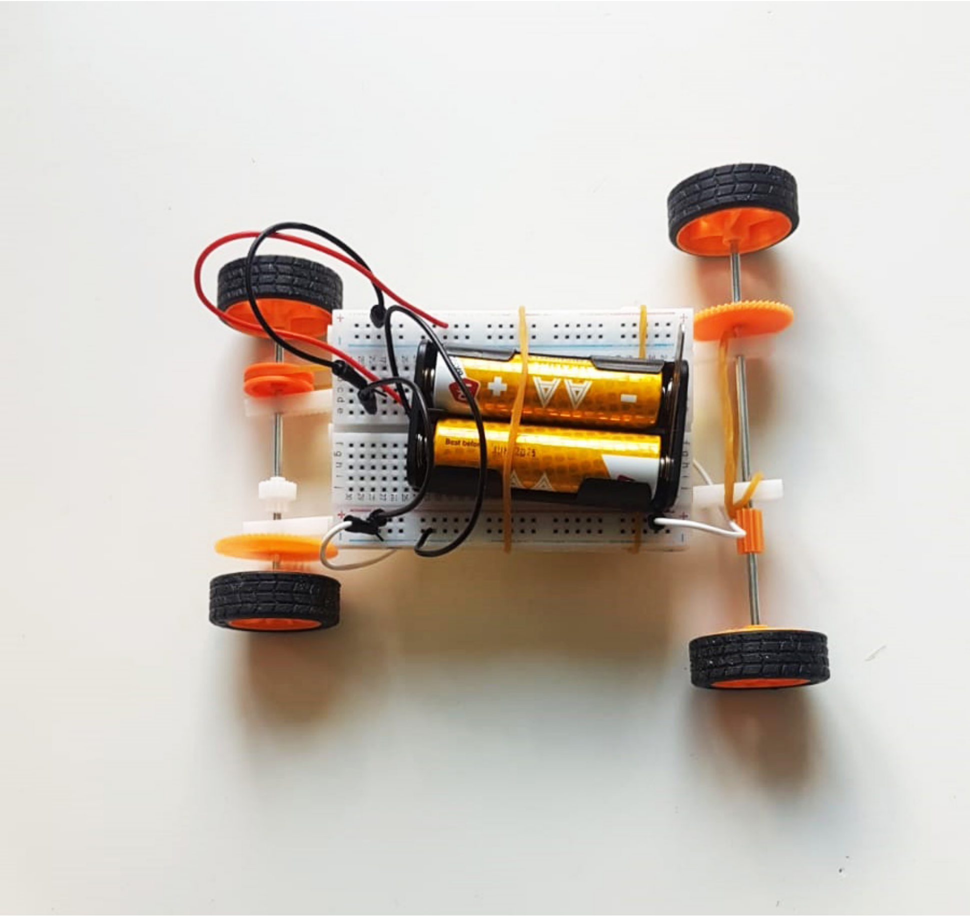
Building an electrical car



ENGINEERS WITHOUT BORDERS · NL

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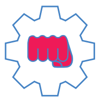
Introduction

In this workshop you are going to build a car. However, before you are able to do that, you need to learn a few things about electronics first. This workshop consists of 6 modules. If you follow all the modules, you exactly learn how to build a small electric car. But do not worry if you miss a module! In each module there is a small summary, so you can quickly learn what you need to know in order to complete the module you want to complete. And of course your fellow students and the teacher can help you if you do not understand something.

Module 1: Electronics, sensors and actuators
Module 2: The Electric motor
Module 3: Combining Circuits
Module 4: The electric car
Module 5: Workshop time
Module 6: Science fair

The modules consist of theoretical and practical parts. When you see the following icons you know if the assignment is theoretical or practical:


Theory


Practical


Safety rules

Safety rules:
It is important that you can work in a safe way. Therefore, the first thing in the Student's guide is a few safety rules.

- Never change something in the electrical circuit if it is still connected to the power source. The power source is the first thing you disconnect from the breadboard and the last thing you connect to the breadboard.
- Always connect a load and/or a resistor to your electrical circuit. Otherwise you could short circuit the electrical circuit. During a short circuit the wires and/or battery in the circuit might become too hot and be destroyed.
- Try not to touch any exposed conductors while you add or remove elements in your breadboard.

At the end of this student guide you can find a list of mistakes that are frequently made when a circuit does not work. In this way you can find the problem by yourself.

In addition to this Student's guide your teacher will provide a list of components. In this list it is explained how to use certain components.

Table of content

Module 1 - Electronics, sensors and actuators

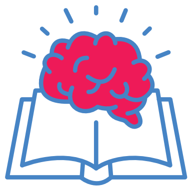
A lot is possible with electronics. In order for you to get to know these possibilities, you first need to learn the basics. Therefore you get the chance to play around with electronics in this module.

First the most basic principle of electronics will be explained, so you can make your first electrical circuit. This will be expanded during this module with the inclusion of some extra components you can add to this electrical circuit. Then you will get the opportunity to make you own electrical circuits with the components you know at the end of the module.

At the end of this module you:

- know what is essential to make a working electrical circuit and know why this is essential;
- can make a working electrical circuit that can react to surroundings;
- know what sensors such as a light sensor, a proximity sensor and a button can do in an electrical circuit;
- know what a LED is and can do in an electrical circuit;
- can use sensors and actuators in an electrical circuit.

The electrical circuit



1. What do you think is necessary to make a working electrical circuit? (Think about the icebreaker you did at the start of this module)

Now the teacher will explain something about an electrical circuit.

2. What are the necessities for an electrical circuit and why?

Now the teacher will explain something about an electrical circuit.

3. Indicate in the breadboard below which holes are connected and where you can connect the plus and minus side of the battery to the breadboard.

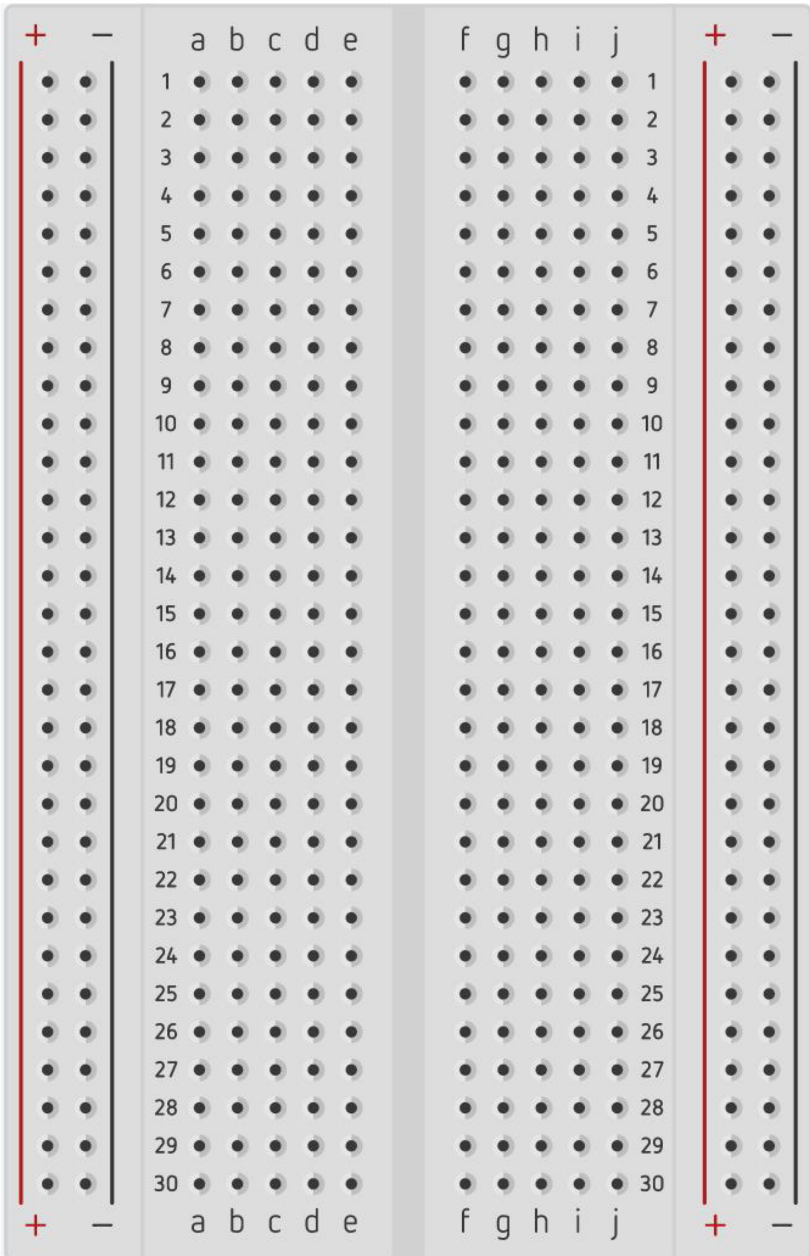


Figure 1.1. Breadboard

Practical: Make your first electrical circuit

In this practical you will learn how to make an electrical circuit.

Materials:

- Battery pack
- Jumper wires
- Button
- 220 Ω Resistor
- LED

What to do?

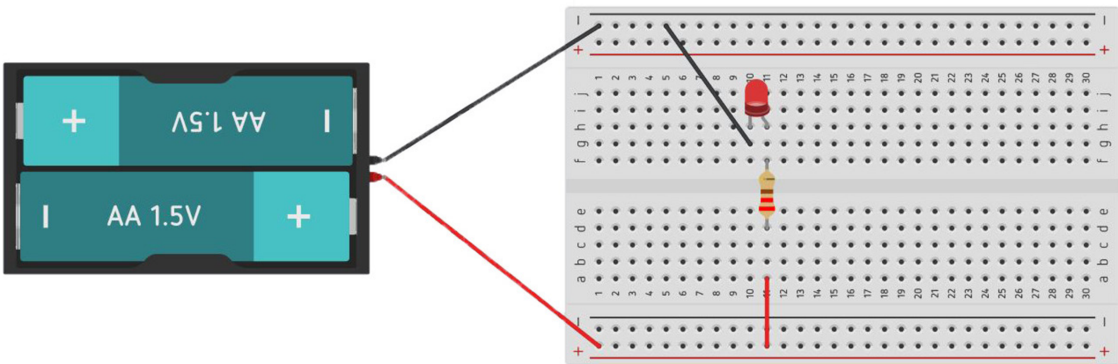
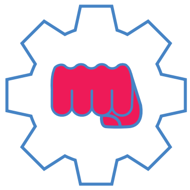


Figure 1.2. Circuit LED

Make sure you keep in mind the safety rules.

1. Put the LED somewhere in the breadboard, it does not matter where.
2. Grab the resistor and make sure it is connects the negative side/short pin of the LED to the other side of the breadboard.
3. Connect the positive side/long pin of the LED to the plus side of the breadboard.
4. Connect the resistor to the minus side of the breadboard.
5. Connect the plus side of the battery to the plus side of the breadboard you used and the minus side of the battery to the minus side of the breadboard you used.
6. If you have done everything right, your LED should be lit up.

Well done, you made your first electrical circuit!



Practical: Light? Temperature? Or a button?

Your teacher assigned you a practical that you now should work on.
This will be practical 1, 2 or 3.

Make sure you keep in mind the safety rules.

1. The .....

Now make the circuit a shown in the figure below.

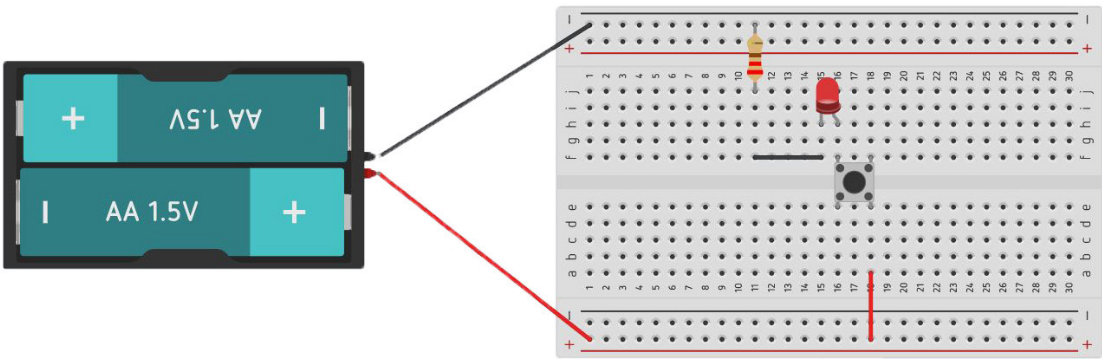


Figure 1.3. Circuit 1

4. What do you think this component does?

5. Can you think of an application of this component in a real car?

2. The .....

Now make the circuit a shown in the figure below.

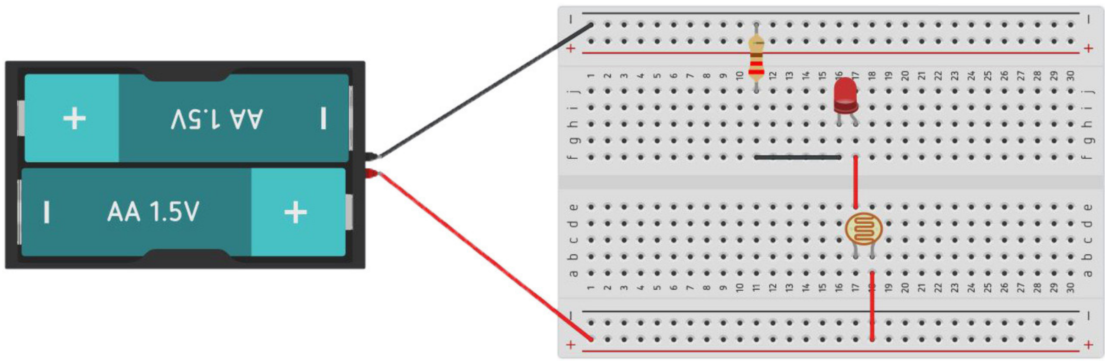


Figure 1.4. Circuit 2

6. What do you think this component does?

7. Can you think of an application of this component in a real car?

Module 1 - Electronics, sensors and actuators

3. The .....

Now make the circuit a shown in the figure below.

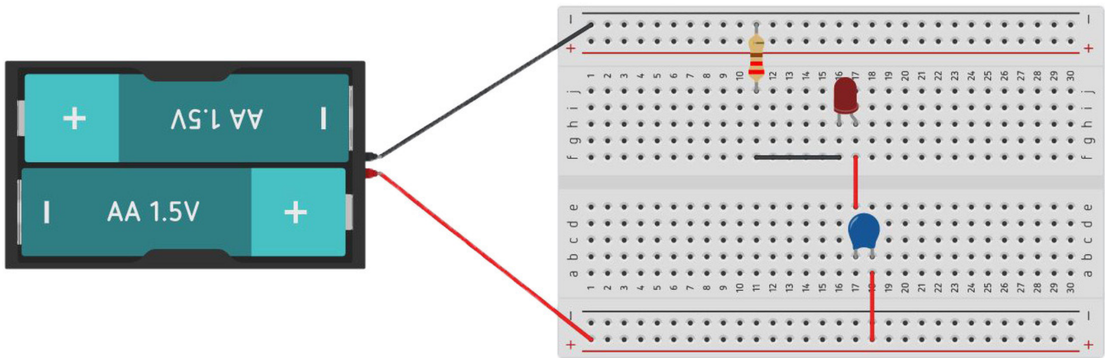


Figure 1.5. Circuit 3

8. What do you think this component does?

9. Can you think of an application of this component in a real car?

Practical: Make your own electrical circuit

Now you can try to make your own electrical circuit. Try to combine certain components or use multiple LED’s and see what happens for every example.

Make sure you keep in mind the safety rules.

You can draw your circuit in the breadboard below.

