CANKAYA UNIVERSITY
FACULTY OF ENGINEERING AND ARCHITECTURE
MECHANICAL ENGINEERING DEPARTMENT

ME 313 Heat Transfer
Midterm Exam II

FALL 2018

1) Atmospheric air at 20 ^{0}C flows with a velocity of 2 m/s over 3 m by 3 m surface of a wall which absorbs solar energy flux at a rate of 500 W/m^2 and dissipates heat by convection into the air stream .Assuming that the other surface of the wall has negligible heat loss , determine the average temperature of the wall under equilibrium conditions.
Hint: Evaluate the fluid properties at the $T_\infty = 20\,^0$C . Do not iterate.

At 20°C

$\nu = 1{,}581 \times 10^{-5}$ m²/s $k = 0.02568$ W/mK

$Pr = 0{,}71$

$Re_L = \frac{u_\infty L}{\nu} \cong 3{,}8 \times 10^5 <$ Laminar flow

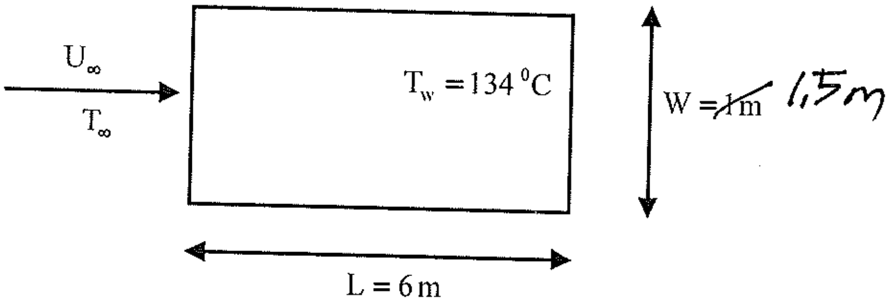
$$\overline{T_w - T_\infty} = \frac{(L/k) q''}{0{,}6795 \sqrt{Re_L}\; Pr^{1/3}} \approx 156\ °C$$

$$\overline{T_w} = 156 + 20 \approx 176\,°C$$

Next $T_f = \frac{\overline{T_w} + T_\infty}{2} = \frac{176+20}{2} = 98°C$

evaluate fluid properties and repeat calulation until convergence is obtained.

2) Air at 1 atm pressure and 20 ^0C flows with a velocity of 8 m/s over a 1.5 m by 6 m flat plate whose temperature is 134 ^0C.



Determine the rate of heat transfer from the plate.

$$T_f = \frac{T_w + T_\infty}{2} = \frac{134+20}{2} = 77°C = 350K$$

$\rho = 0{,}995\ kg/m^3$ $C_p = 1{,}009\ kJ/kg\,K$

$\mu = 208{,}2 \times 10^{-7}\ N\,s/m^2$ $k = 30 \times 10^{-3}\ W/m\,K$

$Pr = 0{,}7$

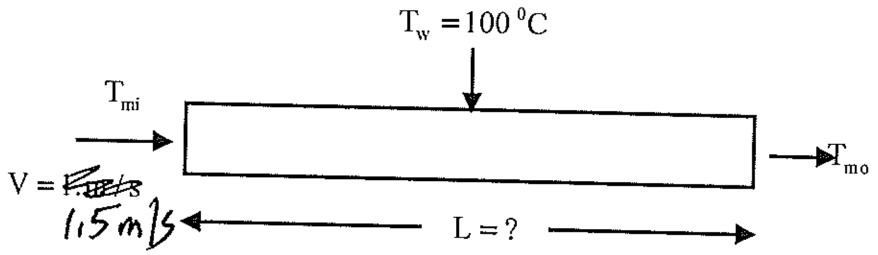
$$Re_L = \frac{\rho U_\infty L}{\mu} \cong 2{,}3 \times 10^6 > 500\,000 \quad \text{turbulent flow}$$

$$\overline{Nu}_L = \left[0{,}037\, Re_L^{0{,}8} - 871\right] Pr^{1/3} = 3248$$

$$\bar{h} = \frac{k}{L}\overline{Nu}_L = 16{,}25\ W/m^2 K$$

$$q = \bar{h}\,(WL)\,(T_w - T_\infty) = 16\,672\ W$$

3.) Water at a velocity of 1.5 m/s is passed through a smooth 2 cm inner diameter tube, The mean temperature of the water at the inlet is 20 ⁰C. The tube wall is at a constant temperature of 100 ⁰C. Estimate the tube length required to heat the water to a mean temperature of 60 ⁰C.



Take

$$\overline{T_m} = \frac{T_{mi}+T_{mo}}{2} = \frac{20+60}{2} = 40^{\circ}C = 313K \approx 315K$$

$\rho = 1000\ kg/m^3$ $\quad c_p = 4180\ J/kg.K$

$\mu = 631 \times 10^{-6}\ N.s/m^2$ $\quad k = 0.634\ W/mK$

$Pr = 4.16$

$$Re_D = \frac{\rho V D}{\mu} = 47543 > 10\,000 \text{ fully turbulent}$$

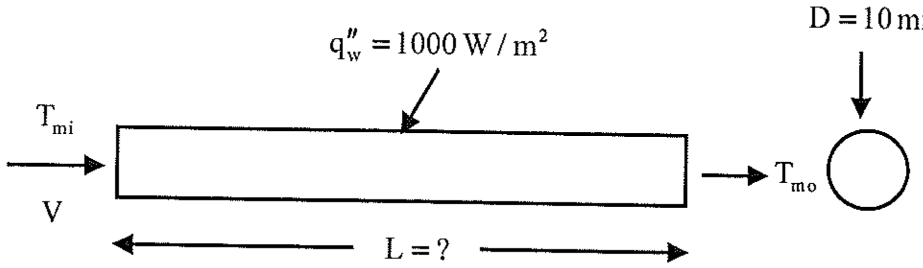
$$\overline{Nu_D} = 0.023\,(47543)^{0.8}(4.16)^{0.4} = 224.4$$

$$\overline{h} = \frac{k}{D}\overline{Nu_D} = 7747.4\ W/m^2K$$

$$\dot{m} = \rho V A = \rho V \frac{\pi D^2}{4} = 0.471\ kg/s$$

$$L = \frac{\dot{m} c_p}{\pi D \overline{h}} \ln\left[\frac{T_w - T_{mi}}{T_w - T_{mo}}\right] \approx 2.8\ m$$

4.) A water heater is fabricated by a resistance wire wound uniformly over a 10 mm diameter tube. The resistance element maintains a uniform heat flux of 1000 W/m² . The



mass flow rate of water is 12 kg/hr. The mean inlet and outlet temperature of water is 10 °C and 24 °C respectively.

a) Estimate the tube length

b) Assuming that flow is thermally and hydrodynamically fully developed, estimate the average pipe surface temperature.

$\overline{T_m} = \frac{T_{mi} + T_{mo}}{2} = \frac{10+24}{2} = 34/2 = 17°C = 290K$

$\rho = 1000\ kg/m^3 \qquad c_p = 4184\ J/kg\,K$

$\mu = 1080 \times 10^{-6}\ \frac{N.s}{m^2} \qquad k = 598 \times 10^{-3}\ W/mK$

$Pr = 7{,}56$

a) $\dot{m} c_p (T_{mo} - T_{mi}) = q''(\pi D L)$

$L \cong 6{,}21\ m$

b) $q''(\pi D L) = \bar{h}(\pi D L)(\overline{T_w} - T_{mo})$

$\overline{T_w} = \frac{q''}{\bar{h}} + T_{mo}$

$z_{fd,H} = 0{,}05\, Re_D D$

$z_{fd,T} = 0{,}05\, Re_D D\, Pr$

$Nu_D = 4{,}36 \rightarrow \bar{h} = ?$

$$Re_D = \frac{\rho V D}{\mu} = \frac{4\dot{m}}{\pi D \mu} = 393 < 2300$$

flow is laminar

$$Z_{fd,H} = 0.05\, Re_D\, D = 0.1964\ m \quad HFD$$

$$Z_{fd,T} = 0.05\, Re_D\, D\, Pr = 1.4854\ m \quad TFD$$

$$\bar{h} = (4.36)\left(\frac{k}{D}\right) = 260.7\ W/m^2K$$

$$\bar{T}_w = 24 + \frac{1000}{260.7} \cong 27.81°C$$