Introduction to Transport Phenomena: Exercises Module 3

Exercise 3.1

(Fourier's Law)

A plastic panel with a surface area of $A = 0.929m^2$ and a thickness $Y = 6.4mm$ conducts heat at a rate of $3W$ ($\dot{Q} = 3W$) in steady state when the temperatures were set at $T_0 = 24°C$ and $T_1 = 26.0°C$ on the two main surfaces.

a) What is the thermal conductivity of the plastic?
b) If $\dot{Q} = 30W$, what thickness of the same plastic would be necessary to keep the same T_0 and T_1.

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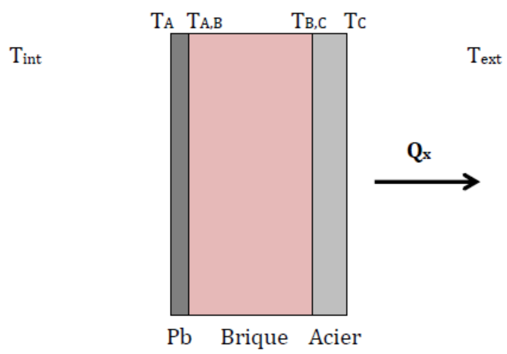
Exercise 3.2

(Newton's Law of cooling and thermal resistances)

Composite reactor: During a chemical reaction occurring in a well-mixed reactor, the temperature of the fluid rises to $T_{int} = 123\,°\,C$. The interior face of the reactor wall is coated with a lead sheet $3mm$ thick with $k_{Pb} = 30\,\frac{W}{mK}$. The outside of the reactor is constituted by a steel sheet $12\ mm$ thick ($k_{steel} = 38.7\,\frac{W}{mK}$). As the reactor is placed in a room (at $T_{ext} = 27°C$) frequently visited by workers, the outside temperature of the reactor should not exceed $T_C = 55°C$ to avoid burns. To make sure the outside of the reactor is cool enough, a layer of brick is inserted$\left(k_{brique} = 0.74\,\frac{W}{mK}\right)$.



What brick thickness should be interposed between lead and steel? Given the heat transfer coefficient for the outer surface of the reactor ($h_{ext} = 10.2\,\frac{W}{m^2K}$) as well as its inner surface ($h_{int} = 7400\ W/m^2K$).

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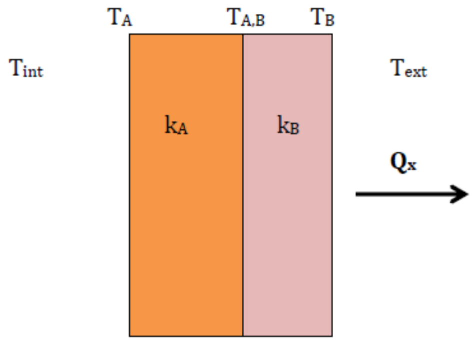
Exercise 3.3

Furnace walls: The wall of a furnace is composed of two layers, the first layer A is of thickness 22.86 cm and consists of refractory bricks $k_A = 1.19 \frac{W}{mK}$, the second layer B is of thickness 13 cm insulation brick $k_B = 0.15 \frac{W}{mK}$. The temperature inside the furnace is $T_{int} = 1649\,°C$ and the heat transfer coefficient to the inner wall of the wall is $h_{int} = 60 \frac{W}{m^2K}$. The temperature of the ambient air is $T_{ext} = 27\,°C$ and the heat transfer coefficient for the outside wall is $h_{ext} = 9.8 \frac{W}{m^2K}$. Calculate a) the heat loss per m^2 of surface of the wall and b) the temperature of the inner surface T_A and outer surface T_B.



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Exercise 3.4

Bolts in an insulating wall. A 3 cm thick wall of insulating material (k_{wall} = 0.34 W m^{-1} K^{-1}) separates a hot room for drying powder and an office. Unfortunately, for every 0.015 m^2 (on average) of wall surface there is a circular metal bolt (traversing the wall as shown) with a diameter of 7mm (k_{bolt}= 45.6 W m^{-1} K^{-1}) .

a) What fraction of the wall area is metal bolts?

b) What fraction of the heat conducted by the wall goes though the bolts?

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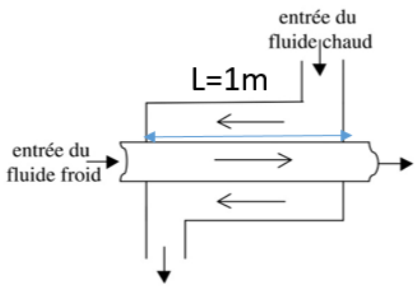
Exercise 3.5

Review of heat exchanger. Consider the heat exchanger sketched here on the side (with length 1 m). Water (c_p = 4.187 kJ kg^{-1} K^{-1}) is used as both the cold and the hot fluid. The mass flow rate of the cold fluid is 2 g s^{-1} , $T_{cold,out}$ = 37°C and $T_{cold,in}$ =20°C. Knowing that $T_{hot,in}$ = 70°C and $T_{hot,\,out}$ =32.5°C, can you estimate the required flow rate of hot water?

If the overall heat transfer coefficient is equal to 106.47 $Wm^{-2}K^{-1}$, can you calculate the heat transfer area? Remember for a counter-current heat exchanger, $\dot{Q} = UA\Delta T_{LM}$, where $\Delta T_{LM} = \frac{\Delta T_1 - \Delta T_2}{\ln\left(\frac{\Delta T_1}{\Delta T_2}\right)}$, $\Delta T_1 = T_{hot,in} - T_{cold,out}$ and $\Delta T_2 = T_{hot,out} - T_{cold,in}$



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