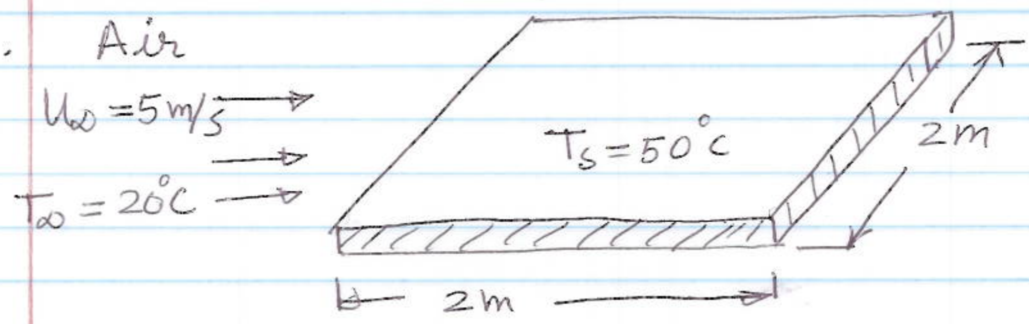
Homework-8

1. Air



Constant surface temperature:

Correlation: $Nu_x = 0.0296\, Re_x^{4/5}\, Pr^{1/3}$ (Turbulent)

$T_f = (50+20)/2 = 35^\circ C = 308\,K$. $\rho = 1.134$

$\mu = 188.4 \times 10^{-7}$

$$Re_{L=2m} = \frac{2 \times 5 \times 1.134}{188.4 \times 10^{-7}} = 6.019 \times 10^5$$ $Pr = .706$

$$Nu\Big|_{x=2} = (6.019 \times 10^5)^{4/5} \times .0296 \times (.706)^{1/3}$$

$K = 26.9 \times 10^{-3}$

$$= 1.1 \times 10^3$$

$$\therefore h = \frac{1.1 \times 10^3 \times 26.9 \times 10^{-3}}{2} = \underline{14.8}$$

@ $x = 0.5\,m$ $\quad Re = \dfrac{0.5 \times 5 \times 1.134}{188.4 \times 10^{-7}} = 1.5 \times 10^5$

$\therefore$ Laminar flow

$$\therefore Nu\Big|_{x=.5} = 0.332 \times (1.5 \times 10^5)^{1/2} \times (.706)^{1/3}$$

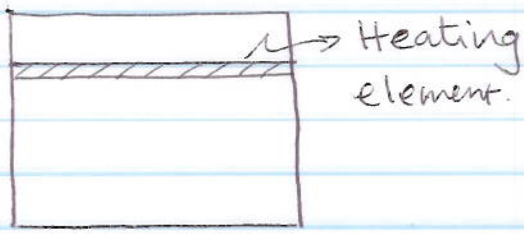
$$= 114.5$$

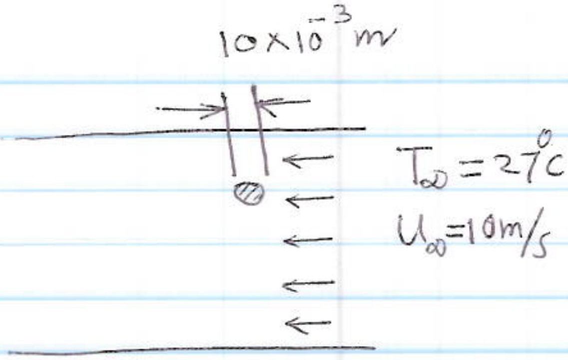
$$\therefore h = \frac{114.5 \times 26.9 \times 10^{-3}}{0.5} = \underline{6.16}.$$

$$\delta(0.5) = \frac{4.64 \times 0.5}{\sqrt{Re_x}} = 5.99 \times 10^{-3}\,m \qquad \delta_t(0.5) = 5.99 \times 10^{-3} \times \frac{1}{(.706)^{1/3}}$$

$$= 6.73 \times 10^{-3}\,m$$

2.





