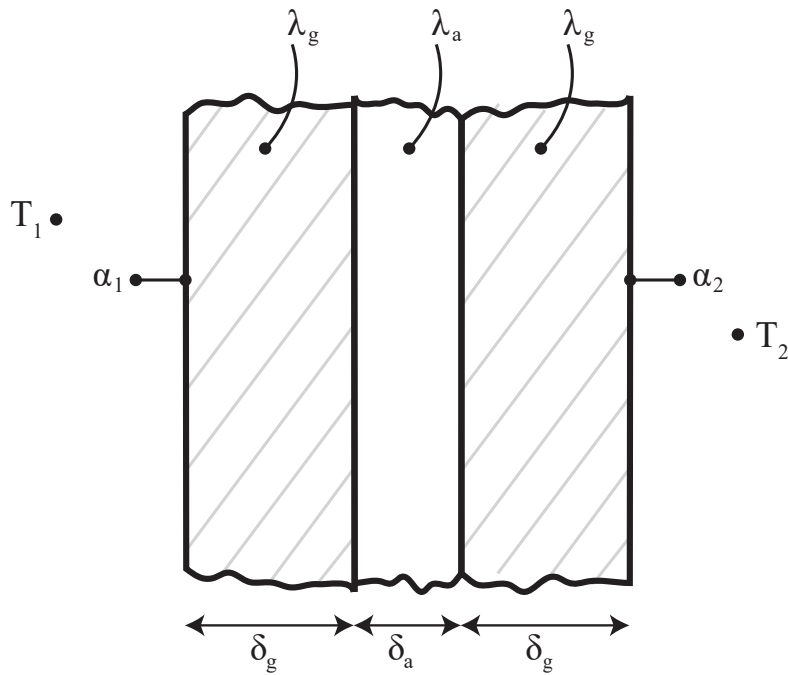


1.4 Window insulation



Consider a 1.2-m-high and 2-m-wide double-pane window consisting of two layers of glass ($\delta_g = 3 \text{ mm}$, $\lambda_g = 0.78 \text{ W/mK}$) separated by a stagnant air space ($\delta_a = 15 \text{ mm}$, $\lambda_a = 0.026 \text{ W/mK}$). Take the convection heat transfer coefficients on the inner and outer surfaces of the window to be $\alpha_1 = 10 \text{ W/m}^2\text{K}$ and $\alpha_2 = 25 \text{ W/m}^2\text{K}$, and disregard any heat transfer by radiation.



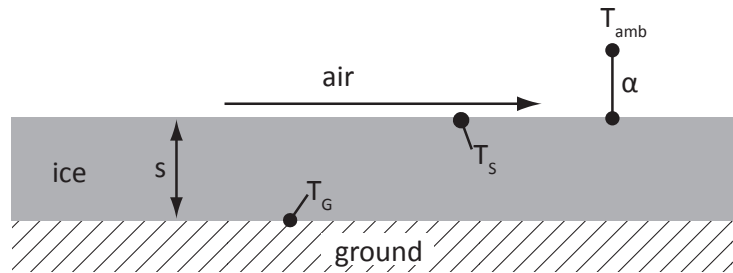
Tasks:

- Determine the steady rate of heat transfer through this double-pane window and the temperature of its inner surface for a day during which the room is maintained at $T_1 = 22^\circ\text{C}$ while the temperature of the outdoors is $T_2 = -7^\circ\text{C}$.
- Compare your results with a three-layer glass (3-mm-thickness) with two stagnant air spaces filled with krypton ($\delta_k = 8 \text{ mm}$, $\lambda_k = 0.00949 \text{ W/mK}$).
- Discuss the reason for choosing a three-layer glass and scrutinise all assumptions made in task a) and b).

