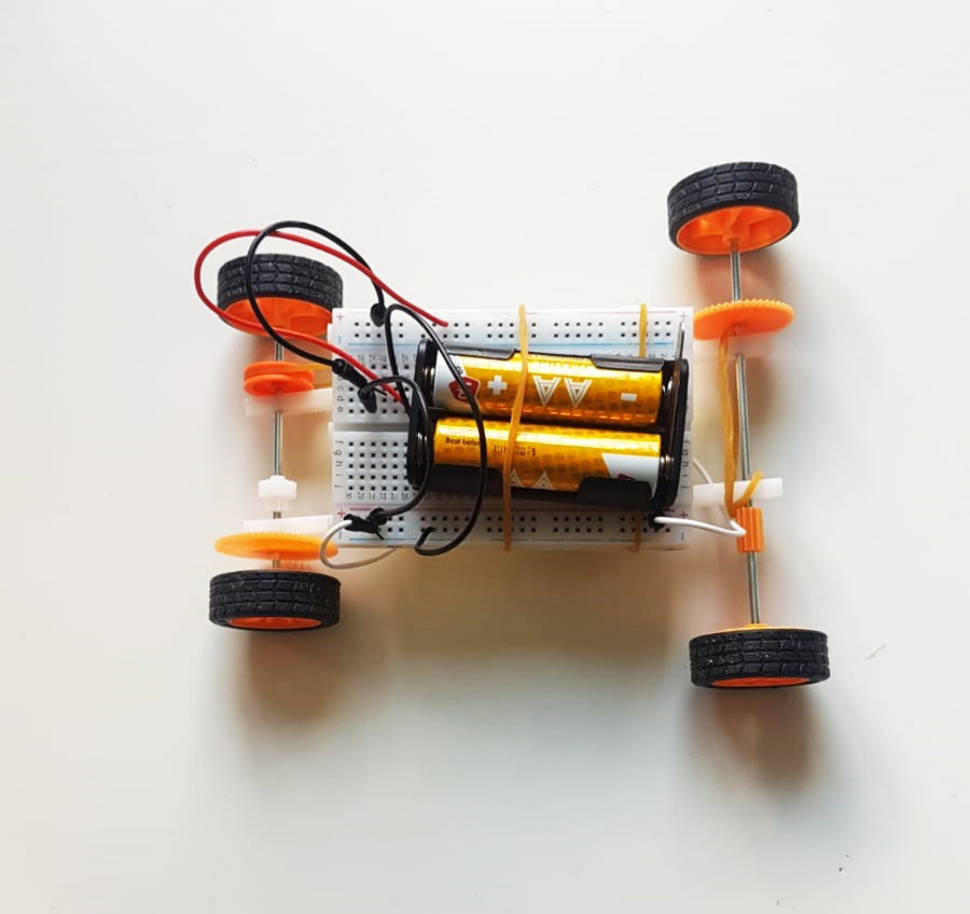
Building an electrical car - Teacher Guide



ENGINEERS WITHOUT BORDERS · NL

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Introduction

Welcome to the teacher's guide of the electronics workshop "Building an electric car". In this guide you can find information to help you, the teacher, to make this workshop a success for your students. In this introduction you will find general information about the goals, the length and the structure of the workshops. Furthermore, a small section is dedicated towards explaining the structure of the rest of the teachers guide.

The workshop is created to make students enthusiastic about electronics and science in general. This is done by letting students experience the endless possibilities when creating electrical circuits. This workshop should be focussed on letting students experiment, play and learn, driven by an inherent interest in technology, science and electronics. This teacher's guide should help you make technology something each student can discuss about, experiment on, and learn from.

The workshop is a combination of 6 modules. These modules are structured such that they can be given in a lesson of 2 hours. The deployment of the modules is flexible, you can choose to teach all modules in one week, or plan them over the span of several weeks. The modules can mostly be followed independently, a student does not necessarily have to follow the first module to join the second module. The full workshop is designed to be given by one teacher to a class of approximately 30 students. If you are confident that you as a teacher can supervise more than 30 students, this workshop will also allow more students to participate.

The teacher's guide, the document you are reading now, starts off with simple "Tips and Tricks for Teaching". These tips and tricks can be used to get an idea of how you can best educate a group of students. They will help you motivate the students, making sure that everyone is doing their best. After these tips and tricks for teaching, we continue on to the actual modules of the workshop.

For each module, the following information about the module is summed up:

- Introduction to the subject
- Summary of the content
- Learning objectives
- Teacher's foreknowledge
- Preperation
- What to do if a student missed a previous module?
- Materials and resources
- Time schedule

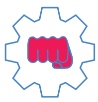
Introduction

After this, the actual content of the module, the lesson guide, is given. In most modules, this part starts with an “Icebreaker”, a quick game or experiment which is designed to activate students and make them perceptive to new ideas. Then, the main part of a module is given, the material you can teach and the practical assignments the students can do to learn about the subject of the module. For each part of the module the guide will show what you can explain, what the students can do to practise, and what materials the students could use for this. A recommendation for the time spent on each part of the module is given as well. However, this is only a recommendation. Try to take the wishes of the students into account, such that they enjoy the workshop as much as possible while learning at the same time. The last part of each module shows extra material you can use to either help the students which are struggling with the material, or some exercises you can give to excelling students that want to learn more.

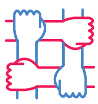
Next to the teacher’s guide to each module, a “Student’s guide” is provided. In this student’s guide a summary of the theory of each module, material needed for doing practical assignments and exercises for the students are given. Make sure that this guide can be accessed by students at any time during the workshop (e.g. print a student’s guide for each student and hand it out to the students at the first day of the workshop).

The modules consist of theoretical and practical parts. When you see the following icons you know if the assignment is theoretical or practical or it is a reference to the safety rules or the tips for guiding groupwork (both explained later):

 Theory

 Practical

 Safety rules

 Tips for guiding groupwork

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Tips and tricks for teaching

In this section some tips and tricks for teaching the workshop are given. This is important to read when you do not have much experience in teaching. However, it can be interesting to read when you do have some experience.

We start with some general tips on how to act, and deal with your strengths or weaknesses.

- Be yourself. If this is your first time teaching this age group, you may think you need to adopt a "role". Although indeed you do this, it is not a fake role. You should in the basis be yourself.
- Making mistakes is nothing to worry about! Don't get discouraged when you make a mistake, not everything has to be perfect. Most students probably won't even notice your mistake!
- If you start to panic - then don't. It's that simple. If you feel any panic, note that it is very normal. There are a lot of things you need to watch (or think you need to watch) during a lesson, and if it overwhelms you, that's normal. Just acknowledge it, and continue. It will be fine!
- Have fun! Conducting the workshops can be a lot of fun, and can be very rewarding for you as well as the students! If you have a positive attitude, then the students will pick it up with a good probability.
- Play to your strengths. You know your strong and weak points. Focus on your strong points, and ignore your weak ones for now. Are you very enthusiastic about electronics but do not know how to keep students in check? Show your enthusiasm, and focus on that!

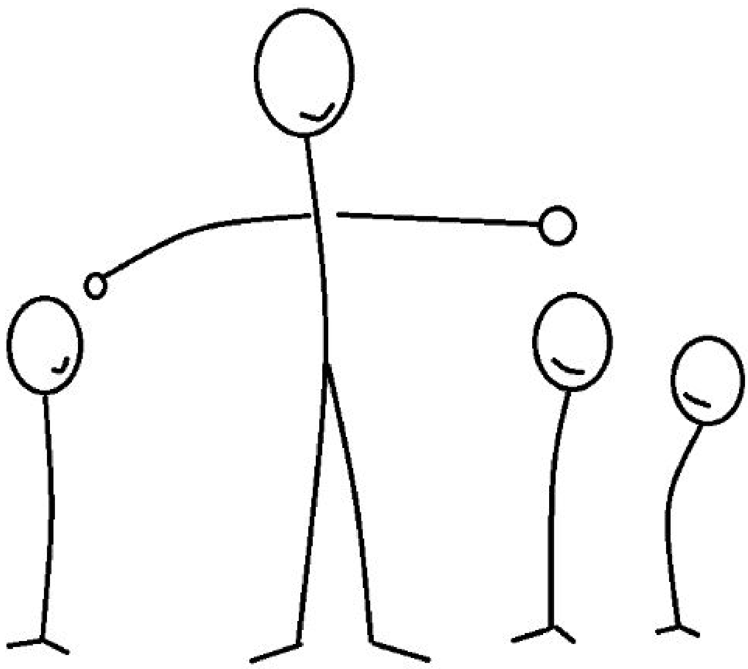
Then, organisationally, we'd like to give you the following tips:

- Prepare. Know what is in the material, have it thought through how you want to organise the workshop. Don't overestimate yourself, and don't go by your talent of dealing with people or your natural charisma. These things quickly become unimportant if you don't have a clear sense of what you want to do when!
- Make a schedule. Plan what you want to do when. You can always deviate, but in the heat of the moment it's good to be able to depend on something you've written before. Really, write something down on paper!
- Be flexible. After you made your preparation and schedule, you can now deviate from it. Things can often go differently in practice.

Tips and tricks for teaching

In interacting with students we give the following tips:

- Ask your students to help you. The workshop is a 2-way street, your students are as much responsible for a successful workshop as you are.
- Be approachable. The high-up professor has no contact with his students, but if you show that you are a “human being” with interest in electronics, you are much closer to them. Make sure they are not scared of you, and are willing to approach you with a question.
- Be concise. Just tell them what they need to know, clear and short. Attention span of young kids can be short..
- Be the teacher. Your students behave in a certain way, but you should not automatically go with them in their behavior, or energy, etc.
- Don’t negotiate. You decide the rules, they have to follow them. (At the same time, keep this all balanced. Don’t be a dictator. State the rules, and then no one will go against them, so you don’t need to worry about it.)
- Keep the number of rules small and clear. If you want to state some rules, make it short and concise. Like: no dangerous or frivolous use of materials (and not listing all the bad things you can do with a copper wire, and forbidding all of them). Tell them to use common sense.
- You don’t need to know everything. If you are honest about this, they will value that which you do know way more.



Now we will go into specific aspects/issues you may run into.

Tips and tricks for teaching

How do I motivate students?

First, realize that you cannot motivate every student. Motivation is individual, and some students are impossible to motivate, while others are impossible to demotivate. What helps a lot is if you can show your own enthusiasm about certain topics or aspects of the workshop. Show your fun.

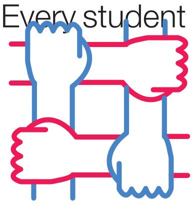
Sometimes, a student is not motivated about one aspect, but can be motivated about something else. So for example, the student might be motivated in seeing the end result, while he thinks the intermediate modules are boring. Then, focus the student towards the goal.

Also, note that sometimes students are not motivated due to other reasons. They may be tired, stressed, etc. It is not up to you to now solve their problems.

In any case: never take it personal if a student is not motivated or seems to be uninterested.

How to guide group work?

There is one important rule to keep in mind when guiding group work. Every student is different and therefore every group is different as well. There is not one right way of guiding groups since every group can need a different type and amount of guidance.



- In each module de students will be working in groups of two students. You can decide whether you make the groups or you let the students make them on their own. If the amount of students is uneven, then you can make one group of three students. The groups do not have to consist of the same students in every module.
- Make sure the classroom supports the group work. This means that the students should be able to sit with their desks together, without having too much distraction from other groups. Try to avoid arranging the desk into one row of group members, but try to arrange the desks in such a way that the group members can look at each other. In this way it is easier for them to discuss and collaborate.
- Instruct the students first on what they are going to do during the module before you instruct them to do anything in their group. When the students are working in the groups the classroom will be a bit more chaotic, so it might be harder to instruct the students in this setting.
- Make sure the students know what they should be doing. So after you tell them

Tips and tricks for teaching

what they are going to do, ask them if there are any questions about it. If there is a blackboard present, write on the blackboard the steps that the students should follow this module. This can prevent the same questions from multiple groups, about what they should be doing. Only if there are no more questions, give the students a signal to start working.

- There might be very enthusiastic students that will start working before you are finished with your instruction. To prevent this, only give the students access to the materials when they are allowed to start working.
- When you talk to all students make sure all students are looking at you. Ask the students to turn in your direction and wait for the students to do this. When all the students look at you, you can start talking.
- The workshop consists of a lot of practical work. This is the work that should be done in the groups of students. At first, it is important that the teacher provides the students with space and time to let them try and work, without immediately interfering the group work. Students should first try together to solve the problem. Only if they are not able to do the practical work with the help from their group members, the teacher should guide them with it.
- Guidance does not always mean immediately giving the right answer or saying how work should be done. Students learn the most if they figure something out themselves. When they need help, the teacher should nudge them in the right way for example by asking open questions or giving examples in the same area.
- When you are talking to a group it is hard to pay attention to the other students. Try to keep interactions with each group short, so you can help all groups.
- If you notice that multiple groups ask the same questions, or have the same problem, it might be a good idea to explain the solution to all students. Ask for their attention first before you speak to the whole group!
- When the students are working in groups they might be too loud. Don't be afraid to ask individual groups, or all groups to keep their voices down.

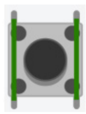
There are many, many more things we could say to help you in your didactics, but let us repeat the most important one: Have fun!

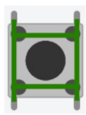
Tips and tricks for teaching

How to help a group with a circuit that doesn't work?

When you are teaching a module you might encounter students that ask for help because their circuit does not work. Here are some steps for finding problems that occur often.

1. Motivate the students to first try to solve the problem themselves. Point them to the "Help! My circuit doesn't work" section in their workbook.
2. If they tried themselves, follow the same steps as in the student workbook yourself. These steps are written below. Often students don't notice the small mistakes even after checking for them. So it is important that you check for these simple mistakes yourself, even if the students tell you they did it themselves!
3. Check if the circuit is connected correctly. Follow all the wires and components and make sure they are connected by the breadboard.
4. Check if the battery is not empty.
5. 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.
6. If you are using LEDs, make sure there is another component (with resistance) connected before or after the LED, or the LED will break.
7. 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!
8. 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!

9. If you couldn't find the mistake, you can use a multimeter to check the circuit.
    - You can check with a multimeter if two parts of the circuit are connected.
    - You can check if there is voltage over a component.
    - you can measure the voltage over the batteries to check if they are empty.
    - You can check the resistance of the components.

   This may help you spot a defect component in the circuit.
10. If no problem can be found, instruct the student to rebuild the circuit from scratch.

The workshop - Building an electrical car

Here you will find the main information about the workshop. First we note which materials are used during the workshop. Make sure you are familiar with these materials. After this, the various modules in this workshop are given.

The electronics kit

The students will use electronics in these modules. Therefore, each student will receive an electronics kit which they should use during the workshop. Each kit contains a set of electronic components which can be used to make the various circuits found in the Teacher's and Student's guide. You and your team should prepare these electronic kits, so make sure you know how many students will follow the workshop. The following materials should be included in the kit for each student:

- 1 Breadboard
- 20 jumper wires
- 1 Battery pack with 2 AA (1.5V) batteries
- 5 220Ω resistor
- 3 Slide switches
- 5 Push button
- 1 Potentiometer
- 5 LEDs
- 2 Electric motors (DC motor)
- 2 RC wheels
- 1 RC axle
- 1 set of plastic gears
- 2 RC fans
- 2 Rubber bands (1 small, 1 big)
- 1 Active buzzer
- 1 NTC sensor
- 1 LDR sensor
- 1 Proximity sensor

The workshop - Building an electrical car

Material list workshop

Here all materials which are needed for this workshop are listed. The materials shown here are a bare minimum to do the icebreakers and practicals of each module. This list is provided such that you can check before giving the workshop if you have all the materials. The list is made based on N students following the workshop, if 20 students will follow the workshop, N=20.

