

Induced Drag

Lecture 5

ME EN 415

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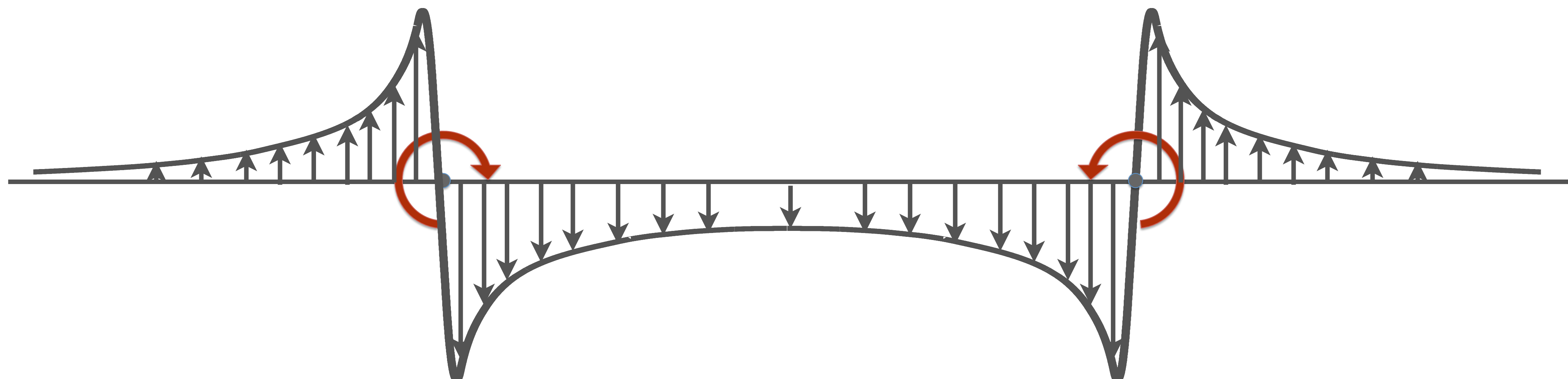
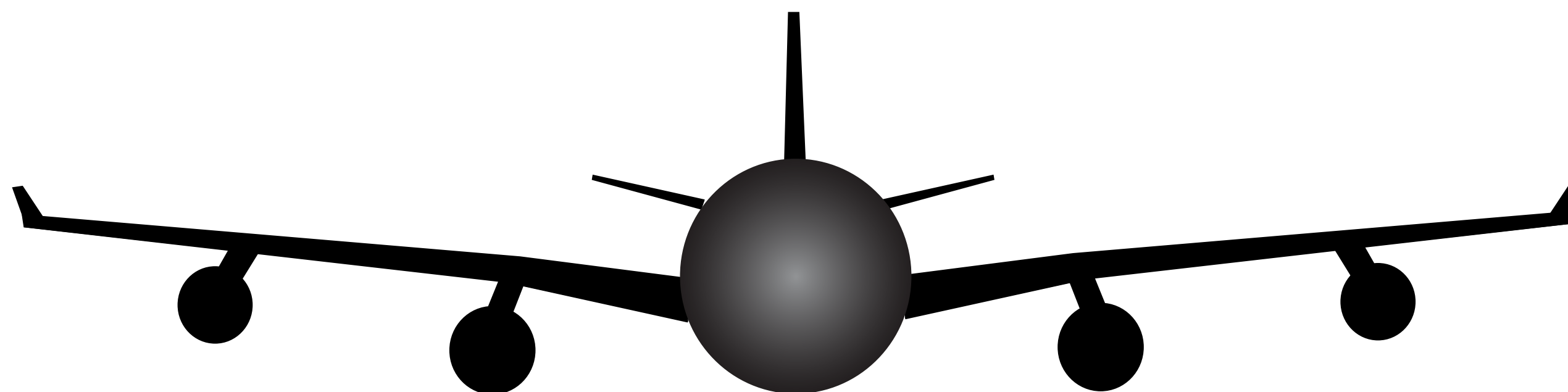