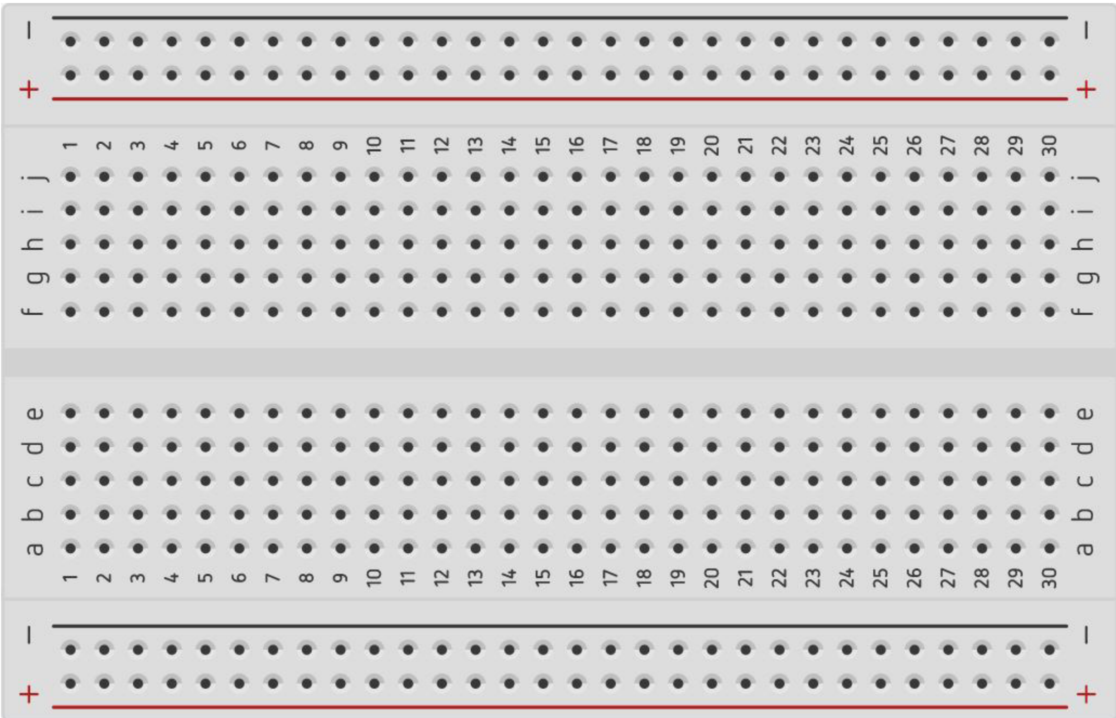


Figure 1.6. Breadboard

10. Explain how your electrical circuit works and how you can use it in a car.

Extra material

If ou want to have more challenge in this module you can try to connect a buzzer or a motor instead of the LED in a circuit. Also, you can try to find out what a proximity sensor does. If you have a working circuit with (one of) these components, then you can think of an application in an electric car. If you want to do any of the extra material, ask your teacher what components you need and how to correctly connect them.

Summary

This is a picture from a breadboard and the holes that are automatically connected.

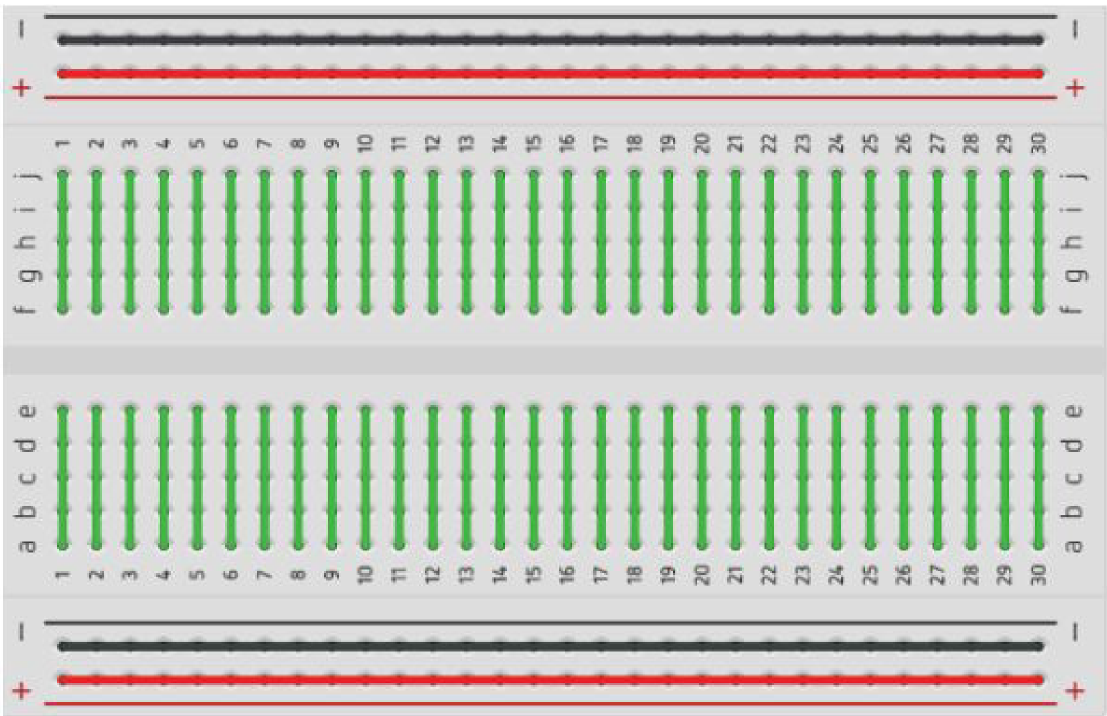


Figure 1.7. Breadboard connections

The necessities of a working electrical circuit are:

- Power source
- Closed conductive wire
- Load

Module 2 - The electric motor

One of the basic properties of a car is that it should be able to move itself. In general, a car has some kind of energy that it uses to convert to kinetic energy (motion). For example, a car driven on gasoline uses a combustion engine: chemical energy is directly converted to kinetic energy.

In this workshop, you will be building an electric motor. An electric motor is something that converts electrical energy to kinetic energy and this will be able to move your car! But how can we do this? And how is this able to move our electric car? That is what we are going to see in this module!

The module consists of one experiment which you will carry out with a partner. You will build a simple electric motor.

At the end of this module you:

- can name different types of energy
- know some daily examples of different energy conversions
- know what a magnetic field is and what the magnetic field lines mean
- know how an electric motor works
- know some examples where electric motors are used/implemented

To be able to carry out the experiments, you need to know how to connect different electrical components together to make an electrical circuit. In this module, we make use of breadboards. If you weren't present during Module 1, we suggest you to look over the summary of module 1. There, the breadboard is briefly explained. You can ask your teacher or a classmate to help if you encounter any problems during this module.

Module 2 - The electric motor

Practical: Electric motor

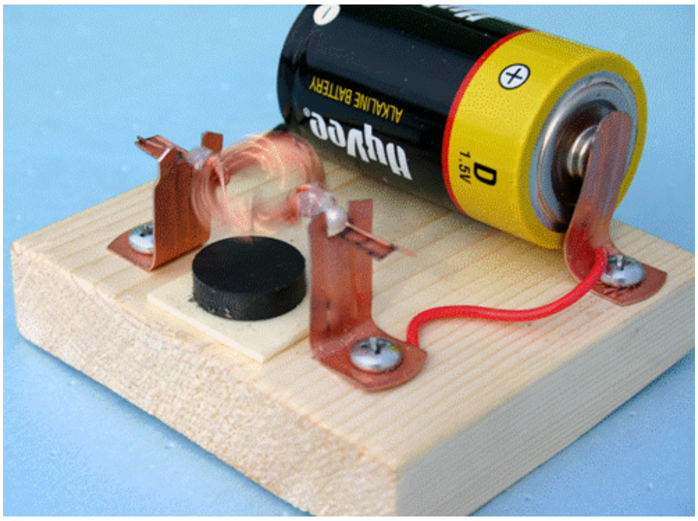


Figure 2.1. Electric motor

In this experiment you will build a simple electric motor. You will be doing this in pairs. Before we begin the experiment, it is important to know where our energy comes from and how we call this energy.

1. Complete the sentence

First, the battery converts ……………………….. energy to …………………….. energy. Then, by making use of an electric motor, the ……………………..energy is converted to ……………………… energy.

Now you can start to build a simple electric motor making use of the materials and set-up described in the next section. If you're done, you can continue to the section 'Theory' where your experiment is explained! Also, a couple of questions are included which you will answer.

Materials:

- Breadboard
- Battery pack with 2 AA batteries
- 2 jumper wires
- Magnet
- Copper wire: 1 x 2m, 2 x 3cm and 2 x 6cm
- Press button
- Piece of sandpaper
- Nipper
- Paper (1 x A4)
- Tape

Make sure you keep in mind the safety rules.

What to do?

1. Read through the materials and gather the needed components.
2. Use a nipper to create copper wires of the following lengths: one wire of 2 meters, two wires of 3 cm and two wires of 6 cm.

2 m

3 cm

6 cm

3. The copper wires have a coating. For the 2m and the 6cm wires, this coating has to be removed on the ends (this is indicated in red in the figure below). For the 2 m wire, use 3 cm for the ends. For the 6 cm wires, use 1 cm for the ends. Remove the coating by rubbing it with a piece of sandpaper.

2 m - ends of 3 cm

3 cm

6 cm - ends of 1 cm

4. Make a coil of the 2 m wire as shown in figure 2.2. Make sure you have left 5 cm on each side. The diameter of the loop should be around 2 cm. Secure the coil with the two 3cm wires by twisting them around your loop coil. Now the loop coil can't uncoil.

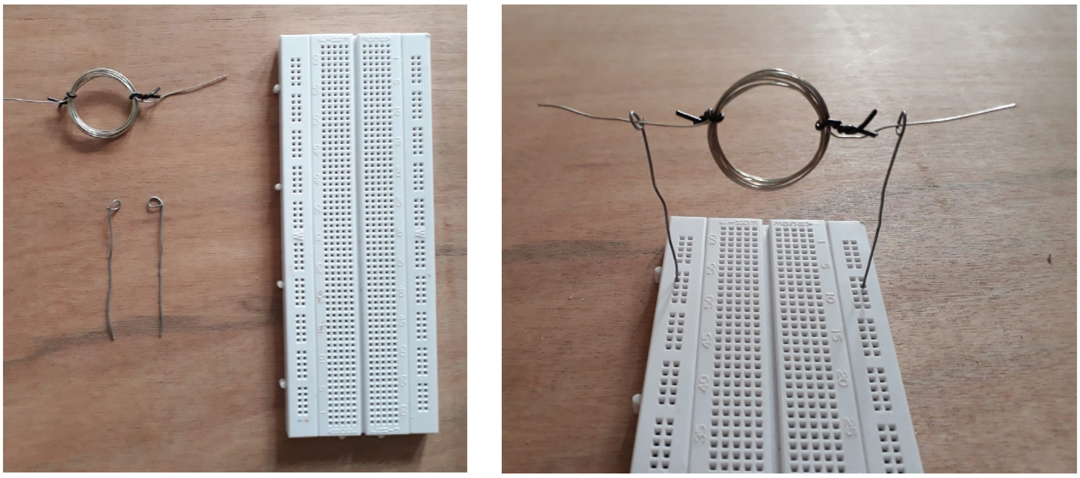


Figure 2.2. Coil

5. Make a circle at the ends of the 6 cm wires round. These will be put in the breadboard (but not yet) as in figure 2.2 with the loop coil in it.
6. Now build the following circuit as in figure 2.3. The component in the blue circle represents your loop coil as built in step 4! Note: you probably have to locate your loop coil somewhere else in the breadboard. However, the way of wiring the loop coil should be the same.

Module 2 - The electric motor

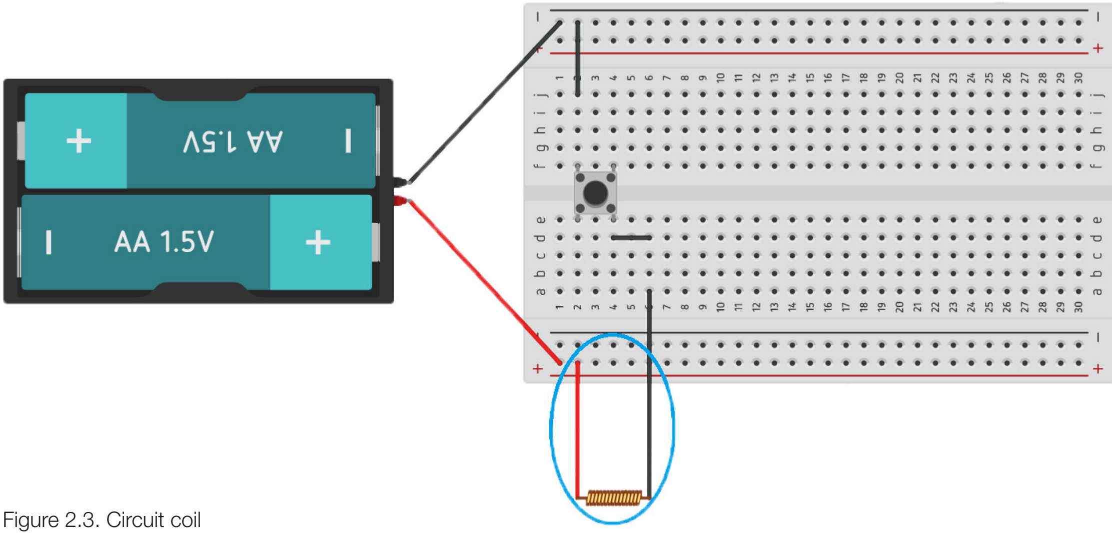


Figure 2.3. Circuit coil

7. Try out your circuit by pressing the button.
8. Now hold the magnet close to the coil. The loop coil should start turning now!

But how is this possible? This is explained in the theoretical part of the section on the next page! You can also check the summary at the end of the module.

An electric motor in an electrical circuit

The electric motor yyou have built can be used to let various things rotate (wheels, propellers etc.). An electric motor bought from the store uses exactly the same concept, but its coil and magnet are much smaller and fit in the electric motor itself. The icon for the electric motor is shown below in figure 2.4. In modules 4 and 5, you can use this component when building your own electric car!

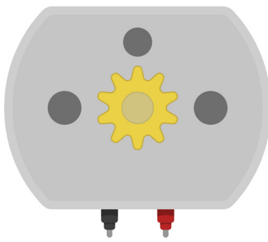


Figure 2.4. Electric motor

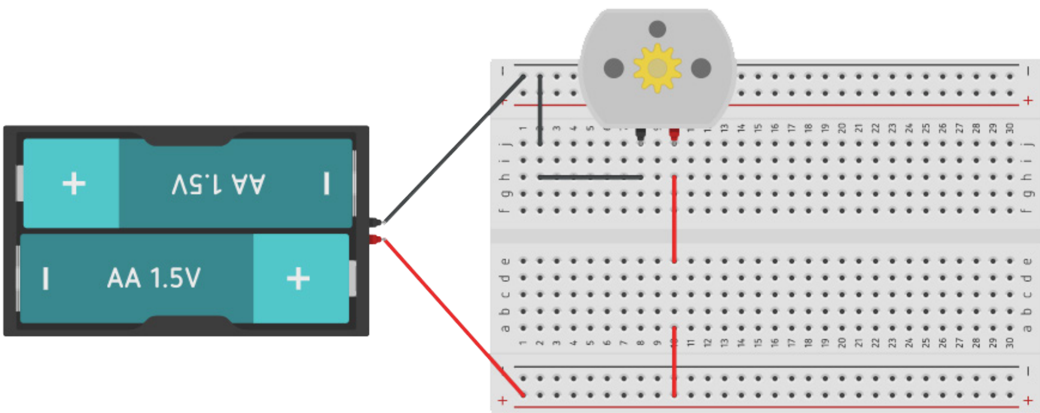
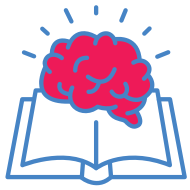


Figure 2.5. Circuit electric motor

Practical versus theoretical



Practical versus theoretical consists of two parts. One part is practical and one part is theoretical. You can choose which one you want to execute. In the practical part, you will work a bit more with the electric motor you have built. In theoretical part it is explained how your electric motor works.

