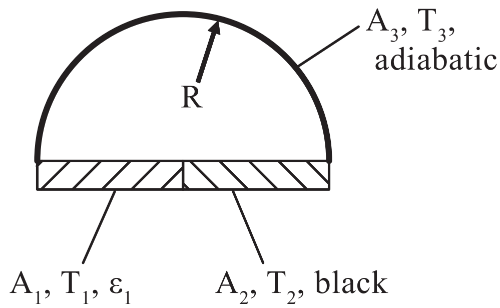
1.6 Cupola ★ ★ ★

Both semi-circular slabs A_1 and A_2 of the geometric configuration depicted below are conditioned to maintain a constant temperature of $T_1 = 150\,°C$ and $T_2 = 20\,°C$, respectively. Surface A_1 exhibits an emissivity of $\varepsilon_1 = 0.6$, surface A_2 can be considered a black body and the hemispherical surface A_3, situated above the slabs, of radius $R = 3\,m$ is adiabatic. Surfaces A_1 and A_3 are grey bodies and emit difuse radiation. The hemispherical volume is filled with vacuum. All surfaces are intransparent to radiation.



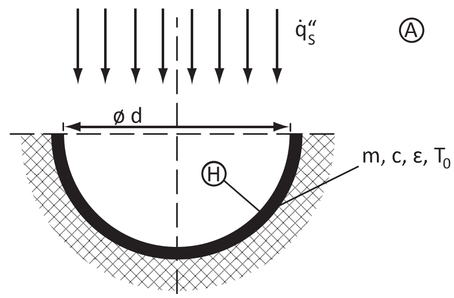
Tasks:

a) Compute the amount of heat transfered through radiation between the surfaces A_1 and A_2 (= net radiative flux through surface A_2).

b) Which temperature T_3 is obtained for surface A_3?

1.7 Pokè bowl ★ ★ ★

An empty bowl, that is used for serving the typical traditional Hawaiian dish called pokè bowl, has the homogeneous temperature T_0 and is adiabatically insulated at its convex side. At the time T_0, the bowl is suddenly exposed to parallel radiation from the sun.



Tasks:

a) Determine the surface brightness of the bowl $\dot{Q}_{\mathrm{H}}$.

   Hint: In nonsteady state, the surface brightness of a grey, adiabatic body is not the same as the surface brightness of a black body.

b) Derive the differential equation for the temperature as function of time and the necessary starting condition to solve this differential equation.

c) Determine the steady-state final temperature T_{S} of the bowl.

d) Draw the temperature as a function of time qualitatively in the given diagram on the next page.

Hints:

- The bowl radiates grey and diffuse and has a homogeneous temperature at any time.
- Influences from the ambient or the atmosphere can be neglected.
- The sun is a black body.

Given variables:

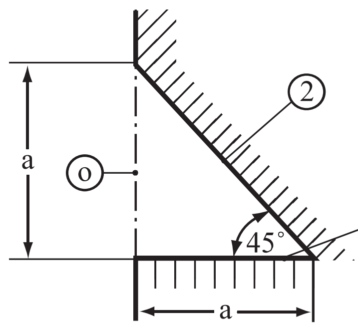
- Mass of the bowl: m

- Specific heat capacity of the bowl: c
- Emissivity of the bowl: $\epsilon \approx 0.5$
- Starting temperature of the bowl: T_0
- Diameter of the bowl: d
- Heat flux of the solar radiation on the ground: $\dot{q}''_\mathrm{S}$
- View factor of the bowl to the ambient: Φ_BA
- View factor of the bowl to itself: Φ_BB

1.8 Radiation within a wedge-shaped opening ★ ★ ★

For an infinitely long opening with a wedge-shaped cross section, the following data are known:

The surface (1) is $a = 30\,\text{cm}$ wide, has an emission coefficient of $\varepsilon_1 = 1$ and a temperature of $T_1 = 1000\,\text{K}$. The side comprising the opening, too, is 30 cm wide and perpendicular to surface (1). Surface (2) is a grey body and adiabatically insulated at the back. The space surrounding the opening can be considered to be a black body with a temperature of 0 K. Influences due to convection shall be disregarded.



