إنتقال حرارة

Ministry of Higher Education
The Higher Institute of Engineering and Technology in New Damietta
Course title: Heat Transfer
Course code: CHE.402
Semester: Summer Midterm

Department: Chemical Engineering
Level:3
Time allowed: 90 Minutes
Date: 29/7//2018 Day: Sun.
Full Mark: 20
No. of exam pages: 1

Model Answer attached

Answer the following four questions.
Pay attention: Problem draft drawings will be considered.

Question:1 **(5 Marks)**

Calculate the rate of heat loss through the vertical walls of a boiler furnace of size 4 m by 3 m by 3 m high. The walls are constructed from an inner fire brick wall 25 cm thick of thermal conductivity 0.4 W/ m°K, a layer of ceramic blanket insulation of thermal conductivity 0.2 W/ m°K and 8 cm thick, and a steel protective layer of thermal conductivity 55 W/m°K and 2 mm thick. The inside temperature of the fire brick layer was measured at 600 °C and the temperature of the outside of the insulation 60 °C. Also **find** the interface temperature of layers.

Question:2 **(5 Marks)**

Air at 20°C blow over a hot plate 50 x 75 cm and thick 2 cm maintained at 250°C. The convection heat transfer coefficient is 25 W/m^2 °C. **Calculate** the inside plate temperature if it is made of carbon steel and that 300 W is lost from the plate surface by radiation, where thermal conductivity is 43 W/m °C.

Question:3 **(5 Marks)**

A steam pipe of 10 cm ID and 11 cm OD is covered with an insulating substance, (k = 1 W/ m°K). The steam temperature is 200 °C and ambient temperature is 20 °C. If the convective heat transfer coefficient between insulating surface and air is (h_{air} =8 W/m^{2}K), find the critical radius of insulation for this case, (r_c) . **Calculate** the heat loss per m of pipe ($\frac{Q}{L}$) , and the outer surface temperature, (T_o). *Neglect steel pipe thermal resistance.*

Question:4 **(5 Marks)**

One meter length steel pipe (K = 45.0 W/ m°K), having a 0.05m O.D is covered with a 0.042 m thick layer of magnesia (K = 0.07W/ m°K) which in turn covered with a 0.024 m layer of fiberglass insulation (K = 0.048 W/ m°K). The pipe wall outside temperature is 370 °K and the outer surface temperature of the fiberglass is 305 °K.? Also, *Neglecting steel pipe thermal resistance*, **Calculate:**

a-The steady state heat transfer.
b-The interfacial temperature between the magnesia and fiberglass.
c-The overall heat transfer coefficient, considering area of steel outside surface.

With my best wishes,

Dr: Salah Dafea

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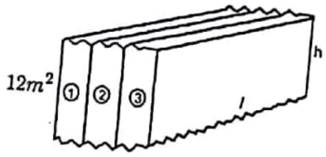
Question:1 **(5 Marks)**



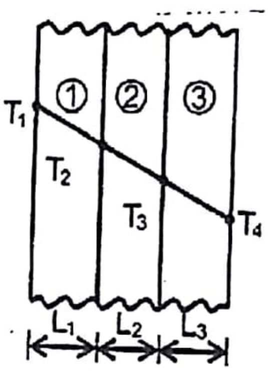
$A = 4 \times 3 = 12\ m^2$

$\Delta T = 600 - 60 = 540^\circ C$

$R_{th_1} = \dfrac{L_1}{k_1 A_1} = \dfrac{0.25}{0.4 \times 12} = 0.052\ ^\circ k/W$

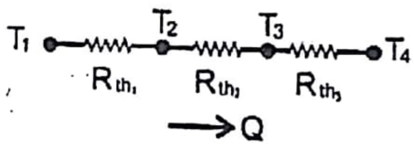
$R_{th_2} = \dfrac{L_2}{k_2 A_2} = \dfrac{0.08}{0.2 \times 12} = 0.033\ ^\circ k/W$

