Q.1 A furnace wall is made up of three layers of thickness 250 mm, 100 mm and 150 mm with thermal conductivity of 1.65 and 9.2 W/m°C respectively .The inside is exposed to gases at 1250°C with a convection coefficient of 25 W/m2°C and the inside surface is at1100 °C, the outside surface is exposed to air at 25°C with convection coefficient of 12 W/m^{2}°C. Determine The overall heat transfer coefficient, thermal conductivity of third layer, heat transfer rate per unit area and intermediate surface temperature.

$U = ?$

$K_3 = ?$

$q/A = ?$ $1250°C = T_g$

$T_2 = ?$

$T_3 = ?$

$T_4 = ?$

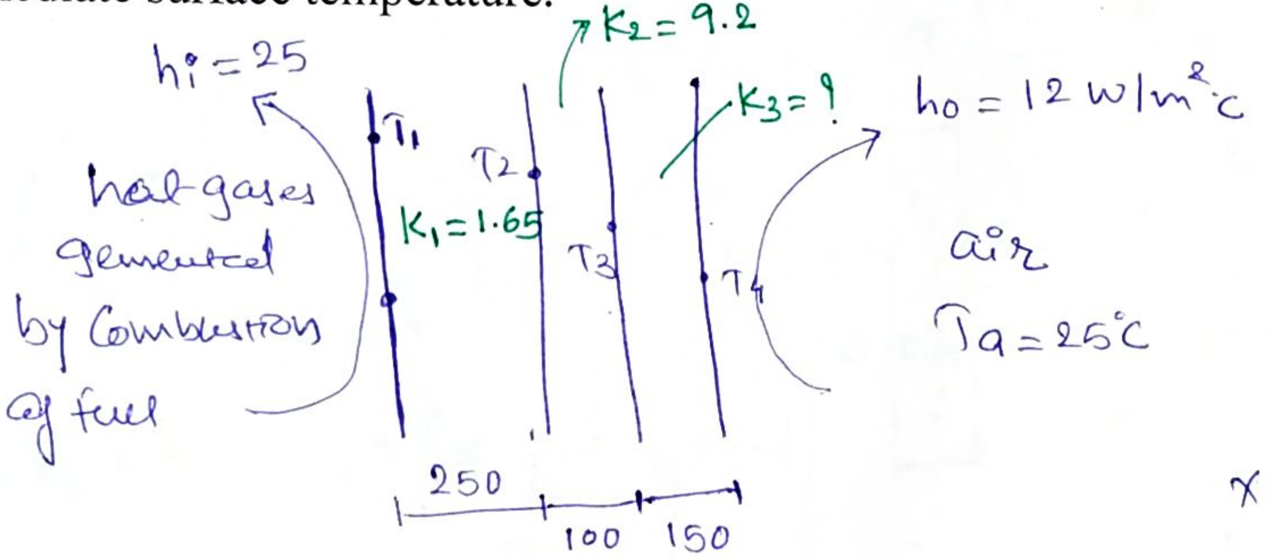
$T_g = 1250°C$

$T_1 = 1100°C$

$T_a = 25°C$

$K_1 = 1.65$

$K_2 = 9.2$



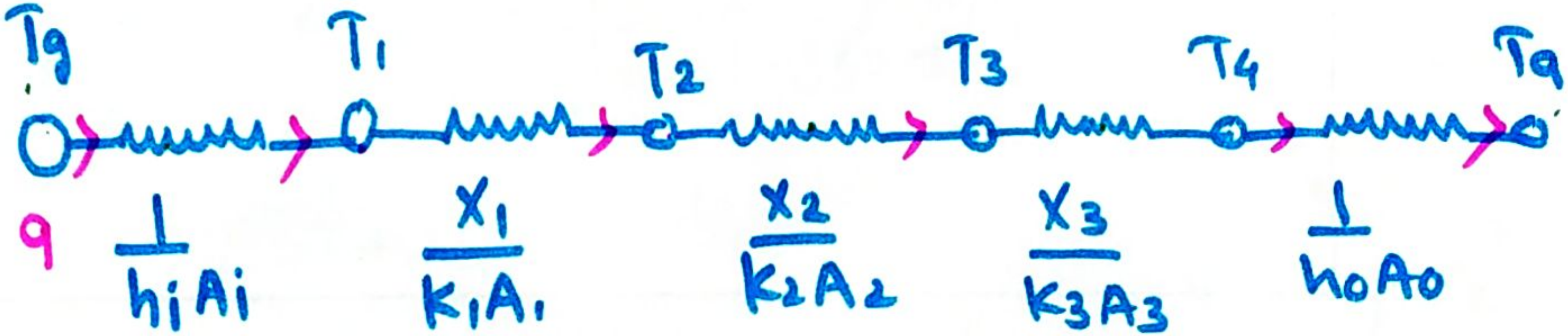
$X_1 = 250\ mm$

$X_1 = 250 \times 10^{-3}\ m$

$X_2 = 100\ mm$

$= 100 \times 10^{-3}$

$X_3 = 150 \times 10^{-3}\ m$



$$q = h_i A_i (T_g - T_1)$$

$$\frac{q}{A} = h_i (T_g - T_1)$$

$$= 25(1250 - 1100)$$

$$= 3750 \ W/m^2$$

$$q = \frac{(T_g - T_a)}{R_{total}}$$

$$R_{total} = R_1 + R_2 + R_3 + R_4 + R_5$$

$$R_{total} = \frac{1}{h_i A_i} + \frac{X_1}{K_1 A_1} + \frac{X_2}{K_2 A_2} + \frac{X_3}{K_3 A_3} + \frac{1}{h_o A_o}$$

$$R_{total} = \frac{1}{A}\left[\frac{1}{25} + \frac{250 \times 10^{-3}}{1.65} + \frac{100 \times 10^{-3}}{9.2} + \frac{150 \times 10^{-3}}{K_3} + \frac{1}{12}\right]$$

