First Name-- January 13, 2016
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Cankaya University
Faculty of Engineering
Mechanical Engineering Department
ME 313 Heat Transfer
Final Exam
Open Book Closed Notes
Fall 2016

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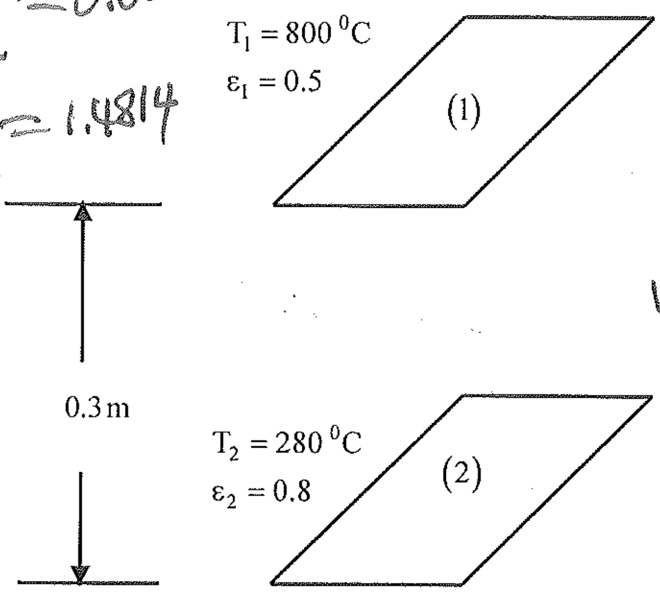
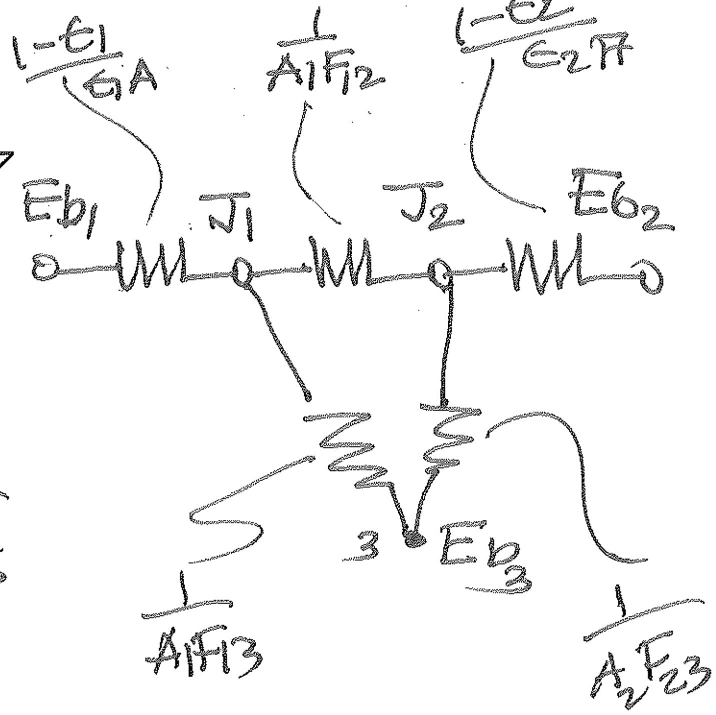
1) It is desired to transmit energy from one spaceship to another. A 1.5-m-square plate is available on each ship to accomplish this. The ships are guided so that the plates are parallel and 30 cm apart. One plate is maintained at 800°C and the other at 280°C. The emissivities are 0.5 and 0.8, respectively. Find (*a*) the net heat transferred between the spaceships in watts and (*b*) the total heat lost by the hot plate in watts. Assume that outer space is a blackbody at 0 K.

$$\frac{1}{A_1F_{12}} = 0.6349 \qquad \frac{1-\epsilon_1}{\epsilon_1 A} = 0.4444$$

$$\frac{1}{A_1F_{13}} = 1.4814 \qquad \frac{1-\epsilon_2}{\epsilon_2 A} = 0.1111$$



