11. Exercise sheet to Experimental Physics (WS 20/21)

Names: Joshua Detrois, Leo Knapp, Juan Provencio

Group: F

Points: ___/___ Σ___

11.1 Exercise 1

a) Given:

- $\alpha_{Zn} = 36 \cdot 10^{-6}$ K^{-1}
- $\alpha_{Fe} = 11 \cdot 10^{-6}$ K^{-1}

In order to counter the expansion of the whole length, in other words:

$$\Delta L = 0 \tag{1}$$

In the picture, we can see that:

$$L_{0Fe} = L + L_{0Zn} \tag{2}$$

And we can input this into our formula for length expansion and we get:

$$\Delta L = 0 = \alpha_{Fe} L_{0Fe} \Delta T - \alpha_{Zn} L_{0Zn} \Delta T \tag{3}$$
$$\alpha_{Fe}(L + L_{0Zn}) = \alpha_{Zn} L_{0Zn} \tag{4}$$
$$11L = 25 L_{0Zn} \tag{5}$$
$$\frac{11}{25} L = L_{0Zn} \tag{6}$$

b) Given:

- $L = 10$ m
- $\Delta L = 0$ for $T = 10°$C
- $\alpha_C = 12 \cdot 10^{-6}$ K
- $E_C = 20 \cdot 10^9$ N m^{-2}
- $\Delta T = 30$ K

i. To determine the pressure on the concrete slabs, we can take a look at the tensile stress:

$$\sigma = E \frac{\Delta L}{L} \tag{7}$$

$$
\begin{aligned}
&= E\frac{\alpha L \Delta T}{L} && (8)\\
&= E\alpha\Delta T && (9)\\
&= 7.2 \cdot 10^6 \text{ Pa} && (10)
\end{aligned}
$$

ii. The compression pressure of the slabs of concrete lies between the shear strength and the compressive strength. However, since the shear strength only acts lengthwise, we need to look at the compressive strength and it is big enough to withstand the pressure occurring due to the thermic changes. This is, however, under the assumption that the concrete slabs are perfectly aligned. if there were any slight deformities, it's possible that the road would suffer damages.

11.2 Exercise 2

Given:

- $V = 2$ l
- $T_0 = 22$ °C
- $d = 10$ cm
- $T_1 = 10$ °C
- $\gamma = \dfrac{1}{273.15 \text{ °C}}$

a) With Gay-Lussac's Law we can determine the Volume of the gas:

$$V(T) = V_0(1 + \gamma T) \tag{11}$$

At the beginning, there are 2 liters of gas:

$$
\begin{aligned}
V(T_0) = 2 \text{ l} &= V_0(1 + \gamma T_0) && (12)\\
V_0 &= \frac{2 \text{ l}}{1 + \gamma T_0} && (13)\\
&\approx 1.85 \text{ l} && (14)
\end{aligned}
$$

When the glas reaches 100 degrees Celsius, the volume of the gas should be

$$
\begin{aligned}
V(T_1) &= V_0(1 + \gamma T_1) && (15)\\
&\approx 2.53 \text{ l} && (16)
\end{aligned}
$$

By dividing the original volume of the jar by the new volume, we get:

$$\frac{V(T_0)}{V(T_1)} \approx 0.7905 \tag{17}$$

Which menas, that approximately 21% of the gas has escaped its containment.

b) Given:

- $T_1 = 100\ °C = 373.15$ K
- $T_2 = 22\ °C = 295.15$ K
- $p_1 = 1013$ mbar
- $d = 10$ cm

  $r = 5$ cm
- $A = \pi r^2 = 0.79\ \text{cm}^2$

To determine the pressure of the jar after it has cooled down, we can use the Law of Gay-Lussac-Boyle-Mariotte.

$$\frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2} \qquad |V_1 = V_2 \tag{18}$$

$$\frac{p_1}{T_1} = \frac{p_2}{T_2} \tag{19}$$

$$p_2 = p_1 \frac{T_2}{T_1} \tag{20}$$

$$= 0.79 p_1 \tag{21}$$

The force we need to open it is

$$F = pA \tag{22}$$

$$= (p_1 - p_2)A \tag{23}$$

$$\approx 167\ \text{N} \tag{24}$$