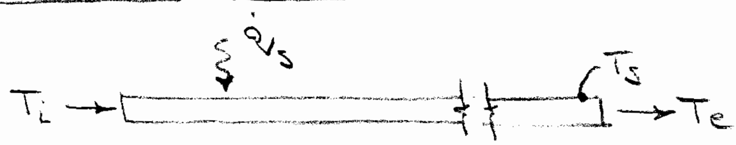
MECH 262 - ASSIGN # 5 SOLUTION

(1)



a) $T_i = 55\,°F = 12.78\,°C$, $T_e = 200\,°F = 93.33\,°C$

$\dot{m} = 4\ lb_m/s = 1.814\ kg/s$

$D = 1.25\ in = 0.03175\ m$

$\dot{q}_s = 350\ \frac{BTU}{hr \cdot FT} = 337\ W/m$ OF LENGTH

b) $\dot{Q} = \dot{m} C_p (T_e - T_i)$ WHERE: $C_p = 4.203\ kJ/kg \cdot K$ @ AVG. TEMP.

so $\dot{q}_s \times \text{LENGTH} = C_p (T_e - T_i)$

$$\text{LENGTH} = \frac{(4.203)(93.33 - 12.78)}{337\ W/m} = 1820\ m$$

LENGTH = 1.82 km

c) AT EXIT: $\rho = 961.5\ kg/m^3$, $\mu = 297 \times 10^{-6}\ m^3/s$ @ 95 °C

$k = 0.677\ W/m \cdot K$

$Pr = 1.85$

$Q = \dot{m} \rho = 1.814 \times 961.5 = 1.89 \times 10^{-3}\ m^3/s$

$V = Q/A = 1.89 \times 10^{-3} / \left[\frac{\pi (0.03175)^2}{4}\right] = 2.38\ m/s$

$$Re = \frac{V D \rho}{\mu} = \frac{(2.38)(0.03175)(961.5\ kg/m^3)}{297 \times 10^{-6}} = 2.45 \times 10^5$$

$Nu = 0.0155\, Pr^{0.5}\, Re^{0.83}$, WATER, TURBULENT

$= 0.0155 (1.85)^{0.5} (2.45 \times 10^5)^{0.83} = 626.4$

$$h = \frac{Nu\, k}{D} = \frac{(626.4)(0.677)}{0.03175} = 13{,}356.\ W/m^2 \cdot K$$

$\dot{q}_s = hA (T_s - T_e)$

$$\text{so } T_s = T_e + \frac{\dot{q}_s}{hA} = 93.33 + \frac{337}{(13{,}356)(\pi \times 0.03175 \times 1)}$$

(LAST METER)

$= 93.33 + 0.283$

$T_s = 93.62\,°C$

$$\frac{\cancel{W}/\cancel{m}}{\frac{\cancel{W}}{\cancel{m^2} \cdot K} \times \cancel{m^2}/\cancel{m} \text{ OF LENGTH}} = K \text{ or } °C$$

so $T_s = 93.62\,°C$

(2) AIR AT 25 °C

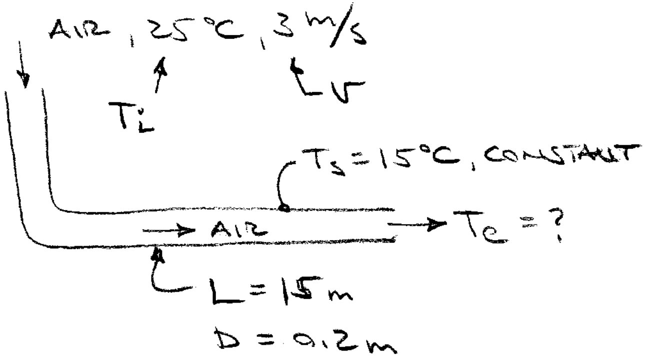
$\rho = 1.184 \; kg/m^3$

$C_p = 1{,}007 \; J/kg \cdot K$

$k = 0.02551 \; W/m \cdot K$

$\mu = 1.849 \times 10^{-5} \; kg/m \cdot s$

$Pr = 0.7296$



a) $Re = \dfrac{VD\rho}{\mu} = \dfrac{(3)(0.2)(1.184)}{1.849 \times 10^{-5}} = 38{,}421$ ∴ TURBULENT.

$Nu = 0.022 \, Pr^{0.6} \, Re^{0.8}$ GASSES, $Pr > 0.5$ & < 1.0

$= 0.022 (0.7276)^{0.6} (38{,}421)^{0.8}$

$= 84.57$

$h = \dfrac{Nu \, k}{D} = \dfrac{(84.57)(0.02551)}{0.2}$

$= 10.79$

$A_s = \pi D L$

$= \pi (0.2)(15)$

$= 9.42 \; m^2$

$\dot{m} = V A \rho = (3)\left(\dfrac{\pi (0.2)^2}{4}\right)(1.184) = 0.112 \; kg/s$

$T_e = T_s - (T_s - T_i) \, e^{\left[-hA_s / \dot{m} C_p\right]}$ FROM TEXT.

$= 15 - (15 - 25) \, e^{\left[-(10.79)(9.42) / (0.112)(1{,}007)\right]}$

$= 15 - (15 - 25) \, e^{[-0.9012]}$

$T_e = 19.06 \; °C$

b) METHOD (1): ALONG PIPE

$\dot{q} = \dot{m} \, C_p \, (T_e - T_i)$

$= (0.112)(1007)(19.06 - 25)$

$= -669.9 \; W$

↳ LEAVES PIPE.

METHOD (2): THRU PIPE WALL

$\dot{q} = h A \Delta T_{LM}$

$\Delta T_{LM} = \dfrac{\Delta T_e - \Delta T_i}{\ln(\Delta T_e / \Delta T_i)}$

$= \dfrac{(-4) - (-10)}{\ln\left((-4)/(-10)\right)}$

$= -6.55 \; °C$

$\Delta T_e = T_s - T_e$

$= 15 - 19$

$= -4$

$\Delta T_i = T_s - T_i$

$= 15 - 25$

$= -10$

∴ $\dot{q} = (10.79)(9.42)(-6.55)$

$= -665.6 \; W$

QUITE CLOSE. EACH USES A DIFFERENT HEAT TRANSFER PATH BUT COME OUT ALMOST THE SAME