- N*2 Meter of copper wire (magnet wire)
- N+1 Electronics kits, one for each student and one for you as the teacher
- N Glue sticks for glue guns
- N Plastic straws
- N/2 Glue guns
- N/2 Magnets
- N/2 Scissors
- N/2 A3 or A4 format paper
- N/2 Sets of drawing utensils/coloring pencils for 2 students
- N/2 (A2) Poster papers or Cloth banners
- 8 Coins
- Rope (~10 m)
- Rope (~6 m)
- Multimeter
- Rubbing alcohol/acetone and cotton/paper towel to remove glue (only for teacher)
- Crafting materials for N students. Examples: (Colored) paper, Cardboard, Paint, Stickers, Rope.
- Blackboard (with blackboard drawing utensils)

Module 1 - Electronics, sensors and actuators

Introduction to the subject

A lot is possible with electronics. In order to make electronics approachable for students, the first module is about letting the students play around with the basics of electronics. Several sensors and actuators will pass by in this module.

Summary of the content

First the most basic principle of electronics will be explained, so the students can make their first and most simple electrical circuit. This will be expanded during this module with the inclusion of sensors and actuators. Then students will get the opportunity to make their own electrical circuits with these sensors and actuators. All the practicals in this workshop will be executed in groups of 2 students.

Learning objectives

At the end of this module the students

- 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.

Teacher's foreknowledge

You, the teacher, should at least know/understand the following topics:

- The essentials for an electrical circuit en why these are essential for a working electrical circuit;
- Know what light sensors, proximity sensors and buttons are and how to use them in an electrical circuit;
- Know what a LED, speaker and motor are and how to use them in an electrical circuit;
- Know the Ohm's law, being able to explain it and show it in an electrical circuit.

Preperation

- Try out all exercises in the Student's guide yourself before teaching the module.
- Create a toolkit for every group of students containing the materials listed above.
- Prepare the icebreaker, as is explained below.
- Organise the classroom, so students can work easily in groups of two.

Module 1 - Electronics, sensors and actuators

Materials and resources

The materials that are needed for this workshop are:
- A rope (~ 6 m)
- Scissors
- 8 coins

and for each group of 2 students:
- 2 Electronic kits

Time schedule

Lesson part	Duration	Content
Icebreaker	10 min	Icebreaker about a closed circuit, a power source and a LED
Explanation electrical circuit	15 min	Essentials electrical circuit: • Conductive closed path • Power source • Load (LED)
Explanation breadboard	10 min	Use breadboard • Safety
Practical: Making your first electrical circuit	20 min	Make an electrical circuit with a power source, wires and a LED
BREAK	10 min	
Practical: Light? Temperature? Or a button?	35 min	Explanation about: • LDR • NTC • Button
Practical: Make your own electrical circuit.	30 min	Little exercises about making electrical circuits and if students are done they can make their own.
Cleaning up and end of module	5 min	Cleaning up and end of module

Module 1 - Electronics, sensors and actuators

Icebreaker

Goal

Students will experience that current cannot go through an electrical circuit if it is not closed.

Necessities

- Rope (~ 6 m)
- Scissors
- 8 coins

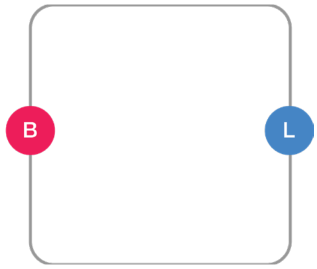


Figure 1.1. Icebreaker circuit

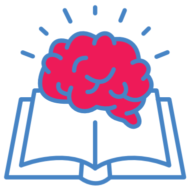
Preparations

- Cut the rope in 2 pieces of 3 meter.
- Put the ropes on the ground as shown in figure 1.1. These ropes will represent the electrical circuit.
- Choose a student who will take the position of the pink dot (B). This student will represent the battery and will have the 8 coins at the start.
- Choose a student who will take the position of the blue dot (L). This student will represent a LED.
- Choose 4 students who will represent the current in this experiment, from now on called ‘current students’. They will start at the power source (red dot)

Guide

1. The current students start at the battery. They all receive one coin from the battery.
2. Then they start walking around the electrical circuit.
3. When they arrive at the LED, they need to give the LED one coin. The LED student can make funny movements or just put his/her arms in the air, to show the LED is shining. The current students can walk further down the electrical circuit.
4. Explain that the LED can only shine if current flows through it.
5. Repeat step 1, 2 and 3.
6. Try to repeat step 1 and 2 again. This time the battery student cannot provide the current students a coin. When the current students arrive at the LED student, they won’t have any coins left to continue.
7. Explain that in this case the battery is empty and is not able to provide the LED with current. When there is no current going through the circuit, the LED will not shine.
8. Explain that without a power source, the LED cannot shine (the LED student won’t receive coins).
9. Explain that without a closed circuit, the LED cannot shine (the current students cannot provide the LED student coins).

Electrical circuit



The icebreaker creates a link to this explanation. The following essentials to an electrical circuit should at least be explained to the students:

- Power source
- Closed conductive wire
- Load

An example explanation strategy will be given. This is a possible way of explaining the above mentioned aspects, but the teachers are of course free to decide on their own strategy:

1. Ask the students what they think is an essential for a working electrical circuit, give them some time to think and let them answer question 1 in their workbook.
2. Then start comparing light to human beings. Humans need food to energize and live. A lightbulb needs current to be able to shine. When there is no power source, the light does not receive the energy it needs to shine.
3. However, the current needs to flow from the power source to the light bulb. Current can only flow through conducting material. This means there should be a conducting wire between the power source and the light bulb. But there should also be a conductive path back to the power source. Otherwise, the current students were not able to receive the next coin to “feed” the LED. Therefore the electrical circuit only works if there is a closed path of conductive wire.
4. Explain that the current students in the icebreaker can be compared with electrons in an electrical circuit. Electrons carry small packages with energy in order to pass a light bulb or resistance. The higher the voltage of the power source, the more energy packages it can provide. If the voltage of the power source is too low, then the electrons cannot provide energy packages anymore. The electrons cannot pass the lightbulb and the lightbulb is not able to shine.
5. Ask the students what they think will happen when there would be no light bulb in the electrical circuit, but the circuit would be closed.
6. Explain that the electrons are not able to deliver their energy packages and then there will be a short circuit. A short circuit is a kind of mini-explosion and can be very dangerous.Therefore there always should be a load in the circuit. A load is such a possibility where current can be lost.
7. Let the students answer question 2 in their workbook.

Breadboard

In the practicals of this workshops the students will use a breadboard. However they first need to know what a breadboard is and how to use it.

1. Explain that a breadboard is a tool to make electrical circuits. If you want to make an electrical circuit you need to connect wires to a powersource or a load. It is difficult to connect those things in a way that it does not disconnect. For this you can use a breadboard. A breadboard makes sure your components in the circuit are connected, at least if you use it in the right way.
2. Explain that the holes in a breadboard are connected as shown in figure 1.2.
3. Let the students answer question 3 in their workbook.

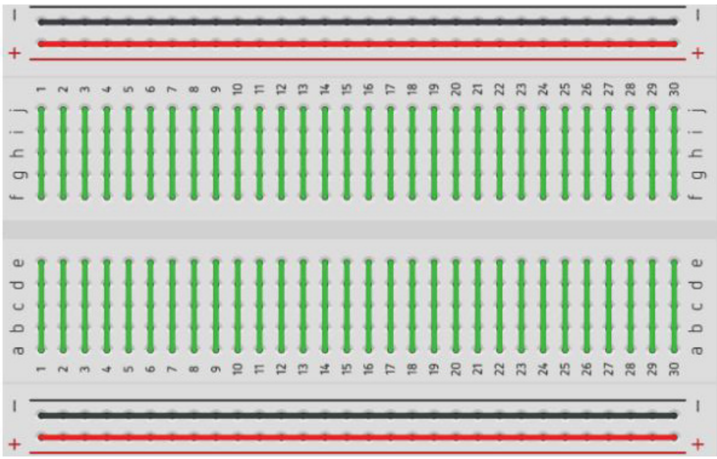


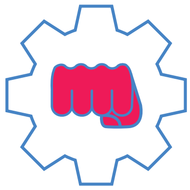
Figure 1.2. Breadboard connection

Safety rules

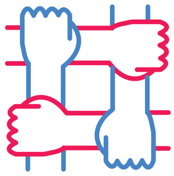
It is important that you can work in a safe way. Therefore, you need to explain the students some safety rules first. Make sure you remind them of those rules each time you start a practical.

- 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.

Practical: Make your first electrical circuit



Make groups of two students. In the chapter 'Tips and tricks for teaching' you can find some tips for making groups.



The students will make their first electrical circuit. You should let the students try to make the circuit by themselves first. You can help them when they have any questions. Keep an eye on the students to make sure they follow the safety rules and intervene when the rules are being broken.

Materials:

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

Make sure you keep in mind the safety rules.

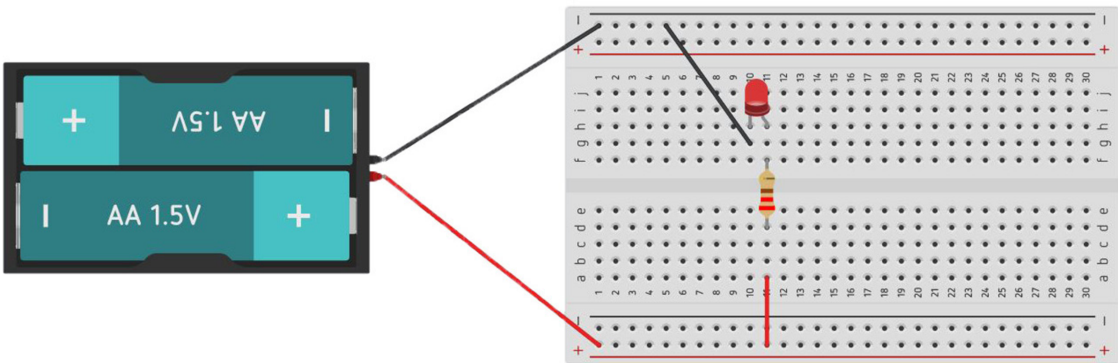
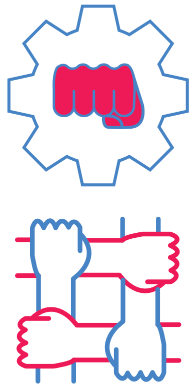


Figure 1.3. Circuit LED

If the students want more challenge they can look at the extra material. This can be done in this practical as well as in the practical 'Make your own circuit'. It is up to you when you tell the students when they can use the extra material.

BREAK (10 min)

Practical: NTC, LDR, button



In this practical the students will learn what a NTC, a LDR and a button are and what they do. They will learn this by trying out one component.

1. Divide the class in three groups, group 1, group 2 and group 3. In these groups the students are going to work in the same groups of two as in the first practical.
2. Explain to the students that they need to find out what the component in their practical does. You can give the students a hint by saying that one of the three components has something to do with light, one with temperature and the button will be quite clear.

The Button

Group 1 will work on the practical with the button as can be seen in the figure below (practical 1 for the students). Make sure all the groups in group one have the materials they need for this practical, since they do not know what they need for this practical.

Materials:

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

Make sure you keep in mind the safety rules.

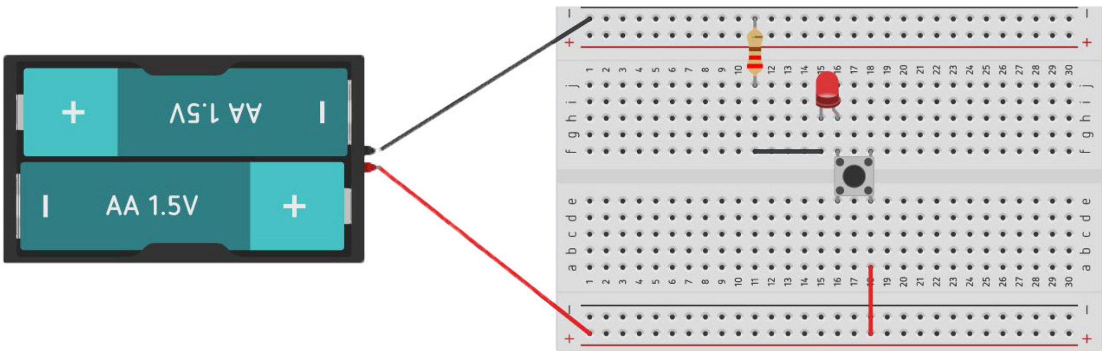


Figure 1.4. Circuit button

The LDR

Group 2 will work on the practical with the LDR as can be seen in the figure below (practical 2 for the students). Make sure all the groups in group one have the materials they need for this practical, since they do not know what they need for this practical.

Materials:

- Battery pack
- Jumper wires
- LDR
- LED

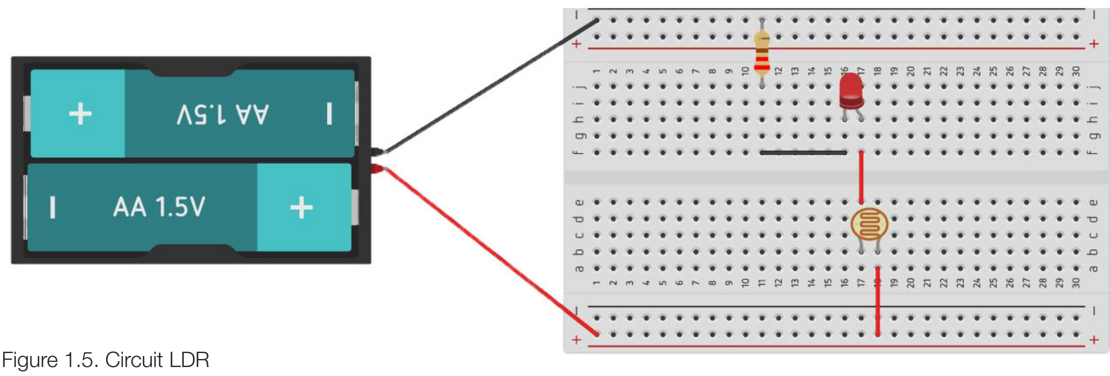


Figure 1.5. Circuit LDR

The NTC

Group 3 will work on the practical with the NTC as can be seen in the figure below (practical 3 for the students). Make sure all the groups in group one have the materials they need for this practical, since they do not know what they need for this practical.

Materials:

- Battery pack
- Jumper wires
- NTC
- LED

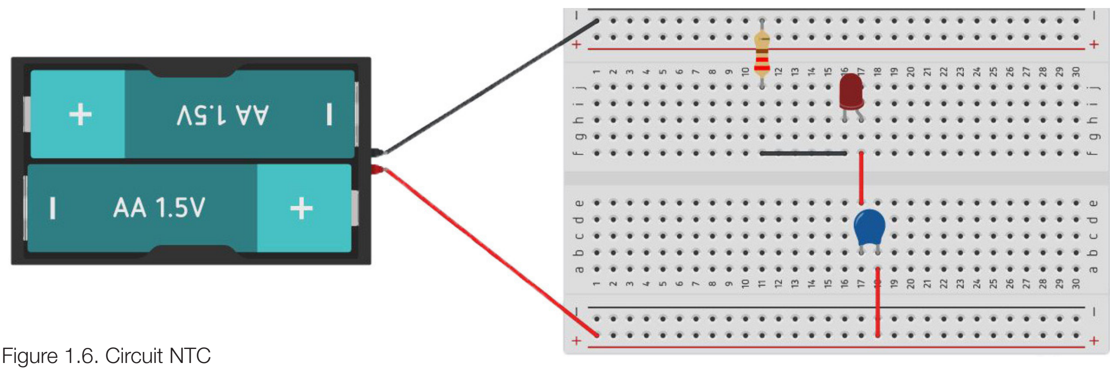


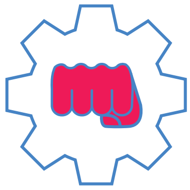
Figure 1.6. Circuit NTC

When the students are finished

When the students made the circuits, they can try to find out what their component does. They need to come up with an application for their component in a car as well.

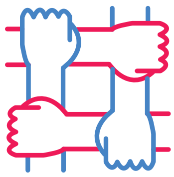
After this, the students need to share the results with their classmates. Choose one group in each of the three large groups that can share the results. If they found out what their component did, then the other groups can fill in the questions from the practical they did not do. You can tell them how the components are called, so the students can complete the title of the practicals. (Practical 1: The button, Practical 2: The LDR, Practical 3: The NTC)

Practical: Make your own electrical circuit



For this practical the same groups of two students can be used.