Practical part

You will now try to optimise your electric motor. This means you'll try to let it rotate as fast as you can!

1. Take another external magnet. What happens when you keep the second external magnet on the other side of the coil at the same time? Can you let the coil rotate faster? (Try both sides of the magnet and experiment with positioning the two magnets)
2. Make another loop coil of 1 meter, but with a different diameter. Can you let the coil rotate faster? Note: a loop coil with a smaller diameter will have more loops than a loop coil with a greater diameter (figure 2.6).

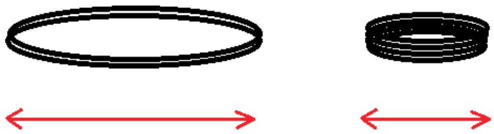


Figure 2.6. Two coils

3. Instead of having 2 batteries connected in your circuit, try it with 3 batteries. Is there a large difference?

Now you can also use the rotation of the loop coil to rotate something else.

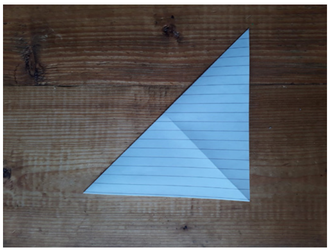
4. Fold a piece of paper into propellers using the steps below (see figure 2.7 for the example images). Attach these two propellers to the two ends of the loop coil. You can use tape to prevent the propellers from falling off (also you can use the nipper to bend the ends of the loop coil if needed).

How to fold a propeller

1. Take a square piece papers (see figure 2.7.1). Because the electric motor is quite small, the propellers should also be small: 3 x 3 cm would be a nice size. However, if this is too hard you can use a bigger square. using some tape.
2. Fold the square two times (figure 2.7.2), so it looks like the square in figure 2.7.3.
3. Cut the piece of paper from all corners to the middle, but not entirely to the middle. In figure 2.7.4 the blue lines indicate where you have to cut (in figure 2.7.5 you can see more clearly where this blue line stops.)
4. Fold the four corners as shown in figure 2.7.5). The propeller should now look like 2.7.6. You can vary the size of the propeller (figure 2.7.7), however the propeller will have to be small to fit on your electric motor.

Attach these two propellers to the two ends of the loop coil. You can use tape to prevent the propellers from falling off (also you can use the nipper to bend the ends of the loop coil if needed).


1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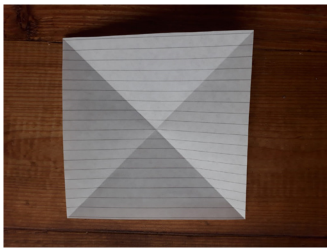
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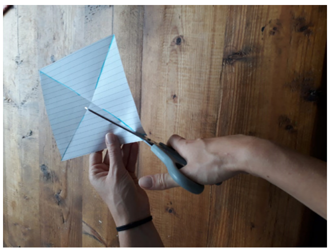
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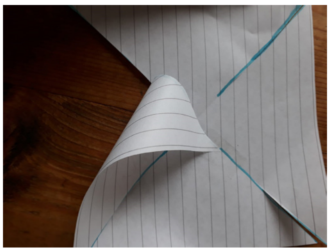
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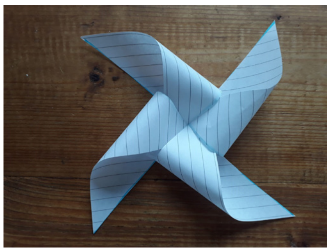
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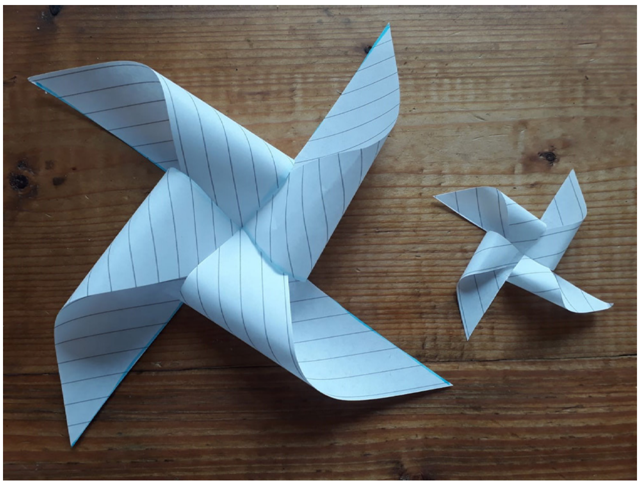
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Figure 2.7 (1-7): The steps to make a propeller.

Module 2 - The electric motor

Theoretical part
In this part, you will learn how the electric motor works. You can also always read the summary, in which it is shortly explained.

For a long time, electricity and magnetism were thought to be unrelated phenomena. But as our scientific understanding evolved over the years, it was found that electricity and magnetism are related. Every electrical current produces a magnetic field! So, to understand why our loop coil rotates, we will first look into the basics of a magnet.

Magnetic field
So how do magnets work? What you probably already know is that magnets can either attract or repulse each other. This has everything to do with the (invisible) magnetic field a magnet creates. How such a magnetic field looks like is displayed in figure 2.8. You can see lines (which are called magnetic field lines) going in and out of the magnet. Where the lines go into the magnet is called the South pole of the magnet, and where the lines go out of the magnet is called the North pole. To illustrate this, the sides of a magnet are given a different color*.

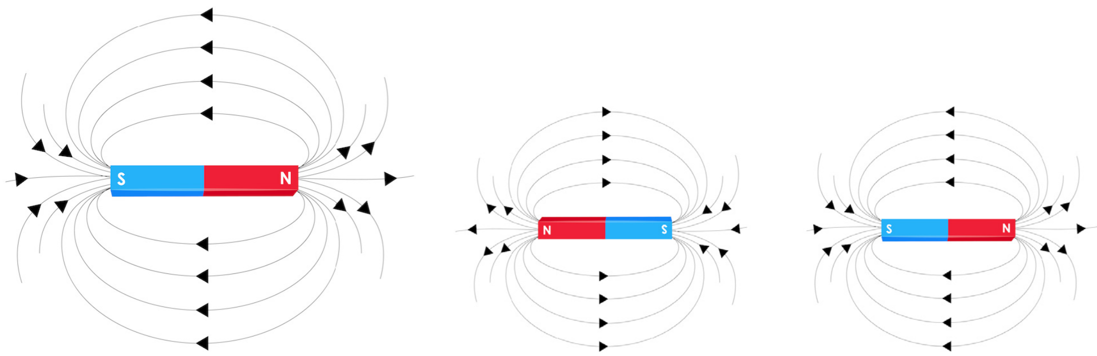


Figure 2.8. Magnetic field

Instead of drawing the whole magnetic field, it's simpler to draw one arrow that indicates the direction of the magnetic field (see figure 2.6a). The magnets repulse each other if the arrows point in the opposite direction and the other way around, they attract each other if the lines point in the same direction.

2. Draw the arrows in the magnets of the middle and right image in figure 2.9 (the left image is shown as an example).

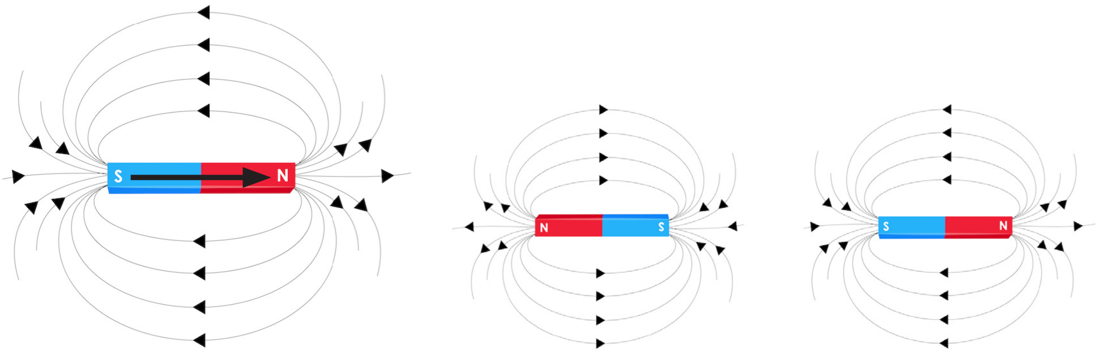


Figure 2.9. Question 2

3. See figure 2.9. Do the middle and right magnet attract or repulse each other? And if you would rotate them both so the red ends are pointing to each other?

Not only magnets produce a magnetic field, but as said earlier, a current also produces a magnetic field. The magnetic field line is circular around the current (see figure 2.10a). When we make a loop, you can see that the loop coil has a circular magnetic field all around the wire (see figure 2.10b). Here you created a magnet. You can see this more clearly in figure 2.10c where multiple loops create a big circular magnetic field. This looks exactly as the magnet described earlier!

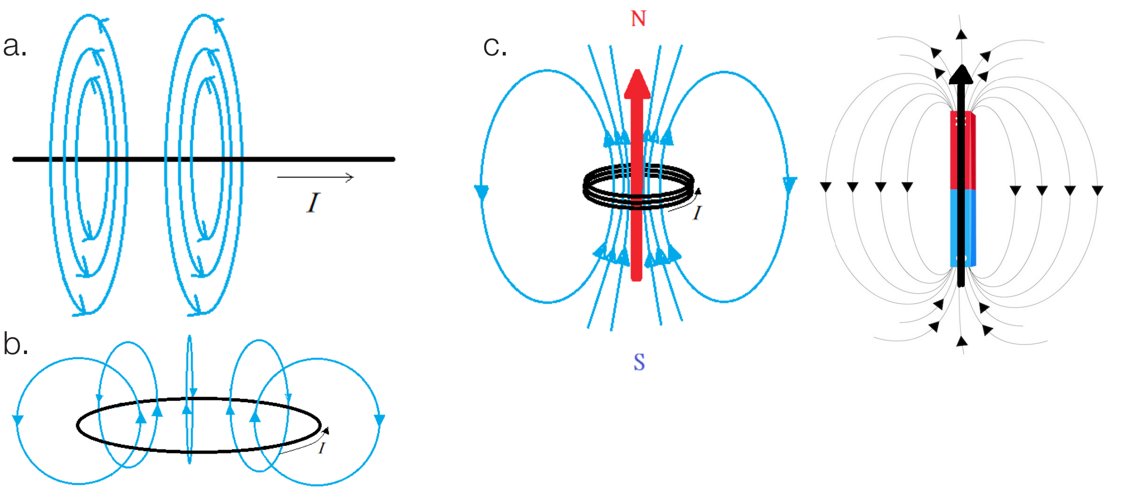


Figure 2.10 (a-c) In c, the direction of the magnetic field is shown as a red (left) and black (right) arrow. It is the same as you saw in figure 2.9.

Thus, you create a magnet by making a loop coil! And you can imagine, the more loops, the stronger its magnetic field becomes.

So if a current will produce a magnetic field, does the magnitude of the current have influence on the magnitude of the magnetic field? Yes! The bigger the current I, the bigger the magnetic field it creates.

4. Can you think of two other ways to increase the strenght of the magnetic field made by the coil? Think about ways to increase the current.

*Note; the magnets that you use are not colored. You could determine the North and South pole of your magnet by taking a magnetic compass and place it close to your magnet. The needle that normally points to the north pole of Earth should point to the South pole of your magnet.

The electric motor (advanced)

Now how does the electric motor work? When you connect a battery to your self-made coil, the coil produces a magnetic field as in figure 2.10. Because we have another external magnet, we will expect them to attract or repulse each other, as they both behave like a magnet. Now the question is, how can the coil continue rotating; why is it being attracted and repulsed?

To understand this, look at the pictures below (figure 2.11). In every position of the coil, the magnetic fields lock differently with the external magnet.

5. Does the magnet attract or repulse the loop coil in figure 2.11b? And in 2.11c?

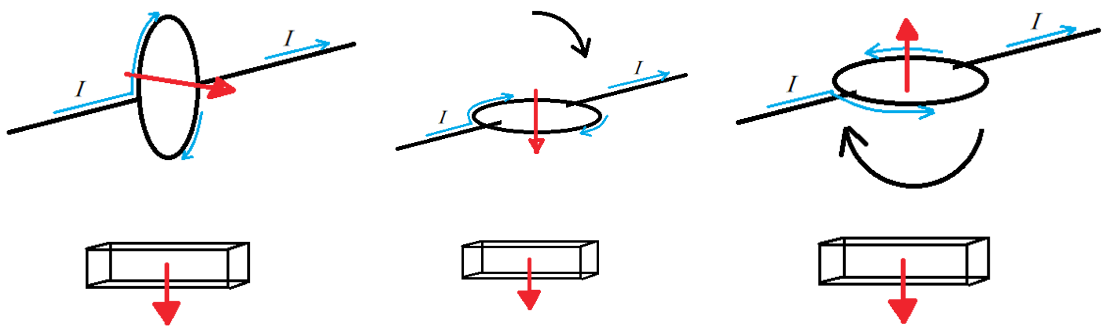


Figure 2.11: Here a loop coil rotating around its axis is shown. Under the loop coil, a magnet is placed. The I symbol with the blue arrow denotes the direction of the electrical current. The red arrows indicates the direction of the magnetic field of the loop coil and the magnet.

Now look back at question 1. We actually miss another sort of energy! This is the magnetic energy. We have to correct question 1! Answer question 6

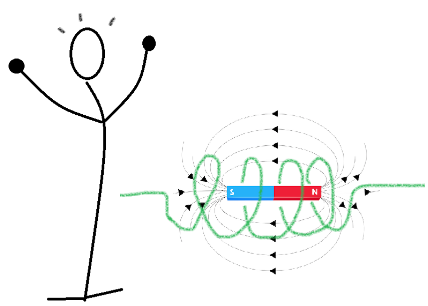
6. Complete the sentence.
First, the battery converts ……………………... energy to …………………… and ………………………….. energy. Then, by making use of an electric motor, the …………………….. energy is converted to ……………………… energy.

Thus, as you can see in figure 2.11, in many cases, the magnetic field of the coil is not pointed in the same direction as the magnetic field of the magnet. Due to this, the coil will turn until the magnetic fields do align. However, the coil cannot stop easily and continues to turn, resulting in, once again, a magnetic field of the coil which is not aligned with the field of the magnet. This keeps happening over and over and the coil will turn around and around.

If the magnetic field of either the magnet or the coil is stronger, this turning effect is stronger and the coil will spin faster. For example: increasing the current through the coil leads to a stronger magnetic field of the coil, and the coil will spin faster due to this.

Summary

In this module you built an electric motor. The energy of the battery is used to let your loop coil rotate. Here, a current in the loop coil makes the loop coil behave as a magnet! This is why the loop coil reacts to the external magnet. You can use the electric motor to rotate different things (think of propellers, wheels or the axle on which wheels are attached). This is why you will implement an electric motor in the last modules of this workshop!



Module 3 - Combining circuits

In a car there are many complex circuits, consisting of many components, for example: lights, motor and sensors. But most cars only have one battery. How can all those circuits be connected to one battery? This is one of the things you will learn in this module.

Most of you have build simple circuits in one of the previous workshops. In this module you will learn how you can combine these simple circuits, to make a more complicated circuit. The circuits you will build today will come in handy when you're going to make an electric car yourself in the next modules!

In this module you will learn:

- How you can combine smaller circuits into bigger ones;
- What a series circuits is;
- What a parallel circuit is;
- How you can combine multiple outputs (LEDs or motors)
- How you can combine different inputs (Buttons and sensors)

If you weren't present in module 1, we suggest you to read the summary of module 1. The basics of an electronic circuit are explained here and how to use a breadboard is briefly explained. You can ask your teacher or a classmate for help if you don't understand something.