Basis: 1m length of the long cylinder.
at steady state:

$$1000 = h(T_W - T_\infty)\cdot(\pi D)$$
$$= h(T_W - 27)\times\pi\times10^{-2}$$

$$h(T_W - 27) = \frac{10^5}{\pi}$$

$\therefore h$ must be estimated. $T_f = \frac{T_W + 27}{2}$. Assume $T_W = 127^\circ C$

$$\therefore T_f = 77^\circ C = 350 K$$

$\rho = .995$ $\nu = 20.92\times10^{-6}$ $Pr = .7$ $K = 30\times10^{-3}$

$$Re = \frac{10\times10^{-3}\times10}{20.92\times10^{-6}} = 4.8\times10^{3}$$

$$\bar{Nu} = .193\times\left[4.8\times10^{3}\right]^{.618}\times\left[.7\right]^{1/3} = 32.19$$

$$\bar{h} = \frac{32.19\times30\times10^{-3}}{10\times10^{-3}} = 96.59$$

$$\therefore \frac{1000}{\pi\times10^{-2}\times96.59} = T_W - 27 \quad \therefore \underline{T_W = 357^\circ C}$$

Now, assume $T_W = 227^\circ C$ and re-calculate. ($T_f = 400K$)

$Re = 3.786\times10^3$ $Pr = .69$ $\bar{Nu} = 28$ $\bar{h} = 94.85$ $T_W = 362^\circ C$

Assue $T_W = 327^\circ C$ $T_f = 450K$

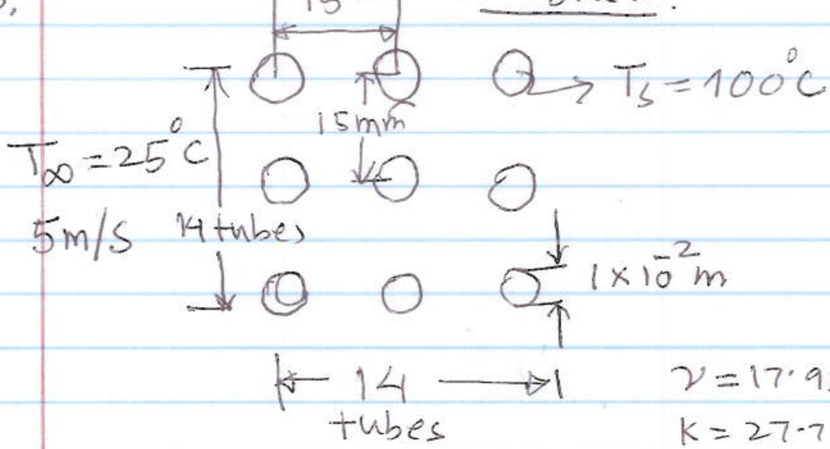
$Re = 3.08\times10^3$ $Pr = .686$ $\bar{Nu} = 25.4$ $\bar{h} = 94.8$ $T_W = 362^\circ C$

$T_W = 350^\circ C$ $T_f = 466K$

$Re = 2.9\times10^3$ $Pr = .685$ $\bar{Nu} = 24.72$ $\bar{h} = 95$ $T_W = 362^\circ C$

3.

Aligned.



T for evaluation of properties

Assume air reaches 70°C

$T_o = 70^\circ C$

$T_f = \frac{70+25}{2} = 47.5^\circ C$

$= 320\,K$

$\nu = 17.9\times10^{-6}$ $Pr = .704$ $Pr_s = .696$

$k = 27.7\times10^{-3}$ $\rho = 1.09$

$V_{max} = 5 \Big/ \frac{(15-10)}{15} = 15\ m/s.$ $Re = \frac{1\times10^{-2}\times15}{17.9\times10^{-6}} = 8.37\times10^{3}$