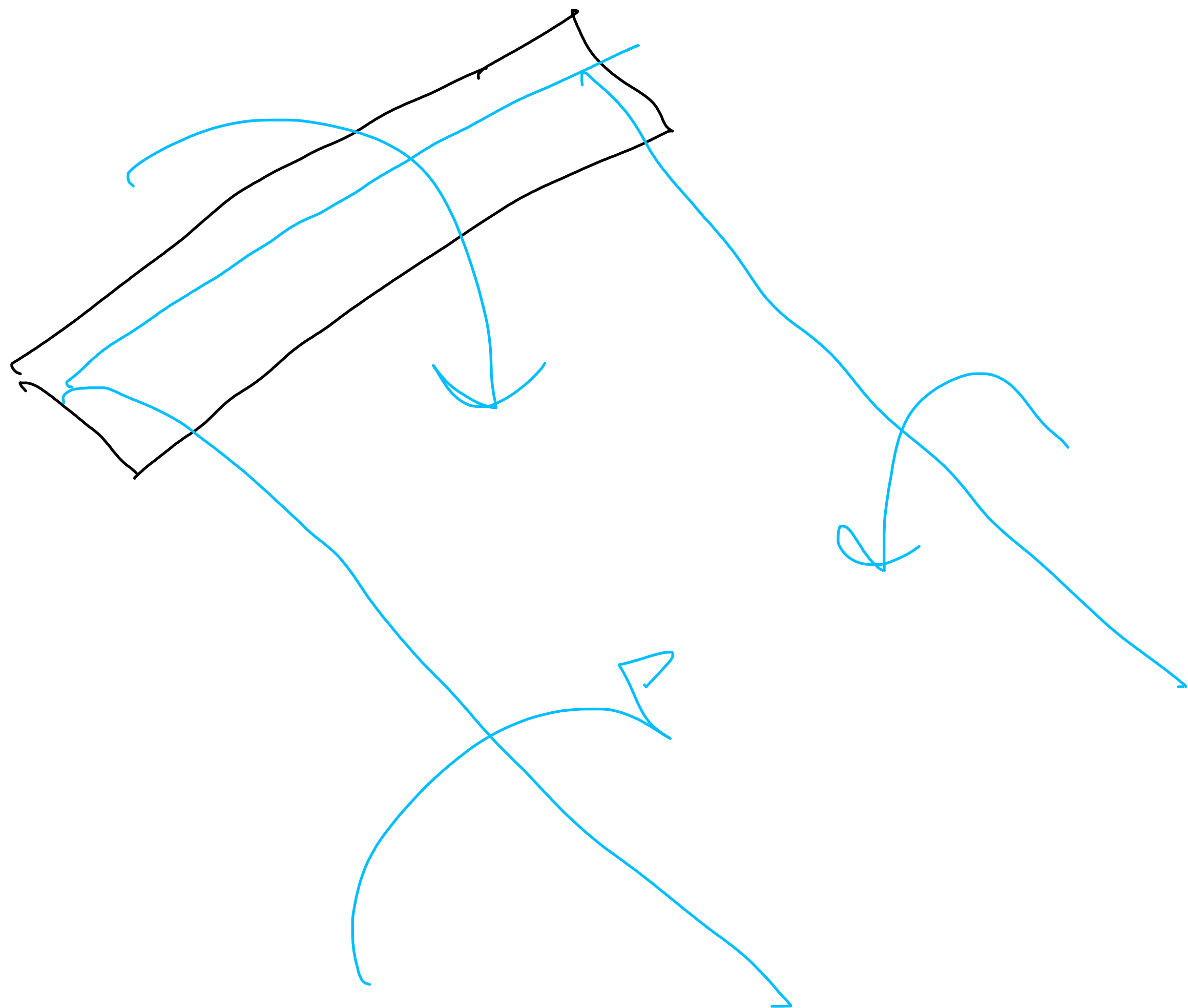
Drag Breakdown

Parasitic Drag + Induced Drag + Compressibility Drag

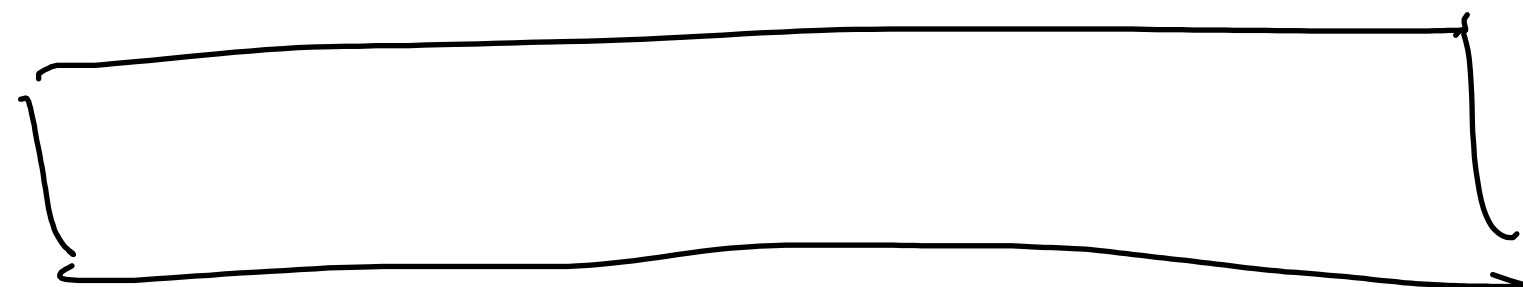
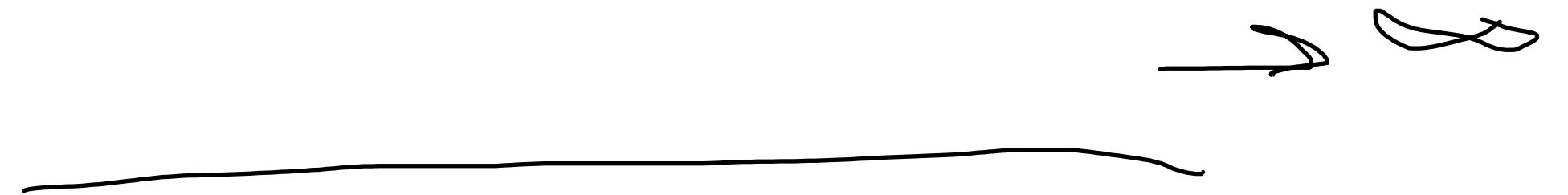
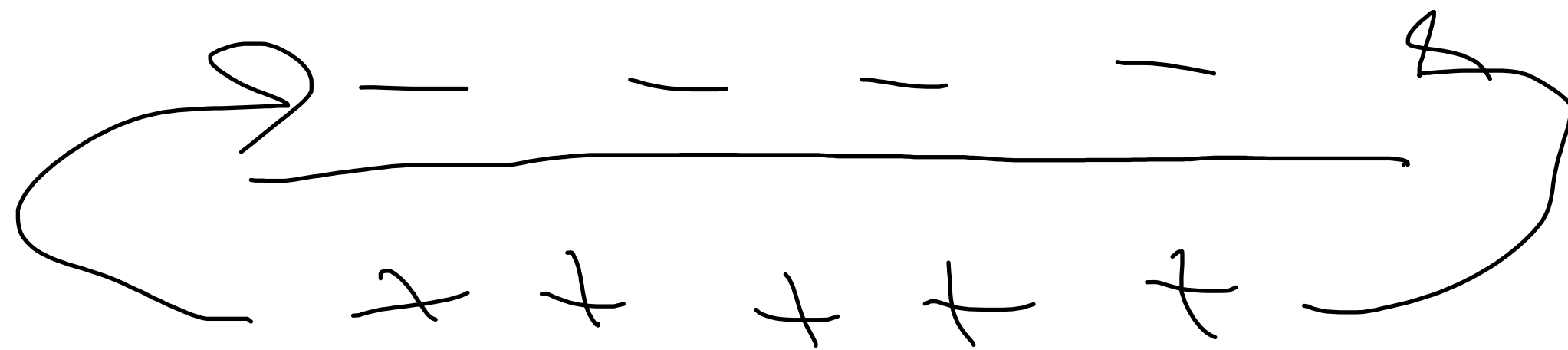
Wake Vortex





