7 PHYSICAL CHARACTERISTICS OF THERMISTOR

Task: Determine physical characteristics of a thermistor (constants A and B) from five temperature and resistance measurement.
Calculate the resistance of the termistor and the temperature coefficient $\alpha_\%$ at 0, 25 °C using the Equations [3] and [5] and the obtained values A and B.

The word **thermistor** is a combination of words “thermal” and “resistor”. A thermistor is a temperature-sensing element composed of sintered semiconductor material which exhibits a large change in resistance proportional to a small change in temperature.

Thermistors can be classified into two types: If the resistance increases with increasing temperature, the device is called a positive temperature coefficient (PTC) thermistor, **posistor**. If the resistance decreases with increasing temperature, the device is called a negative temperature coefficient (NTC) thermistor.

PTC thermistors can be used as heating elements in small temperature-controlled ovens. NTC thermistors are used as resistance thermometers in low-temperature measurements of the order of 10 K. NTC thermistors can be used also as inrush-current limiting devices in power supply circuits. They present a higher resistance initially which prevents large currents from flowing at turn-on, and then heat up and become much lower resistance to allow higher current flow during normal operation.

These thermistors are usually much larger than measuring type thermistors, and are purpose designed for this application. Thermistors are also commonly used in modern digital thermostats and to monitor the temperature of battery packs while charging.

We will deal with NTC thermistor in a more detail. Resistance of the thermistor can be characterized with the exponential function of reciprocal absolute value of temperature:

$$ R = R_a e^{-B(\frac{1}{T_a} - \frac{1}{T})} \quad [1] $$

where $R$ is the resistance of thermistor at the temperature $T$ (in K), $R_a$ is the resistance at given temperature $T_a$ (so called base temperature), $e$ is Euler’s number, $B$ is the material constant ([B]=K)

Supposing the base temperature considerably high (let $T_a \to \infty$), and the thermistor resistance at $T_a$ is $R_a = A$ ([A]=Ω), the Equation [1] can be simplified:

$$ R = A e^{\frac{B}{T}} \quad [2] $$

Figure 1A shows the dependence of the resistance of a thermistor on temperature. We can easy obtain physical characteristics of a thermistor (the constants A and B) by arranging the Equation [2] into a logarithmic form:

$$ \ln(R) = \ln(A) + B \frac{1}{T} \quad [3] $$

$\ln(R)$ is linearly dependent on $1/T$

$B$ is the slope of the straight line $\ln(R) = f(1/T)$
\( \ln (A) \) represents the intercept (Figure 1B).

**Figure 1**  
A – Temperature dependence of the resistance of thermistor  
B – The dependence of \( \ln (R) = f (1/T) \)

The temperature coefficient \( \alpha \) of electric resistance of thermistor expresses a drop in the resistance with a small increase in temperature (usually 1 °C), defined by:

\[
\alpha = \frac{1}{R} \frac{dR}{dT} \tag{4}
\]

Differentiating of Equation [2] with respect to temperature, and substituting into the Equation [4] one obtains:

\[
\alpha = -\frac{B}{T^2} \tag{5}
\]

The unit of \( \alpha \) is \( K^{-1} \) ([\( \alpha \]=\( K^{-1} \)). The temperature coefficient may be expressed in per cent (%) as well. \( \alpha_{\%}=100\alpha \).

\( \alpha_{\%} \) describes by how many per cent drops the resistance of the termistor at increasing temperature by 1°C. The unit of \( \alpha_{\%} \) is \%\( K^{-1} \) ([\( \alpha_{\%} \]=\%\( K^{-1} \)).

**Equipment:**
Thermistor (\( R_t \)), decade resistors box (\( R_d \)), galvanometer (\( G \)), box with two built in resistors of identical value, push-button (\( K \)), galvanic cell 1.5 V, beaker 500 ml, thermometer, wires, burner, tripod with grillwork, stand with holders, mixer

**Experimental procedure:**
1. Connect the circuit according the diagram in Figure 2.
2. Fill the beaker with cold water (~ 15 °C), and put in the thermistor, thermometer and mixer
3. The diagram in Figure 2 represents so called Wheatstone bridge used to measure an unknown electrical resistance by balancing two legs of a bridge circuit. In our diagram, one leg includes the thermistor and the known resistor, in the second is the decade resistors box and the second known resistor. The bridge is balanced, when the current through the galvanometer \( G \) is equal to zero. Because we use two resistors of identical value (one in each leg of bridge), at balance, the resistance of thermistor is equal to the resistance of decade. The resistance of decade box is adjustable. So, at given temperature
we change the resistance of decade box while no current flows through the galvanometer. The value adjusted on the decade box directly indicates the resistance of thermistor.

![Diagram of the circuit](image)

**Figure 2** The diagram of the circuit

4 Repeat the measurement in temperature range 15 – 50 °C, with increment ~5 °C, expected total number of cycles is 5-6.

5 In order to obtain physical characteristics of thermistor (A and B), calculate \( \frac{1}{T} \) and \( \ln (R) \) (see Table 1)

6 Use MS Excell to create dependence \( \ln (R) = f(\frac{1}{T}) \). Fit the experimental points with a straight line. The slope of the straight represents the value of \( B \), and the intercept corresponds to \( \ln (A) \) (see the Eq. [3]). Calculate \( A \).

7 Calculate the resistance of the thermistor and the temperature coefficient \( \alpha_{\%} \) at 0, 25 °C using the Equation. [3] and the obtained values \( A \) and \( B \) (Table 2).

8 Experimental report requires a graphical representation of your data: \( R=f(t) \) and \( \ln (R) = f(\frac{1}{T}) \) as shown in Figure 1.

<table>
<thead>
<tr>
<th>No.</th>
<th>( t ) (°C)</th>
<th>T (K)</th>
<th>( \frac{1}{T} ) (K(^{-1}))</th>
<th>( \ln R )</th>
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<tr>
<th>( t ) (°C)</th>
<th>T (K)</th>
<th>( \alpha_{%} ) (%K(^{-1}))</th>
<th>R (Ω)</th>
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**Table 1** Experimental data

**Table 2** The resistance of the thermistor and the temperature coefficient \( \alpha_{\%} \) at selected temperatures

*Calculation:*
Conclusion: