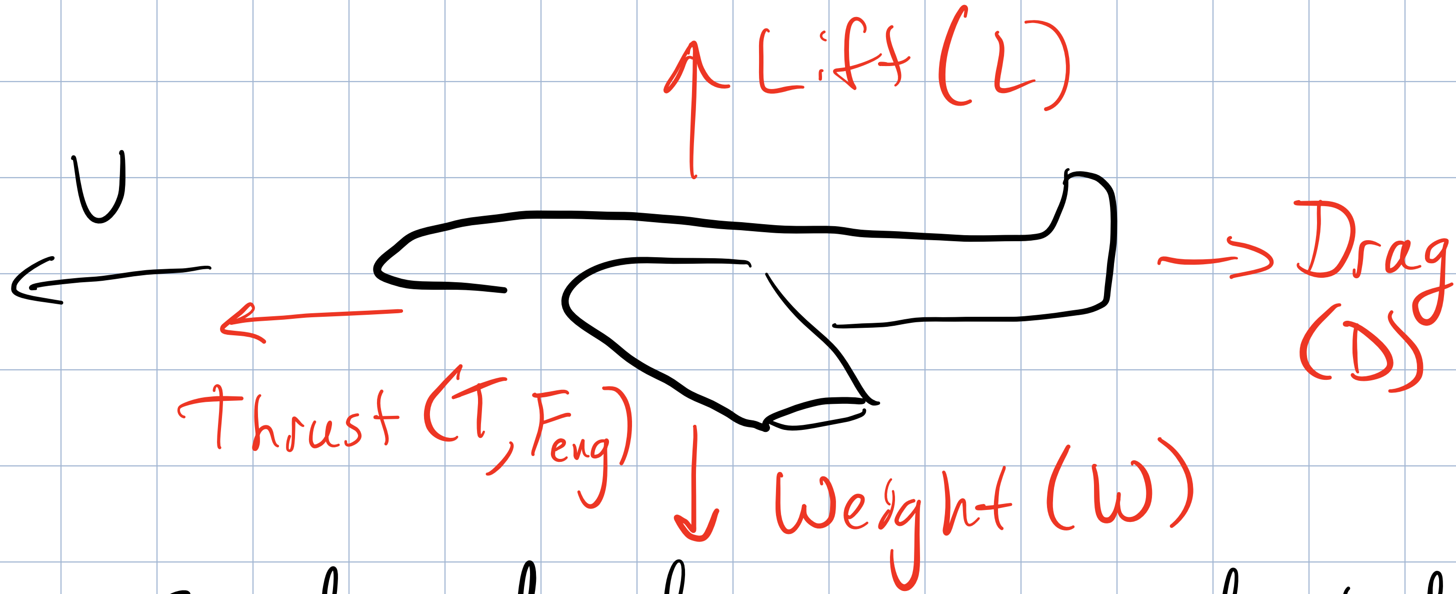
$\uparrow$
aircraft

- "Capacity of an A/C to operate while doing some purpose"

- ex:
  - Speed (max airspeed
    min airspeed (stall airspeed)
  - take off & landing distance

- Endurance ⤳ time
- Range ⤳ distance
- Capacity
- service ceiling → how high you can fly
- climb rate /angle
- descent
- structural efficiency
  - ↳ weight
  - ↳ stability & control
  - ↳ maneuverability

- most performance topics boil down to the balance of 4 basic forces



Steady - level flight: unaccelerated $\Delta V = 0$

& horizontal flight $\gamma = 0°$

(SLF)

