

## Temperature variation of electrical resistance of a superconductor

### Safety hazards and precautions:

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

### Experimental Objectives:

- To measure the critical temperature of a superconductor.

### 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.

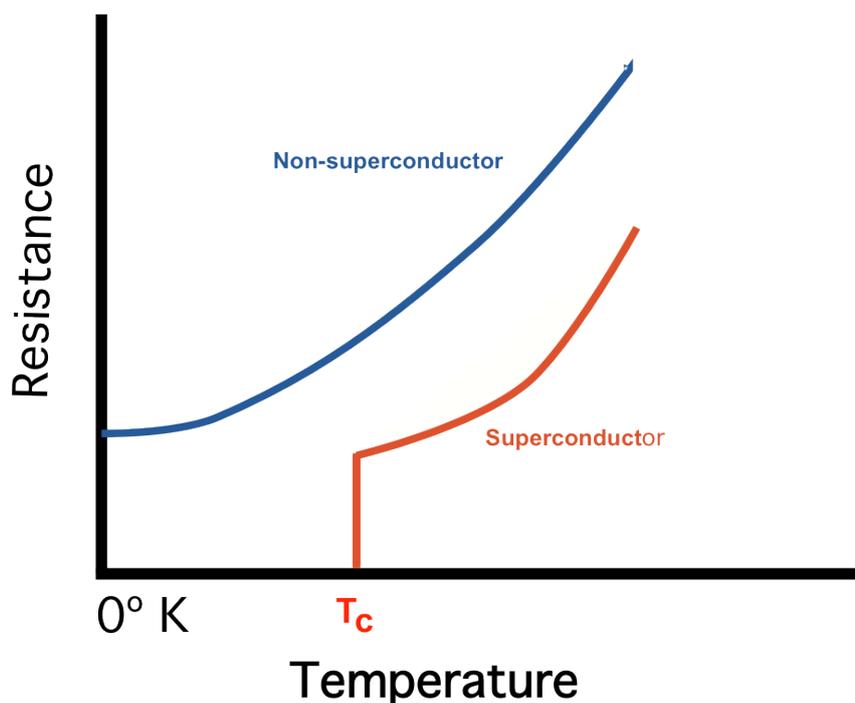
## 1. Introduction

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 Temperature dependent electrical resistivity of superconductors

A superconductor is a material that exhibits zero resistance at and below a critical temperature,  $T_c$ , as shown in Figure 1. A superconducting ring carrying an induced current shows no observable decrease in current over a whole year and no decrease is predicted in  $10^5$  years.



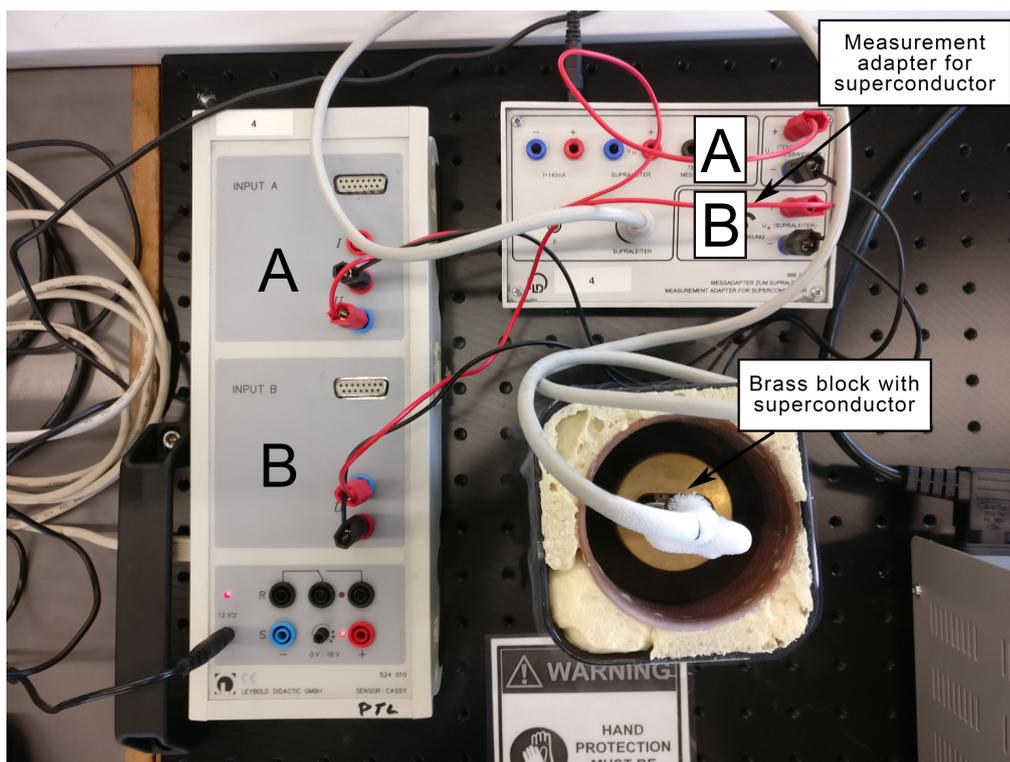
**Figure 1:** Temperature dependence of resistance in a metal and a superconductor

Superconductivity cannot be understood as an extension of ordinary conductivity. The abruptness with which the resistance disappears completely suggests that at  $T_c$ , an ordinary conductor makes a transition to a totally different state of matter. This superconducting phase cannot be explained without quantum physics. This will be taught in more detail in the second year of most physics courses at University. Superconductors are usually made of ceramic materials e.g.  $\text{Bi}_{1.8}\text{Pb}_{0.26}\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10+x}$ . The value of  $T_c$  is non-uniform due to the variations in  $x$ .

