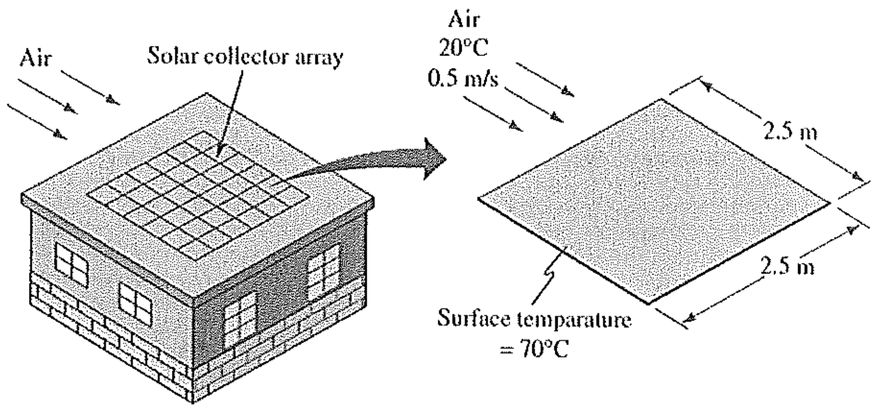
CANKAYA UNIVERSITY
FACULTY OF ENGINEERING
MECHANICAL ENGINEERING DEPARTMENT
ME 313 HEAT TRANSFER

Fall 2016

HW 7

1) Determine the rate of convection heat loss from a solar collector panel array attached to a roof and exposed to an air velocity of 0.5 m/s, as shown in figure The array is 2.5 m square, the surface of the collectors is at 70°C, and the ambient air temperature is 20°C.



Let us use

$$\frac{\bar{h}}{\rho c_p u_\infty} \cdot Pr^{2/3} = 0,93\, Re_L^{-1/2}$$

we evaluate properties at T_∞.

$T_\infty = 20°C$, $\nu = 1,57 \times 10^{-5}$ m²/s

$\rho = 1.16$ kg/m3, $c_p = 1012 \frac{J}{kg\,K}$ $Pr = 0,71$

$$Re_L = \frac{u_\infty L}{\nu} = 79618$$

$$\frac{\bar{h}}{\rho c_p u_\infty} Pr^{2/3} = 0,93(79618)^{-1/2} = 0,0033$$

$\therefore \bar{h} = 2,43$ W/m²°C

$q = (2.43)(70-20)(2.5)(2.5) = 759$ W

2) *Engine oil at 80°C flows over a flat surface at 40°C for cooling purpose, the flow velocity being 2 m/s. Plate is 0.4 m long and 1 m wide. Determine total heat transfer.*

$T_f = \frac{T_w + T_\infty}{2} = 60°C$

$\nu = 83 \times 10^{-6}\ m^2/s$

$Pr = 1050$

$k = 0.1407\ W/mK$

$L = 0.4\ m$

$u_\infty = 2\ m/s$

$Re_L = \frac{(2)(0.4)}{83 \times 10^{-6}} = 9639$

Prandtl number is very high so use experimental $\overline{Nu_L}$

$$\overline{Nu_L} = \frac{0.6774 \sqrt{Re_L}\ Pr^{1/3}}{\left[1 + \left(\frac{0.0468}{Pr}\right)^{0.67}\right]^{1/4}} \cong 676$$

$\bar{h} = \frac{k}{L} \overline{Nu_L} = 237.69\ W/m^2K$

$q = (237.69)(0.4)(1)(80-40) = 3803\ W$

3) *Air at 20°C flows over a flat plate having **a uniform heat flux** of 800 W/m2. The flow velocity is 4 m/s and the length of the plate is 1.2 m. Determine the value of heat transfer coefficient and also the temperature of the plate as the air leaves the plate.*

(1) Take $T_\infty = 20°C$ evaluate fluid properties

$\nu = 15.06 \times 10^{-6}$ $k = 0.02593$ W/mK $Pr = 0.703$

$Re_L = \frac{U_\infty L}{\nu} = 3.187 \times 10^{5} < 500000$, laminar flow

$$\overline{T_w - T_\infty} = \left(\frac{q''L}{k}\right) / \left(0.6795 \sqrt{Re_L}\right)\left(Pr^{1/3}\right)$$

$$= 108.54 \text{ °C}$$

$\overline{T_w} = 128$ °C

(2) now $\overline{T_f} = \frac{\overline{T_w} + T_\infty}{2} = 74°C \approx 350K$

$\nu = 20.92 \times 10^{-6}$ m²/s $k = 30 \times 10^{-3}$ W/mK

$Pr = 0.7$

$Re_L = \frac{U_\infty L}{\nu} = 2.29 \times 10^{5} < 500000$ laminar flow

$$\overline{T_w - T_\infty} = \left(\frac{\frac{q''L}{k}}{0.6795 \sqrt{Re_L} Pr^{1/3}}\right) = 110.4 \text{ °C}$$

