Lecture 3 – Exercises

Exercise 1: Conduction – properties and heat transfer through wall structures

Consider two wall structures detailed in Table 1 having the same total thermal resistance (R_{tot}). As a wall core (load-bearing layer), a concrete block of 150 mm is used in Wall 1, while timber hardwood of 90 mm is used in Wall 2. The inner side of the load-bearing wall is protected by a 10 mm fiber plasterboard. To insulate the wall core, a layer of expanded polystyrene is placed on the outer side of the load-bearing layer (the thickness of the insulation layer varies).

Using the data provided, determine the following:

1. Thermal conductivities k $(\frac{W}{m \cdot K})$ of each material, and comment on the k differences between concrete-wood, concrete-insulation, and wood-insulation.
2. Thermal admittance μ $(\frac{J}{m^2 \cdot K \cdot s^{1/2}})$ of each material, and comment on their heat storage capacity.
3. Total thermal transmittance U_{tot} $(\frac{W}{m^2 \cdot K})$ for both wall structures. The limiting value of the U-value for opaque elements in new buildings is 0.17 $\frac{W}{m^2 \cdot K}$ per Swiss construction norm SIA 380. Do wall structures comply with the standardized requirement?
4. Assuming a 1D steady-state conduction problem shown in Fig. 1, determine the heat losses per unit area through wall structures if the indoor surface temperature is $t_1 = 20$°C, and outdoor surface temperature is $t_4 = 0$°C.
5. Temperatures at intermittent interfaces (t_2 , t_3), and comment on the values for both wall structures considering the thermal properties of the materials used.

Table 1: Composition of walls and thermal properties of layers

#	Layer	Material	L (m)	ρ $(\frac{kg}{m^3})$	c_p $(\frac{J}{kg \cdot K})$	$\alpha \times 10^{-6}$ $(\frac{m^2}{s})$
Wall 1	1	fiber plaster	0.01	837	800	0.27
	2	concrete	0.15	1400	1000	0.36
	3	insulation	0.17	25	1380	0.87
Wall 2	1	fiber plaster	0.01	837	800	0.27
	2	wood	0.09	400	1255	0.28
	3	insulation	0.16	25	1380	0.87

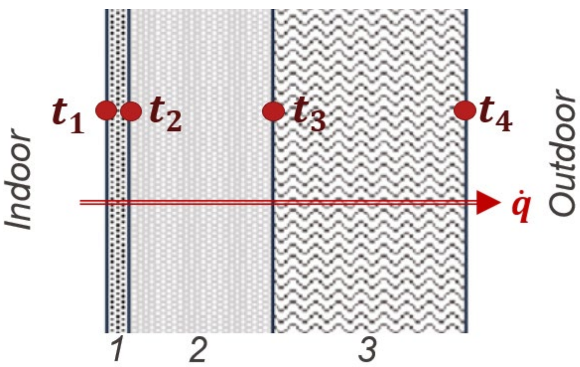

Figure 1: Composition of walls and labeling of temperatures at interfaces

Exercise 2: Radiant performance of windows

Consider radiation heat transfer between two glasses in a double-pane window as illustrated in Fig. 2. The exterior side of the 1st glass has the temperature of $t_1 = 19°C$. The interior side of the 2nd glass has a temperature of $t_2 = -8°C$. In the case (A), both sides have the same emissivity value of $\varepsilon_1 = \varepsilon_2 = 0.88$. In case (B), the second glass is treated with a low emissivity coating with the emissivity of $\varepsilon_2 = 0.09$. Compare the radiative performance of both cases by determining the radiative thermal resistance $R_{rad,1-2}$ and radiant heat flux between the glass panes $\dot{q}_{1-2}$.

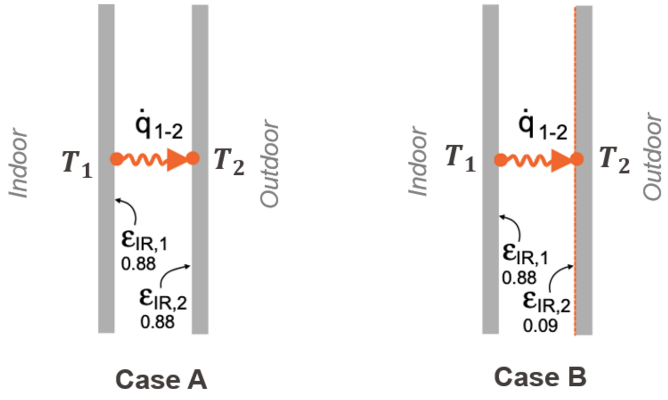

Figure 2: Illustration of cases (A) and (B)

Exercise 3: Surface radiation budget

Consider an East-facing vertical wall illustrated in slide 31.

Determine the radiation budget Q^* of the wall at 9:00 AM, considering that it is a brick wall having $\varepsilon = 0.9$ and $a = 0.4$. The incoming solar radiation is the maximum at 9:00 and reaches $K_\downarrow = 600\, W/m^2$, while the outgoing longwave radiation is $L_\uparrow = 520\, W/m^2$. Consider the temperature of the surface to be 36.5°C. Is net shortwave radiation K^*greater than the net of the longwave radiation L^*?