CH EN 3453 – Heat Transfer

Radiation: Network Representations and Multimode Heat Transfer

Sections 13.2 to 13.3

Reminders…

- Final Heat Exchanger report due Wednesday next week
  - Email PDF version to report@chen3453.com by 8:00 pm
  - 25% loss for every day late
  - Do <u>not</u> bring to class, slip under my door or send by email
  - Remember to check web resources (writing, grading rubric, etc.)
- Homework #11 due today
- Homework #12 due Monday next week
  - Help session Wednesday at 4:30 pm in MEB 2325
- Tons of old homework to pick up
- Final exam Wednesday, December 17
  - This room
  - 8:00 to 10:00 a.m.

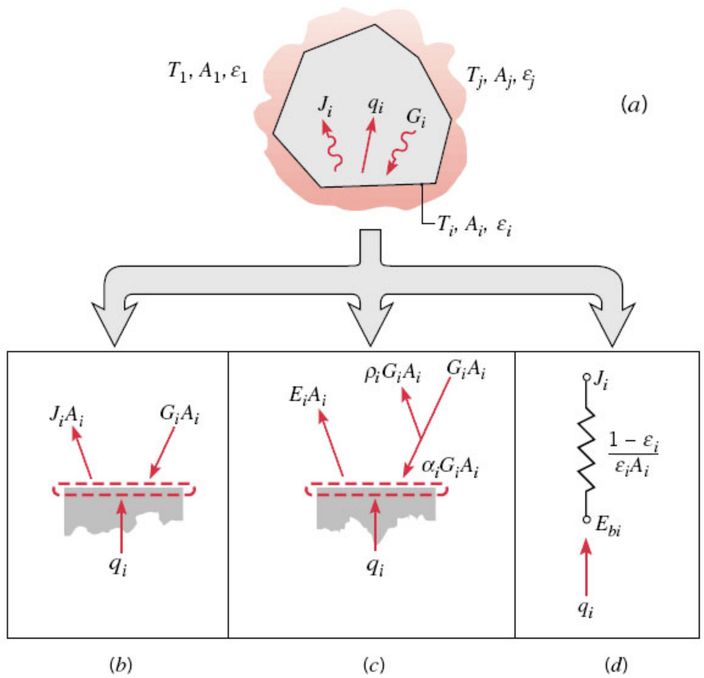
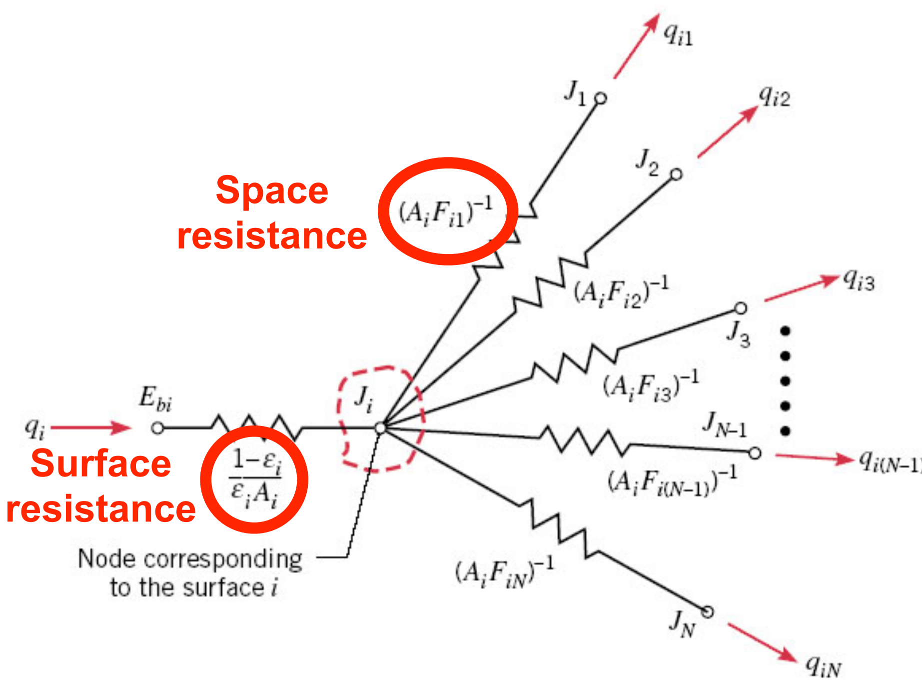
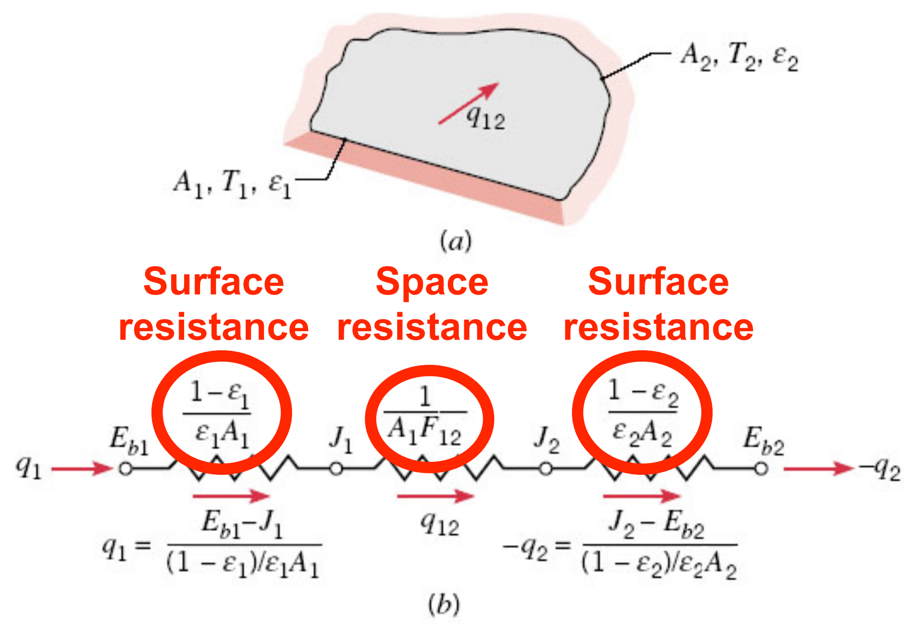


