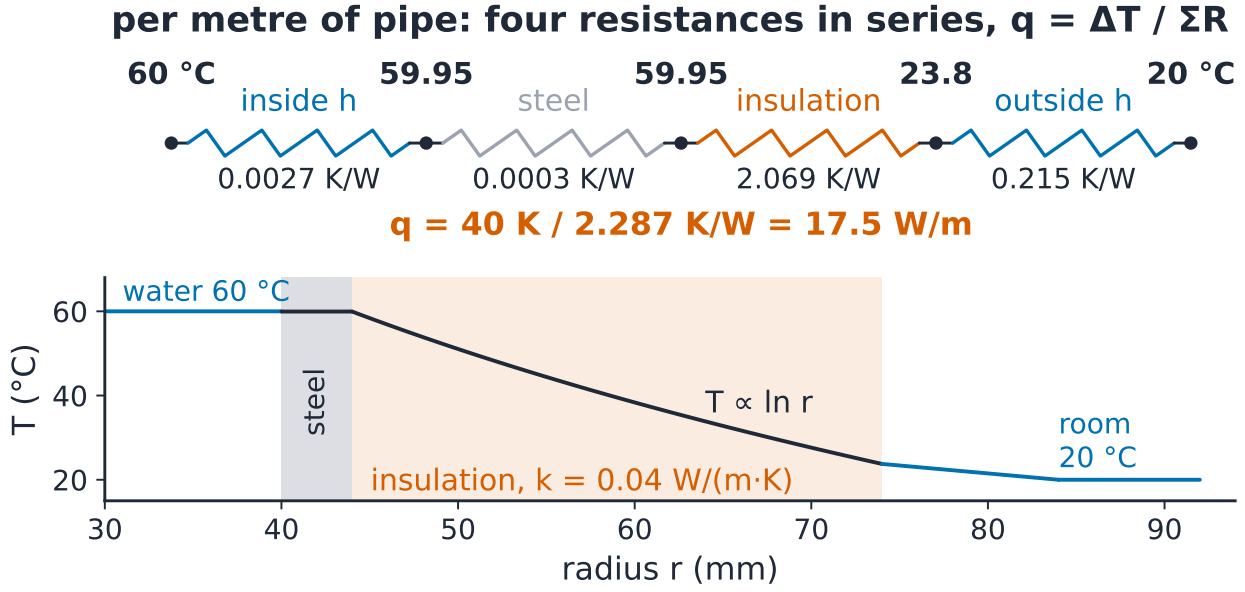
Exercise walk-through

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

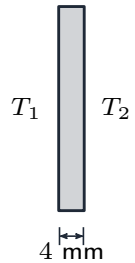
1. **Layers** Brick 200 mm, wool 50 mm, plaster 12 mm on 12 m^2; $h_i = 8$, $h_o = 25$.
2. **Sum** $0.0104 + 0.0238 + \mathbf{0.1042} + 0.0020 + 0.0033 = \mathbf{0.1437}$ K/W.
3. **Rate** $q = 27/0.1437 = \mathbf{188}$ W; the wool takes 73% of the drop.
4. **Critical radius** $r_c = k/h = 4$ mm $\ll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

Decision

Put the insulation where the resistance network says it counts.

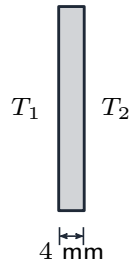
Exercise 2.1

2.1 A single-glazed window is 4 mm thick ($k = 0.80$) and 2.0 m^2 in area. Its faces differ by 15 K. Find the heat flow, and say why the real loss is far smaller. [2]



Exercise 2.1

2.1 A single-glazed window is 4 mm thick ($k = 0.80$) and 2.0 m^2 in area. Its faces differ by 15 K. Find the heat flow, and say why the real loss is far smaller. [2]

