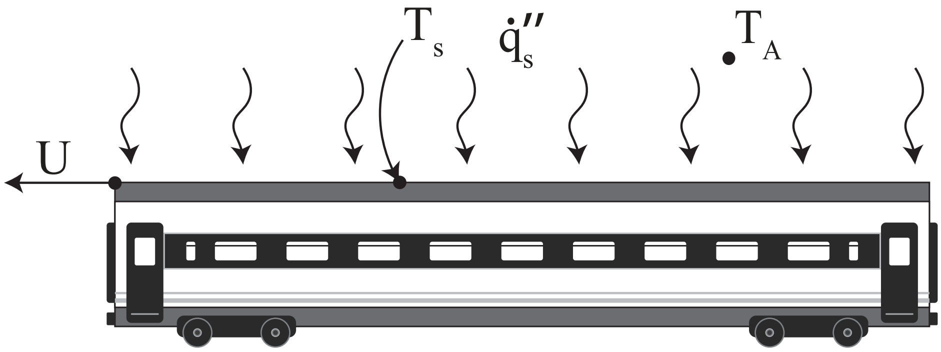
1.4 Moving train ★★

The top surface of the passenger car of a train moving. The top surface is absorbing solar radiation at a rate $\dot{q}''$, and the temperature of the ambient air is T_{A}.



Tasks:

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

Hints:

- Assume the roof of the car to be perfectly insulated.
- Neglect radiation heat exchange with the surroundings.

Given parameters:

Train properties:

- Length: $L = 10$ m
- Width: $W = 3$ m
- Velocity: $U = 50$ km/h

Ambient properties:

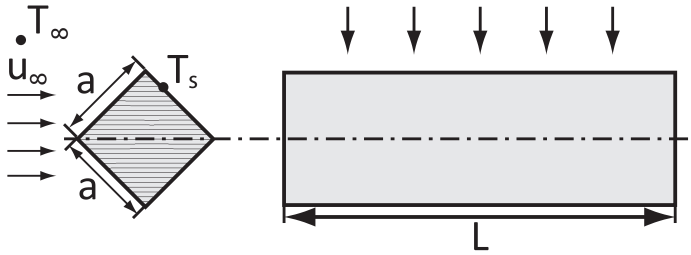
- Ambient temperature: $T_{\mathrm{A}} = 20$ °C
- Solar radiation: $\dot{q}'' = 250\ \mathrm{W/m^2}$

Air properties:

T °C	**ρ** $\mathrm{kg/m^3}$	**c** kJ/kgK	**λ** 10^{-3} W/mK	**ν** $10^{-6}\ \mathrm{m^2/s}$	**a** $10^{-6}\ \mathrm{m^2/s}$	**Pr** -
0	1.275	1.006	24.18	13.52	18.83	0.7179
20	1.188	1.007	25.69	15.35	21.47	0.7148
40	1.112	1.007	27.16	17.26	24.24	0.7122
80	0.9859	1.01	30.01	21.35	30.14	0.7083
100	0.9329	1.012	31.39	23.51	33.26	0.707

1.5 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.



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.

Hint:

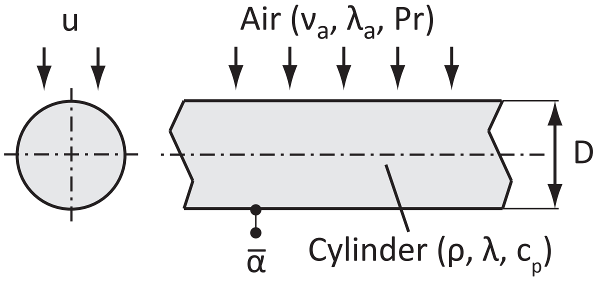
- $10^4 \leq \mathrm{Re} \leq 10^5$

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_∞

1.6 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.



