EXPERIMENT MANUAL

ELECTRICITY & MAGNETISM

THAMES & KOSMOS

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Safety Information for Parents and Children

››› **WARNING:** This toy is only intended for use by children over the age of 8 years, due to accessible electronic components. Instructions for parents or caregivers are included and shall be followed. Keep packaging and instructions as they contain important information.

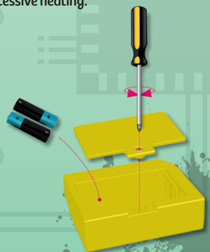
››› **WARNING.** Not suitable for children under 3 years. Choking hazard — small parts may be swallowed or inhaled.

››› **WARNING!** Not suitable for children under 8 years. This product contains small magnets. Swallowed magnets can stick together across intestines causing serious injuries. Seek immediate medical attention if magnets are swallowed.

››› Individual parts in this kit may have sharp edges or corners. Do not injure yourself!

Safety for experiments with batteries

- ››› Never experiment with wall outlets or the household power supply. Never insert wires or other parts into wall outlets! Household voltage can be deadly.
- ››› You will need two 1.5-volt AA batteries for the experiments. Due to their limited shelf life, these are not included in the kit.
- ››› The toy is not to be connected to more than the recommended number of power supplies.
- ››› Avoid short-circuiting the batteries while experimenting; they could explode!
- ››› The supply terminals are not to be short-circuited. Never connect the battery terminals to each other.
- ››› Different types of batteries (e.g., rechargeable and standard batteries) or new and used batteries are not to be mixed.
- ››› Do not mix old and new batteries.
- ››› Do not mix alkaline, standard (carbon-zinc), or rechargeable (nickel-cadmium) batteries.
- ››› Batteries are to be inserted with the correct polarity. Press them gently into the battery compartment.
- ››› To insert the batteries, use a small Phillips-head screwdriver to unscrew the screw securing the battery box cover and remove the cover. Place the batteries into the compartment according to the polarity markings (+ and - symbols) in the compartment, close the cover, and screw the screw back in. (See image to right.)
- ››› Never recharge non-rechargeable batteries. They could explode!
- ››› Rechargeable batteries are only to be charged under adult supervision.
- ››› Rechargeable batteries are to be removed from the toy before being charged.
- ››› Exhausted batteries are to be removed from the toy.
- ››› Dispose of used batteries in accordance with environmental guidelines.
- ››› Make absolutely sure that metallic objects such as coins or key chains are not left in contact with battery terminals.
- ››› Do not bend, warp, or otherwise deform batteries.
- ››› Warning! Do not manipulate the protective device in the battery compartment (PTC). This could cause overheating of wires, eruption of batteries and excessive heating.



Dear Parents,

This experiment kit will teach your children about electricity and magnets in a simple and safe way. They will learn about and experiment with devices such as light switches, electrical circuits, motors, permanent magnets, electromagnets, and compasses.

As with any new science kit, you might have questions about the kit's safety. All electrical experiments are powered by two AA batteries (not included) that need to be installed inside the included battery case. The experiments are thus performed with the very low and safe electrical voltage of only 3 volts.

This experiment kit meets U.S. and European safety standards. These standards impose obligations on the manufacturer, but also stipulate that adults should assist their children with advice and assistance with the experiments. Tell your child to read all the relevant instructions and safety advice, and to keep these materials on hand for reference. Be sure to point out that he or she must follow all the rules and information while performing the experiments.

We wish you and your young electrician fun and success in your electric and magnetic experiments!

››› CONTENTS

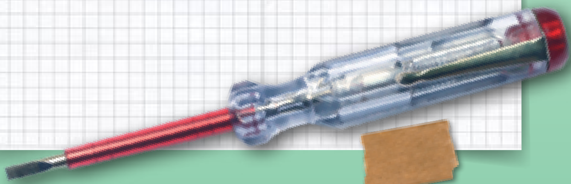
EXPERIMENTS

We can no longer get by without electricity in our homes. In this chapter, you will get to know a few of its basic properties, and you will learn about all the things you can do with switches and lights.

