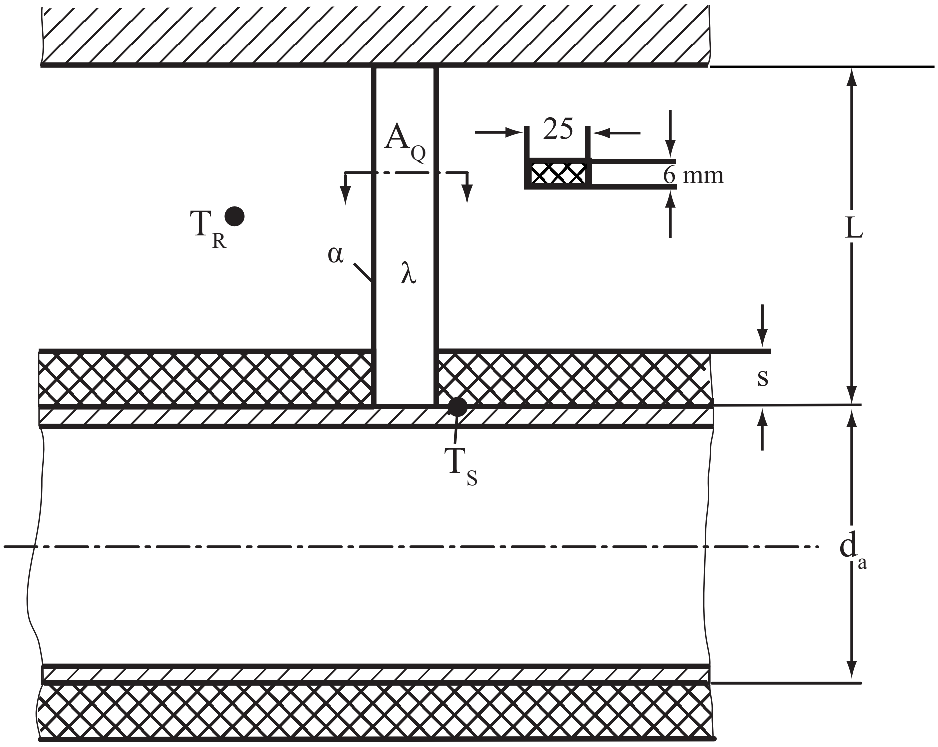
Pipe fastening

A pipe containing brine is insulated with cork and fastened to the ceiling with steel bands welded to the pipe. The outer wall temperature of the brine pipe is $T_B = -23{,}5\,°C$, the room has a temperature of $T_R = 20\,°C$.



Known quantities:

d_o	50	mm	outer diameter of the pipe
s	40	mm	insulation thickness
A_Q	25×6	mm	cross-section of the steel band
L	290	mm	length of the steel band
α	6	$^{W}/_{m^2\,K}$	heat transfer coefficient at the steel band's surface
λ	58	$^{W}/_{m\,K}$	thermal conductivity of the steel band

Tasks:

a) Calculate the heat $\dot{Q}$ from one steel band absorbed by the brine.

