CIV-E1050 Heat and Mass Transfer in Buildings
Final Exam

13:00-16:00, Friday, 23.10.2020 (due time: 16:00 and cut-off time: 16:05)

1. Answer the following questions briefly (hit the points and use max 2-3 sentences for each question).

(1) What is the difference between the forced and natural convection? Is the following correlation for forced or for natural convention? Explain why.

$Nu = 0.125\ (Gr.Pr)^{0.13}$

(2) Describe at least 3 dominant moisture transfer mechanisms in building porous materials.

(3) Condensation may form on outdoor surfaces of good performance glass windows. Explain why this happens, and under what conditions.

(4) Explain the very different moisture contents in an interface between mortar joint and the adjacent brick at an equilibrium condition. Why is there no temperature difference at the interface?

2. Calculate the total thermal resistance of a typical section of a building wall at steady-state condition, assuming that k_{23b} = 50 W/m·K, k_{23a} = 0.03 W/m·K, k_{12} = 0.5 W/m·K, k_{34} = 1.0 W/m·K, L_A= 0.6m, L_B=0.005m, L_{12}=0.01m, L_{23}=0.08m and L_{34}=0.1m.

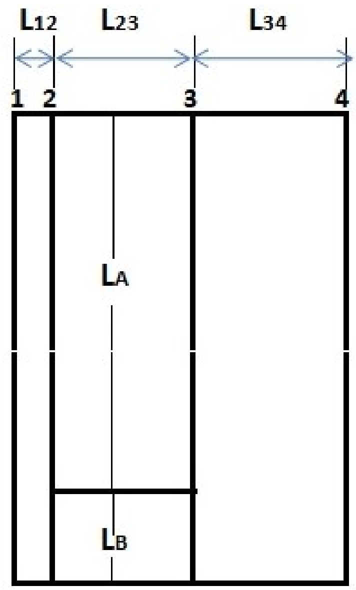


Figure 1. Section of a building wall.

3. Wind is blowing over the house roof with the speed 15m/s and temperature 5℃. The dimension of the roof is: length L=10m width W=3m. The exterior and inner surface temperatures of the roof are 10℃ and 18℃, respectively. Indoor air temperature is 30℃. Calculate the convective heat loss rate from the exterior surface and the convective heat gain rate from the inner surface.

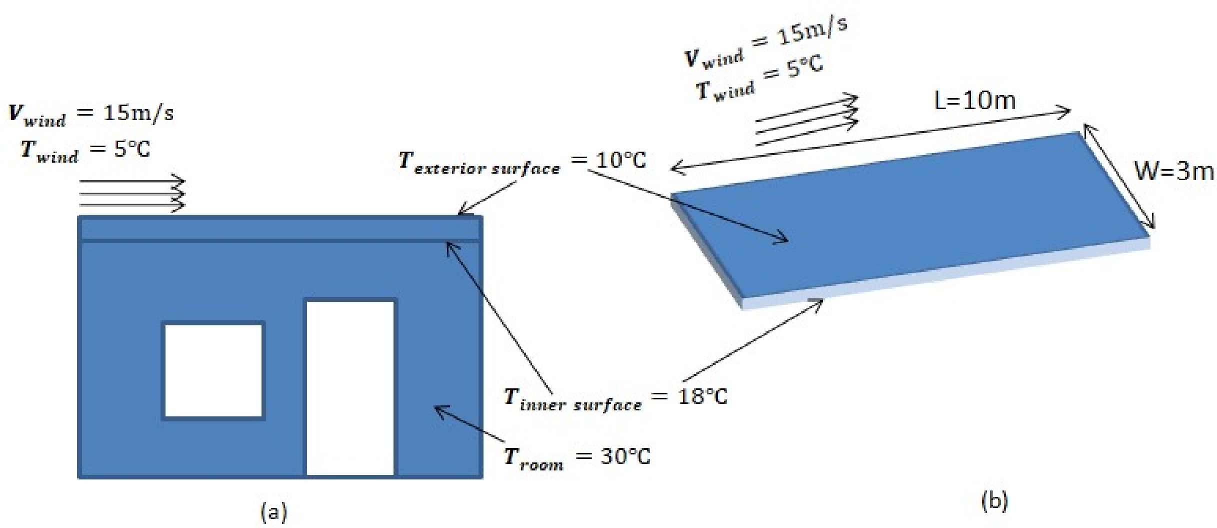
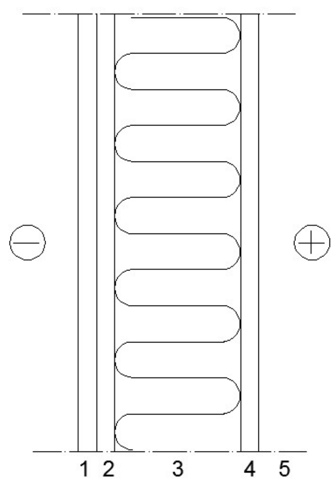


Figure 2. (a) The house in 2D. (b) the roof in 3D.

