DEPARTMENT OF PHYSICS
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UNIVERSITY of York

Temperature variation of electrical resistance of a platinum resistor

Safety hazards and precautions:

- Use of liquid nitrogen – wear gloves and safety glasses.

Experimental Objectives:

- To examine the temperature variation of electrical resistance in metals.

Learning Outcomes:

- Improved understanding of the theory of conduction.
- To learn to handle liquid nitrogen safely.
- To learn to use a modern computer interface for data acquisition.

1. Introduction

The temperature variation of resistance has significant technological implications. Clearly the variation of resistance with temperature will determine energy consumption in all electrical systems based on metals. In the case of a superconductor, there is a temperature below which the material exhibits zero electrical resistance. The goal of superconductor research is to find and create a material with superconductor properties at room temperature, then these could be used in everyday electronic devices and save a lot of energy.

2. Theory

2.1 The model of temperature dependant electrical resistivity of metals

The statistical distribution of the electrons was first determined by Enrico Fermi and Paul Dirac in 1926 and is known as the Fermi-Dirac distribution. At temperatures of more than a few Kelvin, the mobility of electrons, and hence the conductivity, decreases linearly with temperature. Thus, the resistivity and therefore resistance of a metal increases linearly with temperature. Giving the relation,

$$R \propto T \tag{1}$$

where R is the resistance of the metal and T is the temperature. The resistance of a metal can then be written as

$$R(T) = R_0 \alpha_{T_0} (T - T_0) + R_0, \tag{2}$$

where R_0 is the resistance at a temperature T_0 and α_{T_0} is the temperature coefficient of resistance measured at T_0. For platinum, which is the resistor in this experimental set up. Comparing Equation 2 to the equation of a line

$$y = mx + c, \tag{3}$$

the value of R_0 and α_{T_0} can be determined.

3. The Experiment

3.1 Temperature variation of resistance of platinum

A thermocouple with a two-pin plug, platinum resistor thermometer and electric heating element are inserted into a copper block. If you need help identifying each element, ask the demonstrators.

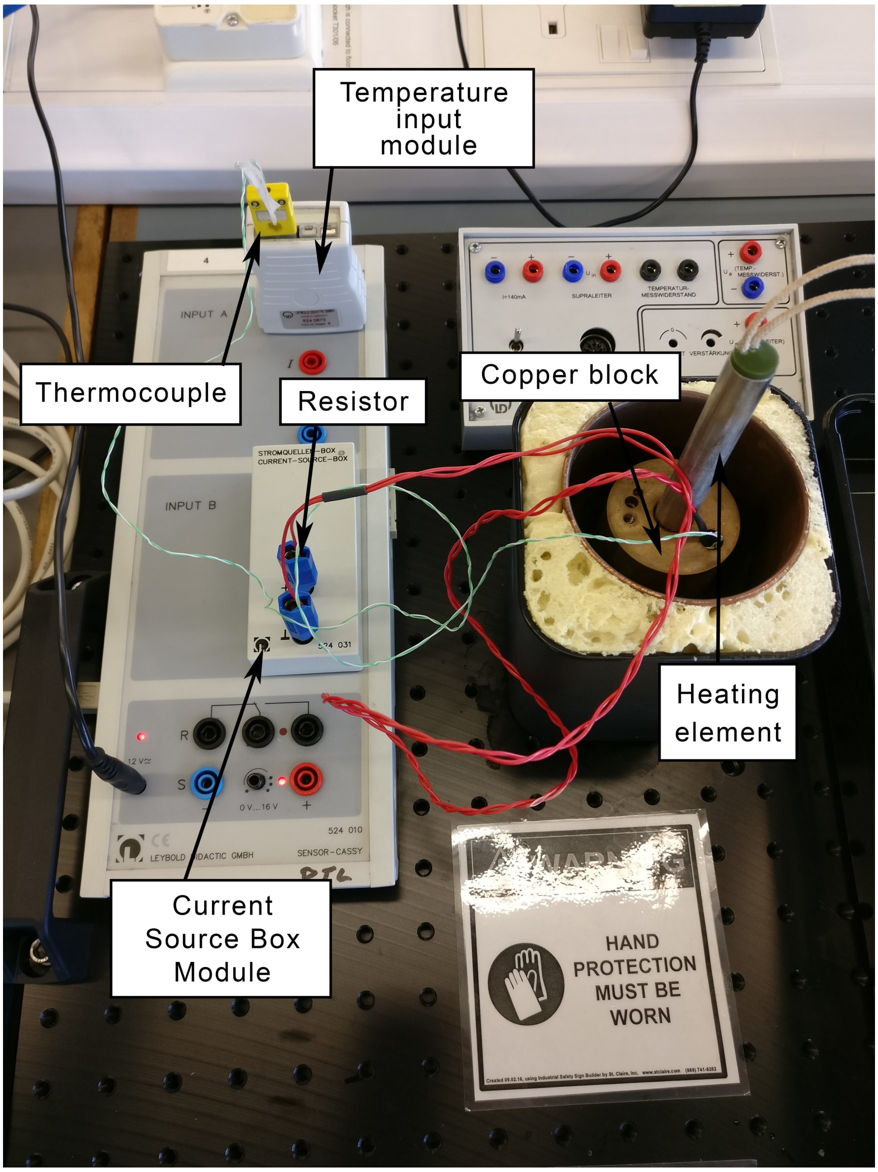

Figure 1: Experimental set-up showing the thermocouple, resistor, copper block, heating element, temperature input module and current source box module.

