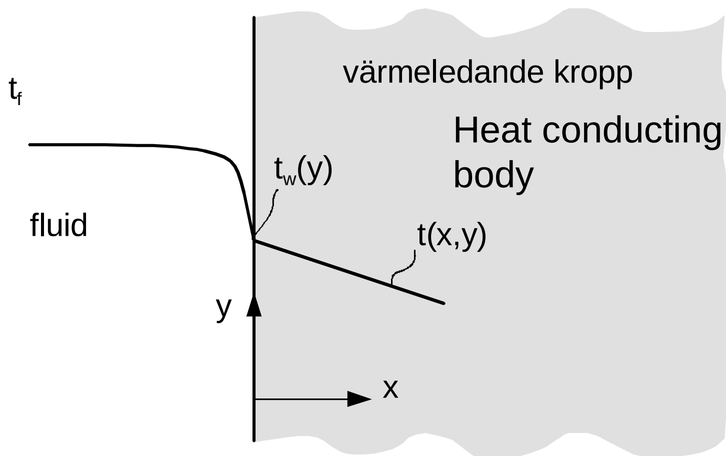
Konvektiv värmeöverföring
Convective heat transfer



$$\dot{Q} = \alpha(t_f - t_w)A$$

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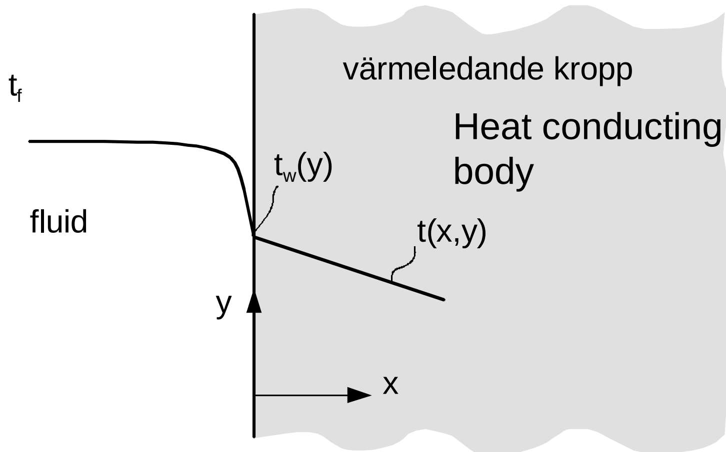

$$\dot{Q} = \alpha(t_f - t_w)A$$

x = 0 $\Rightarrow$ u, v, w = 0 $\Rightarrow$ värmeledning i fluiden,
heat conduction in the fluid

$$\dot{Q} = -\lambda_f A \underbrace{\left(\frac{\partial t}{\partial y}\right)_{x=0}}_{\substack{i\ fluiden \\ in\ the\ fluid}}$$

$$\because \quad \underline{\underline{\alpha}} = \frac{\dot{Q}/A}{t_w - t_f} = \underline{\underline{-\frac{\lambda_f \left(\frac{\partial t}{\partial y}\right)_{x=0}}{t_w - t_f}}} \qquad (6-3)$$

Convective heat transfer

Målsättning: Bestämma α och de parametrar som bestämmer den vid givet $t_w(x)$ eller $q_w(x) = Q/A$

Objective: Determine α and the parameters influencing it for prescribed $t_w(x)$ or $q_w(x) = Q/A$

Storleksordning för värme-övergångskoefficienten α, Order of magnitude for α

Medium		α W/m²K
Luft, air (1bar);	naturlig konvektion natural convection	2-20
Luft, air (1bar);	forcerad konvektion forced convection	10-200
Luft, air (250 bar);	forcerad konvektion forced convection	200-1000
Vatten, Water;	forcerad konvektion forced convection	500-5000
Organiska vätskor; Organic liquids;	forcerad konvektion forced convection	100-1000
Kondensation (vatten) Condensation (water)		2000-50000
Kondensation (organiska ångor) Condensation (organic vapors)		500-10000
Förångning (vatten) Evaporation, boiling, (water)		2000-100000
Förångning (organiska vätskor) Evaporation, boiling (organic liquids)		500-50000

How to do it?
What are the tools?