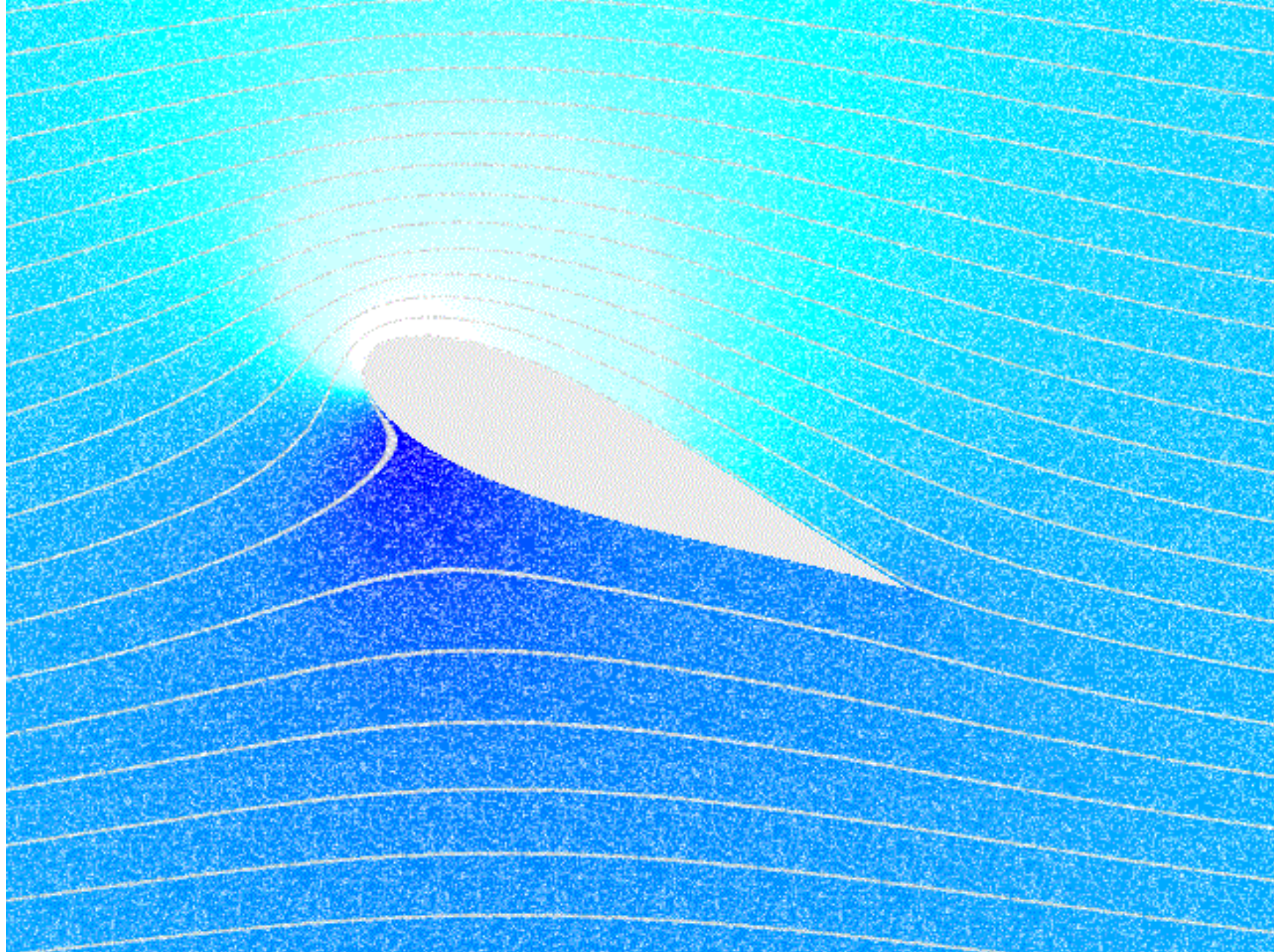


Common Misconceptions



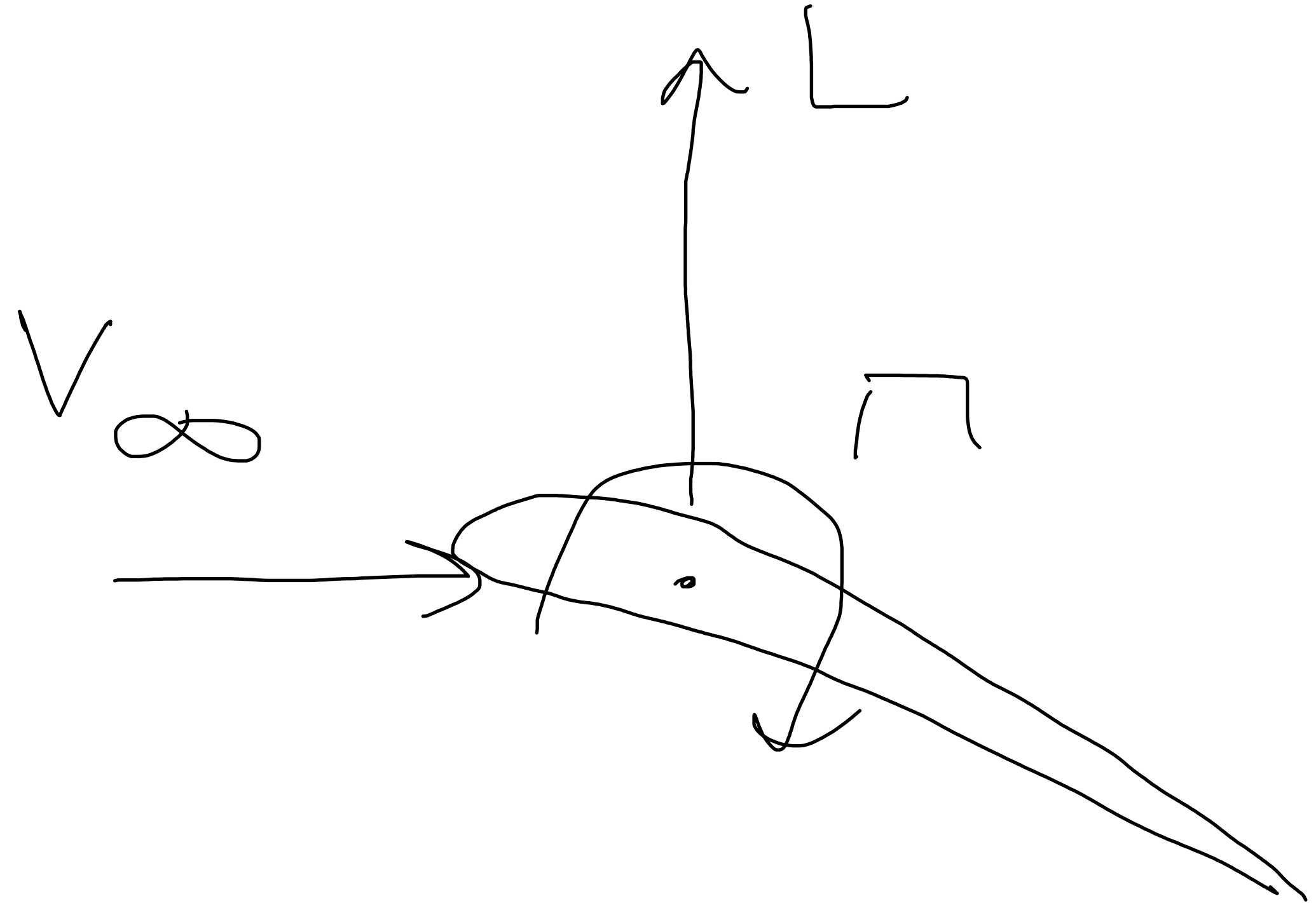
<https://youtu.be/dfY5ZQDzC5s>

Circulation