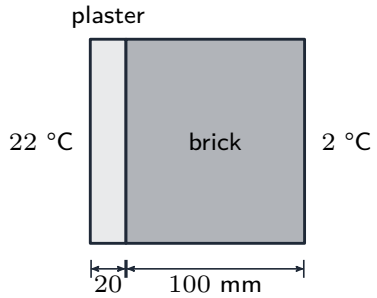


2.1

$\dot{Q} = \dfrac{0.80 \times 2.0 \times 15}{0.004} = \mathbf{6000\ W}$; the air films on each side have much more resistance than the glass, so the faces are nowhere near 15 K apart in practice

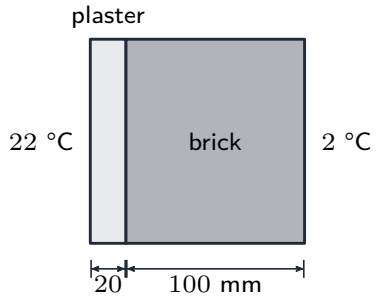
Exercise 2.2

2.2 A wall is 20 mm plaster ($k = 0.50$) on 100 mm brick ($k = 0.70$). Per m^2, the inner face is at 22 °C and the outer face at 2 °C. Find $\sum R$, the heat flow and the temperature between plaster and brick. [3]



Exercise 2.2

2.2 A wall is 20 mm plaster ($k = 0.50$) on 100 mm brick ($k = 0.70$). Per m^2, the inner face is at 22 °C and the outer face at 2 °C. Find $\sum R$, the heat flow and the temperature between plaster and brick. [3]

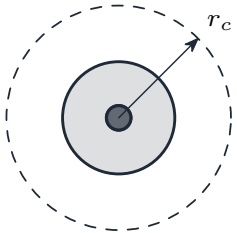


2.2

$\sum R = 0.040 + 0.143 = \mathbf{0.183}$ m^2 K/W; $\dot{q} = \dfrac{20}{0.183} = \mathbf{109}$ **W/m^2**; interface $22 - 109 \times 0.040 = \mathbf{17.6}$ **°C**

Exercise 2.3

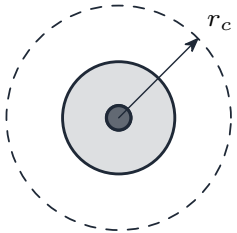
2.3 A 2 mm diameter wire is covered with plastic ($k = 0.20$) in air with $h = 10$ W/(m^2 K). Find the critical radius. Does a thin coat raise or lower the heat loss? [3]



plastic on a wire

Exercise 2.3

2.3 A 2 mm diameter wire is covered with plastic ($k = 0.20$) in air with $h = 10$ W/(m^2 K). Find the critical radius. Does a thin coat raise or lower the heat loss? [3]



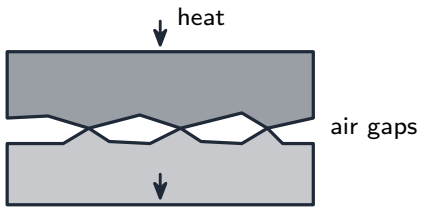
plastic on a wire

2.3

$r_c = \dfrac{0.20}{10} =$ **20 mm**; the wire radius 1 mm is far below it; so coating *raises* the loss until the outer radius passes 20 mm, which helps cool the wire

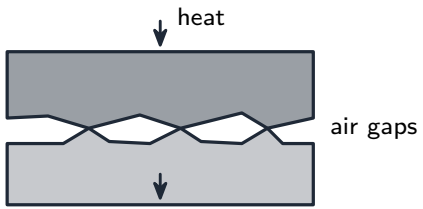
Exercise 2.4

2.4 Two metal blocks are clamped together. Explain why their joint has a **contact resistance** , and one way to reduce it. [2]



Exercise 2.4

2.4 Two metal blocks are clamped together. Explain why their joint has a **contact resistance** , and one way to reduce it. [2]



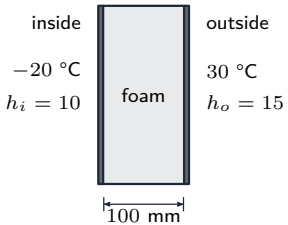
2.4

the surfaces touch only at peaks, and heat must cross the air in the gaps, which has a low k; a thermal paste or a soft pad fills the gaps, or more clamping force

Exercise 3.1

3.1 A cold-store wall is 100 mm of polyurethane foam ($k = 0.025$) between thin steel skins (ignore them). Inside -20 °C with $h_i = 10$; outside 30 °C with $h_o = 15$ W/(m^2 K). The wall area is 40 m^2.

