Exercise 28	DETERMINATION OF THE THERMAL CONDUCTIVITY OF INSULATORS

Measurement procedure

1. List of equipment

- Device for measuring the thermal conductivity of insulators (consisted of: the heater, the heat receiver and the temperature controller),
- Digital thermometer (with one or two thermocouples),
- A set of insulators,
- Caliper,
- Micrometer screw,
- Stopwatch.

2. Goals

- Determination of the thermal conductivity of the insulators.

3. Scheme of the measuring system

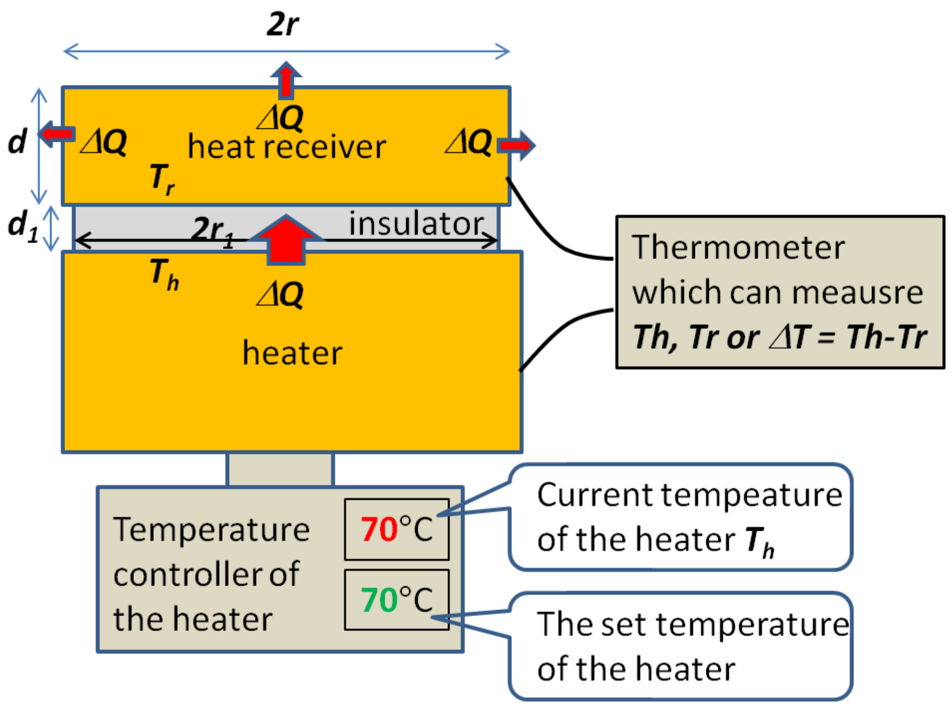

Fig. 1. Scheme of the measuring system in part 1. The insulator, the heater and the receiver have the cylindrical shape.

The main components of the system for measuring the thermal conductivity are the heater and the heat receiver between which the tested insulator is inserted. The insulator is in the form of a thin disc The temperature of the heater is controlled by its power supply, on which the temperature should be set to 70 °C (the green value in fig.1). During the measurements the current value of the temperature of the heater (the red value in fig. 1) should be the same or oscillate very close to the set value.

The temperature difference ΔT between the heater and the receiver is measured directly with the digital thermometer connected to a thermocouple (for the measuring setups 28/1, 29/2, 28/3, 28/4)).

In the setups 28/5, 28/6, 28/7 and 28/8 the thermometer TM-906A with two thermocouples is used. This is why the thermometer can measure separately the temperature of the heater T_h and the receiver T_r and the difference between them ΔT as well. To measure directly the difference of the temperatures ΔT we should use the **FUNCTION** button and choose the function **T_1-T_2**. Then we should use the **1°/0,1°** button to choose more precise measurements.

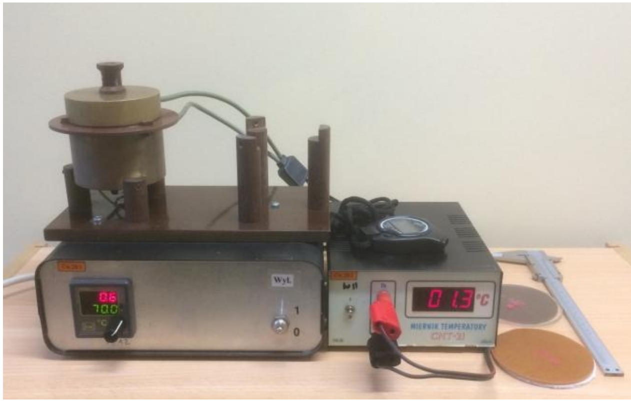

Fig. 2. The setups 28/1 up to 28/4

Fig. 3. The setups 28/5 up to 28/8

4. Measurements

4.1. Using a caliper, measure ten times the thickness d and the diameter $2r$ of the heat receiver and the diameter $2r_1$ of the tested insulator. Measure ten times the thickness d_1 of the insulator with a micrometer screw. Calculate the average values of d, d_1, r and r_1 and their uncertainties.
4.2. Place the heat receiver directly on the heater (without the insulator).
4.3. Turn on the temperature controller. In some controllers the lower display shows the set temperature (should be set to 70°C), the upper shows the current temperature of the heater.
4.4. Turn on the digital thermometer. In the setups 28/5, 28/6, 28/7 and 28/8 choose the function **T_1-T_2** and precision **0,1°C.** Remember that the thermometer measures ΔT i.e. the difference between the temperature of the heater and the temperature of the heat receiver.
4.5. When the temperature of the receiver is close to the temperature of the heater (i.e. $\Delta T \approx 2$°C) insert an insulator between the heater and the receiver. Wait until the system reaches an equilibrium in which the difference ΔT does not change. Write the difference ΔT corresponding to the equilibrium as ΔT_{eq}.