Electric motors produce rotation from electric current. You can also use your electric motor to tell the direction in which current is flowing through your circuit.

How would you like to explore the secret powers of magnetism? Dive into this mysterious world, which has been put to use by early seafaring explorers and today's high-tech engineers alike.

What does electricity have to do with magnetism? Find out in the experiments in this chapter.



TIP!
You will find supplemental information in the "Check it out" sections on pages 22, 23, 30, 31, 49, 63, and 64.

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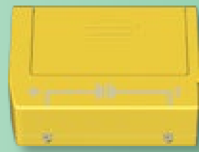
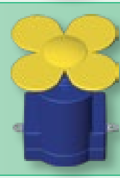
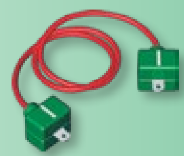
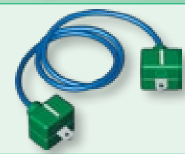
Presenting the assembly components!

This list presents brief descriptions of all the components in the kit, along with illustrations.

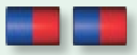
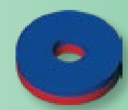
Component	Description	Illustration
Battery case Item No. 704484 Never directly connect these terminals to each other. The batteries and wires can heat up and explode, not to mention that the batteries will be quickly used up.	This power pack supplies the electricity for the experiments. Before starting the experiments, you must install two fresh 1.5-volt AA batteries (also known as penlight or LR6 batteries) inside it, as indicated in the battery compartment. You will need a small Phillips-head screwdriver to open the battery box. You can then obtain electric current from the box's two terminals. 	
Red light Item No. 706415	Later on, electricity will light up this bulb. That will show you that electrical current is flowing.	
Green light Item No. 706417	This is just like the red light, except it's a different color.	
Yellow light Item No. 706416	Again, this is just like the red light, except it's a different color.	
Motor Item No. 706414	When electrical current flows through it, the motor and its yellow propeller will turn quite quickly.	
Two-way switch Item No. 705055 Quantity: 2	Depending on the setting of the switch, one or the other of two contact plugs will be electrically connected.	
Push button Item No. 705054	If you push the button, you create an electrical connection between the terminals. But the connection is only maintained as long as you keep pressing it.	

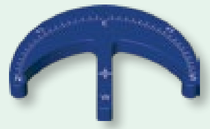
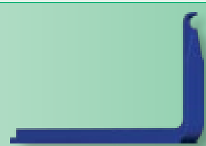
COMPONENTS

Component	Description	Illustration
Connectors with 4 terminals (X-shaped) Item No. 705050 Quantity: 12	For connecting components. The metal prongs of other components such as the push button are inserted into the side slits. In the instructions, they are called **"X-connectors"** for short.	
Straight connectors with 2 terminals (I-shaped) Item No. 705051 Quantity: 4	For connecting components electrically. The two plugs are electrically connected to each other. In the instructions, they are referred to as **"I-connectors"** for short.	
Angled connectors with 2 terminals (L-shaped) Item No. 705052 Quantity: 2	For the electrical connection of components, but in a way that guides the current at an angle. Looks like an "L," hence referred to as an **"L-connector"** for short in the instructions.	
Connector with 3 terminals (T-shaped) Item No. 705053	For electrical connections. The three prongs are electrically connected to each other as indicated by the white lines. In the instructions, they are referred to as **"T-connectors"** for short, because their shape is similar to a "T."	

