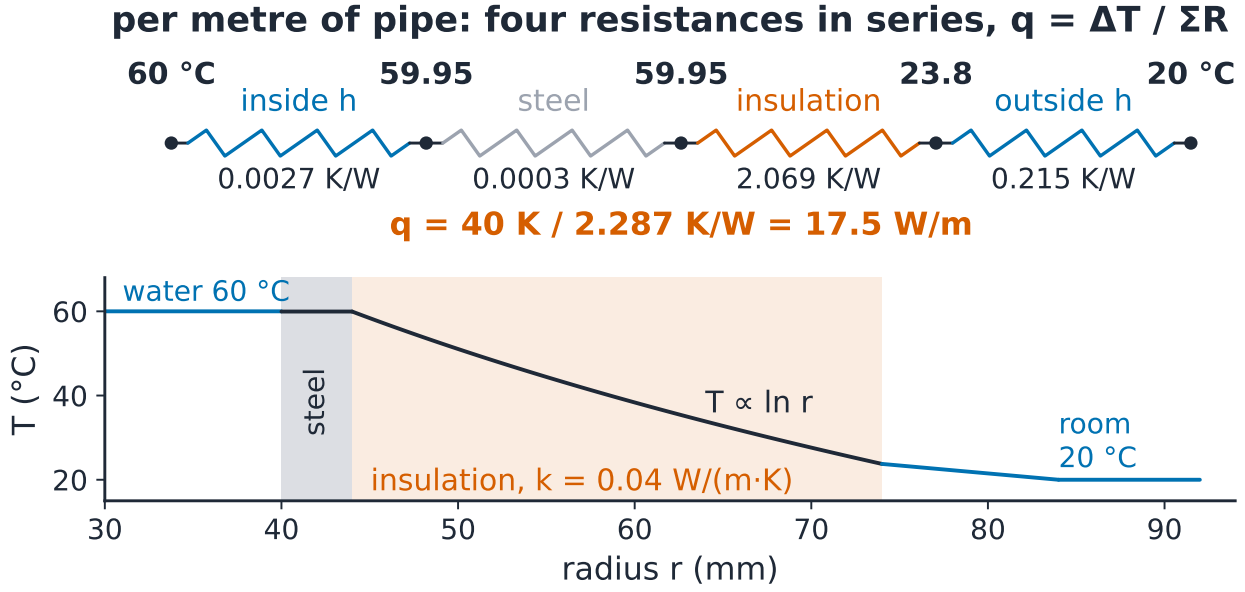
Exercise walk-through

10.1 Conduction

University Mechanical Engineering

The pipe as a resistance network



Per metre: $\sum R = 2.287$ K/W, $q = 40/2.287 = \mathbf{17.5}$ W/m; the bare pipe loses **110** W/m by convection.

A composite wall

1. **Layers** Brick 200 mm, wool 50 mm, plaster 12 mm on 12 m^2; $h_i = 8$, $h_o = 25$.
2. **Sum** $0.0104 + 0.0238 + \mathbf{0.1042} + 0.0020 + 0.0033 = \mathbf{0.1437}$ K/W.
3. **Rate** $q = 27/0.1437 = \mathbf{188}$ W; the wool takes 73% of the drop.
4. **Critical radius** $r_c = k/h = 4$ mm $\ll 44$ mm, so pipe insulation can only help.

Decision

Put the insulation where the resistance network says it counts.

Exercises 2.1·2.2

2.1 A concrete wall 0.25 m thick ($k = 1.4$ W/(m · K)) and 10 m^2 in area has faces at 25 K difference. Find its resistance (five decimals, K/W) and the heat flow (nearest W). [3]

2.2 The wall gains 60 mm of insulation ($k = 0.035$), with $h_i = 8$ and $h_o = 20$ W/(m^2 · K); the air temperatures differ by 25 K. Find the total resistance (four decimals, K/W), the heat flow (one decimal, W) and the temperature drop across the insulation (one decimal, K). [5]

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2.1

- $R = L/(kA) = 0.25/(1.4 \times 10) = \mathbf{0.01786}$ K/W.
- $q = \Delta T/R = 25/0.01786 = \mathbf{1400}$ W.

2.2 The wall gains 60 mm of insulation ($k = 0.035$), with $h_i = 8$ and $h_o = 20$ W/(m^2 · K); the air temperatures differ by 25 K. Find the total resistance (four decimals, K/W), the heat flow (one decimal, W) and the temperature drop across the insulation (one decimal, K). [5]

2.2

- $R_i = 1/(h_i A) = 1/80 = 0.0125$; $R_{wall} = 0.0179$; $R_{ins} = L/(kA) = 0.06/(0.035 \times 10) = 0.1714$; $R_o = 1/200 = 0.0050$ K/W.
- $\sum R = \mathbf{0.2068}$ K/W; $q = 25/0.2068 = \mathbf{120.9}$ W.
- $\Delta T_{ins} = qR_{ins} = 120.9 \times 0.1714 = \mathbf{20.7}$ K, 83% of the whole drop.

Exercise 2.3

2.3 A 5 mm-radius wire is coated with plastic ($k = 0.2$) in air with $h = 10$ W/(m^2 · K). Find the critical radius (mm) and say what a thin coating does to the heat loss. [3]

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2.3

- $r_c = k/h = 0.2/10 = 0.020$ m = **20** mm.
- The wire is below r_c: a coating up to 20 mm radius adds outer area faster than resistance, so it *increases* the loss, useful for cooling cables.

Exercise 3.1

3.1 Water at 80 °C flows in a steel pipe ($r_1 = 25$, $r_2 = 28$ mm, $k = 50$) with insulation to $r_3 = 58$ mm ($k = 0.04$); $h_i = 1000$, $h_o = 10$ W/(m^2 · K), room 20 °C. Per metre, find the four resistances (four decimals, K/W), the heat loss (one decimal, W/m) and the outer surface temperature (one decimal, °C). Compare with the bare pipe's loss. [7]

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3.1

- $R_i = 1/(h_i 2\pi r_1) = 1/(1000 \times 2\pi \times 0.025) = 0.0064$; $R_s = \ln(r_2/r_1)/(2\pi k) = \ln(28/25)/(2\pi \times 50) = 0.0004$ K/W.
- $R_{ins} = \ln(58/28)/(2\pi \times 0.04) = 2.8976$; $R_o = 1/(10 \times 2\pi \times 0.058) = 0.2744$ K/W.
- $q = \Delta T / \sum R = 60/3.1787 = \mathbf{18.9}$ W/m.
- $T_{surface} = 20 + qR_o = 20 + 18.9 \times 0.2744 = \mathbf{25.2}$ °C.
- Bare: $q = 60/(0.0064 + 0.0004 + 1/(10 \times 2\pi \times 0.028)) = 104.3$ W/m, so insulation saves about 82%.