The students will make their own electrical circuit. They can try to combine certain components or use multiple LEDs and see what happens for every example. You should let the students try to make the circuit by themselves. You can help them when they have any questions. Keep an eye on the students to make sure they follow the safety rules and intervene when the rules are being broken.



Make sure you keep in mind the safety rules.

When students are finished, check wheter there circuit is correct or can be improved. Also check if the circuit they need to fill in in their workbook is correct.

If the students want more challenge they can look at the extra material. This can be done in this practical as well as in the practical ‘Make your first electrical circuit’. It is up to you when you tell the students when they can use the extra material.

Extra material

If the students want to have more challenge in this module they can try to connect a buzzer or a motor instead of the LED. Also they can try to find out what a proximity sensor does. If they have a working circuit with (one of) these components, then you can ask them to think of an application in an electric car.

The students will ask you for the components they need if they want to do some extra work. First ask them what they want to do and provide them of the components. Explain to them how they should use and connect the components. They do not have an example, so keep an extra eye on them!

Summary

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

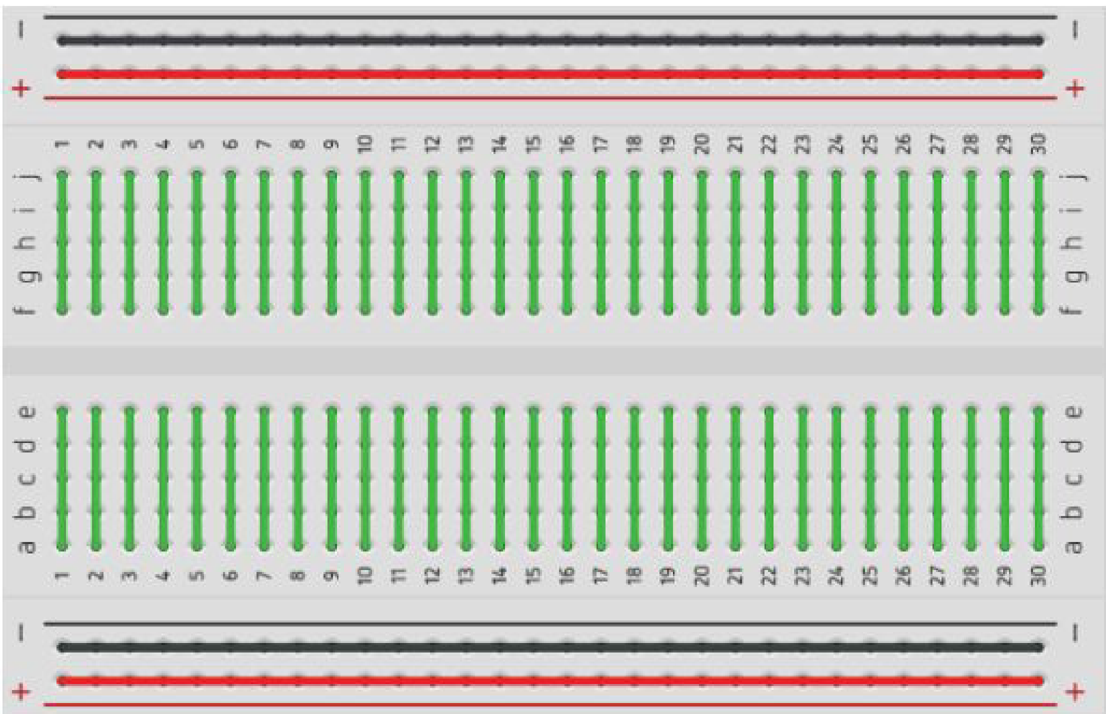


Figure 1.7. Breadboard connections

The necessities of a working electrical circuit are:

- Power source
- Closed conductive wire
- Load

Answers to the questions of module 1

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)

This answer can be different for each student and you do not have to check it with them.

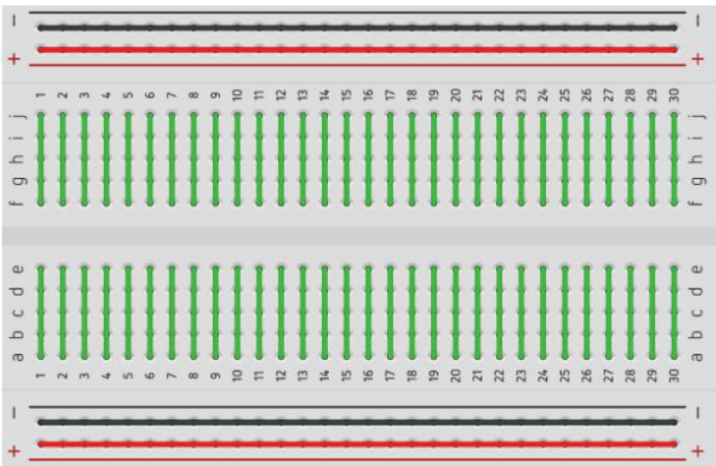
2. What are the necessities for an electrical circuit and why?

Power source: Delivers energy for the load.

Closed conductive path: So the energy can be deliverd to the load.

Load: The component where the energy can be deliverd.

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.



4. What do you think this component does?

This component is called a button. When you press the button it will let through the current and the LED will shine.

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

You don't have to check this answer. Possible answers are: Radio, Flashing light, light in the car itself.

6. What do you think this component does?

This component is called a Light Dependent Resistor (LDR). The value of this resistor depends on the amount of light that shines on the sensor. The more light shines on the LDR, the lower the resistance and the brighter the LED will shine.

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

You don't have to check this answer. Possible answers are: Automatic light system, lighting up the dashboard.

8. What do you think this component does?

This component is called a Negative Temperature Coëfficiënt (NTC). The value of this resistor depends on the ambient temperature. The higher the ambient temperature, the lower the resistance and the brighter the LED will shine.

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

You don't have to check this answer. Possible answers are: Automatic eating/cooling system.

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

This answer can be different for each student and you do not have to check it with them.

Module 2 -The electric motor

Introduction to the subject

One of the basics 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 module, your students will be building an electric motor. Thus, electrical energy will be converted to kinetic energy to move the car. But how can we do this? And how will this move our electric car?

Summary of the content

In this module, your students will see how electrical energy can be converted to kinetic energy. They will use this concept for their own future electric car in the final module. The module will go as follows. First you will have a group discussion to check what students already know about energy and converting energy. Details and handles to these discussions and to the other elements in this module are given in the sections 'The lesson guide' below. After this group discussion your students will make a simple electric motor using their student's guide. If your students have finished making their electric motor, they can continue to the extra materials in which they are able to choose between extra theory or extra practical work. The theory corresponding to this practical is handed by some classical theory given by the teacher and thus, by the extra materials.

Learning objectives

At the end of this module the students:

- 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

Teacher's foreknowledge

You, the teacher, should at least know/understand the following topics:

- Magnetic fields lines: know what different orientations of the lines mean and how two magnetic fields interact with each other.
- Ohm's law: $I = V/R$
- resistance of a wire: $R = \rho*L/(A)$, where rho = resistivity of the material, L is the length, and $A = \pi*r^2$
- know that an electrical current also carries a magnetic field and what this field looks like.

Module 2 -The electric motor

Preparation

- Try out all exercises in the Student's guide yourself before teaching the module.
- Gather the materials for every group of students as described at materials and resources.
- Organise the classroom, so students can work easily in groups of two.

What to do if a student missed a previous module?

The students should know how to connect different electrical components together to make an electrical circuit. In this module, a breadboard will be used. If a student wasn't present during module 1, he or she should look over the summary of module 1. Here a breadboard is briefly explained

Materials and resources

The materials that are needed for this workshop are for each group of 2 students:

- 2 Electronics kits
- Magnet
- Copper wire (magnet wire): 1 x 2m, 2 x 3cm and 2 x 6cm
- Piece of sandpaper
- Nipper
- Piece of paper (A4)
- Tape

Time schedule

Lesson part	Duration	Content
Introduction	5 min	Recap what has been done in the previous module. Explain why this module will contribute to their future electric car.
Brainstorm session	7 min	Discus what sort of energies exist. What concepts can be used for their future electric car to move?

Module 2 -The electric motor

Explanation Pactical electric motor	3 min	Very short what students are going to make and how they will use the student's guide and materials
Practical: electric motor	40 min	Walk through the classroom and check if students need help
BREAK	10 min	
Theory electric motor	15 min	Explain how the electric motor works (simple) and how it can be used
Practical versus theoretical	25 min	The students will work (further) on a practical or theory. They can ask questions
Questions and answers	15 min	Provide the students with answers to the questions in the extra materials
Discussion of experiment and takeaway message	5 min	Ask students how it went and what problems they faced/questions they have. Also, ask which concept they would use for their future electric car. Also give a take away message of this module (conclusion).
Cleaning up and end of module	5 min	Cleaning up concluding the module

Module 2 - The electric motor

Introduction

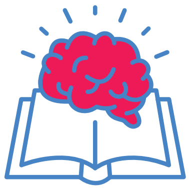
This is the beginning timeslot. Introduce your students to yourself and to the subject. Also include the previous module

1. Welcome your students to this module and tell them that this is the second module in a series of modules where the goal is to build an electric car.
2. Ask who attended the previous module. This way you will have an overview of students that may have questions about building a circuit and how to use a breadboard during this module.
3. Repeat what was done in the previous module (building electrical circuits with different components). You can ask students if they remember which components they used and what their function was (LED, NTC, LDR, etc.).
4. Remind/explain them what the end product will be (a car) and how the previous and this module will help them to be able to make a car in the last module. You can use the section 'introduction to the subject'.

This introduction is meant to structure the module. At the end of the introduction the students will know how the workshop is structured and how this and the previous module contribute to the end product; the electric car.

Module 2 - The electric motor

Brainstorming



In the brainstorm session you can check what your students already know. Let them participate actively by asking them questions about what they already know of energy.

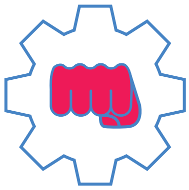
1. Ask what students know of energy.
2. Explain there are different types of energy and ask the students if they can name a type of energy (different energies can be kinetic, chemical, electrical, light, sound etc.). You can ask in which sort of system (device or example) that kind of energy appears (for example chemical energy; in a battery). Explain what those types mean (where can your students 'see' them in daily life).
3. Tell them that one type of energy can be converted to another one and ask if they know an energy conversion? You can help them by giving (an) example(s). See the list below.
4. Make a bridge to the energy conversion we'll need to build a car by asking/explaining to them which energy conversion we'll be using for the car and why.

Examples energy conversions

- LED, or a lamp in general: electrical energy to light
- Combustion engine: chemical energy to kinetic energy
- Kettle: electrical energy to thermal energy (heat)
- Radio: electrical energy to sound (which actually is kinetic energy)

Now your students can name some energies and energy conversions. Teaching them the names of energies will help them to structure a new energy: magnetic energy, which they will learn about in this module.

Explanation practical electric motor



Now you will prepare the students for the practical in this module

1. Tell your students that they will build a simple 'electric motor'. Make sure they know what energy conversion they will see by asking or telling them. You don't need to elaborate on the theory of the electric motor because the students will experience for themselves how this conversion will look like.
2. For all experiments in this module, the students need to be paired. Make (or let them make) pairs.
3. Now prepare your students for working with electronics. They need to hear the safety rules applying to building an electric circuit again.
4. Tell your students how the student's guide is constructed and how they should let the student's guide lead them through the experiment. The students will first do the experiment (which is the section 'Experiment'). If they finished early, they can go to the section 'Practical versus theoretical'. In this section the students can choose to do extra theoretical or practical materials (or both). Tell them they will have 50 minutes for this experiment and then they will have a break.
5. *Optional:* Go through the list of components needed for this module with your students and make sure every student knows how the components are named. While doing this you can show them the components classically.
6. Now your students can start their experiment.

Module 2 - The electric motor

Practical electric motor

Now your students will do the experiment. The students will have a student guide that will help them through this module. However, as a teacher, it is up to you to check if the students really understand what they are doing by helping the students with the set-up and asking questions to students while they are building the electric motor.

1. The students will make the set-up as can be seen in figure 2.1.

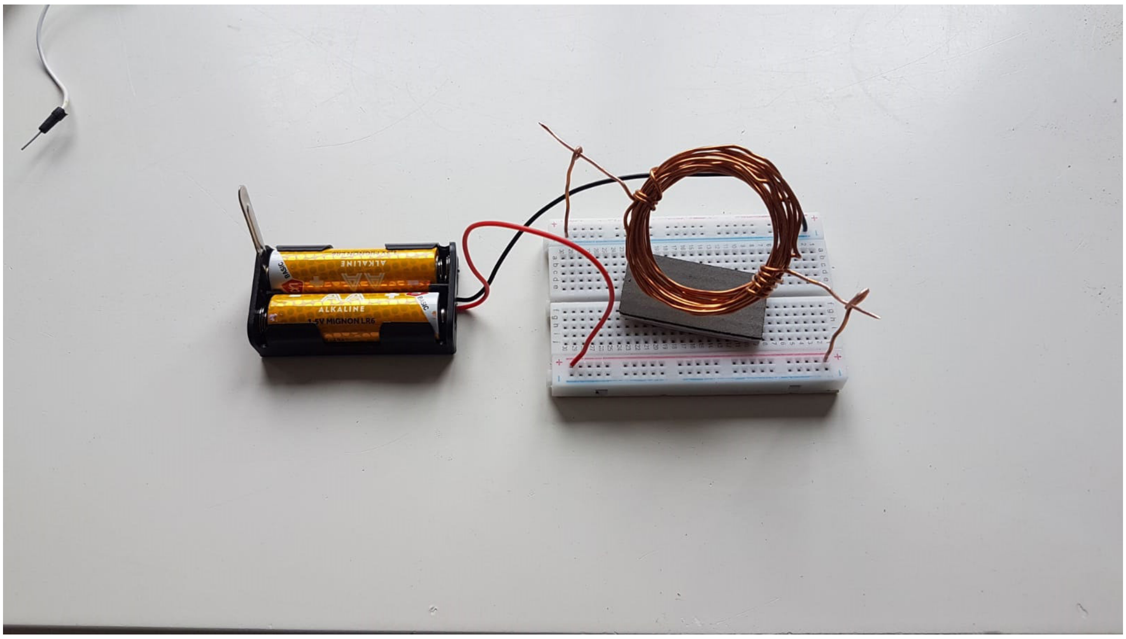


Figure 2.1. Electric motor

2. When the battery is connected, the loop coil should rotate when the magnet is held close by. The coil may need a push to start rotating.
3. Let the students try to find a position of the magnet in which the coil keeps rotating.

Make sure you keep in mind the safety rules.

BREAK (10 min)

Module 2 - The electric motor

Theory electric motor

Now explain how the electric motor works classically. You don't have to get into details yet, it is more important that the students understand the electric motor generally. In the extra theoretical part of the extra materials later on, the students will see how an electric motor works in more detail.

1. Explain that every current creates a (circular) magnetic field
2. Find out what the students already know about a magnetic field. Start with magnets (these have a certain magnetic field). Explain when they attract and repulse each other by giving their magnetic field a direction (the black arrow in the middle). You can show this with two magnets for more clarity.

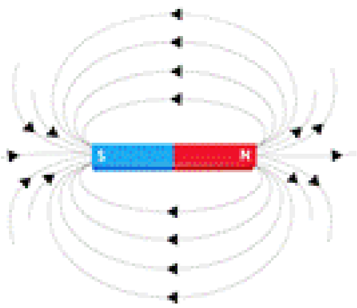


Figure 2.2. Magnetic field

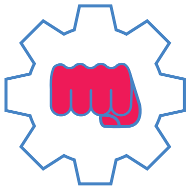
3. Explain that a loop coil will behave as a magnet when a current is present and that this is why the loop coil is attracted or repulsed, causing it to turn around.
4. Explain that a greater current will cause a greater magnitude of the magnetic field, thus the loop coil will rotate faster. Discuss with your students how you can make the loop coil rotate faster (by making the current greater). They will later have an exercise of this in the theoretical part of the extra materials (question 3).
5. You can now name some daily examples in which an electric motor is implemented. Maybe the students can think of examples. Below is a list showing some examples.
    - blender
    - ventilator to cool your room (big)
    - ventilators in your computer to cool it (small)
    - refrigerator compressor
    - pump

    Actually everything which you connect in your wall outlet and has turning components, probably has an electric motor! Don't try this
6. Show the class how the component (electric motor) looks like. They will use this component in their electrical circuits in the following modules 4 and 5. You can refer to the section 'An electric motor in an electrical circuit' in the student's guide. Here the icon of such component is shown and also connect in an electrical circuit.

