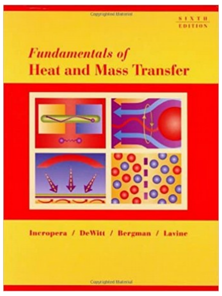


Lista 1 – TCM

Prof. Rafael Gabler Gontijo

Os exercícios abaixo foram extraídos do livro: "Fundamentals of Heat and Mass Transfer", Sexta edição, dos autores Incropera, DeWitt, Bergman e Lavine.

Exercício 1

3.10 The *wind chill*, which is experienced on a cold, windy day, is related to increased heat transfer from exposed human skin to the surrounding atmosphere. Consider a layer of fatty tissue that is 3 mm thick and whose interior surface is maintained at a temperature of 36°C. On a calm day the convection heat transfer coefficient at the outer surface is $25\ \text{W/m}^2 \cdot \text{K}$, but with 30 km/h winds it reaches $65\ \text{W/m}^2 \cdot \text{K}$. In both cases the ambient air temperature is -15°C.

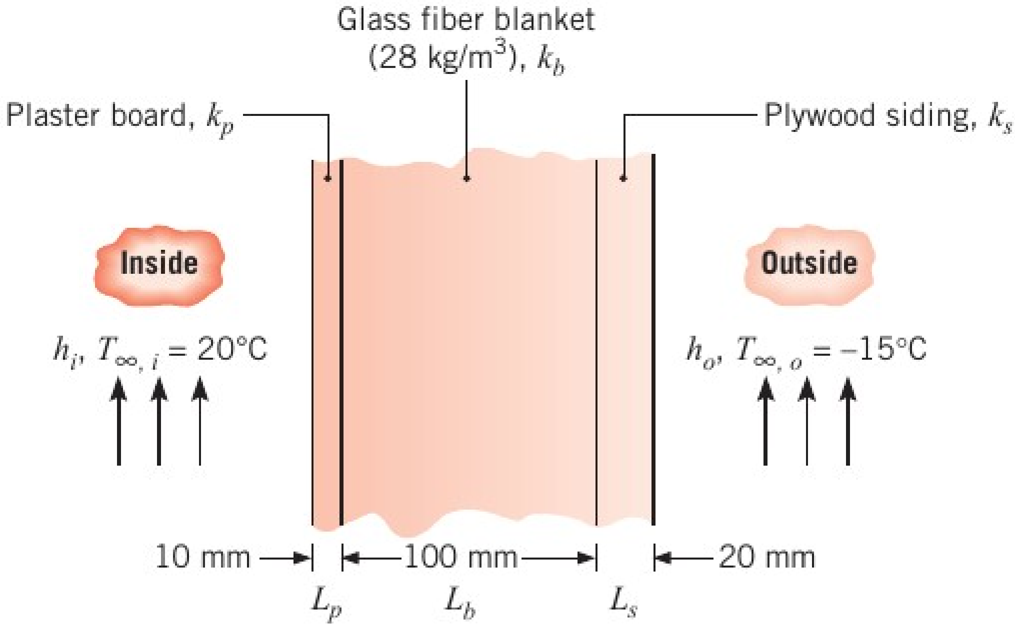
(a) What is the ratio of the heat loss per unit area from the skin for the calm day to that for the windy day?

(b) What will be the skin outer surface temperature for the calm day? For the windy day?

(c) What temperature would the air have to assume on the calm day to produce the same heat loss occurring with the air temperature at -15°C on the windy day?

Exercício 2

3.13 A house has a composite wall of wood, fiberglass insulation, and plaster board, as indicated in the sketch. On a cold winter day, the convection heat transfer coefficients are $h_o = 60\ \text{W/m}^2\cdot\text{K}$ and $h_i = 30\ \text{W/m}^2\cdot\text{K}$. The total wall surface area is $350\ \text{m}^2$.



(a) Determine a symbolic expression for the total thermal resistance of the wall, including inside and outside convection effects for the prescribed conditions.

(b) Determine the total heat loss through the wall.

(c) If the wind were blowing violently, raising h_o to $300\ \text{W/m}^2\cdot\text{K}$, determine the percentage increase in the heat loss.

(d) What is the controlling resistance that determines the amount of heat flow through the wall?

Exercício 3

3.14 Consider the composite wall of Problem 3.13 under conditions for which the inside air is still characterized by $T_{\infty,i} = 20°C$ and $h_i = 30\ W/m^2 \cdot K$. However, use the more realistic conditions for which the outside air is characterized by a diurnal (time) varying temperature of the form

