Airfoils and Wings

Lecture 3

ME EN 415
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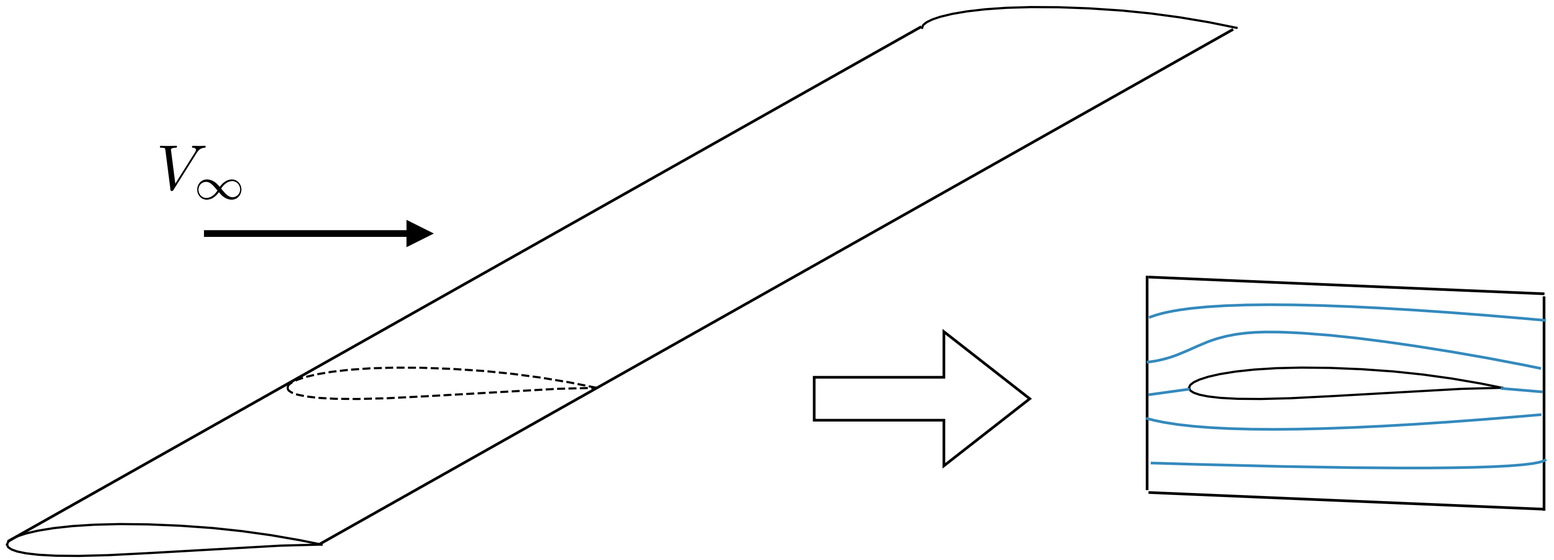
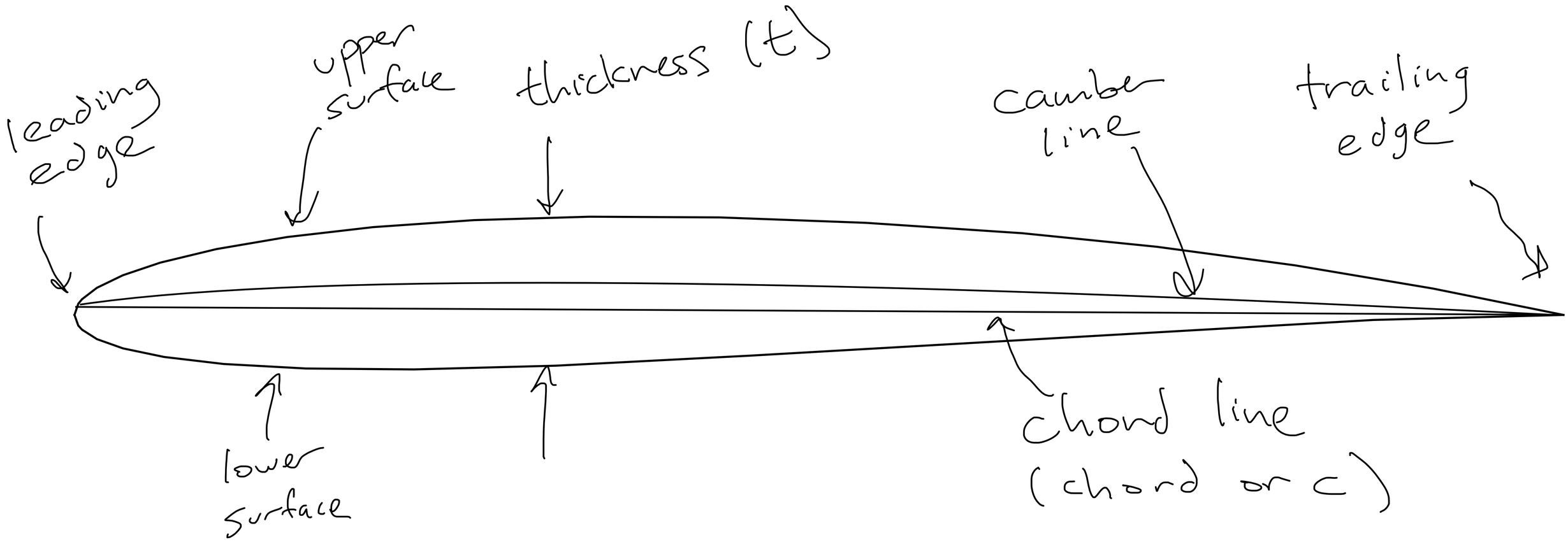
Airfoil

