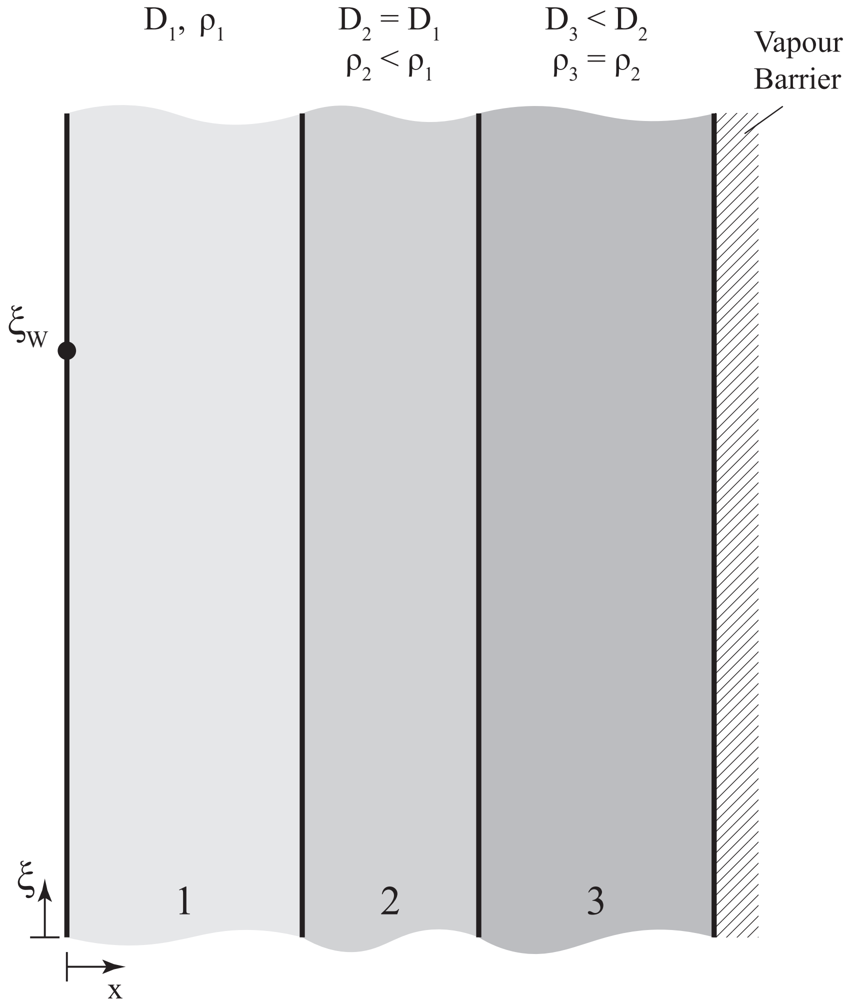
Exercise V.6: (Pipe burst ★★)

Due to a pipe burst in a multilayered wall of a bathroom at the time t0, water starts to diffuse through the wall until it reaches an impermeable layer (vapour barrier).



Hints:

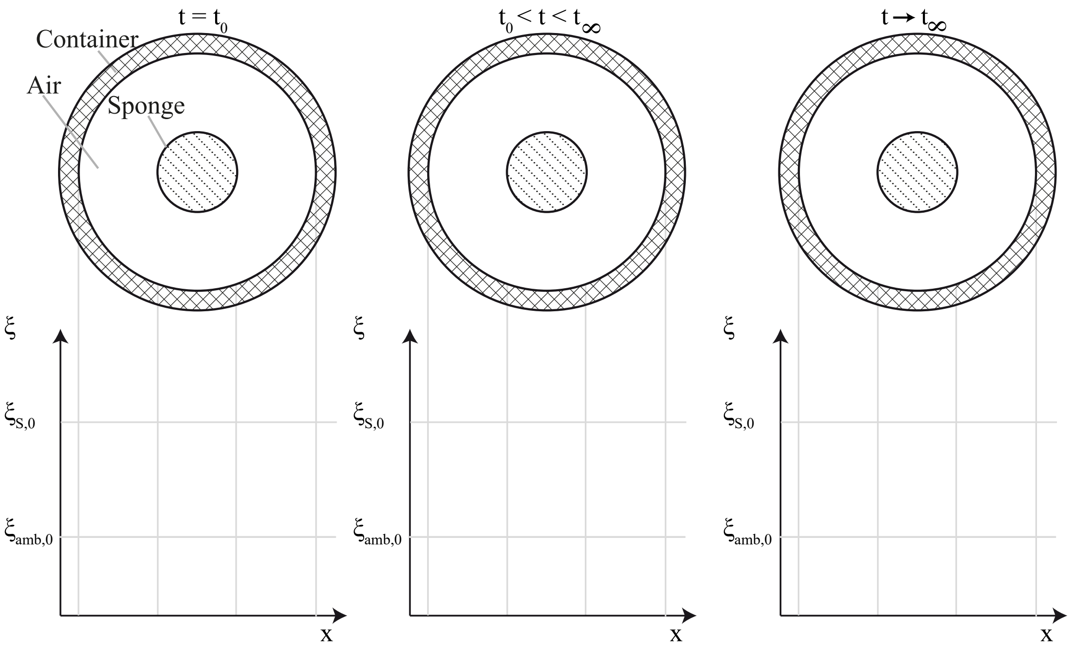
- The properties of the individual wall layers are given in the illustration.
- ξ_W represents the mass fraction of water at the wall-side of the bathroom wall.
- At time t, the steady state has not been reached yet.
- Saturation does not occur at any point inside the wall.

