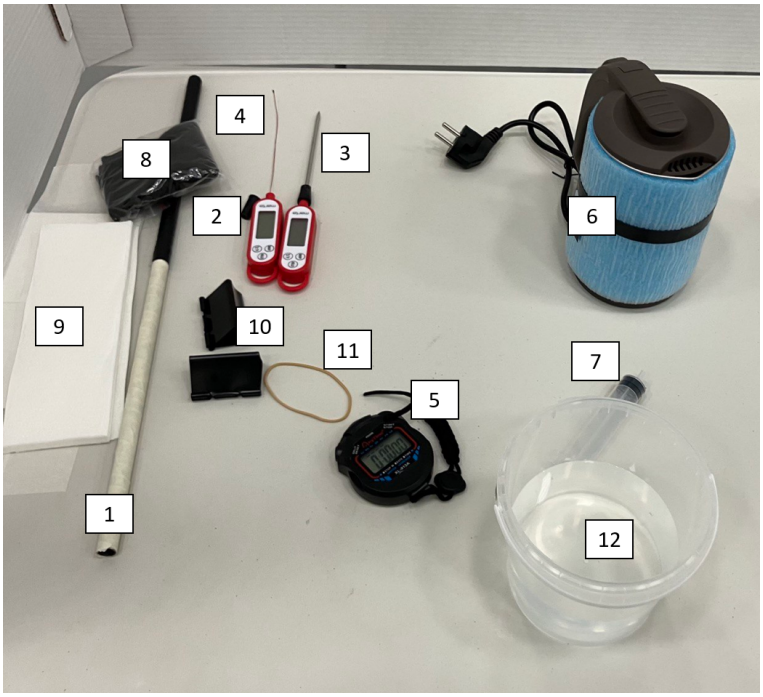
J1B - Non-uniform thermal conductivity

Equipment:

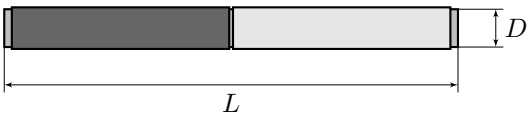
1. Metal tube with winding
2. Rubber cork
3. Thermometer with a rubber cork
4. Thermometer without a casing
5. Stopwatch
6. Water kettle
7. Syringe 20 ml
8. Gloves
9. Wipes for maintaining cleanliness
10. Two clips
11. Rubber band
12. Bucket for draining



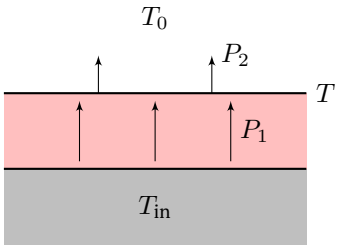
You will need to pour hot water into the metal tube. This should **only** be done with gloves on to avoid burning your hands.

The length of the tube is $L = 50.0$ cm, the outer diameter of the tube is $D = 12$ mm, the density of water is $\rho = 1.00$ g/cm^3, and the specific heat capacity of water is $c = 4.2$ J/(g $\cdot^\circ$ C). The metal part of the tube conducts heat very well. One half of it is wrapped with black electrical tape of thickness $d_b = 0.68$ mm, and the other half is wrapped with white painter's tape of thickness $d_w = 0.38$ mm.

Attention! You must not wet the painter's tape. You mustn't remove rubber cork from the thermometer!



We will study the cooling of water in a tube with non-uniform thermal insulation. The cooling dynamics is governed by two phenomena:



- The heat transfer through a thin layer with area S, thickness d and thermal conductivity κ with the power

$$P_1 = \frac{\kappa S}{d}(T - T_{\text{in}}),$$

  where T_{in} is the temperature inside the tube, and T is the temperature of the surface layer.

- The heat loss to the surrounding environment from a surface with area S heated to temperature T given by the power

$$P_2 = \alpha S(T - T_0),$$

  where T_0 is the environment temperature.

To denote quantities related to the painter's tape, we will use the subscript «w», and to denote quantities related to the electrical tape, we will use the subscript «b».

B1 Measure the dependence of the temperature inside the tube T_{in} and on the surface of electrical tape T_b on time t. Record at least 10 data points. **2.0**

The measurements begin by pouring 20 ml of hot water into the tube. When you do this, the first portions poured in will eventually cool down, as heat is lost to warming up the entire system. Before taking measurements, **vigorously** mix the water inside the tube to achieve a uniform temperature, ensure that the tube is sealed with corks on both ends!

To secure the thermometer without a casing on the surface of the electrical tape, fasten it with a rubber band. During cooling, the tube should be placed on clips to minimize heat exchange with the table.

B2 Plot a graph of T_b versus T_{in}. **1.0**

B3 Measure the dependence of the temperature inside the tube T_{in} and on the surface of painter's tape T_w on time t. Record at least 10 data points. **2.0**

B4 Plot a graph of T_{w} versus T_{in}. **1.0**

B5 Determine the value of κ_b/κ_w using plotted graphs. **2.0**

B6 Using data obtaind in questions **B1** and **B3**, determine the absolute values of κ_b and κ_w. **2.0**