TURBULENT FLOW IN CIRCULAR TUBES: EXAMPLE

Hot air with a mass flow rate \( \dot{m} = 0.050 \text{ kg/s} \) flows through an uninsulated sheet metal duct of diameter \( D = 0.15 \text{ m} \), which is in the crawlspace of a house. The hot air enters at \( T_{m,i} = 103 \, ^\circ\text{C} \) and, after a distance \( L = 5 \, \text{m} \), cools to \( T_{m,L} = 85 \, ^\circ\text{C} \). The heat transfer coefficient between the duct outer surface and the ambient air at \( T_\infty = 0 \, ^\circ\text{C} \) is known to be \( h_o = 6 \, \text{W/m}^2\cdot\text{K} \).

1. Calculate the heat loss from the duct over the length \( L \).
2. Determine the heat flux and the duct surface temperature at \( x = L \).

ASSUMPTIONS

FLUID PROPERTIES

Film temperature: \( \) \hspace{2cm} Outlet temperature: \( \)

Air properties: \( \)
Energy balance for the entire tube:

Heat flux calculation:
An expression for the heat flux can be derived from the thermal circuit representation:

\[ \Rightarrow \]

The convection coefficient \( h_c \) can be obtained by considering an appropriate convection correlation.

Flow regime determination:
The local Nusselt number for fully developed turbulent flow in circular pipes is given by:

\[ \text{Nu}_d = 0.023 \text{Re}^{4/5} \text{Pr}^n \]

For heating, \( n = 0.4 \) and for cooling, \( n = 0.3 \).

**Convection coefficient calculation:**

**Heat flux:**

**Calculation of the surface temperature:**

From the circuit representation: