Physical characteristics of thermistor.

What is a thermistor? 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. Resistors that are not thermistors are designed to keep their resistance almost constant over a wide temperature range.

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:

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

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 and B is the material constant ($[B]=K$)

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

$$R = Ae^{\frac{B}{T}} \qquad [2]$$

Fig. 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 eq. [2] into a logarithmic form:

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

ln (R) is linearly dependent on $1/T$. B is the slope of the straight line ln (R) =f($1/T$), and ln (A) represents the intercept (Fig. 1B).

The temperature coefficient α of electric resistance of thermistor expresses a drop in the resistance with a small increase in temperature (usually 1 ^{o}C), defined by:

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

Differentating of eq. [2] with respect to temperature, and substituting into the eq. [4] one obtains:

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

The unit of α 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^{o}C. The unit of $\alpha_{\%}$ is $\%K^{-1}$ ($[\alpha_{\%}]=\%K^{-1}$).

The aim of work:

1. Determine physical characteristics of a thermistor (constants A and B).
2. Calculate the resistance of the termistor and the temperature coefficient $\alpha_{\%}$ at 0, 25, 50 and 75 ^{o}C using the eq. [3] and the obtained values A and B.

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 Fig. 2.
2. Fill the beaker with cold water (~ 15 ^{o}C), and put in the thermistor, thermometer and mixer
3. The diagram in Fig. 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.
4. Repeat the measurement in temperature range 15 – 80 ^{o}C, with increment ~5 ^{o}C, expected total number of cycles is 10-12.
5. In order to obtain physical characteristics of thermistor (A and B), calculate $1/T$ and ln (R) (see Tab. 1)
6. Use MS Excell to create dependence ln (R) = f($1/T$)). 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 termistor and the temperature coefficient $\alpha_{\%}$ at 0, 25, 50 and 75 ^{o}C using the eq. [3] and the obtained values *A* and *B* (Tab. 2).
8. Experimental report requires a graphical representation of your data: *R*=f(*t*) and ln (*R*) = f(1/*T*) as shown in Fig. 1.

Tab. 1. Experimental data

No.	t (^{o}C)	T (K)	1/T (K^{-1})	R (Ω)	ln R
1					
2					
3					
..					
..					
12					

Tab. 2. The resistance of the termistor and the temperature coefficient $\alpha_{\%}$ at selected temperatures.

t (^{o}C)	T (K)	$\alpha_{\%}$ (%K^{-1})	R (Ω)
0			
25			
50			
75			

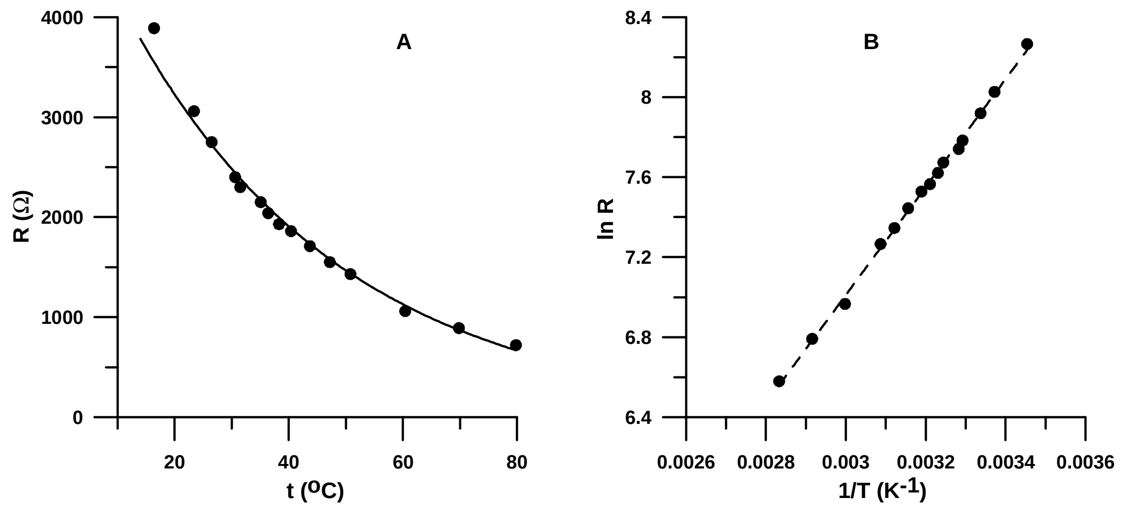

Fig 1. A: Temperature dependence of the resistance of thermistor.
B: The dependence of ln (R) =f (1/T).

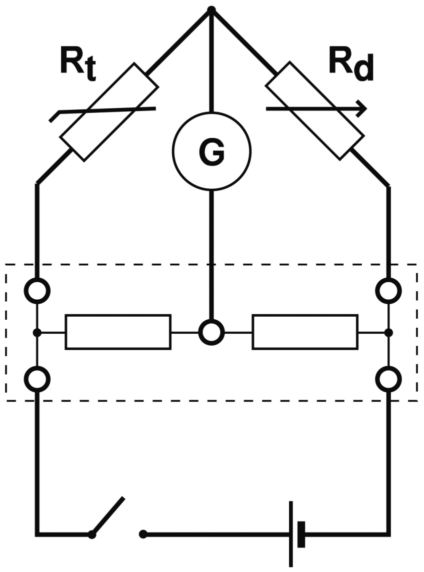

Fig. 2 The diagram of the circuit.

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http://en.wikipedia.org/wiki/Thermistor

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