HW 7

1) a) $Re_x = \frac{\rho v L}{\mu} \rightarrow L = \frac{Re\,\mu}{\rho v} = \cancel{\frac{10^8 \cdot 183.7\times10^{-7}}{1.1614 \cdot 50}}$

$\cancel{\boxed{31.8\ m}}$ $\boxed{31.4\ m} = L = \frac{10^8 \cdot 183.67\times10^{-7}}{1.17 \cdot 50}$

b) $Re = \frac{\rho v L}{\mu} \rightarrow L = \frac{Re\,\mu}{\rho v} = \frac{5\times10^5 \cdot 183.7\times10^{-7}}{1.17 \cdot 50}$

$\cancel{\boxed{= 0.159\ m}}$ $\boxed{= 0.157\ m}$

2) $Nu = 0.04\, Re^{0.85}\, Pr^{1/3}$ $\qquad Nu = \frac{hL}{k}$

$Re = \frac{1.17 \cdot 10 \cdot 0.12}{183.7\times10^{-7}} = \cancel{75497.29} = 76429$

$Pr = 0.707$ $\qquad \therefore Nu = 0.04 \cdot 76429^{0.85} \cdot 0.707^{1/3}$

$\therefore \cancel{Nu = 0.04 \cdot 75497.29^{0.85} \cdot 0.707}$

$\therefore Nu = 504.4 = \frac{hL}{k} \rightarrow \cancel{h = \frac{26.15 \cdot 504.4}{0.12}}$

$\rightarrow h = \frac{26.15\times10^{-3} \cdot 504.4}{0.12} = 109.9\ \frac{W}{m^2 K}$

$q = hA(T_s - T_\infty) \rightarrow T_s = \frac{q}{hA} + T_\infty = \frac{30}{109.9 \cdot 0.04^2} + 25$

$\boxed{= 42.1\,^\circ C}$

HW 7

3) Turbulent $\therefore$ $\overline{Nu} = (0.037\, Re^{4/5} - A)\, Pr^{1/3}$ $A = 0$

$T_{avg} = \frac{523+300}{2} = 411.6$ $\rho = 0.8485$ $k = 3.46\times10^{-2}$

$\mu = 2.35\times10^{-5}$ $Pr = 0.689$

$Re = \frac{\rho V L}{\mu} = \frac{0.8485 \cdot \frac{80000}{3600} \cdot 0.15}{2.35\times10^{-5}} = 1.2\times10^{5}$

$Nu = 0.037\,(1.2\times10^{5})^{4/5} \cdot 0.689^{1/3} = 3.79\times10^{2}$

$h = \frac{Nu\,k}{L} = \frac{3.79\times10^{2} \cdot 3.46\times10^{-2}}{0.15} = 87.5\ \frac{W}{m^2 K}$

