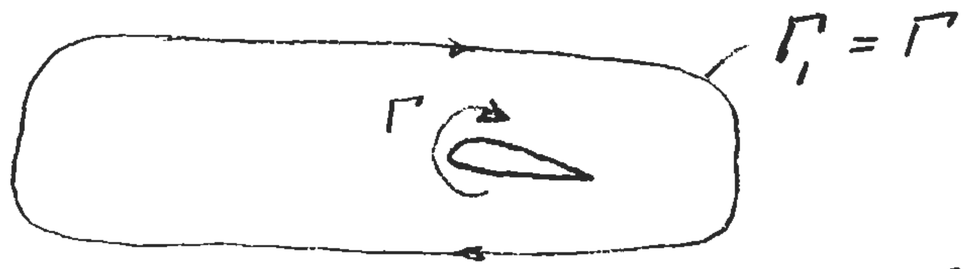
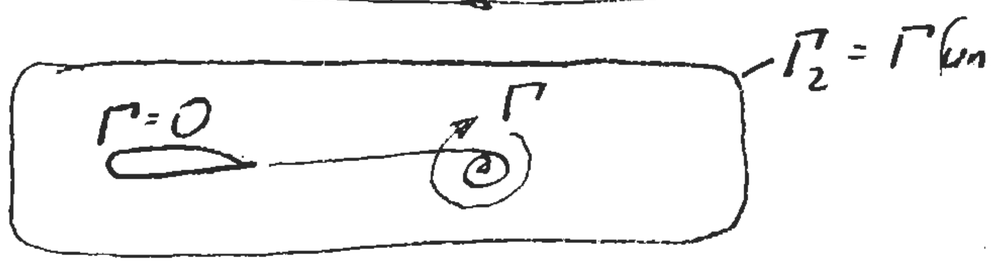
F1a. Before touchdown:



After touchdown:

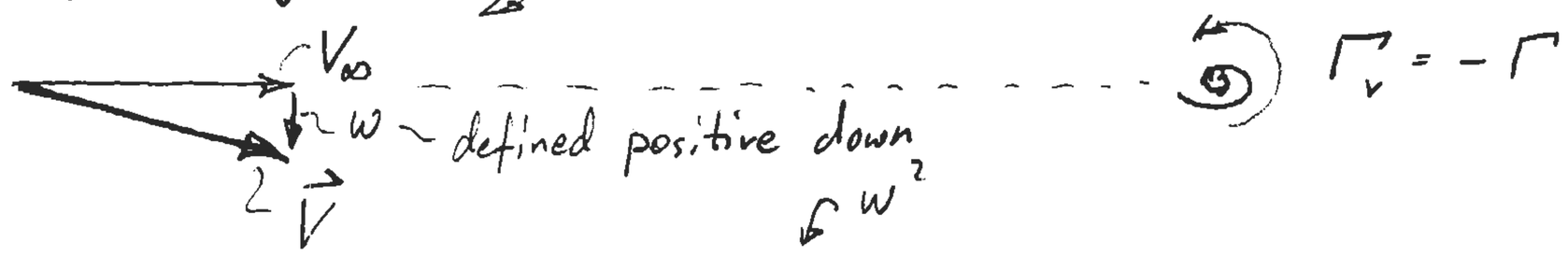


Airfoil sheds a vortex which contains all the airfoil's intial circulation.
Airfoil is left with zero circulation.

F1b. Since initial circulation is zero,

must have $\Gamma_v = -\Gamma$

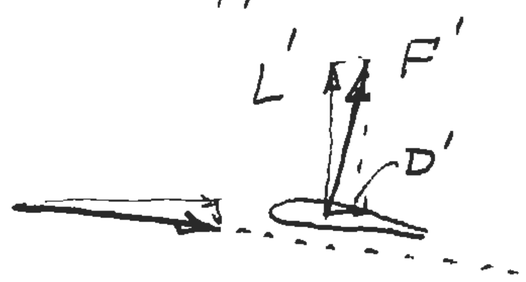
Velocity seen by airfoil



$$w = \frac{\Gamma}{2\pi d}, \quad |\vec{V}|^2 = V_\infty^2 + \left(\frac{\Gamma}{2\pi d}\right)^2 \approx V_\infty^2 \text{ if } w \ll V_\infty$$

Net lift force/span is perpendicular to apparent velocity.

$$F' = \rho |\vec{V}| \Gamma \approx \rho V_\infty \Gamma$$



force & velocity triangles are congruent.

Take components $\perp$ and $\parallel$ to $\vec{V}_\infty$

$$L' = F' \frac{V_\infty}{|\vec{V}|} \approx F' = \rho V_\infty \Gamma \longrightarrow c_\ell = \frac{L'}{\frac{1}{2}\rho V_\infty^2 c} = \frac{2\Gamma}{c V_\infty}.$$

$$D' = F' \frac{w}{|\vec{V}|} \approx F' \frac{w}{V_\infty} = \rho w \Gamma \longrightarrow c_d = \frac{D'}{\frac{1}{2}\rho V_\infty^2 c} = \frac{2\Gamma}{c V_\infty} \frac{w}{V_\infty} = c_\ell \frac{w}{V_\infty}$$

or $c_d = \frac{2\Gamma}{c V_\infty} \cdot \frac{\Gamma}{2\pi d V_\infty} = \frac{1}{4\pi} \frac{c}{d} c_\ell^2$

since $w \sim \frac{1}{d} \sim \frac{1}{\text{time}}$

C_d decreases as $\frac{1}{\text{time}}$