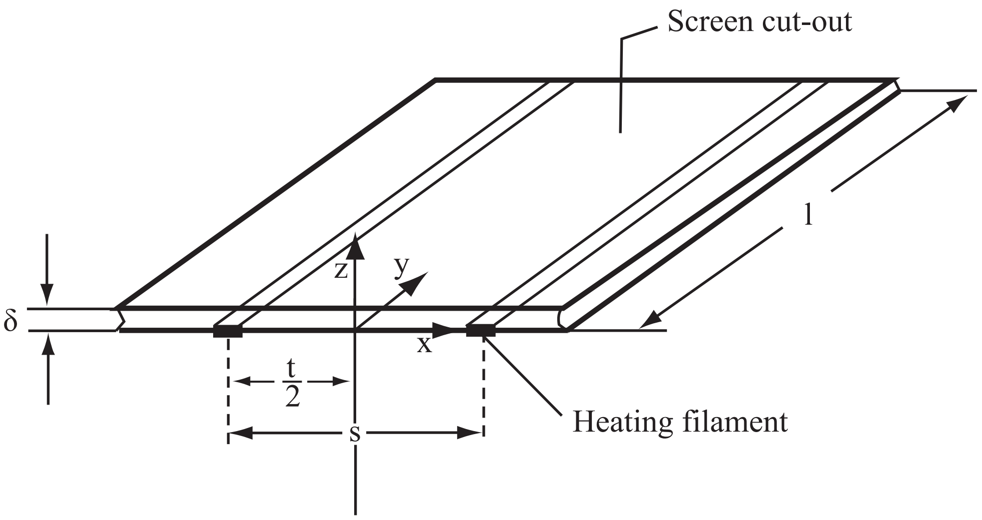
b) Up to which hight h_0 does frost form on the steel ban (h_0 is the distance from the surface of the brine pipe), if the steam content of the air in the surrounding room is above the saturation vapour pressure for the maximum steel band temperature?

Assumptions:

- The temperature distribution in the steel band's cross-section is homogeneous.
- The heat fluxes from the steel bands into both the ceiling and the insulation are negligible.

Foggy rear window

To prevent dew or frost forming at the inner side of a car's rear window, thin electrical heating elements are embedded within the glass. These are used at low ambient temperatures to feed enough energy in order to maintain a temperature above the dew point for the entire window.



Known quantities:

δ	5	mm	window thickness
s	30	mm	distances between the heating wires
λ	1.16	$^{\mathrm{W}}/_{\mathrm{m\,K}}$	thermal conductivity
T_{A}	5	°C	ambient temperature at the outer side
α_{A}	30	$^{\mathrm{W}}/_{\mathrm{m^2\,K}}$	heat transfer coefficient at the outer side
T_{I}	20	°C	ambient temperature at the inner side
α_{I}	3	$^{\mathrm{W}}/_{\mathrm{m^2\,K}}$	heat transfer coefficient at the inner side
T_{τ}	13	°C	permissible minimum temperature = dew point temperature

Tasks:

a) Determine the heating power necessary per unit conductor length to avoid reaching the dew point temperature, while observing the following conditions:

Assumptions/instructions:

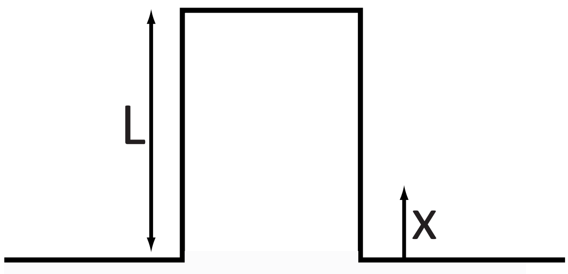
- Steady-state conditions.
- Edge effects are neglected. Due to the symmetry it is sufficient to regard a window section with to wires – refer to the diagramme above.
- Consider the problem to be one-dimensional. The only significant changes in temperature are in x-direction.
- Homogeneous heat flux over the thicnkess of the window δ.
- For reasons of practicality the coordinate system is to be placed exactly in the middle of two heating wires.

New fin material

The material used in the production of a plane fin is switched from copper to aluminium. Because the length L of the fin is also modified, the temperature at the fin head remains identical for both materials. Determine the ratio between the heat flow of the aluminium and the copper fin.

Hints

- The cross section and the thickness remain unchanged.
- There is no change in the convective heat transfer coefficient.
- The temperature at the fin base does not change.
- For both fins, the heat flow through the head is negligible.