Module 2 - The electric motor

Practical versus theoretical

The extra materials are divided in a practical and theoretical part. The students can choose which one they want to work on. Below the questions and answers of the extra materials are provided.

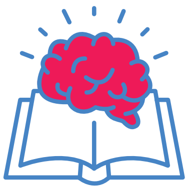


Practical part

Your students can optimize their electric motor by trying a couple of things:

- Two magnets and their optimal positions around the loop coil.
  With two magnets (with the right positioning), the students should be able to let the loop coil rotate faster: the magnetic field of the second external magnet should be positioned so the magnetic fields are summed up.
- Different diameters of the loop coil.
  Decreasing the diameter of the loop will lead to more loops. It causes the magnetic field to be more concentrated which will result in a stronger magnet (and thus the velocity of rotation will increase).
- More batteries
  A greater current will create a greater magnetic field: the loop coil will rotate faster.

Note: this practical part is to let the students play a bit with their electric motor. Why exactly the loop coil turns faster falls outside the scope of this practical part.



Theoretical part

In the theoretical part the students will read some theory and then answer questions. You can help them with the theory if they do not understand it since it can be quite difficult for them. Try to not answer the questions in their workbook, but give some hints or tips to answer them. The students have to try it by themselves first! The answers will be given at the end of this module in the teacher guide.

Discussion of experiment and takeaway message

Your students now have built the electromotor.

- Discuss with them how the experiment went and what problems the students faced classically. This way the students can learn from each other's mistakes and problems.
- Ask your students how they would implement this in their car (if this wasn't clear yet). How can they use the electromotor to move their car? Let them think about connecting the electromotor to their axle attached to the wheels, or attaching the electromotor to propellers.
- Give the students a takeaway message: By making a loop coil, and using an external magnet and a battery, you can let things rotate!

Summary

In this module the students 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. The students can use the electric motor to rotate different things (think of propellers, wheels or the axle on which wheels are attached). This is why the students will use an electric motor in the last modules of this workshop!

Answers to the questions of module 2

1. Complete the sentence

*First, the battery converts **chemical** energy to **electrical** energy. Then, by making use of an electric motor, energy is converted to **kinetic** energy*

2. Draw the arrows in the magnets of the middle and right image in figure 2.4 (the left image is shown as an example).

Middle: arrow pointing to the left. Right: arrow pointing to the right.

3. 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?

They repulse each other. They would still repulse each other.

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.

1. Use materials with good electrical conductivity (low resistance). Examples; copper, silver, iron. (R decreases, i increases)

2. The diameter of the (in this case copper) wire. $R = \rho * L/(\pi * r^2)$. (With increasing r, R decreases and I increases)

3. More batteries (V increases, I increases)

5. Does the magnet attract or repulse the loop coil in figure 2.8b? And in 2.8c?

2.8b: attract. 2.8c: repulse

6. Complete the sentence

*First, the battery converts **chemical** energy to **electrical** and **magnetic** energy. Then, by making use of an electric motor, the **magnetic** energy is converted to **kinetic** energy.*

Module 3 - Combining circuits

Introduction to the subject

There are multiple ways to order components in an electric circuit. The ordering matters as Voltage and current are divided differently over components when they are in a series or parallel circuit. Most students have already built simple series circuits. In this module the students will learn how to build more complex circuits in series and parallel. They will learn how they can make use of the properties of series and parallel circuits to make the circuits behave in a certain way.

Summary of the content

In this workshop the students will first build a simple series and parallel circuit, that will show them different properties of them. They will build these circuits from a template. After this, the students get multiple exercises where they are asked to make a circuit containing specific components that behaves in a certain way. In these exercises they will get an idea of some of the concepts that are in play in series and parallel circuits.

Learning objectives

At the end of this module the students:

- know the difference between series and parallel circuits;
- be able to connect multiple circuits in series and parallel;
- be able to require multiple inputs for one output.

Teacher's foreknowledge

You, the teacher, should at least know/understand the following topics:

- The difference between series and parallel circuits and how voltage, current and resistance play a role in it;
- You should be able to troubleshoot a non-functioning electronic circuit;
- You should be able to build series and parallel circuits

Preperation

- Try out all exercises in the Student's guide yourself before teaching the module.
- Prepare the icebreaker, as is explained below.
- Organise the classroom, so students can work easily in groups of two.

Module 3 - Combining circuits

What to do if a student missed a previous module?

For this module only some knowledge form module 1 is needed and no knowledge about the second module is needed. Students that missed module 1 should look through the summary of module 1. The most important things to know is how to use a breadboard, and that a circuit should always be closed.

Materials and resources

For each group of 2 students you need:

- 1 Electronics kit

For the icebreaker you need:

- Rope (~ 10 m). Not necessary if the icebreaker is done on a sandy surface
- 8 coins
- Paper
- Scissors

Time schedule

Lesson part	**Duration**	**Content**
Icebreaker	20 min	Icebreaker about series and parallel circuits
Introduction and exercise 1	25 min	Introduction to series and parallel circuits, with the help of exercise 1 (series) and exercise 2 (parallel)
BREAK	10 min	
Practical: Combining circuits	55 min	Students work on in groups on exercise 3, 4, 5, 6
Cleaning up and end of module	10 min	cleaning up concluding the module

Module 3 - Combining circuits

Icebreaker

Goal

Students will experience how voltage and current are divided differently over series and parallel circuits, without needing deep knowledge about these concepts.

Material

Rope (~ 10 m). Not necessary if the icebreaker is done on a sandy surface
8 coins
Paper
Scissors

Preparations

- Mark an area on the floor similar to figure 3.1.

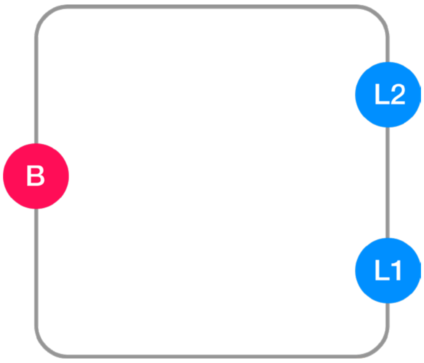


Figure 3.1: Icebreaker layout at the start

- You can use the rope to mark the black rectangle on the floor. If the icebreaker is done on a sandy surface, you can also draw the rectangle in the sand.
- Use a piece of paper to mark the B, L1 and L2 location on the floor.
- Make sure you have space on the right side next to L1 and L2 to expand the 'circuit' later in the icebreaker.
- Choose 7 students for this icebreaker.
- Assign roles to the students:
    - 1 student is the battery and should stand at the B
    - 1 student is an LED/light and should stand at L1
    - 1 student is an LED/light, but should not stand at L2 yet!
    - 4 students are the electricity.
- Give the battery student 8 coins (or pieces of paper)

Guide

1. Explain that in this icebreaker the students will be playing electricity (again) and that this time they will learn about multiple paths in a circuit. The students will later see how you can use this in practice.

2. Instruct the battery to give 2 coins to each student that passes him/her.
3. Instruct the LED students that they are lights, and that they should make funny movements when they get coins. If they get 1 coin, they should move only one arm. If they get 2 coins at once, they should move both arms.
4. Instruct the electricity students to walk along the path starting at the battery, where they will get 2 coins. When an electricity student encounters an LED student they should give them 1 or 2 coins. But there is one extra rule. The coins should be divided fairly between all LED students they encounter on their path. So if there are 2 students LEDs on the path of an electricity student, then both LED students get 1 coin. If there is only one LED student on the path, this LED student gets 2 coins. The next electricity student can only start walking as the previous student returns at the battery (this is done for clarity, and does not have any analog in an actual circuit).
5. Explain that the LED student could burn at full potential. As the LED student waved both arms.
6. Instruct the second LED student to take place on spot L2. Make sure the battery gets all coins back, and instruct the electricity students to walk through the circuit again. This time they should only give one coin to each LED students to divide them fairly.
7. Explain that now the LED students both couldn't burn as bright, as the energy had to be divided between both LEDs.
8. Expand the marking on the ground like this:

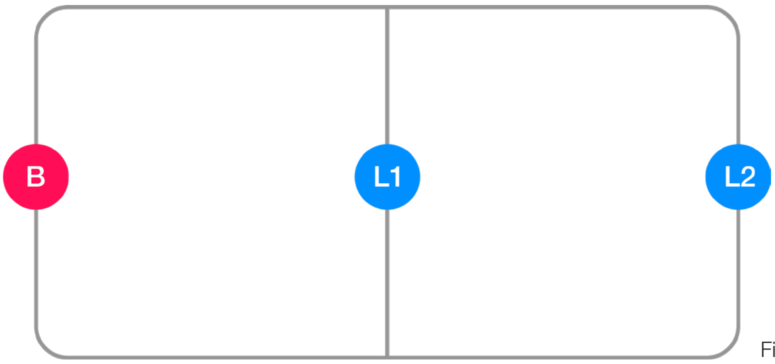


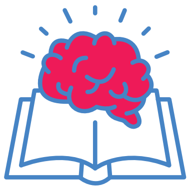
Figure 3.2: Expanded icebreaker layout

Move the L2 marking to the new path.

9. Instruct the electricity students to move through the circuits again. There is a new rule: the students should be equally divided over the paths that go past L1 and L2. Also the students have to go back to the battery directly so, they can't move to L1 and then to L2 and then back to the battery.
10. Explain that now both LEDs could burn as bright as they could, as the LED students both waved both hands. Tell the students that today they will learn how they can use this to their advantage in actual circuits.

Module 3 - Combining circuits

Introduction



First this guide will give you an overview of the introduction. After this the introduction is written out in more detail.

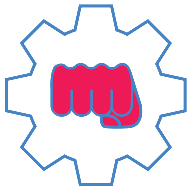
Most students have made simple circuits in the previous modules. In this module the students will learn about combining circuits in series and in parallel. In the introduction the students get the instruction to make a circuit containing multiple LEDs. They will see that adding more LEDs in series makes them dimmer. You will then show them how to connect the LEDs in parallel, this way the LEDs will burn brighter. After the introduction the students get exercises in which they explore series and parallel circuits. In these exercises the students will experiment with building circuits with series and parallel inputs (buttons, sensors) and outputs (LEDs).

1. Before you start the module it is important to check how many students have worked with a breadboard in one of the previous modules. Ask the students to raise their hand if they did not do module 1 or 2. It could be the case that there are students that missed the first or second module. If there are multiple students that did not do the first or second module, it is a good idea to explain the basics of a breadboard and electronic circuits with the help of the first module (up to building your first circuit). If there are multiple instructors during the module it is a good idea to have one instructor work with the students that missed one of the previous module.
2. Tell that most students have made simple circuits involving LEDs, sensors and electric motors.
3. Tell Today we will see how you can combine multiple circuits into one. The simplest way to do this is to connect two circuits together one after the other in one line. We will try this now.
4. In this exercise the students will build a circuit, so it is very important to explain the safety rules again before the students start!
5. Instruct the students to do the first exercise of module 3 in their workbook. Give the students 10 minutes to do this exercise. Tell the students to raise their hand if they have any questions during this exercise.
6. Explain what the students should have observed (the answer exercise 1c)
7. Explain the answer to exercise 1d.
8. Instruct the students to do exercise 2.
9. Explain that the electricity gets divided differently over multiple paths, like we saw in the ice breaker.

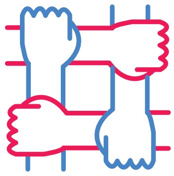
BREAK (10 min)

Module 3 - Combining circuits

Practical: Combining circuits



The rest of the module students will work in groups of 2 on the exercises 3 to 6 in their workbook.



1. Instruct the students to work on the the rest of the exercises of this module in their workbook.
2. While the students are working on the exercises walk through the class to see what they are doing.
3. Tell the students that they can work through the extra exercises when they are done with exercise 1 to 6. Explain that this is for students that are interested and want to learn something extra.
4. Explain The answers for questions 3 to 6 to the students. These answers can be found at the end of this module.
5. Instruct the students to clean up. Ask them to collect all components.
6. Give the students a compliment and thank them for their attention.

Make sure you keep in mind the safety rules.

Module 3 - Combining circuits

Extra material

In the student guide there is extra material that explains Ohm's law and quickly goes into the differences between series and parallel circuits. This is extra material, so you do not need to teach this in the module. Students can work through this section by themselves. But they may ask questions about it, so be prepared to answer those. The students can work through this material if they finished all other exercises in this module or in their own time.

Answers to the questions of module 3

1c. 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?

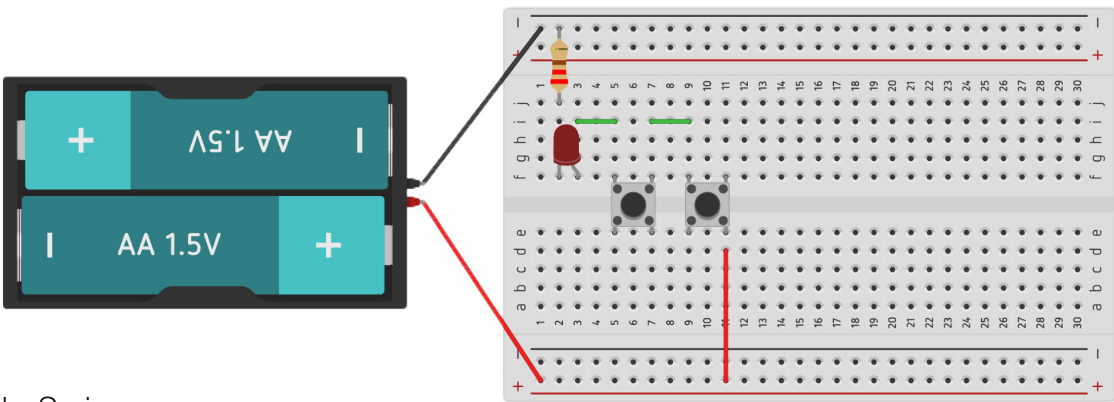
The LEDs get dimmer. When multiple LEDs are added the LEDs get dimmer.

The electricity is divided over all components in the path.

1d. 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.

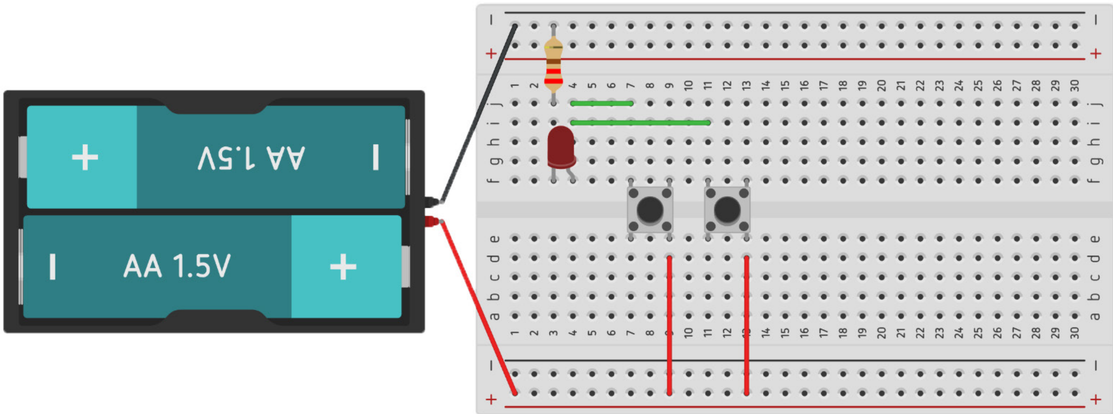
No, you cannot build this circuit. If you add one button it will create a disconnect in the circuit when the button is not pressed. Therefore, when you add two buttons in series, both have to be pressed to create a continuous electric circuit.

3a.



