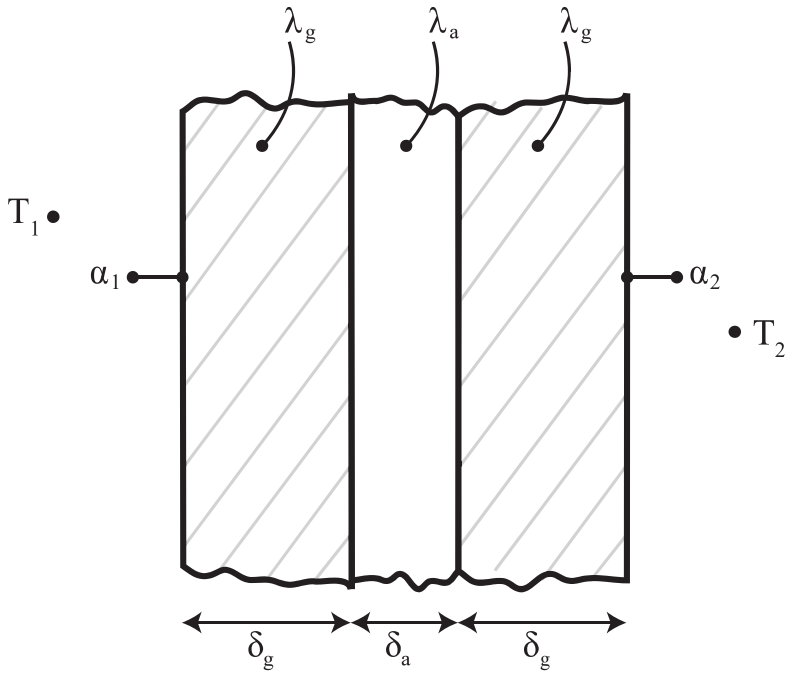
1.4 Window insulation ★

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



Tasks:

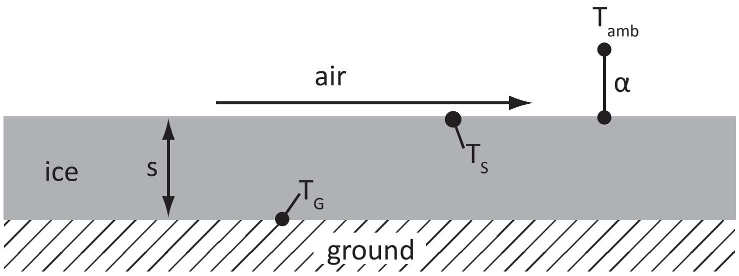
a) Determine the steady rate of heat transfer through this double-pane window and the temperature of its inner surface for a day during which the room is maintained at $T_1 = 22\,^\circ\mathrm{C}$ while the temperature of the outdoors is $T_2 = -7\,^\circ\mathrm{C}$.

b) Compare your results with a three-layer glass (3-mm-thickness) with two stagnant air spaces filled with krypton ($\delta_k = 8\,\mathrm{mm}$, $\lambda_k = 0.00949\,\mathrm{W/m\,K}$).

c) 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 $T_{\mathrm{amb}} = 5°\mathrm{C}$ is flowing over the ice layer. The temperature of the ice is $T_{\mathrm{G}} = -10°\mathrm{C}$ at the interface between the ground and ice. The temperature at the interface between the ice and air is $T_{\mathrm{S}} = -3°\mathrm{C}$. 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.

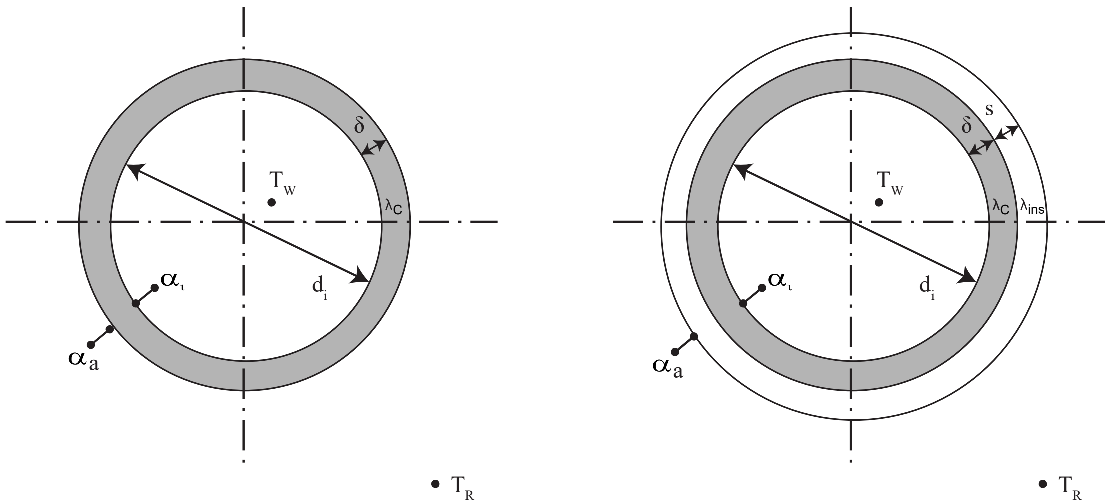


Given parameter

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

1.6 Warm-water pipe ★ ★ ★

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



Known quantities:

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

Tasks:

a) Determine the heat transfered per unit pipe length $\dot{q}'$ for:

- an uninsulated pipe
- an insulated pipe with a $s = 4\,mm$ cork insulation layer ($\lambda_{ins} = 0.042\,{}^{W}/_{m\,K}$).

b) 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.

c) 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.