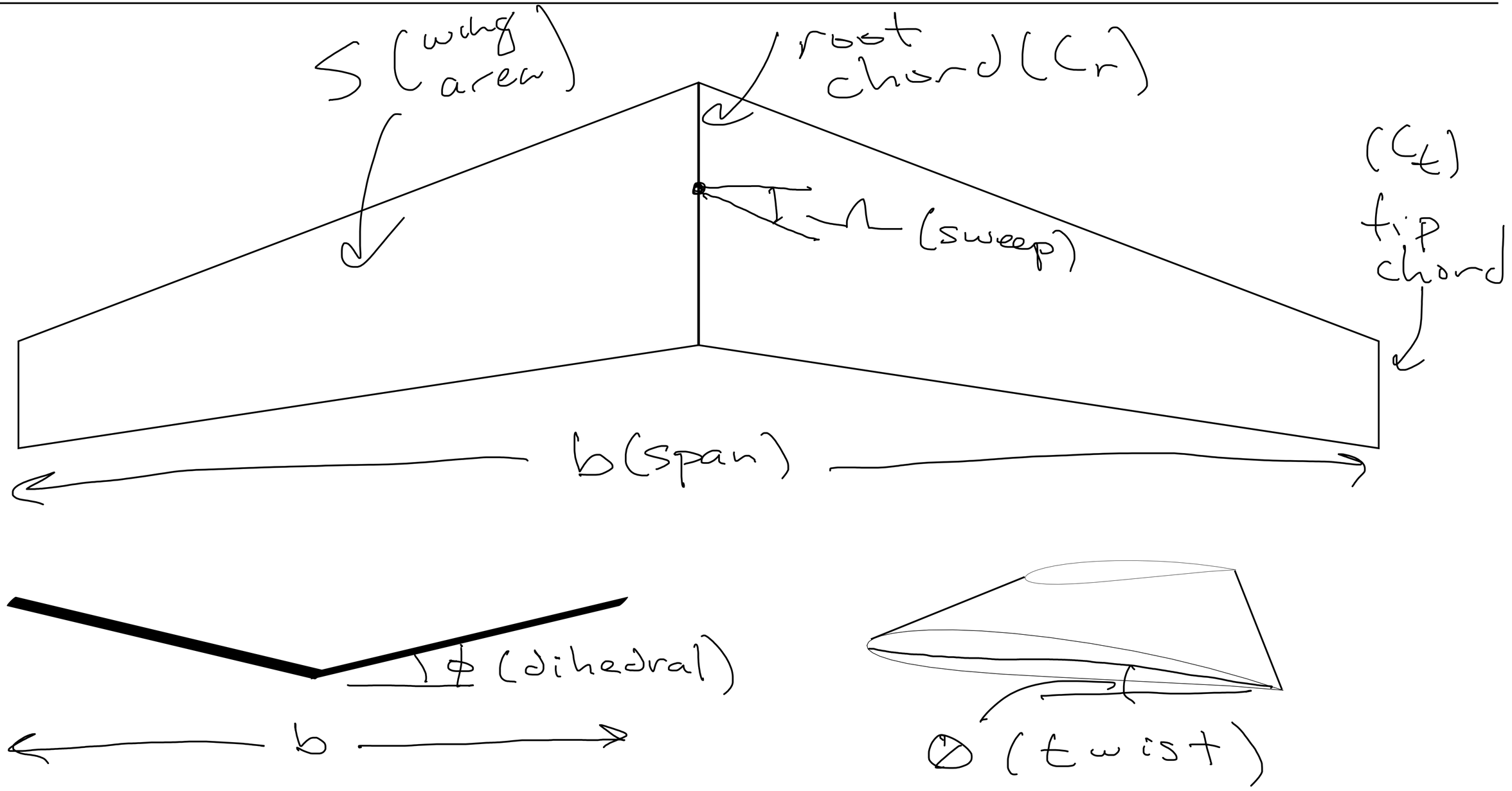


Airfoil Nomenclature



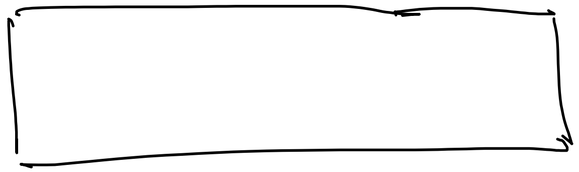
$\frac{t}{c}$: thickness-to-chord ratio

Wing Nomenclature

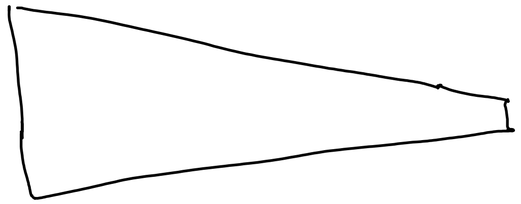


taper ratio

$$\lambda = \frac{C_t}{C_r}$$



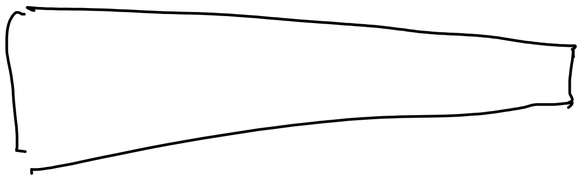
$\lambda = 1$



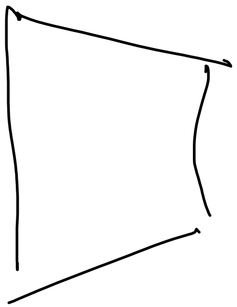
$\lambda = 0.2$

aspect ratio

$$AR = AR = \frac{b^2}{S}$$

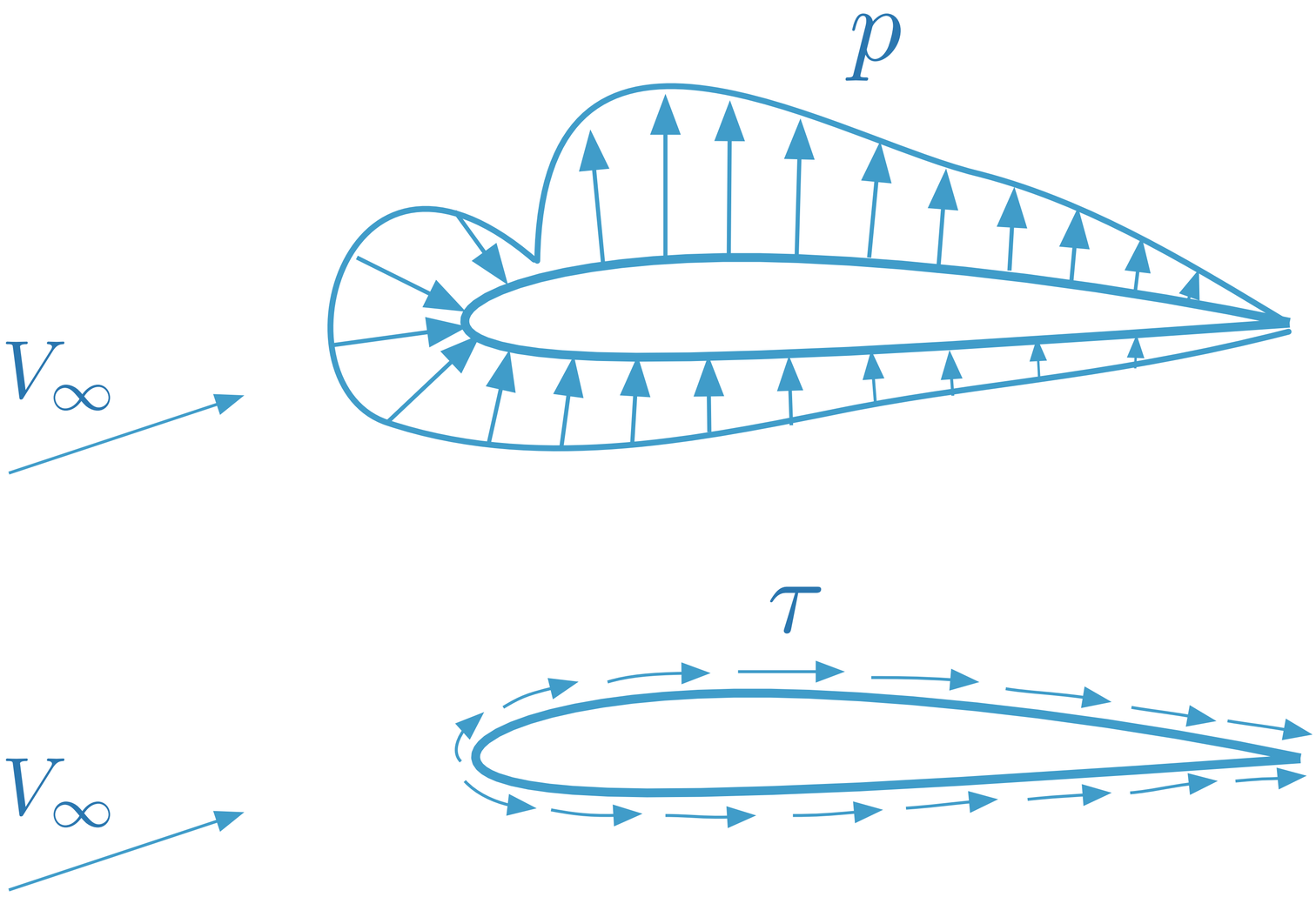


high AR

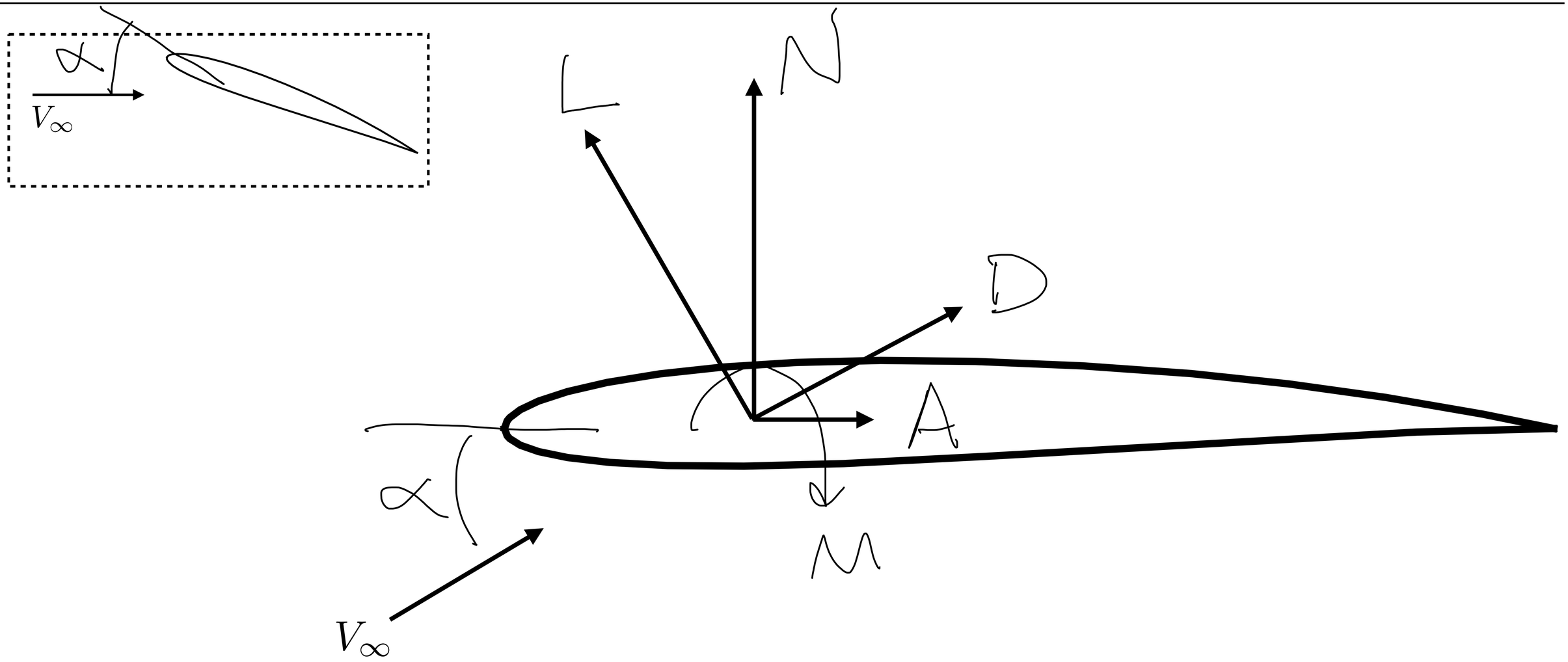


low AR

Forces and Moment



Forces and Moment



Force Coefficients

$$q_\infty = \frac{1}{2}\rho V_\infty^2$$ dynamic pressure

$$c_l = \frac{L'}{q_\infty c}$$ lift coefficient

$$c_d = \frac{D'}{q_\infty c}$$ drag coefficient

