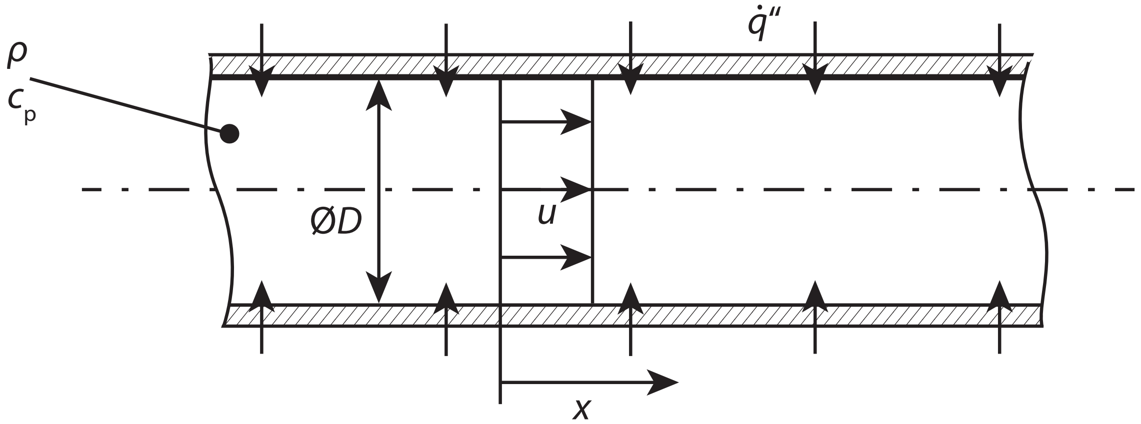
# 1.8 Pipe flow - constant heat flux ★★

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




## Tasks:

a) Derive the transient differential energy balance for the averaged temperature in the fluid in axial direction.

## Hint:

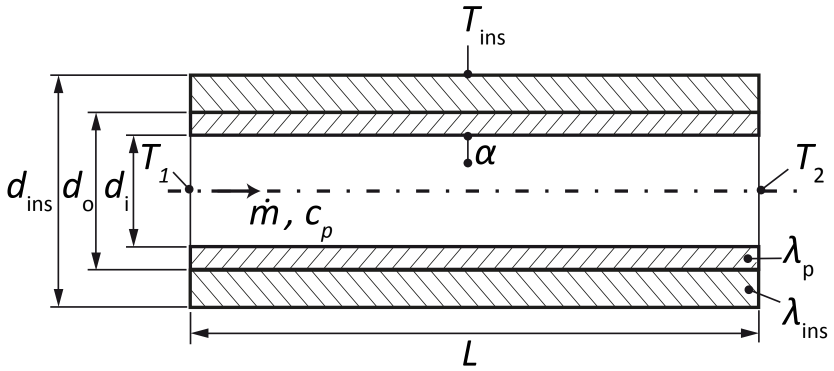
- Axial heat diffusion is negligible.

## Given parameters:

- Average axial velocity: $u$
- Heat flux density: $\dot{q}''$
- Fluid density: $\rho$
- Fluid thermal capacity: $c_\mathrm{p}$
- Inner pipe diameter: $D$

# 1.9 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 $T_{\text{ins}}$.




## Tasks:

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

## Given parameters:

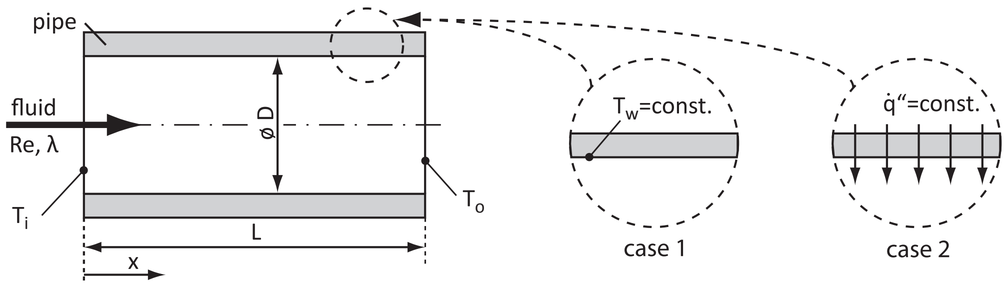
- Temperature of the fluid at the inlet: $T_1$
- Temperature of outer surface area of the pipe: $T_{\text{ins}}$
- Convective heat transfer coefficient: $\alpha$
- Mass flow of the fluid: $\dot{m}$
- Specific heat capacity of the fluid: $c_{\text{p}}$
- Inner diameter of the pipe: $d_{\text{i}}$
- Outer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

# 1.10 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 $T_\mathrm{i}$ (inlet) to $T_\mathrm{o}$ (outlet). For this purpose,

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

is impressed.