Weight = Lift

Thrust = Drag

$$\text{Lift } (L) = \tfrac{1}{2} \rho V^2 S_{REF} C_L$$

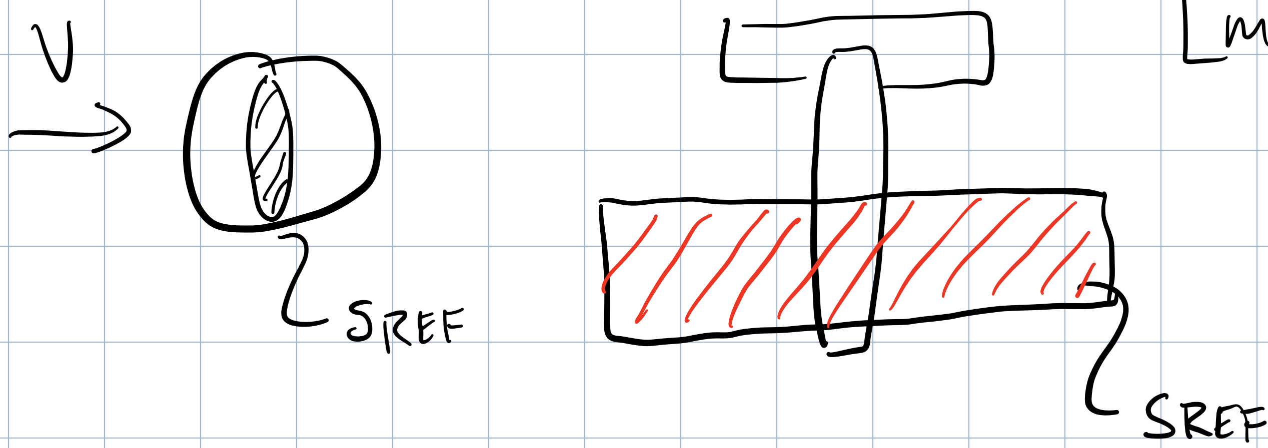
$$\text{Drag } (D) = \tfrac{1}{2} \rho V^2 S_{REF} C_D$$

ρ => density @ altitude in that atmosphere $\left[\frac{kg}{m^3}\right] \left[\frac{slugs}{ft^3}\right]$

V => velocity (airspeed) $[m/s]$ $[ft/s]$ $[\text{knots}] = nmi/hr$

$\frac{1}{2}\rho V^2 \equiv$ dynamic pressure

$S_{REF} \equiv$ Reference surface area $[m^2]$ $[ft^2]$



C_L, C_D => Lift & Drag Coefficients $[-]$

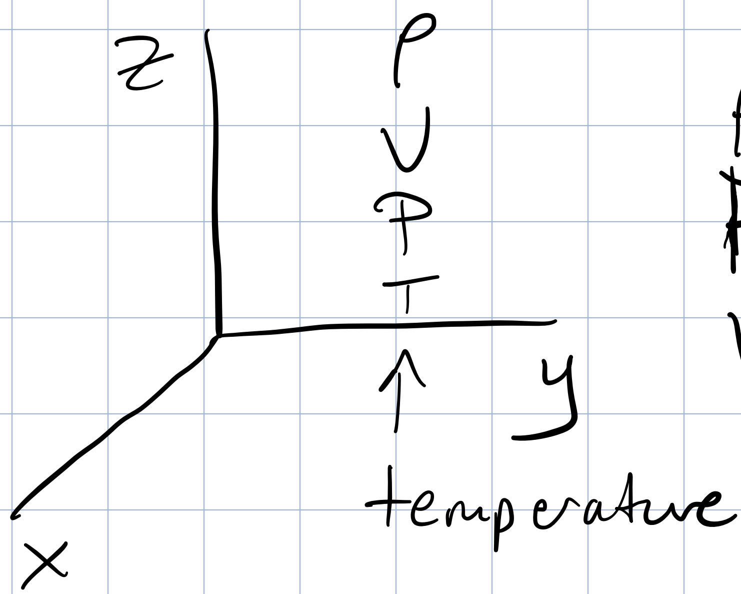
Note units:

$$\left[kg/\cancel{m^3} \right] \left[\cancel{m}/s \right]^2 m^2 \rightarrow \frac{kg\, m}{s^2} \rightarrow N$$

$$\left[\frac{slug}{ft\cancel{^3}} \right] \left[\cancel{ft}/s \right]^2 \cancel{ft^2} \rightarrow slugs \frac{ft}{s^2} \rightarrow lbs$$

