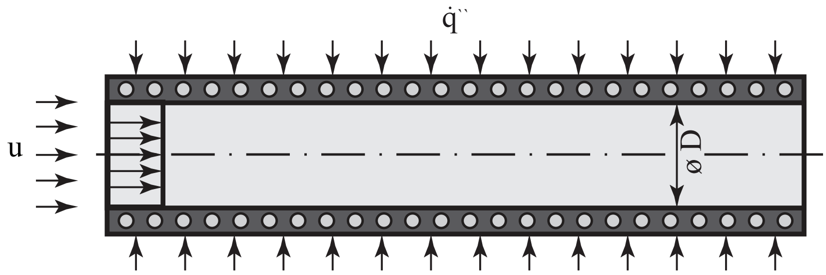
Exercise III.9 (Pipe flow with a constant heat flux ⋆⋆)**:**

A fluid flows through a long cylindrical tube. A constant heat flux density $\dot{q}''$ is imposed on the fluid.



Given parameters:

- Average axial velocity: u
- Heat flux density: $\dot{q}''$
- Fluid density: ρ
- Fluid thermal capacity: c_p
- Fluid thermal conductivity: λ
- Inner pipe diameter: D

Hint:

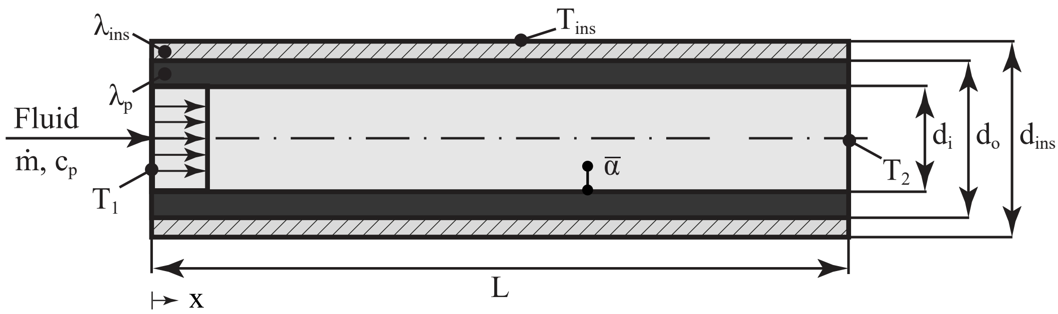
- Axial heat diffusion cannot be neglected.

Tasks:

a) Derive the transient differential energy equation for the mean fluid temperature along the axial direction.

Exercise III.10 (Insulated pipe ⋆⋆):

A pipe is being heated by a stationary flow. The outer surface of the pipe has an insulation layer with its external side kept at a constant temperature T_{ins}.



Given parameters:

- Temperature of the fluid at the inlet: T_1
- Temperature of outer surface area of the pipe: T_{ins}
- Convective heat transfer coefficient: $\overline{\alpha}$
- Mass flow of the fluid: $\dot{m}$
- Specific heat capacity of the fluid: c_{p}
- Inner diameter of the pipe: d_{i}
- Outer diameter of the pipe excluding insulation: d_{o}
- Outer diameter of the pipe including insulation: d_{ins}
- Length of the pipe: L
- Thermal conductivity of the pipe wall: λ_{p}
- Thermal conductivity of the insulation layer: λ_{ins}

Tasks:

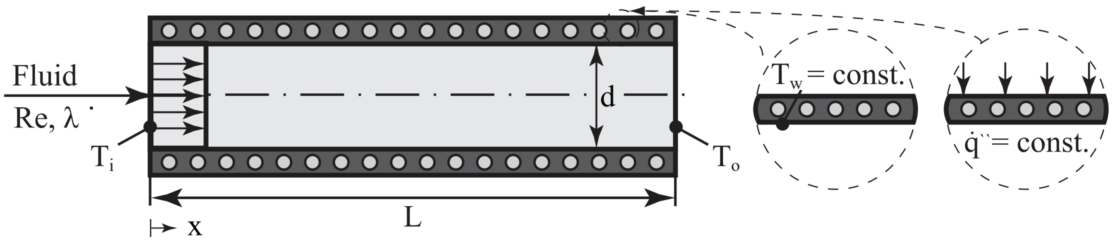
a) Find an expression for the exit temperature T_2 in terms of given parameters.