Fluid motion:

Mass conservation equation

Momentum equations (Newton's second law)

Energy balance in the fluid

First law of thermodynamics for an open system

Kontinuitetsekv. continuity eq.

$$\frac{\partial \rho}{\partial \tau} + \frac{\partial}{\partial x}(\rho u) + \frac{\partial}{\partial y}(\rho v) + \frac{\partial}{\partial z}(\rho w) = 0 \qquad (6-4)$$

Spec. stationärt,
inkompressibelt,
tvådim.,

Especially for

steady state,
incompressible
flow, two-
dimensional case

$$\Rightarrow \boxed{\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0} \qquad (6-5)$$

Resulting momentum equations – 2 dim.

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$$\hat{x}: \quad \rho\left(\frac{\partial u}{\partial \tau}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}\right)=\rho F_x-\frac{\partial p}{\partial x}+\mu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)$$

$$\hat{y}: \quad \rho\left(\frac{\partial v}{\partial \tau}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}\right)=\rho F_y-\frac{\partial p}{\partial y}+\mu\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right)$$

Temperature Equation

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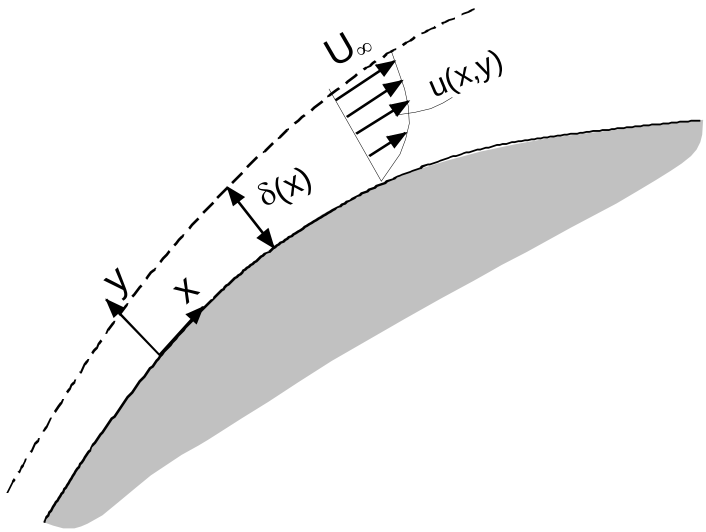
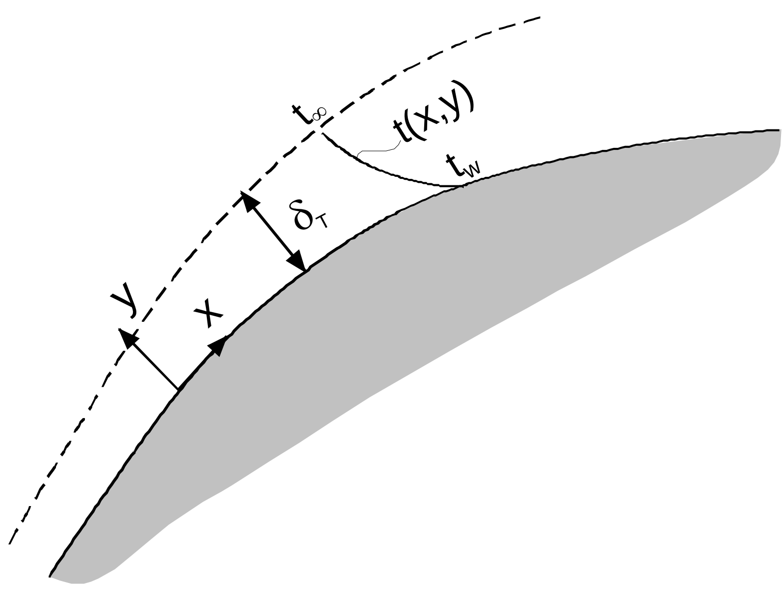
$$u\frac{\partial t}{\partial x}+v\frac{\partial t}{\partial y}+w\frac{\partial t}{\partial z}=\frac{\lambda}{\rho c_p}\left(\frac{\partial^2 t}{\partial x^2}+\frac{\partial^2 t}{\partial y^2}+\frac{\partial^2 t}{\partial z^2}\right)$$