$$c_m = \frac{M'}{q_\infty c^2}$$ (pitching) moment coefficient

$$Re = \frac{\rho V_\infty c}{\mu}$$

$$M = \frac{V_\infty}{a}$$

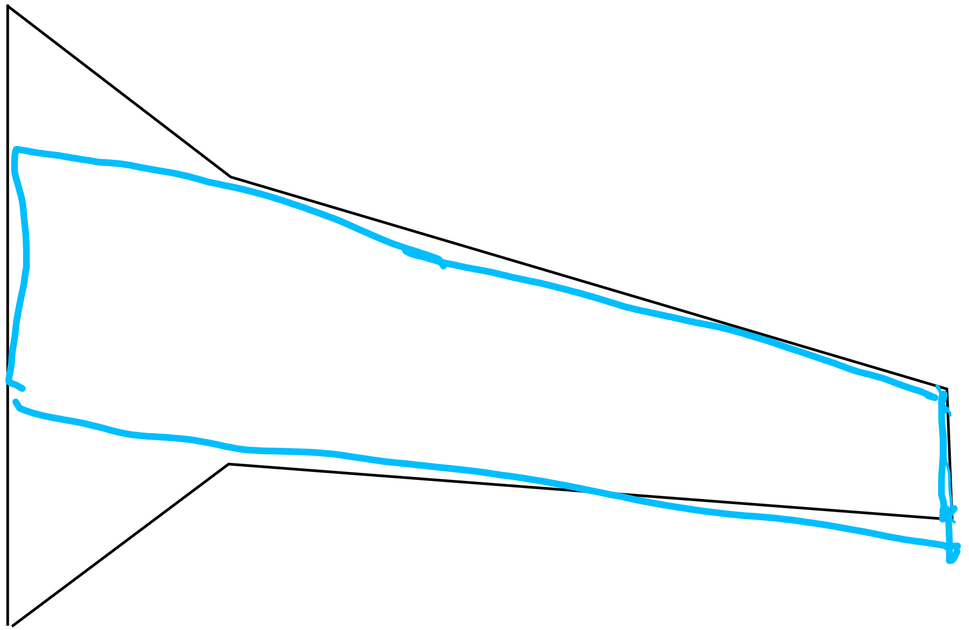
$$c_d = f(\alpha, Re, M, \text{geometry}^*)$$

Force Coefficients for a Wing (Lifting Surface)

$$C_L = \frac{L}{q_\infty S}$$

$$C_D = \frac{D}{q_\infty S}$$

$$C_M = \frac{M}{q_\infty S c}$$



$$C_p = \frac{P - P_\infty}{q_\infty}$$

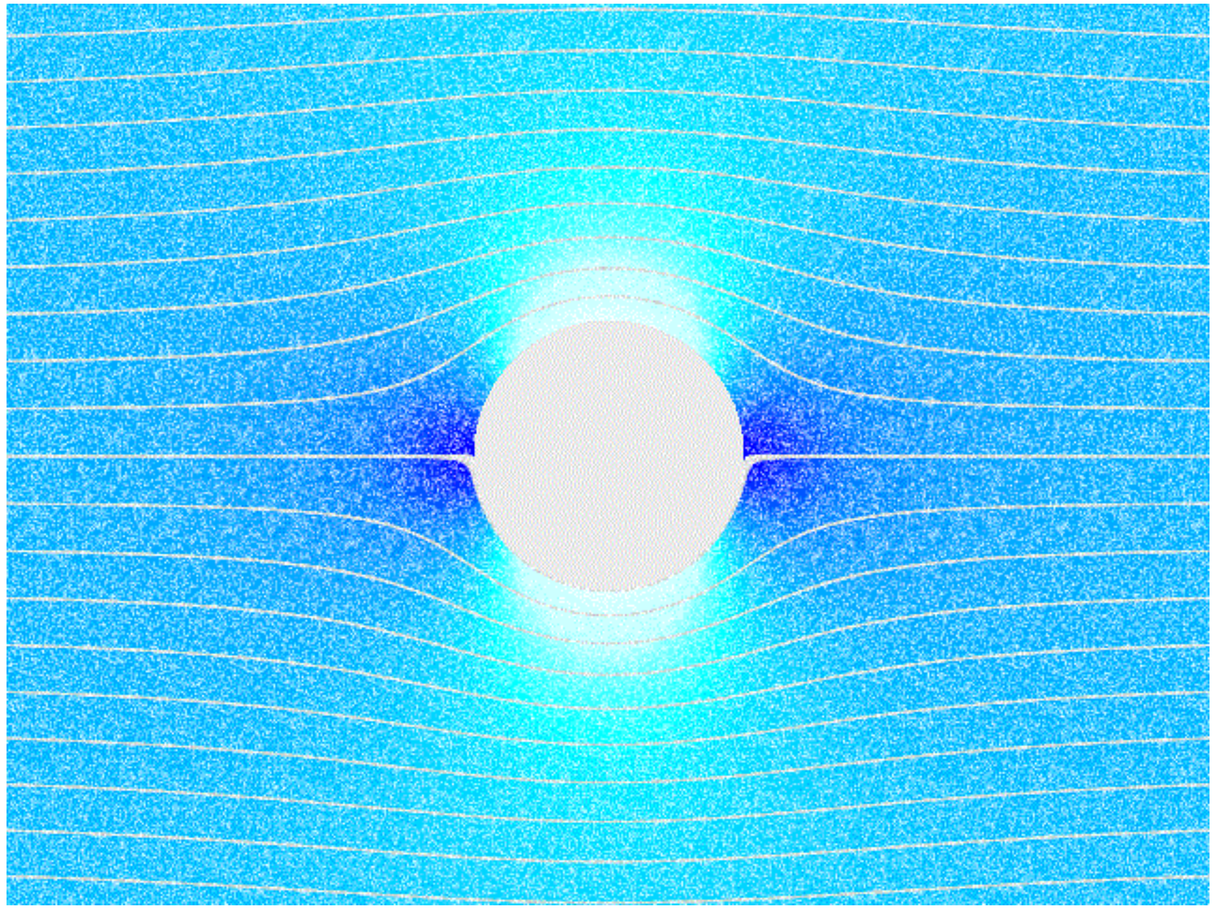
$$P_\infty + \frac{1}{2}\rho V_\infty^2 = P + \frac{1}{2}\rho V^2 \Rightarrow P - P_\infty = \frac{1}{2}\rho\left(V_\infty^2 - V^2\right)$$

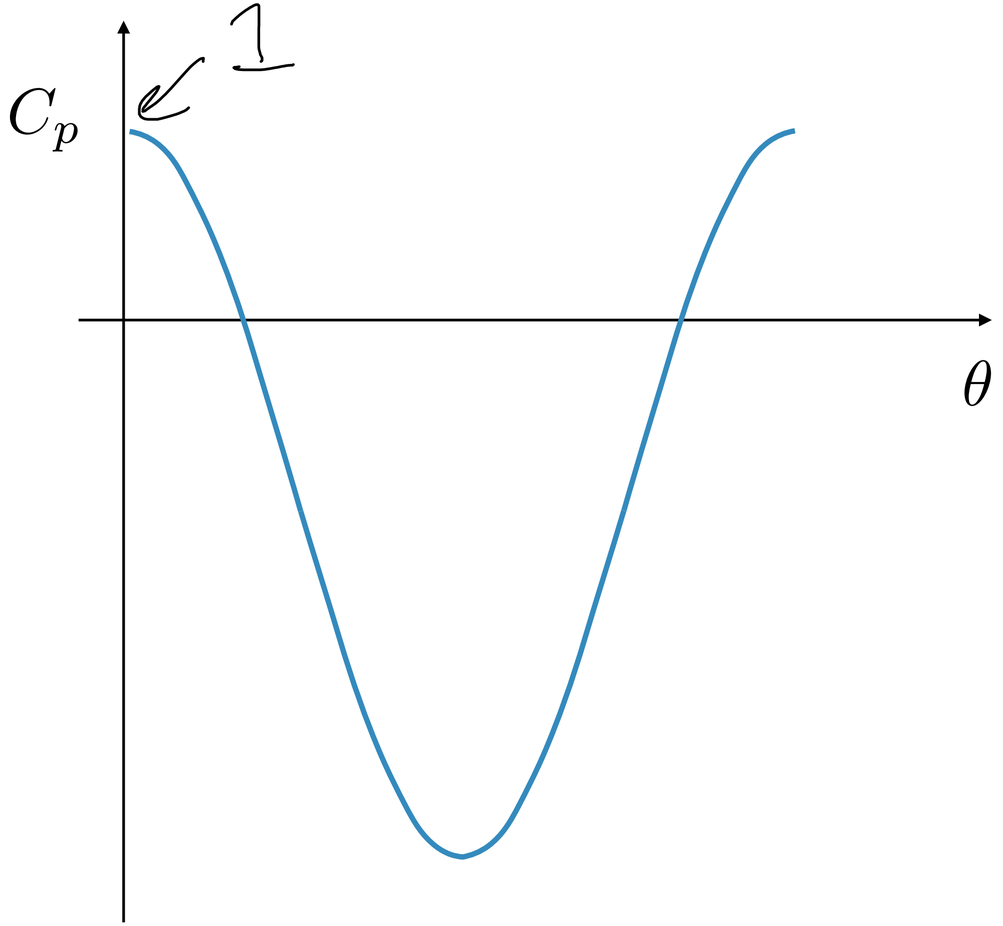
$$C_p = \frac{\frac{1}{2}\rho\left(V_\infty^2 - V^2\right)}{\frac{1}{2}\rho V_\infty^2} = 1 - \left(\frac{V}{V_\infty}\right)^2 \quad \text{(incompressible)}$$