Module 3 - Combining circuits

Introduction

1. In this exercise you will build a circuit containing multiple LEDs. The simplest way to do this is by putting multiple LEDs one after the other in one path.

a. Build the circuit from the picture below.

You will need:

- Breadboard
- LED
- A battery pack with 2 AA batteries
- 220Ω resistor
- 5 jumper wires

Make sure you keep in mind the safety rules.

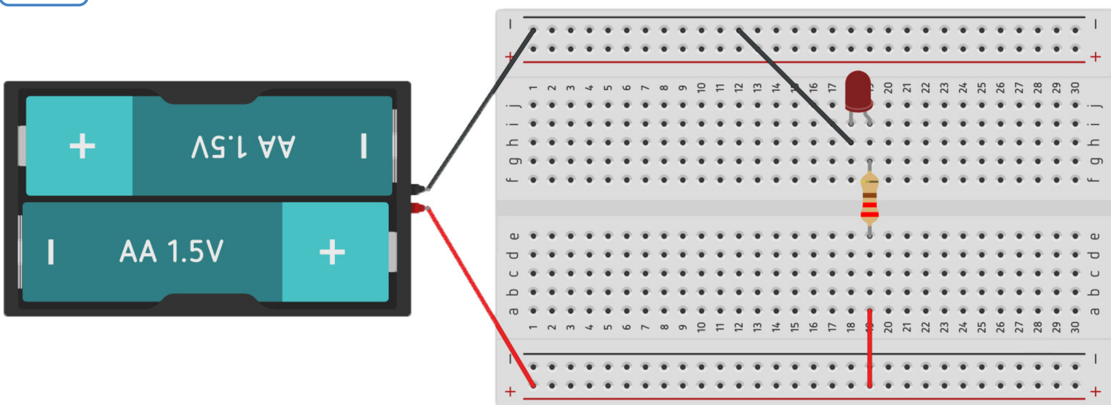


Figure 3.1: Circuit with one LED

b. Add another LED to the circuit. Connect the negative side (short leg) of the first LED to the positive side (long leg) of the new LED. Your circuit should look like the circuit in the picture below. You will need 1 Extra LED and some wires.

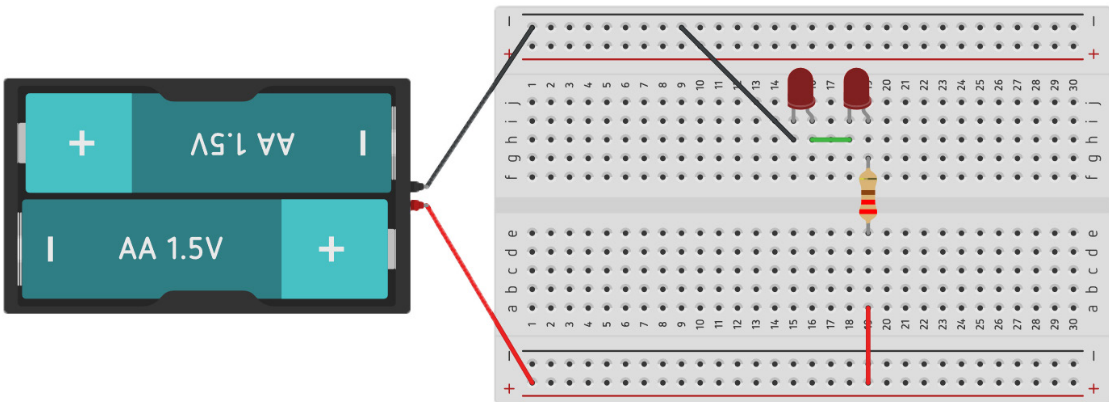


Figure 3.2: Circuit with two LEDs

c. If you look at the first LED, did anything change? If you did not see anything change try adding another LED in the circuit. What happens with the LEDs if you add more?

d. Can you add a button to this circuit in the same path, that turns only one of the LEDs on or off? Explain why you think this is possible or not. If you have time you can try to build this circuit.

2. In the previous exercise you you build a circuits with multiple LEDs.You saw that the LEDs got dimmer when you added more. In this exercise you will learn how you can make a circuit with multiple LEDs that burn brighter.

Build a circuit containing two paths, like in the picture below. You will need:

- 1 breadboard
- 2 LEDs
- 2 220 Ohm resistors (Looks like this: . Make sure the colors are correct)
- some wires

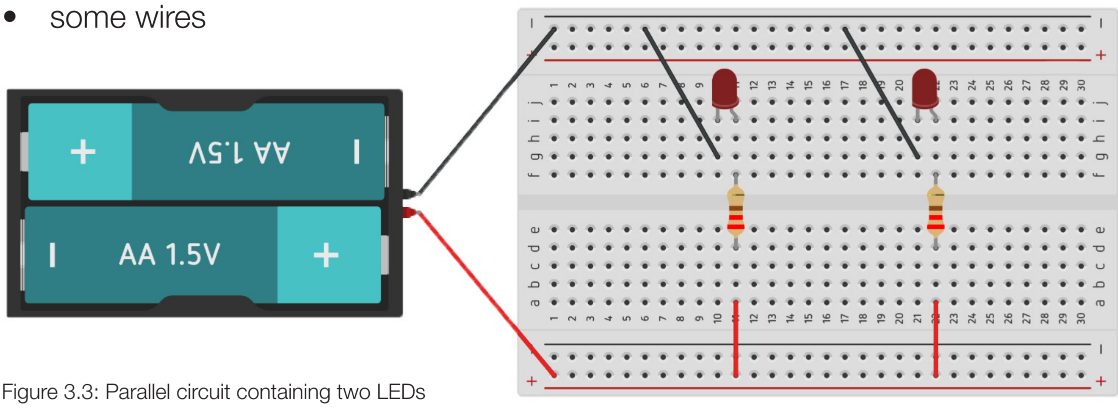
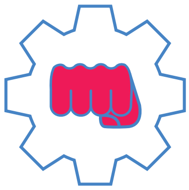


Figure 3.3: Parallel circuit containing two LEDs

Now each path contains less components. This means that in each path there is less resistance and the LEDs burn brighter! Circuits that contain only 1 path, like the circuits in exercise 1 are called series circuits. Circuits with multiple paths, like this circuit, are called parallel circuits.

Practical: Combining circuits



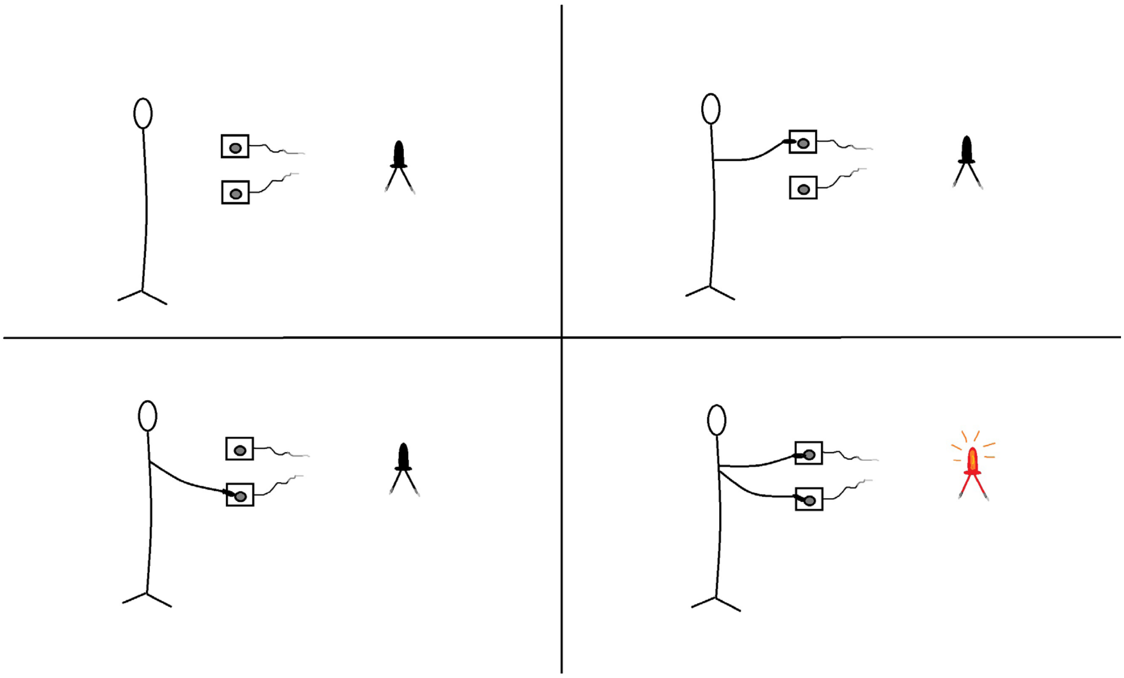
3. In this exercise you will experiment with using multiple buttons.

a. Build a circuit with the following components:

- 1 breadboard
- 1 battery pack
- 1 220 Ohm resistors
- 1 LED
- 2 buttons
- some wires

Make sure you keep in mind the safety rules.

The circuit should do this: The LED should only turn on when you press both buttons at the same time. If you press only one of the buttons the LED stays off.



b. Is the circuit you build series or parallel?

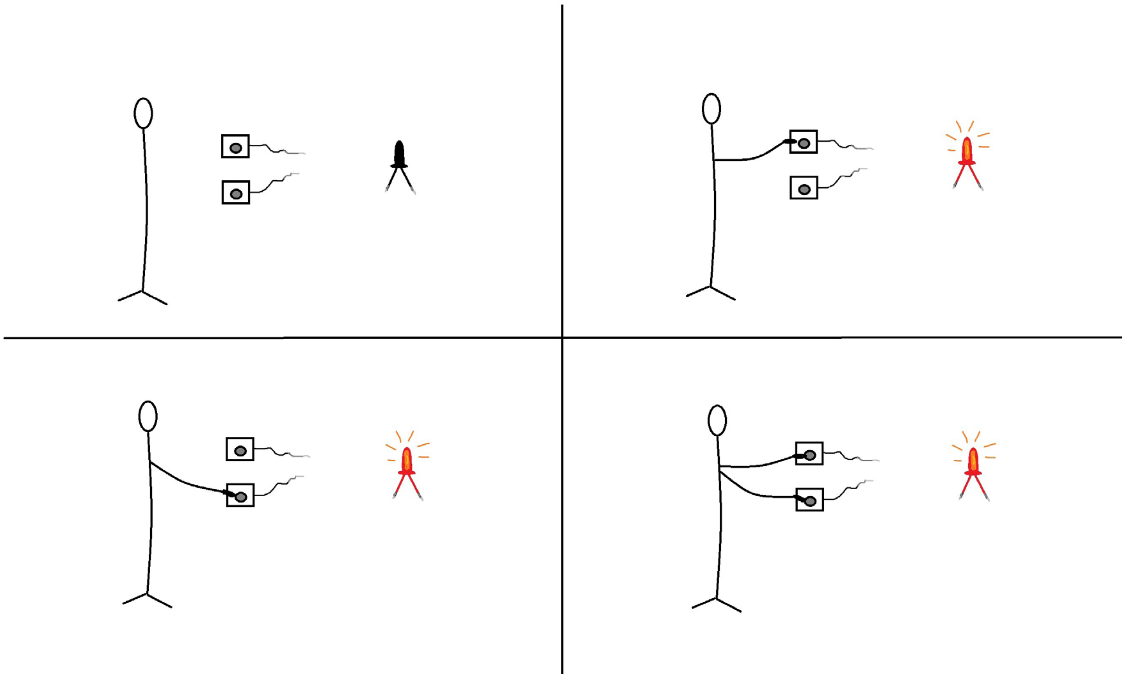
Module 3 - Combining circuits

4. In this exercise you will make a circuit with an LED that is controlled by two buttons.

a. Build a circuit with the following components:

- 1 breadboard
- 1 battery pack
- 1 220 Ohm resistors (Looks like this: . Make sure the colors are correct)
- 2 buttons
- some wires

The circuit should do this: when you press one of the buttons the LED should turn on. So it should not matter which button you press, the LED should always turn on.



b. How could a circuit with two buttons that works like this be used in a car?

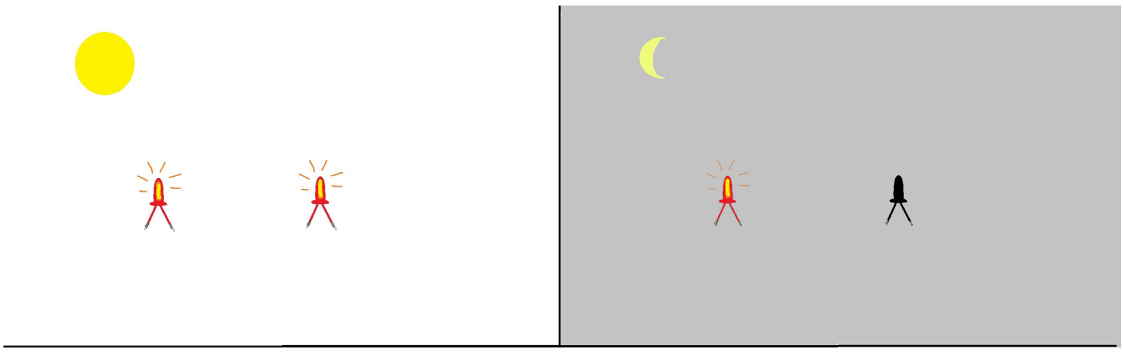
Module 3 - Combining circuits

5. In this exercise you will experiment with combining a circuit containing a sensor

a. Build a circuit containing:

- 1 breadboard
- 1 battery pack
- 1 220 Ohm resistors (Looks like this: . Make sure the colors are correct)
- 2 LEDs
- 1 LDR sensor
- some wires

The circuit should do this: One LED burns always on full brightness the other LED reacts to light using the light sensor (LDR), like in module 1.

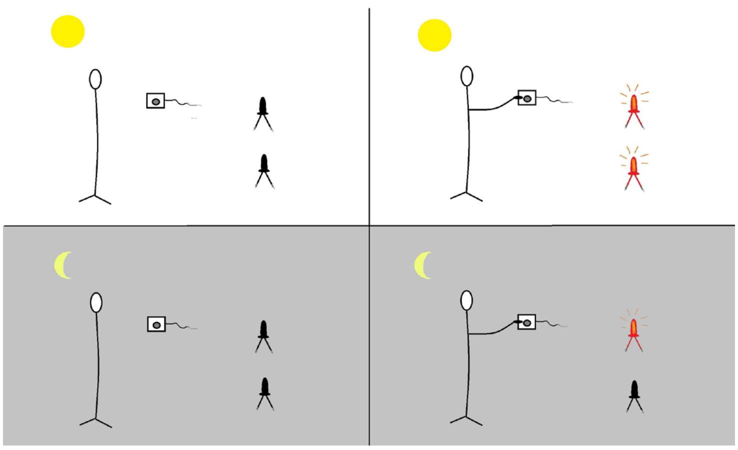


b. Is the circuit you build series or parallel?

c. Add one button to the circuit. Build a circuit that does this Both LEDs should be off when the button is not pressed. If the button is pressed one LED should always burn, the other should react to the light.

You will need:

- Your previous circuit
- 1 button
- some wires



Module 3 - Combining circuits

6. In this exercise you will build a circuit containing multiple LEDs and buttons.

a. Build a circuit with the following components:

- 1 breadboard
- 1 battery pack
- 2 220 Ohm resistors (Looks like this: . Make sure the colors are correct)
- 4 buttons
- some wires

The components should be placed on the breadboard like in the picture below. You will have to add wires to connect the components.

