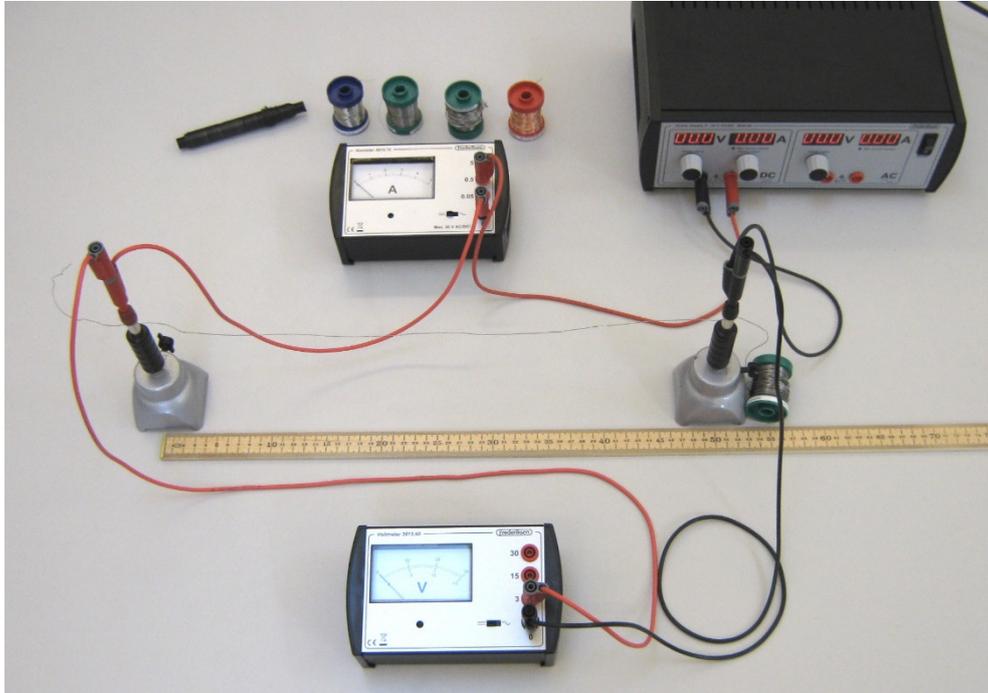


Experiment number	136060-EN	Topic	Electricity		
Version	2017-02-27 / HS	Type	Student exercise	Suggested for	grade 7-10
					p. 1/4



## Objective

To investigate how the resistance in a metal wire depends on the material, the length and diameter.

## Principle

Different metal wires are stretched between two terminal posts. The current through the wire and the voltage across it are measured. The resistance of the wire is found by using Ohm's law.

## Equipment

(Complete list on p. 4)

Power supply (5 A is required)

Voltmeter, ammeter

- 113520 Copper wire un-insol. 0.50 mm
- 114520 Constantan wire 0.50 mm
- 115510 Kanthal wire 0.25 mm
- 115520 Kanthal wire 0.50 mm
- 115530 Kanthal wire 1.00 mm
- 116000 Iron wire 0.5 mm

Stand material

Lab leads

Ruler, 1 m

## Using multimeters

Instead of Frederiksen's analog instruments, you may want to use digital multimeters.

### As an ammeter

Quite large currents are used – up to 5 A.

Look at the sockets of the multimeter: If a separate socket is marked e.g. "10 A" – use this socket together with the "Com" (common) socket.

### As a voltmeter

If the multimeter isn't of the auto-ranging kind, select a range that can measure 10 V.

If both "mV" and "V" sockets are present, use the "V" and the "Com" sockets.

## Procedure

The metal wires for this experiment can be used several times. Avoid cutting the wire unless instructed to do so.

The reel with the rest of the wire can rest next to the setup; rewind the wire after use.

When you use voltmeter and ammeter, advance systematically:

1. First, build the circuit for the **current**
2. Next, connect the voltmeter between the points where the **voltage** is to be measured

When analog instruments are used, you must every time start with the highest measuring range. If the measurement lies within the next (more sensitive) range, change to that to get more precise results

The instruments are set for DC.

