

Exercise 4

Temperature coefficient of resistance

Aim

To determine temperature coefficient of resistance of various materials. To investigate range of validity of Ohm's law.

Required theoretical knowledge

Ohm's law, electric current, resistance and resistivity, temperature dependence of resistivity, difference between metals and semiconductors, methods of resistance measurements, principals of operation of thermocouple

Equipment

The measurement set up is shown in Fig. 1. It consists of power supplier, thermometer, case with elements (NTC, R, Cu) with thermocouple, computer.

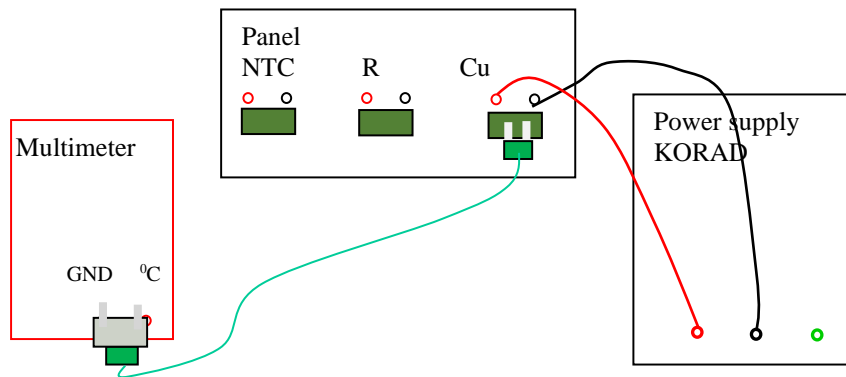


Fig. 1. The measurements setup arranged for Cu wire measurements

Problems for discussion:

Ohm's law

Principals of operation of thermocouple

Dependence of resistance of metals on temperature (including physical origin)

Measurement plan:

1. Turn on the computer and run application *Calc* of *Open Office* suite.
2. Set up a circuit as it is shown in Fig. 1.
3. Connect wires of *Cu* to the power supply and appropriate thermocouple to the multimeter and set it to temperature measurements.
4. Turn on the power supply, by pressing the current button, set the current limit to **1.0 A**. Afterwards, by pressing the voltage button, set it to 0.1 V setting precision.
5. By adjusting the voltage of power supply in a range from **0** to **0.9 V** with step of **0.1 V** write down the values of voltage, current and temperature in application *Calc* in three columns. (Caution the values change with time, it is important to note the stable values for the same moment, preferably after 10-100 s delay). After finishing, set the voltage to **0**.

6. NTC thermistor: connect NTC cables to the power supply together with appropriate thermocouple.
7. Turn on the power supply, set the current limit to **0 A** and voltage limit to **10 V**.
8. By pressing and turning the current regulation knob, set it in the range from **0** to **0.2A** with step of **0.02 A**. Note the values of current, voltage and temperature in application *Calc* in three columns. After finishing, set the voltage and current to **0**.
9. Resistor: connect wires of R to the power supply and appropriate thermocouple.
10. Set the current limit to **0.08 A**.
11. By adjusting the voltage in range from **0 to 3 V** with step of **0.2 V** note the values of voltage, current and temperature in application *Calc* in three columns. After finishing, set the voltage to **0 V** and turn off the power supply.

Problems for discussion:

Which of the measured element can be described using Ohm's law?

What is resistivity and how it depends on the geometrical dimensions of the element?

Dependence of resistance of semiconductors on temperature (including physical origin)

Application of thermistors.

Data processing:

1. In *Calc*, for copper wire calculate the resistance of each measurement pair (V,I) (in separate column)
2. Draw a dependence of resistance (R) vs. temperature (T)
3. Using two parameters regression method calculate coefficients of the equation: $R = aT + b$ (1), and their uncertainties Δa and Δb .
4. Transform equation $R = R_0(1 + \alpha T)$ into form similar to Equation (1) and calculate values of R_0 and α . Using propagation of uncertainties principle calculate $\Delta \alpha$.
5. Assuming geometrical dimensions of copper wire: diameter ($\phi = 0.3 \text{ mm} \pm 0.01 \text{ mm}$) and length ($l = 3 \text{ m} \pm 0.1 \text{ m}$) calculate copper resistivity ρ .
6. For resistor, for each measurement pair calculate its resistance
7. Draw a current-voltage dependence of the measured resistor. Using linear regression calculate its resistance and its uncertainty.
8. In a separate spreadsheet for NTC thermistor calculate resistance for each measurement pair.
9. In a separate column calculate values of $1/T$, and $\ln R$. Draw a graph of $\ln R$ vs. $1/T$.
10. Using linear regression method calculate the slope of $\ln R = a*1/T + b$
11. From the transform equation $R = R_0 * \exp(B*(1/T - 1/T_0))$ into linear dependence, calculate the slope, being B and write it down in Table, together with its uncertainty.

Literature

1. Halliday, Resnick “*Fundamentals of Physics - 8th edition*”, John Wiley 2007,