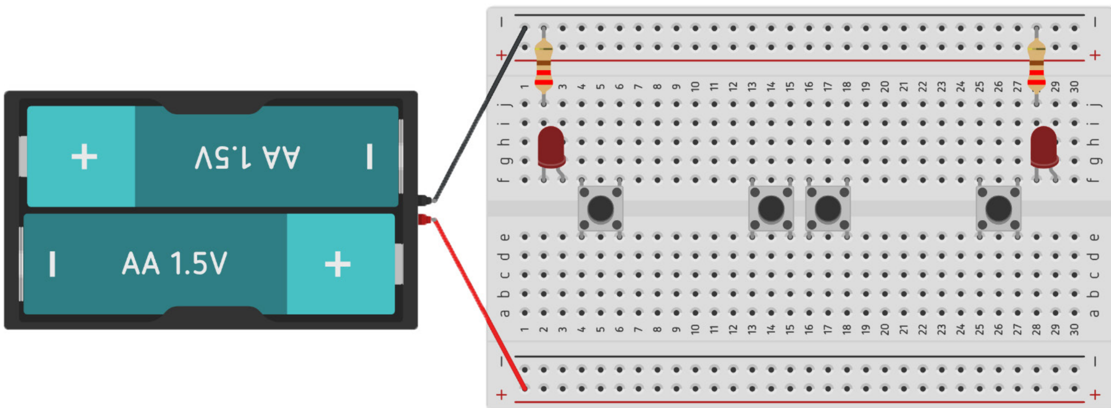
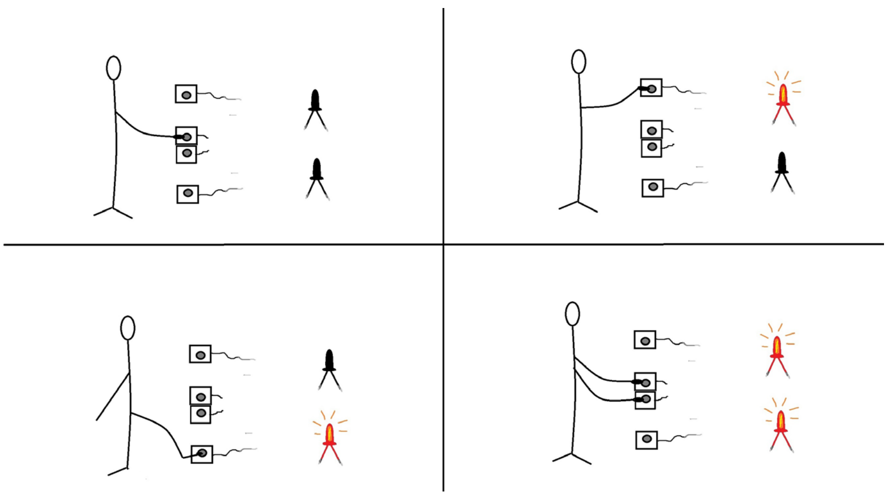


Figure 3.4: Incomplete circuit exercise 6

The circuit should do this:

- If the left button is pressed, the left LED should turn on
- If the right button is pressed the right LED should turn on
- If both middle buttons are pressed, both LEDs should turn on



b. As both the middle buttons should be pressed at the same time, you should use both hands for this.

c. Can you think of a place in a car where this circuit could be used? Write down your answer here:

Extra material

In this section you can learn about some of the mathematics behind electric circuits, and learn a little bit about the difference between series and parallel circuits. It is not necessary to know this for this module or any of the other modules of the workshop. But if you are interested to learn more about electronics, you should give this section a shot! (And feel free to skip it if you don't like it!).

One important formula used in electronic circuits is Ohm's law:
I=V/R
This formula explains the relationship between the current (I in the formula), voltage (V) and resistance (R). What this relationship is and what it means is explained next.

Think back to the icebreaker of this module. Here students walked through an electronic circuit. These students were playing the current that flows through a circuit. They started at the battery where they got coins. These coins can be seen as energy packets that they give to the components in the circuit. These coins represent the voltage in a circuit. When the students encountered a component in the circuit they gave them some coins. These components have resistance, component with resistance use up energy.

Let's take a look at this simple circuit:

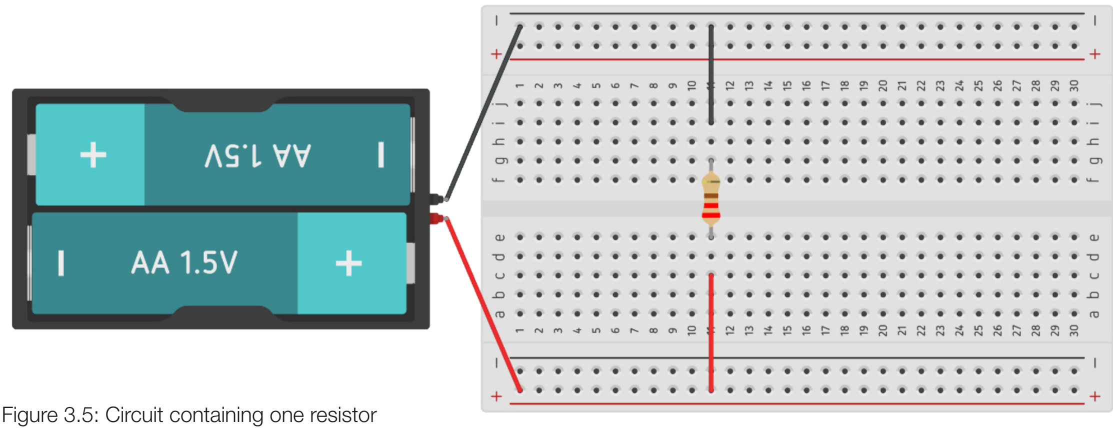


Figure 3.5: Circuit containing one resistor

Module 3 - Combining circuits

This circuit only contains a battery pack and one resistor. This circuit is not very useful in practice, but is useful to learn about Ohm's law.

So, what do we have here. Let's start at the battery. You may have seen that on the batteries there is 1.5 V written (sometimes 1.2 V). This is the voltage that a battery can deliver. When the batteries are connected in series (one after another) like they are in a battery pack you can add up the voltages to calculate the total voltage the batteries can deliver together. In this circuits there are two 1.5 batteries so the total voltage is:
2 * 1.5V = 3V

The next thing we can look at is the resistor. The name of a resistor says exactly what it is, a component with resistance! It doesn't do much besides having resistance (it can only heat up a bit). It is possible to measure how much resistance a resistor has. This is measured in a Ohm unit. The resistors you used in this module were 220 Ohm resistors. Instead of writing Ohm after the amount, an omega () is used. So you used 220 resistors.

Now we have the voltage and resistance we can calculate the current that goes through the circuit with the formule.
I = V * R = 3 V * 220 = 0.014 A
Note that current is measured with Ampere, so after the current we write an A.

Let's try to use the formule yourself:

7. Calculate the current in the following circuit:

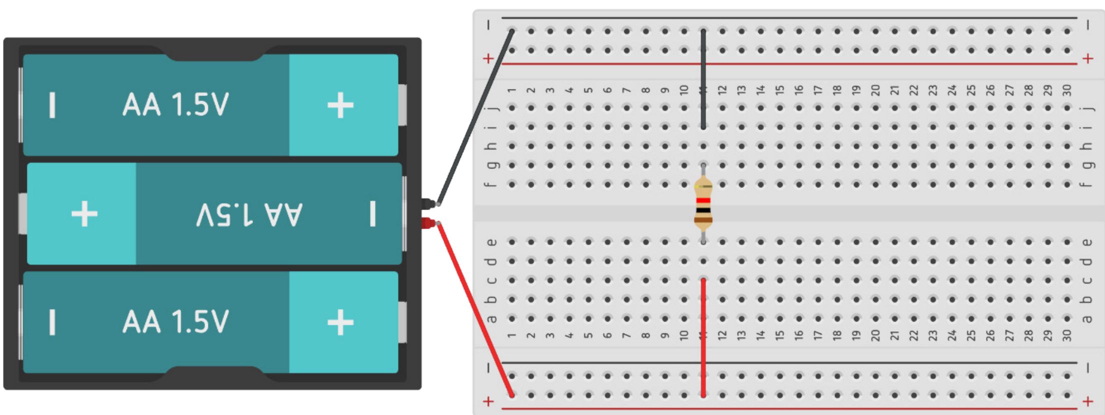
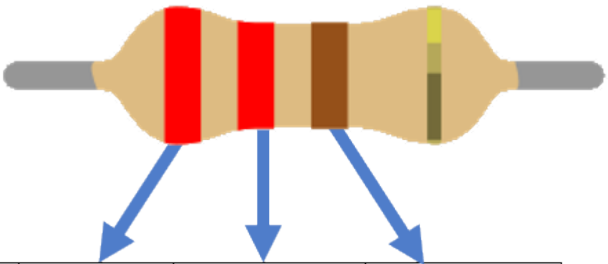


Figure 3.6: Circuit exercise 7

Module 3 - Combining circuits

Note that there are 3 batteries in the battery pack and that we have a different resistor. This is a 1000 resistor (or 1k). What is the current flowing through this circuit? Also write down your calculation.

Instead of measuring the resistance of a resistor, you can also look at the colors of the resistor. In the table below, you can see how you can convert the colors to a number:



Color	First digit	Second digit	Multiplier
Black	-	0	1
Brown	1	1	10
Red	2	2	100
Orange	3	3	1 000
Yellow	4	4	10 000
Green	5	5	100 000
Blue	6	6	1 000 000
Purple	7	7	10 000 000
Grey	8	8	100 000 000
White	9	9	1 000 000 000

Figure 3.7: Explanation resistor colors

So for the resistor in the picture we can calculate the resistance as follows:
The first digit of the resistance is a 2 (first color is red), the second color is also red so again a 2. And the third color is brown therefor the multiplier is 10. So how do you get the resistance? paste the first and second digit together and multiply it by the multiplier. So, 22 * 10 = 220.

Module 3 - Combining circuits

8. Calculate the resistance of the following resistors with the help of the table above.

a.

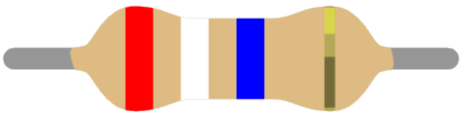


Figure 3.8: Resistor exercise 8.a

b.

Figure 3.9: Resistor exercise 8.b

If we add multiple components with resistance in series, we can simply add the individual resistances to calculate the total resistance of a series circuit. So for the following circuit we can again calculate the current going through the circuit.

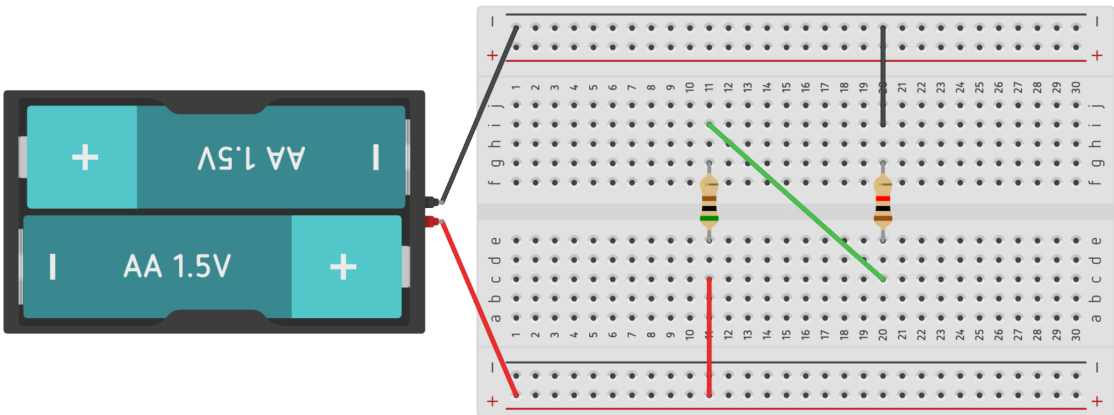


Figure 3.10: Series circuit containing two resistors

There are two resistors in series in this circuit. One 500 resistor (left) and one 1000 resistor (right). So we can calculate the current as follows:
I=V/R = 3V/(500 + 1000) = 3V/1500=0.002A
The current in a series circuit is the same everywhere in a circuit, but the voltage is not! We have seen this in the icebreaker too. The 'voltage coins' of the students got divided over the components in the circuit. We can use Ohm's law on a smaller pieces of the circuits to see and calculate how this works.

We now want to use Ohm's law to see how much voltage each resistor 'uses up'. So now we will use the formula in a different way. Let's look at the first resistor in the circuit. We know the resistance of this resistor, namely, 500. And we now the current that flows through this resistor, we just calculated it! So the current through this resistor is 0.002A. Now we can plug these values in the formula, reorder it and calculate the voltage as follows:

I = V / R
0.002 A = V/500
V = 0.002 A * 500 = 1 V

Let's do the same for the second resistor:
I = V/R
0.002 A = V/1000
V = 0.002 A * 1000 = 2 V

As you can see the voltages over the different resistors is different. The total voltage (3V) is divided over the two components.

What does this mean for the circuits we build in this module? In the first circuit you build in the module, you added two LEDs and a resistor in series. LEDs are a bit more complex than resistors. The resistance of an LED is not constant like a resistor. This means that the resistance of an LED changes depending on the current and voltage that flows through an LED. Therefore we cannot simply use Ohm's law on them. But, we can still use Ohm's law to think about the circuit as a whole.

As we have seen the current in a series circuit is the same everywhere in the circuit. But, the voltage is divided based on the resistance of the components. An LED needs a certain amount of voltage to burn, not to low and not too high. So when we add multiple LEDs are in a series circuit, the voltage that the batteries supply gets divided over both of them, and the resistor. But when there are two LEDs and a resistor the voltage over the LEDs gets to low and they won't burn very bright.

We have also seen that the LEDs do burn bright when they are connected in parallel, like in the picture below. Therefore we know now, that both LEDs have a high enough voltage over them. This is because in parallel circuits the voltage is not divided over both paths, but the same in every path. But now the current is divided over both path. The math in a parallel circuit is a bit more complicated and we won't get into that in this module. But we hope that you now understand the circuits you build a bit better, now you know some of the physics and mathematics behind it.

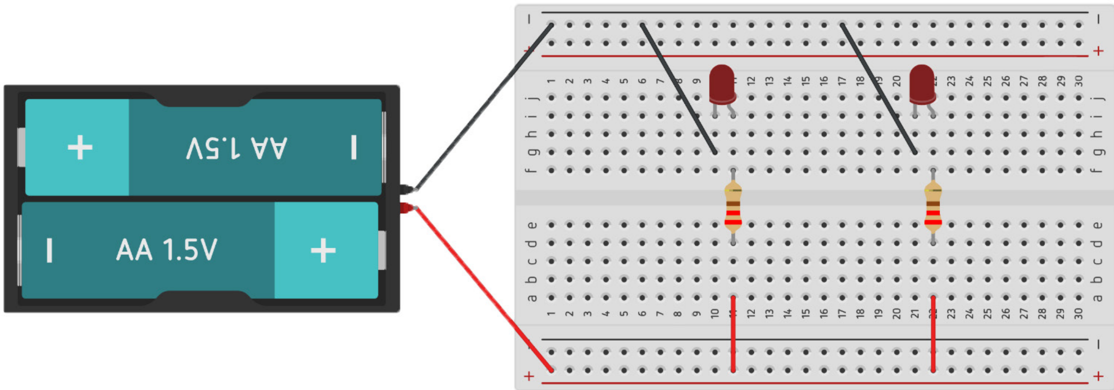


Figure 3.11: Parallel circuit containing two LEDs

Summary

In this module you learned how to connect circuits in different ways. Namely in series and in parallel. You have seen that electricity behaves a bit different when there are multiple paths in a circuit (parallel). If you want to have multiple LEDs all burning bright (or motors turning fast), you want to connect them in parallel. You have also seen that connecting buttons in different ways can create interesting behaviour that might be useful when you are making a car.