1. A Leybold CASSY interface is used to acquire the data measuring the resistance and temperature. This can be found on the Desktop > Physics Teaching > CASSY. Make electric connections using the constant current and temperature input modules on CASSY as shown in Figure 1.
2. The connections to the platinum sample are on leads which should be connected to the current module. The thermocouple for measuring the temperature terminated in a two-pin plug and is connected to the temperature input module.
3. Insert the heating element into the copper block as shown in Figure 1.
4. After opening CASSY Lab software, a screen will automatically appear. A map of the CASSY interface will pop up.

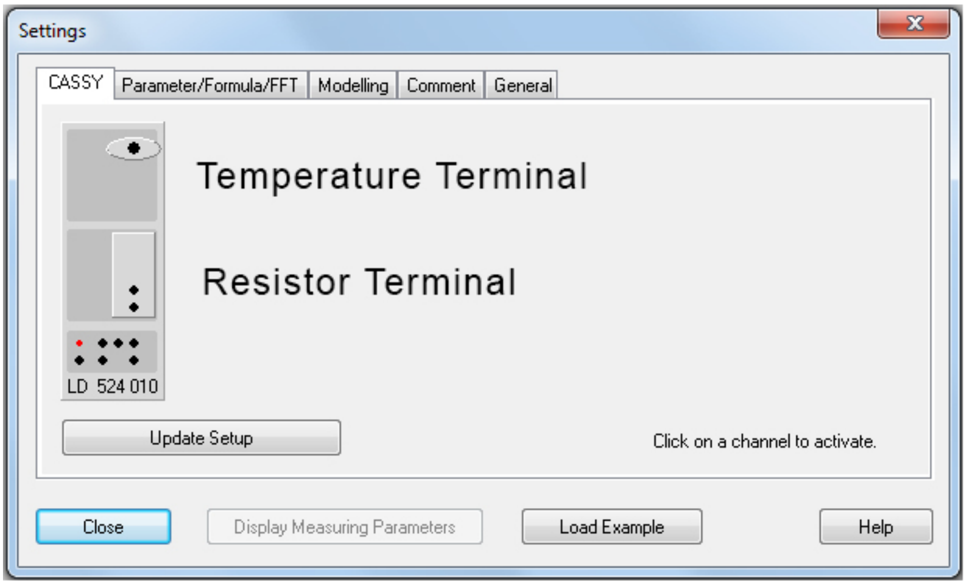

Figure 2: CASSY map of terminals

5. Click on the first terminal on the map as shown on Figure 2. It will detect automatically what is connected to the terminal so that it will show temperature as it is connected to a thermocouple. Set the range to -200°C to 50°C. Select the option of 'average values'.
6. Click on the second terminal on the map. Set the range to 0 to 100 Ω. Select the option of 'average values' again.
7. To choose the graph parameters click on the tools icon and then choose 'display'. Select temperature as the x-axis and resistance as the y-axis.

Why is a large mass of Copper used to hold the samples?

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3.2 Controlling the Temperature

Put on your safety glasses and gloves now

1. Before doing any measurements make sure you calibrate the thermocouple. In order to do this, fill the Copper block with liquid Nitrogen and insert the thermocouple. The boiling point of liquid Nitrogen is 77.4K (-195.6°C).

2. When handling liquid nitrogen **wear gloves and safety glasses at all times.** To cool the copper block, pour liquid nitrogen into the calorimeter and only fill to below the level of the copper block. As the equipment cools it may be necessary to top up the

liquid nitrogen to achieve low temperatures. When the system reaches thermal equilibrium with the liquid Nitrogen it will stop boiling violently and have a gentle simmer.

3. Once the nitrogen has stopped boiling ask a demonstrator to pour out the liquid nitrogen and move on to part 4.

4. To begin heating, an electric heater (Set at 12V and maximum current) is connected to a DC power supply by two cables in the – and + terminals of the power pack.

5. To begin data acquisition, click the clock icon in CASSY lab as shown in Figure 3. Continue taking data for about 10 minutes and then click the clock again to stop data acquisition.

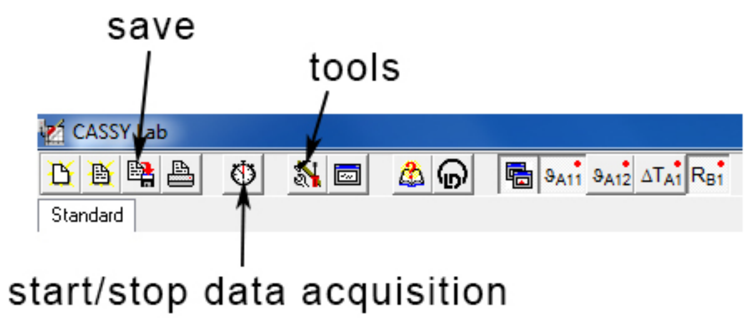

Figure 3: Icons on CASSY lab.

3.3 Data Analysis

To allow for data analysis data should be exported from CASSY lab (save data as .txt then open in Excel as shown in Figure 3). This way data fitting may be performed and units corrected.

1. Click on the save icon as shown in Figure 3
2. Select .txt file and save
3. Open the .txt file, select all and copy
4. Paste the contents into a blank Excel spreadsheet
5. Download the ‘Resistor Spreadsheet’ from (insert link here)
6. Copy and paste the temperature (second column) and resistance (fifth column) columns into the respective columns in the ‘Resistance Spreadsheet’. Leaving all columns that don’t have red headings. The graph will be plotted automatically.
7. Use the equation of the line of best fit to calculate R_0 and α_{T_0}.