Simulation in Thermo and Fluid Dynamics

Aerodynamics of Bluff Bodies and Airfoils

Luca Mangani

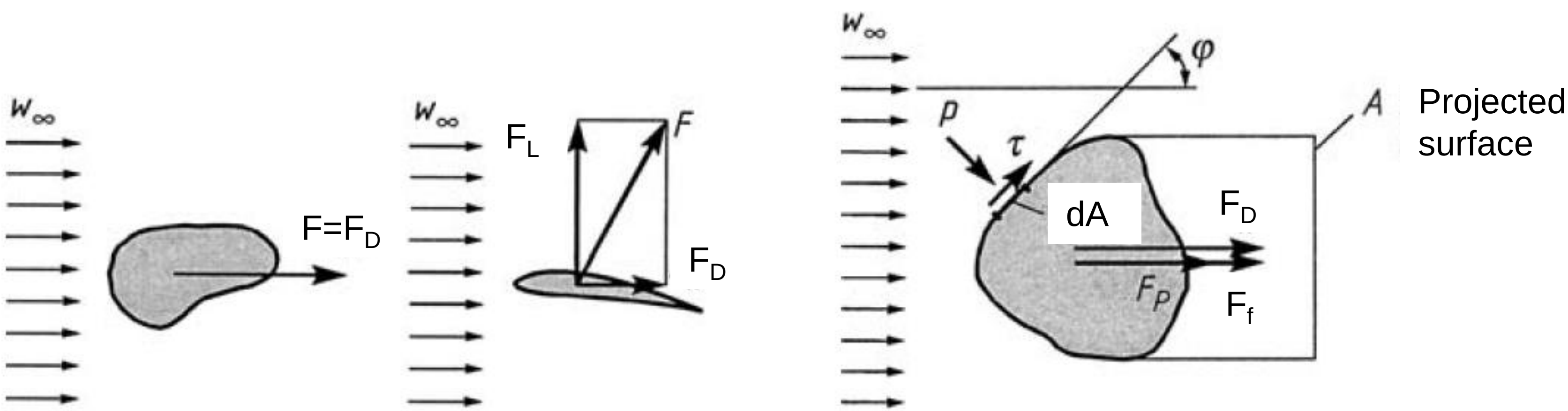
luca.mangani@hslu.ch

Ernesto Casartelli

ernesto.casartelli@hslu.ch

Aerodynamic forces on bodies

- Drag: parallel to flow direction
  - Pressure drag $$F_p = \oint_A p \sin\varphi \cdot dA$$
  - Friction drag $$F_f = \oint_A \tau \cos\varphi \cdot dA$$
- Lift: perpendicular to flow direction



Pictures: Böswirth, Technische Strömungslehre

Definition of dimensionless coefficients

- Dimensional analysis shows that presenting physical data in dimensionless form has considerable advantages when interpreting and using the obtained results

- Lift coefficient

$$F_L = c_L A\rho \frac{c^2}{2} => c_L = \frac{F_L}{A\rho \frac{c^2}{2}}$$

- Drag coefficient

$$F_D = c_D A\rho \frac{c^2}{2} => c_D = \frac{F_D}{A\rho \frac{c^2}{2}}$$

- Pressure coefficient

$$F_p = c_p A\rho \frac{c^2}{2} => c_p = \frac{F_p}{A\rho \frac{c^2}{2}} = \frac{p}{\rho \frac{c^2}{2}}$$