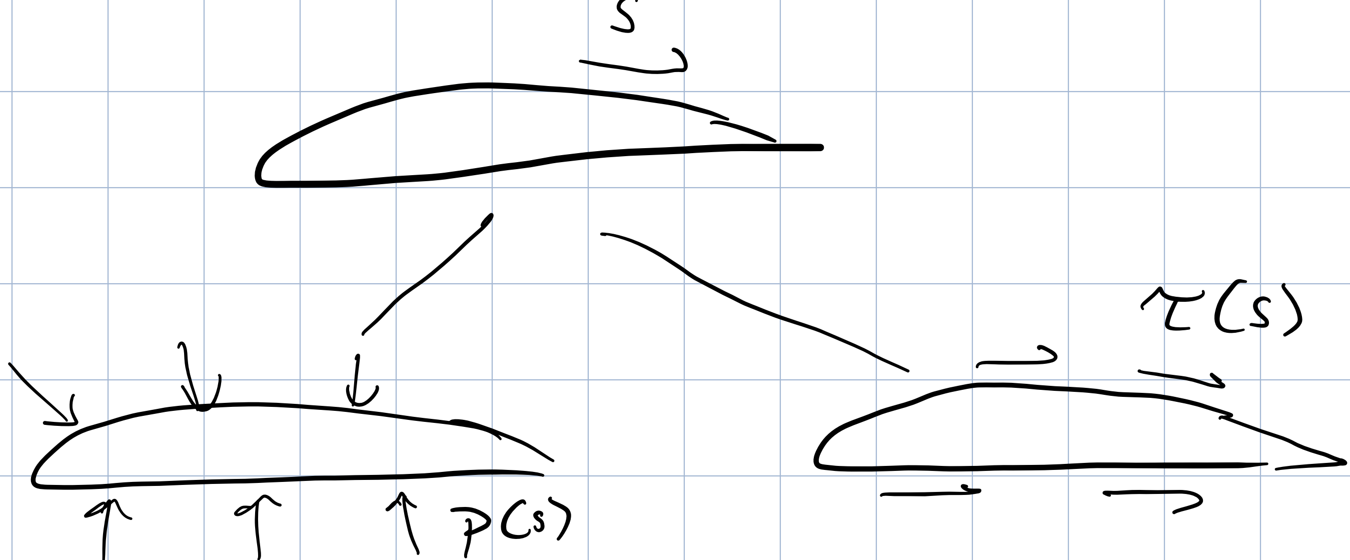
Wing Loading: $\dfrac{\text{Weight}}{S_{REF}}$