$\overline{T_w} = 110 + 20 = 130$ °C

temperature difference is 2°C This close engouh

To find the heat transfer coefficient

$$\overline{Nu_L} = 0.6795\sqrt{Re_L}\,Pr^{1/3}$$

$$= 0.6795\sqrt{2.29\times10^{5}}\,(0.7)^{1/3}$$

$$= 289.7$$

$$\bar{h} = \frac{k}{L}(\overline{Nu_L}) = \frac{(30\times10^{-3})}{1.2}(289.7)$$

$$= 7.24\ W/m^2K$$

To find temperature at the trailing edge of plate we will use

$$(T_w - T_\infty) = \frac{q_w'' x}{k\,Nu_x} = \frac{q_w'' x}{k}\cdot\frac{1}{0.453\sqrt{Re_x}\,Pr^{1/3}}$$

$$= \frac{(800)(1.2)}{30\times10^{-3}}\cdot\frac{1}{0.453\sqrt{2.29\times10^{5}}\,(0.7)^{1/3}}$$

$$= 165.6\,°C$$

$T_w = 185.6\,°C$ at $x = 1.2$ m

3)) Engine oil at 20∘C is forced over a 20-cm-square plate at a velocity of 1.2 m/s. The plate is heated to a uniform temperature of 60 ∘C. Calculate the heat lost by the plate

$$T_f = \frac{T_w + T_\infty}{2} = \frac{20+60}{2} = 40\,^\circ C$$

$\rho = 876\ kg/m^3$ $\qquad \nu = 0.00024\ m^2/s$

$k = 0.144\ W/mK$ $\qquad Pr = 2870$

since Pr is high;

$$Nu_x = \frac{0.3387\sqrt{Re_x}\ Pr^{1/3}}{\left[1+\left(\frac{0.0468}{Pr}\right)^{2/3}\right]^{1/4}}$$

$$Re_L = \frac{u_\infty L}{\nu} = \frac{(1.2)(0.2)}{0.00024} \cong 1000$$

$$Nu_x = \frac{(0.3387)(\sqrt{1000})(2870)^{1/3}}{\left[1+\left(\frac{0.0468}{2870}\right)^{2/3}\right]^{1/3}} = 152.2$$

$$h = \frac{k}{x} Nu_x = \frac{0.144}{0.2}(152.2) = 109.6\ W/m^2\,^\circ C$$

but

$$\bar{h} = 2h = (2)(109.6) = 219.2\ W/m^2K$$

$$q = \bar{h} A (T_w - T_\infty) = (219.2)(60-20) = 350.6\ W$$

5) Air at 20 ∘C and 1 atm flows over a flat plate at 35 m/s. The plate is 75 cm long and is maintained at 60 ∘C. Assuming unit depth in the *z* direction, calculate the heat transfer from the plate.

$$T_f = \frac{T_w + T_\infty}{2} = \frac{20+60}{2} = 40°C = 313K$$

$$\rho = \frac{P}{RT} = \frac{1.0312 \times 10^5}{(287)(313)} = 1.128 \ kg/m^3$$

$$\mu = 1.906 \times 10^{-5} \ kg/m.s \qquad Pr = 0.7$$

$$k = 0.02723 \ W/mK \qquad c_p = 1.007 \ \frac{kJ}{kg°C}$$

$$Re_L = \frac{\rho U_\infty L}{\mu} = \frac{(1.128)(35)(0.75)}{1.906 \times 10^{-5}} = 1.553 \times 10^6$$

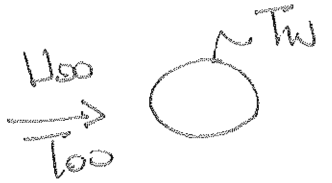
turbulent flow

$$\overline{Nu_L} = Pr^{1/3}\left[0.037 Re_L^{0.8} - 870\right] \approx 2180$$

$$\overline{h} = \frac{k}{L} Nu_L = 79.1 \ W/m^2K$$

$$q = \overline{h} A (T_w - T_\infty) = 2373 \ W$$

6) Air at 1 atm and 35 ∘C flows across a 5.0-cm-diameter cylinder at a velocity of 50 m/s. The cylinder surface is maintained at a temperature of 150 ∘C. Calculate the heat loss per unit length of the cylinder



$$T_f = \frac{T_w + T_\infty}{2} = 92.5\,^\circ C = 365.5\,K$$

$$\rho = \frac{P}{RT} = 0.966 \ kg/m^3$$

$$\mu = 2.14 \times 10^{-5} \ kg/m.s$$

$$k = 0.0312 \ W/mK \qquad Pr = 0.695$$

$$Re_D = \frac{\rho U_\infty D}{\mu} = 1.129 \times 10^{5}$$

from Table $C = 0.027$

$m = 0.805$

$$\overline{Nu_D} = \frac{\bar{h} D}{k} = C \, Re_D^{m} \, Pr^{1/3} = 275.1$$

$$\bar{h} = \frac{k}{D} \overline{Nu_D} = 171.7 \ W/m^2K$$

$$\frac{q}{L} = (\bar{h} \pi D)(T_w - T_\infty) = 3100 \ W/m$$