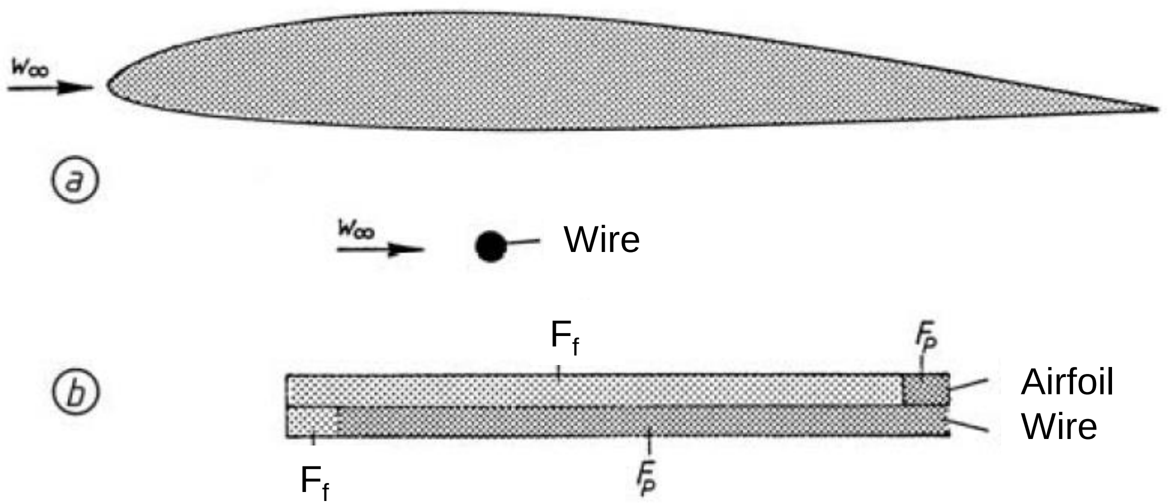
- …

Aerodynamic forces on bodies

- Drag: parallel to flow direction
  - General expression for (drag) forces

$$F_D = c_D A \rho \frac{c^2}{2} = c_D A \cdot p_{Dyn}$$

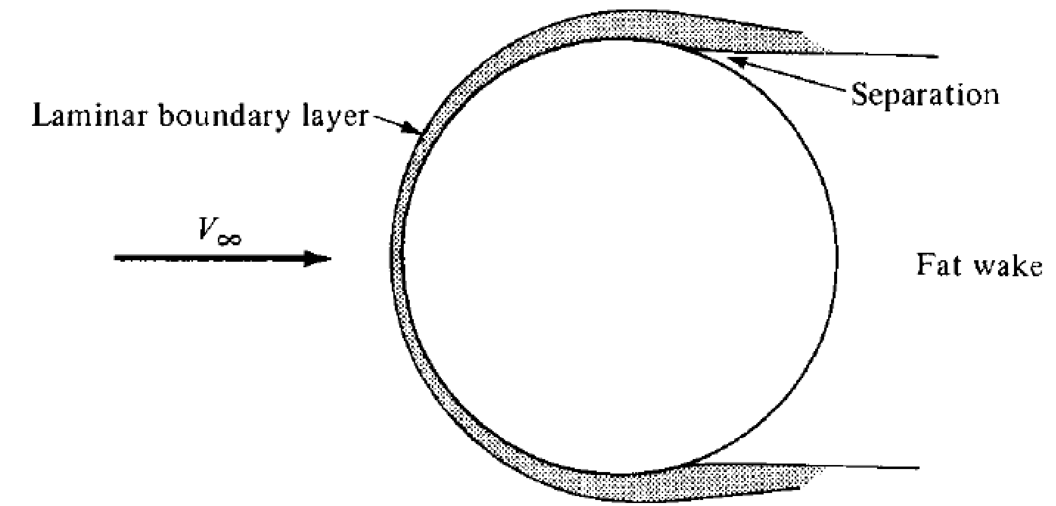
- Aerodynamic vs. bluff body



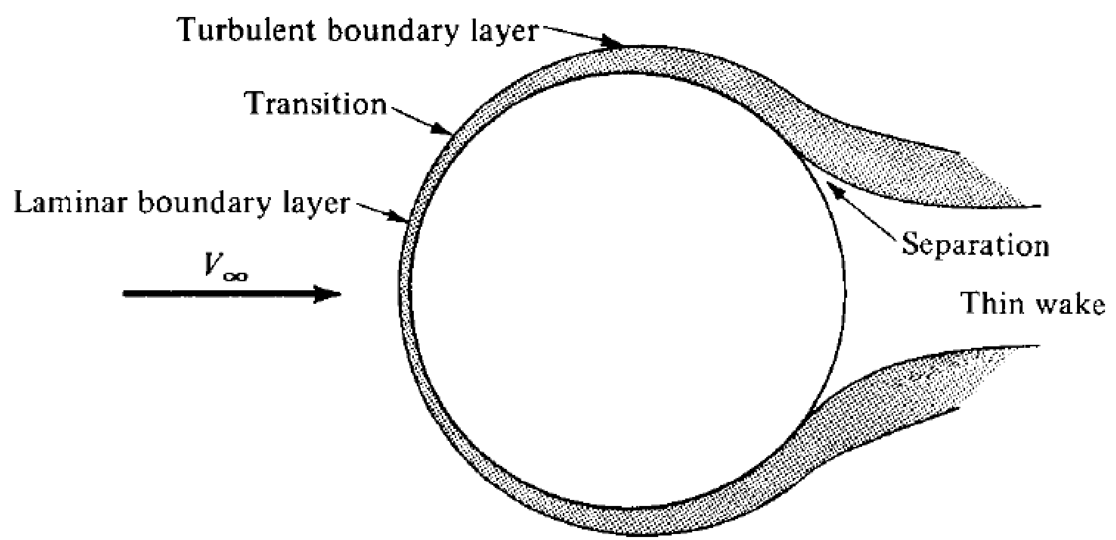
Pictures: Böswirth, Technische Strömungslehre