Tasks:

a) Determine the average heat transfer coefficient $\overline{\alpha}$.
b) At $t = t_\mathrm{c}$ the cylinder reaches the critical temperature T_c at its hottest point. Sketch qualitatively the temperature distribution at time-points $t = 0$ and $t = t_\mathrm{c}$.

Extra task:

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

Hints:

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

Given parameters:

Temperatures:

- 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

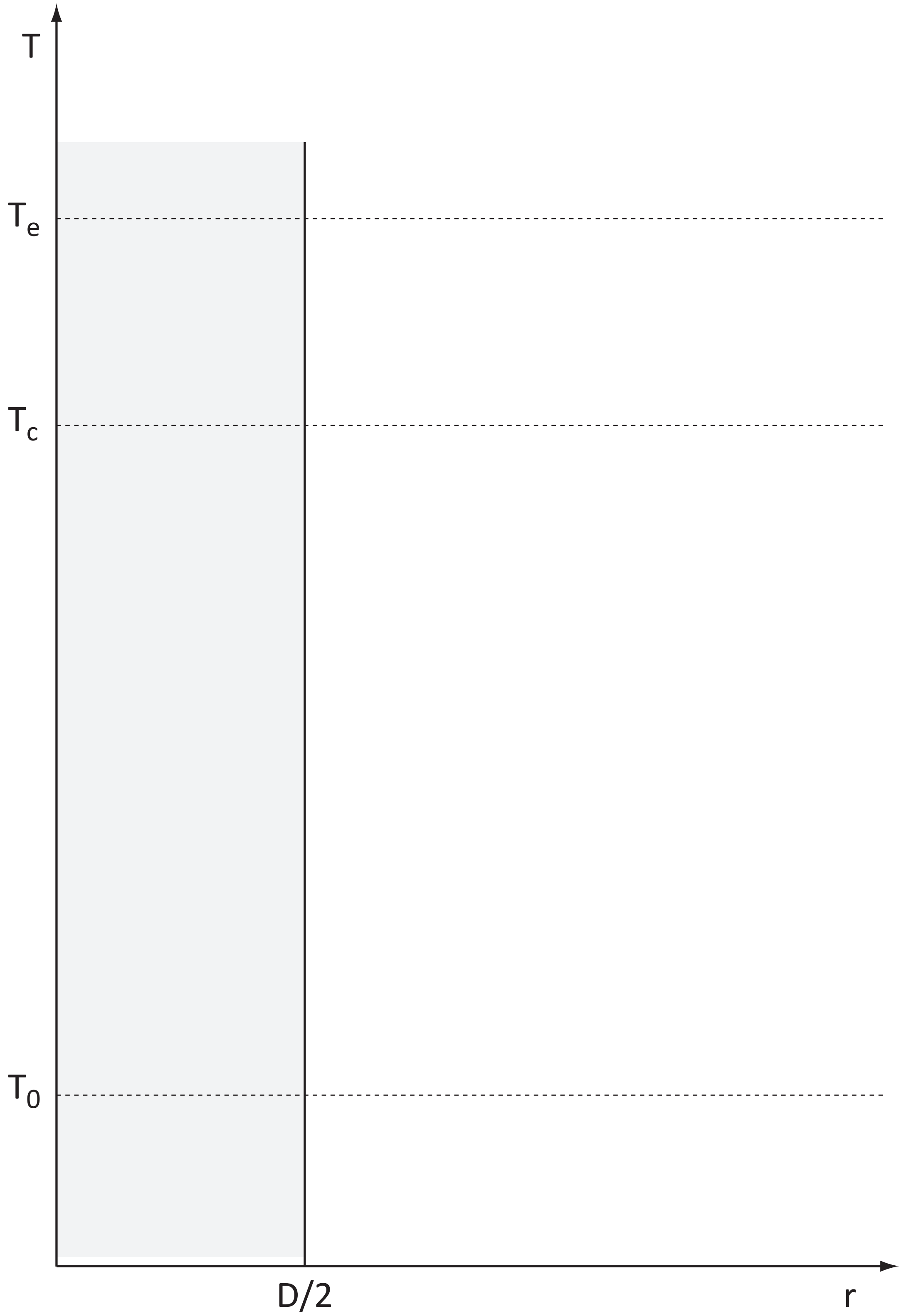
Air:

- Velocity of the air: u = 0.1 m/s
- Thermal conductivity of the air: $\lambda_\mathrm{a} = 25.7 \cdot 10^{-3}$ W/mK
- Kinematic viscosity of the air: ν_a = 15.35 m²/s
- Prandtl number: Pr = 0.71

Cylinder:

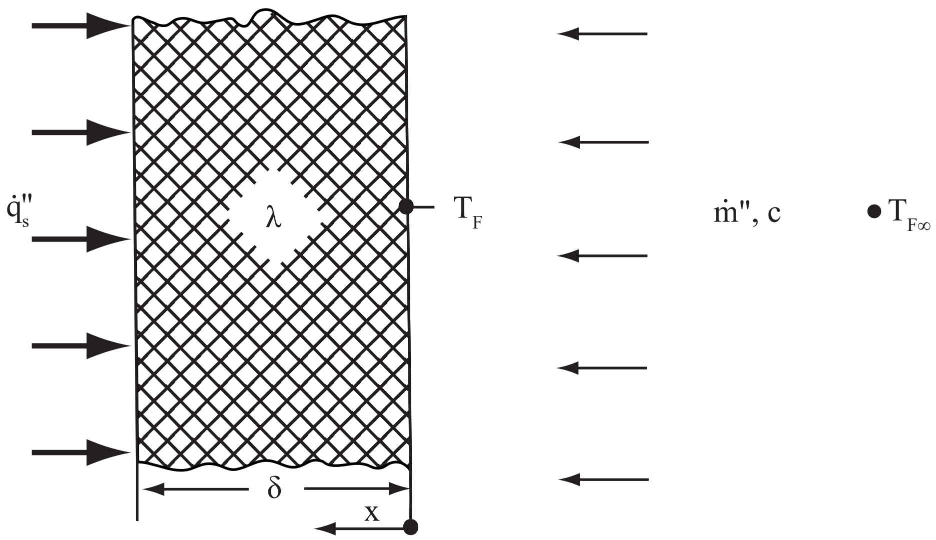
- Diameter of the cylinder:: D = 0.055 m
- Density of the cylinder: ρ = 1500 kg/m³
- Thermal conductivity of the cylinder: λ = 0.119 W/mK
- Heat capacity of the cylinder: c_p = 1000 J/kgK

b)



1.7 Absorption in a porous wall ★ ★ ★

The surface of a porous wall, impermeable to radiation, absorbs a radiative heat flux of. For cooling purposes a coolant is circulated through the wall with a with an inlet temperature is T_{F}.



Tasks:

a) Determine the temperature profile $T(x)$ for the porous wall.
b) Determine the maximum temperature $T_{\max}$ reached within the wall.
c) Determine the heat flux $\dot{q}''_{\mathrm{F}}$ per unit area, which is transmitted into the fluid at $x = 0$.
d) Which temperature $T_{\mathrm{F},\infty}$ does the fluid reach far away from the wall?
e) Sketch the temperature profiles for two different mass fluxes and mark each curve.

Hints:

- Within the wall, conduction of the imposed radiative heat flux is negligible.
- The local fluid and wall temperatures can be assumed to be identical.

Given Parameters:

Wall properties:

- Imposed radiative heat flux: $\dot{q}''_{\mathrm{r}} = 150 \cdot 10^3$ W/mK
- Thickness of the wall: $\delta = 50$ mm
- Thermal conductivity of the wall: $\lambda = 8$ W/mK

Fluid properties:

- Specific heat capacity: $c = 1000$ J/kgK
- Inlet temperature: $T_{\mathrm{F}} = -15$ °C
- Mass flux: $\dot{m}'' = 0.6$ kg/m$^2 \cdot$ s