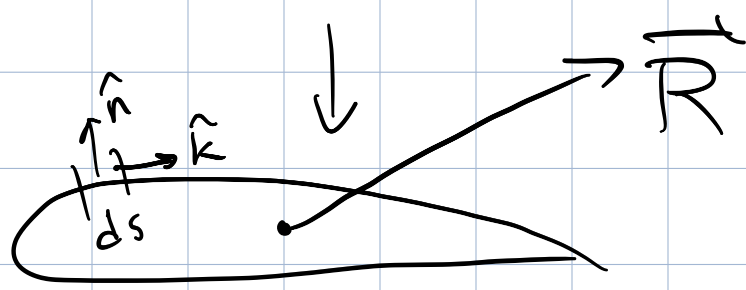
Fluid dynamics



$$\rho = \rho(x, y, z, t)$$
$$P = p(x, y, z, t)$$
$$V = V(x, y, z, t)$$

body immersed in flow



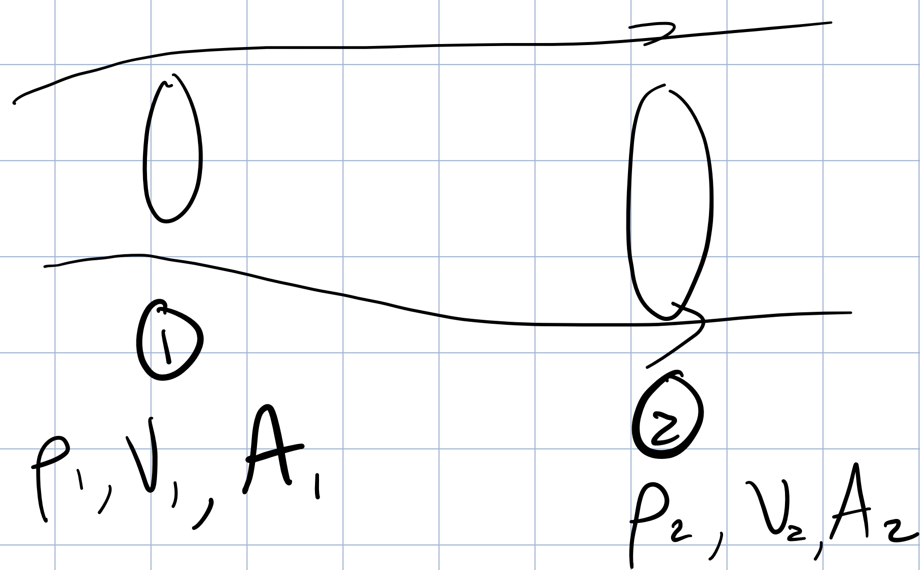


$$\vec{R} = \iint p \cdot \hat{n}\, ds + \iint \tau \cdot \hat{k}\, ds$$

defining relationsips between

ρ, V, P

start with a streamtube



continuity (conservation of mass)

