Volume expansion coefficient

The density of water in the liquid phase can be correlated as:

$$\rho\,(T) = 1000 - 0.0736T - 0.00355T^2$$

Where ρ and T are in kg/m^3 and °C respectively.

a) Determine volume expansion coefficient β at $T = 55$ °C.

b) Sketch the volume expansion coefficient β as a function of the temperature T

Soda can

A soda can is placed horizontally in a refrigerator.

a) Determine the rate of heat transfer if the surface temperature of the can is 20 °C.

Given parameters:

- Can diameter: $D = 6$ cm
- Can length: $L = 15$ cm
- Refrigerator temperature: $T_\infty = 7$ °C

Hints:

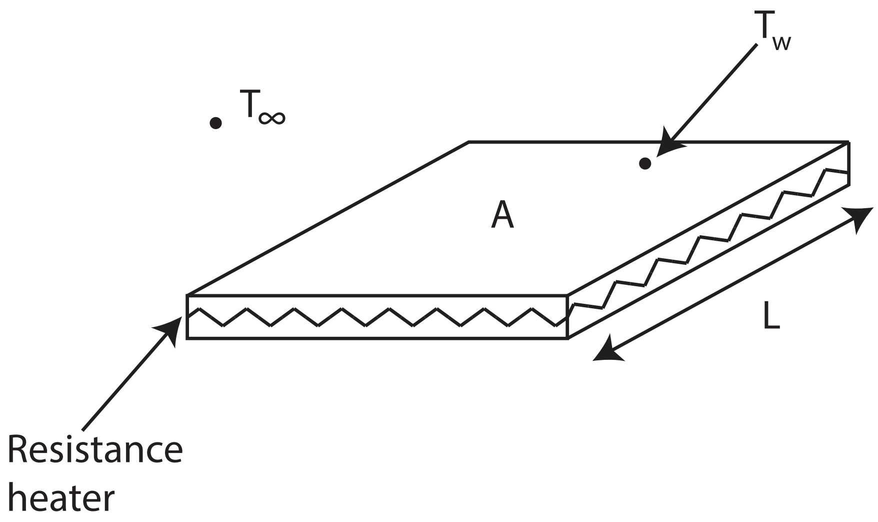
- The heat transfer from the ends of the can can be neglected.
- Radiation is negligible.

T [°C]	ρ [kg/m^3]	c [J/kg $\cdot$ K]	λ [$\cdot 10^{-3}$W/mK]	ν [$\cdot 10^{-6}$ m^2/s]	a [$\cdot 10^{-6}$ m^2/s]	Pr
7	1.188	1007	25.69	15.35	21.47	0.715
13.5	1.216	1007	25.199	14.755	20.612	0.716
20	1.188	1007	25.69	15.35	21.47	0.715

Table 1.2: Properties of air at 1 bar

Electrical resistance heater

A thin horizontal plate is suspended in air. The plate is equipped with electric resistance heating elements. When the heater is turned on, the temperature of the plate will rise.



a) Determine the rate of heat transfer during steady-state operating conditions.

Given parameters:

- Surface area: $A = 320\ \text{cm}^2$
- Plate length: $L = 20\ \text{cm}$
- Air temperature: $T_\infty = 20\ °\text{C}$

Hints:

- Assume an initial surface temperature of 50 °C.
- Radiation can be neglected.

T [°C]	ρ [kg/m^3]	c [J/kg $\cdot$ K]	λ [$\cdot 10^{-3}$W/mK]	ν [$\cdot 10^{-6}$ m^2/s]	a [$\cdot 10^{-6}$ m^2/s]	Pr
20	1.188	1007	25.69	15.35	21.47	0.715
35	1.131	1007	26.793	16.783	23.548	0.711
50	1.08	1008	27.873	18.283	25.715	0.711

Table 1.3: Properties of air at 1 bar

Incandescent lightbulb

A typical lightbulb converts 10% of electrical energy into light, while 90% is converted into heat. A new lightbulb is just placed into a room.

a) Determine the equilibrium temperature of the bulb.