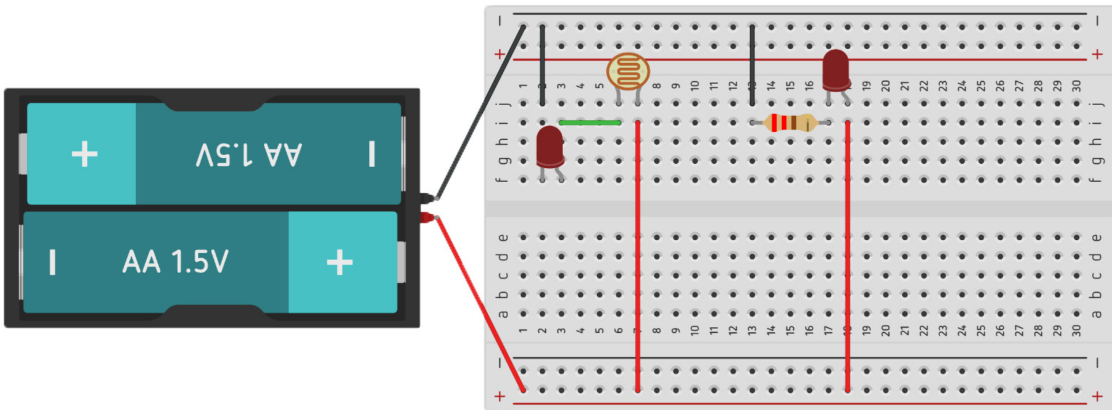
b. Series

4a.



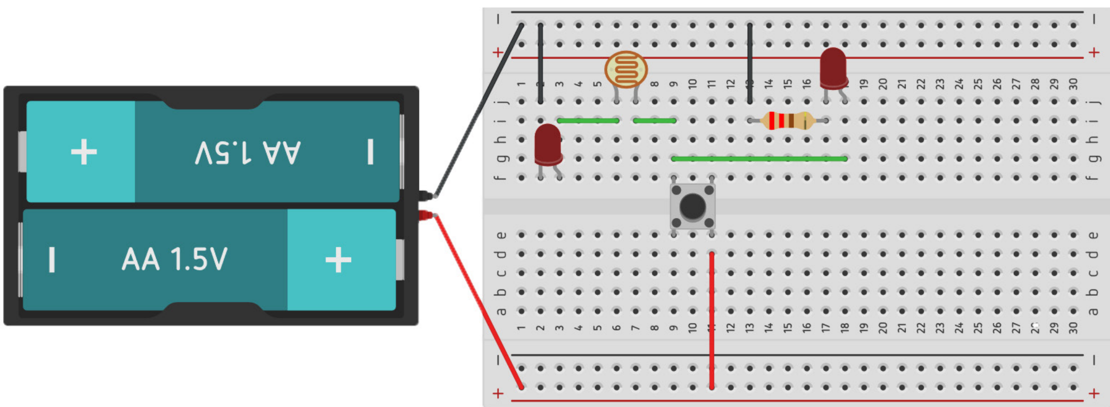
A possible answer is: Some cars have buttons to lower the windows. Often the window on the passenger side can be opened and closed with buttons on the passenger and the driver side.

5a.

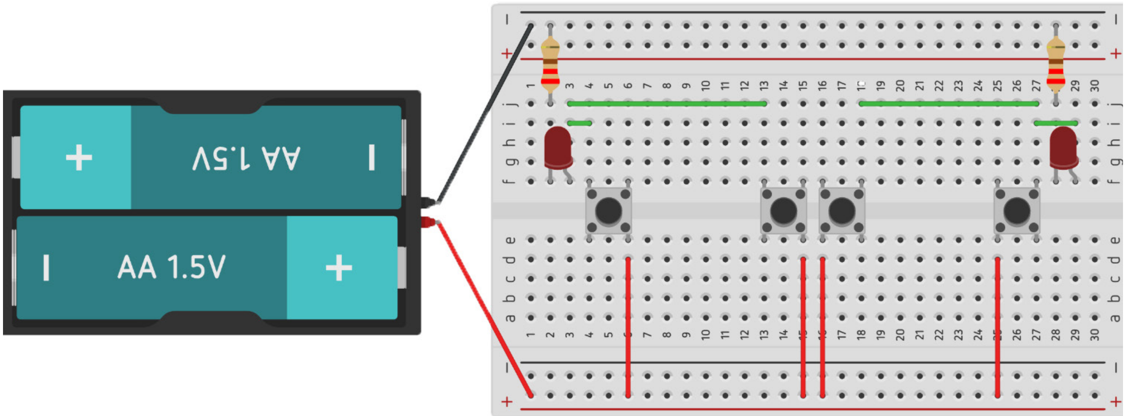


b. Parallel

c.



6a.



b. Can you think of a place in a car where this circuit could be used?

This could be used for the turn signals. They can be activated separately, or both can be on at the same time (hazards lights).

This could also be used for opening and closing the driver and passenger side windows at the same time, while the driver and passenger can also open and close the windows themselves.

7. I = V * R = 31.5 V * 1000 Ω = 0.0045 A

8a. 29 000 000 (29 M)
8b. 500 000 (500 k)

Module 4 - The electric car

Introduction to the subject

Everyone has seen a car speeding down the roads. Some leave trails of smoke and combustion gasses, while others do not. Some make a lot of noise, while others do not. Especially in urban areas, the quiet and clean cars are preferred. These are electric cars, which are powered by big rechargeable batteries rather than fossil fuels. Electric cars have been around for ages, and have even been to the moon (see figure 4.1). But what is needed to create such a car? Using rather simple materials we try to create our own electric car!

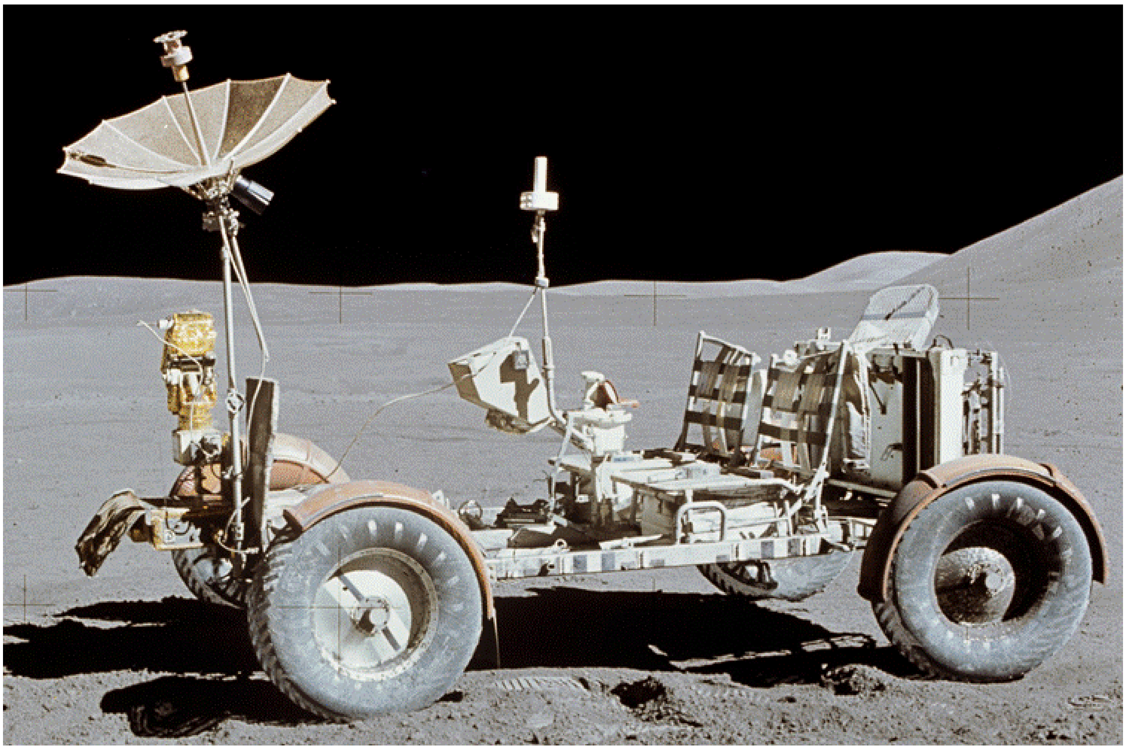


Figure 4.1: The U.S. Apollo Lunar Roving Vehicle from Apollo 15 was the first electric car on the moon in 1971.
Edited from: https://www.hq.nasa.gov/office/pao/History/alsj/a15/AS15-88-11901HR.jpg

Summary of the content

In this module the benefits of using cars with electric motors over cars with fossil fuel motors are explained. We will look at what defines a car: "what do you need a car to do?" To guide you and your students we give some examples of electric cars and what defines them. Next we are going to see how some real car parts can be modelled using only batteries, breadboards, sensors and actuators. Having these examples, we can create our own electric car. Students are set free to experiment on adding parts to their car. This way they can make the electric car of their dreams.

Module 4 - The electric car

Learning objectives

At the end of this module the students:

- know how to take ideas from a real life design of a car and copy them using electronics.
- know which components are needed to make a car.
- know there are many solutions to the same kind of problems.
- think experimenting with electronics is fun.

Teacher's foreknowledge

- Knowledge of electronics from previous modules
- Knowledge of electronics safety rules
- Knowledge of the functioning of the potentiometer

Preperation

- In this module, you are expected to make some choices. These choices are shown in choice boxes. Think about the choice you have when seeing such a box, and fill in your choice. Here is an example of a choice box:

Choices	Circle your answer
Do you want to talk to the students about who has seen an electric car, or do you want to talk about the history of the electric car, or both?	Who has seen an electric car? History of the electric car. Both.

- Make sure all the materials listed in the materials section are present in your classroom.
- Prepare for questions about the electronics by making the circuits yourself before the lesson starts. This way you know for sure if the circuit is working as you expect it to do.

What to do if a student missed a previous module?

The students will be able to follow the biggest part of this module without having followed the previous modules. Only after the break, when you are going to show some examples of electric circuits, the students might not know what is going on all the time. Do not worry, let the students ask questions and let them wonder about the electronics for a bit. In the time that the students are allowed to start creating their own car, you should advise the students which had a hard time following the examples to read the summaries of module 1, 2 and 3. These summaries will help the student understand the electronics a bit better.

Module 4 - The electric car

Materials and resources

Materials for groups of 4 students
- 1 A3 or A4 format paper for "Collaborative drawings"
- 1 A3 or A4 format paper for "Mind mapping"
- 1 Set of drawing utensils/coloring pencils

Materials for groups of 2 students
- 2 Electronics kits
- 2 Plastic straws
- (Colored) paper
- Cardboard
- Glue Gun with glue sticks
- Scissors

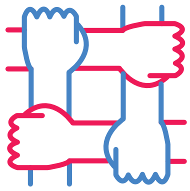
Other materials
- 1 Electronics kit for teacher (same kit as students have)
- Blackboard (and blackboard drawing utensils)
- Rubbing alcohol/acetone and cotton/paper towel to remove glue (only for teacher)

Time schedule

Lesson part	Duration	Content
Icebreaker	10 min	Collaborative drawing
Introduction of the electric car	20 min	Who has seen an electric car and/or The history of the electric car. Advantages & Disadvantages of the electric car over a fuel car
Brainstorm about the electric car	20 min	Content created by stude
Break	10 min	
Examples of car components with electrical circuits	20 min	Electric motor, steering system, lights or car horn, reverse
Practical:	35 min	Let students replicate examples and let them free to experiment
Cleaning up and end of module	5 min	Cleaning up and end of module

Module 4 - The electric car

Icebreaker



Goal

Let the students combine their artistic talents to create the ultimate drawing without seeing what others have drawn!

Material for each group of 4 students

- A3 or A4 format paper folded in 4 equal parts
- Drawing utensils/coloring pencils

Guide

1. Divide the class into groups of 4 students and make them sit around one table.
2. Give each group drawing utensils, coloring pencils, and a piece of A3 or A4 paper.
3. Let one person of the group fold the paper in 4 equal parts along the longest side of the paper as shown in figure 4.2.

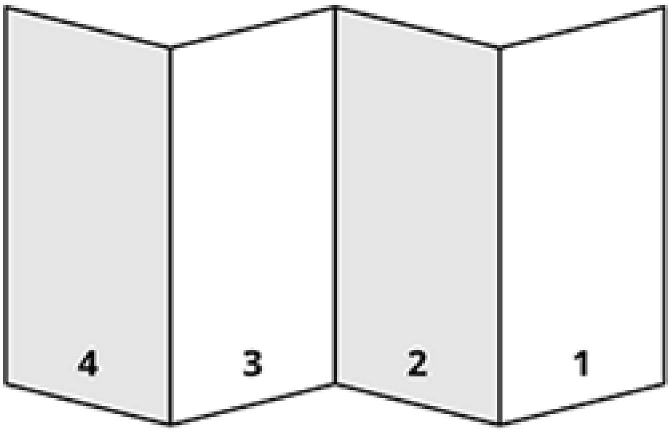


Figure 4.2: Four fold folded paper.
https://www.katfamphoto.com/wp-content/uploads/2019/07/Accordion_Fold_Brochures.png

4. Tell the students to try to draw the most fantastic car they can imagine, but each student can only draw a part of the car.
5. Start a timer of 1 or 2 minutes.
6. The first student can start with the front of the car. He can choose to draw whatever he wants: headlights, front wheels, a big engine popping out of the hood, etc.

7. If the timer beeps, his time is up and he has to fold back the first part of the drawing (see figure 4.3). This student has to make sure a tiny part of his drawing is still visible, so the next student knows how to connect his drawing to the previous part.

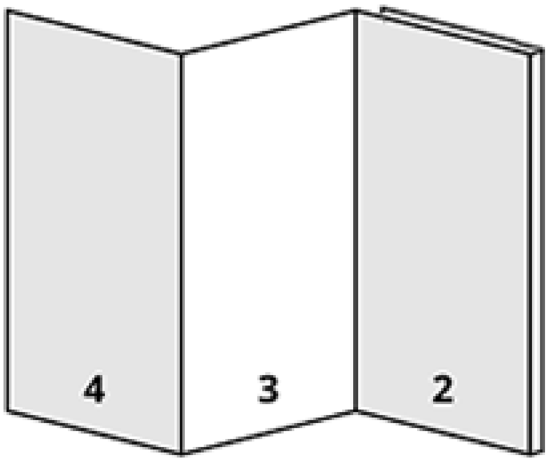
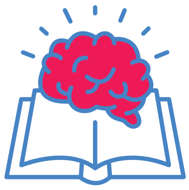


Figure 4.3: Four fold folded paper with panel 1 turned to the back.
Edited from: https://www.katfamphoto.com/wp-content/uploads/2019/07/Accordion_Fold_Brochures.png

8. Restart the timer and let the second person in the group draw a middle part of the car: car door, windows, or wings on the car, let them get creative.
9. At the sound of the timer repeat step 7.
10. Let the third student draw.
11. At the sound of the timer repeat step 7.
12. Let the last student draw
13. At the end of the timer, let the students straighten out their drawing and see what kind of crazy creative cars they have made. If you want, post the cars on windows or doors such that the students can look at all the creations.

Module 4 - The electric car

Introduction of the electric car



In this introduction you will explain the students about the advantages and disadvantages of using an electric motor to run a car.

You can start with a little bit of history about the electric car, or start by asking the students if they have ever seen an electric car. Note, the history of the electric car is also added in the student manual as extra material. Take about 5 minutes for this part, and then continue on to the differences between electric and combustion cars.

Choices	Circle your answer
Do you want to talk to the students about who has seen an electric car, or do you want to talk about the history of the electric car, or both?	Who has seen an electric car? History of the electric car. Both.

Who has seen an electric car?

If one of your students has seen an electric car, you can ask him/her to tell about the car:

- How did the student know it was an electric car?
- What was different from normal cars?
- Would the student like to drive an electric car in the future?

History of the electric car

The history of the electric car is given in this module's section of "Extra material". If you want to talk about how the electric car has developed, you can look at this section. The students will also have the same information available in their Student's guides under the section of "Extra material".

Differences electric and combustion cars

After this small introduction, the students will have some understanding of what the electric car is. Now you can start to compare the electric car to the combustion car. The students might be more familiar with the combustion car, so this way you will expand their knowledge.