$$\frac{dm_1}{dt} = \rho_1 A_1 V_1$$

$$\frac{dm_2}{dt} = \rho_2 A_2 V_2$$

$$\rightsquigarrow \quad \frac{dm_1}{dt} = \frac{dm_2}{dt}$$

$$\boxed{\rho_1 A_1 V_1 = \rho_2 A_2 V_2}$$

consider ρ to generally
Not be constant
AKA flow is compressible

$$\text{Mach \# } (M) = \frac{V}{\text{speed of sound}}$$

if $M < 0.3$

$\rightarrow$ incompressible

if $M > 0.3$

$\rightarrow$ compressible

if incompressible,

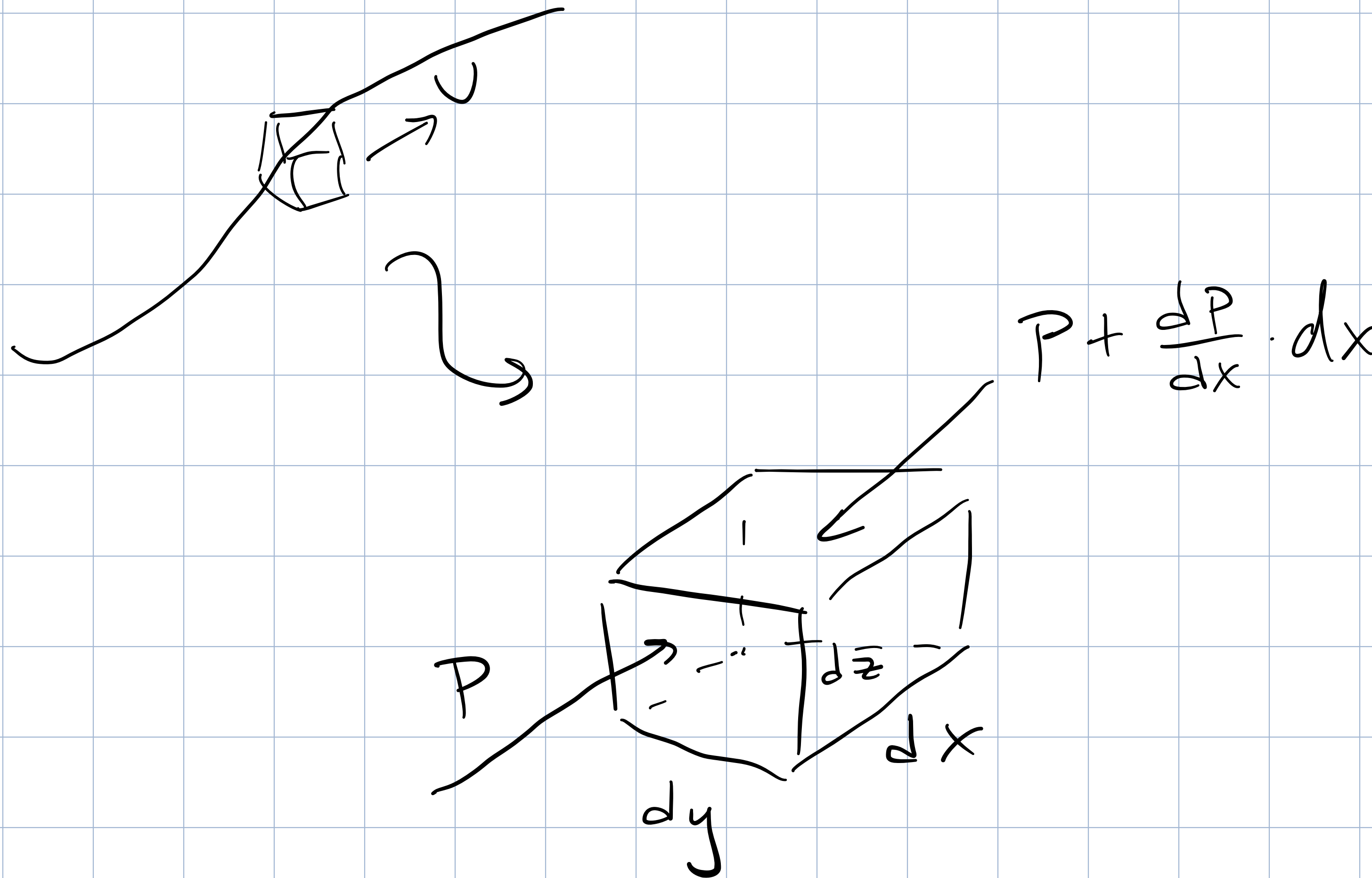
$$\rho = \text{const.} \qquad \rho_1 = \rho_2$$

$$A_1 V_1 = A_2 V_2$$

$$V_2 = \left(\frac{A_1}{A_2}\right) V_1$$

Conservation of Momentum

$\rightarrow$ $F = ma$



- 1. pressures are Normal to the element faces

- 2. friction forces are zero
- 3. gravity negligible

focus on x direction

$$PA = P \cdot dy\,dz \quad \text{left}$$

$$\left(P + \frac{dP}{dx}dx\right) dy\,dz \quad \text{Right}$$

$$P\,dy\,dz - \left(P + \frac{dP}{dx}dx\right) dy\,dz$$

$$-\frac{dP}{dx}\,dx\,dy\,dz = F$$

cons of momentum $\quad F = ma$

$$m = \rho \cdot dx\,dy\,dz$$

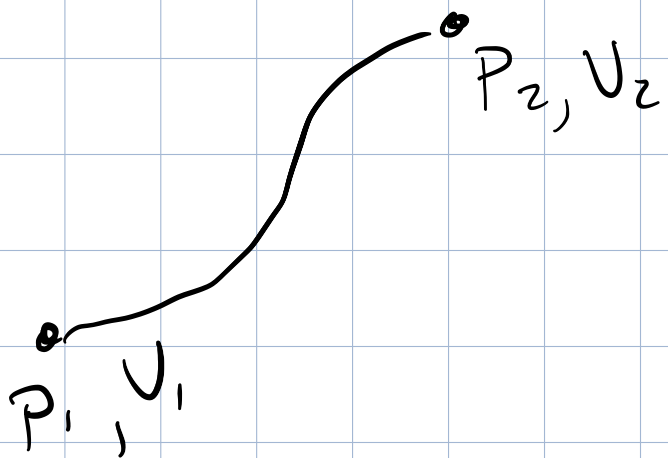
acceleration $\quad a = \frac{dV}{dt} \quad V = \frac{dx}{dt}$