Center of pressure: location where distributed loads effectively act (e.g., zero moments)

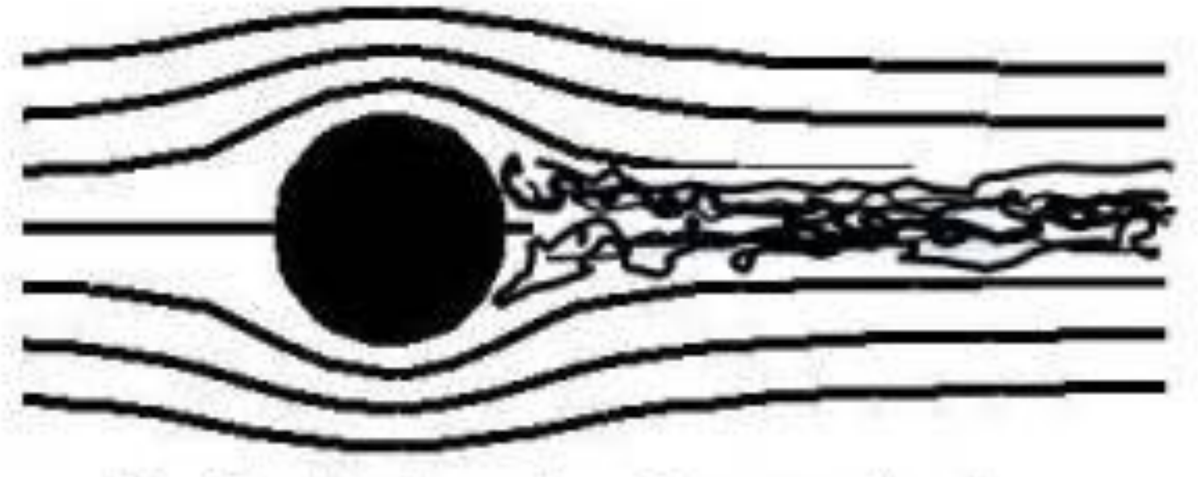
Aerodynamic center: point at which the pitching moment is independent of angle of attack $\frac{dc_m}{d\alpha} = 0$