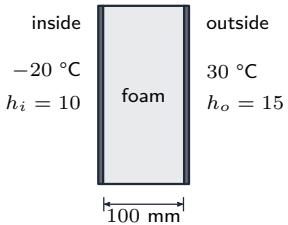
Find $\sum R$ per m^2, the heat gain through the wall and the outer surface temperature. The outside dew point is 24 °C: will the outer skin sweat? [5]



Exercise 3.1

3.1 A cold-store wall is 100 mm of polyurethane foam ($k = 0.025$) between thin steel skins (ignore them). Inside -20 °C with $h_i = 10$; outside 30 °C with $h_o = 15$ W/(m^2 K). The wall area is 40 m^2.

Find $\sum R$ per m^2, the heat gain through the wall and the outer surface temperature. The outside dew point is 24 °C: will the outer skin sweat? [5]



3.1

$\sum R = 0.067 + 4.000 + 0.100 = \mathbf{4.17}$ m^2 K/W; $\dot{q} = \dfrac{50}{4.17} = 12.0$ W/m^2

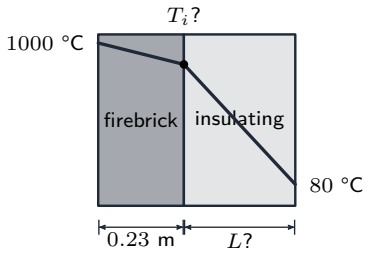
$\dot{Q} = 12.0 \times 40 = \mathbf{480}$ **W**; outer surface $30 - \dfrac{12.0}{15} = \mathbf{29.2}$ **°C**

$29.2 > 24$ °C: no condensation

Exercise 3.2

3.2 A furnace wall has 0.23 m of firebrick ($k = 1.2$) inside insulating brick ($k = 0.15$). The inner face is at 1000 °C and the outer face must be at 80 °C, with a loss of 600 W/m^2. The insulating brick may not exceed 900 °C.

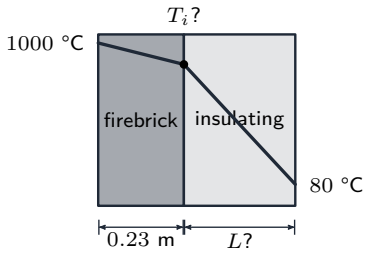
Find the interface temperature and the thickness of insulating brick. Is the brick within its limit? [4]



Exercise 3.2

3.2 A furnace wall has 0.23 m of firebrick ($k = 1.2$) inside insulating brick ($k = 0.15$). The inner face is at 1000 °C and the outer face must be at 80 °C, with a loss of 600 W/m^2. The insulating brick may not exceed 900 °C.

Find the interface temperature and the thickness of insulating brick. Is the brick within its limit? [4]



3.2

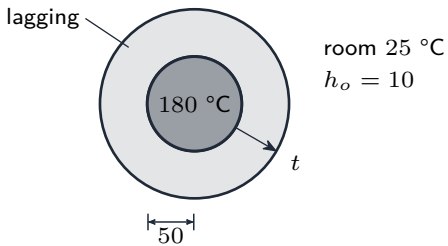
firebrick drop $\dfrac{600 \times 0.23}{1.2} = 115$ K; interface **885 °C**, below 900: OK

$$L = \frac{0.15 \times (885 - 80)}{600} = \mathbf{0.20\ m}$$

Exercise 3.3 (a)

3.3 A steam pipe at 180 °C (outer radius 50 mm; ignore the steel and the steam film) runs in a 25 °C plant room, $h_o = 10$ W/(m^2 K). Lagging has $k = 0.050$. The touch limit is 50 °C. Heat costs 0.30 yuan/kWh; the pipe runs 8000 h a year. Lagging costs 40, 70 and 110 yuan per metre for 25, 50 and 75 mm.

