First Name-- January , 2017

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Cankaya University
Faculty of Engineering
Mechanical Engineering Department
ME 313 Heat Transfer
Final Exam
Open Book Closed Notes
Fall 2017

Key

1) The spectral emissive power E_λ for a diffusively emitting surface is

$$E_\lambda = \begin{cases} 0 & 0 < \lambda < 3\,\mu m \\ 150\ \dfrac{W}{m^2\,\mu m} & 3 < \lambda < 2\,\mu m \\ 300\ \dfrac{W}{m^2\,\mu m} & 12 < \lambda < 25\,\mu m \\ 0 & 25 < \lambda < \infty\ \mu m \end{cases}$$

Temperature of the surface is 600K.

a) Calculate the total emissive power of the surface over the entire wavelength.

b) Calculate the total hemispherical emissivity of surface

c) Calculate the intensity of radiation assuming that intensity is independent of direction.

a) $E = \int_0^\infty E_{\lambda b} d\lambda = \int_0^3 0\, d\lambda + \int_3^{12} 150\, d\lambda + \int_{12}^{25} 300\, d\lambda + \int_{25}^{\infty} 0\, d\lambda$

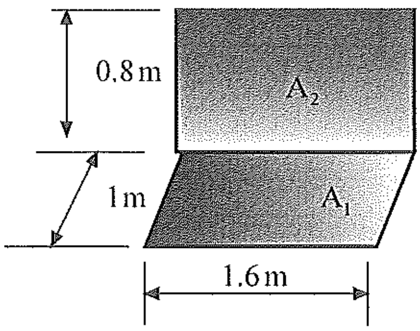
$= 0 + 150(12-3) + 300(25-12) + 0$

$= 5250\ W/m^2$

b) $\epsilon = \dfrac{E}{E_b} = \dfrac{5250}{5.67\times10^{-8}(600)^4} = \dfrac{5250}{7348} = 0{,}714$

c) $I = \dfrac{E}{\pi} = \dfrac{5250}{\pi} = 1671\ W/m^2 sr$

2)Two black rectangular surfaces A_1 and A_2 arranged as shown in the accompanying figure.are located in a large room whose walls are black and kept at 300 K. Determine the net heat transfer exchange between these two surfaces when A_1 is kept at 1000 K and A_2 at 500 . Neglect the radiation from the room.



$T_1 = 1000 K$

$T_2 = 500 K$

$X = 1.6 m$

$Y = 1 m$

$Z = 0.8 m$

$\frac{Z}{X} = \frac{0.8}{1.6} = 0.5$

$\frac{Y}{X} = \frac{1}{1.6} = 0.625$

Fig 13.6 $F_{12} = 0.2$

E_{b1} — $\frac{1}{A_1 F_{12}}$ — E_{b2}

$$q = \frac{E_{b1} - E_{b2}}{\frac{1}{A_1 F_{12}}} = A_1 F_{12} (E_{b1} - E_{b2}) = A_1 F_{12} \sigma (T_1^4 - T_2^4)$$

$$= (1)(1.6)(0.2)(5.67 \times 10^{-8})(1000^4 - 500^4)$$

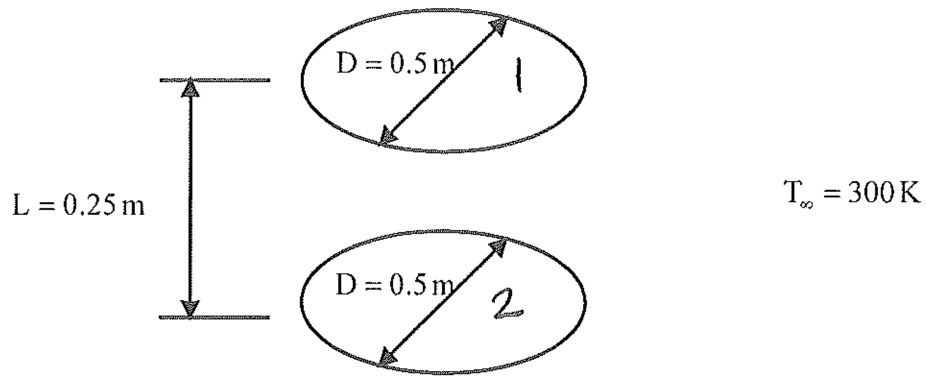
$$= 17\,000 \text{ W}$$

3)Consider two parallel circular discs of equal diameter D=0.5 m separated by L=0.25 m have common control normal as given in the figure. One disk is maintained at $T_1 = 800\,K$ and has an emissivity $\varepsilon_1 = 0.9$. The other is at $T_2 = 500\,K$ and has an emissivity $\varepsilon_2 = 0.7$. These two parallel discs are exposed through the opening between them into an environment which can be regarded as a black medium at $T_\infty = 300\,K$.

