# DC circuits - Lab report

$4^{th}$, $5^{th}$ June, 2018

## 1 Goal of the experiment

In this lab experience you are going to build a few simple circuits and learn to take measurements of resistance, potential differences, and *current*. You will also try to understand what happens when two *resistors* are connected "in series" or "in parallel" in the circuit.

## 2 Theoretical background

The relation between the potential difference and the current in a circuit is fixed by Ohm's first law:

$$V = RI,$$

where $V$ is the potential difference, measured in volts (V), $R$ is the electrical resistance, measured in ohms ($\Omega$), and $I$ is the electrical current, measured in amperes (A).

## 3 Lab indications

### Experimental tools

Every group will receive

- a board equipped with two 1.5 V batteries, electrical contacts (in the form of springs), three *light bulbs*, and a *potentiometer*.
- a multimeter that can measure potential differences, currents, and resistances,
- a few resistors, with different values of electrical resistance,
- a few *conducting wires*.

IMPORTANT: remember to select the right function on the *multimeter* before performing a measurement:

- For **measurements of potential differences** the multimeter must be set on “DC V”. The black *probe* must be inserted into the COM *port*, while the red probe must be inserted into the $V/\Omega$ port.

- For **measurements of currents** the multimeter must be set on “DC A”. The black probe must be inserted into the COM port, while the red probe must be inserted into the $A$ port.

- For **measurements of resistance** the multimeter must be set on “OHM”. The black probe must be inserted into the COM port, while the red probe must be inserted into the $V/\Omega$ port.

## Part 1: basic measurements

Ohm’s first law describes the behavior of a simple circuit as the one represented in Fig. 1. The circuit under consideration is composed by a battery,

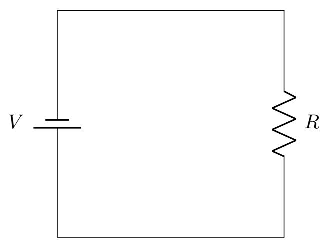


Figure 1: Sketch of a simple circuit composed by a battery and a resistor.

that *supplies* a potential difference $V$, and a single resistor with electrical resistance $R$.

$*\quad*\quad*$

*Try to build this simple circuit using the tools at your disposal.*

$*\quad*\quad*$

Measuring the potential difference at the two ends of the resistor with a *voltmeter*, as in Fig. 2, and the current in the circuit with an *ammeter*, as in Fig. 3, you can obtain the values of $V$ and $I$ and calculate the value of the resistance $R$.

$*\quad*\quad*$

*IMPORTANT: you don’t have a voltmeter and an ammeter. You have a multimeter that can do the work of both these two instruments. Remember that in order to measure potential differences the multimeter must be connected* *"in parallel". On the other hand, to measure currents it must be connected "in series". See Fig. 2 and Fig. 3 for reference.*

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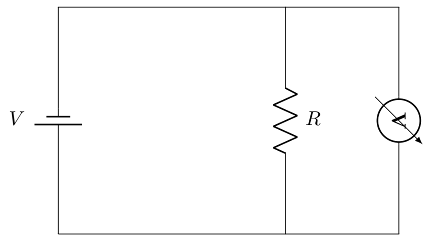


Figure 2: Sketch of a circuit composed by a battery and a resistor, with a voltmeter connected "in parallel" at the two ends of the resistor.

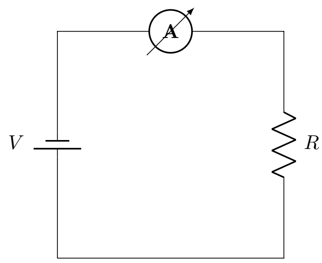


Figure 3: Sketch of a circuit composed by a battery and a resistor, with an ammeter connected "in series" between one of the poles of the battery and the resistor.

- $V =$ ............
- $I =$ ............
- $R =$ ............

To check the correctness of your calculation you can now measure directly the electrical resistance of the resistor using the multimeter.

- $R_{\text{measured}} =$ ............

Do the two values coincide?
...........................................................................
...........................................................................

## Part 2: resistors in series

To begin we clarify the meaning of "connecting two (or more) resistors (or other electrical components) in series".

Electrical components connected **in series** are connected along a single path, so **the same current flows through all of the components**.

The simplest circuit with two resistors in series is the one shown in Fig. 4. Notice that, to go from one pole of the battery to the other, the current flows around the circuit and passes through the two resistors.