Boundary layer approximations





Boundary layer approximations – Prandtl's theory

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$$u >> v$$

$$\frac{\partial u}{\partial y} >> \frac{\partial u}{\partial x}, \frac{\partial v}{\partial x}, \frac{\partial v}{\partial y}$$

$$\frac{\partial t}{\partial y} >> \frac{\partial t}{\partial x}$$

Boundary layer approximations – Prandtl's theory

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$$p = p(x)$$

$$\rho\left(u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y}\right) = \rho F_x - \frac{dp}{dx} + \mu\frac{\partial^2 u}{\partial y^2}$$

$$u\frac{\partial t}{\partial x} + v\frac{\partial t}{\partial y} = \frac{\lambda}{\rho c_p}\frac{\partial^2 t}{\partial y^2}$$

Boundary layer approximations – Prandtl's theory

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$$p + \frac{1}{2}\rho U^2 = \text{konstant}$$

$$\frac{dp}{dx} = -\rho U \frac{dU}{dx}$$

$$\Pr = \frac{\nu \rho c_p}{\lambda} = \frac{\mu c_p}{\lambda}$$

Boundary layer equations

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$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0$$

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=U\frac{dU}{dx}+\frac{\mu}{\rho}\frac{\partial^2 u}{\partial y^2}$$

$$u\frac{\partial t}{\partial x}+v\frac{\partial t}{\partial y}=\frac{\mu}{\rho \Pr}\frac{\partial^2 t}{\partial y^2}$$

Boundary layers

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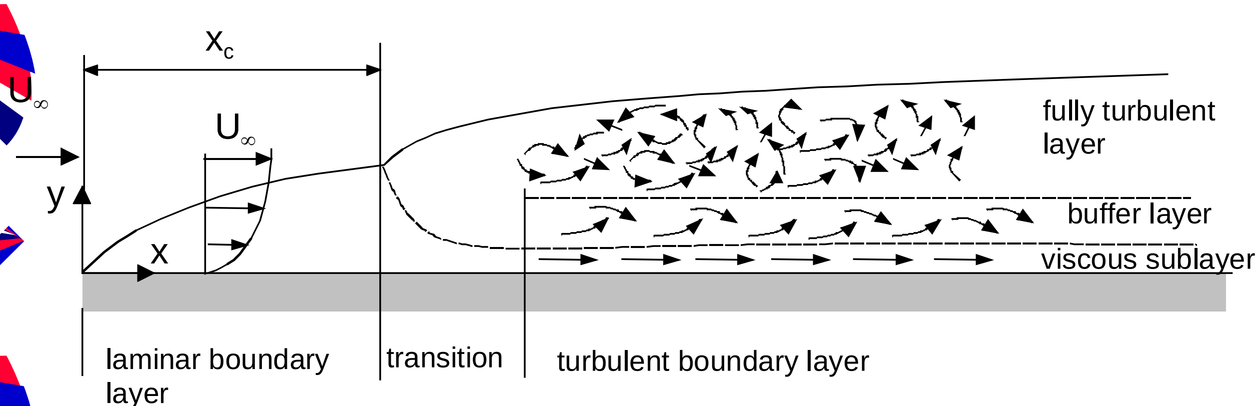

$$\mathrm{Re}_c = U_\infty x_c / \nu \qquad 5 \cdot 10^5$$

$$\mathrm{Nu} = f_7(\mathrm{Re}, \mathrm{Pr})$$