FIGURE 13.8 Radiation exchange in an enclosure of diffuse, gray surfaces with a nonparticipating medium. (*a*) Schematic of the enclosure. (*b*) Radiative balance according to Equation 13.9. (*c*) Radiative balance according to Equation 13.11. (*d*) Network element representing the net radiation transfer from a surface.

Review: Radiation between Surfaces



Review: Two-Surface Enclosure



Multimode Heat Transfer

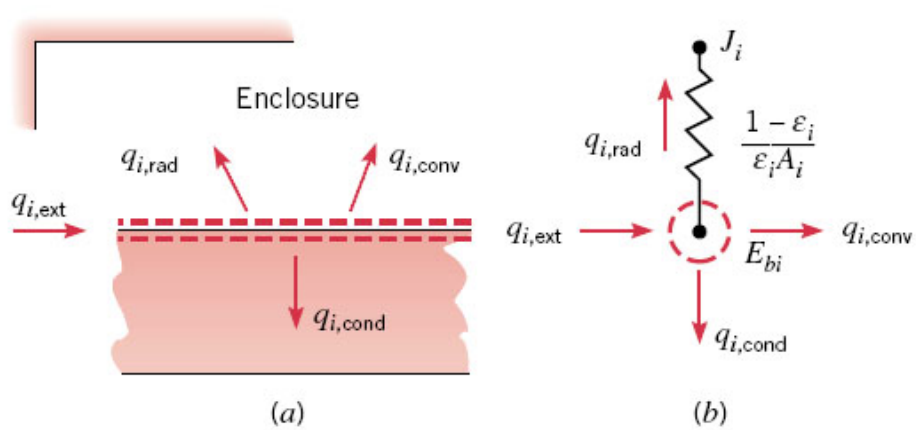
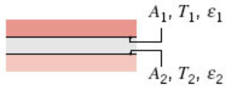


FIGURE 13.13 Multimode heat transfer from a surface in an enclosure. (a) Surface energy balance. (b) Circuit representation.