Component	Description	Illustration
Red connecting wire with plugs Item No. 706428	For connecting the electronic components. At the ends, there are contacts that fit into the green X connectors. Referred to as **"red connecting wire"** in the instructions.	
Blue connecting wire with plugs Item No. 706429	Like the red connecting wire with plugs, but in a different color. In the instructions, it is referred to as **"blue connecting wire."**	
Separator Item No. 706078	An easy way of separating assembled connectors, lights, switches, etc. Simply slide it between the components and pry them apart.	
Red alligator wire Item No. 704486 Never insert the wire into a wall outlet, or connect it in any way to the household current. Electrical current from a wall outlet is deadly!	For connecting the electronic components. At the ends, it has alligator clips (so called because they resemble the jaws of an alligator). If you squeeze the clips, they will open up and you can clamp them onto small metal connection prongs such as those on the battery case, the lights, or the motor. Called **"red alligator wire"** in the instructions.	

COMPONENTS

Component	Description	Illustration
Blue alligator wire Item No. 704487	Like the red alligator wire, but in a different color so you can tell them apart more easily. Called **"blue alligator wire"** in the instructions.	
Bar magnet Item No. 706423 Quantity: 2	A powerful magnet. The different colors (blue, red) mark the two poles of the magnet. The north pole is red, the south pole is blue.	
Ring magnet Item No. 706412 Quantity: 2	With this magnet as well, the red (north) and blue (south) colors designate the two magnetic poles.	
Electromagnet Item No. 706422	Unlike the bar magnets and ring magnets, this only becomes magnetic when electric current flows through it.	

Component	Description	Illustration
Small parts in pouch Item No. 772180	Various metal parts for the experiments, such as screws, nuts, washers, and colored disks with a thin iron ring that you can use for the magnet games.	
Base Item No. 706419	Belongs to the three-part **magnet hanger** consisting of a base, an arm, and a cord with rings.	
Arm Item No. 706420	The L-shaped arm is part of the three-piece **magnet hanger.** It is inserted into the horseshoe-shaped base. The cord with rings hangs on its hook.	
Cord with rings Item No. 706421	Two rings tied together with string, belonging to the **magnet hanger.** The smaller ring is suspended from the hook on the arm. The two bar magnets are secured to the larger ring.	
Box of iron powder Item No. 704449	Finely powdered iron in a sealed container. This is used for making magnetic forces visible.	

TIPS AND TRICKS

Additionally required household items

> *Two 1.5-volt AA batteries, small Phillips-head screwdriver, two rulers (30 cm), pencil, cardboard, cardboard box, felt-tip pens, scissors, paper, tape, metal prong fasteners from a folder, map of your area, paper clips*
> *Aluminum foil, metal pot, metal fork, cup, saucer, large water bowl, cooking spoon, metal baking sheet, aluminum tealight candle holder, bottle, aluminum lid from a jar, bottle closures*
> *Nail, sewing needles, file, sandpaper, piece of wood, handful of sand, various coins, books, twine, textiles, plastic*

Tips and tricks for assembly

It isn't hard at all to assemble the electronic experimental setups in this kit.

- For each experiment, you will find a picture that shows exactly how to fit the parts together.
- **It is easiest to assemble parts that are equipped with plugs or prongs if you first lay them out on a smooth table surface.** Then slide the pieces together on the table, so that the printed white lines meet up properly and the metal prong slides smoothly into the X-connector hole.
- To disassemble the parts, simply insert the separator.
- Do not use force!
- After assembling a circuit, check it against the picture one last time before you switch on the electric current.

Troubleshooting

If something doesn't work, try to isolate the problem:

- Does the assembly match what you see in the picture?
- Could the battery be dead? Check it with a bulb.
- Was a switch installed in the wrong position or the wrong way around?
- Could the light bulb be dead? Test it with the battery or try a different one.
- Is one of the connections loose? Push them all together again one more time.

Don't worry:

If you start with the first experiments in this manual, you will soon have enough practice handling the components that everything will become clear to you.

Foreword

This kit will help you explore two extraordinarily important invisible forces: electricity and magnetism.

Of course, you know electricity by what it does — it makes light bulbs shine and powers appliances such as television sets and vacuum cleaners. You may also have seen a magnet and wondered why it attracts screws and other items made of iron.

