

## Solid-state physics

Conduction phenomena

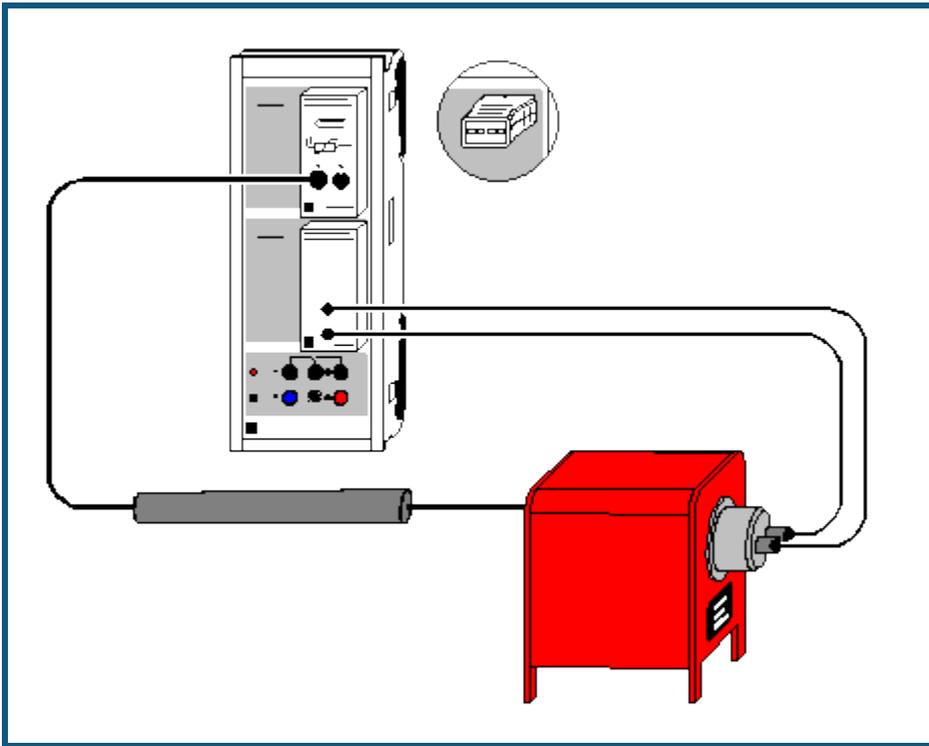
*Electrical conductivity in solids*

Measuring the temperature-dependency of a noble-metal resistor

### Description from CASSY Lab 2

For loading examples and settings, please use the CASSY Lab 2 help.

## Electrical conduction in solid bodies



can also be carried out with [Pocket-CASSY](#) and [Mobile-CASSY](#)

### Experiment description

The temperature-dependency of the specific resistance  $R$  is a simple test for models of electric conductivity in conductors and semiconductors. In electrical conductors,  $R$  rises with the temperature, as the collisions of the quasi-free electrons from the conduction band with the incomplete atoms of the conductor play an increasing role. In semiconductors, on the other hand, the resistance decreases as the temperature increases since more and more electrons move from the valence band to the conduction band, thus contributing to the conductivity.

This experiment measures the resistance values of a noble-metal resistor and a semiconductor resistor as a function of the temperature. For the noble metal resistor, the relationship

$$R = R_0 \cdot (1 + \alpha \cdot \vartheta) \quad (R_0: \text{resistance at } \vartheta = 0 \text{ } ^\circ\text{C})$$

is verified with sufficient accuracy in the temperature range under study. For the semiconductor resistor, the evaluation reveals a dependency with the form

$$R \propto e^{\Delta E/2kT} \quad (k = 1.38 \cdot 10^{-23} \text{ J/K: Boltzmann constant})$$

with the energy band interval  $\Delta E$ .

### Equipment list

1	<a href="#">Sensor-CASSY</a>	524 010 or 524 013
1	<a href="#">CASSY Lab 2</a>	524 220
1	<a href="#">Current source box</a>	524 031
1	<a href="#">Temperature box</a>	524 045
1	Temperature sensor NiCr-Ni	666 193
	or	
1	<a href="#">NiCr-Ni adapter S</a>	524 0673
1	Temperature sensor NiCr-Ni, type K	529 676
1	Noble metal resistor	586 80
1	Semiconductor resistor 5 k $\Omega$	586 821
1	Electric oven, 230 V	555 81
1	Safety connecting box	502 061

- 2 Connecting leads, 100 cm, black 500 444  
 1 PC with Windows XP/Vista/7/8

### Experiment setup (see drawing)

The temperature box at Sensor-CASSY input A measures the temperature of the sensor in the electric oven. Insert the measuring tip into the hole on the back of the oven so that the tip is in direct proximity to the resistor element. The current supply box at input B registers the electrical resistance.

### Carrying out the experiment

#### ■ Load settings

- Start the measurement with  (a value pair is recorded for every temperature increase of 5 K).
- Switch on the oven.
- Stop the measurement with  at the latest when the temperature reaches 470 K (approx. 200 °C).
- Switch off the oven and remove the resistor.
- When the oven has cooled off repeat the measurement with a different resistor.

### Evaluation

When a noble metal (platinum) resistor is used, we obtain a linear increase in resistance as the temperature rises. The temperature coefficient  $\alpha$  of the resistor can be determined easily by fitting a [straight line](#). In this example we observe an increase in resistance of 0.407  $\Omega$ /K and a resistance of 100  $\Omega$  at 0 °C, i.e.  $\alpha = 0.00407$  /K. This agrees very well with the literature value  $\alpha = 0.00392$  /K for platinum.

The resistance of the semiconductor resistor does not decrease linearly as the temperature rises. By fitting a [Free Fit](#) we can confirm the relationship  $R \propto e^{\Delta E/2kT}$ . In the example, this gives us  $\Delta E/2k = 4000$  K for the semiconductor used here, i.e.  $\Delta E = 11.0 \cdot 10^{-20}$  J = 0.69 eV (1 eV =  $1.602 \cdot 10^{-19}$  J).

### Remarks

The measurement will work also during the cooling phase. Then, the error caused by the temperature difference between the temperature sensor and the resistor is smaller, since the cooling phase lasts much longer than the warm-up phase.

When using the old semiconductor resistor (586 82), use the **Settings (noble metal resistor)** for the correct resistance range.