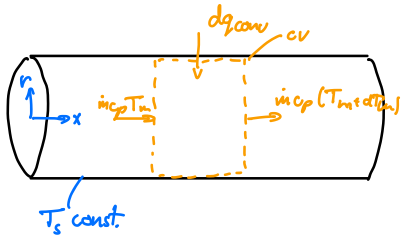
11A - 2ND CLASS



$T_m(x) = ?$

$\cancel{\dot{E}_{st}}^{0} = \dot{E}_{in} - \dot{E}_{out} + \cancel{\dot{E}_g}^{0}$

$\dot{E}_{in} = \dot{E}_{out}$

$\dot{m}c_pT_m + dq_{conv} = \dot{m}c_p(T_m + dT_m)$

$dq_{conv.} = \dot{m}c_p\, dT_m$

differential surface area

$h\, dA_s (T_s - T_m(x)) = \dot{m}\, c_p\, dT_m$

$dA_s = P\,dx$

$h\, \underbrace{P}_{\text{perimeter}} dx\, (T_s - T_m(x)) = \dot{m}c_p dT_m$

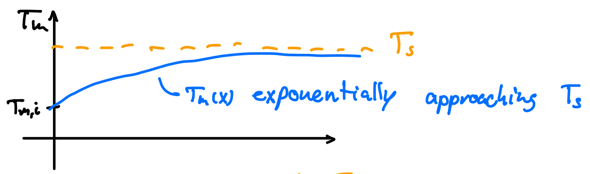
$$\boxed{\frac{dT_m}{dx} = \frac{hP}{\dot{m}c_p}(T_s - T_m(x))}$$

ODE
1st order
Linear
Non-homogeneous

$T_m(x) = T_s - (T_s - T_{m,i})\, e^{\frac{-hP}{\dot{m}c_p}x}$

$T_{m,i} = T_m(x=0)$

$h = \text{const.}$ } Fully developed thermal flow

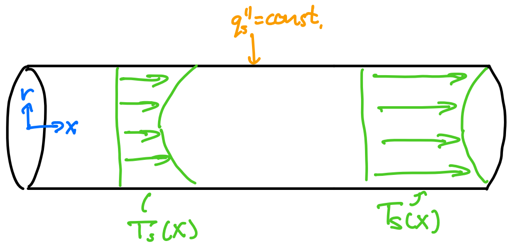


solve for $T(r)$

$h = \dfrac{-k\frac{\partial T}{\partial r}\Big|_{r_o}}{T_s - T_m} = 3.66\,\dfrac{k}{D}$ ← Diameter

$$\boxed{Nu = \frac{hD}{k} = 3.66}$$

laminar flow
$T_s = \text{const.}$



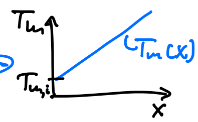
Fully Developed Thermal Flow
$h = const.$

$T_m(x) = ?$

- Differential Control Volume
- Energy Balance
- Differential Equation
- Solve

$$\boxed{T_m(x) = T_{m,i} + \frac{q_s'' P}{\dot{m} c_p} x}$$

Grows Linearly $\rightarrow$



$$q_s'' = h\,(T_s(x) - T_m(x))$$

$$h = \frac{q_s''}{T_s(x) - T_m(x)} = \frac{48}{11}\frac{k}{D} \rightarrow Nu = \frac{48}{11} = 4.36$$

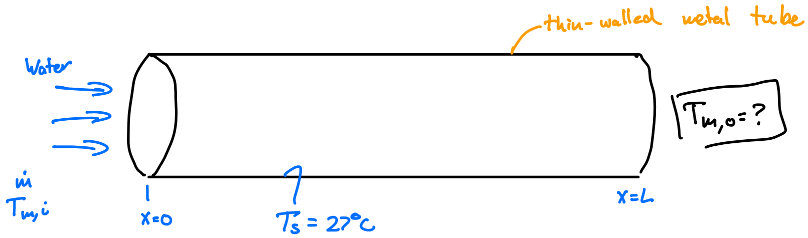
TURBULENT FLOW ($Re_D \gtrsim 2300$)

$$Nu = 0.023\, Re_D^{4/5}\, Pr^n$$

$n = 0.4$ $T_s > T_m$ (Heating the fluid)
$n = 0.3$ $T_s < T_m$ (Cooling the fluid)

Dittus-Boelter Correlation

Assuming:
- local Nusselt Number
- Circular Pipe
- Hydrodynamic + Thermally Fully Developed Flow
- For Both $q_s'' = const.$ & $T_s = const.$



$L = 1m$
$D_i = 3mm$
$\dot{m} = 0.015 \; kg/s$
$T_{m,i} = 97°C$
$T_{m,i} > T_s$
Water is being cooled in pipe

h and $T_{m,o}$ will depend on the flow field.

avg. velocity

$$Re_D = \frac{\rho u_m D_i}{\mu}$$

$$\dot{m} = \rho u_m A_c$$