Flow past a sphere

Laminar
conditions

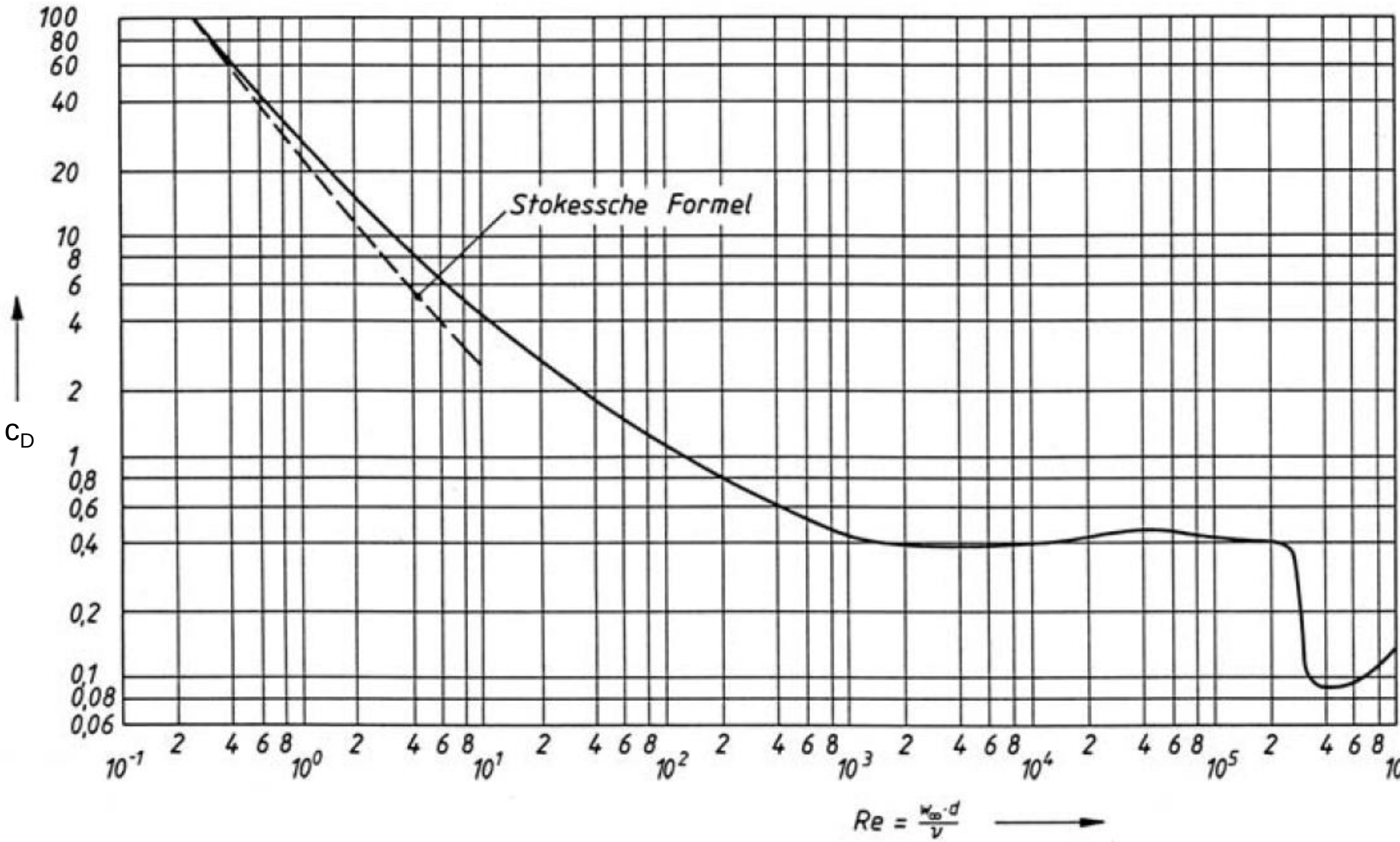


Turbulent
conditions



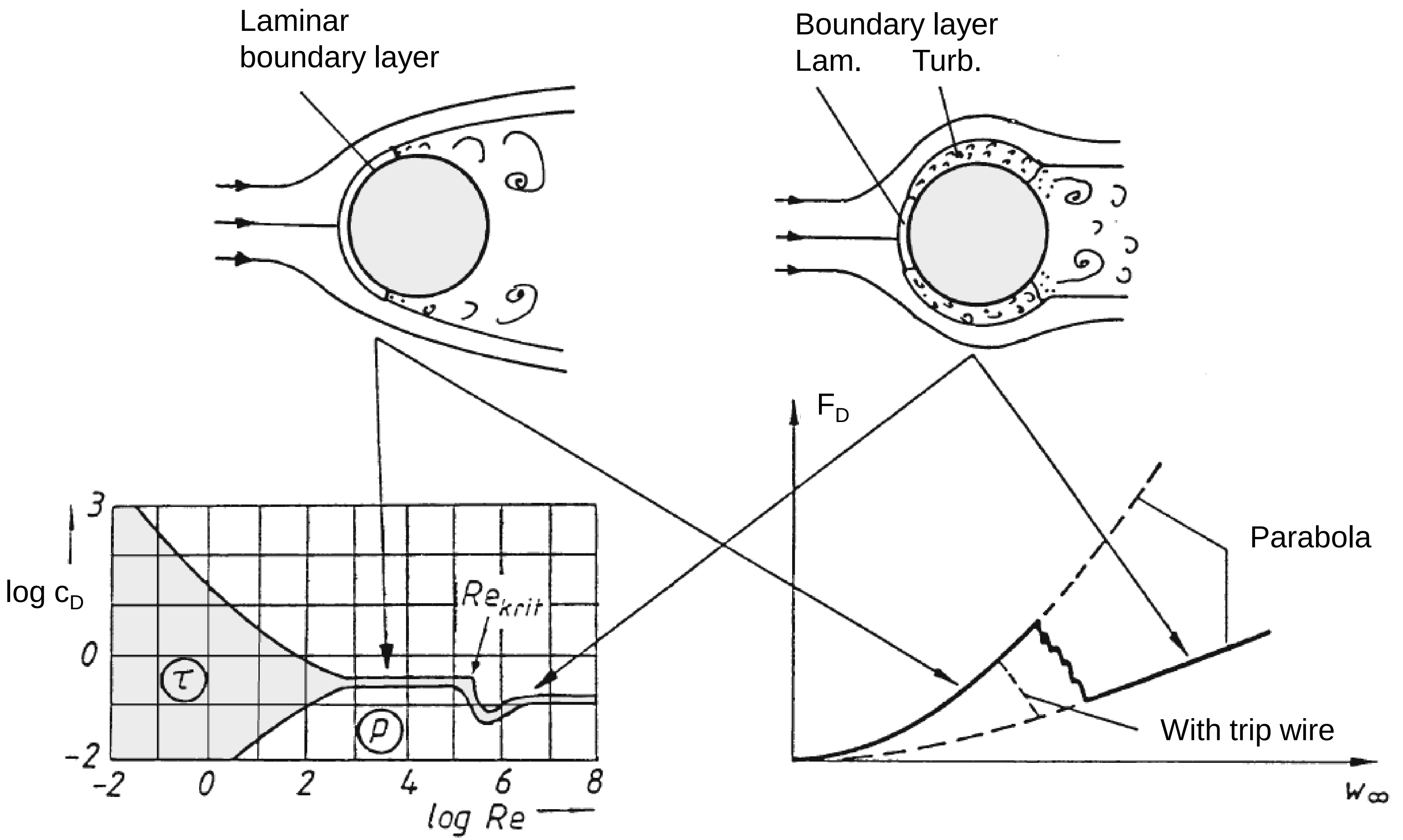
Pictures: Anderson, Introduction to Flight

Flow past a sphere



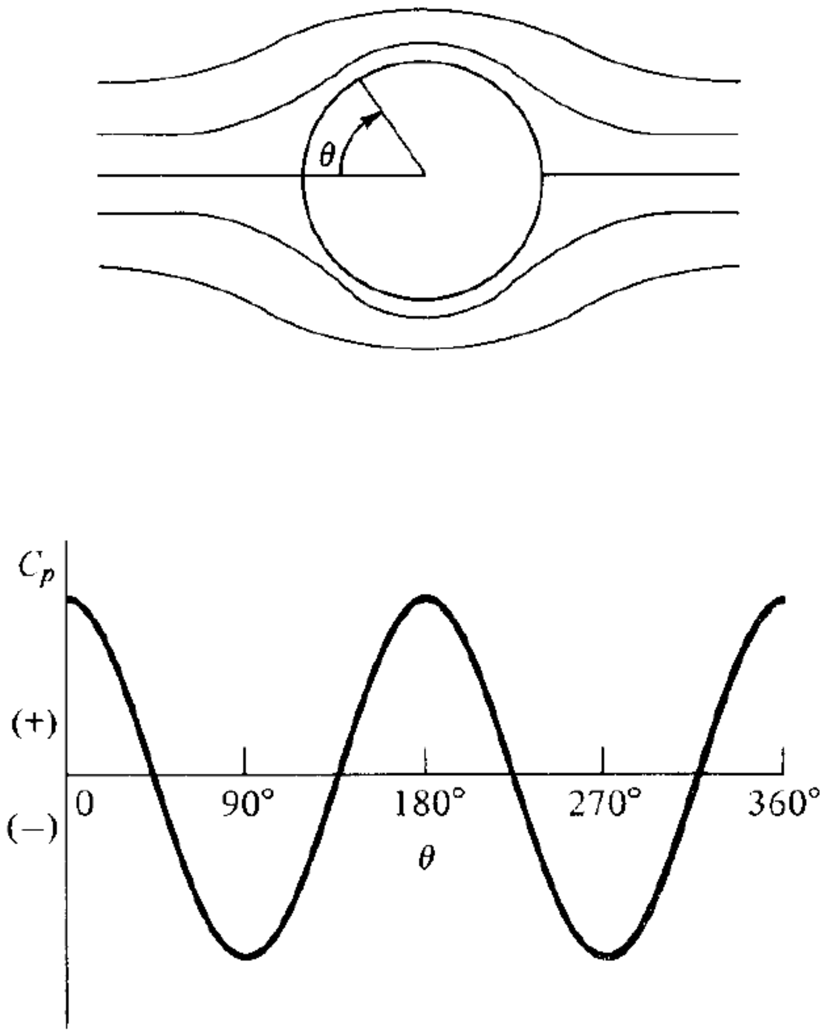
Pictures: Böswirth, Technische Strömungslehre

Flow past a sphere

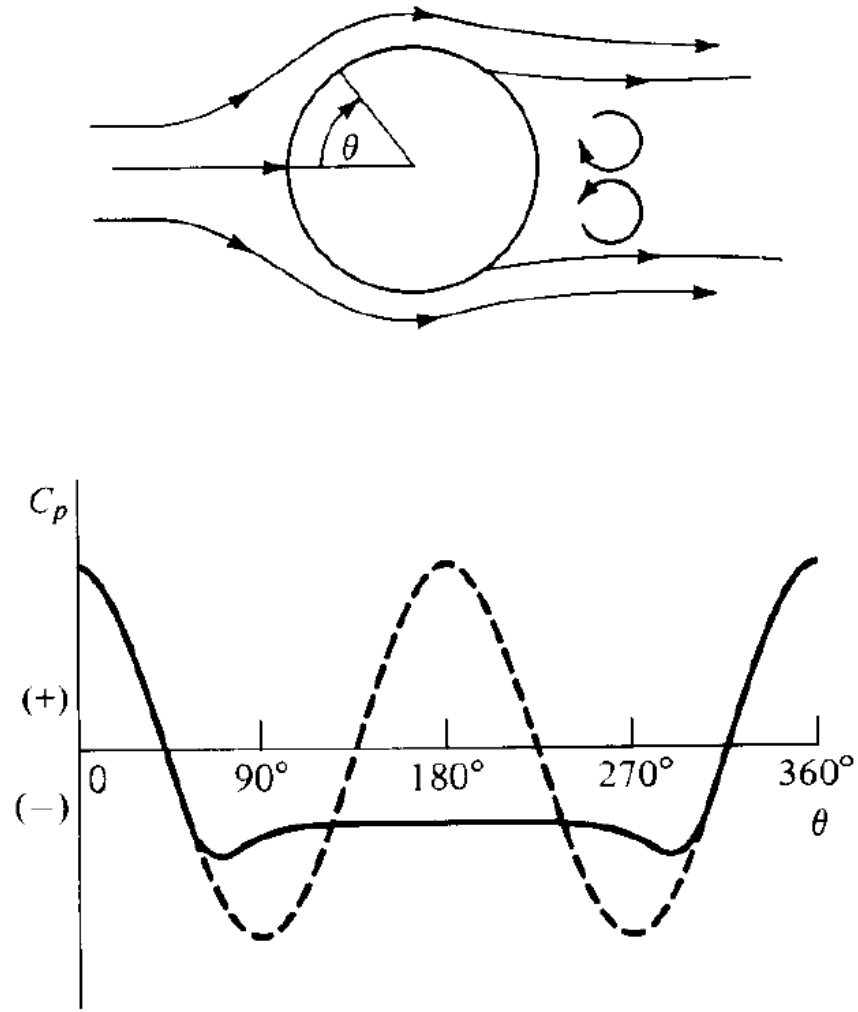


Pictures: Böswirth, Technische Strömungslehre

Flow past a sphere



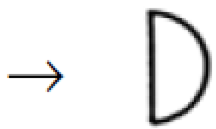
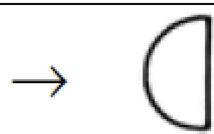
Inviscid flow