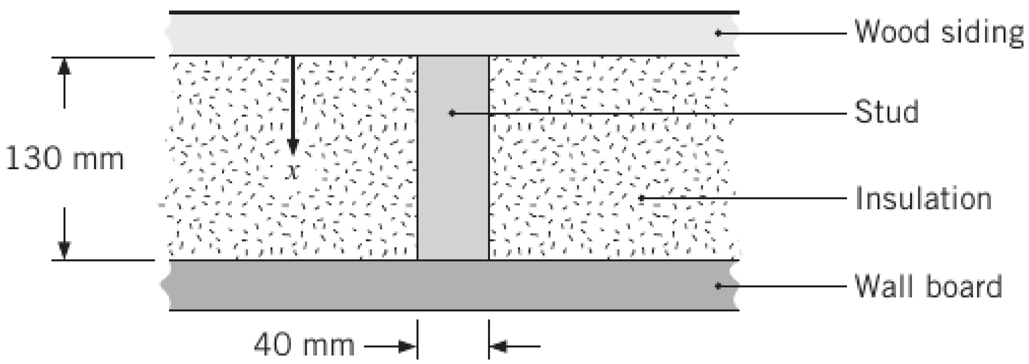
$$T_{\infty,o}(K) = 273 + 5 \sin\left(\frac{2\pi}{24}t\right) \qquad 0 \le t \le 12\ h$$

$$T_{\infty,o}(K) = 273 + 11 \sin\left(\frac{2\pi}{24}t\right) \qquad 12 \le t \le 24\ h$$

with $h_o = 60\ W/m^2 \cdot K$. Assuming quasi-steady conditions for which changes in energy storage within the wall may be neglected, estimate the daily heat loss through the wall if its total surface area is $200\ m^2$.

Exercício 4

3.15 Consider a composite wall that includes an 8-mm-thick hardwood siding, 40-mm by 130-mm hardwood studs on 0.65-m centers with glass fiber insulation (paper faced, $28\ kg/m^3$), and a 12-mm layer of gypsum (vermiculite) wall board.



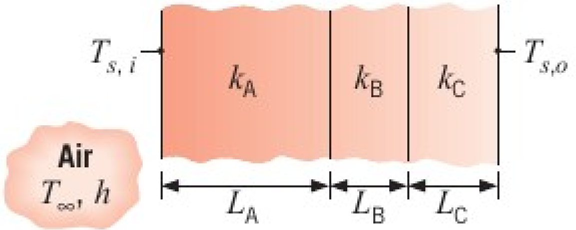
What is the thermal resistance associated with a wall that is 2.5 m high by 6.5 m wide (having 10 studs, each 2.5 m high)? Assume surfaces normal to the x-direction are isothermal.

Exercício 5

3.16 Work Problem 3.15 assuming surfaces parallel to the x-direction are adiabatic.

Exercício 6

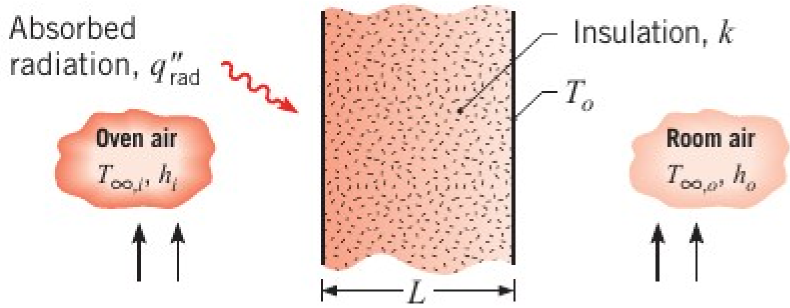
3.18 The composite wall of an oven consists of three materials, two of which are of known thermal conductivity, $k_A = 20$ W/m·K and $k_C = 50$ W/m·K, and known thickness, $L_A = 0.30$ m and $L_C = 0.15$ m. The third material, B, which is sandwiched between materials A and C, is of known thickness, $L_B = 0.15$ m, but unknown thermal conductivity k_B.



Under steady-state operating conditions, measurements reveal an outer surface temperature of $T_{s,o} = 20°C$, an inner surface temperature of $T_{s,i} = 600°C$, and an oven air temperature of $T_\infty = 800°C$. The inside convection coefficient h is known to be 25 W/m^2·K. What is the value of k_B?

Exercício 7

3.19 The wall of a drying oven is constructed by sandwiching an insulation material of thermal conductivity $k = 0.05$ W/m·K between thin metal sheets. The oven air is at $T_{\infty,i} = 300°C$, and the corresponding convection coefficient is $h_i = 30$ W/m^2·K. The inner wall surface absorbs a radiant flux of $q''_{rad} = 100$ W/m^2 from hotter objects within the oven. The room air is at $T_{\infty,o} = 25°C$, and the overall coefficient for convection and radiation from the outer surface is $h_o = 10$ W/m^2·K.



(a) Draw the thermal circuit for the wall and label all temperatures, heat rates, and thermal resistances.