Cylinder

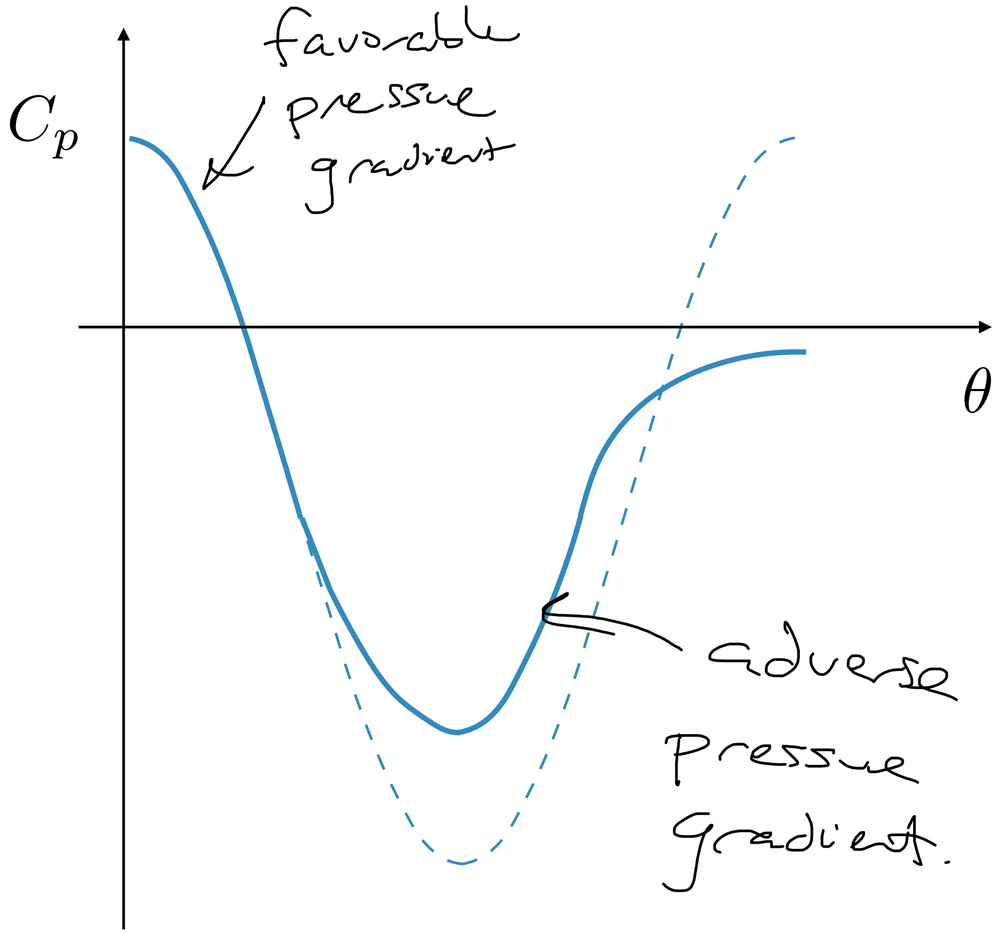




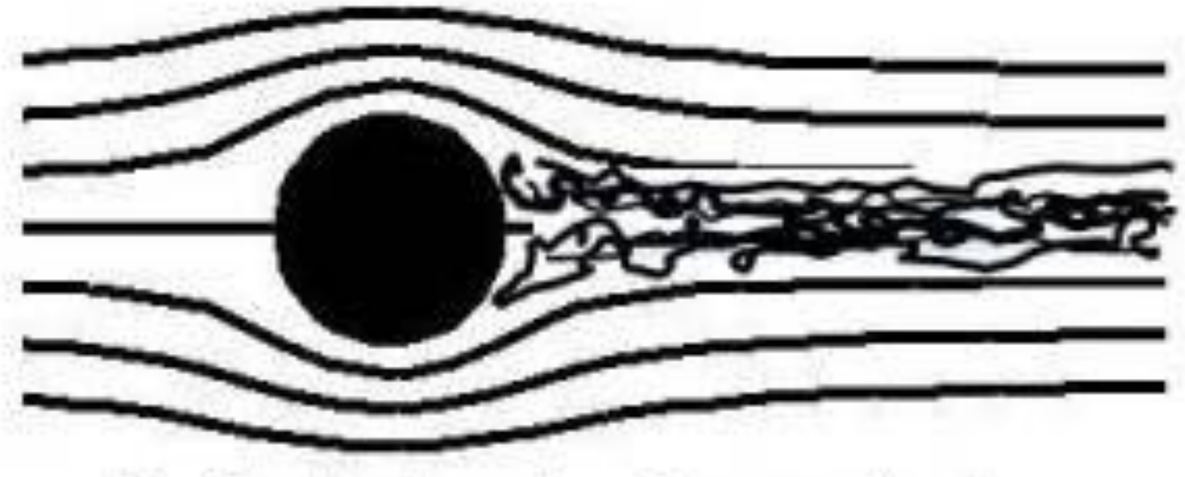
Cylinder



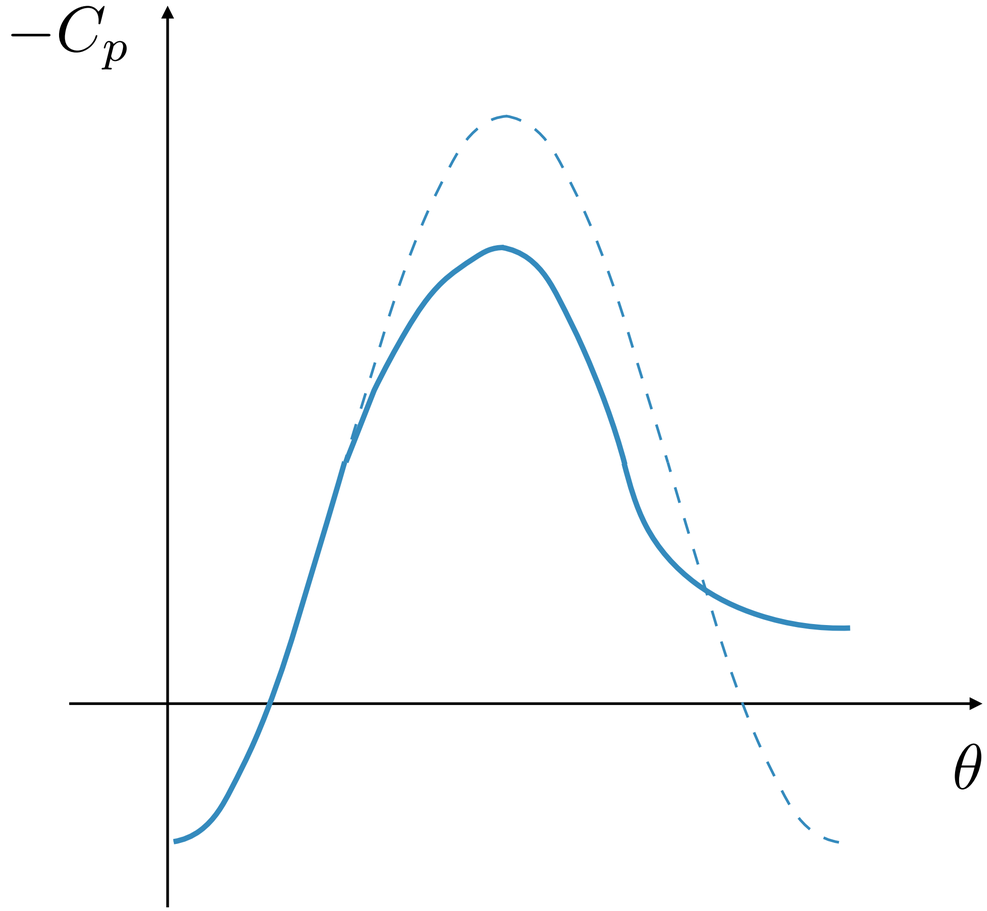
NASA



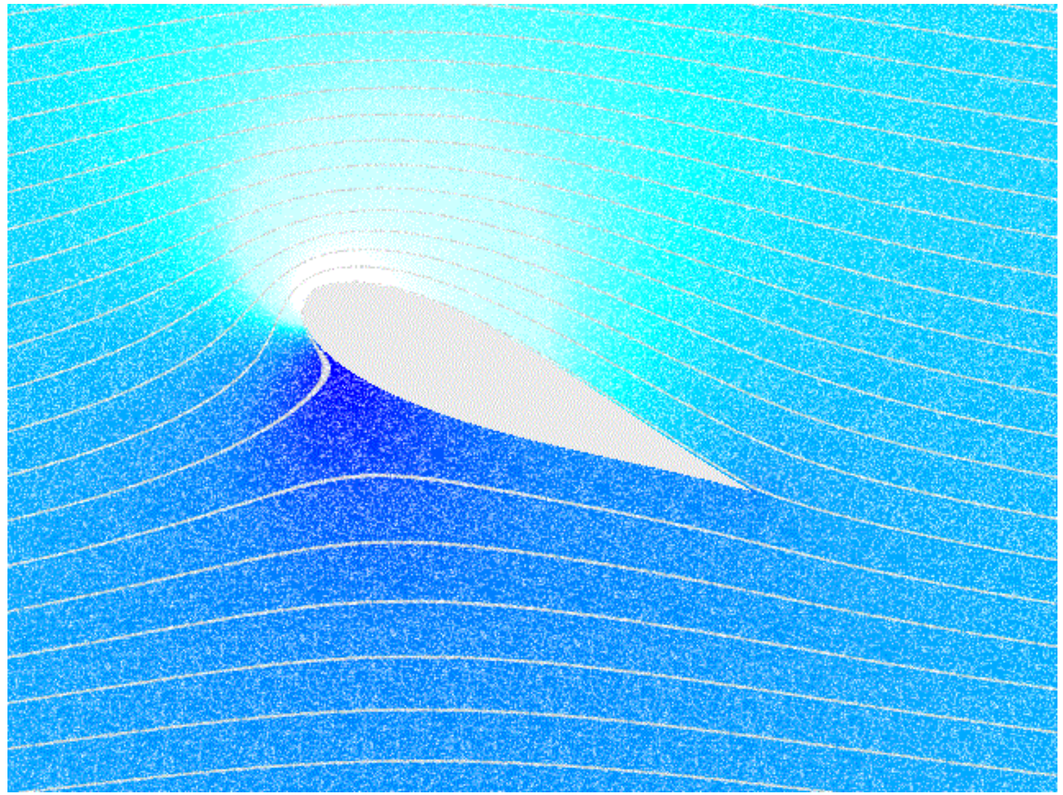
Cylinder

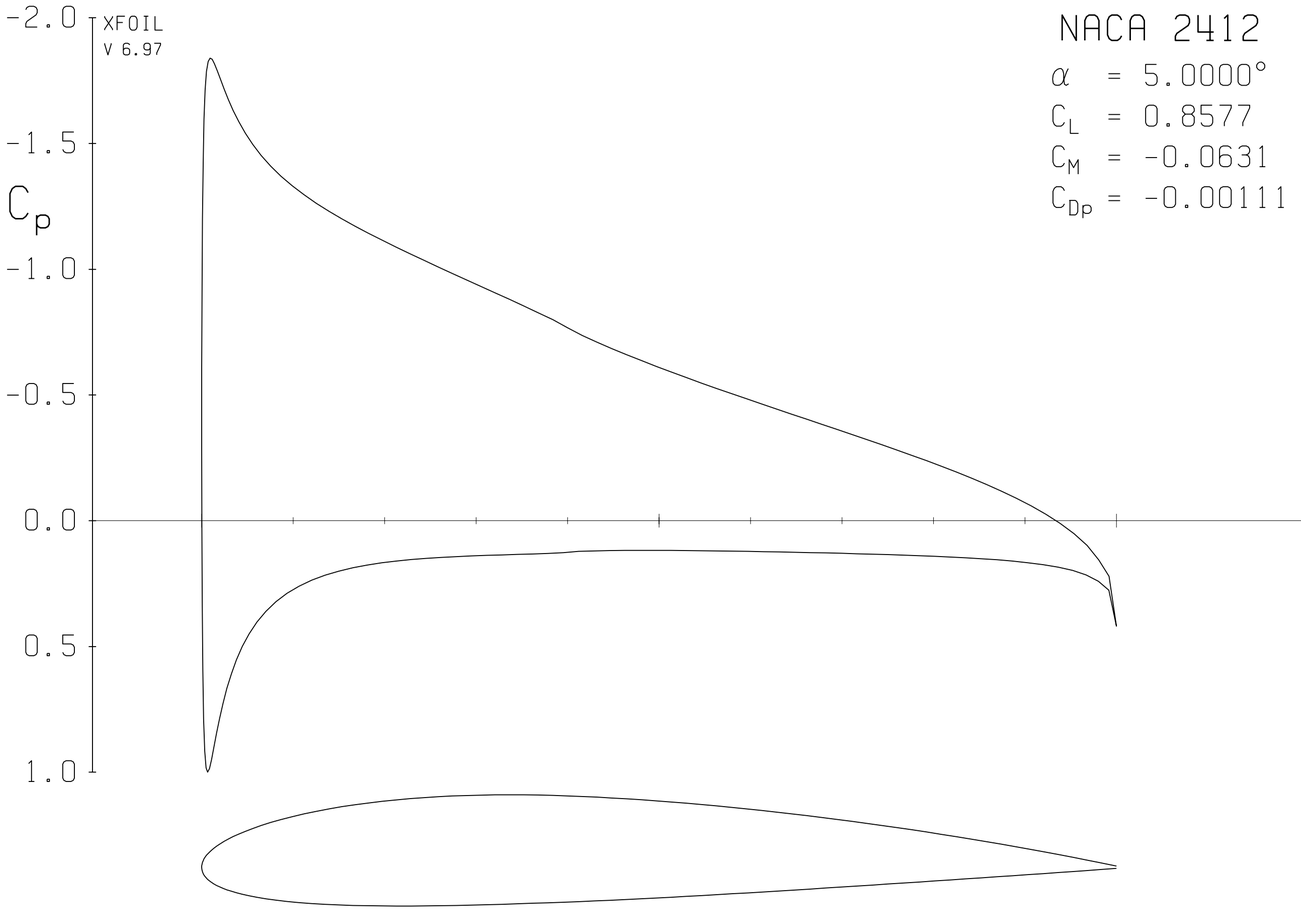


NASA