a) Sketch the radiation network

b) Calculate the radiation heat transfer between the two discs

c) Calculate the total heat lost into ambient



$D_1 = 0.5\,m$ $\quad$ $D_2 = 0.5\,m$

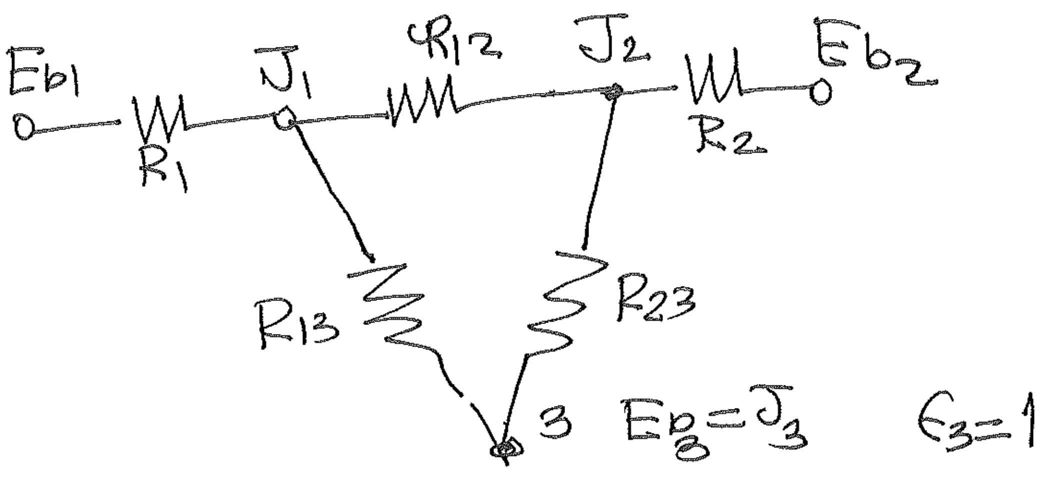
$T_1 = 800\,K$ $\quad$ $T_2 = 500\,K$

$\epsilon_1 = 0.9$ $\quad$ $\epsilon_2 = 0.7$

$F_{12} = 0.39$ $\quad$ $A_1 F_{12} = A_2 F_{21}$ $\quad$ $A_1 = A_2 \therefore F_{21} = 0.39$

$F_{13} = 1 - 0.39 = 0.61$ $\quad$ $F_{23} = 1 - 0.39 = 0.61$

$A_1 = A_2 = \frac{\pi D^2}{4} = 0.19635$



$R_1 = \frac{1-\epsilon_1}{A_1\epsilon_1} = 0.5658$

$R_{12} = \frac{1}{A_1F_{12}} = \frac{1}{(\frac{\pi}{16})(0.39)} = 13.05$

$R_2 = \frac{1-\epsilon_2}{A_2\epsilon_2} = \frac{1-0.7}{\frac{\pi}{16}(0.7)} = 2.182$

$R_{13} = \frac{1}{A_1F_{13}} = \frac{1}{(\frac{\pi}{16})(0.61)} = 8.349$

$R_3 = \frac{1-\epsilon_3}{A_3\epsilon_3} = 0$ since $\epsilon_3 = 1$

$R_{23} = \frac{1}{A_2F_{23}} = \frac{1}{(\frac{\pi}{16})(0.61)} = 8.349$

$E_{b1} = \sigma T_1^4 = 23224 \text{ W/m}^2$

$E_{b2} = \sigma T_2^4 = 3544 \text{ W/m}^2$

$E_{b3} = \sigma T_3^4 = 459.3$

$$\frac{E_{b1}-J_1}{R_1} + \frac{J_2-J_1}{R_{12}} + \frac{E_{b3}-J_1}{R_{13}} = 0$$

$$\frac{E_{b2}-J_2}{R_2} + \frac{J_1-J_2}{R_{12}} + \frac{E_{b3}-J_2}{R_{13}} = 0$$