4.6. Remove the insulator and place the heat receiver directly on the heater. In this position, heat the receiver until its temperature is about 3°C higher than the temperature which corresponded to the equilibrium (at that moment the temperature difference ΔT on the display of the thermometer will be 3°C lower than ΔT_{eq}).

4.7. Move the heat receiver to a special holder (fig. 4) and just after that start the stopwatch and while the free-standing receiver is cooling down record the readings of the temperature difference ΔT every 10 seconds until ΔT increases up to about 3°C above ΔT_{eq}.

4.8. Turn off the devices and tidy up the desk.

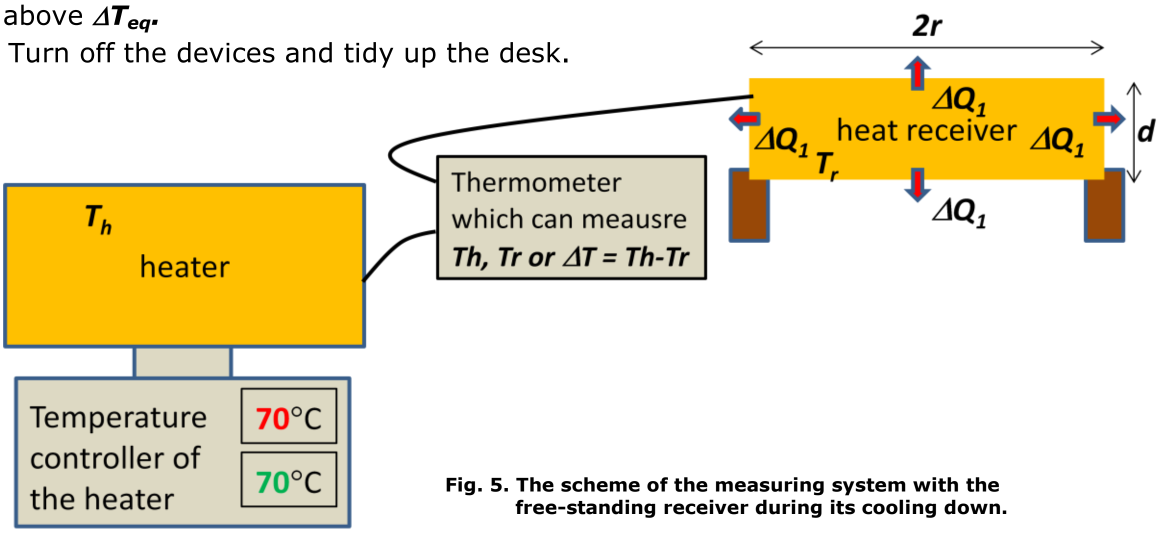

Fig. 5. The scheme of the measuring system with the free-standing receiver during its cooling down.

5. Calculations and analysis of the results

5.1. To get the cooling rate of the free-standing receiver $n = \Delta T/\Delta t$ plot the graph $\Delta T = f(t)$ (temperature difference vs. time) using the data recorded in the point 4.7. Find out the rate n as the slope of the linear part of the plotted line close to the region where $\Delta T = \Delta T_{eq}$. The best way to find out the slope and its uncertainty is the method of linear regression.

5.2. Calculate the thermal conductivity using the formula:

$$k = \frac{m_i \cdot c_i \cdot n \cdot d_1 \cdot (r + 2d)}{2\pi \cdot r_1^2 \cdot \Delta T_{eq}(r + d)} \qquad (1)$$

where:

m_i - mass of the heat receiver,

$m_1 = (690{,}5 \pm 0{,}5)$ g	$m_5 = (834{,}5 \pm 0{,}5)$ g
$m_B = (832{,}5 \pm 0{,}5)$ g	$m_6 = (834{,}5 \pm 0{,}5)$ g
$m_C = (830{,}5 \pm 0{,}5)$ g	$m_7 = (834{,}5 \pm 0{,}5)$ g
$m_D = (621{,}5 \pm 0{,}5)$ g	$m_8 = (834{,}5 \pm 0{,}5)$ g

c_i - specific heat of the material from which the heat receiver is made,
specific heat of copper = (385 ± 1) J/(kgK) (for m_1),
specific heat of brass = (389 ± 1) J/(kgK) (for the other receivers),

n - the rate at which the heat receiver cools down,

d_1, r_1 - the thickness and the radius of the insulator,

d, r - the thickness and the radius of the heat receiver,

ΔT_{eq} - the difference between the temperature of the heater and the temperature of the heat receiver (measured directly).

5.3. Calculate the compound uncertainty $\boldsymbol{u_c(k)}$ of the thermal conductivity. Which of the directly measured quantities contribute the most to the compound uncertainty $\boldsymbol{u_c(k)}$?

5.4. Enter the results of the measurements and calculations into the table.

6. Proposed table (to be approved by the supervisor)

lp.	m [kg]	c $\left[\frac{J}{kg \cdot K}\right]$	n $\left[\frac{K}{s}\right]$	ΔT_{eq} [K]	d_1 10^{-3}[m]	$2r_1$ 10^{-3}[m]	r_{1av} 10^{-3}[m]	d 10^{-3}[m]	$2r$ 10^{-3}[m]	r_{av} 10^{-3}[m]	k $\left[\frac{J}{m \cdot s \cdot K}\right]$
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
$\bar{X}$											
ΔX											
$u(X)$											
$u_c(X)$											

av - means the average value.