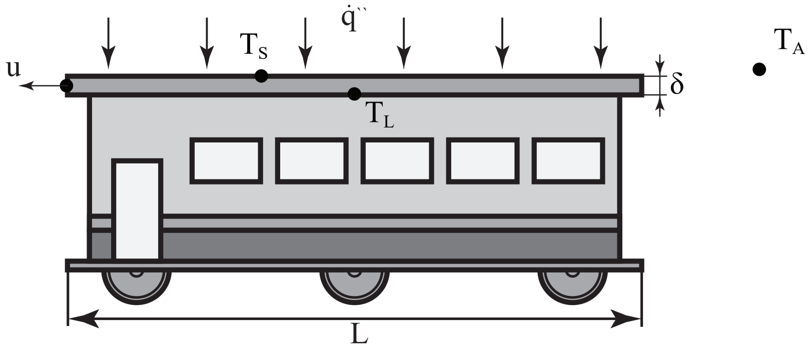
**Exercise III.6** (Moving train ⋆):

Consider the roof surface of a passenger car on a moving train. This surface is exposed to solar radiation, with an incident heat flux denoted as $\dot{q}''$. The ambient air temperature is represented by $T_\mathrm{A}$.




**Given parameters:**

- Velocity of the train: $u = 50$ km/h
- Length of the train roof: $L = 10$ m
- Width of the train roof: $W = 3$ m
- Thickness of the train roof: $\delta = 20$ cm
- Thermal conductivity of the train roof: $\lambda = 0.03$ W/mK
- Lower temperature of the train roof: $T_\mathrm{L} = 16$ °C
- Ambient temperature: $T_\mathrm{A} = 15$ °C
- Solar irradiation: $\dot{q}'' = 288$ W/m$^2$
- Properties of air:

| T [°C] | $\rho$ [kg/m$^3$] | $c$ [kJ/kg·K] | $\lambda$ [W/mK] | $\nu$ [m$^2$/s] | Pr [−] |
|---|---|---|---|---|---|
| 0 | 1.275 | 1.006 | $24.18 \cdot 10^{-3}$ | $13.52 \cdot 10^{-6}$ | 0.7179 |
| 20 | 1.188 | 1.007 | $25.69 \cdot 10^{-3}$ | $15.35 \cdot 10^{-6}$ | 0.7148 |
| 40 | 1.112 | 1.007 | $27.16 \cdot 10^{-3}$ | $17.26 \cdot 10^{-6}$ | 0.7122 |
| 80 | 0.9859 | 1.008 | $30.01 \cdot 10^{-3}$ | $21.35 \cdot 10^{-6}$ | 0.7083 |
| 100 | 0.9329 | 1.009 | $31.39 \cdot 10^{-3}$ | $23.51 \cdot 10^{-6}$ | 0.7073 |

**Hints:**

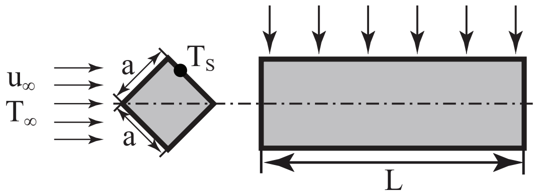
- Assume steady-state heat transfer to be one-dimensional
- Neglect radiation heat exchange with the surroundings.

**Tasks:**

a) Determine the equilibrium temperature of the top surface $T_\mathrm{s}$.

**Exercise III.7** (Transverse flow ⋆⋆):

Air flows transversely across a beam of length $L$, with a square cross-sectional area, as can be seen in the figure. The circles with crosses indicate streamlines that are moving away from the observer.




**Given parameters:**

- Beam geometrical dimensions: $a$,$L$
- Material properties of the air: $\eta$,$\rho$, $\Pr$ ,$\lambda$
- Velocity of the crossflow: $u_\infty$
- Temperatures of the surface and ambient: $T_\mathrm{s}$, $T_\infty$

**Hints:**

- Assume steady-state conditions
- $10^4 \le \mathrm{Re} \le 10^5$
- Heat loss from the sides is negligible.

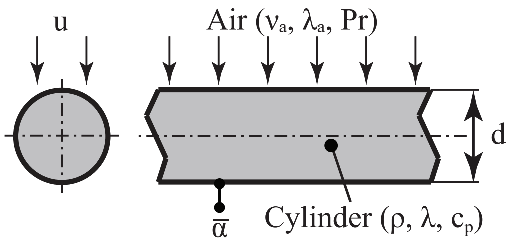
**Tasks:**

a) Provide an expression for the rate of heat loss in terms of the given parameters.

b) Determine the percentual change of the heat transfer coefficient if we had a similar-form rod with four times the crosswise width at double flow velocity.

**Exercise III.8** (Heating of a cylinder ★★)**:**

A long cylinder is kept at a homogeneous temperature $T_0$. This cylinder is suddenly, at time $t = 0$, exposed to a warm air flow with temperature $T_a$ and a transverse velocity of $u$.




**Given parameters:**

- Diameter of the cylinder: $d = 0.055$ m
- Density of the cylinder: $\rho = 1500$ kg/m$^3$
- Thermal conductivity of the cylinder: $\lambda = 0.119$ W/mK
- Heat capacity of the cylinder: $c_p = 1000$ J/kgK
- Initial homogenous temperature of the cylinder: $T_0 = 10$ °C
- Critical temperature of the cylinder: $T_c = 38$ °C
- Temperature of the air flow: $T_a = 40$ °C
- Velocity of the air: $u = 0.1$ m/s
- Thermal conductivity of the air: $\lambda_a = 25.7 \cdot 10^{-3}$ W/mK
- Kinematic viscosity of the air: $\nu_a = 15.35 \cdot 10^{-6}$ m$^2$/s
- Prandtl number of the air: Pr = 0.71

**Hints:**

- The average heat transfer coefficient $\overline{\alpha}$ is steady in time.
- The material properties can be taken as constant.

**Tasks:**

a) Determine the initial rate of heat transfer per unit length of the cylinder.

b) At $t = t_c$ the cylinder reaches the critical temperature $T_c$ at its hottest point. Sketch qualitatively the temperature distribution at time-points $t = 0$ and $t = t_c$.

c) Determine the time $t_c$, until the cylinder reaches the critical temperature $T_c$ at its hottest point.