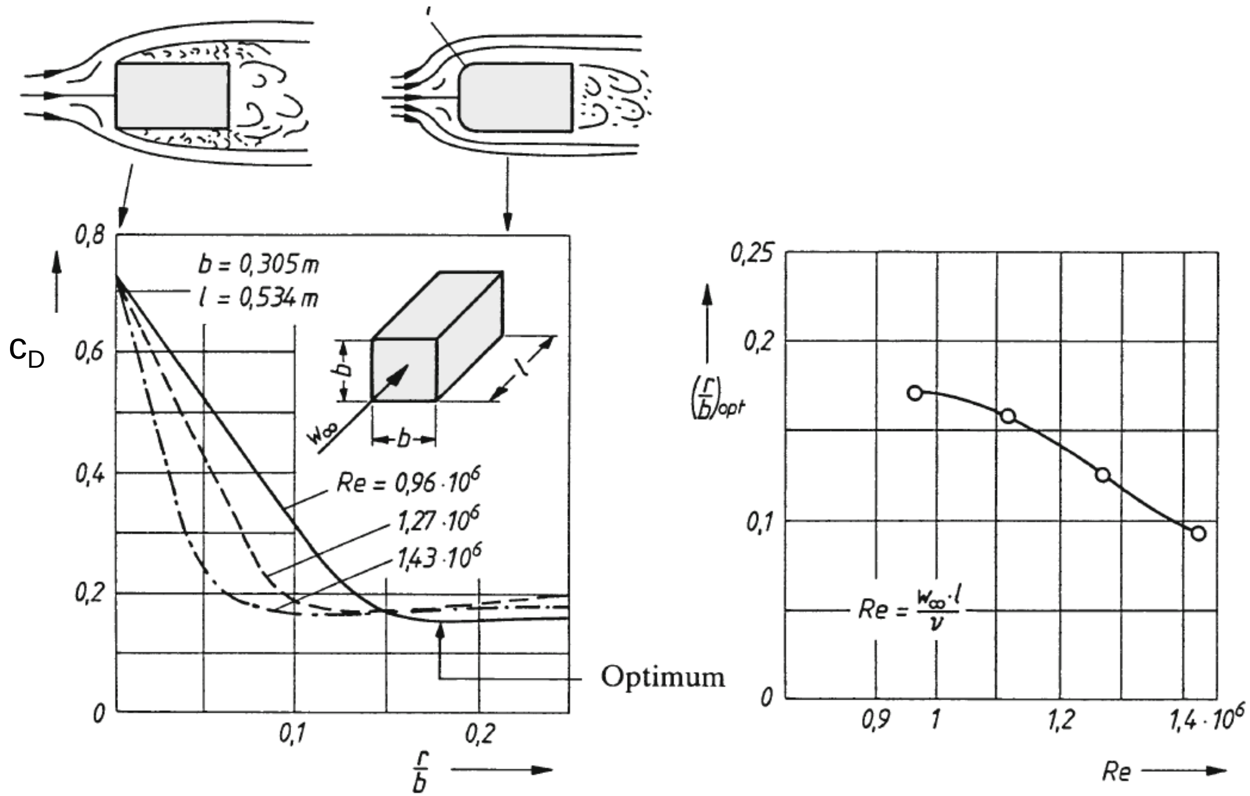


Viscous flow

Pictures: Anderson, Introduction to Flight

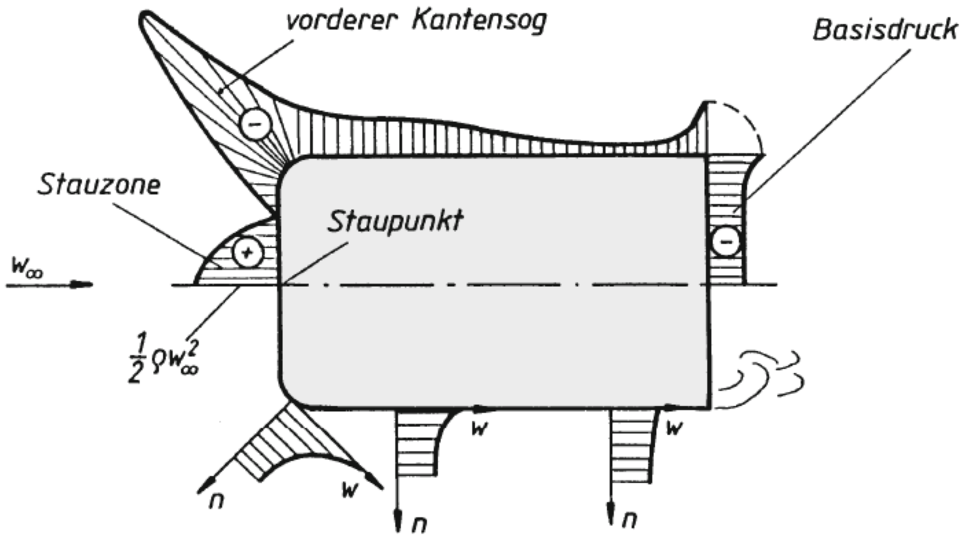
Drag coefficient for flow past various bodies