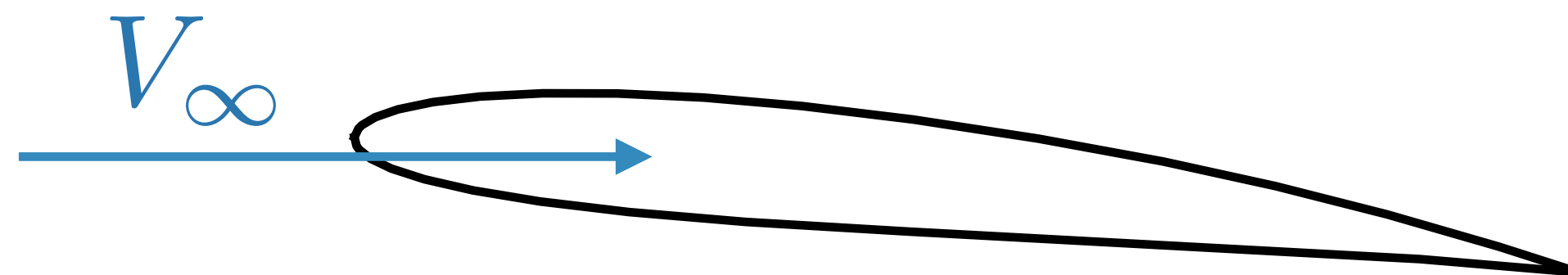


Kutta Joukowski Theorem

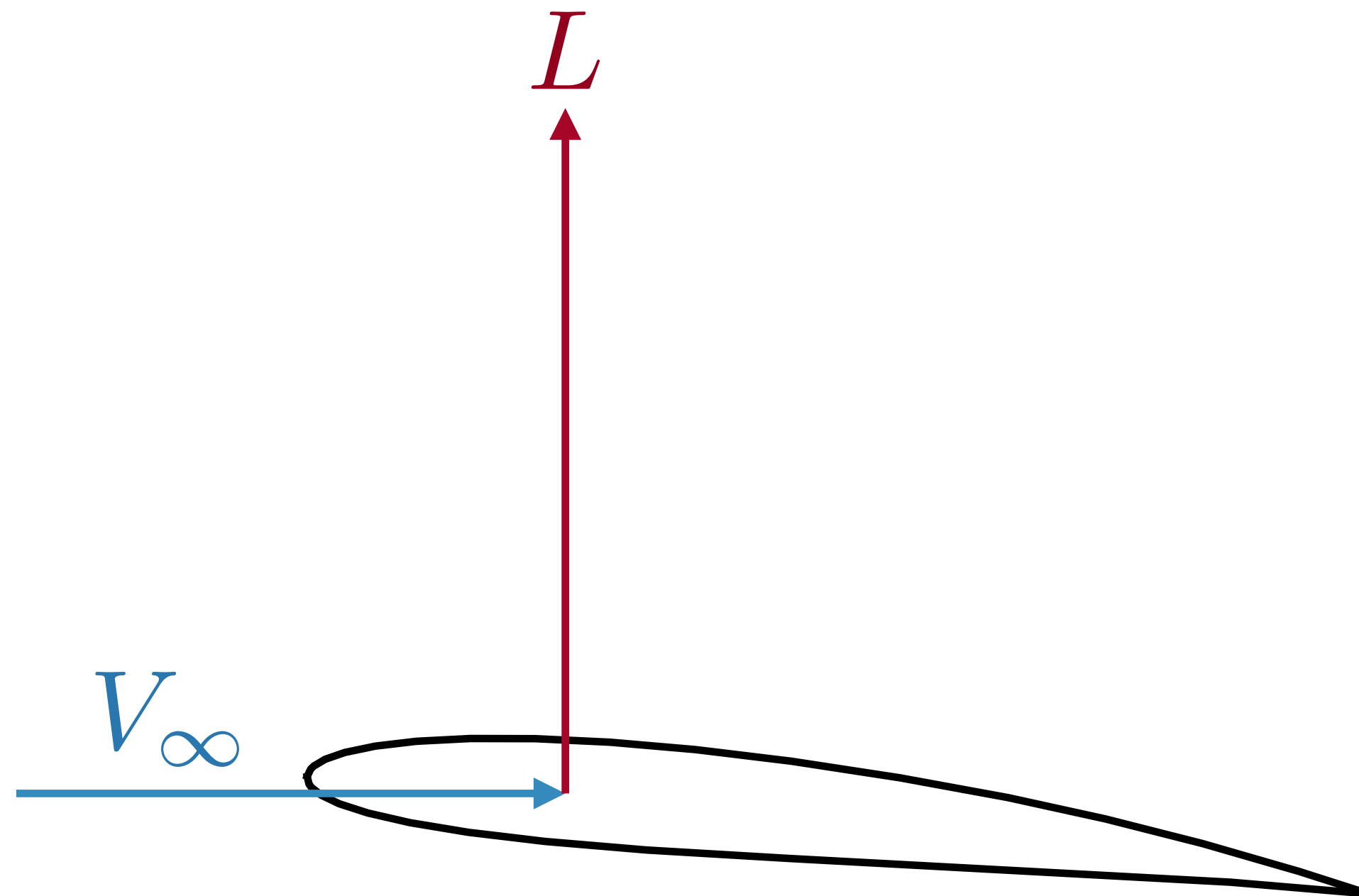
$$L' = \rho \vec{V}_{\infty} \times \vec{\Gamma}$$