$$a = \frac{dV}{dx}\frac{dx}{dt} = \frac{dV}{dx} \cdot V$$

$$F = m\,a$$

$$-\frac{dP}{dx}(dx\,dy\,dz) = \rho\,dx\,dy\,dz\,\frac{dV}{dx}\cdot V$$

$$dp + \rho V\,dV = 0$$



assume incompressible flow

$$\int_{P_1}^{P_2} dp + \rho \int_{V_1}^{V_2} V\,dV = 0$$

$$\hookrightarrow \quad P_2 - P_1 + \rho\,(V_2^2 - V_1^2)/2 = 0$$

Rewrite $\boxed{P_2 + \rho\frac{V_2^2}{2} = P_1 + \rho\frac{V_1^2}{2}}$

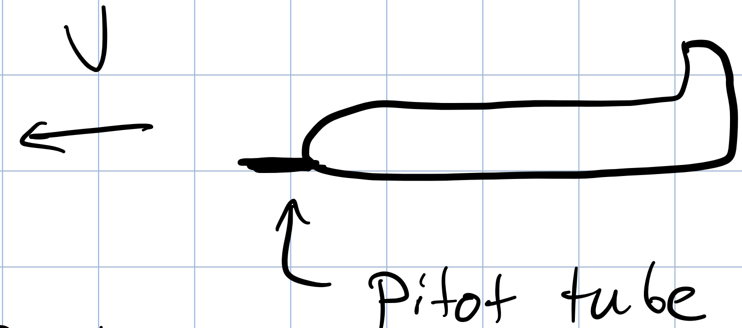
Bernoulli's equation

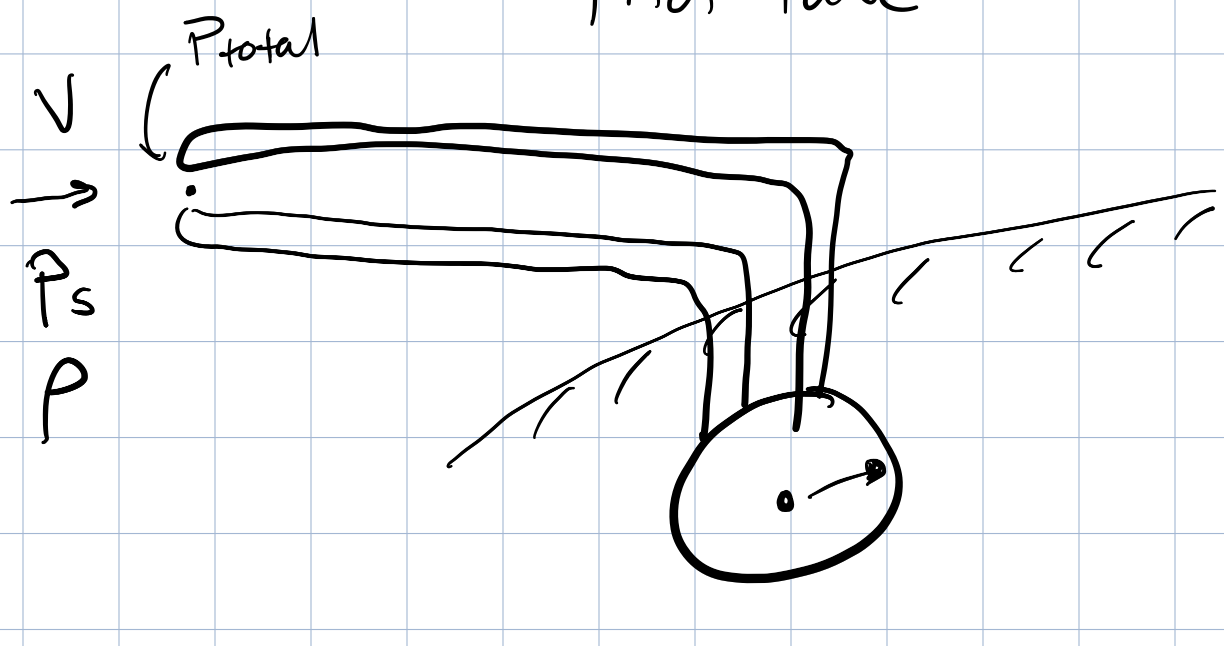
$\rho_1 A_1 V_1 = \rho_2 A_2 V_2$ cons of mass