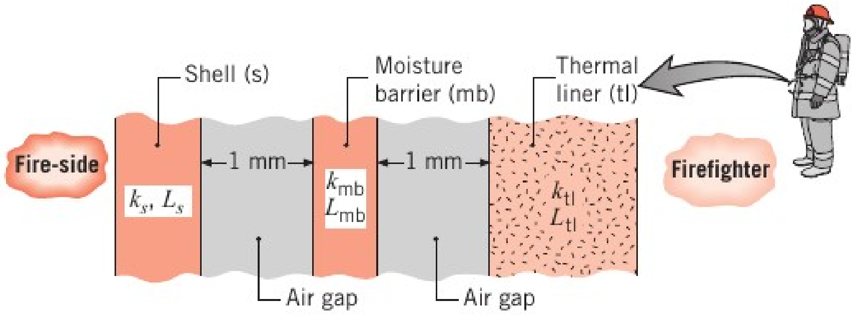
(b) What insulation thickness L is required to maintain the outer wall surface at a *safe-to-touch* temperature of $T_o = 40°C$?

Exercício 8

3.20 The $t = 4$-mm-thick glass windows of an automobile have a surface area of $A = 2.6\ m^2$. The outside temperature is $T_{\infty,o} = 32°C$ while the passenger compartment is maintained at $T_{\infty,i} = 22°C$. The convection heat transfer coefficient on the exterior window surface is $h_o = 90\ W/m^2 \cdot K$. Determine the heat gain through the windows when the interior convection heat transfer coefficient is $h_i = 15\ W/m^2 \cdot K$. By controlling the airflow in the passenger compartment the interior heat transfer coefficient can be reduced to $h_i = 5\ W/m^2 \cdot K$ without sacrificing passenger comfort. Determine the heat gain through the window for the reduced inside heat transfer coefficient.

Exercício 9

3.24 A firefighter's protective clothing, referred to as a *turnout coat*, is typically constructed as an ensemble of three layers separated by air gaps, as shown schematically.



Representative dimensions and thermal conductivities for the layers are as follows.

Layer	*Thickness* (mm)	*k* (W/m · K)
Shell (s)	0.8	0.047
Moisture barrier (mb)	0.55	0.012
Thermal liner (tl)	3.5	0.038

The air gaps between the layers are 1 mm thick, and heat is transferred by conduction and radiation exchange through the stagnant air. The linearized radiation coefficient for a gap may be approximated as, $h_{rad} = \sigma(T_1 + T_2)(T_1^2 + T_2^2) \approx 4\sigma T_{avg}^3$, where T_{avg} represents the average temperature of the surfaces comprising the gap, and the radiation flux across the gap may be expressed as $q''_{rad} = h_{rad}(T_1 - T_2)$.

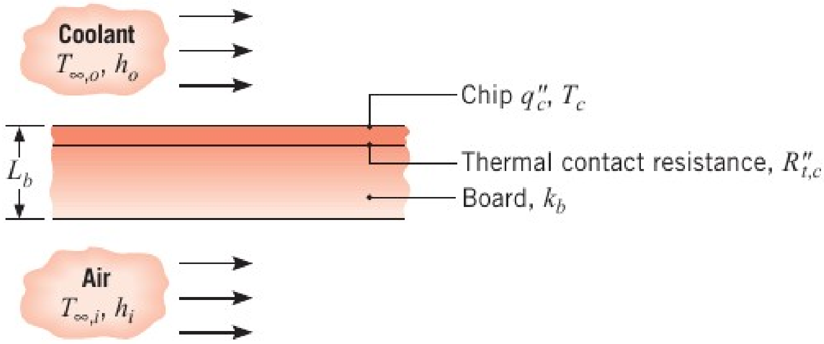
(a) Represent the turnout coat by a thermal circuit, labeling all the thermal resistances. Calculate and tabulate the thermal resistances per unit area ($m^2 \cdot K/W$) for each of the layers, as well as for the conduction and radiation processes in the gaps. Assume that a value of $T_{avg} = 470$ K may be used to approximate the radiation resistance of both gaps. Comment on the relative magnitudes of the resistances.

(b) For a *pre-flash-ove* fire environment in which firefighters often work, the typical radiant heat flux on the fire-side of the turnout coat is 0.25 W/cm^2.

What is the outer surface temperature of the turnout coat if the inner surface temperature is 66°C, a condition that would result in burn injury?

Exercício 10

3.27 Approximately 10^6 discrete electrical components can be placed on a single integrated circuit (chip), with electrical heat dissipation as high as 30,000 W/m^2. The chip, which is very thin, is exposed to a dielectric liquid at its outer surface, with $h_o = 1000$ W/m$^2 \cdot$K and $T_{\infty,o} = 20$°C, and is joined to a circuit board at its inner surface. The thermal contact resistance between the chip and the board is 10^{-4} m$^2 \cdot$K/W, and the board thickness and thermal conductivity are $L_b = 5$ mm and $k_b = 1$ W/m$\cdot$K, respectively. The other surface of the board is exposed to ambient air for which $h_i = 40$ W/m$^2 \cdot$K and $T_{\infty,i} = 20$°C.



(a) Sketch the equivalent thermal circuit corresponding to steady-state conditions. In variable form, label appropriate resistances, temperatures, and heat fluxes.

(b) Under steady-state conditions for which the chip heat dissipation is $q''_c = 30{,}000$ W/m^2, what is the chip temperature?