Exercise III.11 (Heating of a pipe ⋆⋆⋆):

A fluid is flowing through a pipe. The flow is thermally and hydrodynamically developed. A heat flow that is transferred from the wall by convection is heating the fluid from T_i to T_o. For this purpose,

- in case 1: a constant, homogeneous **wall temperature** T_w
- in case 2: a constant, homogeneous **heat flux** $\dot{q}''$

is impressed.



Given parameters:

- Temperature of the fluid at the inlet: T_i
- Temperature of the fluid at the outlet: T_o
- Wall temperature (case 1): T_w
- Heat flux (case 2): $\dot{q}''$
- Length of the pipe: L
- Inner diameter of the pipe: d
- Reynolds number of the flow: $\mathrm{Re} < 2300$
- Density of the fluid: λ
- Dynamic viscosity of the fluid: η
- Conductivity of the fluid: λ

Hints:

- Heat conduction in the direction of the fluid flow is negligible.
- Difference in fluid properties in the radial direction is negligible.

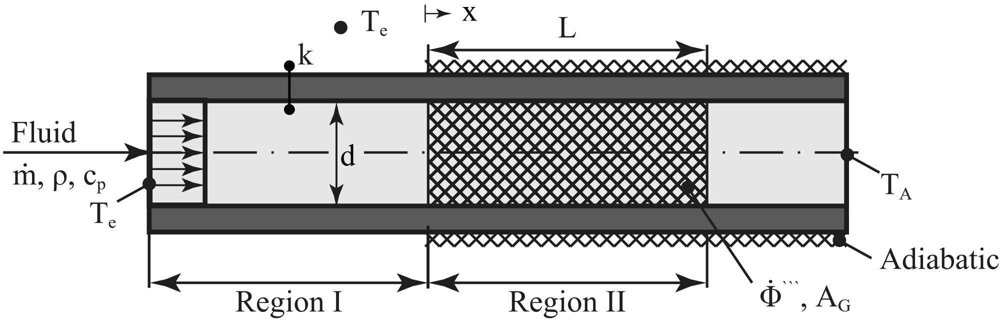
Tasks:

a) Write out the global energy balance in terms of given parameters, determine the mean heat transfer coefficient $\overline{\alpha}$ and provide the respective mean temperature difference ΔT_m between the inner wall of the tube and the fluid for both cases.

b) Draw qualitatively for both cases the profile of the wall temperature T_w and the mean fluid temperature T_fl.

Exercise III.12 (Flow through a grid ⋆⋆⋆):

Water flows through a long tube that has adiabatic walls from a certain location $x = 0$. The area upstream of $x = 0$ is named region I. Between the point $x = 0$, and $x = L$ (region II) a very fine-meshed, electrically heated grid is located in the flow. Well ahead of the grid, the flow has the ambient temperature T_e, and downstream of the grid, the temperature T_A.



Given parameters:

- Water temperature before the grid: T_e
- Environment temperature: T_e
- Water temperature after the grid: T_A
- Mass flow rate: $\dot{m}$
- Thermal conductivity: λ
- Specific heat capacity: c_p
- Diameter of the pipe/grid: d
- Length of the grid: L
- Average heat flux on the surface of the grid: $\dot{q}''$
- Heat transfer area of the grid: A_G
- Overall heat transfer coefficient between water and environment, based on the inner pipe wall area k

Hint:

- The problem is steady and one-dimensional.
- The electrically heated mesh is so fine that a homogeneous heat flux is introduced.
- The volume of the fine-meshed grid can be neglected.

Tasks:

a) Determine the volumetric heat release $\dot{\Phi}'''$ created by the electrically heated grid.

b) Derive the differential equations for the temperature profile of the water in the pipe in regions I and II. It is unknown whether heat diffusion is negligible, and thus should be included in the equation.

c) Provide all the coupling or boundary conditions required for the solution of the problem (regions I and II).

d) Sketch the temperature profiles of the water in the pipe with and without consideration of the diffusive heat transport.