ME 353 M.M. Yovanovich

Week 13

Lecture 1

- Last lecture of the term.
- Hand in laboratory writeup to the teaching assistants.
- Ignore the problems for Chapter 11 which deals with Heat Exchanger Design. This topic will be covered in second heat transfer course in 4A.
- Last tutorial today. Radiation problems will be discussed.
- Effect of radiation shield(s)

Two isothermal gray surfaces separated by a gray shield. See Fig. 13.12.
Surface 1: $A_1, \epsilon_1, T_1, R_{s1} = (1-\epsilon_1)/(A_1\epsilon_1)$
Surface 2: $A_2, \epsilon_2, T_2 < T_1, R_{s2} = (1-\epsilon_2)/(A_2\epsilon_2)$
Shield is very thin and it has high thermal conductivity. Therefore $\Delta T = 0$ and there is one temperature for the shield: T_3 which lies between T_1 and T_2.
Shield: $A_3, \epsilon_{3,1}, \epsilon_{3,2}, R_{s3,1} = (1-\epsilon_{3,1})/(A_3\epsilon_{3,1}), R_{s3,2} = (1-\epsilon_{3,2})/(A_3\epsilon_{3,2})$

- Radiation network has 7 radiative nodes: $E_{b1}, J_1, J_{3,1}, E_{b3}, J_{3,2}, J_2, E_{b2}$

and 6 radiative resistances: $R_{s1}, R_{13}, R_{s3,1}, R_{s3,2}, R_{32}, R_{s2}$ which are in series.

- Heat balances: $Q_{13} = Q_{32}$ and

$$Q_{12} = \frac{E_{b1} - E_{b2}}{R_T} = \frac{\sigma(T_1^4 - T_2^4)}{R_{s1} + R_{13} + R_{s3,1} + R_{s3,2} + R_{32} + R_{s2}}$$

- Spatial radiative resistances: $R_{13} = 1/(A_1 F_{13}), R_{32} = 1/(A_3 F_{32}) = 1/(A_2 F_{23})$

- What is the temperature of the shield, T_3

$$Q_{13} = Q_{32}$$

gives relationship

$$\frac{\sigma(T_1^4 - T_3^4)}{R_{s1} + R_{13} + R_{s3,1}} = \frac{\sigma(T_3^4 - T_2^4)}{R_{s3,2} + R_{32} + R_{s2}}$$

Cancel σ and solve for T_3:

$$T_3 = \left[\frac{T_1^4 R_{T3,2} + T_2^4 R_{T1,3}}{R_T}\right]^{1/4}$$

• N identical shields having identical emissivities equal to the surface emissivities.

$$Q_{12N} = \frac{1}{N+1} Q_{12}(\text{without shields})$$

• Reradiating (refractory, adiabatic surfaces). See Fig. 13.13.
• Three isothermal gray surfaces where one is reradiating.
• Surface 1: $A_1, \epsilon_1, T_1, R_{s1} = (1-\epsilon_1)/(A_1\epsilon_1)$
• Surface 2: $A_2, \epsilon_2, T_2 < T_1, R_{s2} = (1-\epsilon_2)/(A_2\epsilon_2)$
• Surface 3 is reradiating: $A_3, \epsilon_3, T_1 > T_3 > T_2, R_{s3} = (1-\epsilon_3)/(A_3\epsilon_3)$
• Net radiative heat transfer from surface 1 to surface 2 with reradiating surface effect:

$$Q_{12} = \frac{E_{b1} - E_{b2}}{R_{s1} + \dfrac{1}{A_1 F_{12} + [1/(A_1 F_{13}) + 1/(A_2 F_{23})]^{-1}} + R_{s2}}$$

See Fig. 13.13 for radiative network. Text uses subscript R to denote reradiating surface.
See Maple worksheets on Website on radiation calculations.

• Final examination. Closed book. Two crib sheets (both sides) are allowed. Calculator. Five problems of equal value. Conduction (transient), Forced convection (external and internal), Natural convection, radiation. See old final exams from 1996 and 1997.