Tasks:

a) Sketch the water mass fraction profile across the different layers for a determined point in time $t > t_0$.

Exercise V.7: (Wet sponge ⋆⋆)

A long, cylindric sponge is placed in the center of a long, cylindric container. Following that, the container is sealed compound–impermeable. At the time $t = t_0$ the sponge is homogeneously charged with water with a mass fraction $\xi_S(t = t_0) = \xi_{S,0}$, while the air within the container exhibits a mass fraction $\xi_{amb}(t = t_0) = \xi_{amb,0}$.



Hints:

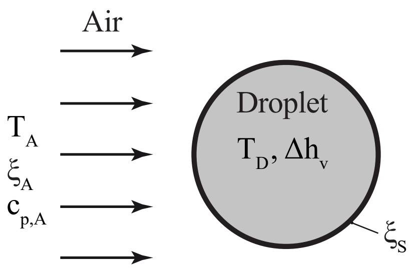
- Convective transfer can be neglected.

Tasks:

a) Draw the radial distribution of the mass fraction in both zylinder and sponge using the provided diagrams for the specified points in time.

Exercise V.8: (Evaporating droplet ⋆⋆)

A fuel droplet with constant and homogeneous temperature T_D evaporates in hot air $T_\mathrm{A} > T_\mathrm{D}$.



Given parameters:

- Mass fraction of fuel in air: ξ_A
- Mass fraction of fuel to droplet surface: ξ_S
- Ambient temperature: $T_\mathrm{A} > T_\mathrm{D}$
- Enthalpy of vaporization: Δh_v
- Heat capacity: c_p,A

Hints:

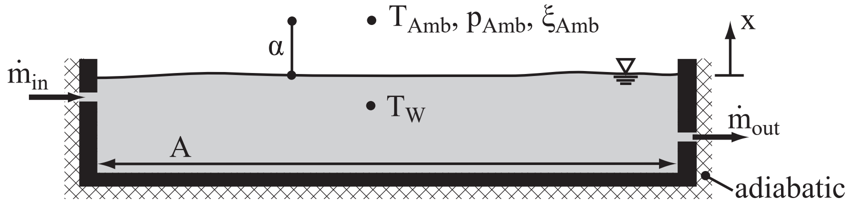
- Thermal radiation effects are neglectable.
- The Lewis number is equal to one (Le = 1).

Tasks:

a) Determine the droplet temperature as a function of the given variables.

Exercise V.9: (Thermal bath ⋆⋆⋆)

During cold ambient temperatures, the operating company of a thermal bath has to compensate for the heat and water losses of its outdoor pool to guarantee a constant water temperature.



Given parameters:

- Ambient temperature: T_{amb}
- Ambient pressure: p_{Amb}
- Water concentration in the ambient air: ξ_{Amb}
- Water surface: A
- Molar mass of air: M_{Air}
- Molar mass of water: M_{W}
- Saturation vapour pressure of water at T_{W}: $p_{\text{sW}}(T_{\text{W}})$
- Enthalpy of evaporation of water at T_{W}: $\Delta h_{\text{V}}(T_{\text{W}})$
- Mass flow of the inflowing water: $\dot{m}_{\text{in}}$
- Convective heat transfer coefficient: α
- Thermal conductivity of humid air: λ
- Specific heat capacity of humid air: $c_{\text{p,Air}}$
- Specific heat capacity of liquid water: $c_{\text{p,W}}$
- Lewis-number: Le = 1

Hints:

- The water temperature in the pool is homogeneous.
- Radiation is negligible.