The kit has more than 60 experiments on these topics, and once you try them you will know a lot more about electricity and magnetism than you do now. You will find almost everything you need contained in the kit: switches, lights, a motor, magnets, connector pieces and, for your power supply, a battery case in which you will have to install two 1-5-volt AA batteries. You will also find a box for letting you see otherwise-invisible magnetic forces.

The experiments are easy to perform, since precise drawings show you how to assemble them, and everything is explained in the instructions as well. Stick to the pictures as closely as possible and read the tips on the left side of this page. That way, everything will work properly.

Have fun with the experiments!

Electricity

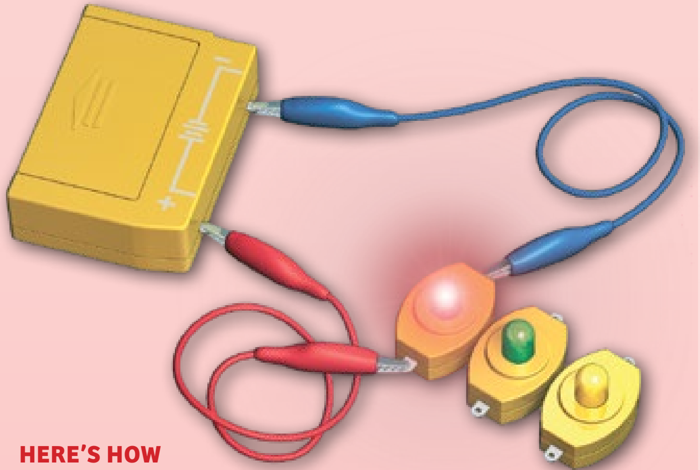
We use electricity every day. We only really tend to notice how much we depend on it when we don't have it. Electricity gives us light and powers televisions and radios, washing machines and refrigerators, electric ovens and stereo systems. Electricity from batteries powers flashlights, transistor radios, and MP3 players.

You too, no doubt, have electric lighting in your room that you can turn on and off with the flick of a switch. But how does it actually work? How does this mysterious electrical current make light bulbs glow? That's what you'll find out in the experiments in this chapter.

EXPERIMENT 1

Circulating current

Your kit contains three different-colored light bulbs. Try lighting them up! The battery case will supply the necessary current.



HERE'S HOW

Use the red alligator wire to connect one of the battery case's terminal prongs to one of the prongs of the red light. Does the bulb light up? No, it doesn't.

Do you think the bulb might be dead? Try the yellow or green one. Now try connecting both of the light's terminal prongs to the two battery case terminal prongs. Break the connection somewhere. What do you see?

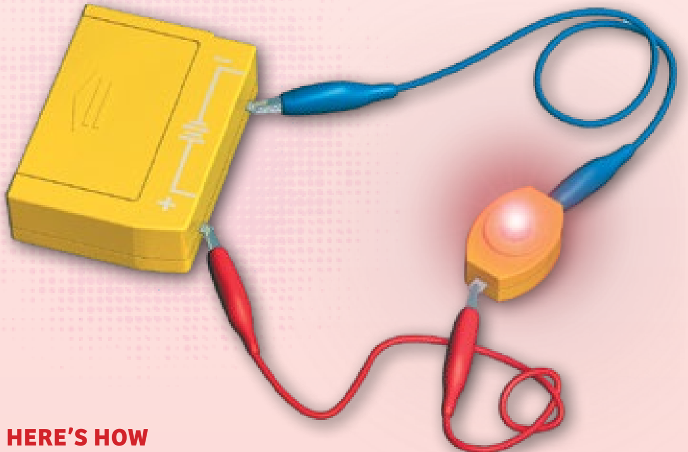
WHAT'S HAPPENING?

