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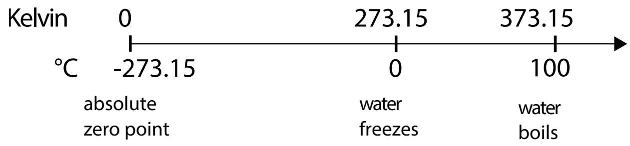
Exercises and Complements for the Introduction to Physics I for Students of Biology, Pharmacy and Geoscience

Sheet 12 / November 7, 2017 **Solutions**

Exercise 48.
(a) A change of temperature by 1 °C corresponds to a change in temperature by 1 K.
From this it follows: $30°C + 273.15K \hat{=} 30K + 273.15K = 303.15K$
(b)



(c) As mention before, a change of temperature by 1 °C corresponds to a change in temperature by 1 K. Therefore $77K + 70K = 147K$.

Exercise 49.
The volume of the mercury expands during warming up on the left side. Because of this, it spreads to the right side towards the attachment. The center of mass of the heated up mercury shifts to the right and therefore also the center of mass of the entire system. Due to this, the left side rises.
By heating up the iron tube on the left side, this end gets elongated. Due to this, the center of mass shifts to the left and therefore the left side sinks.

Exercise 50.
At T_0 :

$$l = l_B - l_A$$

At $T_0 + \Delta T$:

$$l = l_B + \alpha_B l_B \Delta T - l_A - \alpha_A l_A \Delta T = l_B - l_A + (\alpha_B l_B - l_A \alpha_A)\Delta T$$

Constraint:

$$\alpha_B l_B = \alpha_A l_A \quad \Rightarrow \quad l_B = \frac{l_A \alpha_A}{\alpha_B} = 27.5 \text{ cm}$$

Exercise 51.

(a) Heat flow rate:

$$\dot{Q} = \lambda A \frac{\Delta T}{l} = 6.1 \text{ W}$$

(b) Thermal gradient (temperature difference per length):

$$\frac{\Delta T}{l} = 50 \text{ K/m}$$

(c) Thermal resistance:

$$R = \frac{l}{\lambda A} = 16.3 \text{ K/W}$$

Exercise 52.
Since the main ingredient of tea is water we assume a specific heat capacity of 4186 J/kg K. We calculate the mass from the density and the volume:

$$m = \rho V = 0.20 \text{ kg}$$

By using the conservation of energy we can state that:

$$\text{heat dissipation of the tea} = \text{heat absorption of the cup}$$

$$m_{tea} c_{tea} (\{95 + 273.15\}K - T) = m_{cup} c_{cup} (T - \{20 + 273.15\}K)$$

where T is the unknown temperature. We solve the equation for T and we obtain $T = 358K \mathrel{\hat{=}} 85.2°C$. The temperature of the tea decreases by about 10° if it is in thermal equilibrium with the cup.
You can solve this example with an alternative approach. The total transferred heat in and out of the isolated system is zero:

$$\sum Q_i = 0$$

Each term is written as $Q = mc(T_A - T_E)$, with T_A and T_E the beginning respectively the end temperature.

Additional Exercise:
The absorbed heat energy Q is given by:

$$Q = mc\Delta T$$

by using 50 l/h, we obtain:

$$\frac{dQ}{dt} = \frac{d(mc_W \Delta T)}{dt} = c_W \Delta T \frac{dm}{dt} = 407.07 \text{ J/s}$$