Window insulation

Consider a 1.2-m-heigh and 2-m-wide double-pane window consisting of two 3-mm-thick layers of glass ($\lambda_g = 0.78\,\mathrm{W/m\,K}$) separated by a 15-mm-wide stagnant air space ($\lambda_{air} = 0.026\,\mathrm{W/m\,K}$). 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 $22\,°\mathrm{C}$ while the temperature of the outdoors is $-7\,°\mathrm{C}$.

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

c) Discuss the reason for choosing a three-layer glass and scrutinise all assumptions made in task a) and b).

Brine pipeline

A steel brine pipeline, with an inner diameter of $d_\mathrm{i} = 50\,\mathrm{mm}$ and a wall thickness of $\delta = 5\,\mathrm{mm}$, traversing a room with an average air temperature of $T_\mathrm{R} = 20\,°\mathrm{C}$ holds brine with an average temperature of $T_\mathrm{B} = -20\,°\mathrm{C}$.

Known quantities:

α_i	2300	$\mathrm{W/m^2\,K}$	heat transfer coefficient at the inner side of the pipe
α_o	6	$\mathrm{W/m^2\,K}$	heat transfer coefficient at the outer side of the pipe
λ_R	54	$\mathrm{W/m\,K}$	thermal conductivity steel
λ_ins	0.042	$\mathrm{W/m\,K}$	thermal conductivity insulation

Tasks:

a) Determine the thickness of the insulation δ_ins such that no condensate is formed at the surface of the insulation is formed, even when the maximum dew point temperature of the surrounding air of $T_\mathrm{dew} = 15\,°\mathrm{C}$.

b) Determine the amount of heat $\dot{q}'$ absorbed by the brine per unit pipe length and time under the conditions given above.

Electrical wire

A 2.2-mm-diameter and 10-m-long electric wire is tightly wrapped with a 1-mm-thick plastic cover whose thermal conductivity is $\lambda_\mathrm{p} = 0.15\,\mathrm{W/m\,K}$. Electrical measurements indicate that a current of 13 A passes through the wire and there is a voltage drop of 8 V along the wire. The insulated wire is exposed to a medium at $T_\infty = 30\,°\mathrm{C}$ with a heat transfer coefficient of $\alpha = 24\,\mathrm{W/m^2\,K}$. Assume that the temperature in the electrical copper wire is homogeneous.

Tasks:

a) Determine the temperature at the interface of the wire and the plastic cover in steady state operation. Also determine if doubling the thickness of the plasti cover will increase or decrease this interface temperature.

b) Qualitatively draw the temperature profile from the inside of the copper wire up to the point where the ambient temperature is reached.

Warm-water pipe

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

Known quantities:

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

Tasks:

a) Determine the heat transfered per unit pipe length for $\dot{q}'$.
   - an uninsulated pipe, and
   - an insulated pipe with a $s = 4\,\mathrm{mm}$ cork layer ($\lambda = 0.042\,\mathrm{W/mK}$).

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.

Spherical vessel

A sphereical vessel, 3.0 m in diameter (and negligible wall thickness), is used for storing a fluid at a temperature of $T_{\text{fl}} = 0\,°\text{C}$. The vessel is covered with a 5.0-cm-thick laxer of an insulation $\lambda_{\text{ins.}} = 0.2\,\text{W}/\text{m K}$. The surrounding air is at $T_\infty = 22\,°\text{C}$. The inside and outside heat transfer coefficients are $\alpha_i = 40\,\text{W}/\text{m}^2\,\text{K}$ and $\alpha_o = 10\,\text{W}/\text{m}^2\,\text{K}$, respectively.

Tasks:

a) Calculate all thermal resistances in K/m.

b) Calculate the heat loss under steady state conditions.

c) Calculate the temperature difference across the insulation layer.