Electric current always has to flow in a circle, or circuit. If this kind of circuit is broken in just one place, the flow of electricity immediately stops — the bulb will go out, or not light up at all, if the light and battery case are connected with just one wire.

EXPERIMENT 2

Electric roller coaster

The wires run nice and straight. But will a wire also conduct current if it is tangled up?



HERE'S HOW

Tie a loose knot in the red wire. Don't pull it too tight, or you might damage the wire!

Next, assemble a closed circuit again with the battery case, light, and the other alligator wire.

WHAT'S HAPPENING?

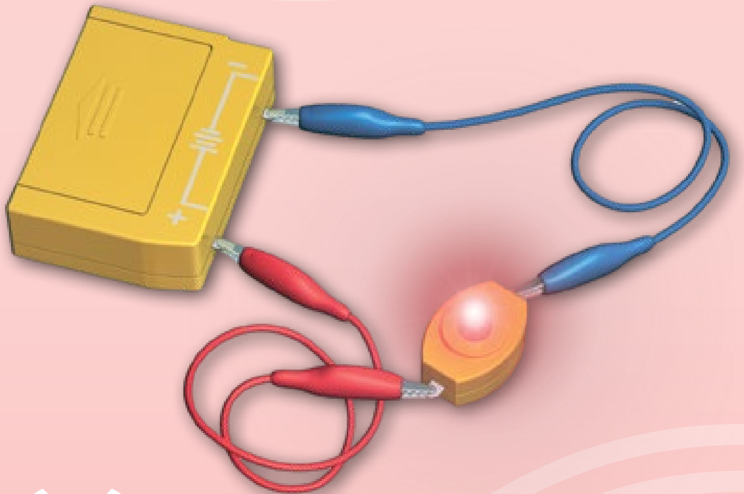
The bulb lights up just as brightly as before, because the current is so agile that even a "roller coaster ride" through multiple knots won't throw it off it at all.

ELECTRONS

Electric current is invisible. You can only see it by its effects, such as a glowing light bulb or a turning motor.

Current consists of a flow of tiny particles known as **electrons.** They are even much smaller than atoms, and they can move through something like the metal in a metal wire.

They flow through your wires more or less like water flows through a pipe.



Reversed connections

Does it make any difference which direction the current flows through the light? You can easily find out.

HERE'S HOW

Assemble a circuit again. The bulb will light up.

Now remove the two wires from the light's prongs, turn the light unit around, and reconnect the wires. Does the bulb light up now?

WHAT'S HAPPENING ?

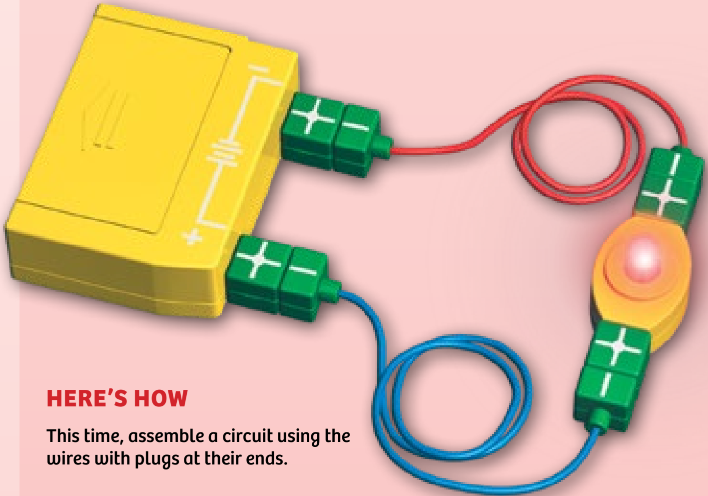
Yes, the bulb lights up just as well as before, even though the current is now flowing in the opposite direction.

Light bulbs, such as the ones in your kit, are among those electronic components that work equally well regardless of which direction the current flows through them. But as you will discover later on, there are also components for which the direction does matter.