$q' = 2h \cdot L \cdot (T_s - T_\infty) = 2 \cdot 87.5 \cdot 0.15\,(-300+523)$

$\boxed{= 5.85\times10^{3}\ \frac{W}{m}}$

4) a) $Re < Re_c$ $\therefore$ Laminar $T_{avg} = 348.15$

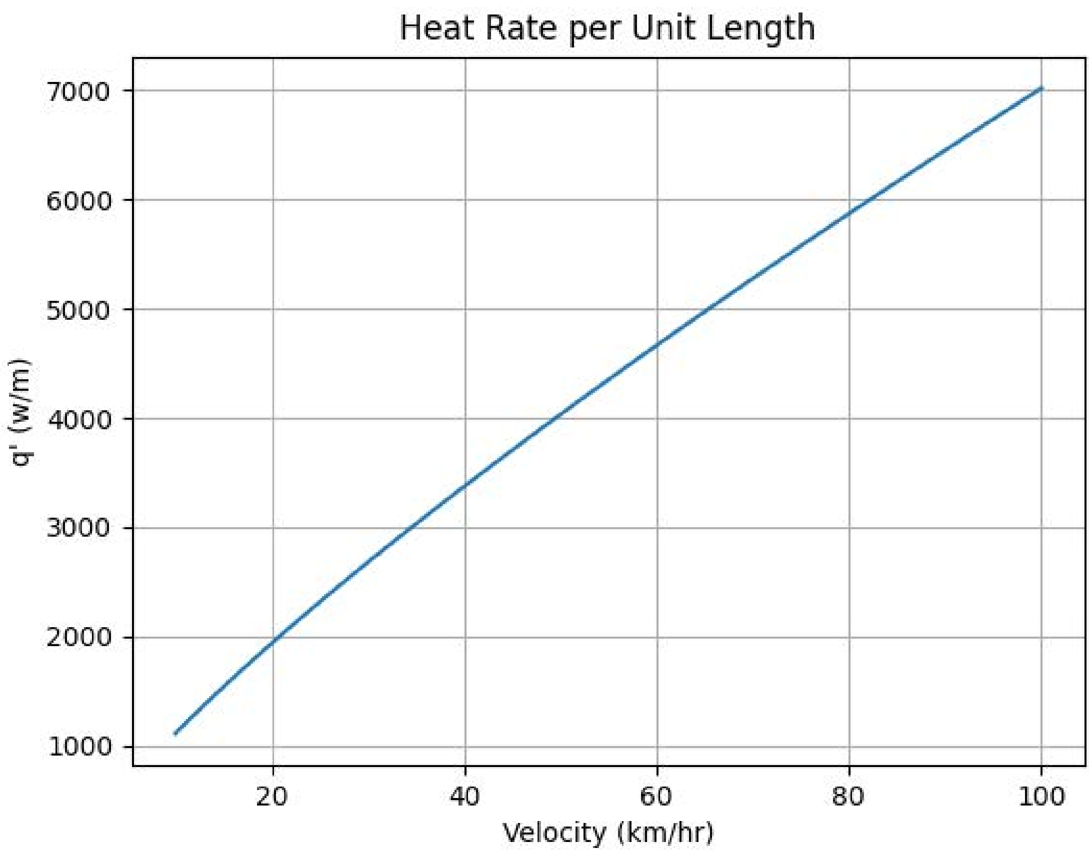
$\rho = 1.001$ $\mu = 2.07\times10^{-5}$ $k = 2.99\times10^{-2}$

$Pr = 0.7003$ $Re = 40000$

$\overline{Nu} = 0.664\, Re^{1/2} \cdot Pr^{1/3} = 118$

$h = \frac{Nu\,k}{L} = \frac{118 \cdot 2.99\times10^{-2}}{0.2} = 17.6\ \frac{W}{m^2 K}$

$q = hA(T_s - T_\infty) = 17.6 \cdot 0.2 \cdot 0.1\,(50)$ $\boxed{= 17.6\ W}$


Heat Rate per Unit Length
q' (w/m)
7000
6000
5000
4000
3000
2000
1000
20
40
60
80
100
Velocity (km/hr)

HW 7

4.) b) if $P_2 = 10 P_1$ then $\rho_2 = 10\rho_1$ $\cancel{\ldots}$ $\frac{\nu_1}{10}$

$$v_1 = \frac{Re_1 \cdot \mu}{L \cdot \rho_1} = 4.14 \frac{m}{sec}$$

$$Re_2 = \frac{10\rho_1 \cdot L \cdot 2v_1}{\mu} = 20 Re_1 = \underline{8\times10^5}$$

$\therefore$ Laminar + Turbulent

$$\bar{Nu} = \left(0.037 Re^{4/5} - A\right) Pr^{1/3}$$

$$A = 0.037 Re_c^{4/5} - 0.664 Re_c^{1/2} \qquad Re_c = 5\times10^5$$

$\therefore A = 871.3$

$$\bar{Nu} = \left(0.037 (8\times10^5)^{4/5} - 871.3\right) 0.7003^{1/3}$$

$$= 960 \rightarrow h = \frac{Nu\,k}{L} = \frac{960 \cdot 2.99\times10^{-2}}{0.2} = 143 \frac{W}{m^2K}$$

$$q = hA(T_s - T_\infty) = 143 \cdot 0.2 \cdot 0.1 \cdot 50 \boxed{= 143\,W}$$

HW 7

5.) Mixed Boundary layer ∴

$\overline{Nu} = \left(0.037 Re_L^{4/5} - A\right) Pr^{1/3}$

$A = 0.037 Re_c^{4/5} - 0.664 Re_c^{1/2}$

$Re_c = \frac{\rho \cdot v \cdot L_c}{\mu} = \frac{1 \cdot 5 \cdot 1}{1.85 \times 10^{-5}} = 2.7 \times 10^{5}$

$\therefore A = \underline{474}$

$Re_L = \frac{1 \cdot 5 \cdot 10}{\mu} = \underline{2.7 \times 10^{6}}$

$\therefore \overline{Nu} = \left(0.037 \left(2.7 \times 10^{6}\right)^{4/5} - 474\right) \cdot 0.707^{1/3}$