The main differences between electric cars and combustion cars is 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).

Write these differences down onto a blackboard, so that students can hear, and read what the differences are. Noting them down helps with thinking of advantages and disadvantages in the next part of the introduction.

Advantages and disadvantages of the electric car

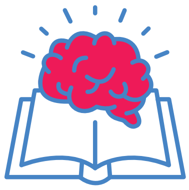
The differences between electric and combustion cars lead to electric cars having advantages, but also disadvantages. You can ask your students to try and think of advantages/disadvantages and make a list together on the blackboard. If the students do not know any advantages or disadvantages you can use the following list to explain some of them. The students have some space in their Student's guides to write down these advantages and disadvantages. Motivate students to write their own answers down into their guides.

Advantages	Disadvantages
Electricity is much cheaper than gasoline/benzine.	Recharging batteries can take a long time, it often takes 4-6 hours to recharge completely.
Electric motors do not produce carbon emission/pollution.	You need access to a power station for recharging your car. This is expensive if you have to install it at your home.
Electric engines make less noise than combustion engines.	Less noise can be a disadvantage is people do not hear your car coming. They might cross a road without looking.
Electric engines are low maintenance. Combustion engines need lubrication and work on the engine is often expensive.	Batteries cannot hold a lot of energy, therefore the car is limited by driving range and speed. The range is often between 100 and 200 km.
Some governments cut the tax on electric cars, making them cheaper to buy and drive.	Batteries do not live forever, most of them need to be changed every 3-10 years, which can become quite expensive.

This completes the introduction of electric cars. You have opened up the minds of the students to the concept of the electric car. Now it is time for them to brainstorm about this concept.

Module 4 - The electric car

Brainstorming



Brainstorming is a way of guided thinking. You set out to structure your thoughts, and often find extra information about the subject you are thinking about.

In this part of the module the students brainstorm about what makes an electric car an electric car. One of the main questions one can ask here is: “What parts does an electric car need?”. During the icebreaker, students have already subconsciously thought about this question, or at least what parts a combustion car needs. But now the students should try to order their thoughts using a brainstorming method.

Mind Mapping

Mind mapping works by defining a central topic and making associations around this topic. In the following images (figure 4.4 and 4.5) you see two mind maps, one about health, the other about starting a new project.

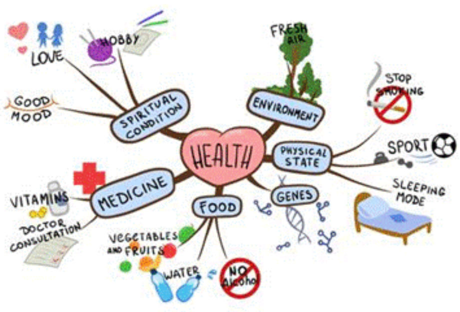


Figure 4.4: Mind map showing possible concepts connected with health.
https://nl.pinterest.com/pin/312507661641818569/

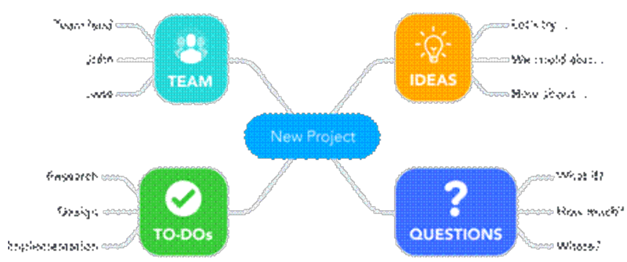
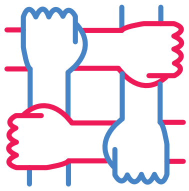


Figure 4.5: Mind map showing possible concepts connected with setting up a new project.
https://www.mindmeister.com/nl

Both mind maps show a central theme, with lines to big associations around that theme. Each association is then linked to multiple concepts. This shows how our central theme is dependent on many small concepts, which should all be included if we want to work on the central theme.

In this module the students should create a mindmap about the electric car. This will be the central theme in the mindmap. Associations might be: Transport, Energy and Safety or Chassis, Motor and Steering. Any association is good. Concepts connected to safety can be: Airbags, Seatbelts and Material of the chassis. The goal of the mind mapping is that students will think about the parts that make up an electric car, and why these parts are needed.

Module 4 - The electric car



Let's start

1. Divide the students in groups of four (you can use the same groups as the ones used during the icebreaker)
2. Give each group a paper and some pens to draw their mindmap.
3. Tell the students that they have 5-10 minutes to think up the mindmap and to draw it on their paper.
4. Wait for 5-10 minutes. During this time you can walk around the class and see if students understand what they should be doing. You can help them by asking questions if they get stuck. Questions could be: "What parts do you see when you sit in a car?" or "What things should a car be able to do, and what parts does it need for this?".
5. After the time is up, call attention to yourself again. Summarize the mind mapping by making a big mind map on a blackboard. Ask the students for their associations and concepts and add them to the blackboard. Take about 10 minutes for this.
6. Motivate students to copy their group mindmap in their own student manual, and let them add associations and concepts as you are doing it as well on the blackboard. The student manual contains a blank page on which the mind map can be drawn.
7. Hopefully, the students have come up with lots of parts of the electric car. Tell the students that you are going to explain how some of these car parts work and how they can be built using an electronic circuit. Examples for these explanations are given in the following section.

If none of the parts that are given in the next section are present in the mind map, you can add them to the mind map yourself, such that you can explain them in the next part of the module.

BREAK (10 min)

Module 4 - The electric car

Examples of car components with electrical circuits

In this section you can give students ideas on how to build actual components of a car. “How do you need to wire your circuit if you want to make two engines run instead of one?” “How do you wire lights and car horn independently?” “How can you make a car go into reverse using a switch?” These are some questions the students might have when they want to build an actual car. Here are some examples that you can explain. Depending on how much time you want to spend on this topic, and how fast the students are learning, you can choose to do multiple of these examples. Here you can also make the choice if you want to talk about the examples, or if you want students to follow your lead and make the examples.

If you choose to build the circuits as an example for your students, make sure you know how, and make sure you take the materials from your own “Electronics kit”. This electronics kit should be the same as the electronics kit from your students, such that they can easily copy you while making the circuit. Making the examples costs more time, but you can guide the students step by step.

Choices	Your answer
Which of the examples do you want to cover in the time you have available?	
Which, if any, of these examples will you explain by discussion/writing on blackboard?	
Which, if any, of these examples will you explain by building the circuits, and letting the students follow your lead?	

The circuits shown in these explanations will also be included in the Student’s guide. This way the student can follow your explanation easier, or try to rebuild the circuit when experimenting in the last part of this module.

Make sure you keep in mind the safety rules.

The electric motor

Electric cars run on electricity. This electricity is provided by rechargeable batteries, which are connected to each other in big battery packs. The electricity is led to the electric motor. The electric motor converts the electricity to movement. A schematic drawing of an electric car is shown in figure 4.6.

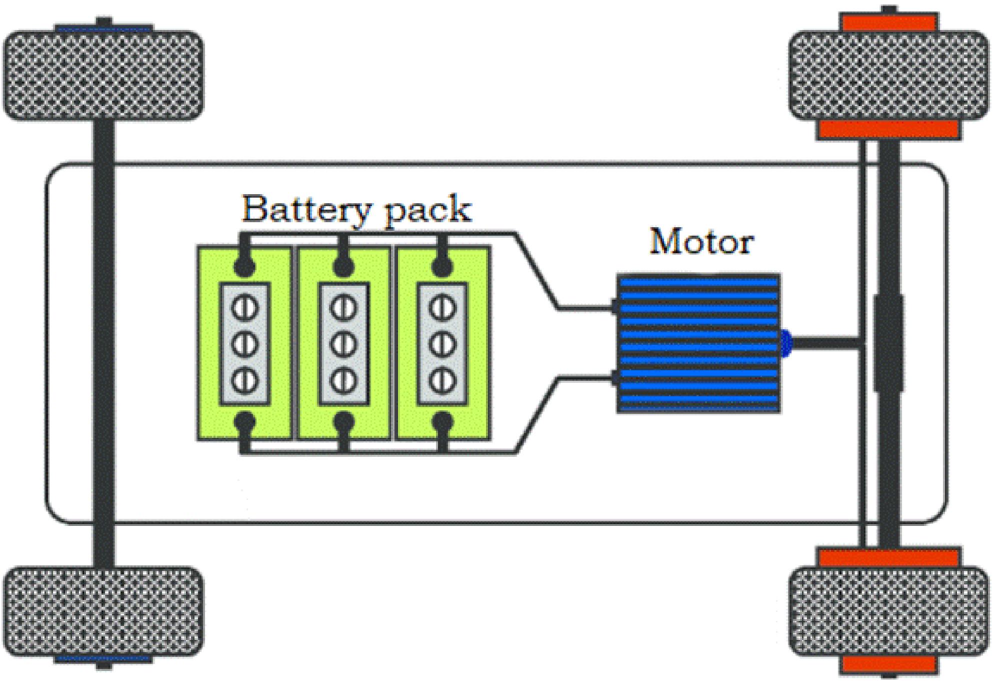


Figure 4.6: Schematic of a car running on an electric motor.
Edited from: https://www.researchgate.net/publication/221916329_Efficient_Sensorless_PMSM_Drive_for_Electric_Vehicle_Traction_Systems/figures?lo=1

A very simple version of the electric motor of the car can be made by connecting a battery pack directly to a DC electric motor, as shown in figure 4.7. The electricity stored in the batteries will let the electric motor turn. However, the motor will only turn in one direction. If you would make a car using this design you could only drive forward, and this way the car could never stop. So making a car only using this connection is not such a good idea.

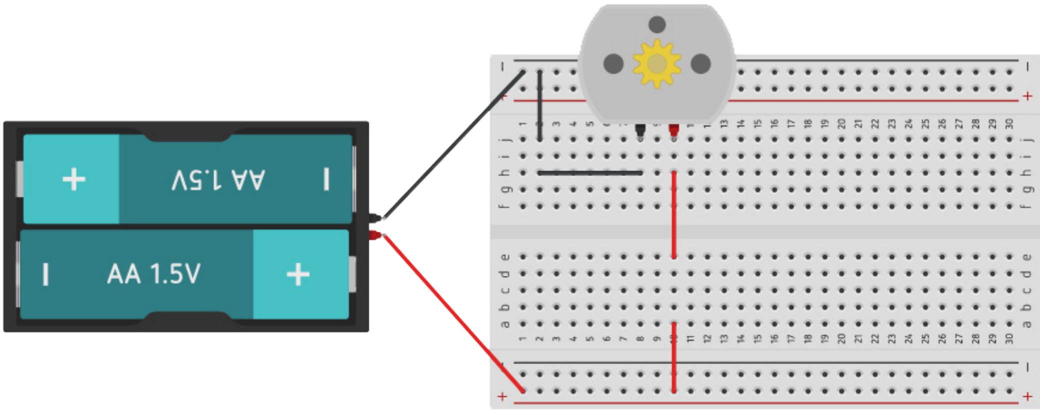


Figure 4.7: Schematic drawing showing an electric motor connected to a battery pack.

Materials needed for this circuit:

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

Instead of connecting a wheel to the electric motor, you could also connect a propellor to the electric motor. In this case you could make a boat, or a propellor driven car by putting the motor on the back of your vehicle.

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 as shown in figure 4.8. The potentiometer, in combination with an controller, gives the driver control over how much voltage the electric motor receives, and thus how fast you are driving. The potentiometer is actually a resistance that can be varied. If you turn the dial on the potentiometer one way, there is almost no resistance, but if you turn it the other way, the resistance increases a lot.

If a driver wants to go faster he will, by pressing the pedal, turn the dial of the potentiometer and increase the voltage output towards the controller. The controller notices that the voltage input from the potentiometer is higher, and increases the amount average voltage output to the electric motor. This makes the electric motor rotate faster, which makes the car go faster.

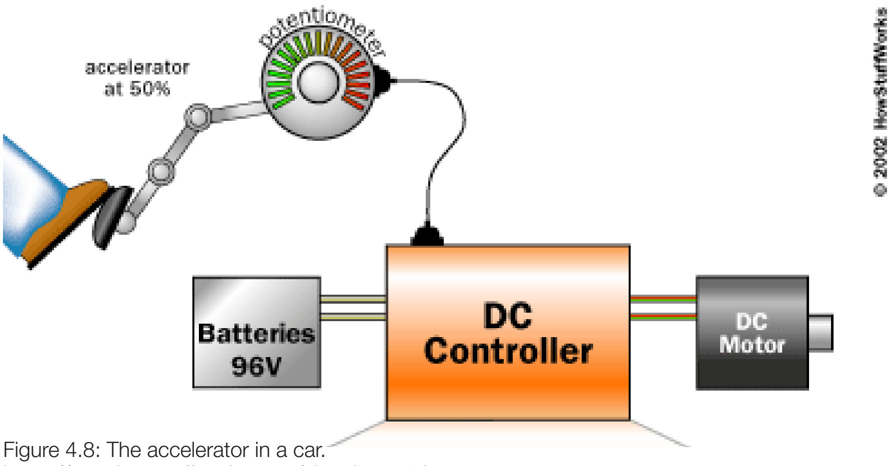


Figure 4.8: The accelerator in a car.
https://auto.howstuffworks.com/electric-car2.htm

In our simple workshop we are not using the high voltage batteries and therefore we do not need a controller, only using the potentiometer will be sufficient to control the speed of the electric motor. With the circuit shown in figure 4.9 you can turn up and down the speed of the electric motor by turning the dial on the potentiometer.

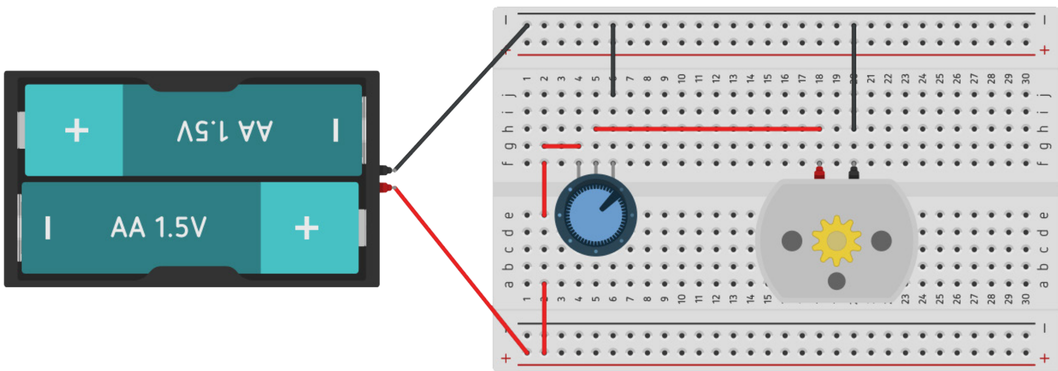


Figure 4.9: Schematic drawing of a circuit with a potentiometer which can be used to control the turning speed of the electric motor.

Materials needed for this circuit:

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

If you want to point out that there is extra material on the potentiometer, this is a nice moment to do this.

The steering system

Unless you want to crash into things constantly, you want to steer your car. We can use a DC motor and a special switch to make a steering wheel, or we use two independent motors to control independent wheels for steering.

1. Independent motors

Using buttons we can make one motor in a circuit turn 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. A circuit which makes this happen is shown in figure 4.10.

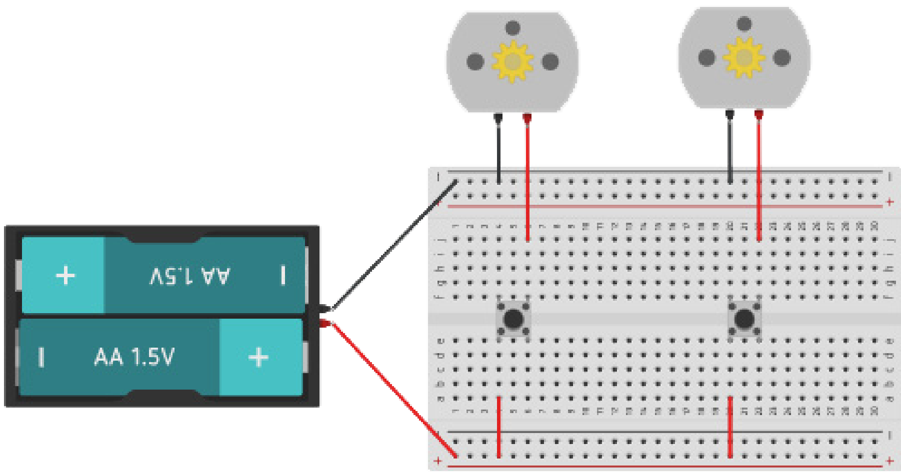


Figure 4.10: Schematic drawing of a circuit allowing independent control of the left and right electric motor.