### 3. The Experiment

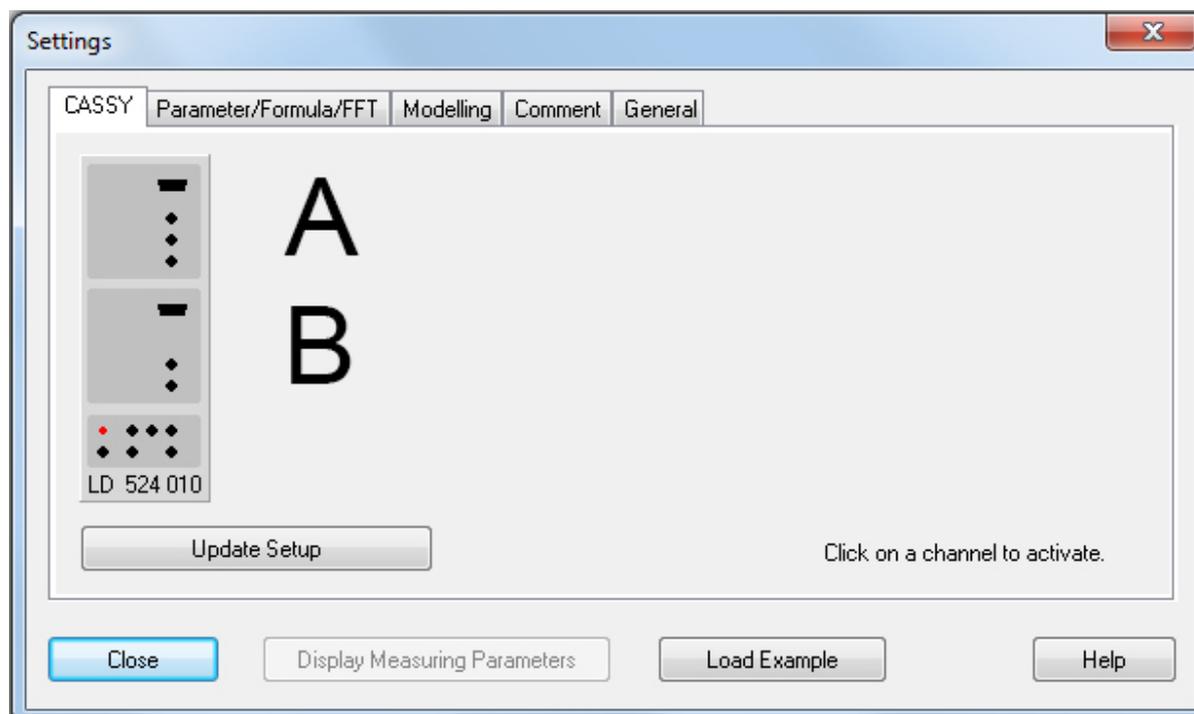
#### 3.1 Critical Temperature of a Superconductor

1. The CASSY interface is used to acquire data. Temperature and resistance are measured using an adapted box labelled 'measurement adapter for superconductor' as shown in Figure 2. Make sure the adapter is plugged in and switched on.



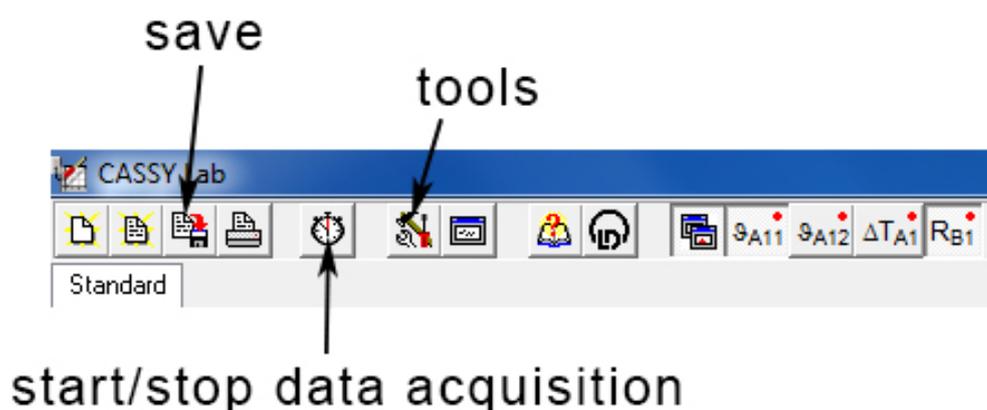
**Figure 2:** Arrangement for measuring the critical temperature of a superconductor.