(3) Free space at $T_3 = 0$ K



$A_1 = A_2 = (1.5)^2 = 2.25\ m^2$

$T_1 = 1073\ K \qquad \epsilon_1 = 0.5$

$T_2 = 553\ K \qquad \epsilon_2 = 0.8$

$T_3 = 0\ K$

$F_{12} = 0.7$ → Fig 13.4

$\frac{X}{L} = \frac{1.5}{0.3} = 5$

$\frac{Y}{L} = \frac{1.5}{0.3} = 5$

$F_{12} = 0.7$

$F_{13} = F_{23} = 0.3$

$E_{b_1} = 75146 \ W/m^2$

$E_{b_2} = 5302 \ W/m^2$

$E_{b_3} = 0$

$\cancel{F_{11}}^{0} + F_{12} + F_{13} = 1$

$F_{13} = 1 - F_{12} = 0.3$

$F_{21} + \cancel{F_{22}}^{0} + F_{23} = 1$

$F_{23} = 0.3$

(1) $$\frac{75146 - J_1}{0.44} + \frac{J_2 - J_1}{0.6349} + \frac{0 - J_1}{1.481} = 0$$

(2) $$\frac{J_1 - J_2}{0.6349} + \frac{0 - J_2}{1.481} + \frac{5302 - J_2}{0.1111} = 0$$

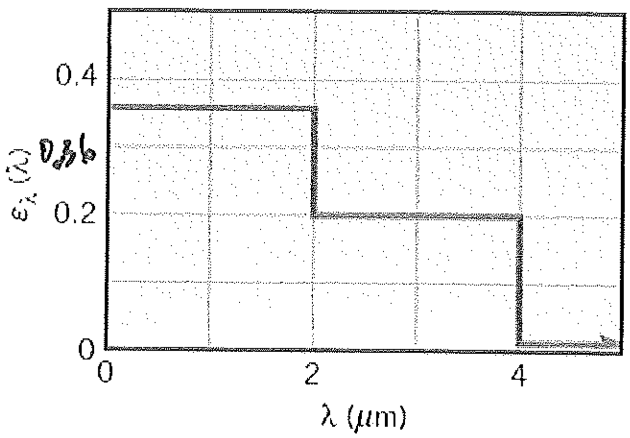
$J_1 = 41070 \ W/m^2$

$J_2 = 9992 \ W/m^2$

$$q_1 = \frac{75146 - 41070}{0.4444} = 76671 \ W$$

$$q_2 = \frac{5302 - 9992}{0.1111} = -42210 \ W$$

A certain surface maintained at ~~1400~~ 2000 K has the following spectral emissive characteristics



a) Determine the total hemispherical emissivity of the surface
b) Calculate the emissive power of the surface.

$$\epsilon = \int_0^{\infty} \epsilon_\lambda E_{\lambda b} d\lambda / E_b$$

$$= \frac{\epsilon_1 \int_0^2 E_{\lambda b} d\lambda}{E_b} + \frac{\epsilon_2 \int_2^4 E_{\lambda b} d\lambda}{E_b} + 0$$

or interms of fraction

$$= \epsilon_1 F_{0-\lambda_1 T} + \epsilon_2 \left[F_{0-\lambda_2 T} - F_{0-\lambda_1 T} \right]$$

$\lambda_1 T = (2)(2000) = 4000\ \mu m . K \qquad F_{0-\lambda_1 T} \cong 0.481$

$\lambda_2 T = (4)(2000) = 8000\ \mu m . K \qquad F_{0-\lambda_2 T} \cong 0.856$

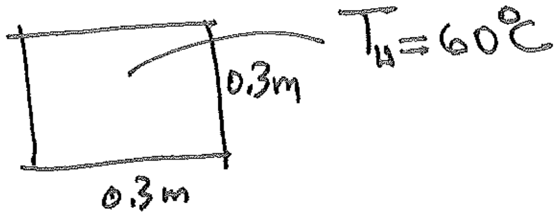
$$\epsilon = (0.36)(0.481) + (0.2)(0.856 - 0.481)$$

$$= 0.25$$

$$E = \epsilon E_b = \epsilon \sigma T^4 = (0.25)(5.67 \times 10^{-8})(2000)^4$$

$$= 2.27 \times 10^5\ W/m^2$$

3) An engine-oil heater consists of a large vessel with a square-plate electric-heater surface in the bottom of the vessel. The heater plate is 30 cm by 30 cm and is maintained at a constant temperature of 60 ^{0}C. Calculate the heat-transfer rate for an oil temperature of 20 ^{0}C.