If the power supply has a current limiter, turn it fully up so only the voltage is adjusted. Every time the wire is changed, the voltage must be turned down to 0.

### 1 – Same wire – varying length

For this part you will use a **0.50 mm Kanthal wire**.

The wire should be properly tightened to the stand poles with approx. 25 cm between them when the wire is taut.

Don't waste time trying to make the length precisely 25 cm – just measure the actual distance accurately and enter it into the table.

Turn up to let about 0.75 A run through the wire.

Again: Adjust until you are in the vicinity of 0.75 A but read the precise value of the current and write it down.

Write down the voltmeter read on the voltmeter as well.

Turn down and repeat with the other wire lengths in the table.

### 2 – Fixed length – varying material and diameter

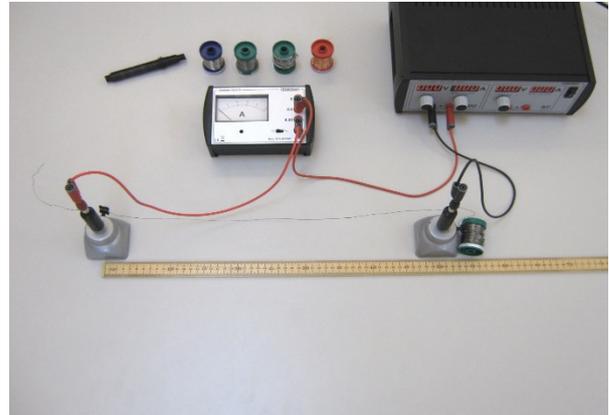
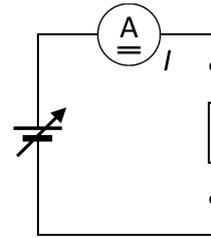
In this part, the wires all have a **length of 1 m** between the binding posts.

You will compare different wires with the same length so this should be controlled within 2-3 mm.

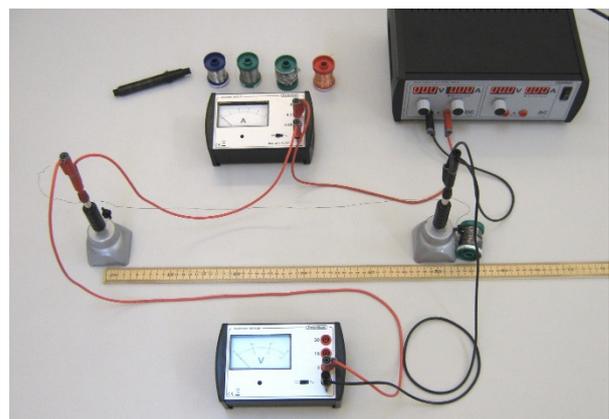
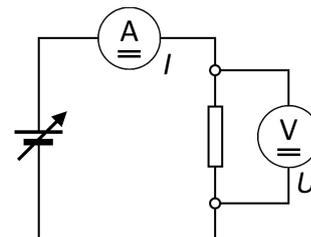
The results are recorded in a copy of table 2 (next page).

For two of the wires, the current defines the measurement (like in part 1) – for the rest, the voltage is used to set the conditions. See table 2.

In all case, the precise values of voltage and current are recorded.



1 First the circuit for the current ...



2 ... next, add the voltmeter

## Tables for the results

Make a copy of the two tables below.

Note: Only fill out the grey fields initially! (The rest of the table is explained in the text.)