Tasks:

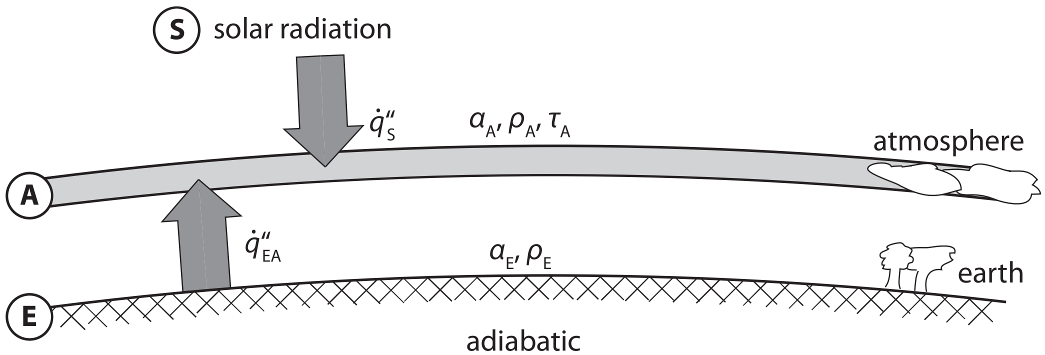
a) Determine the view factors $\Phi_{1,2}, \Phi_{2,1}, \Phi_{1,o}, \Phi_{2,o}$

b) Determine the energy through the opening $\dot{q}'_{o,\text{loss}}$ for a unit length of the opening.

c) Determine the temperature T_2 of surface (2).

1.9 Earth's atmosphere ★ ★ ★

The climate on earth is influenced by the atmosphere to a great extent. To describe heat transfer between earth and space, it is assumed that the atmosphere surrounds the earth as a thin, distinct layer.



When balancing radiative heat flows, long-wave and short-wave radiation must be distinguished (indices LW and SW). Earth and atmosphere (indices E and A) have specific absorption, reflection and transmission coefficients (α, ρ, τ) for long-wave and short-wave radiation each. The spectrum of solar radiation ($\dot{q}''_S$) is assumed to be in the short-wave range only, whereas emission from earth and atmosphere is in the long-wave range only.

Additionally to the radiative heat fluxes, a net heat flux $\dot{q}''_{EA}$ is carried from the earth into the atmosphere, which is lead back to convective heat transfer and vaporization.

Tasks:

a) Determine the flux of short-wave radiation which hits onto the earth's surface $\dot{q}''_{\mathrm{SW\ to\ E}}$.

b) Give all energy balances and surface brightnesses necessary to determine the temperature at the earth's surface. You may assume that the spectrum of black body radiation is completely within the long-wave range for that temperature.

Hints:

- Curvature is negligible, i.e. earth and atmosphere have the same surface area and the atmosphere does not radiate onto itself.
- The atmosphere emits equally into both directions.
- For long-wave radiation, the earth has an absorption coefficient of $\alpha_{\mathrm{E,LW}} = 1$.
- The given heat fluxes are averaged across the entire earth and over multiple years. Do not distinguish between the light and dark hemispheres.
- Assume steady state.

Numbers:

- Averaged heat fluxes:
- solar radiation: $\dot{q}''_{\mathrm{S}} = 341\ \mathrm{W/m^2}$ short-wave
- Convection and vaporization: $\dot{q}''_{\mathrm{EA}} = 101\ \mathrm{W/m^2}$
- Radiative properties:
- reflection coefficients: ρ (tabulated)
- transmission coefficients: τ (tabulated)
- absorption coefficients: α (tabulated)

	short-wave	long-wave
atmosphere	$\rho_{\mathrm{A,SW}} = 0,23$ $\tau_{\mathrm{A,SW}} = 0,54$ $\alpha_{\mathrm{A,SW}} = 0,23$ emission negligible	$\rho_{\mathrm{A,LW}} = 0,34$ $\tau_{\mathrm{A,LW}} = 0,10$ $\alpha_{\mathrm{A,LW}} = 0,56$ emission
earth	$\rho_{\mathrm{E,SW}} = 0,16$ $\alpha_{\mathrm{E,SW}} = 0,84$ emission negligible	2*$\alpha_{\mathrm{E,LW}} = 1,00$ emission
solar radiation	emission	emission negligible