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HW 12

1) $q'' = \varepsilon \sigma (T_s^4 - T_\infty^4)$

$q'' = 1500 \frac{W}{m^2}$

$\varepsilon = 0.5$

$\sigma = 5.67E-8$

$T_s = ?$

$T_\infty = 0$

$$T_s = \left(\frac{q''}{\varepsilon \sigma}\right)^{1/4} = 480.\ K$$

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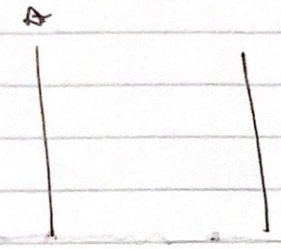
2)



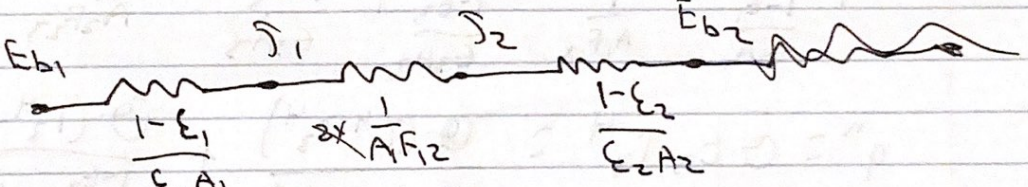
$A_1 = A_2 = 2.25\ m^2 \rightarrow F_{12} = F_{21} = 0.85$

$T_1 = 1073\ K$

$T_2 = 553\ K$

$\varepsilon_1 = 0.5$

$\varepsilon_2 = 0.8$



$$\frac{E_{b1} - J_1}{\frac{1-\varepsilon_1}{\varepsilon_1 A_1}} = \frac{J_1 - J_2}{\frac{1}{(A_1 F_{12})}} \rightarrow$$

$$\frac{E_{b2} - J_2}{\frac{1-\varepsilon_2}{\varepsilon_2 A_2}} = \frac{J_2 - J_1}{\frac{1}{(A_1 F_{12})}} \rightarrow J_2 = \frac{\frac{1}{F_{12} A_1} \cdot \sigma T_2^4 + J_1 \cdot \frac{1-\varepsilon_2}{\varepsilon_2 A_2}}{\frac{1-\varepsilon_2}{\varepsilon_2 A_2} + \frac{1}{A_1 F_{12}}}$$

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2)

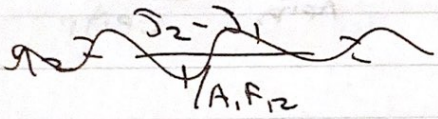
$$J_1 = \frac{\frac{1}{A_1 F_{12}} \cdot \sigma T_1^4 + J_2 \cdot \frac{1-\varepsilon_1}{\varepsilon_1 A_1}}{\frac{1-\varepsilon_1}{\varepsilon_1 A_1} + \frac{1}{A_1 F_{12}}}$$

input J_2, solve for $J_1 \rightarrow J_1 = 52069.$

$$J_2 = 1.35 \times 10^4$$

$$q_1 = \frac{J_1 - J_2}{1/A_1 F_{12}} = \frac{52069 - 1.35 \times 10^4}{1/A_1 F_{12}} = 7.38 \times 10^4 \text{ W}$$

$q_1 = 73.8$ kW



$$q_2 = \frac{\sigma T_2^4 - J_1}{\frac{1-\varepsilon_1}{\varepsilon_1 A_1}} = 520 \text{ kW}$$

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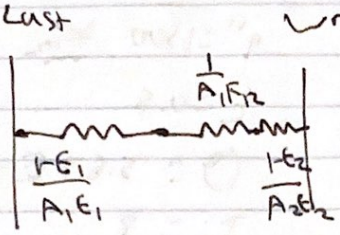
3)

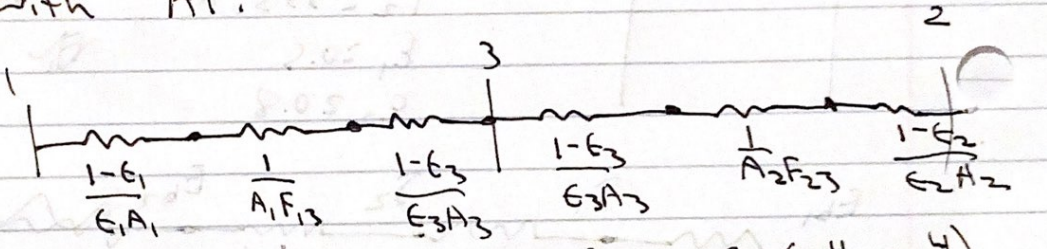


$T_1 = 1088.7$
$T_2 = 533.15$
$T_3 = ?$
$\epsilon_1 = 0.7$
$\epsilon_2 = 0.91$
$\epsilon_3 = 0.09$

$$q'' = \frac{\sigma(T_1^4 - T_2^4)}{\frac{1-\epsilon_1}{\epsilon_1} + \frac{1}{1} + \frac{1-\epsilon_2}{\epsilon_2}}$$

$$q'' = 49.149 \ \frac{kW}{m^2}$$

With Al:



$$q'' = \sigma\epsilon_3 T_3^4 = \frac{\sigma(T_1^4 - T_3^4)}{\frac{1-\epsilon_1}{\epsilon_1 A_1} + 1 + \frac{1-\epsilon_3}{\epsilon_3 A_3}} + \frac{\sigma(T_3^4 - T_2^4)}{\frac{1-\epsilon_3}{\epsilon_3 A_3} + 1 + \frac{1-\epsilon_2}{\epsilon_2 A_2}}$$

$$\rightarrow T_3 = 911 \text{ K} \approx 1180^\circ\text{F}$$

$$q''_{Al} = 3429 \ \frac{W}{m^2}$$

$$\frac{q'' - q''_{Al}}{q''} = \frac{45721}{49149} = 0.93 = 93.0\% \text{ reduction}$$

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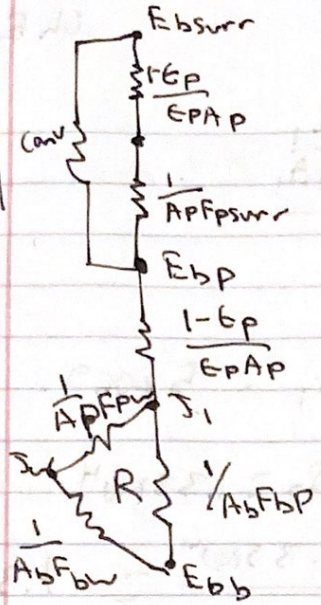
4)



$T_p = 400$

$T_{surr} = 300$

$\epsilon_p = 0.8$

$F_{pb} = F_{pw} = F_{bw} = 0.2$

$h = 25 \frac{W}{m^2 K}$

$A_b = A_p = A_w = 0.04\ m^2$

a) $$q = hA(T_p - T_{surr}) + \frac{\sigma(T_p^4 - T_{sur}^4)}{\frac{1}{A_p F_{ps}} + \frac{1-\epsilon_p}{\epsilon_p A_p}}$$

$$= 132.\ W$$

b) $$132\ W = \frac{\sigma(T_p^4 - T_b^4)}{R + \frac{1-\epsilon_p}{\epsilon_p A_p}}$$

$$\frac{1}{R} = \frac{1}{\frac{1}{A_p F_{pb}}} + \frac{1}{\frac{1}{A_b F_{bw}} + \frac{1}{A_p F_{pw}}} = 0.012$$

$\therefore R = 83.3$

$\rightarrow T_b = 695\ K$