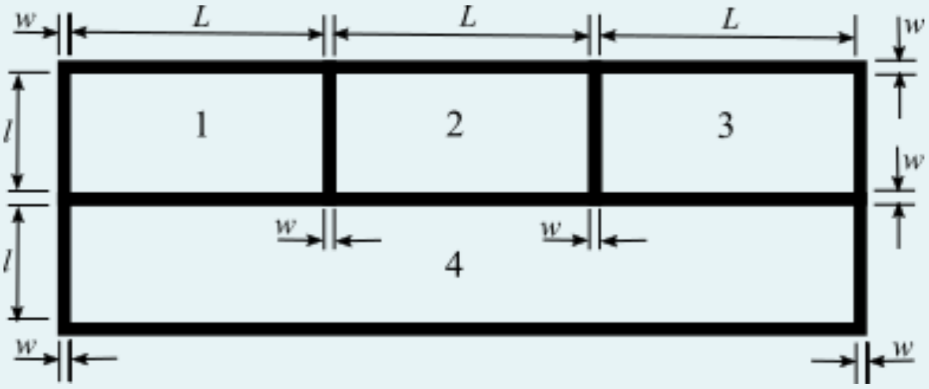
Steady-state heat transfer with advection



Data

Let's consider four rooms: 1, 2, 3 and 4. The temperatures of rooms 1 and 3 are controlled and mantained at set-point temperature T_{1c} = 20.0 °C et T_{3c} = 22.0 °C.

The outdoor temperature is T_o = 0.0 °C.

The dimensions are L = 6.00 m and l = 3.00 m. The height is H = 3.00 m. The widths of the walls are w = 0.20 m.

The thermal conductivity of the walls is λ = 1.70 W/mK.

The short-wave (i.e., solar) radiation absorbed by each exterior wall is E = 200 $\mathrm{W/m^2}$.

The heat convection coefficients are $h_o = 25\ \mathrm{W/m^2K}$ for outdoor air and $h_i = 8\ \mathrm{W/m^2K}$ for indoor air.

The heat exchanges with the floor and the ceiling are neglected.

Questions

1. Considering that all rooms are controlled with the set-point temperatures $T_{1,c}$ = 20.0 °C, $T_{2,c}$ = 20.0 °C, $T_{3,c}$ = 22.0 °C et $T_{4,c}$ = 18.0 °C, find the thermal loads of the rooms q_1 = 2008 W, q_2 = 1323 W, q_3 = 2346 W, q_4 = 4270 W.

Note: the loads are positve if the thermal flow is added to the space and negative if the thermal flow is retrieved from the space.

2. In what follows, the rooms 2 and 4 are not controlled (they are in "free running") and the rooms 1 and 3 are controlled (with the set-point temperatures mentioned above). Find the temperatures θ_2 = 13,1 °C and θ_4 = 11,8 °C of rooms 2 and 4 and the thermal loads q_1 = 1718 W and q_3 = 2056 W of rooms 1 and 3.
3. Room 2 is ventilated with the air-flow rate $\dot{V}$ = 1.0 vol/h ($\rho_{air} = 1.2\ \mathrm{kg/m^3}$, $c_{p,air} = 1000\ \mathrm{J/kg\,K}$). The air enters from outdoors in room 2, then it goes in room 4, from which it gets out. Find the temperatures θ_2 = 11,8 °C and θ_4 = 11,6 °C of rooms 2 and 4 and the thermal loads q_1 = 1759 W and q_3 = 2097 W of rooms 1 and 3.
4. The air-flow in room 2 changes its direction: from outdoors it enters in room 4, then passes in room 2 and, finally, it gets out. The air-flow rate remains the same. Find the temperatures θ_2 = 11,8 °C and θ_4 = 11,6 °C of rooms 2 and 4 and the loads q_1 = 1759 W and q_3 = 2097 W of rooms 1 and 3.