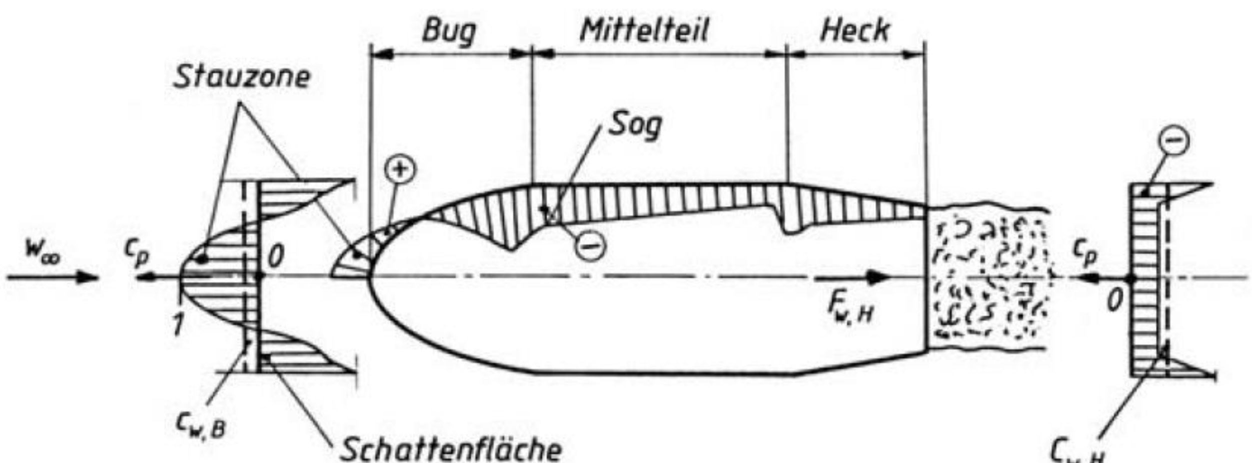
	c_D
	1,33
	1,17
	0,4
	1,11
	2,01 1,19



Pictures: Böswirth, Technische Strömungslehre

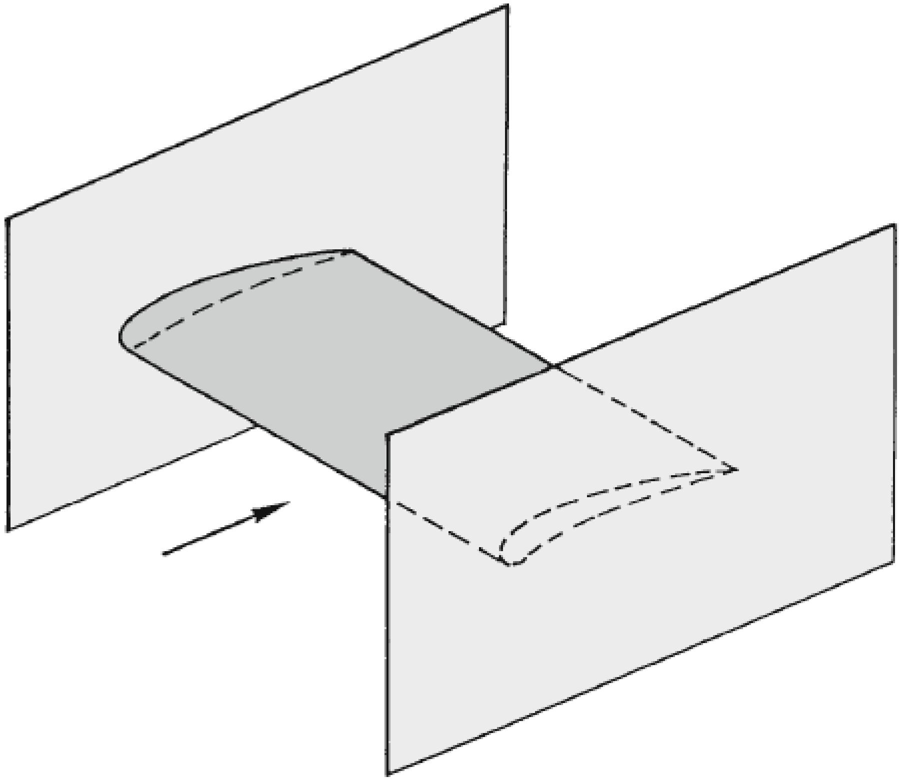
Flow past a bluff body





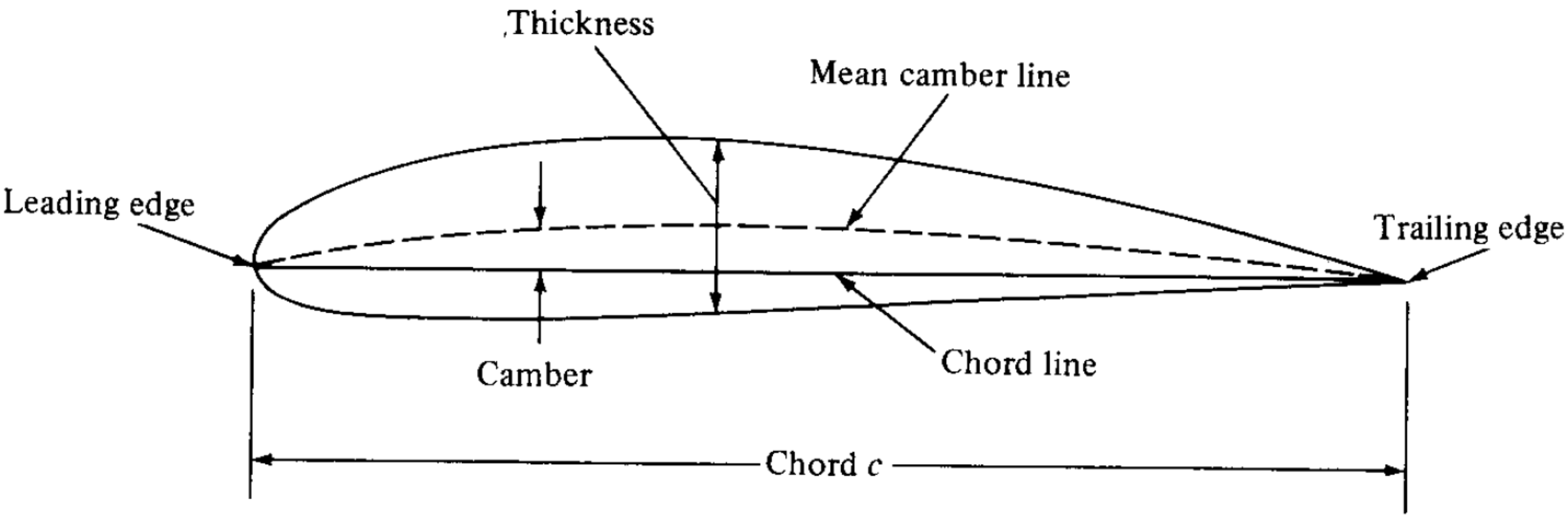
Pictures: Böswirth, Technische Strömungslehre