$= \underline{4.18 \times 10^{3}}$

$h = \frac{Nu\, k}{L} = \frac{4.18 \times 10^{3} \cdot 2.63 \times 10^{-2}}{10} = 11.01 \frac{W}{m^2 K}$

$q = h A (T_s - T_\infty) = 11.01 \cdot 0.5 \cdot 10 \, (110)$

$\boxed{= 6.053 \times 10^{3} \; W}$

7.) $Nu = 0.23 Re^{4/5} Pr^{0.4}$ $\qquad Re = \frac{\rho v D}{\mu}$

$v = \frac{\dot{m} \rho}{A}$ $\qquad A = \pi r^2$

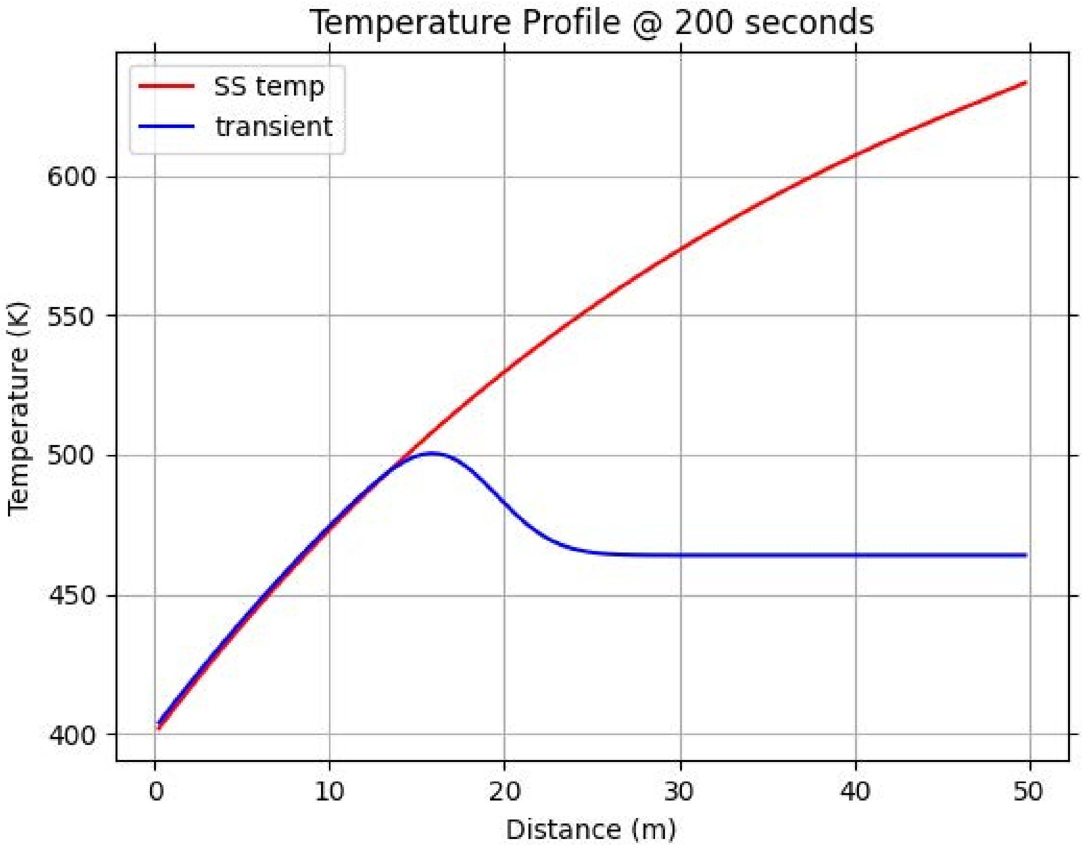
$\therefore v = \frac{3 \cdot 1000}{0.03142} = 0.0955 \frac{m}{sec}$