1.5 Ice layer

★★

During a cold winter day the ground is covered with an ice layer of thickness s . Air with a temperature of $T_{\text{amb}} = 5^\circ\text{C}$ is flowing over the ice layer. The temperature of the ice is $T_G = -10^\circ\text{C}$ at the interface between the ground and ice. The temperature at the interface between the ice and air is $T_S = -3^\circ\text{C}$. The problem is one-dimensional and steady-state. No layer of water is forming on top of the ice. Determine the thickness s of the ice layer.



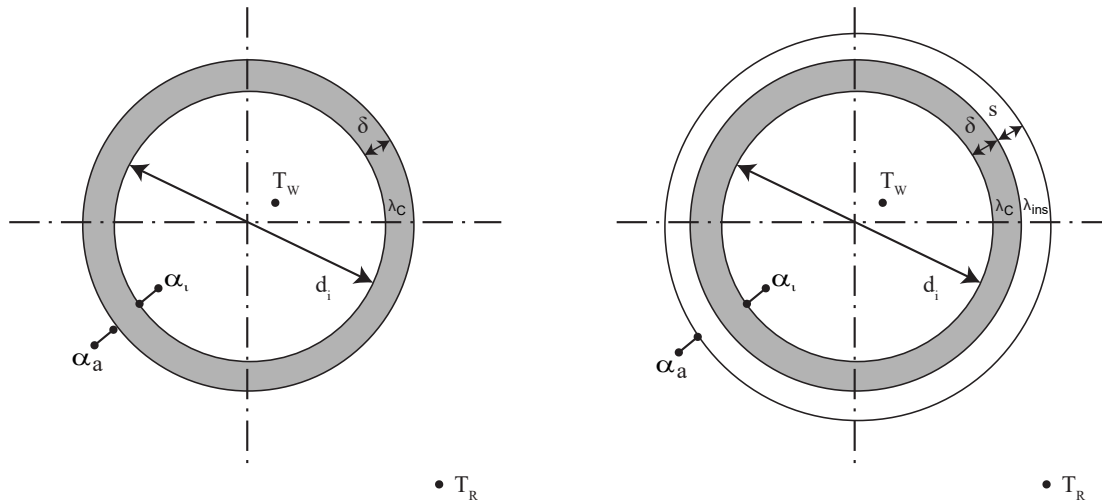
Given parameter

- Conductivity of ice, $\lambda = 2.2 \frac{\text{W}}{\text{m}\cdot\text{K}}$
- Heat transfer coefficient at the ice surface, $\alpha = 10 \frac{\text{W}}{\text{m}^2\cdot\text{K}}$
- Temperature of the air, $T_{\text{amb}} = 5^\circ\text{C}$
- Temperature of the ice at the surface, $T_S = -3^\circ\text{C}$
- Temperature of the ice at the ground, $T_G = -10^\circ\text{C}$

1.6 Warm-water pipe

★ ★ ★

A copper warm-water pipe placed in a room of $T_R = 20^\circ\text{C}$ holds water with an average temperature of $T_W = 80^\circ\text{C}$. The copper pipe ($\lambda = 372 \text{ W/mK}$) has an inner diameter of $d_i = 6 \text{ mm}$ and a wall thickness of $\delta = 1 \text{ mm}$.



Known quantities:

α_i	2300	$\text{W/m}^2\text{K}$	heat transfer coefficient at the inner side of the pipe
α_a	6	$\text{W/m}^2\text{K}$	heat transfer coefficient at the outer side of the pipe

Tasks:

- Determine the heat transferred per unit pipe length \dot{q}' for:
 - an uninsulated pipe
 - an insulated pipe with a $s = 4 \text{ mm}$ cork insulation layer ($\lambda_{ins} = 0.042 \text{ W/mK}$).
- Qualitatively sketch the heat emission profile \dot{q}' as a function of the insulation thickness for different thermal conductivities of the insulation material. Explain the underlying physical principles.
- Determine the necessary thermal conductivity λ_{ins} for the insulating material to obtain a general reduction in heat loss.

Assumptions:

- Changes to the heat transfer coefficient at the outer side of the pipe as a function of the diameter are disregarded.