10.4 Radiation

Name: _____ Class: _____ Date: _____ **Total: 14 marks**

KEY WORDS emissivity

Objective

Find radiation exchange from a surface to its surroundings and between two parallel plates, linearise it as a coefficient h_r, and size a radiation shield.

1 Key knowledge and worked examples

■ Surface and space resistances

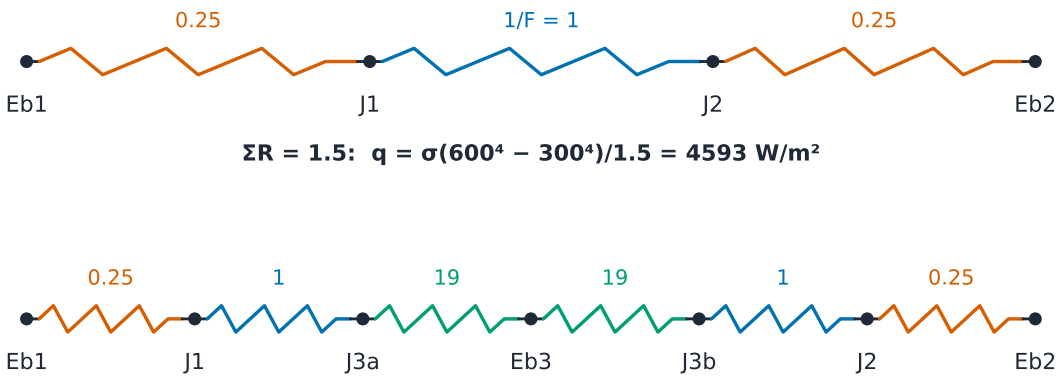
- Small body in a large room: $q = \varepsilon\sigma A(T_s^4 - T_{sur}^4)$, temperatures in kelvin, **emissivity** ε, $\sigma = 5.67 \times 10^{-8}$ W/(m^2 · K^4).
- Linearised: $h_r = \varepsilon\sigma(T_s^2 + T_{sur}^2)(T_s + T_{sur})$, in parallel with h_c.
- Large parallel plates per m^2: $q = \sigma(T_1^4 - T_2^4)/(1/\varepsilon_1 + 1/\varepsilon_2 - 1)$.
- A shield adds $1/\varepsilon_{s1} + 1/\varepsilon_{s2} - 1$ to the denominator.

■ Worked example. A radiation shield

Oven wall 600 K, casing 300 K, both $\varepsilon = 0.8$; per m^2.

- $q = \sigma(600^4 - 300^4)/(1/0.8 + 1/0.8 - 1) = \mathbf{4593}$ W/m^2.
- A polished shield ($\varepsilon = 0.05$) adds $2/0.05 - 1 = 39$: $q = \mathbf{170}$ W/m^2, 3.7% of before.

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2 Practice

$\sigma = 5.67 \times 10^{-8}$ W/(m^2 · K^4); add 273.15 for kelvin.

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]

3 Exam-style questions

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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Solutions

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

- $h_r = \varepsilon\sigma(T_s^2 + T_{sur}^2)(T_s + T_{sur}) = \mathbf{6.95}$ 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.

3.1

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

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