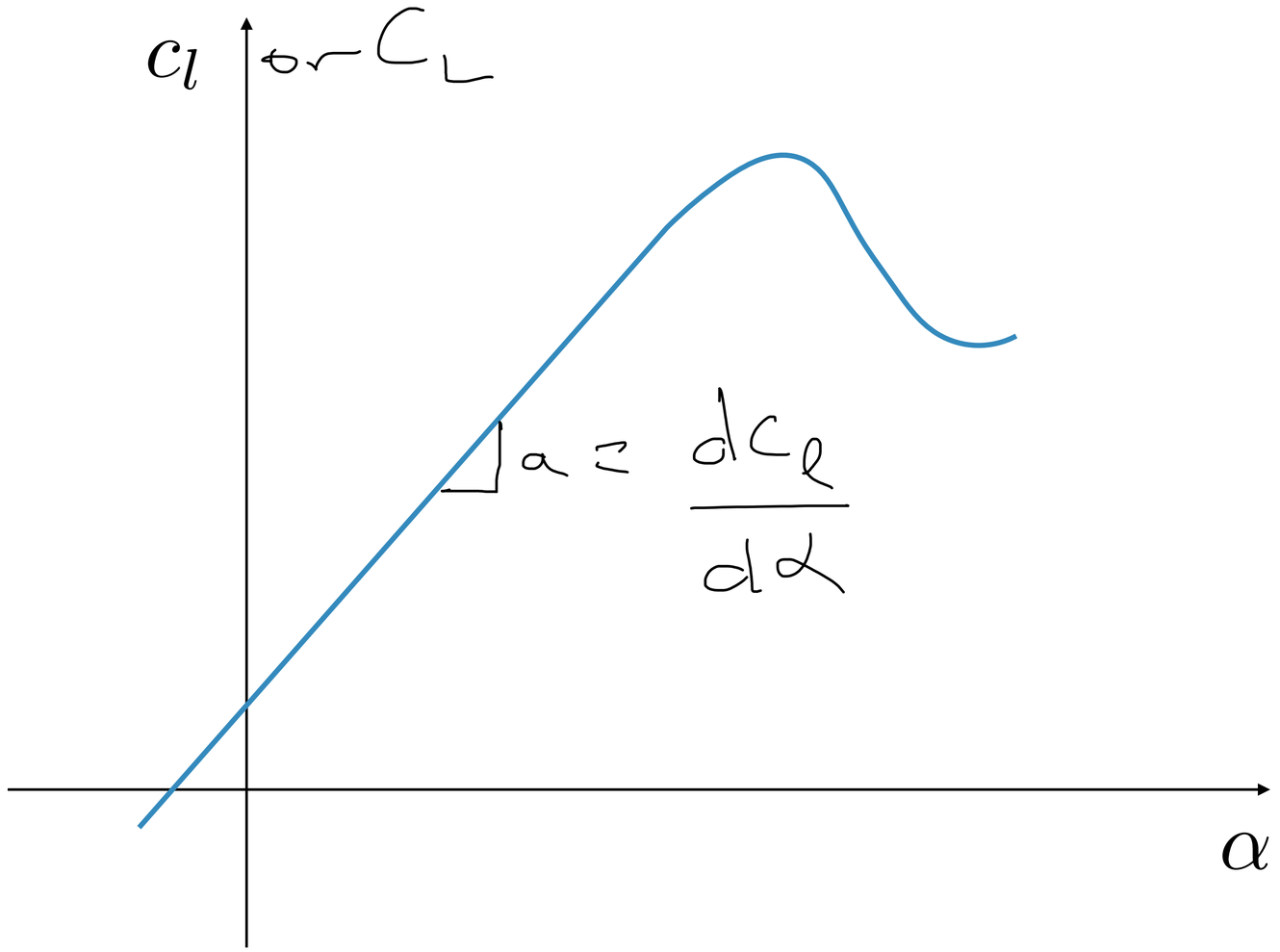


Pressure Distribution

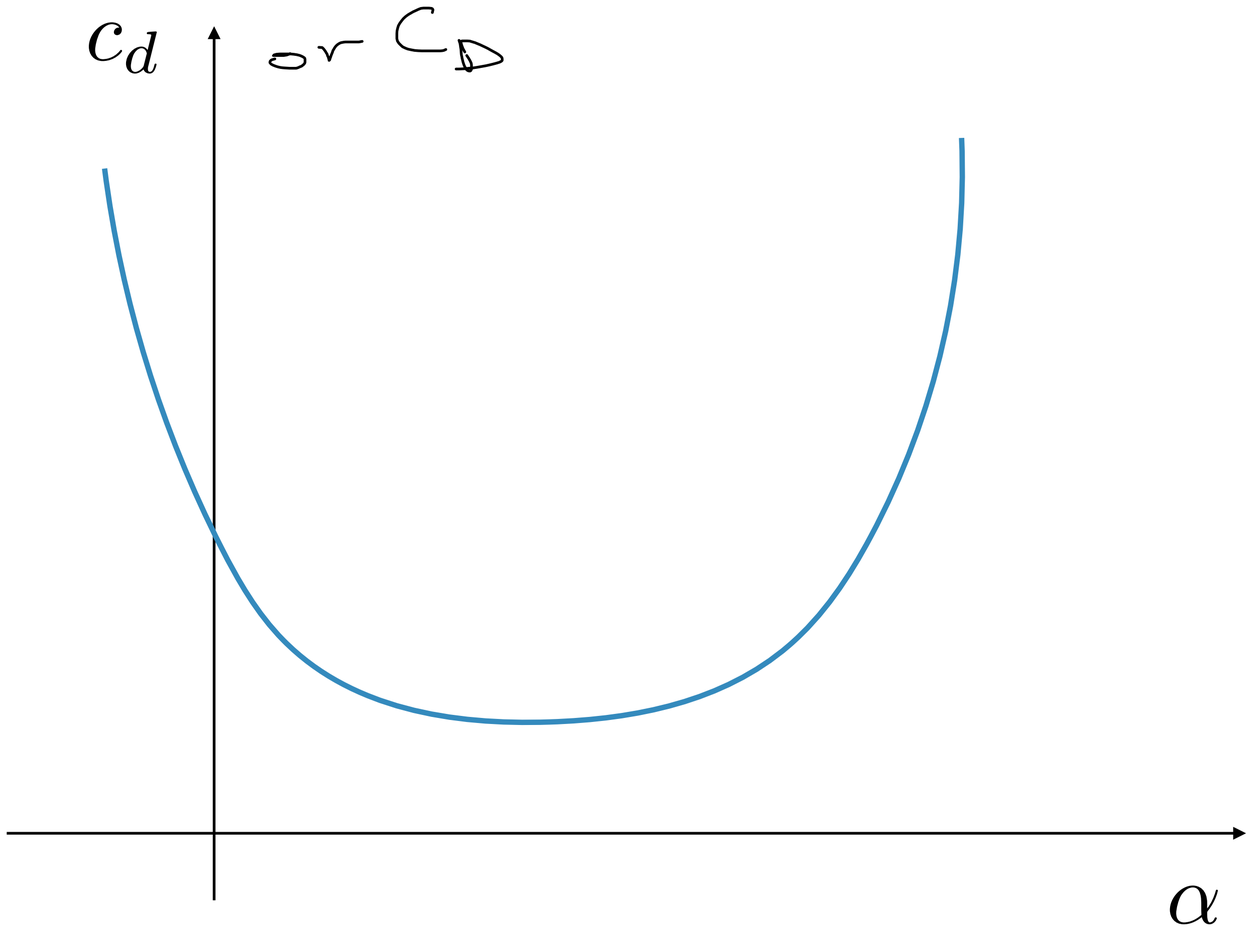




Lift Curve



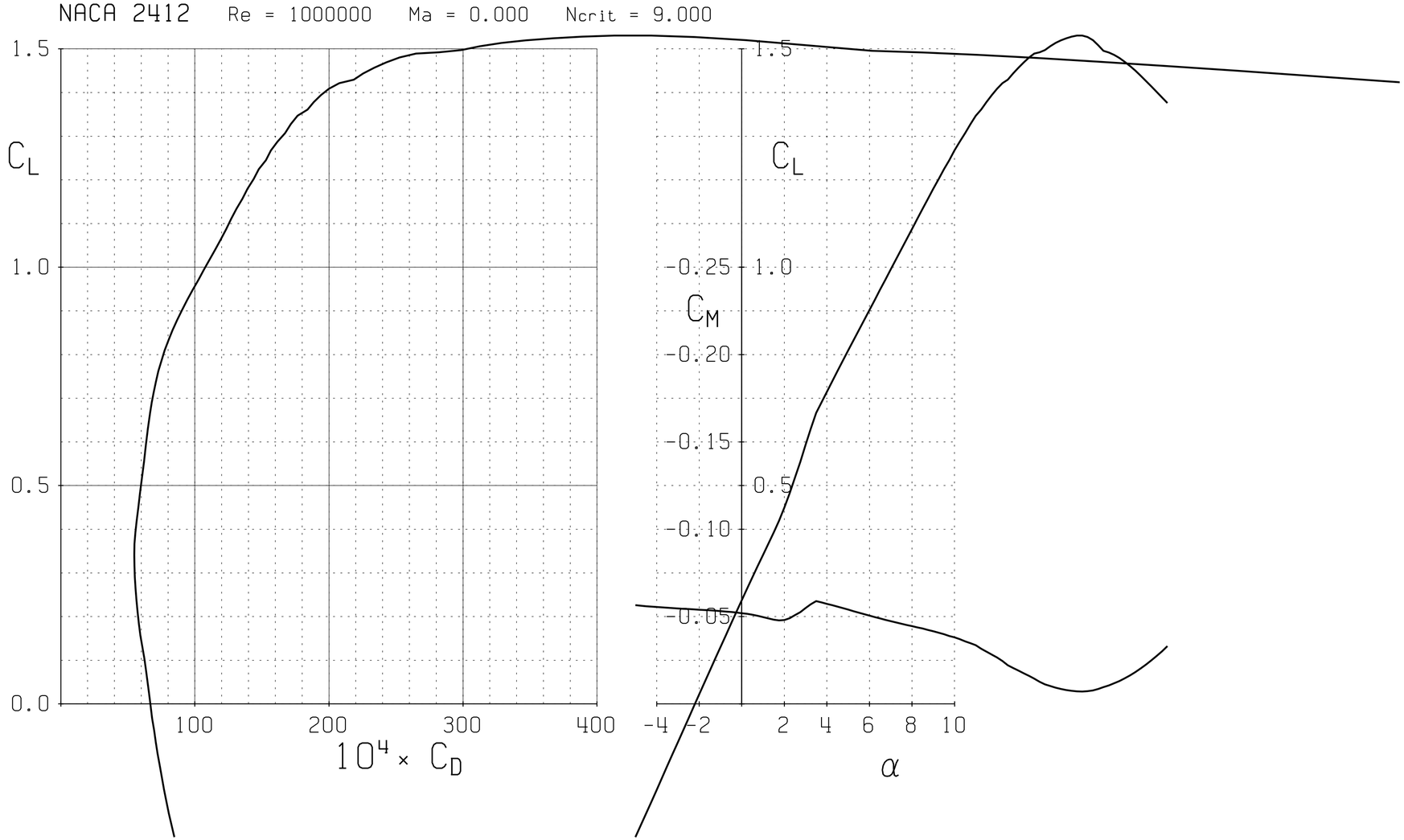
Drag Polar



or more commonly as c_d vs c_l

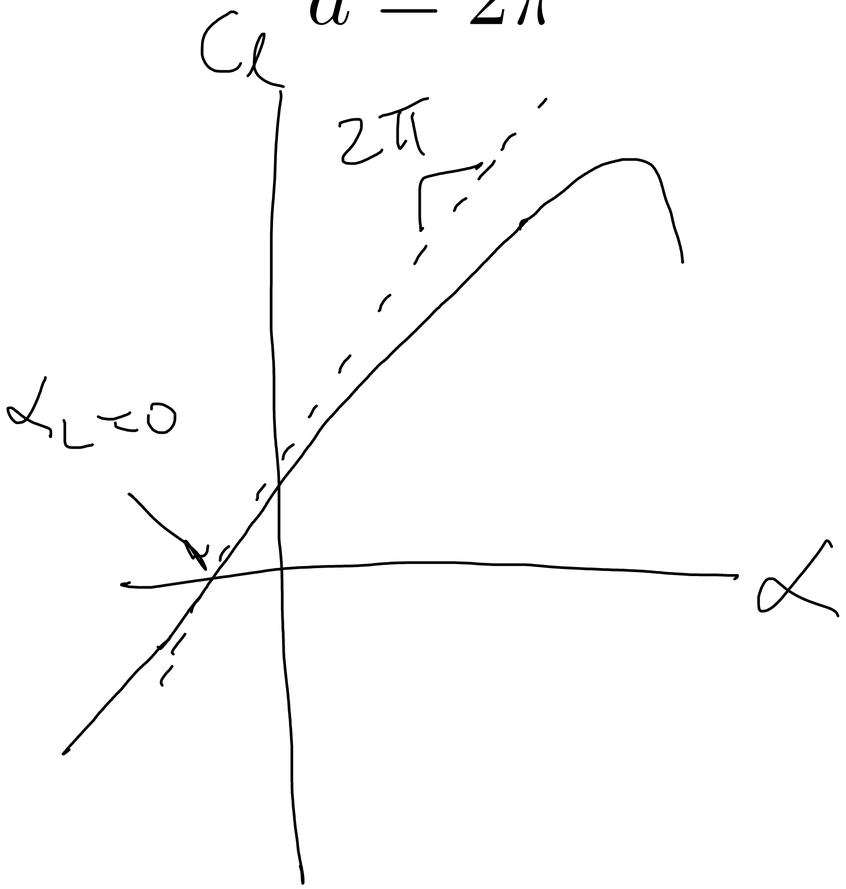
Drag Polar and Lift Curve