EXPERIMENT 4

Prongs instead of alligator clip

In addition to the wires with alligator clips attached to them, you will also find some wires in your kit with green cubes at their ends. Try seeing what you can use them for.



HERE'S HOW

This time, assemble a circuit using the wires with plugs at their ends.

You will have to push an X-connector onto each of the wire's plugs so that they can be attached to the light and battery case.

Then push the X-connector slots onto the light and battery case prongs.

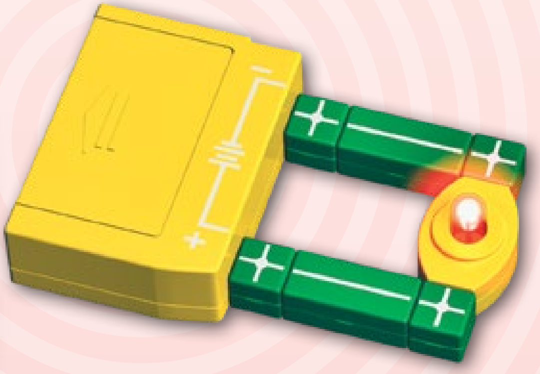
WHAT'S HAPPENING

The bulb lights up. So you can also use this kind of wire for electrical connections.

EXPERIMENT 5

Green conductor

You will find other green connectors in your kit besides the green X-connectors. Do you think you can use them to assemble a circuit without any wires at all?



HERE'S HOW

Connect up the components and the green connectors exactly as you see in the drawing.

Be sure that the prongs are inserted securely into the slots.

WHAT'S HAPPENING

The bulb lights up as soon as all the components are securely connected.

The current flows through the wires that are hidden inside the green connectors, as shown by the white lines.

So you can also use the green components for your electrical connections.

ELECTRIC VOLTAGE

The battery pushes electrons through your light like a water pump pushes water through a pipe. And just like a water pump, the battery creates “pressure” to push the electrons along.

In the language of electronics, this “pressure” is known as **voltage**. Its unit of measure is the volt (abbreviated “V”).

Each of your batteries supplies 1.5 volts, and when they are connected together in a line they add up to 3 volts.

WHAT’S HAPPENING

The experiment shows that a single battery accomplishes less than two. Now you also know why you always have to fill all the battery compartments of a battery-powered device. Don’t forget to re-insert the second battery for the next experiments.

With half the force

Your battery case holds two batteries, which join forces to power your circuits. Do you think the bulb will light up if it is supplied with current from just one of them?

HERE’S HOW

Open the battery case cover and remove one of the batteries.

Connect the battery case to the light using the two plug wires and X-connectors. The bulb won’t light up because the removed battery was part of the circuit, which is therefore no longer closed.

To close the circuit, connect together the terminals in the empty section of the battery compartment by using the red alligator wire. Now the bulb will indeed light up, even if not nearly as brightly as it did when you used two batteries.

EXPERIMENT 7

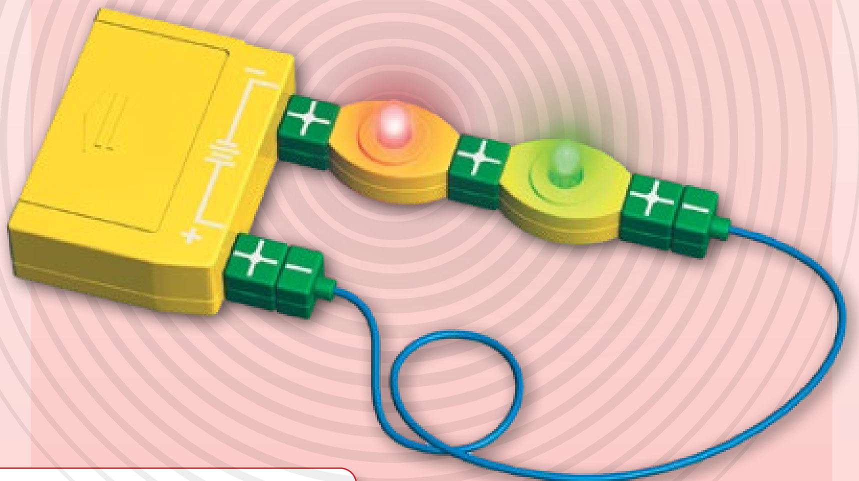
Two bulbs, half the brightness

If one battery does less than two, will it also make a difference if they have to supply two lights with electricity instead of one?