$P + \frac{1}{2}\rho V^2 = \text{¢}$ cons of momentum

$P = \rho R T$ → equation of State

Ex: Airspeed Indicators



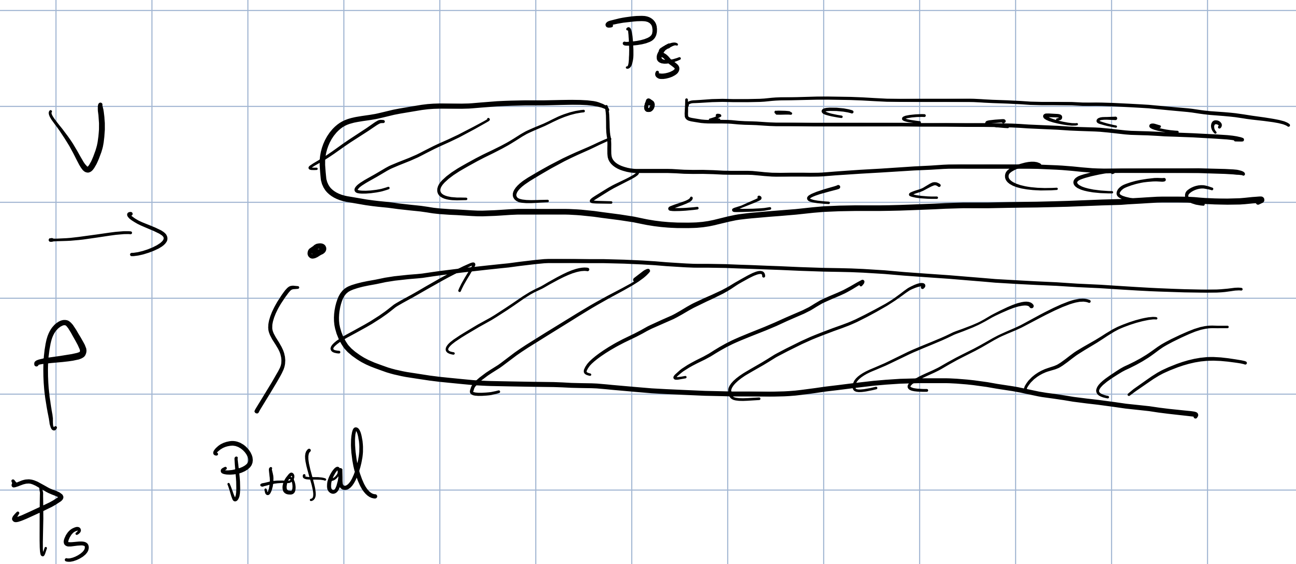


$$P_{total} = P_s + \tfrac{1}{2}\rho V^2$$

P_s ↑ static pressure in atmosphere

$\tfrac{1}{2}\rho V^2 \rightarrow$ dynamic pressure

ρ ↑ density of atmosphere



$$P_{total} = P_s + \tfrac{1}{2}\rho V^2$$

$$\tfrac{1}{2}\rho V^2 = P_{total} - P_s$$

$$V = \sqrt{\frac{2}{\rho}\left(P_{total} - P_s\right)}$$

$$\text{Lift} = \tfrac{1}{2}\rho V^2 \cdot S_{REF} \cdot C_L$$