Module 4 - The electric car

In this fourth part of the workshop you will work on making an electric car together with one or two partners! First your teacher will explain some things about electric cars, and how they are different from combustion cars. Then you will get to think about the components an electric car needs. The teacher will explain how you can make some of these components with an electrical circuit. After this you can start creating your team's dream car.

In this module you will learn:

- Which components are needed to make an electric car.
- How to copy the real life design of an electric car using electronics.
- That there are many solutions to the same kind of problems.
- That experimenting with electronics is fun.

If you weren't present in one of the previous modules, we suggest you to read the summary of these modules. You can ask your teacher or a classmate for help if you don't understand something.

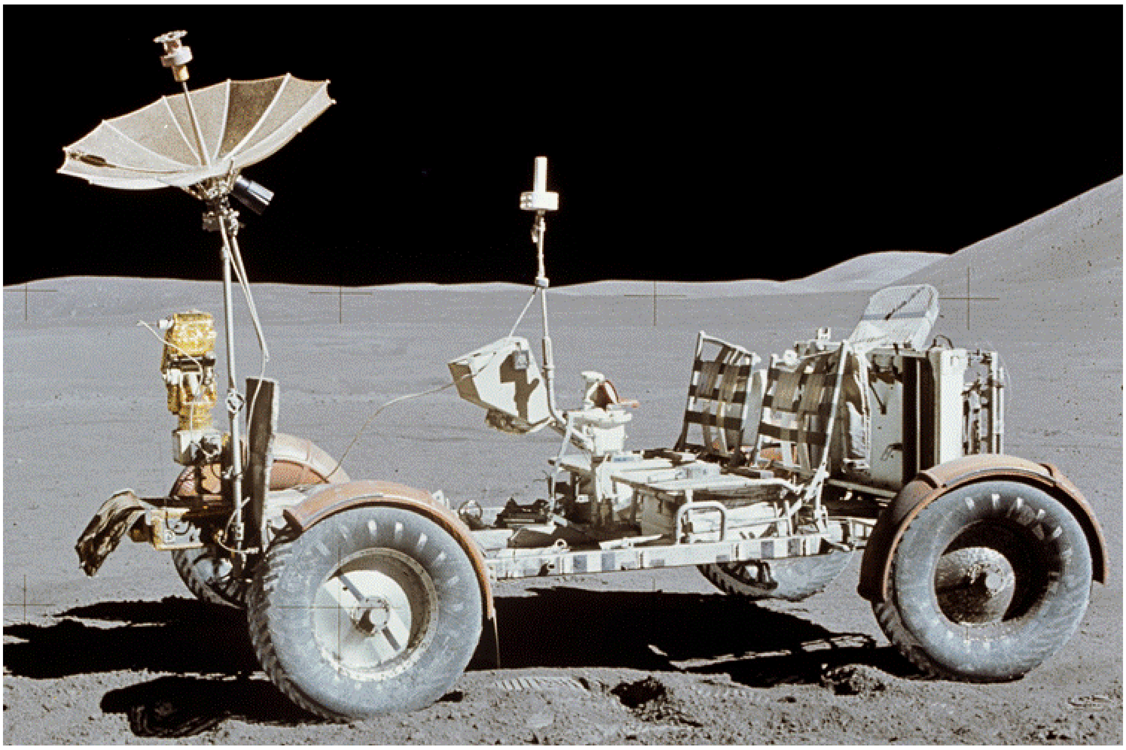
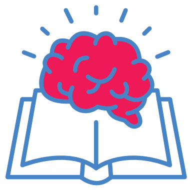


Figure 4.1: The U.S. Apollo Lunar Roving Vehicle from Apollo 15 was the first electric car on the moon in 1971.
Edited from: https://www.hq.nasa.gov/office/pao/History/alsj/a15/AS15-88-11901HR.jpg

Advantages and disadvantages of the electric car



Your teacher explained what the differences are between electric cars and cars which run on fuel. Some of these differences lead to the electric car having an advantage over the car which runs on fuel, but some lead to disadvantages. Write down in your own words: What are the advantages and disadvantages of the electric car?

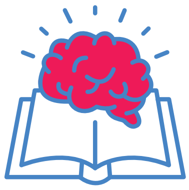
Advantages:

Disadvantages:

Brainstorming

Use this page to create your own Mind map

Example car components



Here you will find some examples of electric circuits, which can be useful for building your own circuit for an electric car. These examples are here to spark your creativity, so use them, combine them, and make something awesome!

The electric motor

A very simple version of the electric motor circuit of the car can be made by connecting a battery pack directly to a DC electric motor, as shown in figure 4.2. The electricity stored in the batteries will let the electric motor turn. However, the motor will only turn in one direction. You can connect a wheel, an axle or a propellor to the motor to make these items rotate.

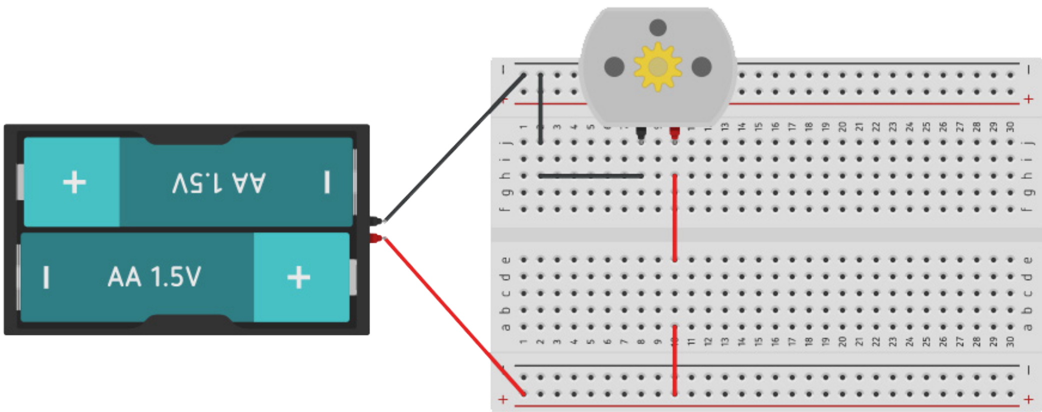


Figure 4.2: Schematic drawing showing an electric motor connected to a battery pack.

Materials needed for this circuit:

- Breadboard
- Battery holder with 2 AA batteries
- DC motor
- 6 jumper wires

The accelerator

In electric cars you can control the speed of the car by simply pushing a pedal, the accelerator, with your foot. Behind the scenes this pedal is controlling a potentiometer. The potentiometer gives the driver control over how much voltage the electric motor receives. If the driver wants to go faster he will press the pedal down. This will turn the dial of the potentiometer one way and increase the voltage output towards the electric motor. This makes the electric motor rotate faster, which makes the car go faster. If the driver lifts his foot off the pedal, the dial of the potentiometer is turned the other way. Now the voltage output to the electric motor is decreased, and the motor will rotate slower, or not at all. In the schematic circuit in figure 4.3 a potentiometer is included between the electric motor and the battery. Now, the voltage towards the electric motor can be controlled by turning the dial of the potentiometer.

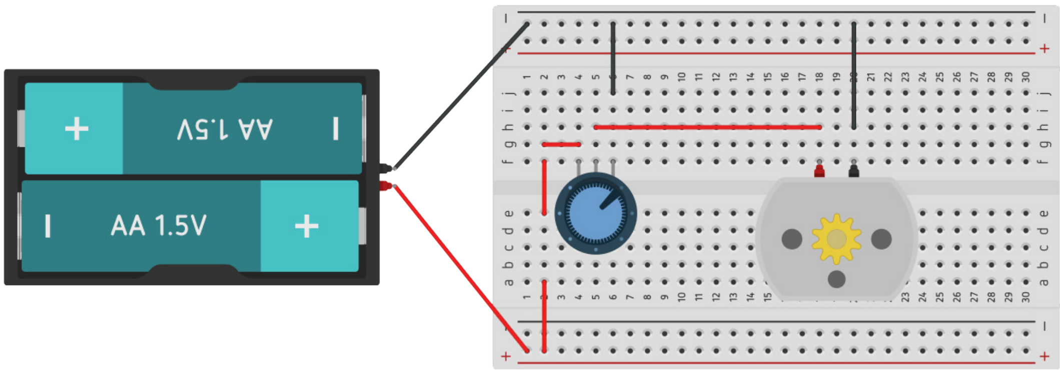


Figure 4.3: Schematic drawing showing a circuit with a potentiometer which can be used to control the turning speed of the electric motor.

Materials needed for this circuit:

- Breadboard
- Battery holder with 2 AA batteries
- DC motor
- Potentiometer
- 8 jumper wires

At the end of this module there are some pages with extra material. Here you can find more information on the potentiometer if you want to know how it works!

The steering system

Unless you want to crash into things constantly, you want to steer your car. Here two options are given how to connect your circuit if you want to steer your electric car.

1. Independent motors

Using buttons you can make one motor in a circuit rotate while the other is standing still. If you place the first motor on a wheel on the left side of a car, and the second on the right side of a car you can make the car turn right. If you only let the second motor run, your car will turn to the left. This will allow you to turn your car with the push of a button. Figure 4.4 shows a circuit which allows you to control the wheels using the buttons.

Module 4 - The electric car

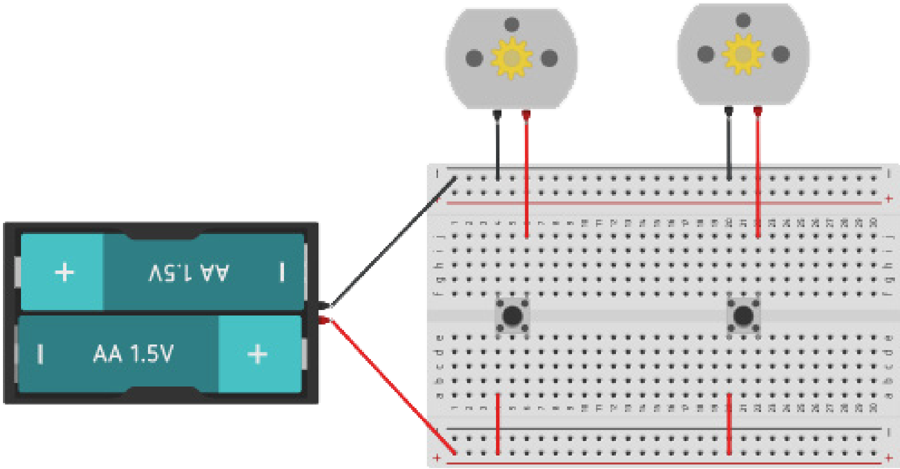


Figure 4.4: Schematic of a circuit allowing independent control of the left and right electric motor.the electric motor.

Materials needed for this circuit:

- Breadboard
- Battery holder with 2 AA batteries
- 2 DC motors
- 2 press buttons
- 8 jumper wires

If you want to go straight, you should let both motors run. You can do this by pushing both buttons in the previous circuit. Another way is to build a more advanced circuit which lets you go forward using a third and fourth button attached to each other. This more advanced circuit is shown in figure 4.5. This circuit is very similar to the one you have built in module 3 exercise 6, but now the led lights have been replaced with electric motors.

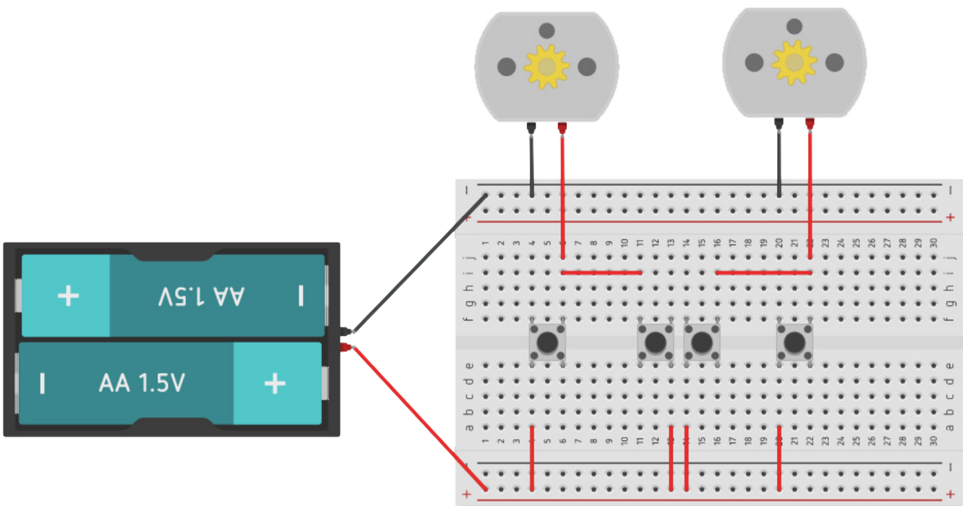


Figure 4.5: Schematic of a circuit allowing independent control of the left and right electric motor. Two extra switches are combined into one to allow both electric motors to turn at the same time.

Materials needed for this circuit:

- Breadboard
- Battery holder with 2 AA batteries
- 2 DC motors
- 4 press buttons
- 12 jumper wires

2. Turning the wheels

This might be challenging to build. If you feel confident you can handle the challenge and are eager to learn, try to make it, otherwise you could try option 1.

Real cars turn by turning their wheels in the direction they want to go. Often the front wheels are used for this. In some cars the steering wheel is directly connected to the axle of the front wheels. If this is the case, you can turn your car by turning the steering wheel. Using this steering system, you need to pull the steering wheel hard to make your wheels turn. In some other cars, there is an electric motor which turns your wheels. Using your steering wheel you can make this motor turn clockwise, or anti-clockwise. This makes it easier to turn the steering wheel. In figure 4.6 a circuit is shown which you can use to control an electric motor. Using the switches, you can make the motor rotate in the clockwise direction, or, if you switch the switches to the other side, in the anti-clockwise direction.

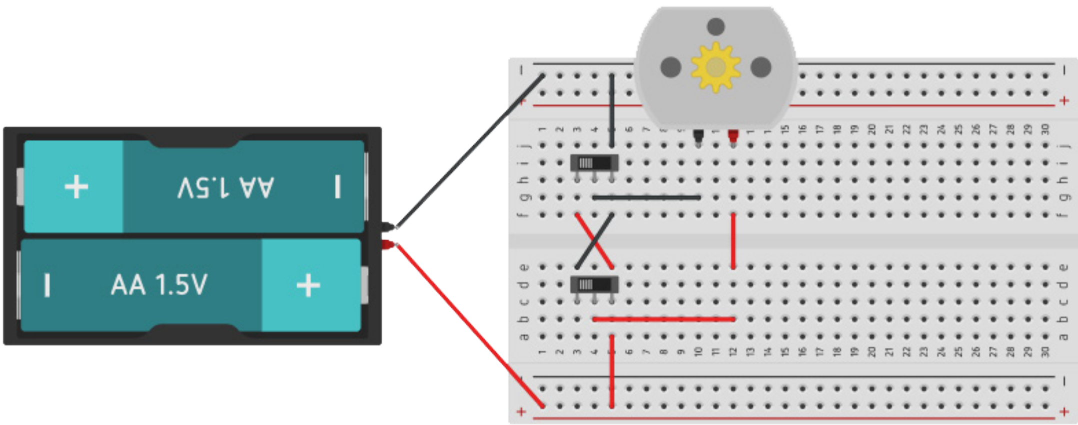


Figure 4.6: Schematic drawing showing a circuit in which the turning direction of an electric motor can be controlled with the use of two slide switches. If both switches are slid down, the motor turns in the clockwise direction. If both switches are slid up, the motor turns in the anti-clockwise direction. If one is slid up and one is slid down, no closed electric circuit is made and nothing happens.

Module 4 - The electric car

Materials needed for this circuit:

- Breadboard
- Battery holder with 2 AA batteries
- DC motor
- 2 slide switches
- 9 jumper wires

In the following module you can use this circuit to connect the axle of the electric motor with some elastic band to the steering axle of a set of wheels. Especially building this steering axle can be difficult. An example of an electric car with an electric motor connected to a steering axle is shown in figure 4.7.