$$T_f = \frac{60+20}{2} = 40°C$$

$\nu = 0.00024\ m^2/s$

$k = 0.144\ W/m°C$

$Pr = 2870$

$$Ra = Gr\,Pr$$

$$= \frac{(9.81)(0.7\times10^{-3})(60-20)(0.3)^3(2870)}{(0.00024)^2} = 3.69\times10^{8}$$

$$\overline{Nu}_L = 0.15\,Ra_L^{1/3} \Rightarrow \bar{h} = \frac{0.144}{0.3}(0.15)(3.69\times10^{8})^{1/3}$$

$$= 51.6\ W/m^2°C$$

$$q = \bar{h}A(T_w - T_\infty)$$

$$= (51.6)(0.3)^2(60-20) = 185.6\ W$$

4) Water flows in a D=2-cm-diameter tube at an average flow velocity of 8 m/s. If the water enters at 20 ^{0}C and leaves at 30 ^{0}C and the tube length is L=10 m, estimate the average wall temperature T_w necessary to effect the required heat transfer.

$T_{mi} = 20°C \quad T_{mo} = 30°C \quad T_m = 25°C$

$\rho = 996\ kg/m^3 \quad \mu = 8.96 \times 10^{-4}\ kg/m\,s\ (N.s/m^2)$

$k = 0.611\ W/mK$

$Pr = 6.13 \quad c_p = 4180\ J/kg\,K$

$$Re = \frac{\rho V D}{\mu} = 1.78 \times 10^5$$

$$\overline{Nu}_D = 0.023\ Re_D^{0.8}\ Pr^{0.4}$$

$$\bar{h} = \frac{k}{D}\left[0.023\ Re_D^{0.8}\ Pr^{0.4}\right] = 23000\ W/m^2°C$$

$$q = \dot{m} c_p (T_{mo} - T_{mi})$$

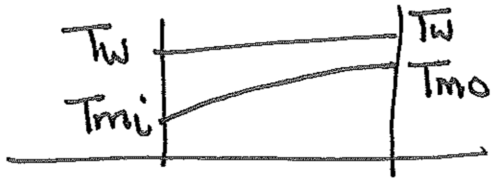
$$q = \bar{h} A_s \left[T_w - \frac{1}{2}(T_{mo} + T_{mi})\right]$$

$A_s = \pi D L$

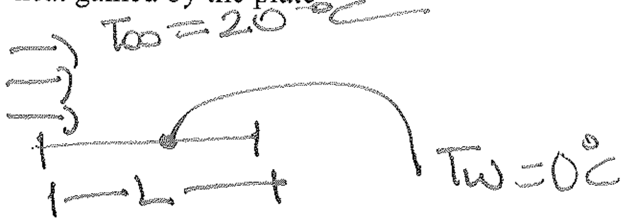
$$\dot{m} c_p (T_{mo} - T_{mi}) = \bar{h} (\pi D L) \left[T_w - \frac{1}{2}(T_{mo} + T_{mi})\right]$$

$T_w = 32.2°C$

we can also use ΔT_{LMTD}



5) Ethylene glycol at 20 °C flows across an isothermal plate maintained at 0 °C. The plate is 20 cm square and the Reynolds number at the end of the plate is 100,000. Calculate the heat gained by the plate



$T_f = \frac{T_w + T_\infty}{2} = 10\ °C$

$= 283\ K$

$Pr \approx 400$ $\qquad T_f \approx 280\ K$

$k \approx 0.244\ W/mK$

$L = 20\ cm = 0.2\ m$ $\qquad Re_L = 100\ 000$

$$\overline{Nu_L} = \frac{2(0.3387)\sqrt{Re_L}\,Pr^{1/3}}{\left[1 + \left(\frac{0.0468}{Pr}\right)^{2/3}\right]^{1/4}}$$

$$= \frac{2(0.3387)\sqrt{100\ 000}\,(400)^{1/3}}{\left[1 + \left(\frac{0.0468}{400}\right)^{2/3}\right]^{1/4}} = 1577$$

$$\bar{h} = \frac{k}{L}\overline{Nu_L} = \left(\frac{0.244}{0.2}\right)(1577) = 1923\ W/m^2K$$

$$q = \bar{h}A(T_w - T_\infty) = (1923)(0.2)(0.2)(-20 + 0)$$

$$= -1538\ W$$

Heat flows into plate