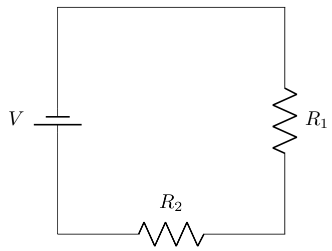


Figure 4: Sketch of a circuit composed by a battery and two resistors connected in series.

* * *

*Try to build this simple circuit using the tools at your disposal.*

* * *

How can we describe this circuit that includes more than one resistor? Again with Ohm's first law! In order to do so we have to use a concept *named* "equivalent resistance". In practice we think of a simplified version of the circuit in which the two resistors are replaced by a single resistor that has an effect "equivalent" to the one of the two separate resistors. In this part of the experiment we will find out what is the value of this "equivalent resistance" for our circuit. Start by measuring the potential difference between a point before the first resistor and a second point after the second resistor , as in Fig. 5. This will give you the value of the potential difference supplied by the battery. Then measure the current, as in Fig. 6. Try to connect the ammeter in different places around the circuit: you will see that the value of the current is always constant. From the values of $V$ and $I$, using the relation

$$V = R_{eq} I$$

you can measure the value of the "equivalent resistance".

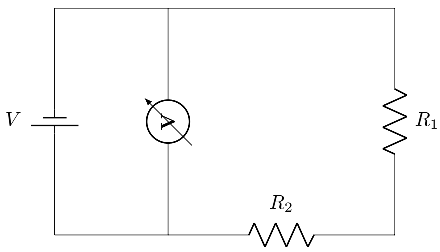


Figure 5: Sketch of a circuit composed by a battery and two resistors connected in series, with a voltmeter connected "in parallel" to a point before the first resistor and a point after the second resistor.

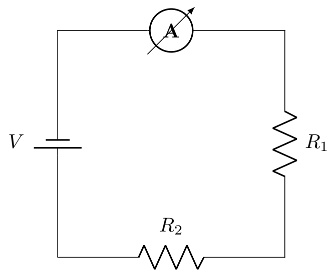


Figure 6: Sketch of a circuit composed by a battery and and two resistors connected in series, with an ammeter connected "in series" between one of the poles of the battery and one of the two resistors.

- $V = \ldots\ldots\ldots\ldots$
- $I = \ldots\ldots\ldots\ldots$
- $R_{eq} = \ldots\ldots\ldots\ldots$

Now use the multimeter to measure the resistance of the two resistors.

- $R_1 = \ldots\ldots\ldots\ldots$
- $R_2 = \ldots\ldots\ldots\ldots$

What do you observe?
.......................................................................
.......................................................................

Now repeat this experiment using two resistors that have different values of the resistance.

- $V = \ldots\ldots\ldots\ldots$
- $I = \ldots\ldots\ldots\ldots$

- $R_{eq} = \dots\dots\dots\dots$

Now use the multimeter to measure the resistance of the two resistors.

- $R_1 = \dots\dots\dots\dots$
- $R_2 = \dots\dots\dots\dots$

What do you observe?
............................................................................
............................................................................
Now you should be able to guess what is the relation between the "equivalent resistance" $R_{eq}$ , and the resistance of the two resistors $R_!$ and $R_2$.

$$R_{eq} = \dots\dots\dots\dots$$

What result do you obtain if you measure the potential difference between a point before the first resistor and one between the two resistors? And if you measure the between a point between the two resistors and one after the second resistor?

- $V_1 = \dots\dots\dots\dots$
- $V_2 = \dots\dots\dots\dots$

Now calculate the following values

- $R_1 I = \dots\dots\dots\dots$
- $R_2 I = \dots\dots\dots\dots$

What do you observe?
............................................................................
............................................................................

## Part 3: resistors in parallel

If two or more components in a circuit are connected **in parallel** it means that they have the **same potential difference** (voltage) *across their ends*. The potential differences across the components are the same in *magnitude*, and they also have identical *polarities*.

The simplest circuit with two resistors in parallel is the one shown in Fig. 7. While in the circuit with two resistors in series the same current flows across all the components of the circuits, in the circuit of Fig. 7 this does not happen. When the flow of charges reaches the points $A$ and $B$, some of them follow the path that goes through $R_1$ while the others follow the path going through $R_2$.