## Tasks:

a) Determine the mean convective heat transfer coefficient $\overline{\alpha}$ for both cases.
b) Give the respective mean temperature difference $\Delta T_\mathrm{m}$ between the inner wall of the tube and the fluid.
c) Draw qualitatively for both cases the profile of the wall temperature $T_\mathrm{w}$ and the mean fluid temperature $T_\mathrm{fl}$.

## Hint:

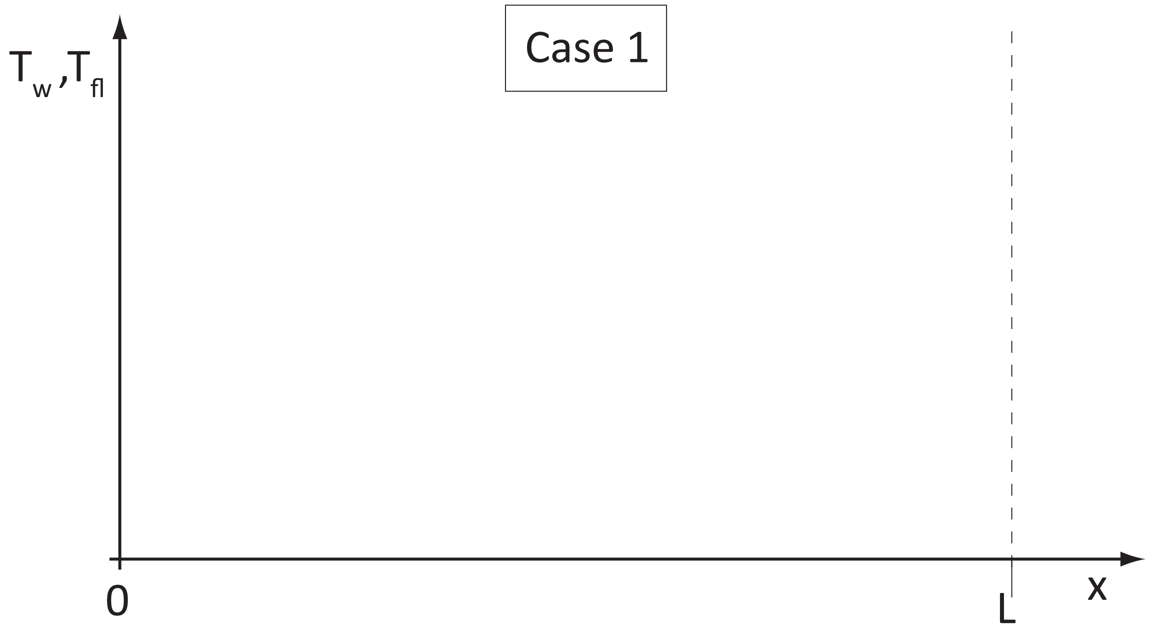
- Heat conduction in the direction of the fluid flow is negligible.
- $\eta = \eta_\mathrm{w}$

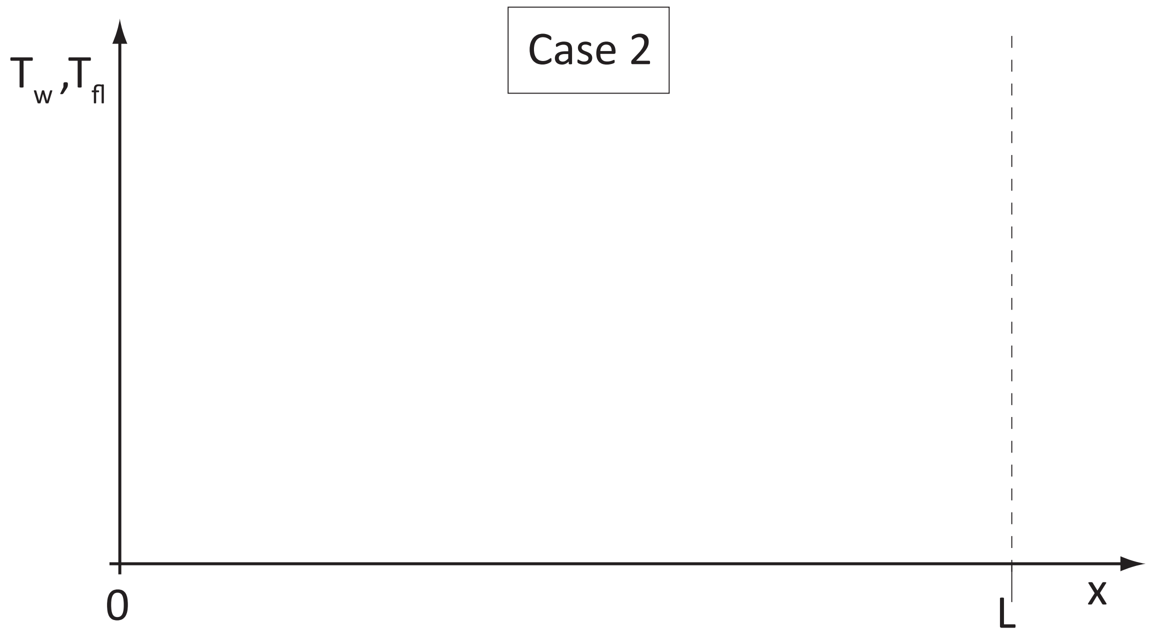
## Given parameters:

- Temperature of the fluid at the inlet: $T_\mathrm{i}$
- Temperature of the fluid at the outlet: $T_\mathrm{o}$
- Wall temperature (case 1): $T_\mathrm{w}$

- Heat flux (case 2): $\dot{q}''$
- Length of the pipe: $L$
- Inner diameter of the pipe: $D$
- Reynolds number of the flow: $\mathrm{Re} < 2300$
- Conductivity of the fluid: $\lambda$

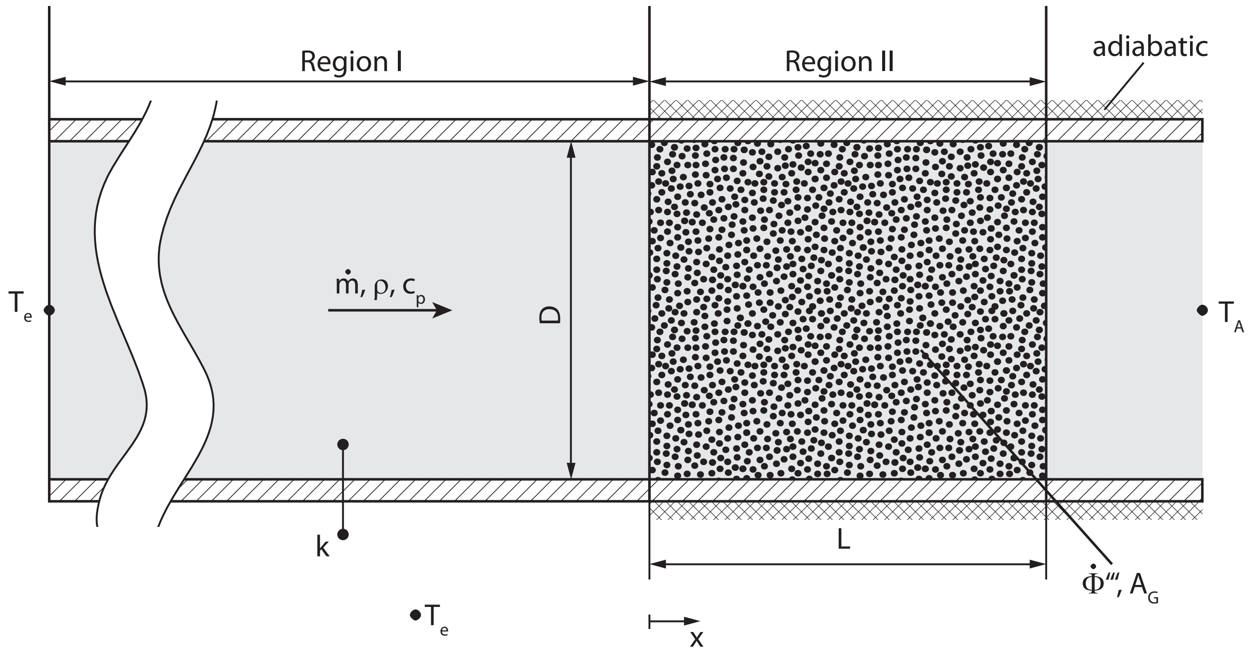
c)



# 1.11 Flow through a grid ★ ★ ★

Water flows through a long tube which 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 $T_A$.




## 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.

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.

## Hints:

- 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.

## Given parameters:

- **Temperatures:**
  - Water temperature before the grid: $T_\mathrm{e}$
  - Environment temperature: $T_\mathrm{e}$
  - Water temperature after the grid: $T_\mathrm{A}$
- **Water:**
  - Mass flow rate: $\dot{m}$
  - Thermal conductivity: $\lambda$
  - Specific heat capacity: $c_\mathrm{p}$
- **Pipe and grid:**
  - 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: $A_\mathrm{G}$
- **Overall heat transfer coefficient:**
  - Overall heat transfer coefficient (inverse of total resistance) between water and environment, based on the inner pipe wall area: $k$