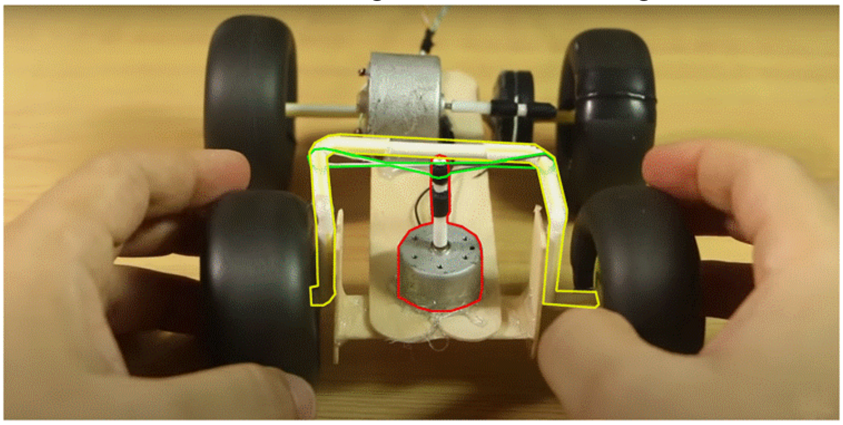


Figure 4.7: An image showing how an electric motor can be connected to a steering axle. The electric motor (1) is connected with a rubber band (2) to the steering axle (3). Edited from: https://www.youtube.com/watch?v=NL5-FV28uRA

The car horn and lights

A car horn is nothing more than a buzzer producing sound when current is going through it. By pressing your car horn button, a current starts flowing towards the buzzer in an electric car and the sound is heard. For a car horn to work in an electric circuit you only need a simple buzzer, a button and a battery. How to connect these materials is shown in figure 4.8.

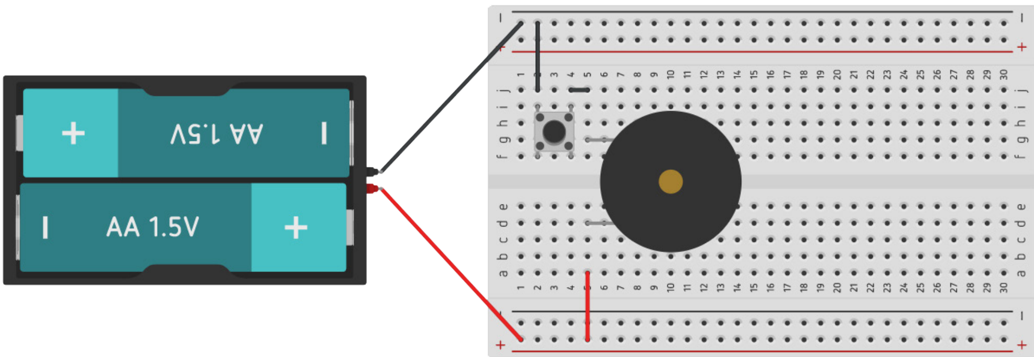


Figure 4.8: Schematic of a circuit allowing control over a buzzer.

Module 4 - The electric car

Materials needed for this circuit:

- Breadboard
- Battery holder with 2 AA batteries
- Active buzzer
- Press button
- 5 jumper wires

For the lights of a car a similar circuit can be used, however you replace the press-button with a slide switch. Also a small resistor is included in the circuit as LED lights are very sensitive and might break if a high current is put through through them. The resistor helps by increasing the resistance in the circuit, which decreases the current through the circuit. The new circuit is shown in figure 4.9.

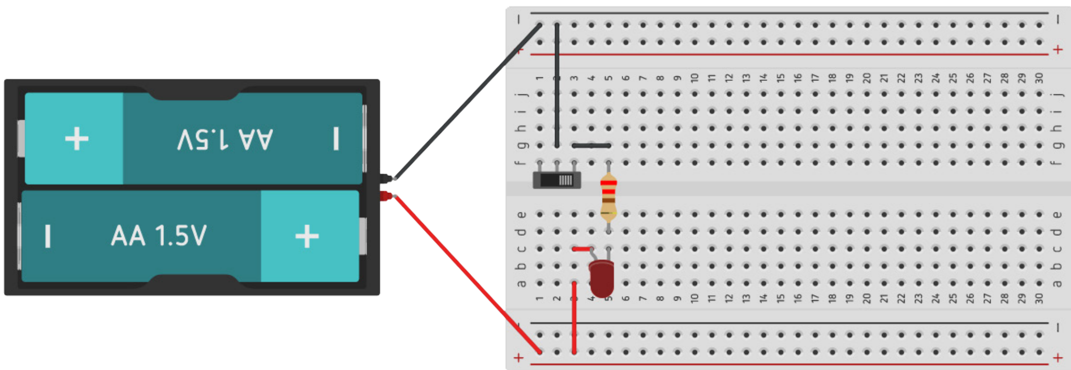


Figure 4.9: Schematic of a circuit allowing control over a LED light.

Materials needed for this circuit:

- Breadboard
- Battery holder with 2 AA batteries
- LED
- 220Ω resistor
- Slide switch
- 6 jumper wires

The reverse switch

What if you are driving and you want to turn around? Sometimes driving in a circle is impossible, so you might want to have an option to drive backwards, in reverse direction. Using an electric motor, reversing the turning direction can simply be done by reversing the direction of the current going through the motor. Reversing the direction of the current through the electric motor can be done by combining two slide switches. The schematic drawing in figure 4.10 shows how you can connect the two slide switches in such a way that the motor will turn in the clockwise direction when the two switches are slid down, but in the anti-clockwise direction when the switches are slid up. With the simple switch of the two switches, we can now reverse our electric motor, and thus the driving direction.

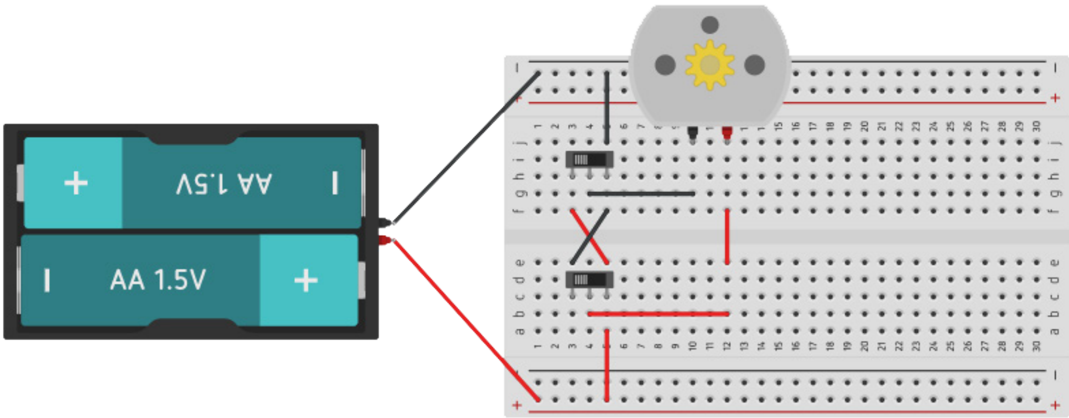


Figure 4.10: Schematic drawing showing a circuit in which the turning direction of an electric motor can be controlled with the use of two slide switches. If both switches are slid down, the motor turns in the clockwise direction. If both switches are slid up, the motor turns in the anti-clockwise direction. If one is slid up and one is slid down, no closed electric circuit is made and nothing happens.

Materials needed for this circuit:

- Breadboard
- Battery holder with 2 AA batteries
- DC motor
- 2 switch buttons
- 9 jumper wires

Get ready to build!

You have learned a lot about electric circuits, and about electric cars. So it is time to build your own electric car together with your partner! On the following pages are some examples of electric cars made by people all over the world. Try to make your own design! Here you can write down what you want your car to look like, which components it should have and what these components should be made of.

Make sure you keep in mind the safety rules.

Module 4 - The electric car

Use this page to draw your own electric car

Some examples of electric cars for your inspiration!

Figure 4.11: Simple car consisting of a battery glued to straws, a switch, a motor, a back and a front axle with wheels and two gears which connect the motor to the front axle.
https://www.instructables.com/id/How-to-Make-MINI-Electric-CAR-DIY-at-HOME-Easy-Sim/

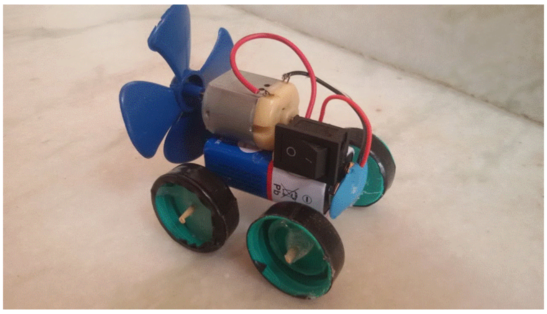


Figure 4.12: A simple car powered by connecting the motor to a fan instead of to the axle of the wheels.
https://www.youtube.com/watch?v=VL6gJe3P-g4

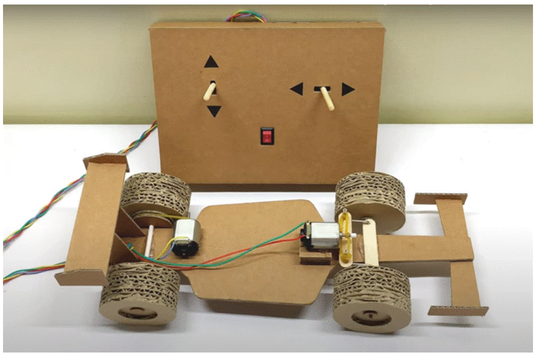


Figure 4.13: Image of an electric car created using two motors. One motor lets the back axle rotate, making the car go forward or backward, the other controls the steering system.
https://www.youtube.com/watch?v=uPhB6I0m-TE&t=145s

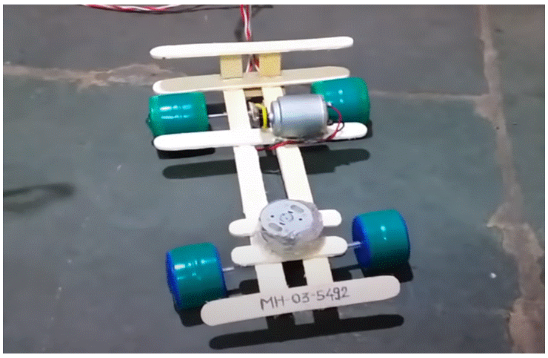


Figure 4.14: Image of an electric car created using two motors. One motor lets the back axle rotate, making the car go forward or backward, the other controls the steering system.
https://www.youtube.com/watch?v=CZ23obsEoys&t=7s

Module 4 - The electric car

Summary

In this module you have learned that electric cars are different from combustion cars. The differences are that electric cars

- need electricity rather than gasoline or benzine to run.
- use batteries to store the electricity rather than tanks to store fuel.
- create movement from electrical energy, rather movement from chemical energy (burning fuel).

These differences bring advantages and disadvantages for the electric car. Some advantages are:

- The fuel is cheaper and cleaner.
- The electric engine makes less noise and is low in maintenance.
- Governments promote buying electric cars, making them cheaper.

However, some disadvantages are:

- Recharging batteries can take a long time.
- Batteries need to be replaced quite often, and can be expensive.
- Not every place has an electric charging station.

Next to this you have brainstormed about what components should be present in a car, and you have seen some examples of how to build these components with the use of electronics. The examples you have seen were:

- The electric motor
- The accelerator
- The steering system
- The car horn
- The car lights
- The reverse switch

Last, but not least, you have tried to make the base of your very own electric car!

Extra material

This is the extra material given to the students. You do not have to include this into the module, but you might want to point out that the students have this piece of extra information in their student manuals.

History of the electric car

Already in the early 19th century professors, inventors and blacksmiths went on to create crude versions of electric cars. Simple designs using nothing more than a steering wheel, an electric motor and early versions of batteries. However, it took some time before the batteries the inventors used, improved enough to actually make a working vehicle. Around 1880 the first machines that could be described as cars were created. In November 1881, Gustave Trouvé presented an electric car at the International Electrical Congress in Paris, France, a drawing of this car is shown in figure 4.15. In 1888, the german inventor Andreas Flocken made what is considered to be the first commercially available electric car, the Flocken Electrowagen, which is shown in figure 4.16.

Figure 4.15: Drawing of Gustave Trouvé in his car.
Edited from: http://academie-de-touraine.com/Tome_25_files/067-092.pdf
https://www.youtube.com/watch?v=uPhB6I0m-TE&t=145s

Figure 4.16: Photograph of Andreas Flocken with his wife in the flocken elektrowagen.
https://commons.wikimedia.org/wiki/File:1903_Flocken_Elektrowagen.jpeg
https://www.youtube.com/watch?v=CZ23obsEoys&t=7s

Advancements in the construction and usage of internal combustion engines (the kind which use diesel or gasoline) in the 20th century made cars using these kinds of engines more popular. Electric cars were produced less as the batteries were not good enough to compete with the internal combustion engines. Now, in the 21st century, electric cars are making a comeback. One of the most recent electric cars, the Tesla roadster is shown in figure 4.17. The batteries are still not strong enough to make electric cars go as far and fast as combustion cars, but improvements are made rapidly. Also the fact that electric cars do not produce emission/pollution makes them more popular in recent years, in which the world is trying to combat the pollution of the air.

Figure 4.17: The Tesla roadster, one of the latest and most popular electric cars on the market.
https://www.tesla.com/nl_NL/roadster

The potentiometer

The potentiometer can be seen as an adjustable resistance. In figure 4.18 you see a potentiometer. It has a blue terminal, a black terminal and a green terminal. The red strip is a resistive strip. We connect the potentiometer by attaching one cable to the green input terminal, and one cable to the black output terminal, which goes on to the rest of the circuit. The current will flow through the green terminal, through a part of the resistive strip, shown in yellow, and then through the black terminal to the rest of your circuit. If you turn the dial, the black terminal is placed at a different position along the resistive strip. In this example, if you turn the dial against the direction of the clock, the current now needs to go through more of the resistive material before it reaches the black terminal. This results in a higher resistance of your potentiometer!

Figure 4.18: Schematic view of a potentiometer showing high and low resistance.
https://randomnerdtutorials.com/electronics-basics-how-a-potentiometer-works/

However, the potentiometer can be used in another way as well. It can be used to divide a voltage over two of its terminals. Here we see the same potentiometer, but now the blue terminal is connected to the ground of the circuit, as can be seen in figure 4.19. Now some of the current goes through the full length of the resistive strip and goes out to the ground terminal. The rest of the current goes through the wiper to the black output terminal. If the dial is turned all the way to the right, so that it is close to the green terminal, the resistance up until the wiper is then very low and only a small voltage drop is expected. However, if the dial is turned all the way to the left, there is a big resistance and a big voltage drop before the current reaches the output terminal. Thus the dial can be used to control the voltage we receive at the black terminal. Using this setup, we have made a voltage divider!