Tasks:

a) Determine the evaporating water mass flow $\dot{m}$!

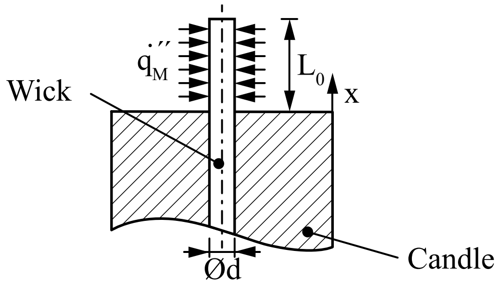
b) Determine the concentration gradient at the air-side of the water surface $\frac{\partial \xi}{\partial x}\big|_{\text{x=0}}$.

c) What temperature T_{in} of the inflowing water is needed?

Hint: Consider the mass flow of evaporating water $\dot{m}$ to be known and to be negligible compared to the inflow (i.e.: $\dot{m}_{\text{in}} \approx \dot{m}_{\text{out}}$).

Exercise V.10: (Burning candle ⋆⋆⋆)

The lights go out at the "Antarctic Research Alliance" station. So the scientists employ candles in order to see in the dark.



Given parameters:

- Net heat flux from the ignition source → wick: $\dot{q}''_{\mathrm{M}}$
- Gravitational constant: g
- Wick diameter: d
- Wick density: $\rho_{\mathrm{Wi}} \ll \rho_{\mathrm{W}}$
- Wick length **after** ignition: L
- Wick local Sherwood number **after** ignition: Sh_{x}
- Air density: ρ_{A}
- Air viscosity: η_{A}
- Air heat capacity: $c_{\mathrm{p,A}}$
- Air thermal conductivity: λ_{A}
- Air ambient temperature: T_{A}
- Wax density: ρ_{W}
- Wax diffusion coefficient in ambient air: D_{WA}
- Wax diffusion coefficient in ambient wick: D_{WW}
- Wax enthalpy of fusion: h_{W}
- Wax initial volume fraction in the wick at $t = 0$: ψ_{W}
- Wax mass fraction in ambient air: $\xi_{\mathrm{A}} = 0$

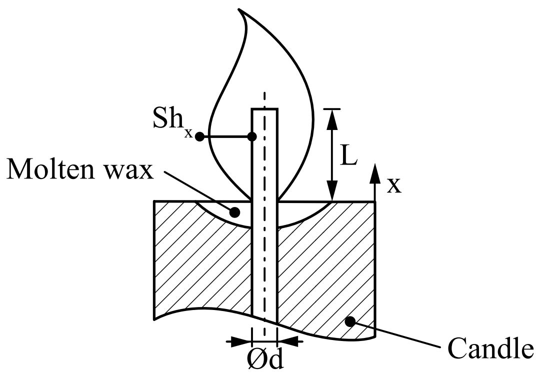
Hints:

- During the melting of the wax, assume a homogeneous and time-constant temperature.
- Assume all given material values as constant.
- The reference density of the mass fraction is similar to the wax density.
- Adopt the Lewis number, Le = 1.

Tasks:

a) To ignite a candle, all the wax in the candle wick has to be melted. For this, the exposed wick is heated with a uniform-constant radiative heat flux $\dot{q}''_{\mathrm{M}}$. Determine the time t_{M} that it takes to melt all the wax, after reaching its melting temperature.

After ignition, the candle burns under steady conditions. The wick now stands in a small pool of liquid wax which diffuses upwards through the wick and later evaporates along the wick and burns at the flame. This flame generates a local Sherwood number Sh_x along the length of the exposed wick. Furthermore, the wick adopts a steady length L, defined by the distance between the wax pool surface and the wick tip. The tip of the wick is defined by the position at which there is no more wax left on the wick, so it burns away.



b) Derive an expression for the wax local mass transfer coefficient g_x from the wick to the environment, in the function of the x.

c) Define a meaningful Biot number Bi_x, that can be used to justify the assumption that the mass fraction ξ of wax along the wick (along the coordinate x) is a one-dimensional case and assume that its value is much smaller than one, therefore: $\mathrm{Bi}_x \ll 1$. Derive the respective differential equation and provide the required boundary conditions.

d) Provide the integral equation for the total mass flow of evaporated wax $\dot{m}_{\mathrm{W}}$, that goes to the flame.

e) Sketch the wax mass fraction along the wick, and provide the initial and final coordinates for the distribution.