Table 13.3 Special Diffuse, Gray, Two-Surface Enclosures

Large (Infinite) Parallel Planes

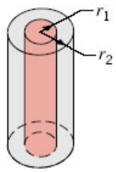


$A_1 = A_2 = A$

$F_{12} = 1$

$$q_{12} = \frac{A\sigma(T_1^4 - T_2^4)}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1} \quad (13.19)$$

Long (Infinite) Concentric Cylinders

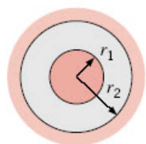


$\frac{A_1}{A_2} = \frac{r_1}{r_2}$

$F_{12} = 1$

$$q_{12} = \frac{\sigma A_1(T_1^4 - T_2^4)}{\frac{1}{\varepsilon_1} + \frac{1 - \varepsilon_2}{\varepsilon_2}\left(\frac{r_1}{r_2}\right)} \quad (13.20)$$

Concentric Spheres

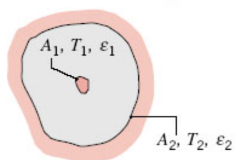


$\frac{A_1}{A_2} = \frac{r_1^2}{r_2^2}$

$F_{12} = 1$

$$q_{12} = \frac{\sigma A_1(T_1^4 - T_2^4)}{\frac{1}{\varepsilon_1} + \frac{1 - \varepsilon_2}{\varepsilon_2}\left(\frac{r_1}{r_2}\right)^2} \quad (13.21)$$

Small Convex Object in a Large Cavity



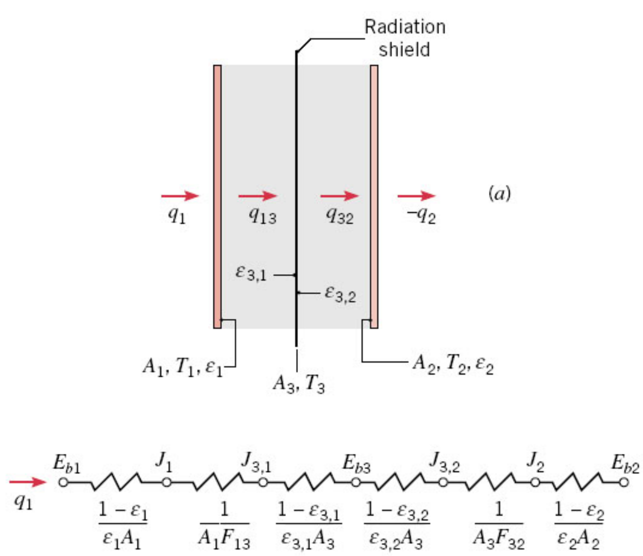
$\frac{A_1}{A_2} \approx 0$

$F_{12} = 1$

$$q_{12} = \sigma A_1 \varepsilon_1 (T_1^4 - T_2^4) \quad (13.22)$$

Radiation Shield

- Low emissivity (high reflectivity) material placed between two surfaces to minimize radiation heat transfer
- Additional resistances associated with emissivity of the two sides of the radiation shield



Reradiating Surface

- Zero net radiation transfer
  - For example, surface insulated on back side
- Temperature independent of emissivity

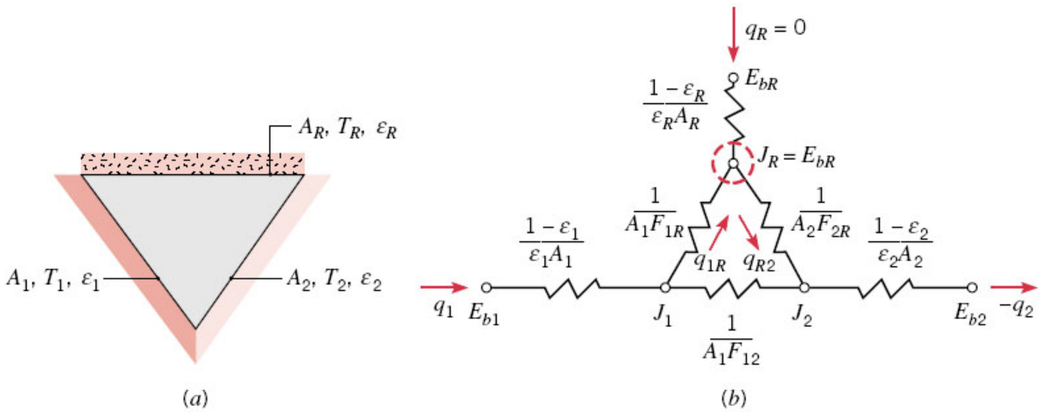


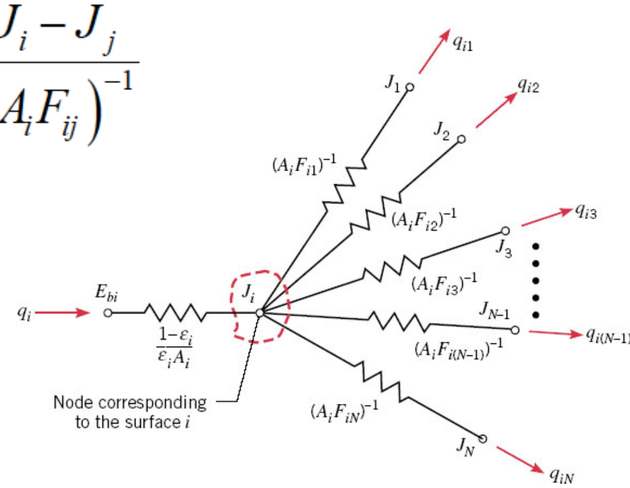
FIGURE 13.12 A three-surface enclosure with one surface reradiating. (*a*) Schematic. (*b*) Network representation.

"Direct Method" for Solving Networks

- Useful for systems with >2 surfaces
- Balance radiant energy around each surface node *i* :

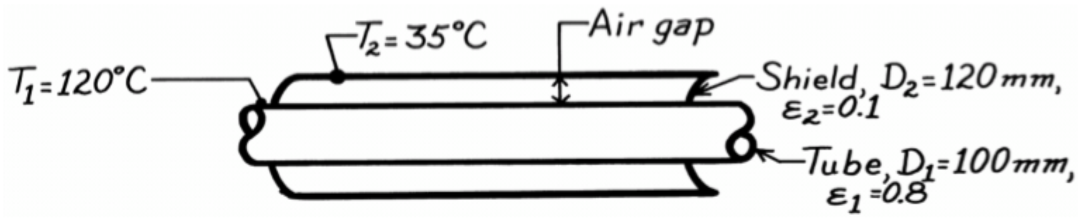
$$\frac{E_{bi} - J_i}{(1-\varepsilon_i)/\varepsilon_i A_i} = \sum_{j=1}^{N} \frac{J_i - J_j}{\left(A_i F_{ij}\right)^{-1}}$$

- Solve system of equations



Example – Book Problem 13.49

A long, thin-walled horizontal tube (ε = 0.8) 100 mm in diameter is kept at 120°C by the passage of steam through its interior. A radiation shield (ε = 0.1) is installed around the tube, providing an air gap of 10 mm between the tube and the shield, and reaches a surface temperature of 35°C. What is the radiant heat transfer from the tube per unit length?



Example: Problem 13.83

Consider a circular furnace that is 0.3 m long and 0.3 m in diameter. The two ends have diffuse, gray surfaces that are maintained at 400 and 500 K, with emissivities of 0.4 and 0.5, respectively. The lateral surface is also gray with an emissivity of 0.8 and a temperature of 800 K. Determine the net radiative heat transfer from each of the surfaces.