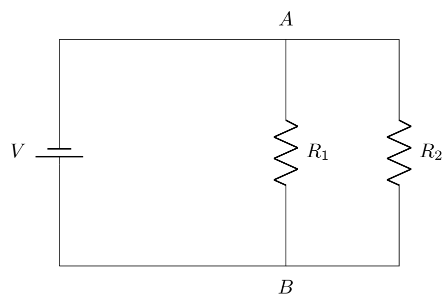


Figure 7: Sketch of a circuit composed by a battery and two resistors connected in parallel.

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*Try to build this simple circuit using the tools at your disposal. IMPORTANT: the first time you build the circuit use two resistors that have the same electrical resistance.*

* * *

Again, in order to describe this circuit with Ohm's first law, we think of a simplified version of the circuit in which the two resistors are replaced by a single resistor that has an effect "equivalent" to the one of the two separate resistors combined. Start by measuring the potential difference between the two ends of the second resistor, as in Fig. **??**. This will give you the value of the potential difference supplied by the battery. You can try to connect the voltmeter in other positions (e.g. at the two ends of the other resistor), and you will obtain the same result. Then measure the current, as in Fig. 9: it is important to measure between one of the poles of the battery and one of

the nodes (points $A$ and $B$) to make sure that you are measuring the total current.
From the values of $V$ and $I$, using the relation

$$V = R_{eq} I$$

you can measure the value of the "equivalent resistance" for this particular circuit. First note down the values for the resistance of the two resistors

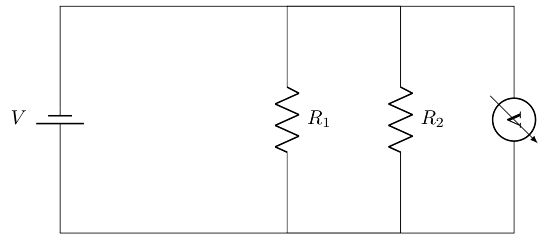


Figure 8: Sketch of a circuit composed by a battery and two resistors connected in parallel, with a voltmeter connected in parallel at the two ends of the resistor $R_2$

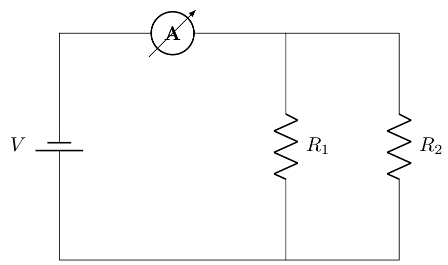


Figure 9: Sketch of a circuit composed by a battery and two resistors connected in parallel, with an ammeter connected in series between one of the poles of the battery and the first resistor.

measured with the multimeter.

- $R_1 = \ldots\ldots\ldots\ldots$
- $R_2 = \ldots\ldots\ldots\ldots$

Then fill the spaces below with the results of the measurements of potential and current and the value for the equivalent resistance obtained from Ohm's first law.

- $V = \ldots\ldots\ldots\ldots$

- $I =$ ...........

- $R_{eq} =$ ............

What do you observe?
.....................................................................
.....................................................................

Now repeat this experiment using two resistors that have different values of the resistance.

- $R_1 =$ ............

- $R_2 =$ ............

- $V =$ ............

- $I =$ ...........

- $R_{eq} =$ ............

What do you observe?
.....................................................................
.....................................................................
The equation that gives the value for the equivalent resistance of a circuit with two resistors in parallel is not as simple as the one for resistors in series. Try to complete the following formula (with numbers or mathematical operations symbols) based on the results you obtained (pay attention to the units involved!)

$$R_{eq} = \left( \frac{1}{R_1} \dots \frac{1}{R_2} \right)^{\cdots}$$

# Glossary

While reading this report you will encounter some words or expressions that you may find difficult to understand: some of them are highlighted by writing them in *italic*, and their meaning is given here below.

- current = intensità di corrente (agli inglesi piace essere sintetici)
- resistor = resistenza (in inglese si usa il termine *resistor* per indicare il componente elettrico vero e proprio che si inserisce nel circuito, e il termine *resistance* per indicare il valore della sua resistenza. Al contrario in italiano si usa il termine resistenza per indicare entrambi.)
- light bulbs = lampadine
- potentiometer = resistenza variabile
- conducting wire = filo conduttore
- multimeter = multimetro
- probe = puntale (letteralmente significa "sonda")
- port = porta/presa
- supplies = fornisce
- voltmeter = voltmetro
- ammeter = amperometro
- named = chiamato
- across their ends = tra i loro estremi
- magnitude = modulo
- polarity = polarità