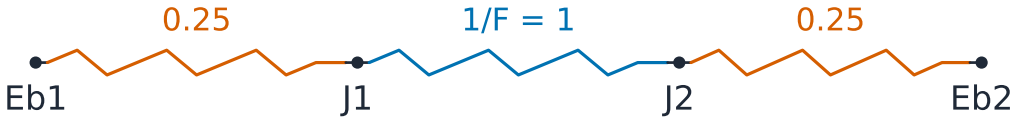
Exercise walk-through

10.4 Radiation

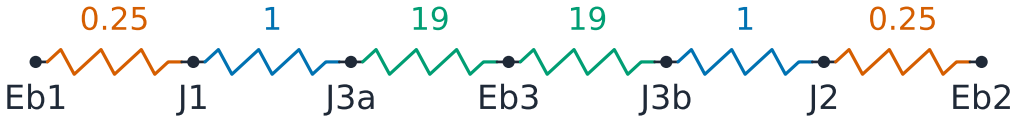
University Mechanical Engineering

Radiation as a network

surface resistances (1−ε)/ε and space resistances 1/F (per m²)



ΣR = 1.5: q = σ(600⁴ − 300⁴)/1.5 = 4593 W/m²



shield ε = 0.05 adds 39: q = 170 W/m², 3.7% of before

600 K / 300 K plates, $\varepsilon = 0.8$: $\mathbf{4593}$ W/m^2; a shield with $\varepsilon = 0.05$ cuts it to $\mathbf{170}$ W/m^2.

The bare pipe, honestly

1. **h_r** $h_r = \varepsilon\sigma(T_s^2 + T_{sur}^2)(T_s + T_{sur}) = \mathbf{5.58}$ W/m^{2}K at 59.5 °C.
2. **Bare** $q = \mathbf{170}$ W/m - convection 109, radiation $\mathbf{61}$.
3. **Insulated** Surface 22.7 °C, $q = \mathbf{18.0}$ W/m.

Decision

Ignoring radiation hid a third of the loss; the true saving is 89%, not 84%.

Exercises 2.1·2.2

2.1 A surface at 80 °C ($\varepsilon = 0.9$) sits in a large room at 20 °C. Find the radiated flux (one decimal, W/m^2). [3]

2.2 Find h_r for that surface (two decimals, W/(m^2 · K)) and say how it compares with a still-air h_c of about 10. [3]

Exercises 2.1·2.2

2.1 A surface at 80 °C ($\varepsilon = 0.9$) sits in a large room at 20 °C. Find the radiated flux (one decimal, W/m^2). [3]

2.1

- $T_s = 353.15$ K, $T_{sur} = 293.15$ K.
- $q'' = \varepsilon\sigma(T_s^4 - T_{sur}^4) = 0.9 \times 5.67 \times 10^{-8}(353.15^4 - 293.15^4) = \mathbf{416.8}$ W/m^2.

2.2 Find h_r for that surface (two decimals, W/(m^2 · K)) and say how it compares with a still-air h_c of about 10. [3]

2.2

- $h_r = \varepsilon\sigma(T_s^2 + T_{sur}^2)(T_s + T_{sur}) = \mathbf{6.95}$ W/(m^2 · K); check $6.95 \times 60 = 417$.
- Comparable with $h_c \approx 10$: ignoring radiation would miss about 40% of the loss.

Exercise 3.1

3.1 Two large parallel plates at 500 K and 300 K both have $\varepsilon = 0.7$. (a) Find the exchange per m^2 (one decimal). (b) A thin shield with $\varepsilon = 0.1$ on both sides is placed between them: find the new exchange (one decimal) and its fraction of (a) (one decimal, %). (c) Find the shield temperature (nearest K). [8]

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3.1

- (a) $q = \sigma(T_1^4 - T_2^4)/(1/\varepsilon_1 + 1/\varepsilon_2 - 1) = 5.67 \times 10^{-8}(500^4 - 300^4)/1.857 =$ **1660.9** $\mathrm{W/m^2}$.
- (b) The shield adds $2/0.1 - 1 = 19$, so the denominator is $1.857 + 19 = 20.857$.
- $q = 5.67 \times 10^{-8} \times 5.44 \times 10^{10}/20.857 =$ **147.9** $\mathrm{W/m^2}$, **8.9**% of (a).
- (c) Hot side to shield: $q = \sigma(500^4 - T_s^4)/(1/0.7 + 1/0.1 - 1)$.
- $T_s^4 = 500^4 - 147.9 \times 10.43/(5.67 \times 10^{-8})$, so $T_s =$ **433** K, nearer the hot plate because the network is symmetric in T^4, not in T.