$Re = \frac{1000 \cdot 0.0955 \cdot 2 \cdot 0.1}{0.000577} = 33099.8$

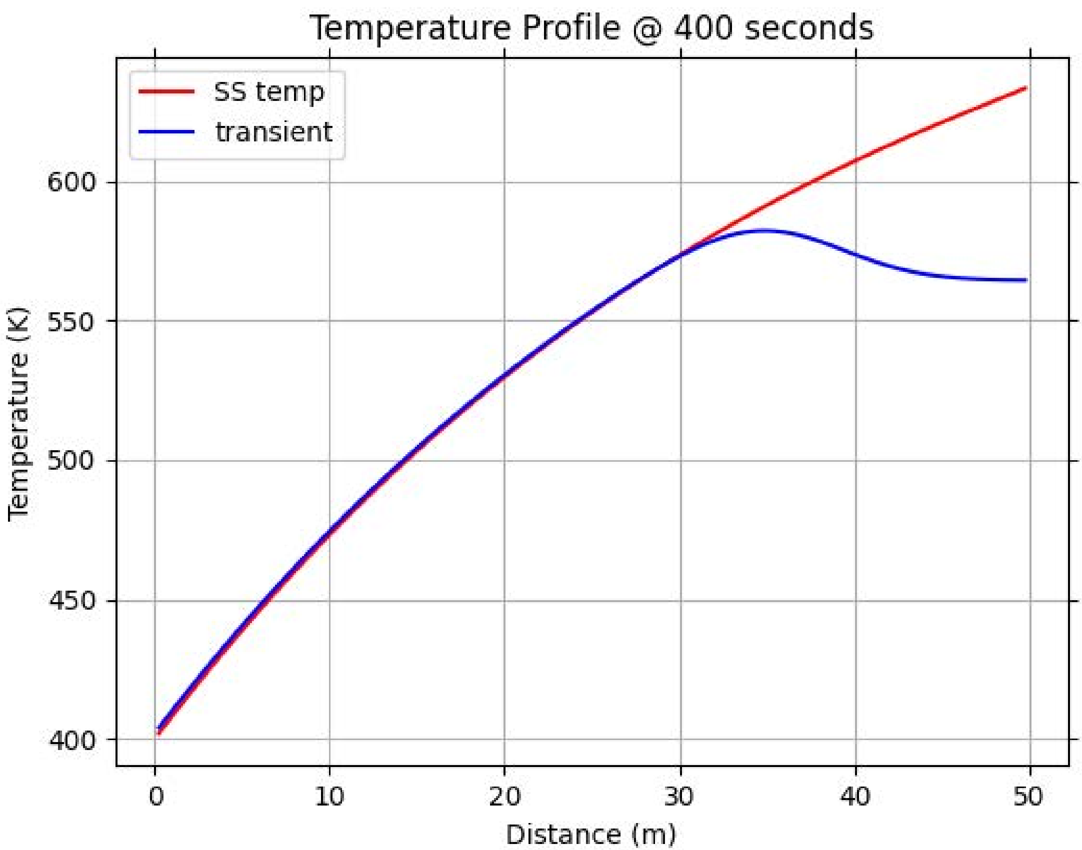
$\therefore Nu = 161.5$ $\qquad h = \frac{Nu\, k}{D} = \frac{161.5 \cdot 0.643}{2 \cdot 0.1}$