### Variation of length

(Table 1)

Length	Voltage	Current	Resistance
L / m	U / V	I / A	R / $\Omega$
apx. 0.25 m (measured)	(measured)	apx. 0.75 A (measured)	(calculated)
apx. 0.50 m (measured)	(measured)	apx. 0.75 A (measured)	(calculated)
apx. 0.75 m (measured)	(measured)	apx. 0.75 A (measured)	(calculated)
apx. 1.00 m (measured)	(measured)	apx. 0.75 A (measured)	(calculated)

### Variation of material and diameter

(Table 2)

Material	Diameter	Voltage	Current	Resistance
	d / mm	U / V	I / A	R / $\Omega$
Iron	0.50	(measured)	apx. 2.5 A (measured)	(calculated)
Copper	0.50	(measured)	apx. 5.0 A (measured)	(calculated)
Constantan	0.50	apx. 3 V (measured)	(measured)	(calculated)
Kanthal	0.50	apx. 3 V (measured)	(measured)	(calculated)
Kanthal	0.25	apx. 10 V (measured)	(measured)	(calculated)
Kanthal	1.00	apx. 2.5 V (measured)	(measured)	(calculated)

## Theory

The relation between the voltage  $U$  across a conductor and the current  $I$  through it is

$$U = R \cdot I$$

Where  $R$  is the *resistance* of the conductor. This relationship is called Ohm's law.

As we will calculate the resistance  $R$ , we solve the equation for this:

$$R = \frac{U}{I}$$

When a formula (like this) is used, you need to take care about the units. If some results are written down in mV or mA, they are converted to V and A, before they are entered into the expression.

## Calculations etc.

Calculate the resistance for all measurements. (The column  $R$  in both tables.)

In the first part, you determine the resistance of different lengths of a given wire. Plot the resistance as a function of the length.

In the second part, you find (among other) how the resistance of 1 m Kanthal wire varies with the diameter. Plot the resistance as a function of the diameter.

## More calculations etc.

(Ask your teacher if you should skip or complete this section.)

For the measurement series with varying diameter, add two columns to the table: The cross-section area  $a$ , and  $1/a$ .

Make a new graph with  $R$  as a function of  $1/a$ .

## Discussion and evaluation

Based on the two graphs you have drawn, try to formulate some rules for the resistance of a wire of a given material:

- A rule about resistance and wire length when the diameter is kept constant.
- A rule about the resistance and the diameter of the wire when its length is kept constant.

(If you completed "More calculations etc.":

The second rule could instead be about resistance and cross-section area.)

In the second part, you measured four wires of different metals which had the same dimensions. Arrange a list of these metals in order from the smallest to the largest resistance.

Which of these metals is the better choice for electric cables? (Why?)

## Teacher's notes

### Concepts used

Voltage  
Current  
Resistance

Please note that resistivity is not used in this lab manual. If you wish, this exercise can be used as a prelude to a treatment of this concept.

### Mathematical skills

Graphs  
Evaluation of a simple expression  
Proportionality \*)

\*) The basic results can just as well be described in qualitative terms.

The "More calculations etc." section is added to make a more quantitative approach possible.

### About the equipment

The specified currents and voltages have been chosen to fit the dimensions and materials of the wires indicated in the equipment list. The choices ensure that the instruments can be read without too much inconvenience – while keeping the wires from getting too hot. When using other kinds of wire, it is the teacher's responsibility to check that these conditions are still fulfilled.

The meters 381560 and 381570 are protected against overload. They will also tolerate wrong polarity although only positive values can be read.

It is possible to read the current on the power supply's built-in ammeter if you wish to avoid an external meter.

However, it would be pedagogically undesirable to use a built-in voltmeter. It would not present any problems with precision in this exercise, but the students should get used to connecting a voltmeter across just the component being measured.

## Detailed equipment list

### Specifically for the experiment

381570	Ammeter	
381560	Voltmeter	
113520	Copper wire un-insol. 0.50 mm	
114520	Constantan wire 0,50 mm	
115510	Kanthal wire 0.25 mm	
115520	Kanthal wire 0.50 mm	
115530	Kanthal wire 1.00 mm	
116000	Iron wire 0.5 mm	

### Standard lab equipment

364000	Power supply (must be able to deliver 5 A)	
435030	Terminal posts, set of two	
000410	Retort stand base, square	(2 used)
Safety cables, silicone:		
105720	50 cm, black	
105721	50 cm, red	(2 used)
105740	100 cm, black	
105741	100 cm, red	
140510	Ruler, wood, 100 cm	