4. This problem is about moisture design for a wall construction. The wall consists of interior gypsum board, insulation, plywood sheathing and wood siding. Assuming moisture transports with vapor diffusion at steady state with indoor 20 °C and 60 % RH and outdoor -16 °C and 70 % RH, justify if moisture could freeze or condense in the insulation.



Material	R [m^2K/W]	Rv10^{-12} [s.m2.Pa/kg]
Outside	0.03	-
1 (siding)	0.14	0.0008
2 (13 mm)	0.23	0.0365
3 (90mm)	2.45	0.000645
4 (13mm)	0.079	0.004
5 (still air)	0.12	-

Figure 3. Wall structure and material property data.

5. A skating hall is dome-shaped with temperature of roof 5 ^oC, audience area 15 ^oC and ice rink -5 ^oC, respectively. The emissivity of these surfaces is 0.9. Calculate the radiative heat transfer rates from the hemispherical roof to both ice rink and audience area.

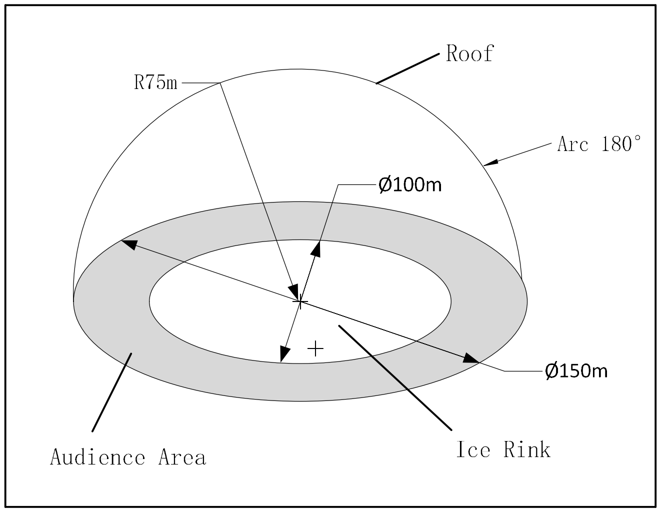


Figure 4. Schematic for the skating hall.

6. Consider 1D steady-state heat transfer

a. An insulation layer (conductivity k=0.01W/mK, length 200mm) is shown in Figure 5, where T_0= 20 °C and its right side loses heat by convection to the surrounding air of T_∞= 0°C with heat transfer coefficient h=5W/m^{2}K. Use 5 nodes and the finite difference scheme to calculate the temperatures at node 1 to node 4

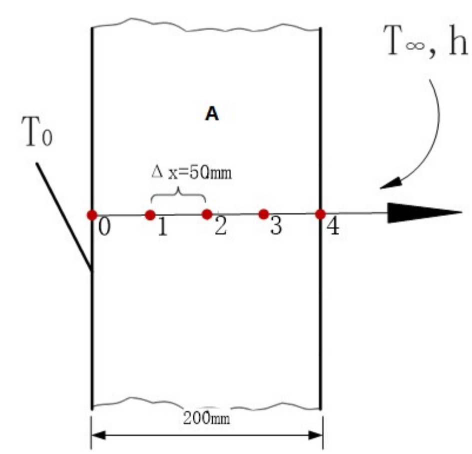


Figure 5. Insulation layer with nodes.

b. Composite plane wall consists of two layers A (conductivity k_A =0.01W/mK) and B (conductivity k_B=0.02 W/mK) in perfect contact at the interface node 1. The wall is insulated at the left (node 0) and subjected to specified temperature (node 2, T_2=20°C). Use finite difference formulation to calculate the temperatures at node 0 and node 1 (assume Δx=0.1m).

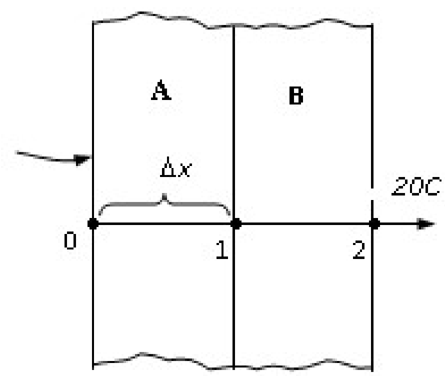


Figure 6. Left insulated wall with three nodes.