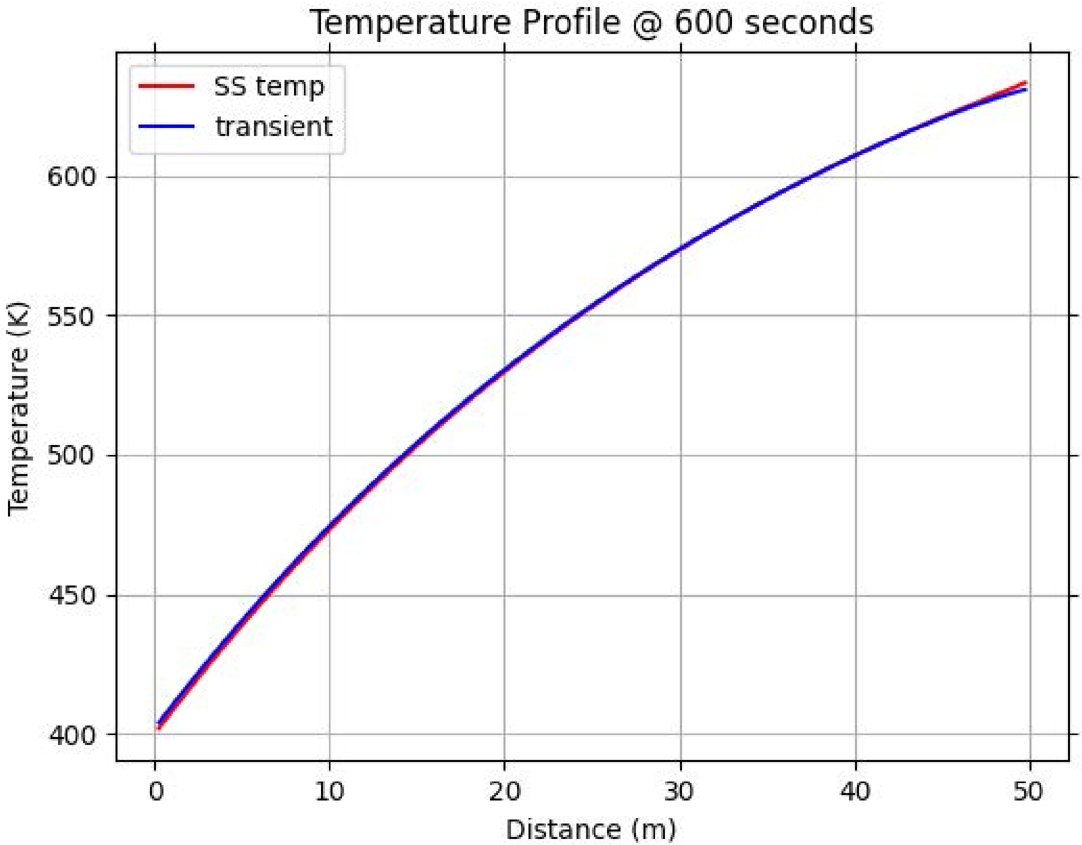
$\boxed{h = 519.2 \frac{W}{m^2 K}}$

Convection Correlation	Restrictions
$Nu_x \equiv \frac{h_x x}{k} = 0.332\, Re_x^{1/2}\, Pr^{1/3} \qquad Pr \gtrsim 0.6$ $\overline{Nu}_x \equiv \frac{\overline{h}_x x}{k} = 0.664\, Re_x^{1/2}\, Pr^{1/3} \qquad Pr \gtrsim 0.6$	Flat plate Laminar Flow (Re <5e5) Isothermal Plate
$Nu_x = \frac{0.3387\, Re_x^{1/2}\, Pr^{1/3}}{[1 + (0.0468/Pr)^{2/3}]^{1/4}} \qquad Pe_x \gtrsim 100 \qquad (7.33)$ with $\overline{Nu}_x = 2Nu_x$.	Liquid Metal Laminar Flow Isothermal plate
$Nu_x = St\, Re_x\, Pr = 0.0296\, Re_x^{4/5}\, Pr^{1/3} \qquad 0.6 \lesssim Pr \lesssim 60 \qquad (7.36)$	Turbulent Flow Isothermal plate
$\overline{Nu}_L = (0.037\, Re_L^{4/5} - A)\, Pr^{1/3} \qquad (7.38)$ $\begin{bmatrix} 0.6 \lesssim Pr \lesssim 60 \\ Re_{x,c} \lesssim Re_L \lesssim 10^8 \end{bmatrix}$ $A = 0.037\, Re_{x,c}^{4/5} - 0.664\, Re_{x,c}^{1/2}$ A=0 for completely turbulent	Mixed boundary layer Isothermal plate
$Nu_x = \frac{Nu_x\vert_{\xi=0}}{[1 - (\xi/x)^{3/4}]^{1/3}}$	Laminar Unheated starting length
$Nu_x = \frac{Nu_x\vert_{\xi=0}}{[1 - (\xi/x)^{9/10}]^{1/9}}$	Turbulent Unheated starting length
$\overline{Nu}_L = \overline{Nu}_L\vert_{\xi=0} \frac{L}{L - \xi} [1 - (\xi/L)^{(p+1)/(p+2)}]^{p/(p+1)}$ $p = 2$ for laminar flow and $p = 8$ for turbulent flow.	Isothermal plate Unheated starting length Laminar OR Turbulent
$Nu_x = 0.453\, Re_x^{1/2}\, Pr^{1/3} \qquad Pr \gtrsim 0.6$	Laminar Constant heat flux Flat plate
$Nu_x = 0.0308\, Re_x^{4/5}\, Pr^{1/3} \qquad 0.6 \lesssim Pr \lesssim 60$	Turbulent Constant heat flux
$\overline{Nu}_L = 0.680\, Re_L^{1/2}\, Pr^{1/3}$	Constant heat flux



Temperature Profile @ 200 seconds
SS temp
transient
Temperature (K)
600
550
500
450
400
0
10
20
30
40
50
Distance (m)


Temperature Profile @ 400 seconds
SS temp
transient
Temperature (K)
Distance (m)
400
450
500
550
600
0
10
20
30
40
50



Temperature Profile @ 600 seconds
SS temp
transient
Temperature (K)
400
450
500
550
600
0
10
20
30
40
50
Distance (m)