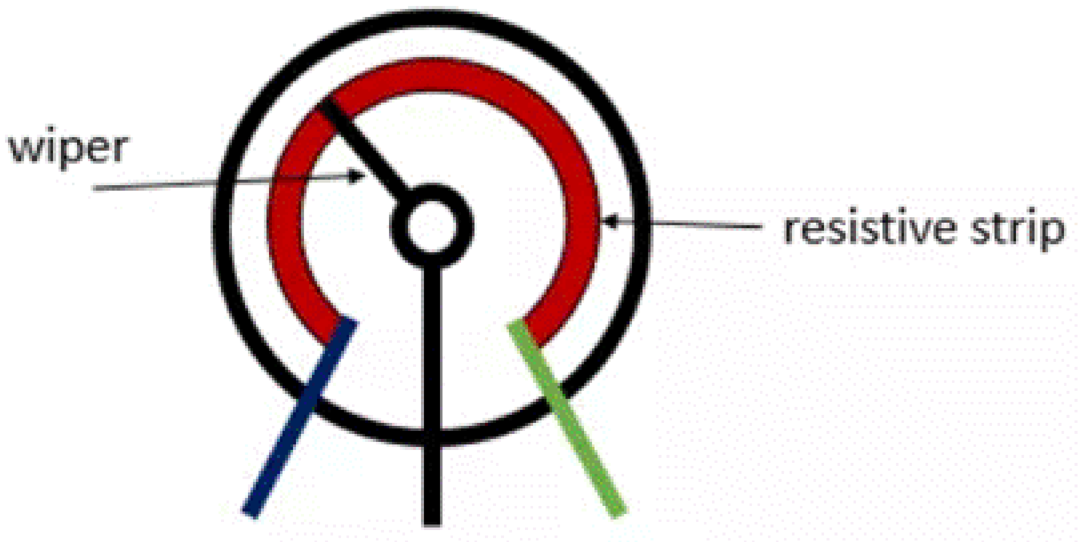


Figure 4.19: Schematic view of a potentiometer showing how to connect it as a voltage divider. The blue terminal leads to the ground of the circuit, which is in our case the negative pole of a battery. The green terminal is connected to the positive pole of the battery. The black terminal is connected to the load of your circuit (a motor or a light).
https://randomnerdtutorials.com/electronics-basics-how-a-potentiometer-works/

Module 5 - Workshop time!

In this module you can work on your car!
Finalize anything you could not finish in the previous modules, and put everything together into something that makes you proud.

If you have created your car, you can use your time to make your car more pretty or interesting by adding colours, paper or any other crafting material.

If you want a challenge: think of something electrical that you can add to your car! Brainstorm with your teacher.

It is your car. Make it into something cool, or weird, or interesting. Whatever you like!
Keep in mind that you will present your work at a science fair.

Note: if your car has an engine, which functions (the car self-propels), that is a big plus. Don't make it too heavy, otherwise it might not roll anymore. Here are some examples to get you creating again!

Module 6 - Science fair

Congratulations, you made it this far! You can present your work at a science fair ! We don't know exactly how, where and to whom you will present your work to, if you will have a table or not, but in principle, presenting is all the same.

Figure 6.1: Poster presentation (source: https://obamawhitehouse.archives.gov/blog/2013/04/22/young-scientists-and-innovators-amaze-president-obama-white-house-science-fair-0)

At the fair you will have a set location or table, and the guests can pass by your table. They may stop to look at what you have, and they might talk to you.

In this module you will learn:

- To present yourself at a fair
- How to make a good poster
- To present your work verbally (using your poster)

Let us first dive into some tips!

Your attitude

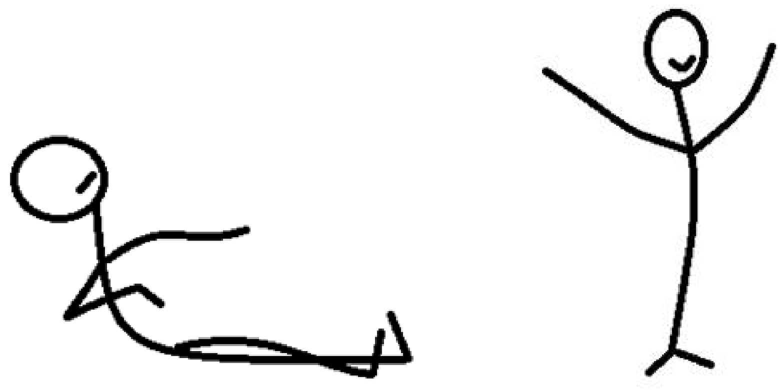


Figure 6.2: Bad and good attitude

Above you see two presenters. The left one is sitting backwards, not making contact with the people passing his booth. He doesn't show he's having fun. Can you imagine that if you pass such a booth, that you might not feel invited talking to the presenters?

The second presenter is active. He might not always be standing, but he is outgoing, and is willing to make contact with passers-by. He actively says "hi" to people and his body language shows "if you want to, you can talk to me".

So, in your presenter's attitude, we can summarize some tips:

- Make contact with people who pass by your booth (say "hello" and look at them).
- Preferrably stand
- Preferably don't do something else.(Of course, if it is very quiet, it is very understandable if you sit and do something else...)

Poster

Figure 6.3: Big poster

Having a poster is really helpful, for several reasons:

- People stop to read it, which gives an opportunity to talk to them.
- You can use the poster in case you explain certain things
- It gives information to passers-by so they can see what your booth actually is about.

Regardless of what material you have at your disposal (a paper and a crayon, or a computer and printer), you should watch the same things when making a poster:

- Readability above content ! If you can't read it, it doesn't matter if it deserves a nobel prize. Watch your handwriting if you make it manually.
- A big title (which people can read from afar), some medium letter size things, and the details smaller (which you can read only from close).
- A picture or diagram is cool !
- A colorful picture or diagram is even cooler!
- Letters can also be in different colors, but please be careful, light letters on a light background (or dark letters on a dark background) are less readable. The optimal is black letters on a white background.

What should you write on a poster ?

- What is the project about? You know exactly what it is, but someone passing by might have no idea and cannot see it from the items on your table.
- Give a brief summary.
- Explain the (most fun/interesting) parts you did
- Anything that helps you with your presentation (see the next item).
- (Only if you have room:) non-functional eye-candy (to attract people). (Don't overdo it.)
- Optional: some of the difficulties you encountered (and perhaps overcame)

Does the poster need to be big?
Well, bigger is potentially better, but small can do the job as well! In particular if you don't have that much paper or room for a poster.

Figure 6.4: Small poster

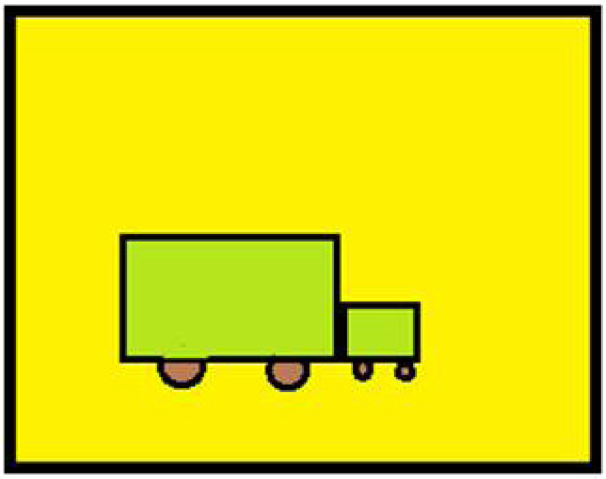
Also: if you have the resources, you can make some flyers for your booth (so people can take something home). However, we expect this to be only doable if you have a printer or at the very least a copying machine. So: flyers are nice, but by far not necessary nor really important.

Assignment 1
on the next few pages, look at the posters you see. Which one do you like the most? What is (mainly) wrong with the other ones?

Um carro feito de papel

Necessidades:

* Papel
* Tesouras
* Cola



O design do carro

* Decidimos modelar nosso carro mais para um caminhão
* As rodas foram escolhidas para serem redondas, para uma melhor condução
* Sem janelas, caso contrário poderíamos ver dentro

O processo de fabricação

* Dificuldades encontradas devido ao papel fraco
* Supere usando muita cola
* Dobrar, cortar, colar levou 3 horas

Do que gostamos?

Achamos muito divertido usar apenas cola para construir um carro de papel. Foi muito interessante ver como funcionava o processo de dobragem. A secagem da cola foi a parte mais chata - queríamos mostrar nosso carro para todos!

Gabriella Langa
Rosha Cossa
Gaia Tembe
Mlenja Sitoe

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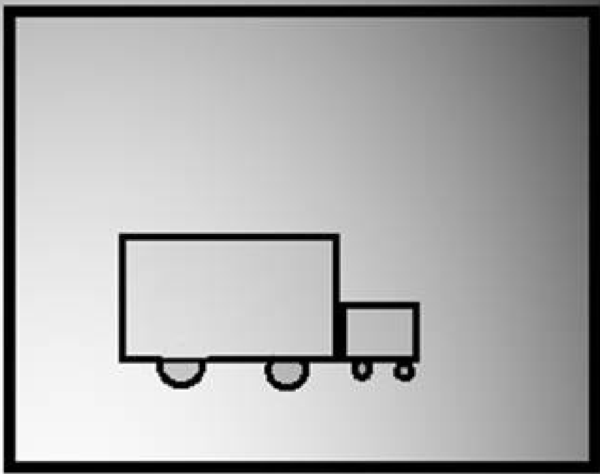

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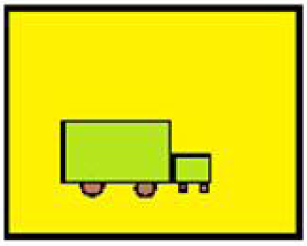

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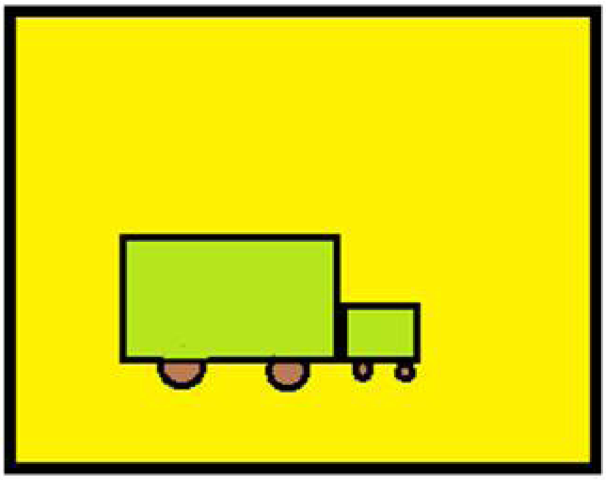

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Gabriella Longa
Rosha Cossa
Saia Tembe
Milenya Sitoe

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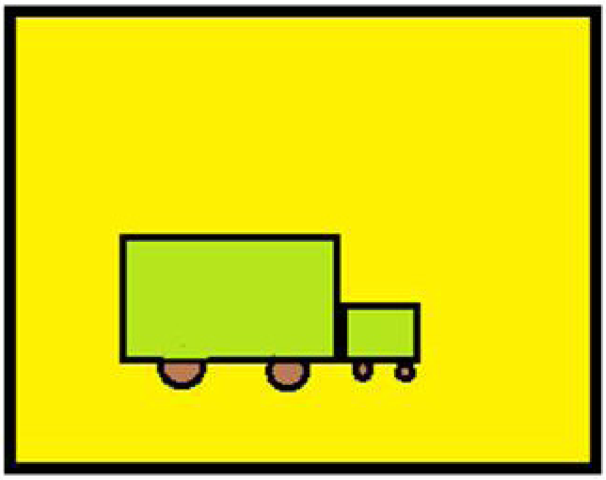

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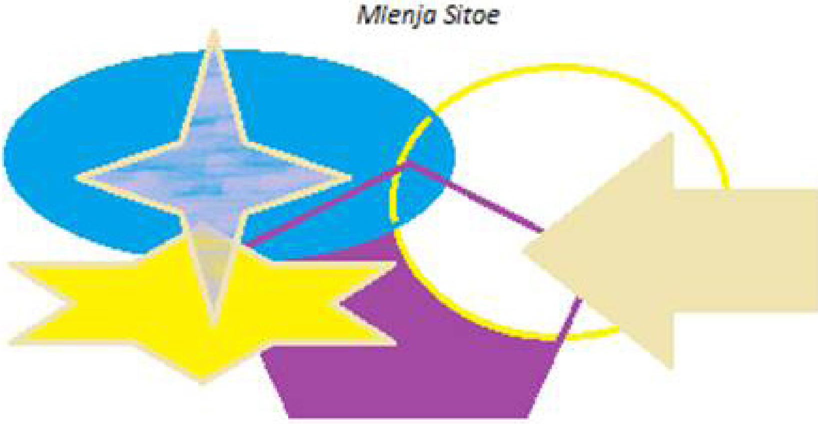

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Important

A poster can look quite different from the example(s) given here, and also the content can be different (you don’t need to list what you used, in fact, it can be quite boring). Put on the poster what you find interesting, or that you want to talk about.

Presentation

Perhaps the word "presentation" seems a bit over the top, normally a presentation is if you are standing in front of a crowd and you present something. But, a presentation can also be a presentation for just one person. If you have someone talking to you at your booth, you need to present your work. It makes sense to think this over, before you are behind your booth. And this is the main tip:
Think about what you are going to tell people who come to your booth.

Another tip is:
Prepare as if you would present to a crowd.

In that case, you always have something to fall back on.

So, what can you talk about?
Essentially, the same things as which are on a poster, but structured:

- Explain the project.
- Say which parts of the project you did. Potentially, you can ask the audience on which part they like to hear more.
- Don't be shy to say personal stuff, like what obstacles you encountered. But, still keep it smooth, this is not a time to complain.
- Show your enthusiasm, your pride, your satisfaction, your interest. It's contagious!

Then, last but not least, we would like to rephrase:
Also, in this last part. Have fun! Express your fun, also.

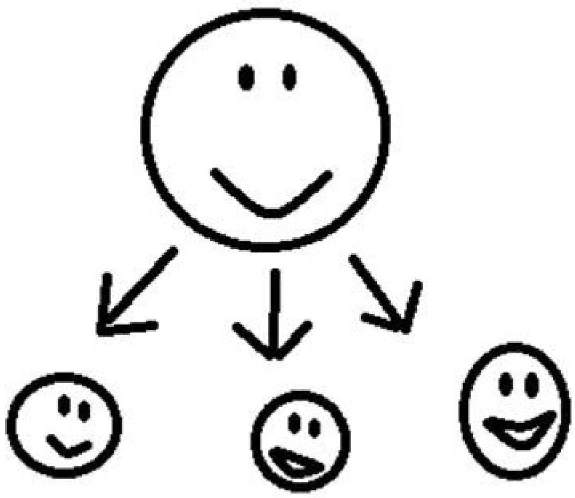


Figure 6.5 Have fun!

If you give smiles, then you get smiles back !

Module 6 - Science fair

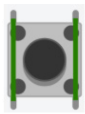
Summary

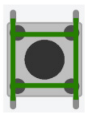
- Make a clear poster
- Practice your presentation (using the poster and your car)
- While doing nothing at your booth, be inviting - look at people, do not “hide” yourself
- While presenting to people, be open towards them (look at them, make contact with them).
- Have fun!

Help! My circuit doesn’t work

It may happen that you build a circuit and it doesn’t work. With the following steps you might be able to discover the problem and solve it! Note that these steps won’t always solve your problem, but you will make sure that you didn’t make a small common fault.

1. Check if the circuit is connected correctly. Follow all the wires and components and make sure they are connected by the breadboard. It is really common to put a wire or component in the wrong row, it happens to everyone!
2. Double check if the wires and components are all connected and connected to the battery!
3. Check if the battery is not empty. Ask if you can borrow the batteries of another group to test this. Connect their battery instead of your own. If the circuit works now, ask the teacher of the module for new batteries. Don’t forget to give back the batteries to the other group!
4. If you are using LEDs, make sure the LEDs are connected correctly. The longest leg should be connected to the positive side of the battery.
5. If you are using LEDs, make sure there is another component (with resistance) connected before or after the LED, or the LED will break.
6. If you are using LEDs, one of you LEDs might be broken or faulty. Replace the LEDs one by one with a new one. Make sure you check step 4 before you connect the battery again!
7. If you are using a button, make sure the button is connected correctly.

A button that is not pressed is connected like this: . Note that the two left pins and the two right pins are always connected, even if the button is not pressed.

A pressed buttons is connected like this: . Now all pins of the button are connected!

8. If you can’t find the problem, don’t be afraid to ask the teacher of the module!