$R_{th_3} = \dfrac{0.002}{55 \times 12} = 0.000003\ ^\circ k/W$



$\Delta T = Q\, R_{th}$

$\therefore Q = \Delta T / \Sigma R_{th}$



$= \dfrac{540^\circ}{0.052 + 0.033 + 0.000003} = 6320.96\ W$ ※ ans

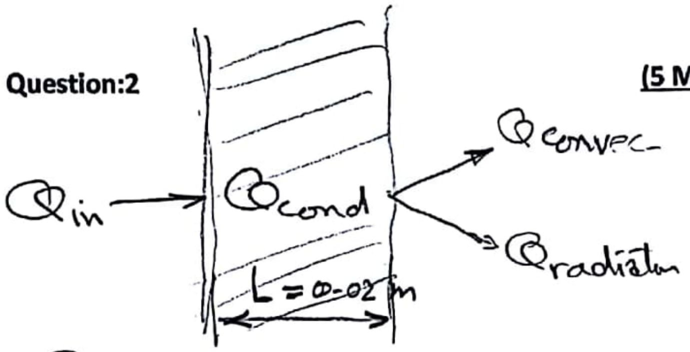
For steel layer only :

$Q = \dfrac{T_{inner} - 60}{R_{th_3}} \Longrightarrow T_3 - 60 = Q\, R_{th}$

$\therefore T_3 - 60 = 6320 \times 0.000003 = 0.0196\ ^\circ K$

$T_3 = 60.02\ ^\circ K$

Question:2 **(5 Marks)**



$h_{air} = 25 \ W/°K\,m^2$

$k = 43 \ W/°K.m$

$A = 0.5 \times 0.75$
$= 0.375 \ m^2$

$$Q_{conv.} = hA\Delta T$$
$$= 25 \times 0.375 \times (250 - 20)$$
$$= 2.156 \ kW$$

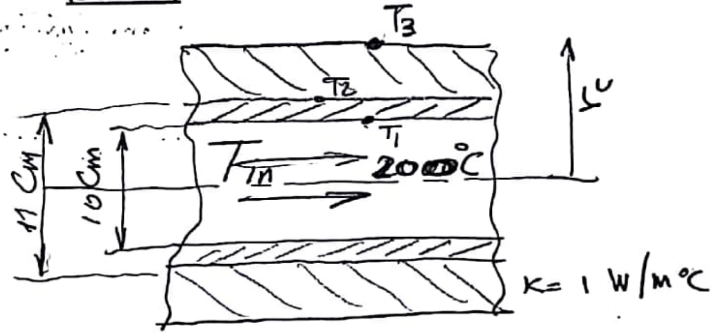
$$Q_{rad} = 300 \ W = 0.3 \ kW$$

$$Q_{tot} = 0.3 + 2.156 = 2.456 \ kW$$

$$Q_{tot} = Q_{in} = 43\,(0.375) \times \frac{T_1 - 250}{0.02} \longrightarrow T_1 = 253.05 °C$$

Question:3 **(5 Marks)**

$$r_c = \frac{k}{h_o} = \frac{1}{8} = 0.125 \ m$$



$$\Delta T = Q \sum R_{th}$$

$$\sum R_{th} = \left(\frac{\ln \frac{r_c}{r_o}}{2\pi k L} + \frac{1}{h_o r_c} \right)$$

$$= 2\pi L \left(\frac{\ln (r_c/r_o)}{k} + \frac{1}{h_o r_c} \right)$$

$$= 2\pi \times 1 \left(\frac{\ln \frac{0.125}{0.5}}{1} + \frac{1}{8 \times 0.125} \right) = 0.289$$

$$\frac{Q}{L} = \frac{\Delta T}{\sum R_{th}} = \frac{-180}{0.289} = 622 \ W/m \longrightarrow \text{ans}$$

For convection heat transfer;

$$Q = \frac{\Delta T}{R_{th}} = \frac{T_3 - 20}{\frac{1}{8 \times 2\pi \times 0.125 \times 1}}$$

