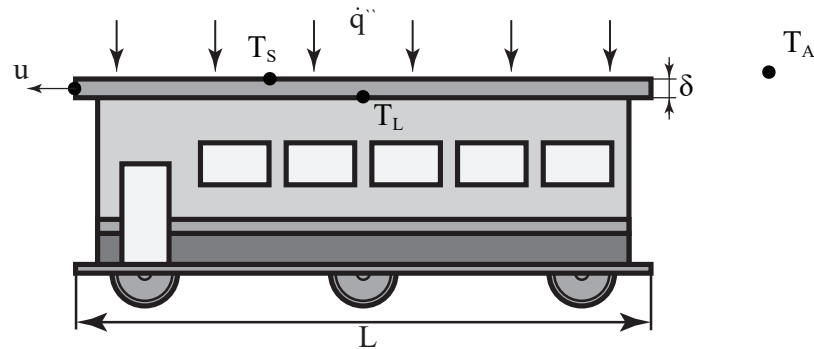## Exercise III.6: (Moving train ⋆)

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_A.

Given parameters:

- Velocity of the train: $\qquad\qquad\qquad\qquad\qquad$ $u = 50$ km/h

- Length of the train roof: $\qquad\qquad\qquad\qquad$ $L = 10$ m

- Width of the train roof: $\qquad\qquad\qquad\qquad$ $W = 3$ m

- Thickness of the train roof: $\qquad\qquad\qquad$ $\delta = 20$ cm

- Thermal conductivity of the train roof: $\qquad$ $\lambda = 0.03$ W/mK

- Lower temperature of the train roof: $\qquad$ $T_L = 16$ °C

- Ambient temperature: $\qquad\qquad\qquad\qquad$ $T_A = 15$ °C

- Solar irradiation: $\qquad\qquad\qquad\qquad\qquad$ $\dot{q}'' = 288$ W/m^2

- Properties of air:

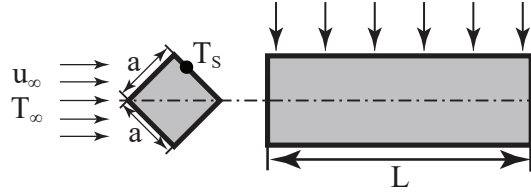| T (°C)	ρ $\left(\text{kg/m}^3\right)$	c (kJ/kg·K)	λ (W/mK)	ν $\left(\text{m}^2/\text{s}\right)$	Pr (−)
0	1.275	1.006	$24.18 \cdot 10^{-3}$	$13.52 \cdot 10^{-6}$	0.7179
20	1.188	1.007	$25.69 \cdot 10^{-3}$	$15.35 \cdot 10^{-6}$	0.7148
40	1.112	1.007	$27.16 \cdot 10^{-3}$	$17.26 \cdot 10^{-6}$	0.7122
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_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: $\eta, \rho, \mathrm{Pr}, \lambda$

- Velocity of the crossflow: u_∞

- Temperatures of the surface and ambient: T_s, T_∞
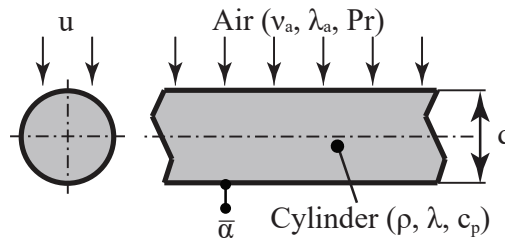
Hints:

- Assume steady-state conditions

- $10^4 \leq \mathrm{Re} \leq 10^5$

- 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: $\qquad$ $d = 0.055$ m

- Density of the cylinder: $\qquad$ $\rho = 1500$ kg/m^3

- Thermal conductivity of the cylinder: $\qquad$ $\lambda = 0.119$ W/mK

- Heat capacity of the cylinder: $\qquad$ $c_p = 1000$ J/kgK

- Initial homogenous temperature of the cylinder: $\qquad$ $T_0 = 10$ °C

- Critical temperature of the cylinder: $\qquad$ $T_c = 38$ °C

- Temperature of the air flow: $\qquad$ $T_a = 40$ °C

- Velocity of the air: $\qquad$ $u = 0.1$ m/s

- Thermal conductivity of the air: $\qquad$ $\lambda_a = 25.7 \cdot 10^{-3}$ W/mK

- Kinematic viscosity of the air: $\qquad$ $\nu_a = 15.35 \cdot 10^{-6}$ m^2/s

- Prandtl number of the air: $\qquad$ 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.