Given parameters:

- Bulb diameter: $d = 8$ cm
- Bulb power consumption: $P = 30$ W
- Room temperature: $T_\infty = 20$ °C

Hints:

- Radiation can be neglected.
- Nusselt number of a sphere (valid if $\mathrm{Gr_d Pr} \leq 10^{12}$ and $\mathrm{Pr} \geq 0.7$):

$$\overline{\mathrm{Nu}}_\mathrm{d} = 2 + \frac{0.589\,(\mathrm{Gr_d Pr})^{1/4}}{\left[1 + (0.469\mathrm{Pr})^{9/16}\right]^{4/9}}$$

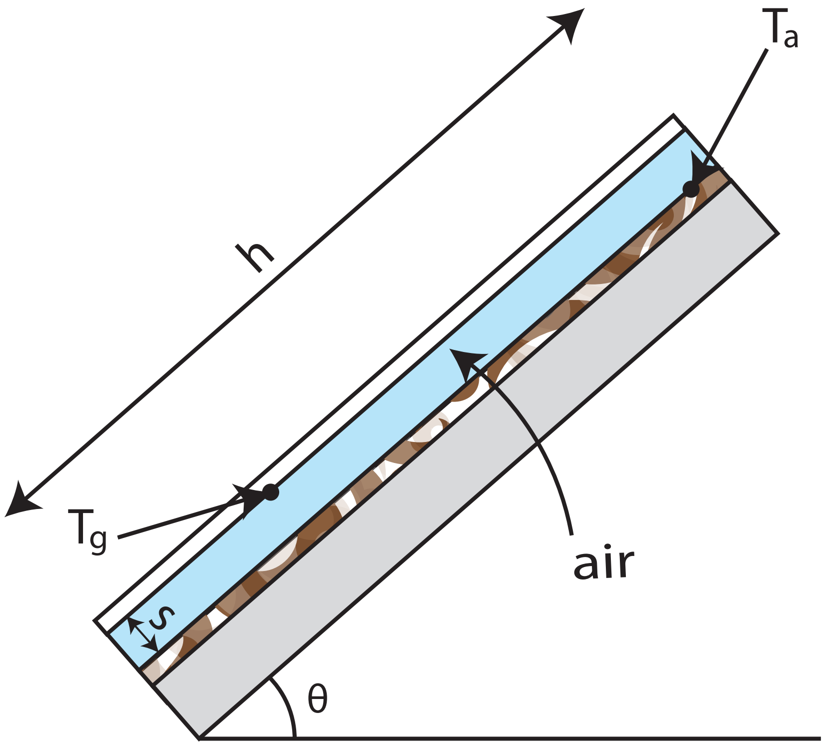
- This exercise can be solved iterative.

Solar collectors

Often are solar collectors tilted up toward the sun, in order to obtain a greater efficiency. The tilt angle θ affects the rate of heat loss.

a) Determine the rate of heat loss for $\theta = 0^o$.

b) Determine the rate of heat loss for $\theta = 90^o$.



Given parameters:

- Collector height: $h = 0.8$ m
- Collector width: $w = 3$ m
- Space between absorber plate and glass cover: $s = 2$ cm
- Glass cover temperature: $T_g = 40$ °C
- Absorber plate temperature: $T_a = 80$ °C

Hints:

- Radiation can be neglected.
- The back side of the absorber is heavily insulated.

T [°C]	ρ [kg/m^3]	c [J/kg $\cdot$ K]	λ [$\cdot 10^{-3}$W/mK]	ν [$\cdot 10^{-6}$ m^2/s]	a [$\cdot 10^{-6}$ m^2/s]	Pr
40	1.112	1007	27.16	17.26	24.24	0.712
60	1.049	1009	28.585	19.305	27.19	0.71
80	0.986	1010	30.01	21.35	30.14	0.708

Table 1.4: Properties of air at 1 bar