From which

$T_3 = 118.72 °C$ ⟶ ans

Question:4 **(5 Marks)**

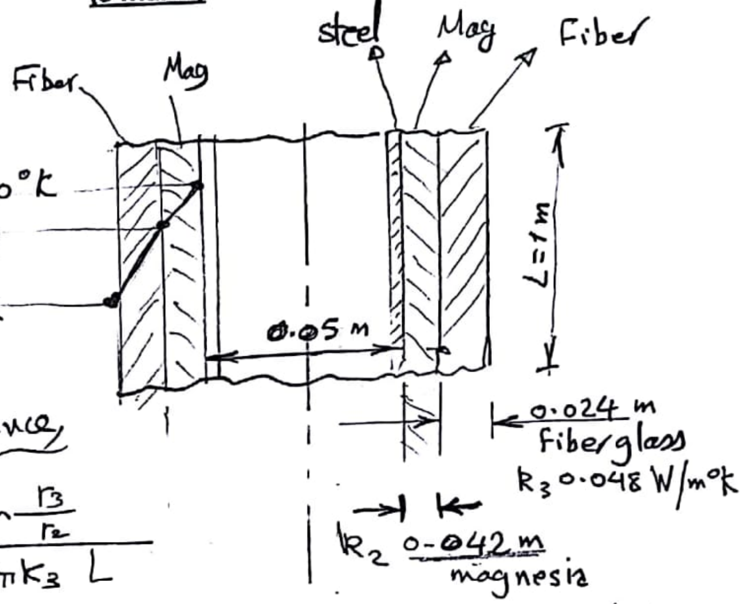
$\Delta T_{overall} = 370 - 305 = 65\,°K$

$r_1 = 0.025\ m$

$r_2 = 0.025 + 0.42$
$= 0.067\ m$

$r_3 = 0.067 + 0.024$
$= 0.091\ m$

T_1 370°K
$T_2 = ??$
T_3 305°K



neglecting pipe steel resistance

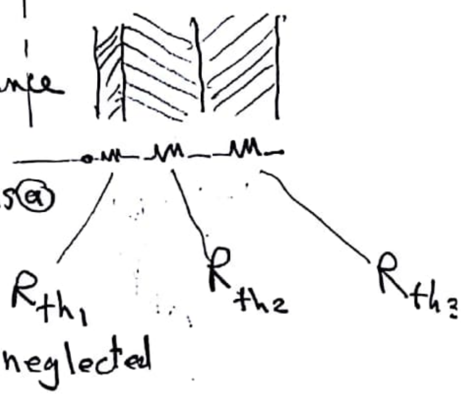
$$\Sigma R_{th} = \frac{\ln\frac{r_2}{r_1}}{2\pi k_2 L} + \frac{\ln\frac{r_3}{r_2}}{2\pi k_3 L}$$

$$= \frac{\ln\frac{0.067}{0.025}}{2\pi \times 0.07 \times 1} + \frac{\ln\frac{0.091}{0.067}}{2\pi \times 0.048 \times 1}$$

$$= 2.24 + 1.02$$

$$= 3.26\ °K/W$$

Thermal Resistance



$$Q = \frac{\Delta T}{\Sigma R_{th}} = \frac{65}{3.26} = 19.9\ W \longrightarrow \text{ans (a)}$$

For Magnesia only

$$Q = \frac{\Delta T}{R_{th}}$$

$$19.9\ W = \frac{(370 - T_2)}{\left(\frac{\ln\frac{0.067}{0.025}}{2\pi \times 0.07 \times 1}\right)} = \frac{370 - T_2}{2.24}$$

$$\therefore T_2 = 19.9 \times 2.24 - 370 = 325.62\ °K \longrightarrow \text{ans (b)}$$

$$\because Q = UA\cancel{\Delta T} = \frac{\cancel{\Delta T}}{R_{th}}$$

$$U = \frac{1}{R_{th} \cdot A} \longrightarrow = \frac{1}{3.26 \times 2\pi(0.025) \times 1}$$

$$U = 1.95\ W/°K.m \longrightarrow \text{ans (c)}$$

3/3