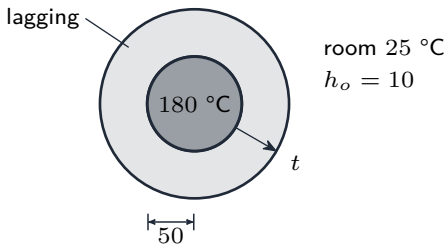
(a) For 50 mm lagging find R_{ins}, R_o, the loss per metre and the outer surface temperature. [3]



Exercise 3.3 (a)

3.3 A steam pipe at 180 °C (outer radius 50 mm; ignore the steel and the steam film) runs in a 25 °C plant room, $h_o = 10$ W/(m^2 K). Lagging has $k = 0.050$. The touch limit is 50 °C. Heat costs 0.30 yuan/kWh; the pipe runs 8000 h a year. Lagging costs 40, 70 and 110 yuan per metre for 25, 50 and 75 mm.

(a) For 50 mm lagging find R_{ins}, R_o, the loss per metre and the outer surface temperature. [3]



(a) $R_{ins} = \dfrac{\ln(100/50)}{2\pi \times 0.050} = 2.21$ K/W, $R_o = \dfrac{1}{10 \times 2\pi \times 0.100} = 0.159$ K/W; $\dot{Q} = \dfrac{155}{2.37} =$ **65.5 W/m**; surface $25 + 65.5 \times 0.159 =$ **35.4 °C**

Exercise 3.3 (b)

3.3 A steam pipe at 180 °C (outer radius 50 mm; ignore the steel and the steam film) runs in a 25 °C plant room, $h_o = 10$ W/(m^2 K). Lagging has $k = 0.050$. The touch limit is 50 °C. Heat costs 0.30 yuan/kWh; the pipe runs 8000 h a year. Lagging costs 40, 70 and 110 yuan per metre for 25, 50 and 75 mm.

(b) The loss is 103 W/m with 25 mm and 51 W/m with 75 mm. Find the five-year cost (lagging plus heat) for each thickness, and choose. [3]

Exercise 3.3 (b)

3.3 A steam pipe at 180 °C (outer radius 50 mm; ignore the steel and the steam film) runs in a 25 °C plant room, $h_o = 10$ W/(m^2 K). Lagging has $k = 0.050$. The touch limit is 50 °C. Heat costs 0.30 yuan/kWh; the pipe runs 8000 h a year. Lagging costs 40, 70 and 110 yuan per metre for 25, 50 and 75 mm.

(b) The loss is 103 W/m with 25 mm and 51 W/m with 75 mm. Find the five-year cost (lagging plus heat) for each thickness, and choose. [3]

(b) heat cost per W over five years $= 0.30 \times 8000 \times 5/1000 = 12$ yuan; 25 mm: $40 + 1236 = 1276$; 50 mm: $70 + 786 = 856$; 75 mm: $110 + 611 =$ **721** yuan; choose 75 **mm**

Exercise 3.3 (c)

3.3 A steam pipe at 180 °C (outer radius 50 mm; ignore the steel and the steam film) runs in a 25 °C plant room, $h_o = 10$ W/(m^2 K). Lagging has $k = 0.050$. The touch limit is 50 °C. Heat costs 0.30 yuan/kWh; the pipe runs 8000 h a year. Lagging costs 40, 70 and 110 yuan per metre for 25, 50 and 75 mm.

(c) Check your choice against the touch limit, and give one other reason for it. [2]

exercises.lol exercises.com.cn

Exercise 3.3 (c)

3.3 A steam pipe at 180 °C (outer radius 50 mm; ignore the steel and the steam film) runs in a 25 °C plant room, $h_o = 10$ W/(m^2 K). Lagging has $k = 0.050$. The touch limit is 50 °C. Heat costs 0.30 yuan/kWh; the pipe runs 8000 h a year. Lagging costs 40, 70 and 110 yuan per metre for 25, 50 and 75 mm.

(c) Check your choice against the touch limit, and give one other reason for it. [2]

(c) surface about 31 °C, well under 50 °C; less heat into the plant room, or more margin if the lagging gets wet or damaged