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 this circuit, or build a more advanced circuit which lets you go forward using a third button (composed of 2 buttons which should be pressed together. This more advanced circuit is shown in figure 4.11

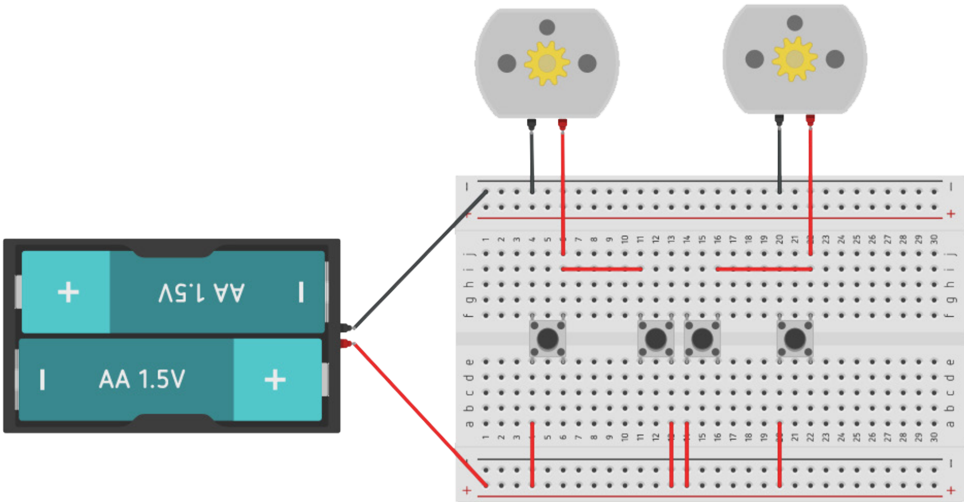


Figure 4.11: Schematic drawing of a circuit allowing independent control of the left and right electric motor. Two extra switches are combined into one to allow both electric motors to turn at the same time.

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 the students can handle the challenge and are eager to learn, try to explain it, otherwise only explain option 1.

In figure 4.12 we see how the front wheels of a care are connected to a bar, which can be controlled with a steering wheel. Rotating your steering wheel makes a circular gear turn. This circular gear is connected to a linear gear, which moves sideways if the circular gear turns. The movement of this linear gear results in the tires tilting to one side. In this way you can steer a car with your bare hands.

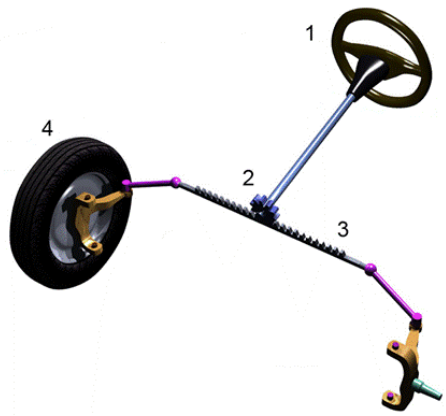


Figure 4.12: Steering system of a car consisting of: Steering wheel (1), circular gear (2), linear gear (3) and wheel (4).
Edited from: https://commons.wikimedia.org/wiki/File:Steer_system.jpg

As it can take a lot of power to rotate your wheels by turning the steering wheel, the assisted steering wheel was invented. This assisted steering wheel has its connection of the steering wheel to the rotating gear replaced by a connection to an electric motor, as can be seen in figure 4.13. Rotating the steering wheel results in powering the electric motor. Turning the steering wheel one way lets the axle of the motor turn in clockwise direction, while turning the steering wheel the other way makes the motor turn in an anti-clockwise direction. Connecting the motor to the circular gear allows us to turn the wheel using the power of this electric motor.

Figure 4.13: Steering system with an assisted steering wheel consisting of: Steering wheel (1), electric motor (2), circular gear (3), linear gear (4).
Edited from: https://www.zf.com/products/de/cars/products_31808.html

From this example of an assisted steering wheel we know what materials we need to make an electric steering system:

- An electric motor.
- A battery powering the motor.
- Something which determines the direction of this motor, just like the steering wheel.
- A connection between the electric motor and the steering axle of the wheels.

Figures 4.14 and 4.15 show how a small toy car using these materials would look like, and how an electric motor can be connected to a battery such that the turning direction can be reversed using two switches.

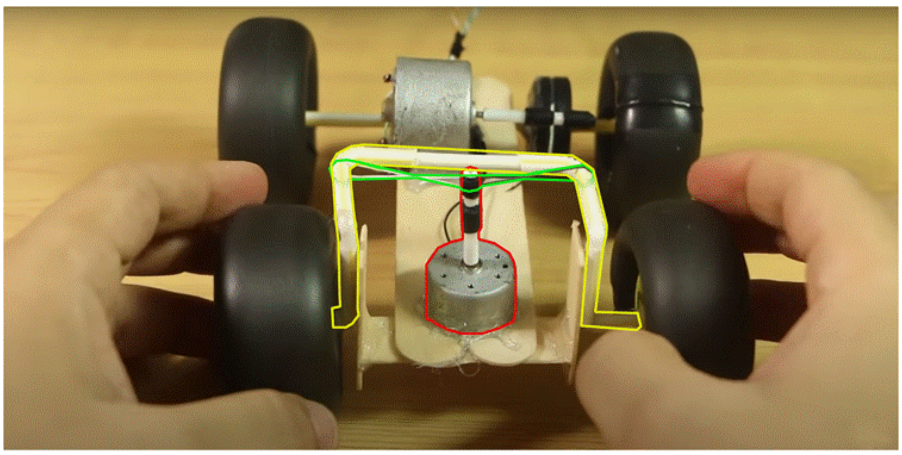


Figure 4.14: An image showing how an electric motor can be connected to a steering axle. The red outline shows the electric motor, the green outline shows a rubber band connecting the motor to the steering axle which is shown in yellow.
Edited from: https://www.youtube.com/watch?v=NL5-FV28uRA

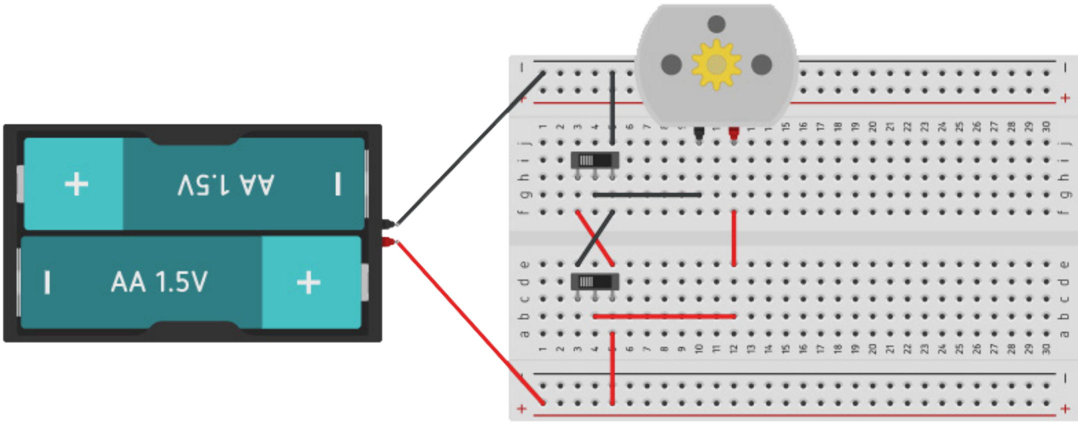


Figure 4.15: Schematic drawing of a circuit in which the turning direction of an electric motor can be controlled with the use of two slide switches. If both switches are slid down, the motor turns in the clockwise direction. If both switches are slid up, the motor turns in the anti-clockwise direction. 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

Car horn and Lights

A car horn is nothing more than a speaker producing sound when current is going through it. And by pressing your car horn button, the current starts flowing and the sound is heard. Thus for a car horn to work we only need a simple speaker, a button and a battery, as shown in figure 4.16.

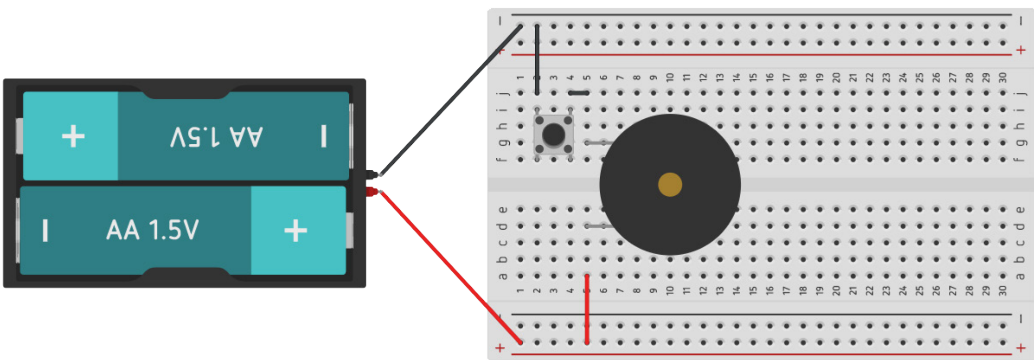


Figure 4.16: Schematic drawing of a circuit allowing control over a buzzer.

Materials needed for this circuit:

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

In figure 4.17 you can see a circuit resembling the circuit used for controlling the car horn, however we replaced the press-button with a switch. If we place the to the left, current can run through it, if it is placed to the right, no current gets through. We include a small resistor in the circuit as LED lights are very sensitive and might break if we put a high current through them. The resistor helps by increasing the resistance in the circuit, which decreases the current through the circuit.

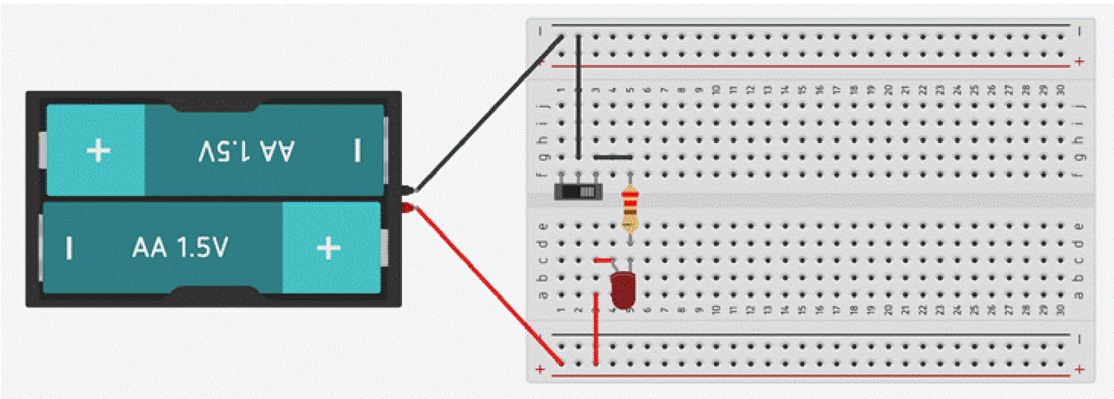


Figure 4.17: Schematic drawing of a circuit allowing control over a LED light.

Materials needed for this circuit:

- Breadboard
- Battery holder with 2 AA batteries
- LED
- 220Ω resistor
- Switch button
- 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 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 4.18 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 two switches, we can now reverse our electric motor, and thus the driving direction.

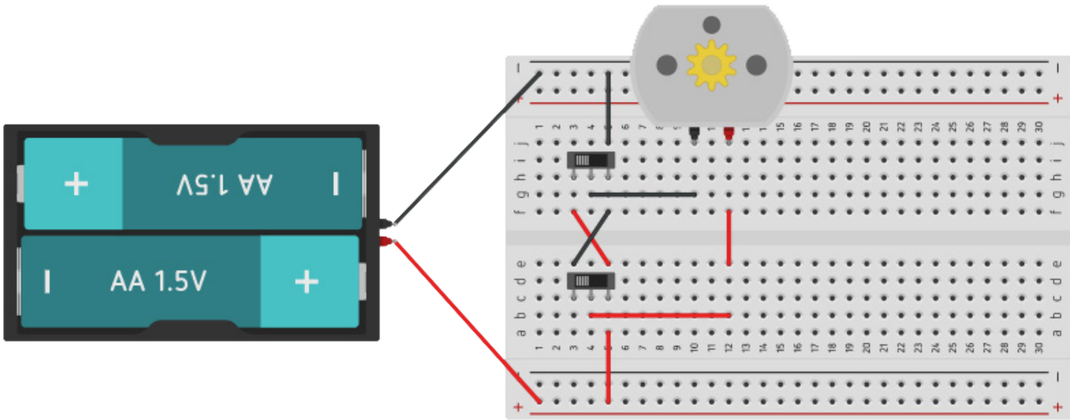


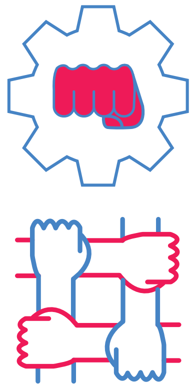
Figure 4.18: Schematic drawing of a circuit in which the turning direction of an electric motor can be controlled with the use of two slide switches. If both switches are slid down, the motor turns in the clockwise direction. If both switches are slid up, the motor turns in the anti-clockwise direction. 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

Module 4 - The electric car

Students start with building their own electric car



At this point of the module, the students will have ideas about what an electric car should look like, which components it consists of and how they could make some of these components with simple electronics. Now it is of the essence that they can experiment with these ideas. In these 40 minutes, the goal is to create the base of a car. This base can be used to connect motors to, support the breadboard and battery pack and any other components the students might add. The base of the car defines what the rest of the car might look like.

1. Advise the students to draw up some kind of building plan. The students can draw a sketch or list components in their Student manual. In the next module, the students will get a lot of time to create their dream car.
2. To encourage cooperation, the students should work in groups of 2 persons. You can choose to make the groups yourself, or let the students choose their partner. If you have an uneven number of students, you can make some groups of 3 persons. Note down which students are partnered up. These partnerships will continue to hold for the next two modules, until the end of the workshop

Choices	Circle your answer
Do you want to make groups of 2 students yourself, or do you want to let the students choose their partner?	I choose Students choose

3. Explain the students
    - that they will have to work with one partner. This person will be their partner for the rest of the workshop.
    - that they have time to draw sketches and list components for their car to make a building plan.
    - that they can use the materials available in the classroom.
    - that it is wise to build the base of your car in during this module, and do most of the electronics in the next module. This way you can connect your electronics to your base as soon as you make them.
    - that, if any of the students did not attend module 1-3, or had difficulty following the examples, they should work together closely their partner, or with other groups with more experienced students. next to this, they can read the summaries of module 1-3.
    - that asking questions is a good thing. You are there to help the students make a nice electric car!

4. Let the students start drawing, writing and building. As you have prepared the materials in the classroom before the module started, the students should have plenty of materials to work with.
5. In this last part of this module your role is to advise and help students, and to make sure they handle the electronics safely.
6. Give tips if students are stuck and point them to the examples in the Student's guide if they do not know what to build. Encourage students by showing interest in what they are creating. Motivate students to work together with other groups as well, if they have a problem, maybe their neighbours will know how to solve it.

