Quinlan Lewis
4/12/21
ASEN 3113

Exam 3

Honor Code Signature:

Question 1

a) $\boxed{\text{False}}$

b) $\boxed{\text{True}}$

c) $\boxed{\text{False}}$

d) $\boxed{\text{True}}$

e) $\boxed{\text{True}}$

f) $\boxed{\text{False}}$

g) $\boxed{\text{False}}$

h) $\alpha = \alpha_{emit} - \alpha_{incident}$

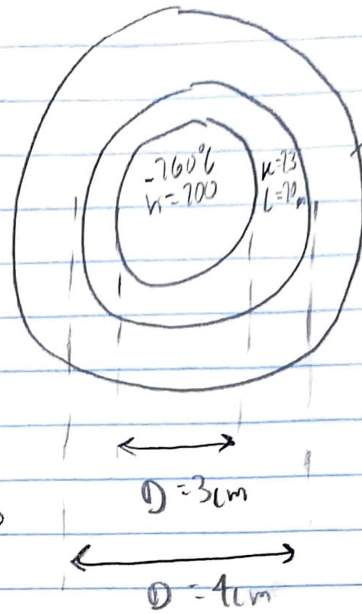
$\boxed{\text{TRUE}}$

i) $\boxed{\text{False}}$

j) $\boxed{\text{True}}$

Question 2

T_{∞_1} = inside
T_{∞_2} = outside

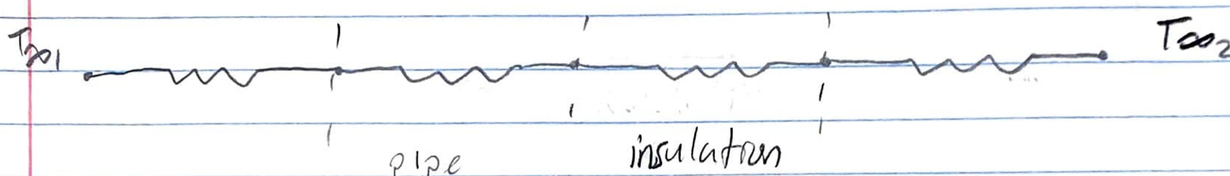


Option ①: $k = 0.6\ W/mK$
$t = 5cm$
Option ②: $k = 1.0\ W/mK$
$t = 8cm$

Assumptions:
- Steady Heat Transfer
- One-dimensional
- constant properties

$T_\infty = 40°C$
$h = 50\ W/m^2K$
dew point = 10°C

i) Cylinder with multiple layers



$$R_{tot} = R_{conv,1} + R_{cyl,pipe} + R_{cyl\,ins.} + R_{conv,2}$$

ii) Want temp of surface of insulation to be > 10°C
→ $T_s > 10°C$

$$\frac{T_{\infty_2} - T_{\infty_1}}{R_{tot}} = \frac{T_{\infty_2} - T_s}{R_{conv,2}}$$

$$R_{tot} = \frac{1}{(2\pi r_1 L) h_1} + \frac{\ln(r_2/r_1)}{2\pi L k_1} + \frac{\ln(r_3/r_2)}{2\pi L k_2} + \frac{1}{2\pi r_3 L h_2}$$

$L = 20m$
$r_1 = 0.015m$, $r_2 = 0.02m$, $r_{3,1} = 0.07m$
$r_{3,2} = 0.1\ m$

$h_1 = 200$ $h_2 = 50$
$k_1 = 23$, $k_{2,1} = 0.6$
$k_{2,2} = 1.0$

Option 1: $R_{tot} = \dfrac{1}{(2\pi)(0.05)(20)(200)} + \dfrac{\ln\left(\frac{0.02}{0.015}\right)}{(2\pi)(20)(23)} + \dfrac{\ln\left(\frac{0.07}{0.02}\right)}{(2\pi)(20)(0.6)}$

$+ \dfrac{1}{(2\pi)(0.07)(20)(50)} = 0.022$

$R_{conv,2} = \dfrac{1}{(2\pi)(0.07)(20)(50)} = 0.0023$

$\dfrac{T_{\infty_2} - T_{\infty_1}}{R_{tot}} = \dfrac{T_{\infty_2} - T_s}{R_{conv,2}} \rightarrow T_s = -\left(\dfrac{R_{conv}}{R_{tot}}\left(T_{\infty_2} - T_{\infty_1}\right) - T_{\infty_2}\right)$

$T_s = -\left(\dfrac{0.0023}{0.022}\left(40 - -260\right) - 40\right) = 8.48°C$

$T_s = 8.48°C < 10°C \rightarrow \boxed{\text{condensation occurs}}$

Option 2: $R_{tot} = \dfrac{1}{(2\pi)(0.015)(20)(200)} + \dfrac{\ln\left(\frac{0.02}{0.015}\right)}{(2\pi)(20)(23)} + \dfrac{\ln\left(\frac{0.1}{0.02}\right)}{(2\pi)(20)(1)}$

$+ \dfrac{1}{(2\pi)(0.1)(20)(50)} = 0.017$

$R_{conv,2} = \dfrac{1}{(2\pi)(0.1)(20)(50)} = 0.0016$

$T_s = -\left(\dfrac{0.0016}{0.017}\left(40 - -260\right) - 40\right) = 12.16°C$

$T_s = 12.16°C > 10°C \rightarrow \boxed{\text{no condensation occurs}}$

iii) Option 2 met requirement

$\dot{Q} = \dfrac{T_{\infty_2} - T_1}{R_{tot}} = \dfrac{40 - -260}{0.017} = 17491.5\ W$

$= \boxed{17500\ W}$

Question 3

$T_i = 20°C$ $\quad$ $T_\infty = 300°C$

$\rho = 2700\ kg/m^3$ $\quad$ $h = 85\ W/m^2K$

$c_p = 950\ J/kgK$

$k = 240\ W/mK$

i) To determine lumped system need to find Bi

$$Bi = \frac{hL_c}{k} \qquad L_c = \frac{V}{A_s} = \frac{\frac{\pi D^3}{6}}{\pi D^2} = \frac{D}{6} = \frac{0.08}{6} = 0.013\,m$$

$$Bi = \frac{(85)(0.013)}{240} = 0.00472 < 0.1$$

$\boxed{\text{because } Bi < 0.1 \text{ then a lumped system analysis can be applied}}$ ✓

ii) $Max = 100\% \rightarrow 1 - .85 = 0.15$

$$\frac{T(t) - T_\infty}{T_i - T_\infty} = 0.15 \text{ for } 85\% \text{ energy}$$

$$0.15 = e^{-bt} \qquad b = \frac{hA_s}{\rho V c_p} = \frac{h}{\rho L_c c_p} = \frac{85}{(2700)(0.013)(950)} = 0.0025$$

$$0.15 = e^{-(0.0025)t}$$

$$\boxed{t = 763.3\ sec.}$$

iii) $\dfrac{T(t) - T_\infty}{T_i - T_\infty} = e^{-bt}$

$t = 763.3 \, sec$

$b = 0.0025$

$T_\infty = 300°C$

$T_i = 20°C$

$T(t) = T_\infty + (T_i - T_\infty) e^{-bt}$

$= 300 + (20 - 300) e^{-(0.0025)(763.3)}$

$\approx \boxed{258°C}$