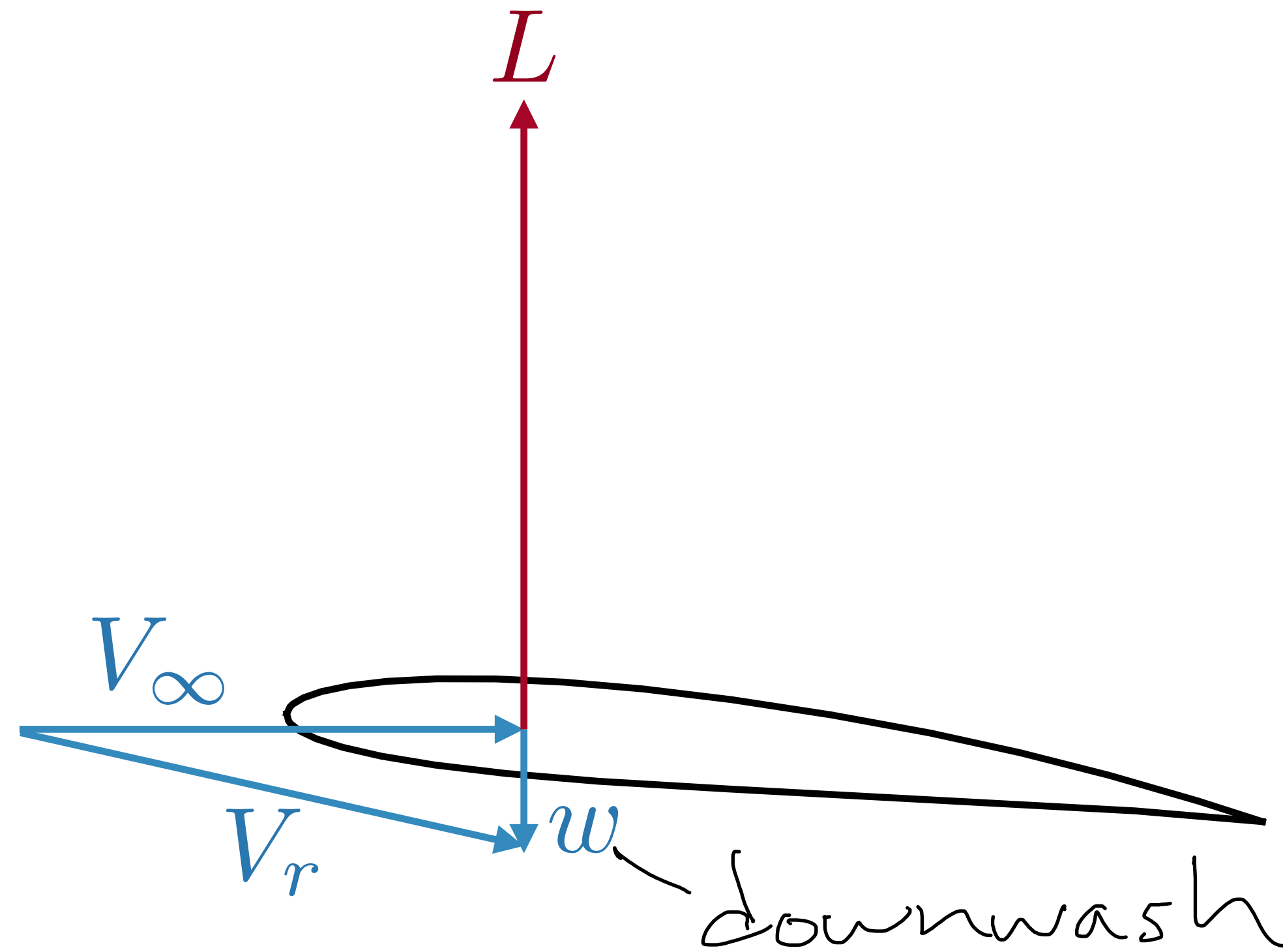
Induced Drag



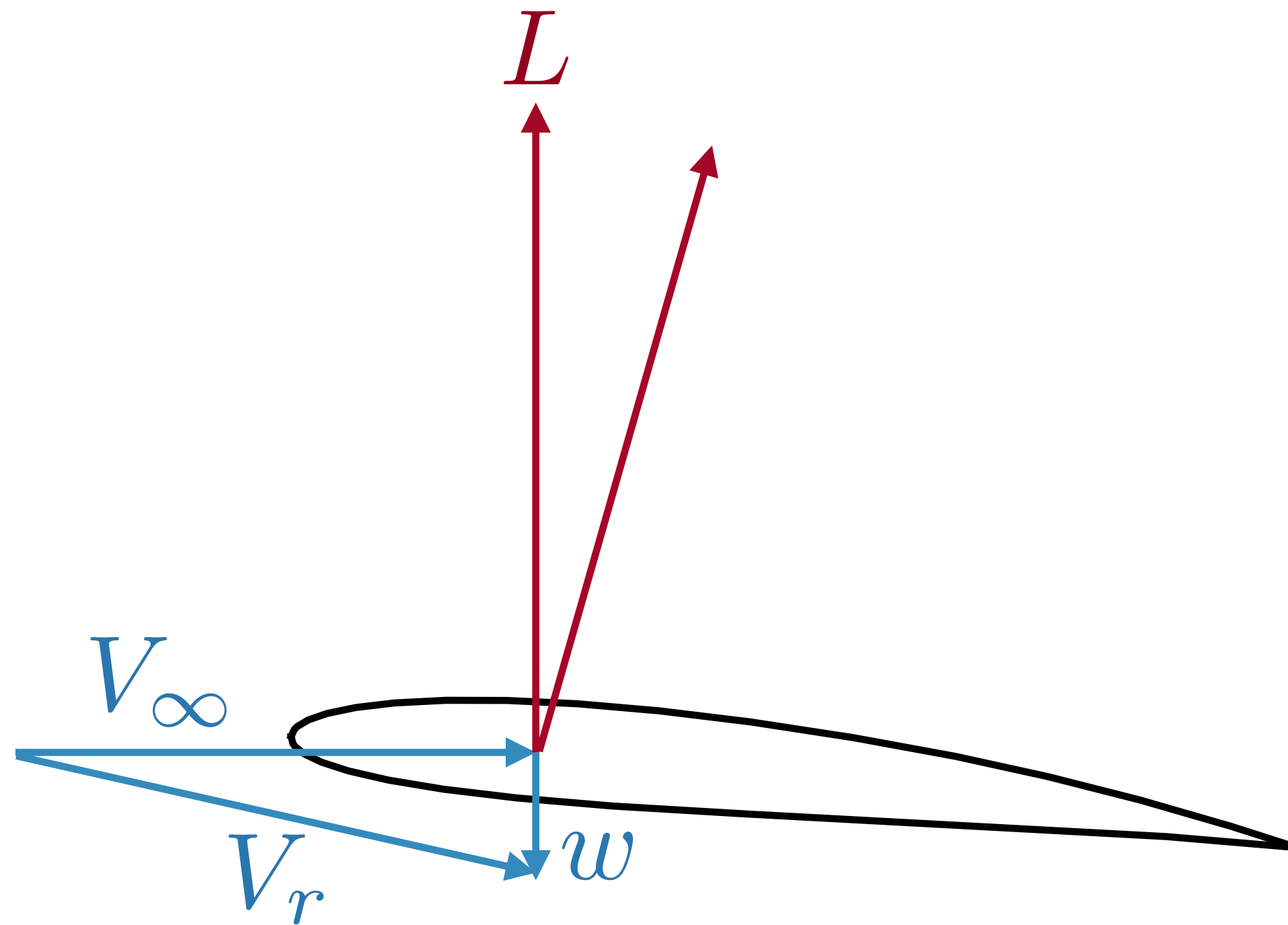
Induced Drag



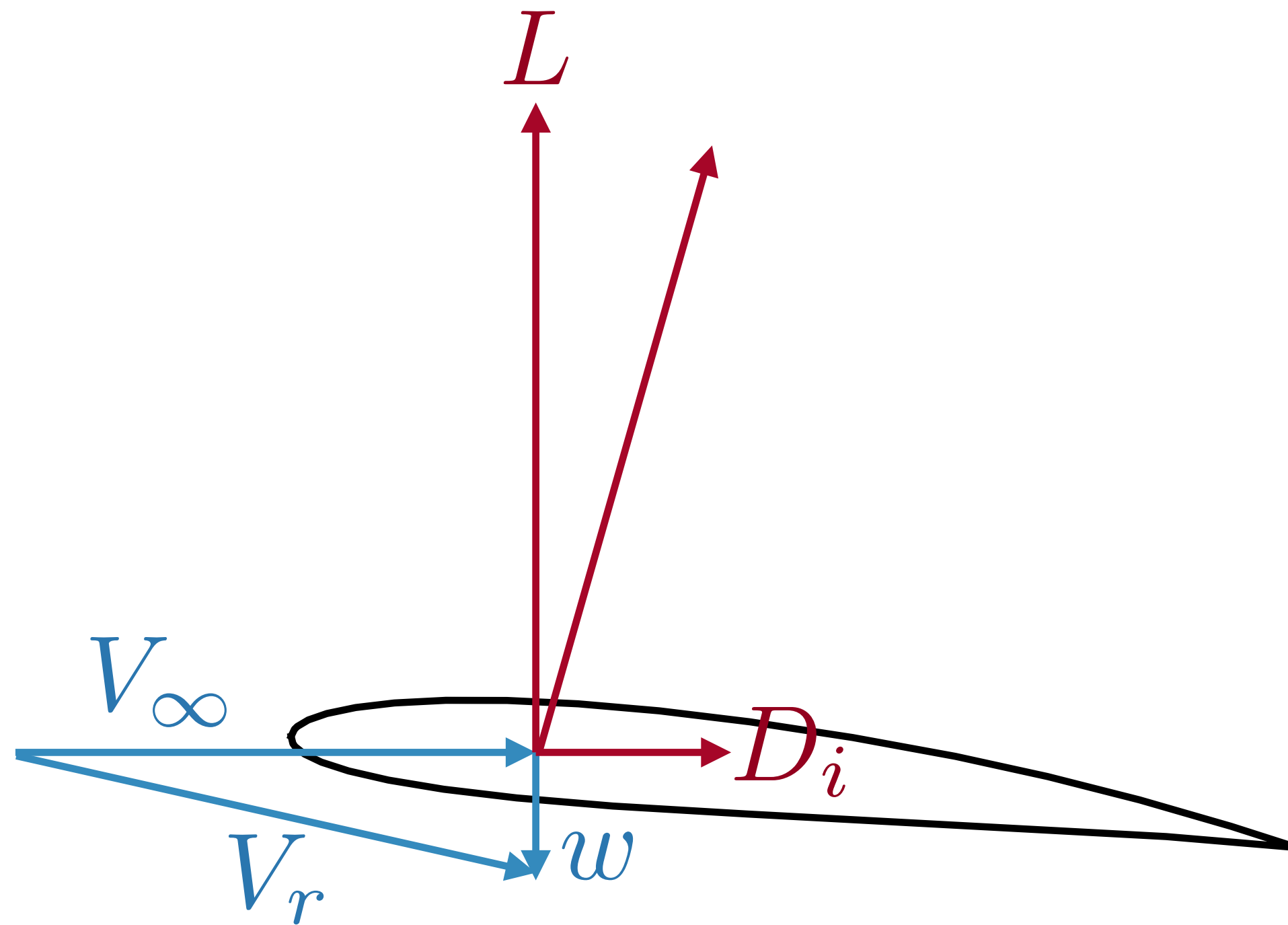
Induced Drag



Induced Drag



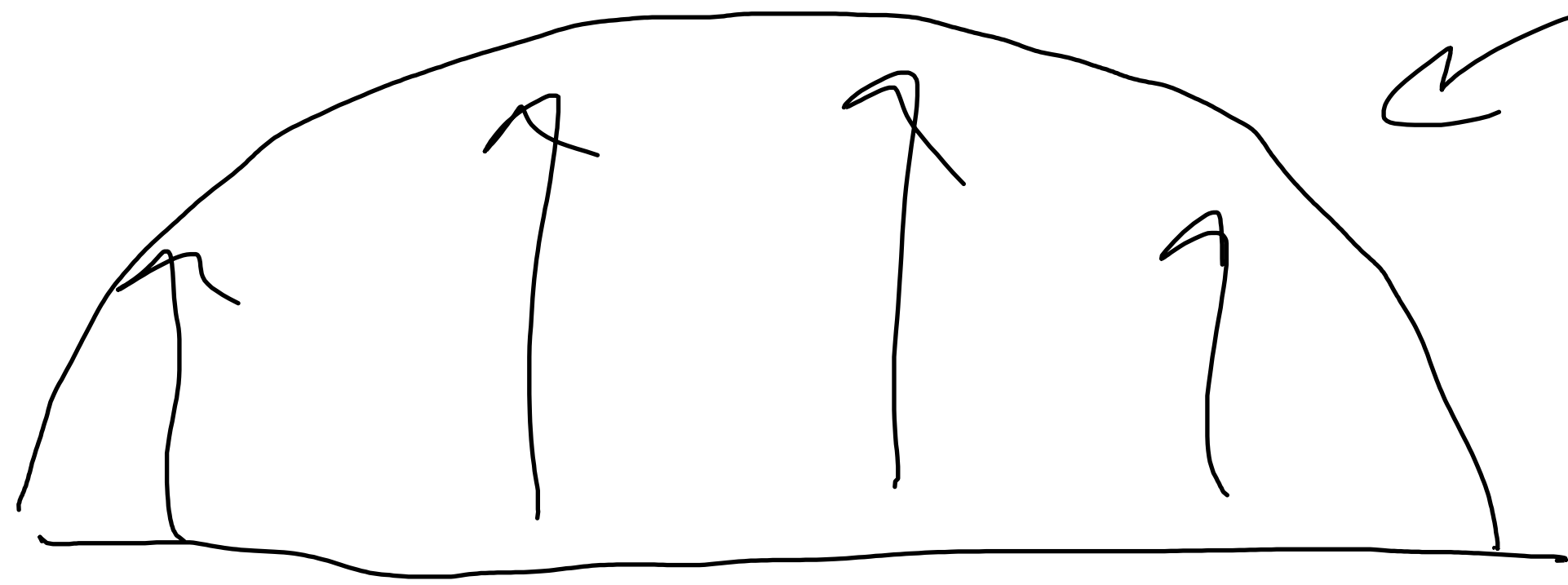
Induced Drag



Inviscid Induced Drag