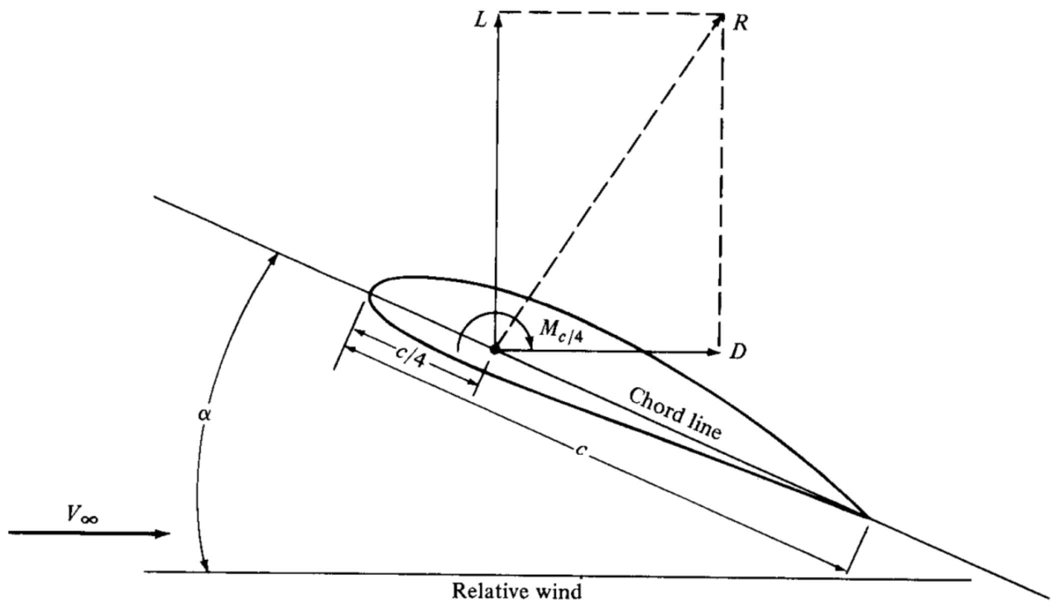
Airfoils: 2D (idealized) flow



Pictures: Böswirth, Technische Strömungslehre

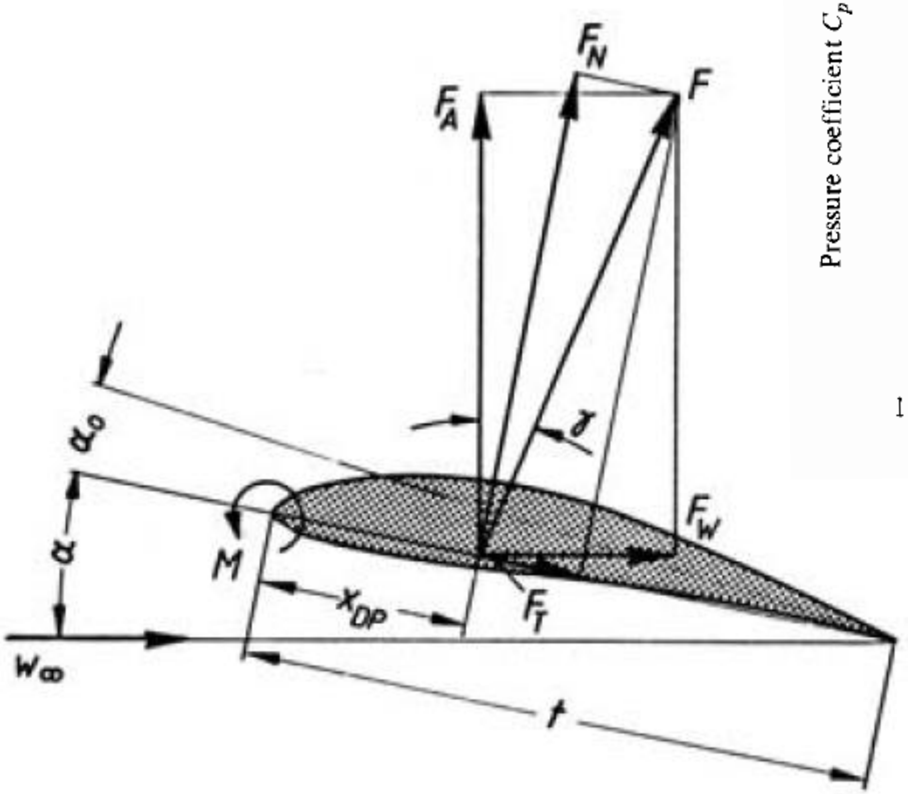
Airfoils: geometry definition

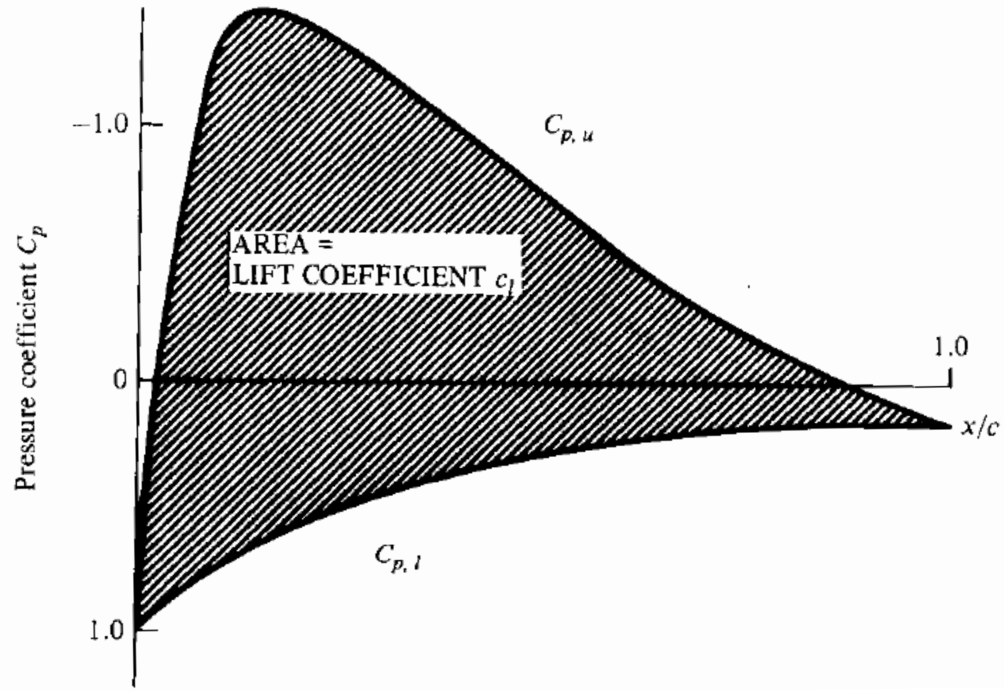




Pictures: Anderson, Introduction to Flight

