Introduction to Transport Phenomena: <u>Solutions Module 3</u>

Solution 3.1

a) At steady-state, we can simply write the Fourier's law:

$$q = \frac{\dot{Q}}{A} = -k\frac{dT}{dy} = k\frac{T_1 - T_0}{Y}$$

$$k = \frac{\dot{Q}}{A}\frac{Y}{T_1 - T_0} = \frac{3 * 6.4 * 10^{-3}}{0.929 * (26-24)} = 1.03 * 10^{-2}\frac{W}{m\ * K}$$

b) From the Fourier's law:

$$Y = kA\frac{T_1 - T_0}{\dot{Q}} = 0.64\,mm$$

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Solution 3.2

Composite reactor:

$$q = \frac{\dot{Q}_x}{A} = \frac{T_{int} - T_{ext}}{\frac{1}{h_{int}} + \frac{L_{Pb}}{k_{Pb}} + \frac{L_{brique}}{k_{brique}} + \frac{L_{acier}}{k_{acier}} + \frac{1}{h_{ext}}}$$

In order to calculate L_{brique} we need to know the heat flux. We haven't use T_c yet. We can write the following:

$$q = \frac{\dot{Q}_x}{A} = h_{ext}(T_c - T_{ext})$$

Therefore:

$$\frac{T_{int} - T_{ext}}{\frac{1}{h_{int}} + \frac{L_{Pb}}{k_{Pb}} + \frac{L_{brique}}{k_{brique}} + \frac{L_{acier}}{k_{acier}} + \frac{1}{h_{ext}}} = h_{ext}(T_c - T_{ext})$$

$$(T_{int} - T_{ext}) * \frac{1}{h_{ext}} = (T_c - T_{ext})\left(\frac{1}{h_{int}} + \frac{L_{Pb}}{k_{Pb}} + \frac{L_{brique}}{k_{brique}} + \frac{L_{acier}}{k_{acier}} + \frac{1}{h_{ext}}\right)$$

$$L_{brique} = k_{brique}\left(\frac{T_{int} - T_{ext}}{T_c - T_{ext}} * \frac{1}{h_{ext}} - \frac{1}{h_{int}} - \frac{L_{Pb}}{k_{Pb}} - \frac{L_{acier}}{k_{acier}} - \frac{1}{h_{ext}}\right)$$

$$L_{brique} = 0.74\left(\frac{96}{28} * \frac{1}{10.2} - \frac{1}{7400} - \frac{0.003}{30} - \frac{0.012}{38.7} - \frac{1}{10.2}\right)$$

$$L_{brique} = 0.74(0.3361 - 0.00013 - 0.0001 - 0.00031 - 0.098) = 0.176m$$

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Solution 3.3

Furnace walls:
a) The heat flux through the system is given by:

$$q_x = \frac{Q_x}{A} = \frac{T_{int} - T_{ext}}{\frac{1}{h_{int}} + \frac{L_A}{k_A} + \frac{L_B}{k_B} + \frac{1}{h_{ext}}} =$$

$$= \frac{1649 - 27}{\frac{1}{60} + \frac{0.2286}{1.19} + \frac{0.13}{0.15} + \frac{1}{9.8}} = 1377 \frac{W}{m^2}$$

b)

$$q_x = h_{int}(T_{int} - T_A)$$
$$T_A = 1649 - \frac{1377}{60} = 1626°C$$

$$q_x = h_{ext}(T_B - T_{ext})$$
$$T_B = T_{ext} + \frac{q_x}{h_{ext}}$$
$$T_B = 27 + \frac{1377}{9.8} = 167.5°C$$

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Solution 3.4

Let us consider a total wall area of A m^2

Cross section area per metal bolt = $\pi \times r^2 = 3.84 \times 10^{-5} m^2$
Number of bolts = A/0.015

So, area of the wall with metal bolts (A_{bolt}) = $\frac{A}{0.015} \times 3.84 \times 10^{-5} m^2$

a)Therefore the fraction of the wall with metal bolts = $\frac{(\frac{A}{0.015} \times 3.84 \times 10^{-5})}{A}$ = 0.0025

b)Heat conducted through a given section is given by $\frac{\kappa \times A}{l}$
Heat conducted by bolts = $k_{bolt} * A_{bolt}/l$= $A \times 0.0025 \times 45.6/0.03$
Heat conducted by wall = $k_{wall} * A_{wall}/l$= $A \times 0.9975 \times 0.34/0.03$

Therefore the fraction of heat conducted by the bolts = $\frac{A \times 0.0025 \times 45.6/0.03}{A \times 0.9975 \times 0.34/0.03} = 0.33$

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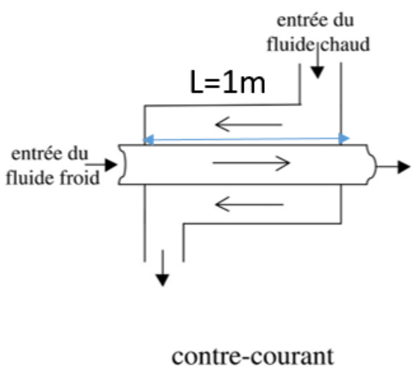
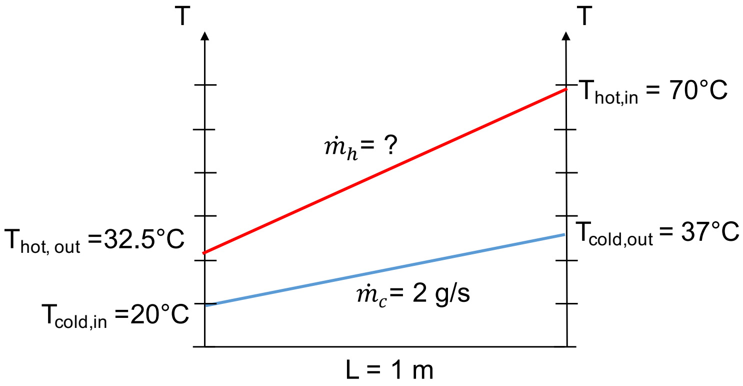
Solution 3.5





The first step is to draw the temperature profile corresponding to the heat exchanger described in the exercize (on the right)

The first question is to calculate the mass flow rate $\dot{m}_{hot}$

For the heat balance, we can write: $\dot{Q} = \dot{Q}_c = \dot{Q}_h$

We can calculate:

$$\dot{Q}_c = \dot{m}_c c_p (T_{cold_{out}} - T_{cold_{in}}) = 2 * 10^{-3} * 4.187 * 10^3 * 17 = 142.3 \text{ W}$$

$$\dot{m}_h = \frac{\dot{Q}_h}{c_p(T_{hot_{in}} - T_{hot_{out}})} = \frac{142.3}{4.187 * 10^3 * (70 - 32.5)} = \mathbf{0.907\ gs^{-1}}$$

The second question is to calculate the heat transfer area, which can be done from the equation

$$\mathrm{Q = UA\Delta T_{LM}}$$

$$\Delta T_{LM} = \frac{\Delta T_1 - \Delta T_2}{\ln\left(\frac{\Delta T_1}{\Delta T_2}\right)} = 21.2K$$

$$\Delta T_1 = T_{hot_{in}} - T_{cold_{out}} = (70 + 273) - (37 + 273) = 33K$$

$$\Delta T_2 = T_{hot_{out}} - T_{cold_{in}} = 12.5K$$

$$A = \frac{Q}{U\Delta \mathrm{T_{LM}}} = \frac{142.3\ W}{106.47\ Wm^{-2}K^{-1} * 21.2K} = \mathbf{0.063\ m^2}$$