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

Sheet 12 / 7.12.2020 **Solutions**

Exercise 56.

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:

$$\alpha_B l_B = \alpha_A l_A \quad \Rightarrow \quad l_B = \frac{l_A \alpha_A}{\alpha_B} = \frac{20\text{ cm} \cdot 16.8 \cdot 10^{-6}\frac{1}{\text{K}}}{12.0 \cdot 10^{-6}\frac{1}{\text{K}}} = 28.0\text{ cm}$$

Exercise 57.

(a) Heat flow rate:

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

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

$$\frac{\Delta T}{l} = \frac{100\text{ K}}{2\text{ m}} = 50\ \frac{\text{K}}{\text{m}}$$

(c) Thermal resistance:

$$R = \frac{l}{\lambda A} = \frac{2\text{ m}}{390\ \frac{\text{W}}{\text{K}\cdot\text{m}} \cdot \pi \cdot (0.01\text{ m})^2} = 16.3\ \frac{\text{K}}{\text{W}}$$

Exercise 58.

Since the main ingredient of tea is water, we assume a specific heat capacity of $c_{tea} = 4182\ \frac{\text{J}}{\text{kg}\cdot\text{K}}$. The specific heat capacity of glass is $c_{glass} = 710\ \frac{\text{J}}{\text{kg}\cdot\text{K}}$. The mass of the tea can be calculated from the density and the volume:

$$m = \rho_{H_2O} \cdot V = 0.2\ \text{kg}$$

By using the conservation of energy, we can state that:

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

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

Here, T is the unknown temperature. We solve the equation for T and we obtain:

$$0.2\ \text{kg} \cdot c_{tea} \cdot 368.15\ \text{K} + 0.15\ \text{kg} \cdot c_{glass} \cdot 293.15\ \text{K} = 0.15\ \text{kg} \cdot c_{glass} \cdot T + 0.2\ \text{kg} \cdot c_{tea} \cdot T$$

$$T = \frac{0.2\ \text{kg} \cdot c_{tea} \cdot 368.15\ \text{K} + 0.15\ \text{kg} \cdot c_{glass} \cdot 293.15\ \text{K}}{0.15\ \text{kg} \cdot c_{glass} + 0.2\ \text{kg} \cdot c_{tea}} = 359.7\ \text{K} = 86.5\ °\text{C}$$

Exercise 59.

The absorbed heat energy Q is given by:

$$Q = mc\Delta T$$

by using 50 l/h, we obtain:

$$\frac{dQ}{dt} = \frac{d(mc_W \Delta T)}{dt} = c_W \Delta T \frac{dm}{dt} = 4182\ \frac{\text{J}}{\text{kg} \cdot \text{K}} \cdot 7\ \text{K} \cdot \frac{50\ \text{l}}{3600\ \text{s}} = 406.6\ \frac{\text{J}}{\text{s}} = 406.6\ \text{W}$$

Exercise 60.

(a) Here, the ideal gas law $pV = nRT$ can be used. From $T_1 = T_2$ follows $p_1 V_1 = p_2 V_2$. This results in:

$$\frac{V_2}{V_1} = \frac{p_1}{p_2} = 2.0$$

(b) From $pV^\gamma = \text{constant}$ follows:

$$p_1 V_1^\gamma = p_2 V_2^\gamma$$

therefore

$$\frac{V_2}{V_1} = \left(\frac{p_1}{p_2}\right)^{\frac{1}{\gamma}} = 2^{\frac{1}{1.66}} = 1.52$$