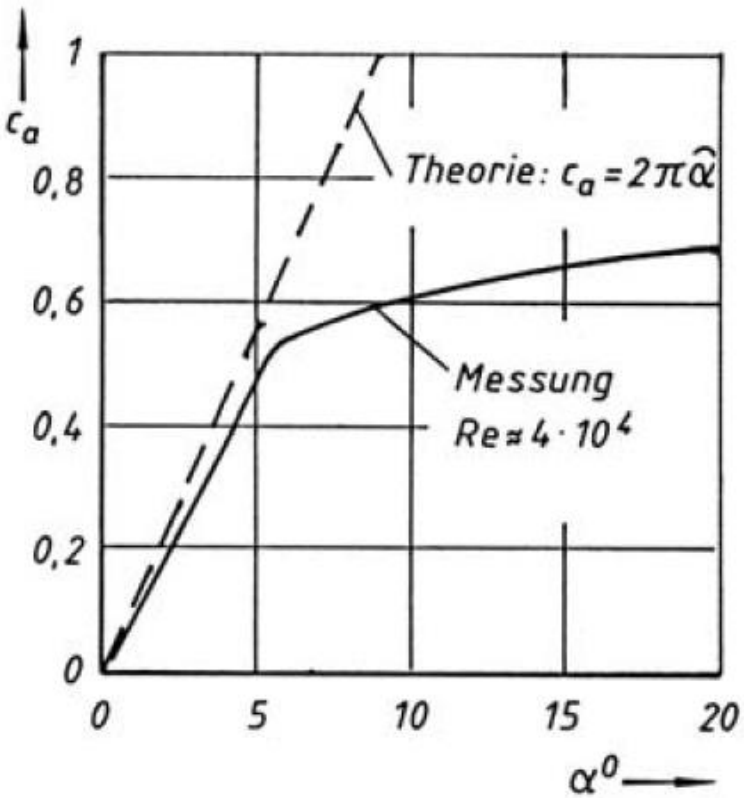
Airfoils: forces

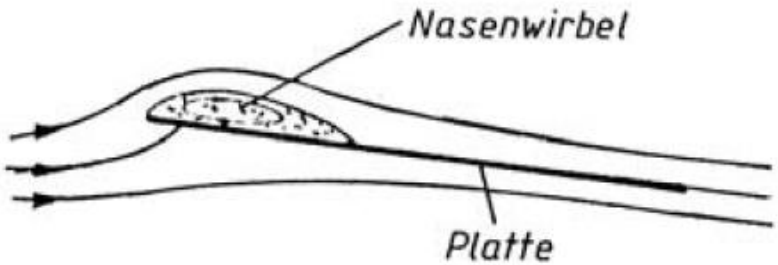




Pictures: Böswirth and Anderson

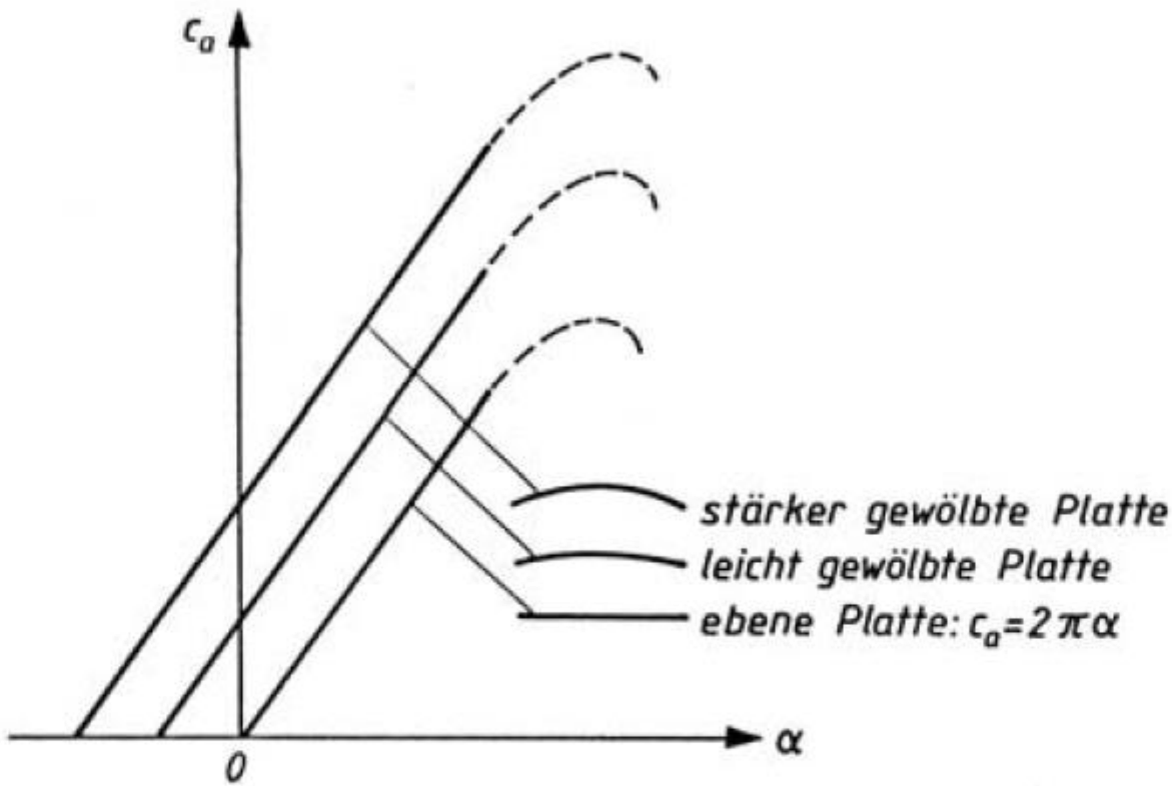
Airfoils: comparison to flat plate





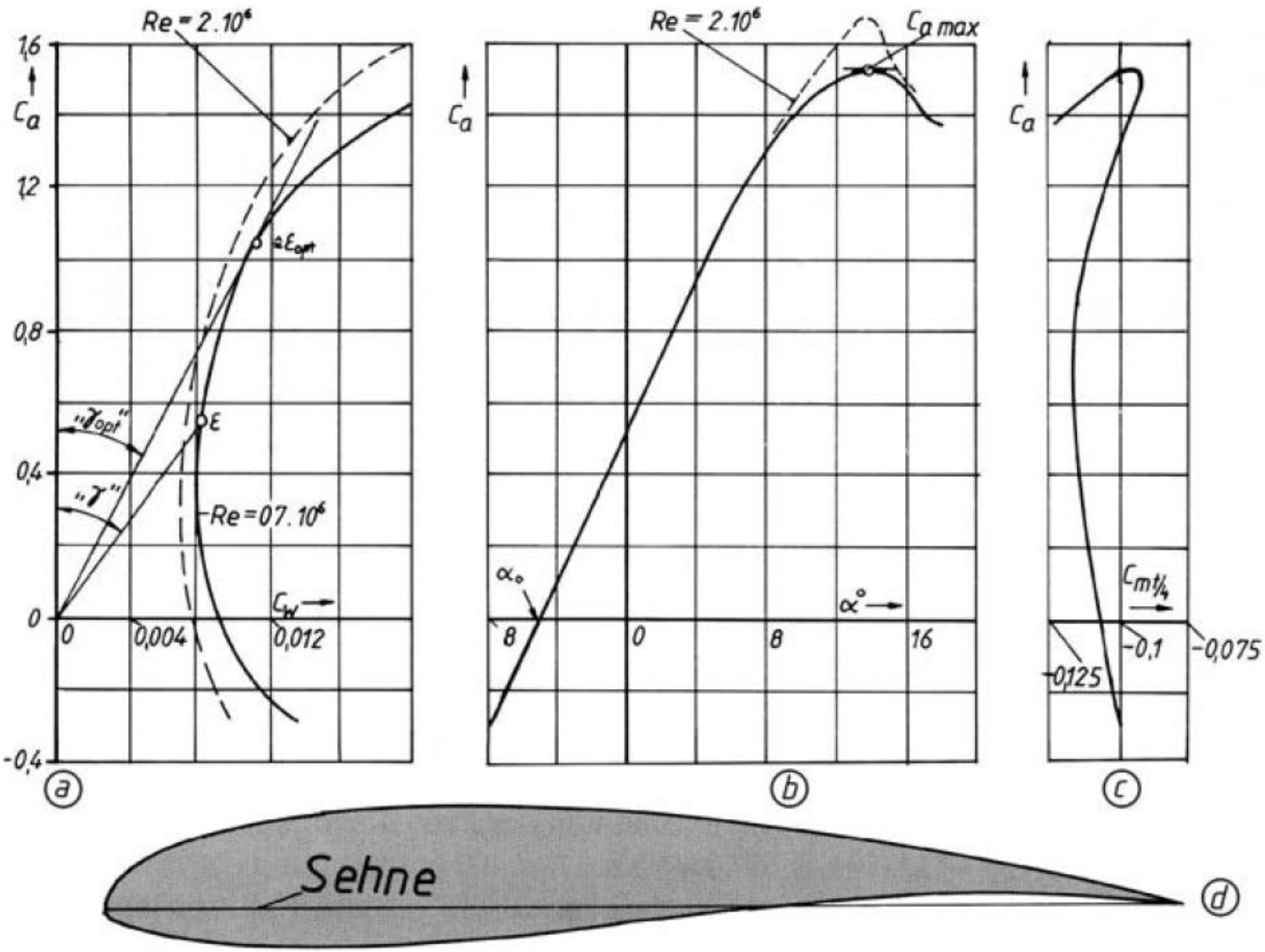
Pictures: Böswirth, Technische Strömungslehre

