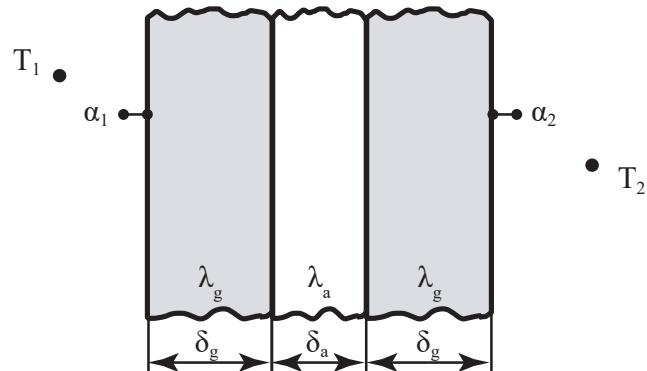


Exercise II.4: (Window insulation ★)

Consider a 1.2-m-height and 2-m-wide double-pane window consisting of two layers of glass separated by a stagnant air space. Convection occurs at the inside and outside of the pane window. Disregard any heat transfer by radiation.

**Given parameters:**

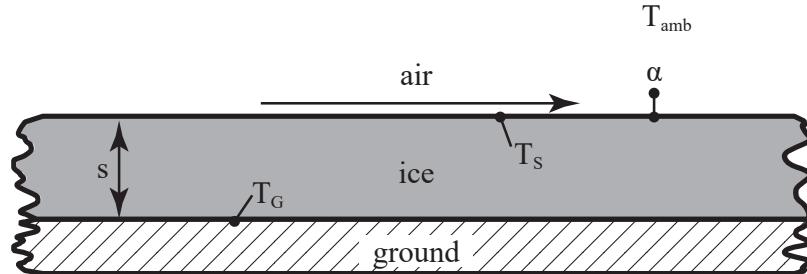
- Conductivity of glass: $\lambda_g = 0.78 \text{ W/mK}$
- Conductivity of air: $\lambda_a = 0.026 \text{ W/mK}$
- Thickness of glass layer: $\delta_g = 3 \text{ mm}$
- Thickness of air layer: $\delta_a = 15 \text{ mm}$
- Inside convection coefficient: $\alpha_1 = 10 \text{ W/m}^2\text{K}$
- Outside convection coefficient: $\alpha_2 = 25 \text{ W/m}^2\text{K}$
- Inside temperature: $T_1 = 22 \text{ }^\circ\text{C}$
- Outside temperature: $T_2 = -7 \text{ }^\circ\text{C}$

Tasks:

- Determine the steady heat transfer rate through this double-pane window and the temperature of its inner surface.
- Compare your results with a three-layer glass (3-mm-thickness) with two stagnant air spaces filled with krypton ($\delta_k = 8 \text{ mm}$, $\lambda_k = 0.00949 \text{ W/m K}$).
- Discuss the reason for choosing a three-layer glass and scrutinize all assumptions made in tasks a) and b).

Exercise II.5: (Ice layer ★★)

During a cold winter day, the ground is covered with an ice layer of thickness s . Air is flowing over the ice layer. The problem is one-dimensional and steady-state. No layer of water is forming on top of the ice.

**Given parameters:**

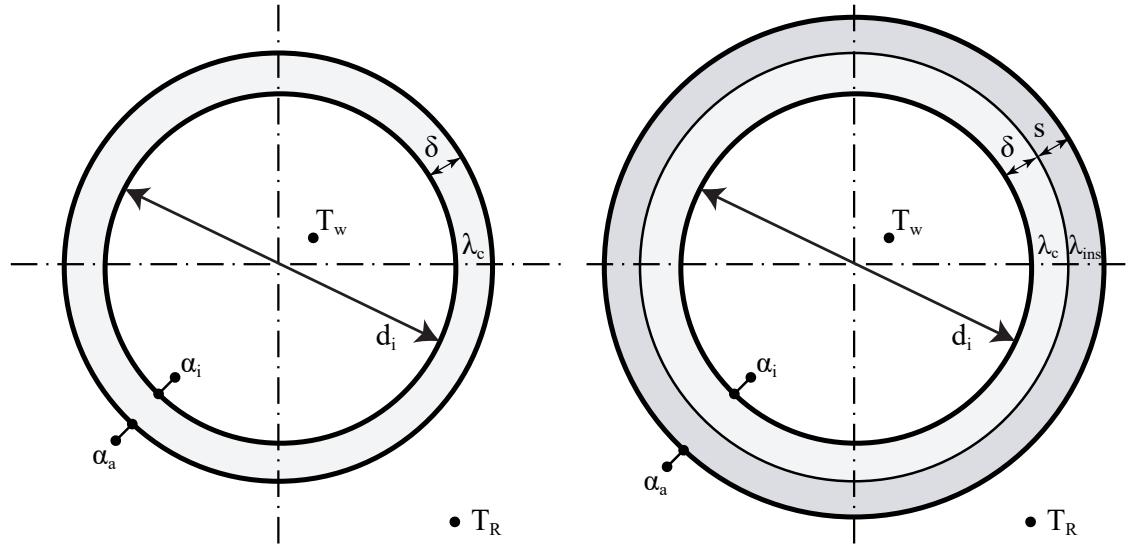
- Conductivity of ice: $\lambda = 2.2 \text{ W/mK}$
- Heat transfer coefficient at the ice surface: $\alpha = 10 \text{ W/m}^2\text{K}$
- Temperature of the air: $T_{\text{amb}} = 5 \text{ }^{\circ}\text{C}$
- Temperature of the ice at the surface: $T_s = -3 \text{ }^{\circ}\text{C}$
- Temperature of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

Tasks:

- Determine the thickness s of the ice layer.

Exercise II.6: (Warm-water pipe ★★)

In a room, a copper warm-water pipe is utilized to contain water. This copper pipe features an inner diameter of d_i and a wall thickness denoted as δ . During a chilly winter day, insulation measures are taken, involving the addition of an extra insulation layer with a thickness of s .

**Given parameters:**

- Heat transfer coefficient at the inner side of the pipe: $\alpha_i = 2300 \text{ W/m}^2\text{K}$
- Heat transfer coefficient at the outer side of the pipe: $\alpha_a = 6 \text{ W/m}^2\text{K}$
- Temperature of the room: $T_R = 20 \text{ }^\circ\text{C}$
- Temperature of the water: $T_w = 80 \text{ }^\circ\text{C}$
- Conductivity of copper: $\lambda_c = 372 \text{ W/mK}$
- Conductivity of insulation material: $\lambda_{ins} = 0.042 \text{ W/mK}$
- Inner diameter of the copper pipe: $d_i = 6 \text{ mm}$
- Thickness of the copper pipe: $\delta = 1 \text{ mm}$
- Thickness of the insulation layer: $s = 4 \text{ mm}$

Hints:

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

Tasks:

- a) Calculate the heat transferred per unit length of the pipe, denoted as \dot{q}' , for both an uninsulated pipe and an insulated pipe. What noteworthy observations can be made from your findings?
- 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) Calculate the required thermal conductivity for the insulating material to always achieve a reduction in heat loss, regardless of the thickness of the insulation.