2. On the adapter box is a connection labelled 'supraleiter'. You connect the superconductor which is inserted into the brass block to the supraleiter.
3. The temperature is transferred to the computer through CASSY. The temperature is measured by a platinum resistance thermometer, in the same circuit as the superconductor, that is linearised and converted to a voltage signal of 0 to 200mV corresponding to a temperature range 0 to -200°C. To get the sensible readings you must connect A to A and B to B as shown in Figure 2 and connect red to blue and vice versa.
4. After opening CASSY Lab software, a screen will automatically appear. A map of the CASSY interface will pop up.



**Figure 3:** CASSY map of terminals

5. Click on terminal A on the map and choose the range of -0.3V to 0.3V. Select 'Average values'.
6. Click on terminal B on the map and choose the same range as above. Again select 'average values'.
7. To choose the graph parameters, click on the tools icon as shown in Figure 4 and choose 'display'. For the first plot have time as the x-axis and two y-axes for temperature and voltage drop. This way you will be able to see the progress of the resistance.



**Figure 4:** Icons on CASSY lab

8. In the tools 'display' panel choose 'new display' and plot the voltage drop against the temperature. This graph will allow for the determination of the critical temperature  $T_c$  of the superconductor.

**Put on your safety glasses and gloves now**

9. Immerse the superconductor and brass block in liquid nitrogen and cool to 77.4K (-195.6°C).
10. Once the nitrogen has stopped boiling ask a demonstrator to pour out the liquid nitrogen and move on to part 11.
11. Click on the clock as shown in Figure 4 to start data acquisition. Continue taking data until the critical temperature has been reached and then click the clock icon again to stop taking data.

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

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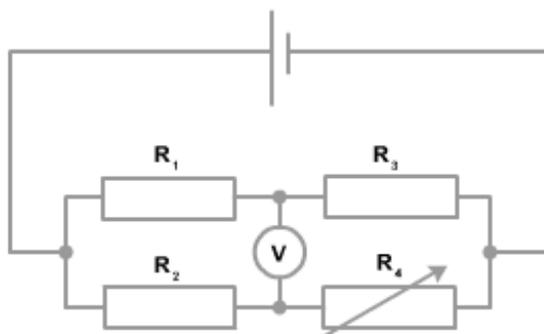
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### 3.2 Data Analysis

You should now have a graph with temperature on the x-axis and resistance on the y-axis. Use this graph to determine the critical temperature of the superconductor.

### Appendix The Wheatstone Bridge



The circuit shown above is called a Wheatstone bridge circuit. It can be used to find the resistance of a resistor or it can be used with sensors, such as thermistors, to make measurements.

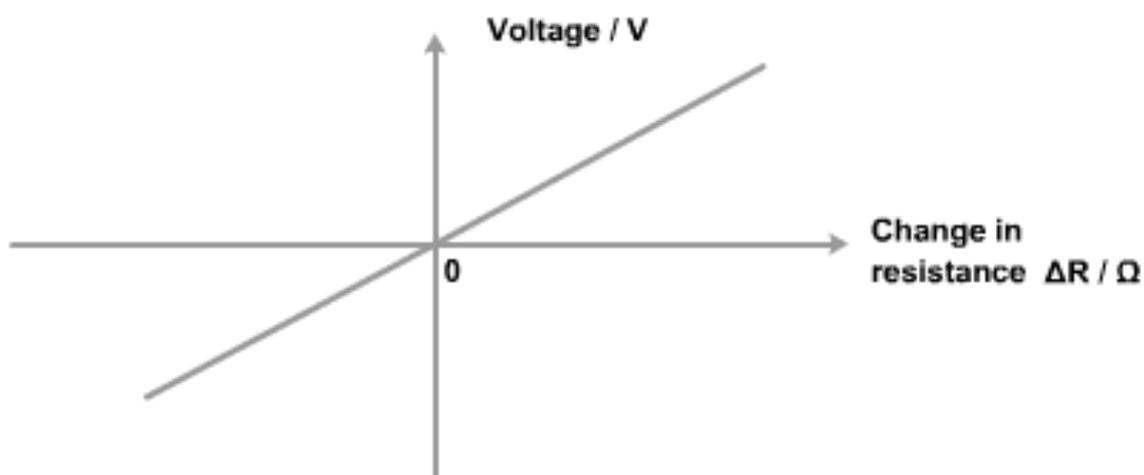
The variable resistor,  $R_4$ , is adjusted until the voltmeter reads zero volts. At this point we say that the bridge is balanced.



When a Wheatstone bridge is balanced  $R_1/R_2 = R_3/R_4$ . If we know the value of three of the resistors in a balanced Wheatstone bridge circuit, we can calculate the value of the fourth resistor.

If a Wheatstone bridge is balanced the voltmeter will have a zero reading.

If the bridge is put out of balance by altering the resistance of one of the resistors, a reading will be obtained on the voltmeter. The reading on the voltmeter is proportional to the change in the resistance of the resistor.



The graph above shows that voltage is proportional to the change in resistance. However, it is important to note that this is true only when the change in resistance is very small. Large changes in resistance are not proportional to voltage.