$$q = \frac{T_g - T_a}{\frac{1}{A}\left[\frac{1}{25} + \frac{250 \times 10^{-3}}{1.65} + \frac{100 \times 10^{-3}}{9.2} + \frac{150 \times 10^{-3}}{K_3} + \frac{1}{12}\right]}$$

$$\frac{q}{A} = \frac{1250 - 25}{0.04 + 0.1515 + 0.0163 + \frac{0.15}{K_3} + 0.0833}$$

$$3750 = \frac{1225}{0.2911 + \frac{0.15}{K_3}}$$

$$K_3 = 2.817 \ W/m^\circ C$$

Overall heat Transfer co-efficient

$$U = \frac{1}{R_{total}}$$

$$R_{total} = \frac{1}{25} + \frac{0.25}{1.65} + \frac{0.15}{2.817} + \frac{0.1}{9.2} + \frac{1}{12}$$

$$= 0.3266 \ ^{\circ}C\, m^2/W$$

$$U = \frac{1}{R_{total}}$$

$$= \frac{1}{0.3266} = 3.06 \ W/m^2 \cdot {}^{\circ}C$$

$$T_3 = 398.6^{\circ}C$$

$$T_4 = 337.5^{\circ}C$$

$$q = \frac{T_1 - T_2}{\frac{x_1}{K_1 A_1}}$$

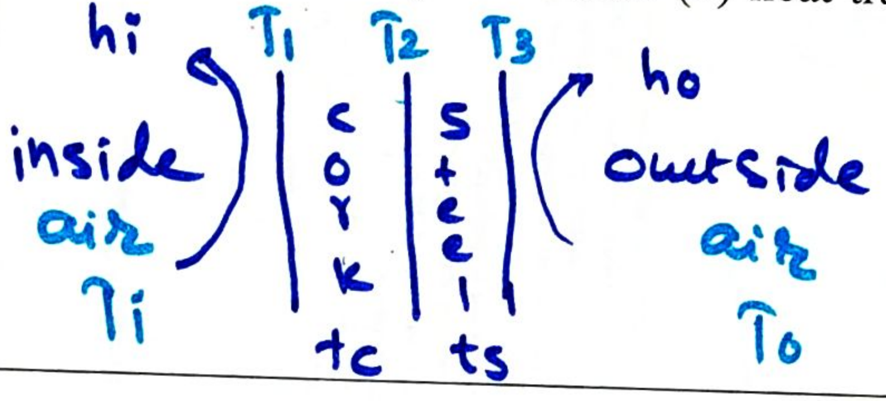
$$3750 = \frac{1100 - T_2}{0.25/1.65}$$

$$T_2 = 531.8^{\circ}C$$

$$q = \frac{T_2 - T_3}{\frac{x_2}{K_2 A_2}}$$

$$q = \frac{T_3 - T_4}{x_3/K_3 A_3}$$

Q.2 The walls of a refrigerated truck consist of 1.2 mm thick steel sheet (k=18 W/m-K) at the outer surface, 22 mm thick cork (k=0.04 W/m-K) on the inner surface. Consider Heat transfer coefficient of 5 W/m^2-K (between inside air and inside surface) and Heat transfer coefficient of 30 W/m^2-K (between outside air and outside surface). The temperatures at the inside and outside air are 0C & 35 C respectively. Calculate (1) heat transfer rate (2) steel-cork interface temp.