$\therefore \quad -1.9634 J_1 + 0.0766 J_2 = -41092$

$\quad 0.0766 J_1 - 0.6545 J_2 = -1678.5$

$J_1 = 21253 \text{ W/m}^2$

$J_2 = 5052 \text{ W/m}^2$

Net heat transfer

$$q_{12} = \frac{J_1-J_2}{R_{12}} = \frac{21253-5052}{\frac{1}{0.0768}} = 1241 \text{ W}$$

Heat transfer to environment

$$q = \frac{E_{b3}-J_1}{R_{13}} + \frac{E_{b3}-J_2}{R_{23}} =$$

$$= \frac{459.3-21253}{\frac{1}{0.1198}} + \frac{459.3-5052}{\frac{1}{0.1198}}$$

$$= -3041.3\ W$$

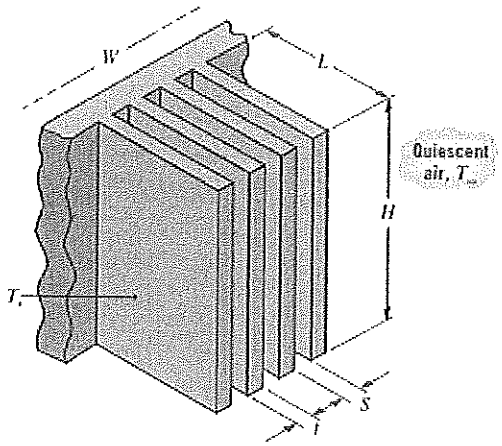
Heat loss from disk 1

$$q_1 = \frac{E_{b1}-J_1}{R_1} = \frac{23244-21253}{0.5658} \cong 3519\ W$$

Heat loss from disk 2

$$q_2 = \frac{E_{b2}-J_2}{R_2} = \frac{3544-5052}{2.182} = -691\ W$$

4) Consider an array of vertical rectangular fins, which is to be used to cool an electronic device mounted in quiescent, atmospheric air at $T_\infty = 27\,^0C$. Each fin has L=20 mm and H=150 mm and operates at an approximately uniform temperature of $T_s = 77\,^0C$.



There exists an optimum fin spacing S=34 mm. For the optimum value of S and a fin thickness of t =1.5 mm,

a) Estimate the number of fins for an array of width W = 355 mm.
b) Estimate the total rate of heat transfer from the fins .

Air: At $T_f = 325K$ $\quad \nu = 18.41 \times 10^{-6}\ m^2/s$

$k = 0.0282\ W/mK$ $\quad Pr = 0.703$

From Fig 9.4 of text

$$\eta = \frac{\delta}{H}\left(\frac{Gr_H}{4}\right)^{1/4} \approx 5$$

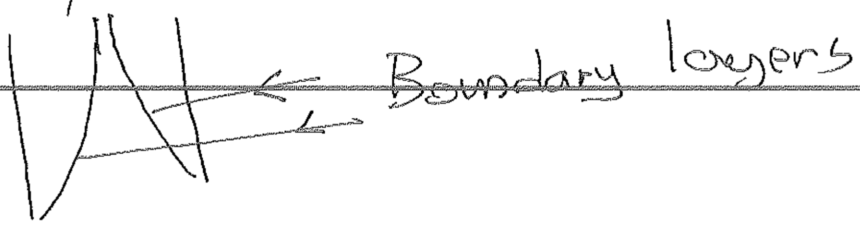
$$S_{opt} = \delta_{x=H}$$

$$Gr_H = \frac{g\beta(T_w - T_\infty)}{\nu^2} = 1.5\times 10^7$$

$$\delta = \frac{5(0.15m)}{\left[\frac{1.5\times 10^7}{4}\right]^{1/4}} \approx 0.017m = 17\ mm$$

$S_{opt} \cong 34\ mm$ ← optimum distance between fins. We do not ...

the boundary layers coalesce.



b) # of fins

$$N = \frac{W}{S_{opt}+t} = \frac{355}{35.5} \approx 10$$

Heat loss

$$q = 2N\bar{h}(HL)(T_w - T_\infty)$$

$$\overline{Nu}_H = \overline{Nu}_L = 0.68 + \frac{0.67\, Ra_L^{1/4}}{\left[1+\left(\frac{0.492}{Pr}\right)^{9/16}\right]^{4/9}} = 3.0$$

$$\bar{h} = \frac{k}{H}\overline{Nu}_H = 5.6 \ W/m^2K$$

$$q = 16.8 \ W$$