$\overline{Nu}_D = .985\times.27\times Re^{.63}\cdot(.704)^{0.36}\left(\frac{.704}{.696}\right)^{1/4}$

$= 69.38$

$\bar{h} = 192$

$T_s - T_o = (100-25)\exp\left(-\frac{\pi\times1\times10^{-2}\times196\times192}{1.09\times5\times14\times15\times10^{-3}\times1\times10^{3}}\right)$

$= 26.69$

$T_o = 73$

$\therefore \Delta T_{lm} = \frac{(73-25)}{\ln(75/27)} = 47^\circ C$

$\therefore q = 192\times47\ \frac{W}{m^2}$

$= 9\ kW/m^2$

Total area$/m$ $= 6.16\,m^2$

$\therefore Q = 56\ kW$

@ 280 K

4. $Re_D = \frac{20\times10^{-3}\times2\times1\times10^{3}}{1.377\times10^{-3}} = 2.9\times10^{4}$

μ_s (at 340 K) $= 4.1\times10^{-4}$ Pas

C_p (") =

$(\mu/\mu_s) = \frac{1.377\times10^{-3}}{4.1\times10^{-4}} = 3.35$

$Pr = 9.67$.

Temperature varies from 360 to 320. But because all properties except μ_s are evaluated at T_∞, we can either obtain μ_s at a set of temperatures and conduct the calculation for each segment, or use an avg μ_s.

(although one parameter exceeds slightly, the correlation

$\overline{Nu}_D = 2 + \left(0.4\,Re_D^{1/2} + 0.06\,Re_D^{2/3}\right)Pr^{0.4}\,(\mu/\mu_s)^{1/4}$ may be used.

$\overline{Nu}_D = 421 \quad \therefore \bar{h} = 1.227\times10^{4}$

Now, using eqn 11.1.5 (Middleman).

$$\frac{320-280}{360-280} = \exp\left(-\frac{1.227\times10^{4}\times\pi\times(2\times10^{-2})^{2}\times6}{8960\times376\times\pi(2\times10^{-2})^{3}}\,t\right)$$

$$\frac{1}{2} = \exp(-1.09t)$$

$\therefore t \sim .65$ s.

$\therefore$ Depth required $= 1.3$ m

(5) $R_2 = 5\ mm \quad R_1 = 1\ mm \qquad S_e = 2W/cm^3 = 2\times10^6\ W/m^3$

$= 5\times10^{-3}\ m \quad = 1\times10^{-3}\ m. \qquad T_a = 20^\circ C$

$$T_i(R) - T_a = \frac{S_e R_1^2}{2K_i}\cdot\frac{K_i}{hR_2} = \frac{S_e R_1^2}{2hR_2}$$

$$T_i(R) = T_a + \frac{S_e R_1^2}{2hR_2}$$

If $T_i(R) = 25^\circ C$

$$(25-20) = \frac{2\times10^6 \times 1\times10^{-6}}{2h\times5\times10^{-3}}$$

$$5 = \frac{1}{5h\times10^{-3}}$$

$$h = \frac{1}{25\times10^{-3}} = 40\ \frac{W}{m^2\cdot K}$$

$D_o = 10\times10^{-3}\ m \quad T_f = 22.5^\circ C = 295\ K \quad K_{air} = 26\times10^{-3}\ \frac{W}{m\cdot K}$.

$$\therefore \overline{Nu_D} = \frac{40\times10\times10^{-3}}{26\times10^{-3}} = 15.38 \qquad Pr = .708$$

$$\therefore C\,Re_D^{m} = 17.26$$

Assume Re in the range 4–40 $\therefore C = .911 \quad m = .385$

$$Re_D = 2080$$

Assume Re in the range 40–4000 $\therefore C = .683 \quad m = .466$

$$Re_D = 1023 = \frac{10\times10^{-3}\times U_\infty\times1.18}{180\times10^{-7}}$$

$$U_\infty = 1.56\ m/s.$$