$q = ?$

$T_2 = ?$

$T_s = 1.2\,mm$

$= 1.2 \times 10^{-3}\,m$

$T_c = 22\,mm$

$T_c = 22 \times 10^{-3}\,m$

$k_s = 18\ W/mK$

$k_c = 0.04\ W/mK$

$\frac{1}{h_i A_i}$ $\quad \frac{x_1}{k_1 A_1}$ $\quad \frac{x_2}{k_2 A_2}$ $\quad \frac{1}{h_o A_o}$

$h_i = 5\ W/m^2K$

$h_o = 30\ W/m^2K$

$R_{total} = R_1 + R_2 + R_3 + R_4$

$T_i = 0°C$

$T_o = 35°C$

$$q = \frac{T_i - T_o}{R_{total}}$$

$$\frac{q}{A} = \frac{35}{\frac{1}{h_i} + \frac{T_c}{k_c} + \frac{T_s}{k_s} + \frac{1}{h_o}}$$

$$\frac{q}{A} = \frac{35}{\frac{1}{5} + \frac{22\times10^{-3}}{0.04} + \frac{1.2\times10^{-3}}{18} + \frac{1}{30}}$$

$$= \frac{35}{0.2 + 0.55 + 6660\times10^{-5} + 0.033}$$

$$\frac{q}{A} = \frac{35}{0.7834}$$

$$\boxed{\frac{q}{A} = 44.67 \ W/m^2}$$

$$q = h_i A_i (T_i - T_1)$$

$$\frac{q}{A} = h_i (T_i - T_1)$$

$$44.67 = 5\times(0^{\circ} - T_1)$$

$$T_1 = 8.93$$

$$q = \frac{(T_1 - T_2)}{\frac{T_c}{k_c \times A}}$$

$$\frac{q}{A} = \frac{(T_1 - T_2)}{T_c/k_c}$$

$$44.67 = \frac{8.93 - T_2}{0.022}$$

$$\boxed{T_2 = 15.63}$$

Q.3 A steam pipe pipe is covered with two layers of insulation, first layer being 3 cm thick and second 5 cm. the pipe is made from steel (k = 58W/m-K) having ID of 160 mm and OD of 170 mm. The inside and outside film coefficients are 30 and 5.8 W/m^2-K , resp. Draw electrical analogy for system and calculate the heat lost per meter of pipe, if the steam temperature is 300 °C and air temperature is 50°C. The thermal conductivity of two materials are 0.17 and 0.093 W/m-K, resp.

$$q = \frac{T_s - T_a}{R_{total}}$$

$$q = \frac{(T_s - T_a)}{\frac{1}{h_i A_i} + \frac{1}{2\pi k l}\ln(r_2/r_1) + \frac{1}{2\pi k_1 l}\ln(r_3/r_2) + \frac{1}{2\pi k_2 l}\ln(r_4/r_3) + \frac{1}{h_o A_o}}$$