Airfoils: curved plates



Pictures: Böswirth, Technische Strömungslehre

Airfoils: example



Pictures: Böswirth, Technische Strömungslehre

Airfoils: effect of Reynolds number

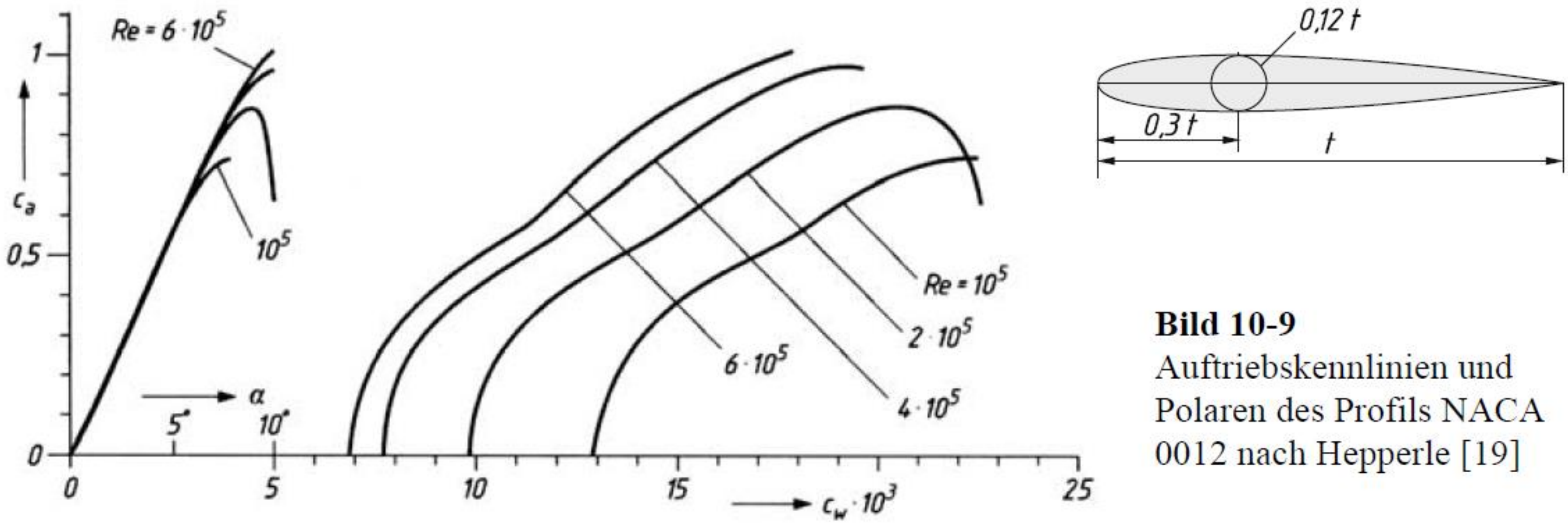
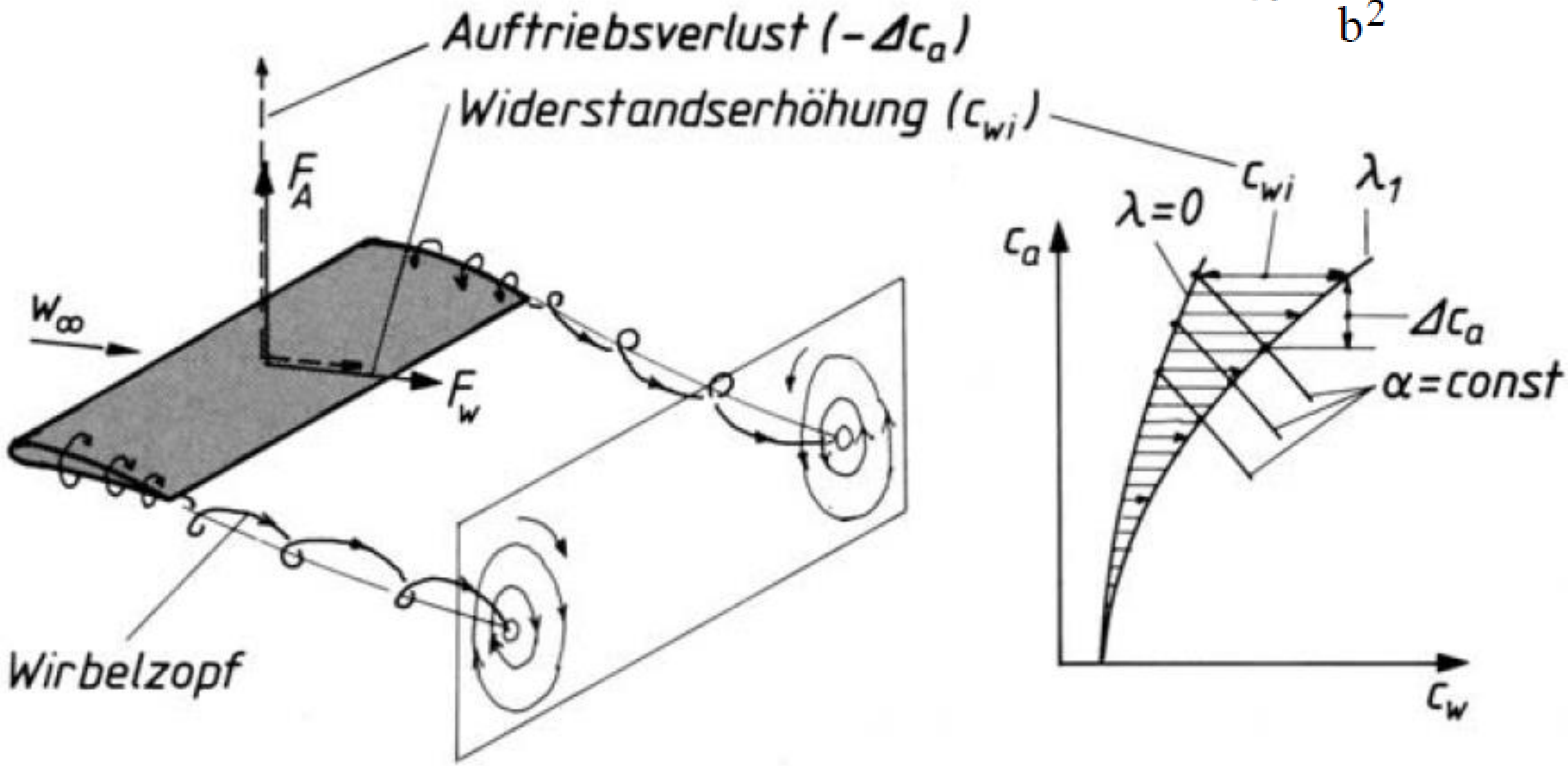


Bild 10-9
Auftriebskennlinien und Polaren des Profils NACA 0012 nach Hepperle [19]

Pictures: Böswirth, Technische Strömungslehre

Airfoils: 3D effects

$$\lambda = \frac{A}{b^2}$$



Pictures: Böswirth, Technische Strömungslehre