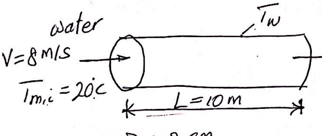
**Example:** Water flows in a 2 cm diameter tube with a length of 10 m at an average flow velocity of 8 m/s. If the water enters at 20 ℃ and leaves at 30 ˚C, determine $T_w$, temperature of the wall necessary to affect the required heat transfer.




$$\bar{T}_m = \frac{T_{m,i}+T_{m,o}}{2} = \frac{20+30}{2} = 25^\circ C \quad (298\,K)$$

From table A.6

$$\rho = 996\ kg/m^3,\quad \mu = 8.96\times10^{-4}\ Pa.s$$

$$P_r = 6.13,\quad C_p = 4180\ J/kg\,K,\quad k = 0.611\ W/m.$$

$$Re_D = \frac{\rho V D}{\mu} = \frac{998\times 8\times 0.02}{8.96\times10^{-4}} = 1.78\times10^{5} > 2300 \text{ turbulent}$$

$$\text{eq } 8.60 \longrightarrow \overline{Nu}_D = 0.023\, Re_D^{0.8}\, Pr^{0.4}$$

$n=0.3$ cooling

$n=0.4$ heating

$$\bar{h} = \frac{k}{D}\left[0.023\, Re_D^{0.8}\, Pr^{0.4}\right]$$

$$= \frac{0.611}{0.02}\left[0.023(1.78\times10^{5})^{0.8}(6.13)^{0.4}\right]$$

$$= 23000\ W/m^2K$$

$$\dot m = \rho A V = \rho\left(\frac{\pi D^2}{4}\right)V = 996\left(\frac{\pi(0.02)^2}{4}\right)\times 8 = 2.5\ kg/s$$

$$q = \dot m\, c_p\,(T_{m,o}-T_{m,i}) = 2.5\times 4180(30-20) = 104500\ W$$

$$q = \bar{h}\pi D L\, \Delta \bar{T}_{lm} \Rightarrow \Delta \bar{T}_{lm} = \frac{q}{\bar{h}\pi D L} = \frac{104500}{23000(\pi)(0.02)(10)}$$

$$= 7.2348$$

$$\Delta T_{lm} = \frac{\Delta T_o - \Delta T_i}{\ln\frac{\Delta T_o}{\Delta T_i}} = \frac{(T_w - T_{m,o}) - (T_w - T_{m,i})}{\ln\left[\frac{(T_w - T_{m,o})}{(T_w - T_{m,i})}\right]}$$

$$\bar{T}_w = 33.3^\circ C$$