$$q = \frac{(300 - 50)}{1.134} = 220.5 \text{ W/m}$$

$r_1 = 80\ mm$

$r_2 = 85mm$

$K_1 = 0.17$

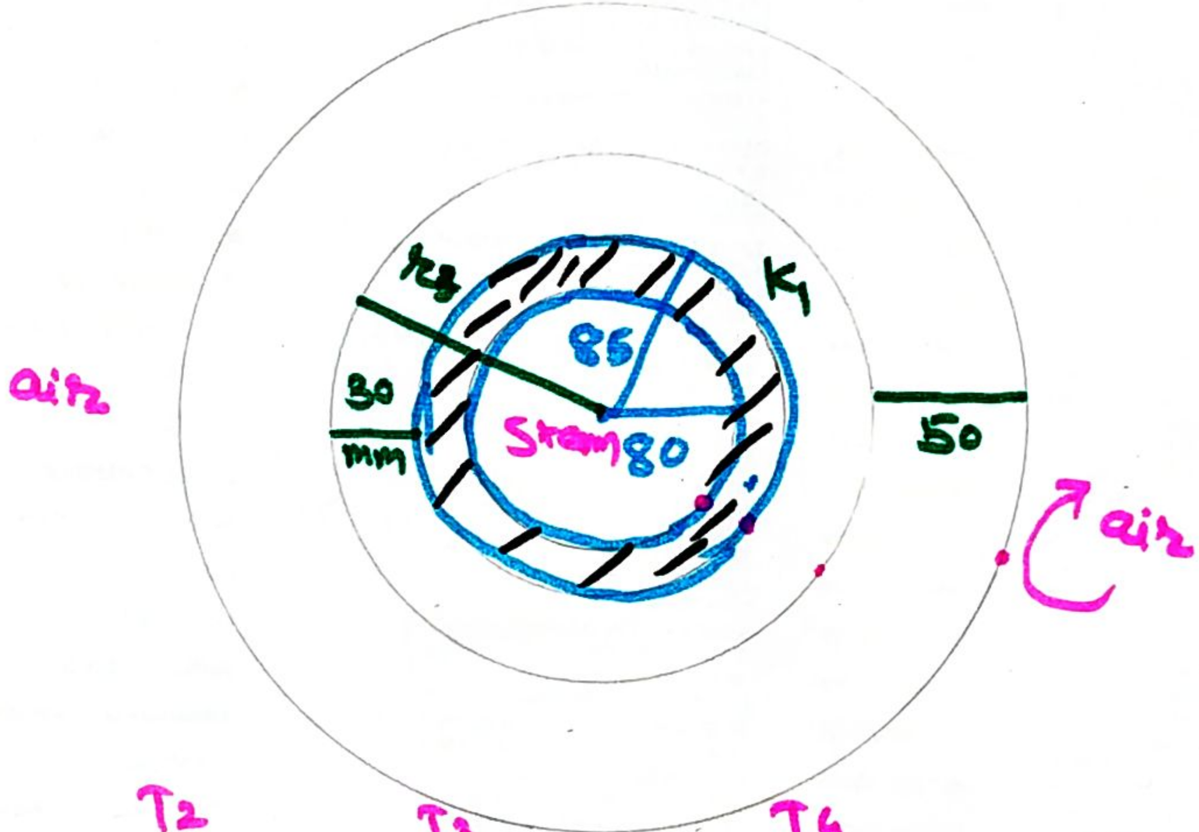
$r_3 = 85 + 30$

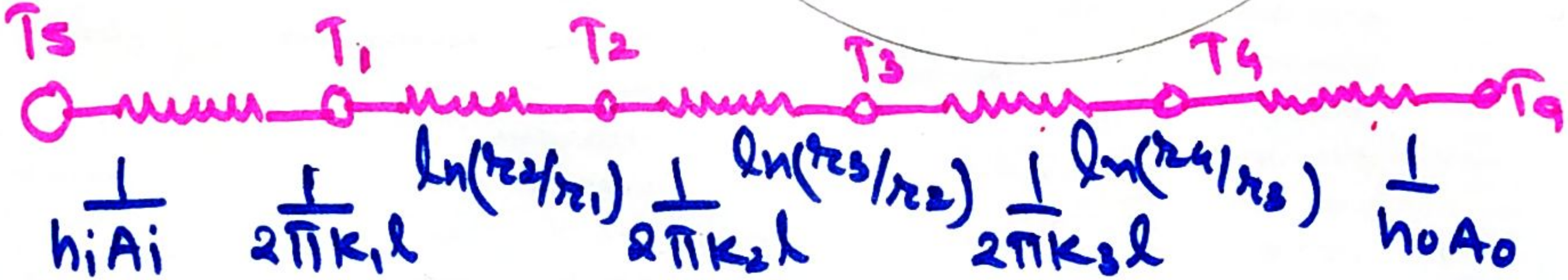
$= 115mm$

$r_4 = 115 + 50$

$= 165mm$

$K_2 = 0.093$





$$R_1 = \frac{1}{h_i A_i}$$

$$= \frac{1}{30 \times 2\pi r_1 l}$$

$$= \frac{1}{30 \times 2\pi \times \frac{80}{1000} \times 1}$$

$$R_1 = 0.0663 \ K/W$$

$$R_2 = \frac{\ln(r_2/r_1)}{2\pi k l}$$

$$= \frac{\ln(85/80)}{2\pi \times 58 \times 1}$$

$$R_2 = 1.663 \times 10^{-4} \ K/W$$

$$R_3 = \frac{\ln(r_3/r_2)}{2\pi k_1 l}$$

$$= \frac{\ln(115/85)}{2\pi \times 0.17 \times 1}$$

$$= 0.283 \ K/W$$

$$R_4 = \frac{\ln(r_4/r_3)}{2\pi k_2 l}$$

$$= \frac{\ln(165/115)}{2\pi \times 0.093 \times 1}$$

$$= 0.618$$

$$R_{total} = 1.134$$

$$R_5 = \frac{1}{h_o A_o}$$

$$= \frac{1}{h_o \times 2\pi r_o l}$$

$$= \frac{1}{5.8 \times 2\pi \times \frac{165}{1000} \times}$$

$$= 0.166$$