Solution to Exercise Nr. 7

Solar Flat Plate Collectors

1)

$$h_{r,p-w} = \frac{\sigma\left(T_p + T_w\right)\left(T_p^2 + T_w^2\right)}{\frac{1}{\varepsilon_p} + \frac{1}{\varepsilon_w} - 1} = 8.1 W/m^2C$$

$$h_{r,w-s} = \frac{\sigma\varepsilon_w\left(T_w^4 - T_s^4\right)}{\left(T_w - T_a\right)} = \sigma\varepsilon_w\left(T_w^2 + T_s^2\right)\left(T_w + T_s\right) = 5.6 W/m^2C$$

$$U_L = \left(\frac{1}{h_{c,p-w} + h_{r,p-w}} + \frac{1}{h_{c,w-a} + h_{r,w-a}}\right)^{-1} = \left(\frac{1}{5+8.1} + \frac{1}{15+5.6}\right)^{-1} = 8 W/m^2C$$

2)

$$m = \sqrt{U_L/k\delta} = \sqrt{\frac{8}{385 \cdot 5 \cdot 10^{-4}}} = 6.45$$

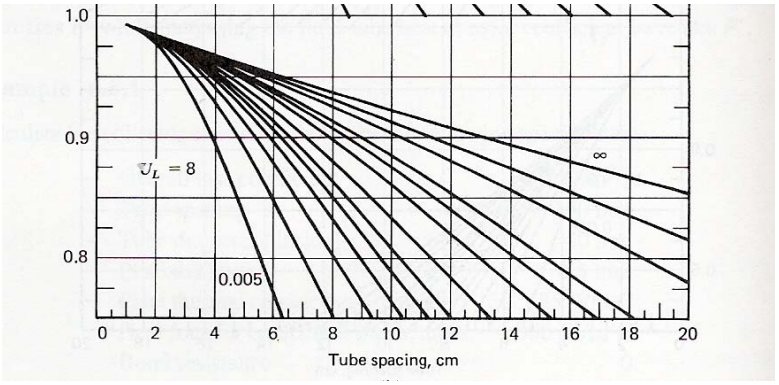
$$F = \frac{\tanh\left[m(W-D)/2\right]}{m(W-D)/2} = \frac{\tanh\left[6.45(0.15-0.01)/2\right]}{6.45(0.15-0.01)/2} = 0.94$$

3)

$$F' = \frac{1/U_L}{W\left[\frac{1}{U_L\left[D+(W-D)F\right]} + \frac{t_b}{k_b w_b} + \frac{1}{h_f \pi D_i}\right]}$$

$$= \frac{1/8}{0.15\left[\frac{1}{8\left[0.01+(0.15-0.01)0.94\right]} + \frac{1}{300 \cdot 0.01\pi}\right]} = 0.84$$

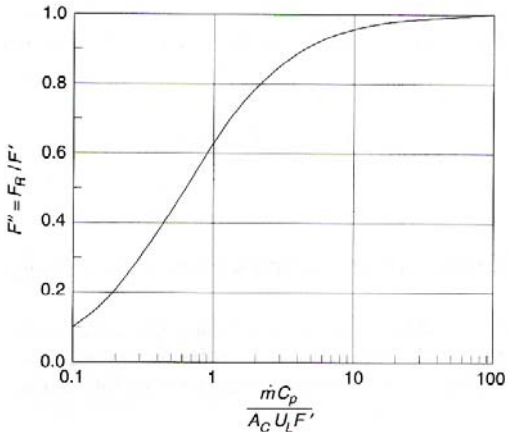
Or using Figure ($U_L = 8 W/m^2C, k\delta = 0.1925 W/C, W = 15cm$):



4)

$$F_R = \frac{\dot{m}C_p}{A_c U_L}\left[1-\exp\left(-\frac{A_c U_L F'}{\dot{m}C_p}\right)\right] = \frac{0.03\cdot 4190}{2\cdot 8}\left[1-\exp\left(-\frac{2\cdot 8\cdot 0.84}{0.03\cdot 4190}\right)\right] = 0.79$$

Or using the graph: $\frac{\dot{m}C_p}{A_c U_L F'} = 9.35 \rightarrow \frac{F_R}{F'} = 0.95 \rightarrow F_R = 0.79$



5)

$$\left.\begin{array}{l} R \longrightarrow \dfrac{2\rho}{1+\rho} = 0.08 \\ T \longrightarrow \dfrac{1-\rho}{1+\rho} = 0.92 \end{array}\right\} (\tau\alpha)_{av} \approx 0.96\cdot(\tau\alpha)_b = 0.96\cdot\frac{T\alpha}{1-(1-\alpha)R} = 0.96\cdot\frac{0.92\cdot 0.95}{1-(1-0.95)0.08} = 0.84$$

$$\eta_c = F_R\left[(\tau\alpha)_{av} - \frac{U_L\left(T_{f,in}-T_a\right)}{I_T}\right] = 0.79\left[0.84-\frac{8(20-10)}{400}\right] = 0.51$$