$$D_i = \frac{L^2}{q_\infty \pi b^2 e_{inv}}$$

$$C_{D_i} = \frac{C_L^2}{\pi A R e_{inv}}$$



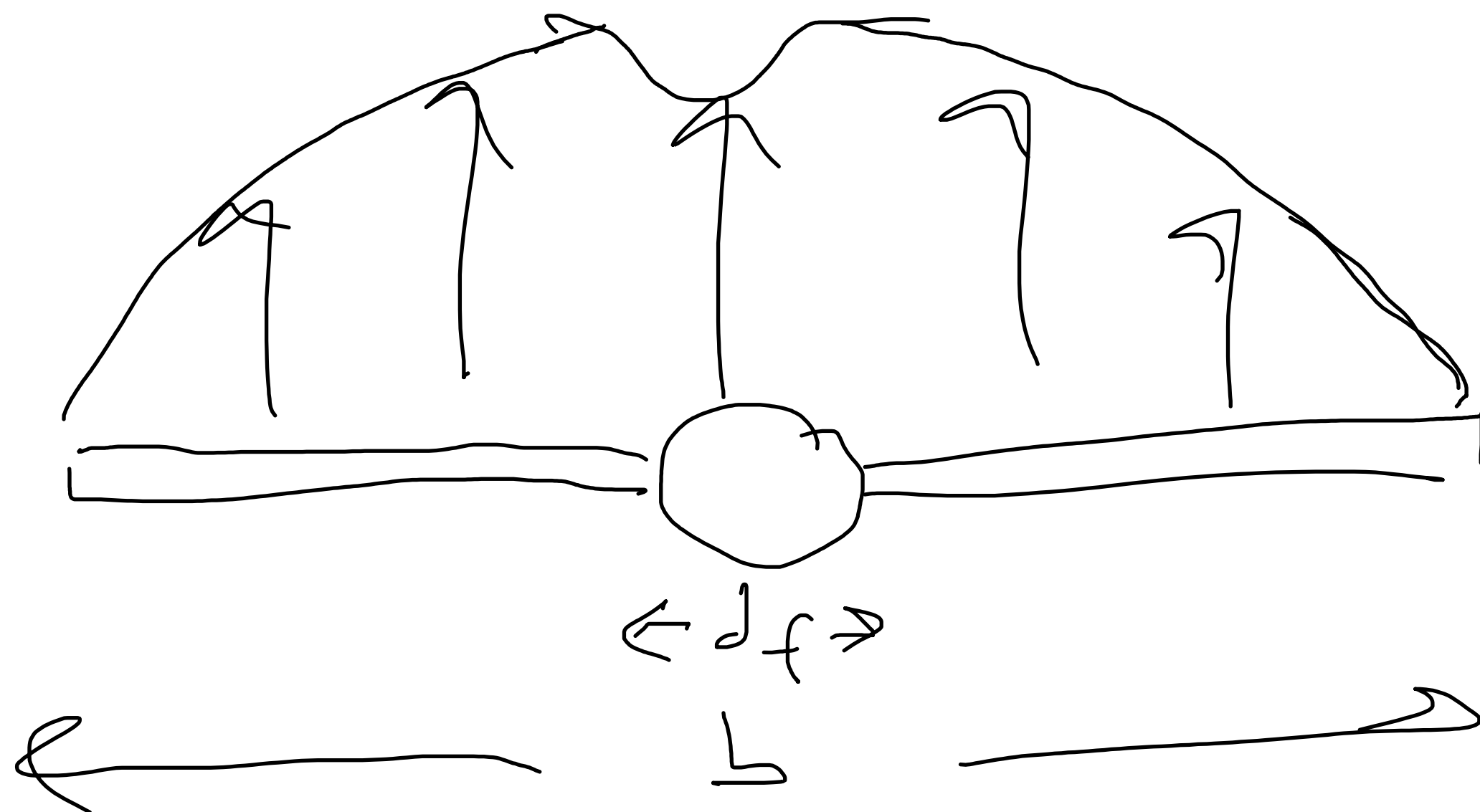
lift distribution

elliptic $\Rightarrow e_{inv} = 1$

$$e_{inv} \sim 0.98$$

↓
inviscid span efficiency

$$e_{inv} \approx 0.99 \left[1 - 2 \left(\frac{d_F}{b} \right)^2 \right]$$



Viscous Induced Drag

$$C_{Di,v} = K C_{Dp} C_L^2$$

$$K \sim 0.38$$

$$C_{Di} = \underbrace{\frac{C_L^2}{\pi A R e_{inv}}}_{\text{inviscid}} + \underbrace{K C_{Dp} C_L^2}_{\text{viscous}}$$

$$e_{inv} \sim 0.98$$

$$e \sim 0.7 - 0.85$$

$$= \frac{C_L^2}{\pi A R} \left(\underbrace{\frac{1}{e_{inv}} + K C_{Dp}}_{1/e} \right)$$

$$\Rightarrow \boxed{C_{Di} = \frac{C_L^2}{\pi A R e}} \text{ where}$$

Oswald efficiency factor

$$e = \frac{1}{\frac{1}{e_{inv}} + K C_{Dp} \pi A R}$$