The following examples of electric cars (figures 4.19-4.22) will be shown in the Student's guide to inspire the students:

Figure 4.19: 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/

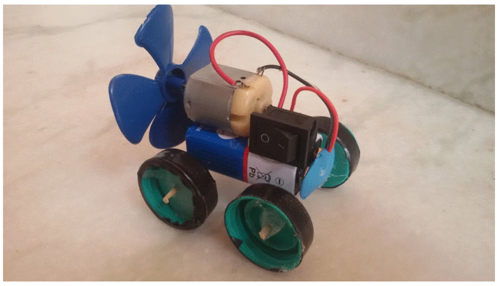


Figure 4.20: A simple car powered by connecting the motor to a fan instead of to the axle of the wheels.
https://www.youtube.com/watch?v=VL6gJe3P-g4

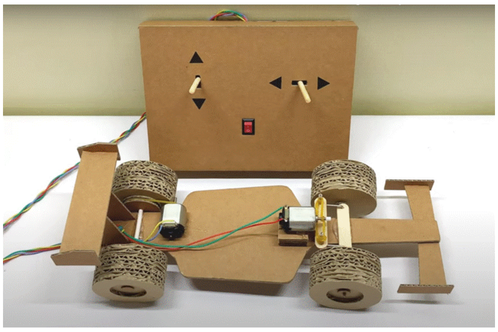


Figure 4.21: Image of an electric car created using two motors. One motor lets the back axle rotate, making the car go forward or backward, the other controls the steering system.
https://www.youtube.com/watch?v=uPhB6I0m-TE&t=145s

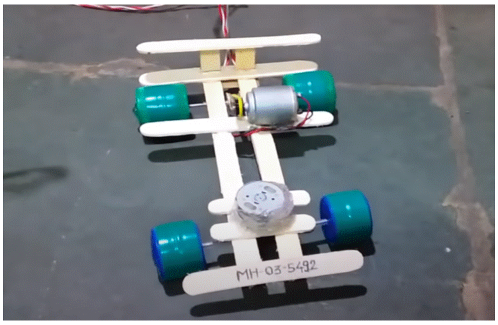


Figure 4.22: Image of an electric car created using two motors. One motor lets the back axle rotate, making the car go forward or backward, the other controls the steering system.
https://www.youtube.com/watch?v=CZ23obsEoys&t=7s

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 4.23. 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 4.24.

Figure 4.23: 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 4.24: 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 4.25. 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 4.25: 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 4.26 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 4.26: 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 4.27. 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!

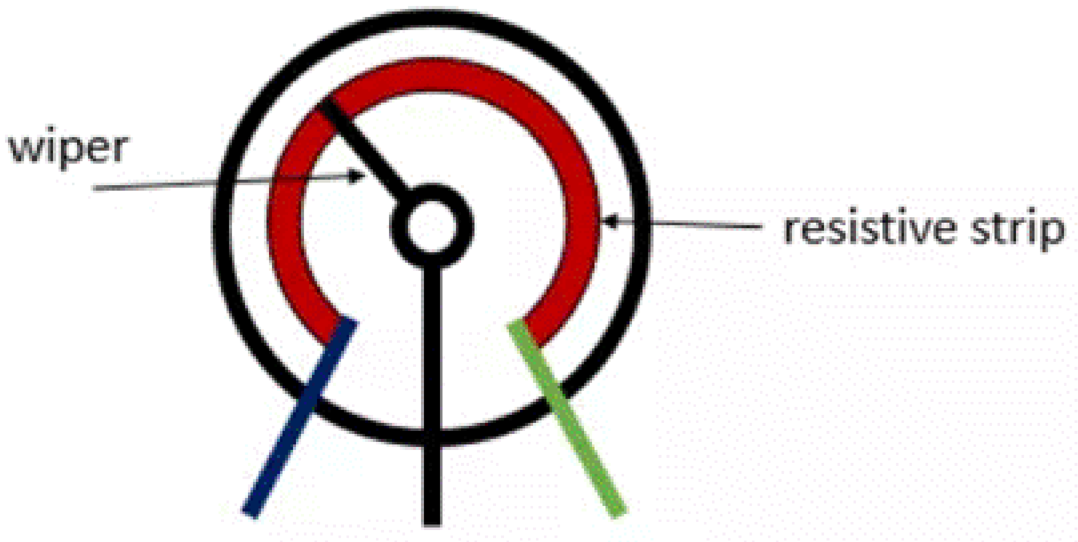


Figure 4.27: Schematic view of a potentiometer showing how to connect it as a voltage divider. The blue terminal leads to the ground of the circuit, which is in our case the negative pole of a battery. The green terminal is connected to the positive pole of the battery. The black terminal is connected to the load of your circuit (a motor or a light).
https://randomnerdtutorials.com/electronics-basics-how-a-potentiometer-works/

Module 5 - Workshop time!

Introduction to the subject

The purpose of this module is to give students the opportunity to finish some of their previous work, and to finalize their car for the science fair.

Summary of the content

The main part is to bring the material and keep track of the time schedule.

Learning objectives

At the end of this module the students:

- Will have developed their teamwork skills
- Worked under time pressure
- Worked without preset result
- Made a plan into something concrete

Teacher's foreknowledge

No extra knowledge on top of the previous modules.

What to do if a student missed a previous module?

If some students missed too many modules to help their group members with this one, let them choose if they want to do another module in this time frame. However, this module is the most practical so it will probably be the one that interests them the most. If they want to do this module they can help for example with the decoration of the car or maybe they can even help with the more simple parts if they read the summaries of all the other modules first.

Materials and resources

Have all resources of previous modules, so that the various groups can finish these if necessary. Have additional material to "fancify" the car (colored paper, etc).
No extra materials on top of the previous modules, except for if some students already want to start on a poster (see module 6)

Materials are mostly the materials from module 4, plus some additional materials to make the car pretty. The amounts are not specified below, this depends on how many students you have and how many have what on their cars.

Materials for 2 students

- The students (rudimentary) car
- 2 Electronics kits
- 2 plastic straws
- Cardboard
- Glue Gun with glue sticks
- Scissors

Module 5 - Workshop time

Tools

- Blackboard (and blackboard drawing utensils)
- Glue Guns with glue sticks
- Rubbing alcohol/acetone and cotton/paper towel to remove glue (only for teacher)
- Scissors

Ornamental material:

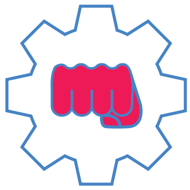
- Next to the electronic stuff, students can also make their car more fancy looking. This is not the goal of the workshop, but the students should be given the opportunity to make their work a bit more visually interesting. Suggestions for material are:
- Tape (better than glue, if it is of the type that can be easily removed).
- Colored paper
- Pieces of plastic
- Pieces of metal
- (coloured) rope or wire
- Cloths (old clothes etc).

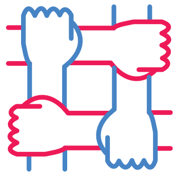
Time schedule

Lesson part	**Duration**	**Content**
Opening	5 min	Gather the students, and tell them what they could do during this module.
Workshop time (Break in between)	105 min (10 min)	Work time. The teacher walks around, and interacts with each individual group to keep them on track of what is most important to do now.
Cleanup time/ closing remarks	10 min	Cleanup time, gather up students and address them for a final word. Show them your satisfaction, tell them you are proud of them ! (This is not the moment to emphasize issues, failures or imperfections.)

Module 5 - Workshop time

Lesson guide





The bulk of students will need time to finalize the car and finish previous workshops. However, some students may be already finished. They now have the opportunity to either make their car visually appealing, or add an extra feature which they may come up with themselves.

Tips what to look out for:

- Give them freedom to explore, but keep an eye on them that they don't destroy their previous work or forget that there's a time limit.
- Prevent students from only focussing on the looks: hint to them that they can add in extra LEDS for example
- Don't let students destroy the breadboards (glue,water)
- Since this workshop is free-form, some students may be "lost" and have trouble deciding what to do/make. This is an important learning experience! Guide them a bit give them ideas, help them in making a time schedule for today, but still leave them free reign.
- Some students will be very active, some will find the freedom difficult. That is normal.

Module 6 - Science fair

Introduction to the subject

The students will present their work at a science fair.
How the science fair is organised, is up to the school/you/the students. This also decides who comes to the science fair to watch what the students did: parents, passers-by, teachers, other students?
This module is not about how this is organised, and at the very least the school should help you in organising this (and preferably, the school should organise it without you having to organise it). Nevertheless, it will make sense to prod the school about this fair, or at least check up if they are organising it.
Also, it is important for you to figure out how they organise it. I.e. that you
know where the fair is,
who will visit the fair,
how long will it last
Etc.

Summary of the content

The first part of this chapter (together with the student's guide) give you handholds to help your students prepare for the science fair.
The second part is on certain examples of posters which have flaws.

Learning objectives

The students learn how to present their material. But above all, this is supposed to be a moment of victory: the students have made their material, and now can show it with pride. The goal of the workshops is to get students interested in electronics and technology, and the goal of this part, the science fair, is mainly to make them feel good. As such, "normal" learning objectives are secondary to the main learning objective: that it is fun, and cool, to work on technology.

Teacher's foreknowledge

There is not much foreknowledge you need, though it helps if you made a poster or presented at a booth yourself before. In any case, read the Student's guide.

Materials and resources

- A2 poster paper
- Set of drawing utensils/coloring pencils

and/or

- Cloth banner
- Paint

Module 6 - Science fair

Time schedule

Lesson part	Duration	Content
Instruction	10 min	Showing examples of posters , explaining what the presentation encompassess.
Assignment	> 5 min	Let the students look at the posters in their booklet, and decide which one they like the best, and what they think is wrong with some of the posters.
Talking about the assignment	> 5 min	Discuss with them the posters.
Free work time Break	< 80 min 10 min	Consisting of: • Working on poster • Working on presentation Make sure students who haven't prepared a presentation start doing it 10 minutes before the end of this section.
Testing presentation phase	5 min	Gather up the students. Link up 2 groups, who then present to each other.
First group presents to the second group.	5 min	
Second group presents to the first group.	5 min	
Closure	5 min	Prepare for the fair

Alternatively (if time permits, and there are not too many groups) every group can present multiple times (i.e. make another pairing). One has to adjust the time schedule accordingly, though. Assume each group needs about 5 minutes.

Module 6 - Science fair

Lesson guide

The main part where you have to be active is in the start of the module,, where you tell the students what they are going to do.

1. Explain to them the fair, and what it encompasses:
    - What is the goal? (To present their work to whomever comes to the fair)
    - What will happen? (Stand somewhere till someone talks to you?)
    - How will it look like? (Show them the location? Do they have a table assigned them, or a board where they can stick their poster to?)
2. Tell them to read the part of the student's manual after you are done (but you probably have discussed most of it - the manual is also there to let students work on posters when they are already done with the rest).
3. Tell them about the poster and the presentation part.

On the poster, you can now proceed by giving some "mock" examples (these are in their booklet). Ask them (for a bit less than 5 mins) to look at all the poster examples, and decide which they like the most, and what critique they have on them.

Also point out to them that their poster does not need to resemble the (best) example! They can put on their poster whatever they want to put there, what they like to emphasize (the making process, what the car can do, or electricity in general, etc.).

Now, the students can start working. The teacher can walk around and keep an eye on the students, answer questions, and discuss with them.

If few students ask questions, pass by each group and ask them about their plan, and perhaps brainstorm with them a bit.

- Make sure they not only work on a poster, but at the same time think on how to present their work
- Ask them about their plans beforehand
- Let students not start drawing as crazy on a piece of paper that is going to be their poster, but let them think about a layout first, and fill in details later.
- Keep track of time, let students know if they are lagging behind

Closure: Can be brief (and less than 5 mins), but prepare them mentally for the fair (be on time, bring what you need, etc.).

Examples

Um carro feito de papel

Necessidades:

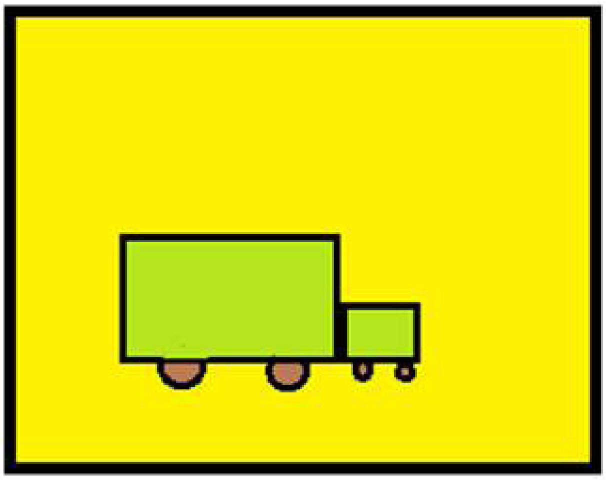
* Papel
* Tesouras
* Cola

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

This is an example of a good poster. There's a picture, there is large text and small text, and it is all functional. The student can use it to present his work.

This is an example of a poster with bad contrast. It is OK to do it in black and white (but color is better), but make sure the text is readable. Too light letters or too dark background impair readability.

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 contrario poderiamos ver dentro

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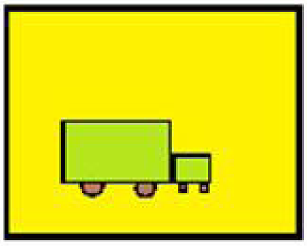


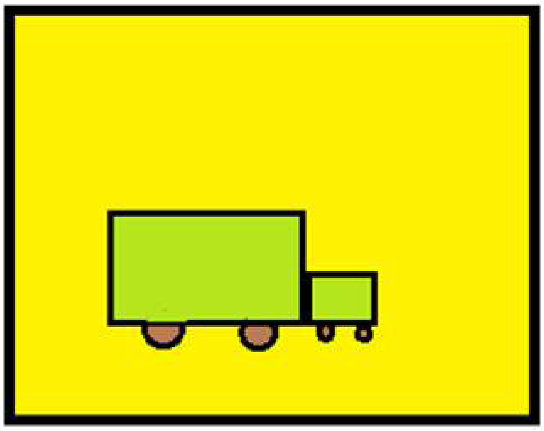
The text on this is not be big enough. Ask students to stand at two meter, and then add two more since these kids will have good eyes probably. They should be able to read the top part, medium letters from 1 meter, and smaller when standing in front.

Tekst should be straight, and readable. When writing, it is often difficult to see if you are writing straight. Keep an overview.

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

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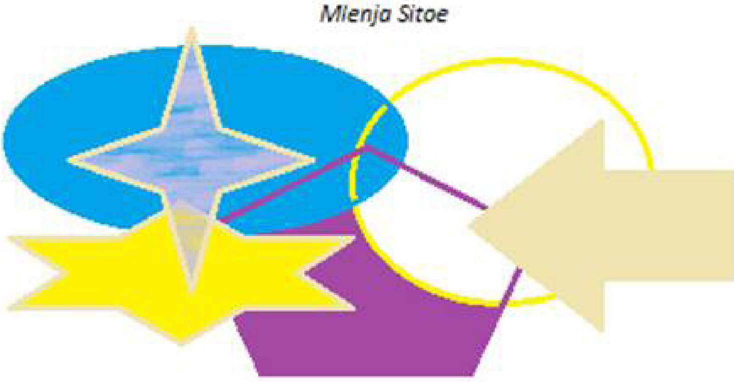

Pictures are nice, and a bit of ornamentation is OK. However, if there is too much of it, then it will distract. Many people passing this poster will ask about the bottom part, which is just an artistic expression of the makers, and which has nothing to do with the project.

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

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* 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

Of course, it is not really a problem to have no picture. However, most students will feel that this poster is lacking.

Module 6 - Science fair

The science fair

How the science fair exactly is organised, may differ from school to school. Before you gave the previous module we hope you found out how the science fair will take place.
In this section, we want to point out some additional pointers for the science fair that you can optionally do.

- Be there. You have been with them along the whole workshop, so we hope you can be there. It often is very inspiring to see “your” kids present their work!
- Let them present to you. Walk together with some visitors, or walk alone along the fair, and let your students present to you.
- Feel-good moment: At the end of the fair, gather up the students, even if it is only briefly. Do whatever you like: congratulate them, do some handshake, or a yell. If you have more time, you can let them reflect on the workshop, say what they really liked.
- A competition: You can opt for handing out a (or several) prize(s) for the best booth/ workshop product. However, the fair and workshop are not about winning, that should be clear.
- Remember: it is all about making students enthusiastic about technology. That is the ultimate goal.

Then, to finalize, we would like to thank you, for supervising this workshop. You have been imperative to its realization. Thank you!