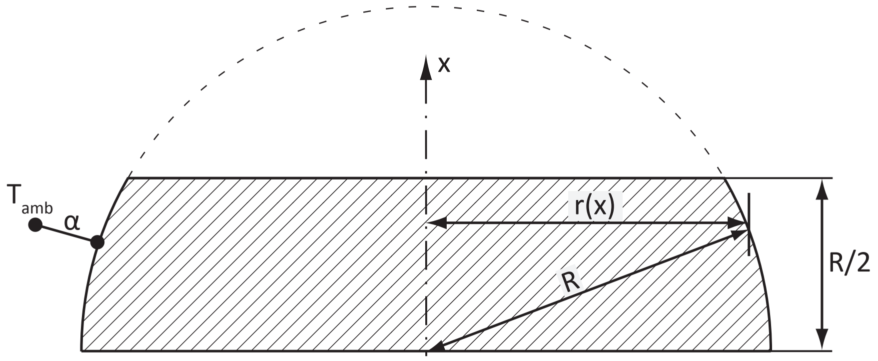


Given parameter

- Thermal conductivity of copper λ_C
- thermal conductivity aluminium λ_A

Spherical fin

A solid, hemispherical body that is cut off (radius R, hight $R/2$) is transferring heat to its ambient. Derive the differential equation of the temperature in this fin as a function of x. The heat conduction is one-dimensional in x-direction.



Given parameter

- Radius of the hemisphere, R
- Heat transfer coefficient to the ambient, α
- Conductivity of the fin, λ
- Ambient temperature, T_{amb}

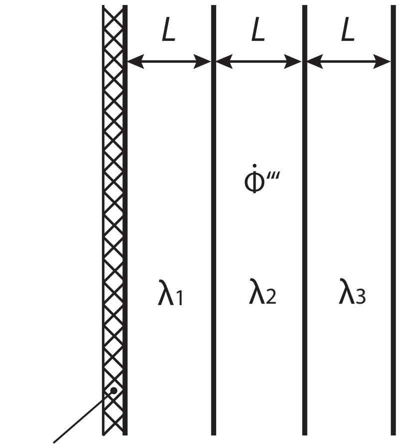
Rod fin

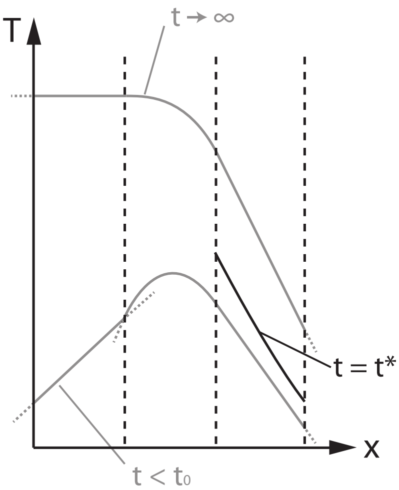
A rod-fin of length L, with a temperature equal to the ambient T_{amb} at the end of the fin, is given. What is the total heat flux carried away from the fin? Give the expression for this heat flux as a function of the given variables.

- Fin geometry, U, A_c, L
- Fin material properties, λ
- Surface heat transfer coefficient, α
- Fin base temperature and environment temperature, T_F, T_{amb}

Draw temperature profile

A triple layer wall is given. A source term $\dot{\Phi}'''$ is placed at the center layer. At instant t_0 an adiabatic insulation layer is applied to the left outer wall, which will give at $t \to \infty$ a stationary temperature profile across the three layers. Within the given figure, plot the temperature profile corresponding to a finite determined time $t^* > t_0$.





Comparison of transient heat transfer processes

Two different blocks A and B have at the instant $t = 0$ the temperature T_0. Both of them are cooling down due to the temperature difference with the surrounding environment. Determine the time t^*, at which the temperature difference between block A and the environment is half of the difference between the temperatures of block B and the environment.

- Initial conditions, $T(t = 0) = T_0$
- Heat transfer surfaces, $A_\mathrm{A}, A_\mathrm{B}$
- Absolute heat capacities, $c \cdot m_\mathrm{A}, c \cdot m_\mathrm{B}$
- Heat transfer coefficient, α
- Ambient temperature, T_amb

Hints

- The Biot number is much less than one.
- Omit thermal radiation.