$\frac{L}{D}$



Thin Airfoil Theory

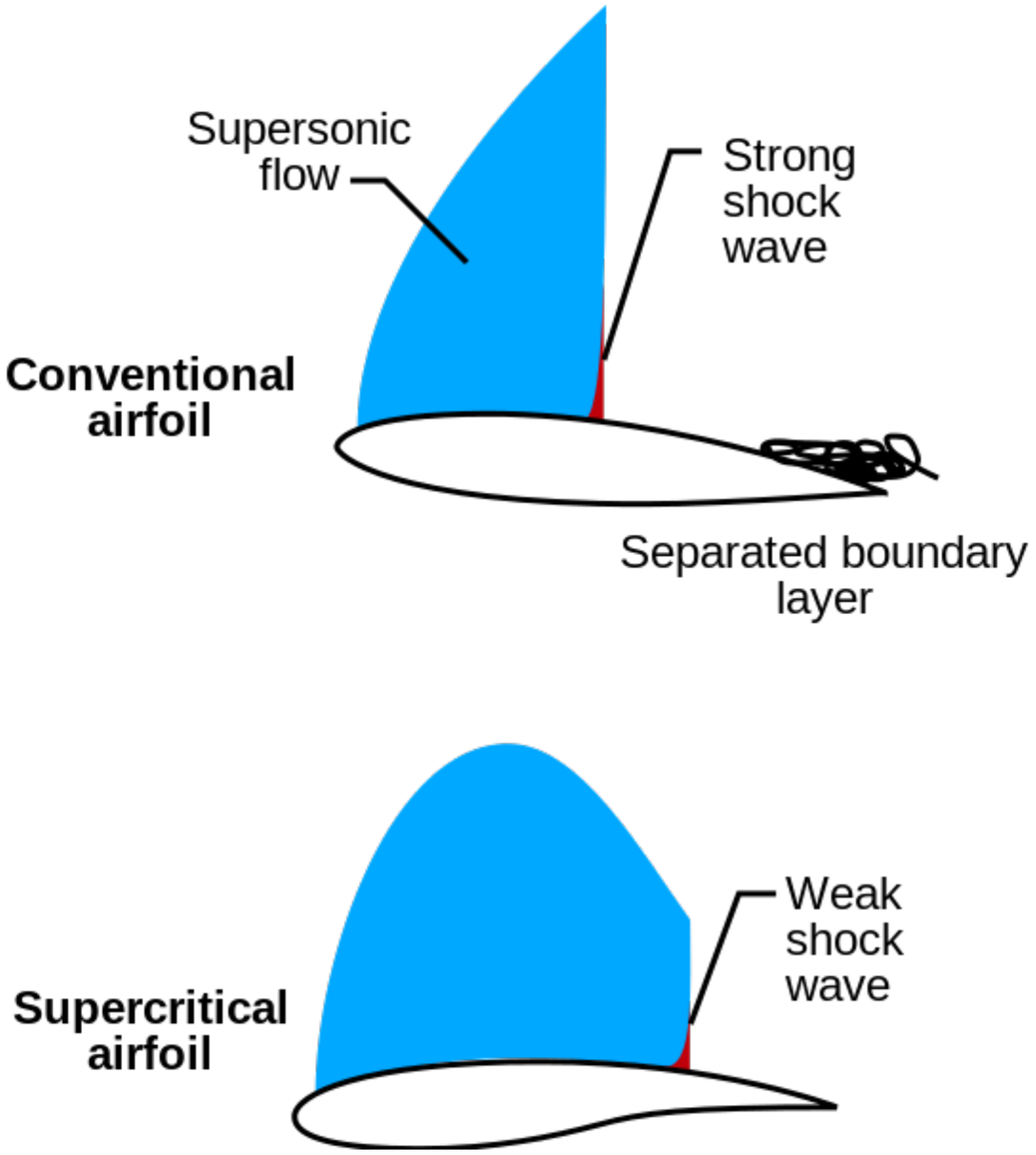
$a = 2\pi$

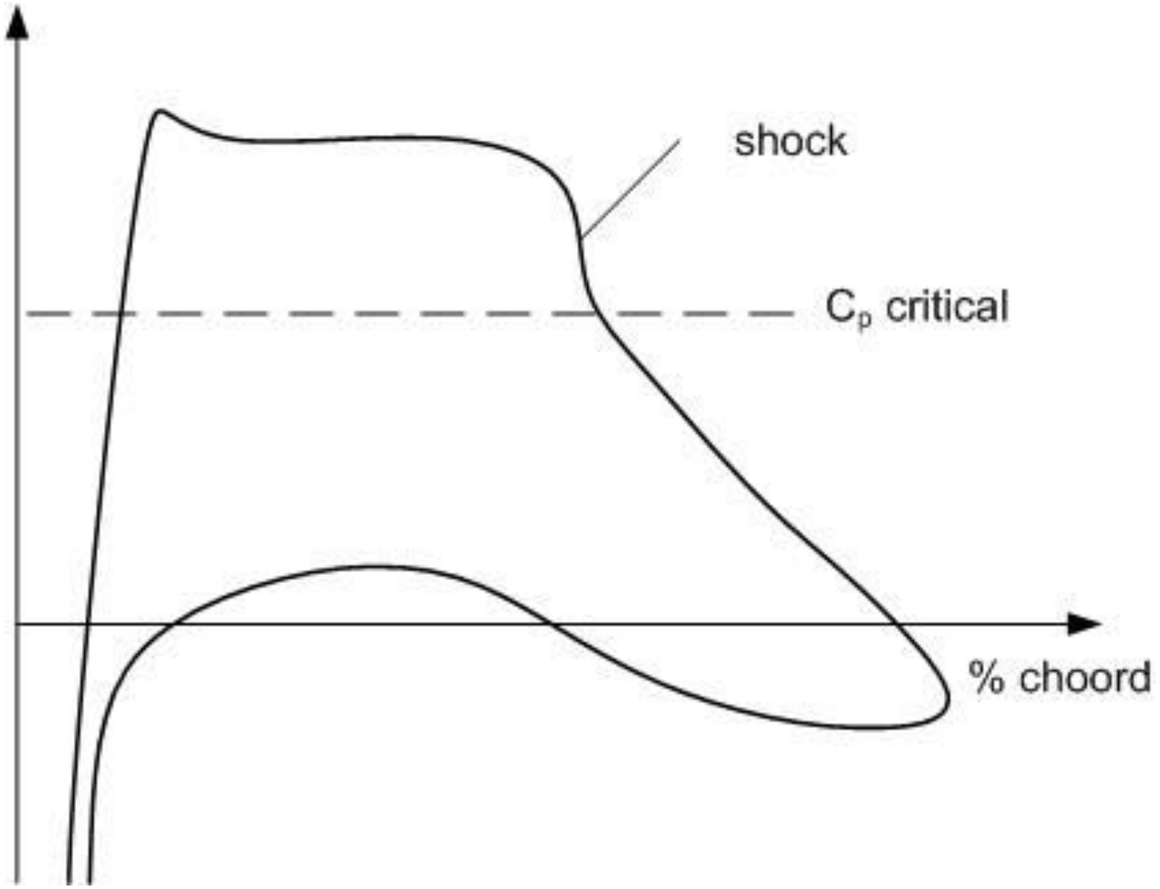


$$C_l = a(\alpha - \alpha_{L=0})$$

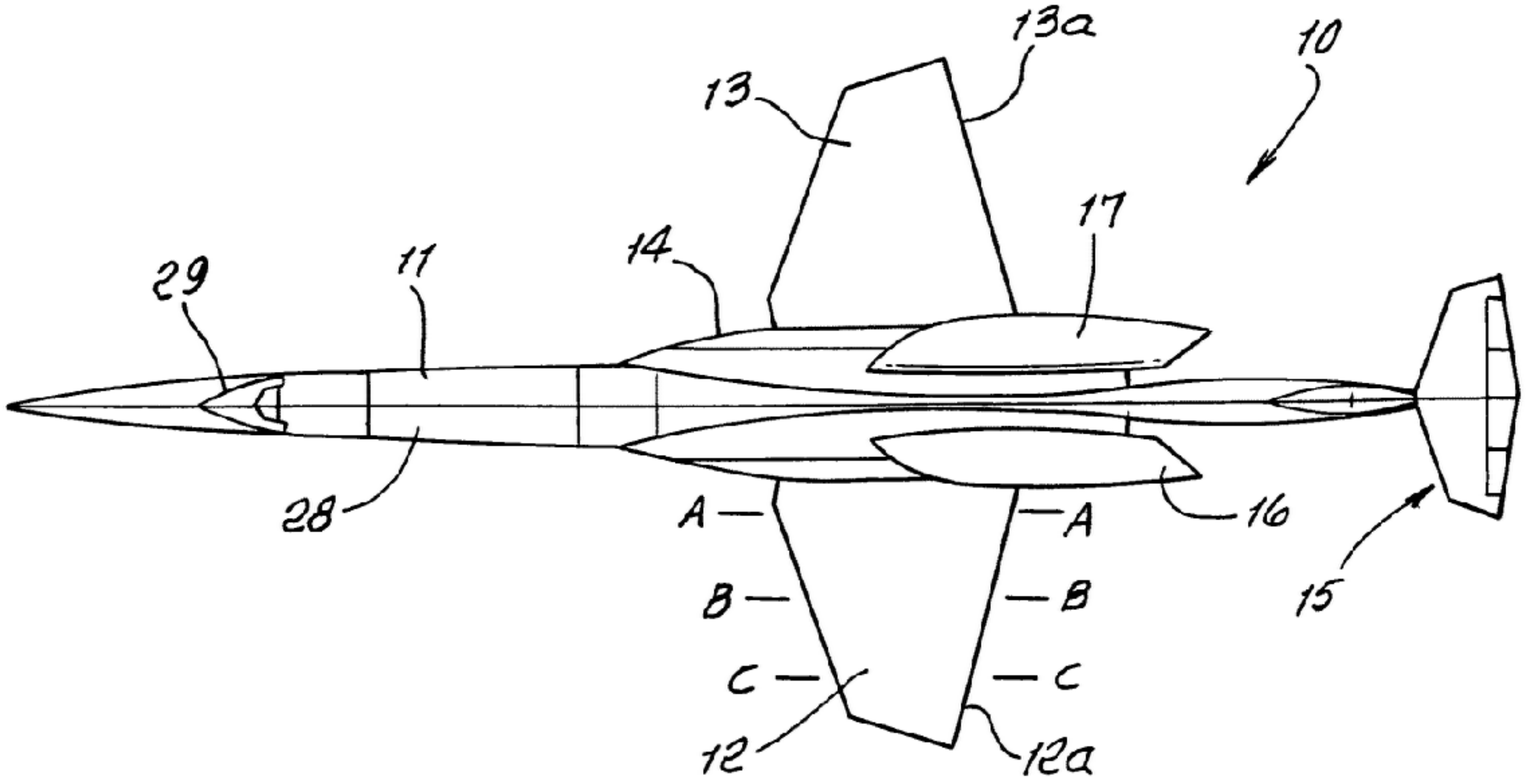
$c_{m,c/4}$ is independent of α

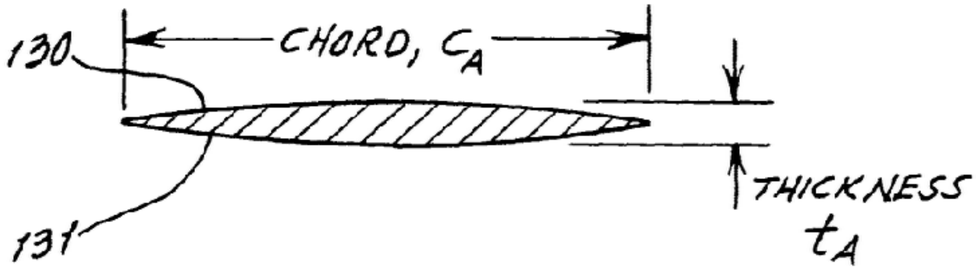
Transonic


Supersonic flow
Strong shock wave
Conventional airfoil
Separated boundary layer
Weak shock wave
Supercritical airfoil


shock
C_p critical
% choord

Supersonic


13a
10
13
17
14
29
11
28
A
A
16
B
B
15
C
C
12
12a


130
CHORD, C_A
131
THICKNESS
t_A