HERE'S HOW

Assemble a circuit with X-connectors and one plug wire.

This time, insert two lights in a row so the current has to flow through both, one after the other.



WHAT'S HAPPENING

Both bulbs light up, although less brightly than with one. This kind of arrangement with two lights installed in a row is called a **series circuit.** It apparently lets less current flow than when you use just a single bulb, which is why the light is less bright. An electrician would say that the current strength is lower.

CURRENT STRENGTH

Current strength, or amperage, is a measurement of how many electrons run through a wire per second — comparable to the number of liters of water flowing through a pipe per second.

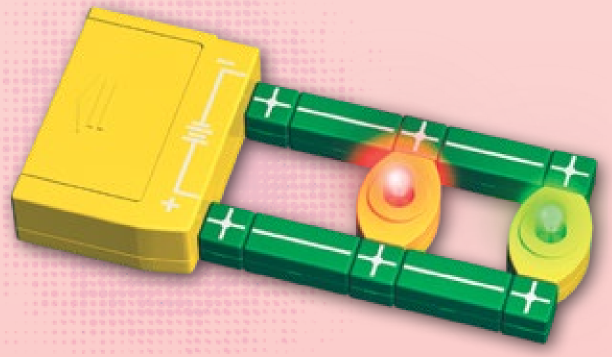
Current strength is measured in amperes (abbreviated "A"), a unit of measure named after the French physicist André-Marie Ampère (1775–1836).

Only about one tenth of an ampere flows through your light, while several hundred amperes flow through the engine of an electric train.

EXPERIMENT 8

All yoked up

Do you know another way connect two lights to a battery? Exactly: You can try connecting each light directly to the battery terminals.



HERE'S HOW

Connect two of your lights to the battery using four X-connectors and six I-connectors.

The picture shows the simplest way to hook up the circuit. How brightly do the bulbs light up now?

WHAT'S HAPPENING

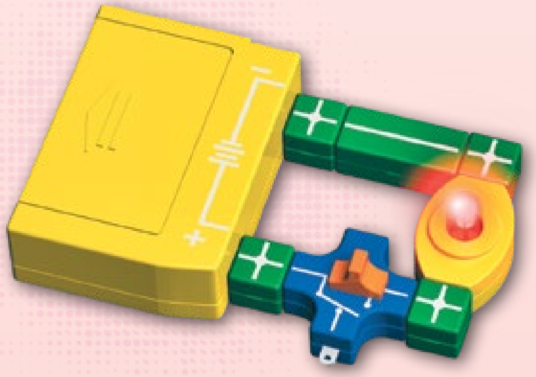
Now, both bulbs light up with their full brightness.

If you follow the path of the current, you will find two circuits. Both are fed by the same battery, and each supplies current to one light. This type of arrangement is known as a **parallel circuit**.

EXPERIMENT 9

Quick switch

If you let the bulb shine for a long time, the batteries will get used up. On the other hand, it can be inconvenient to have to keep reassembling the circuit. Luckily, there's a solution to this problem: a switch.



HERE'S HOW

In your circuit, replace one of the I-connectors with the two-way switch.

Now you can turn the light on and off by pushing the orange-colored switch.

WHAT'S HAPPENING

Depending on its setting, the two-way switch opens or closes the two contacts and, thus, the circuit. This is very much like the way a wall switch works when you use it to turn the light on or off in a room.

EXPERIMENT 10

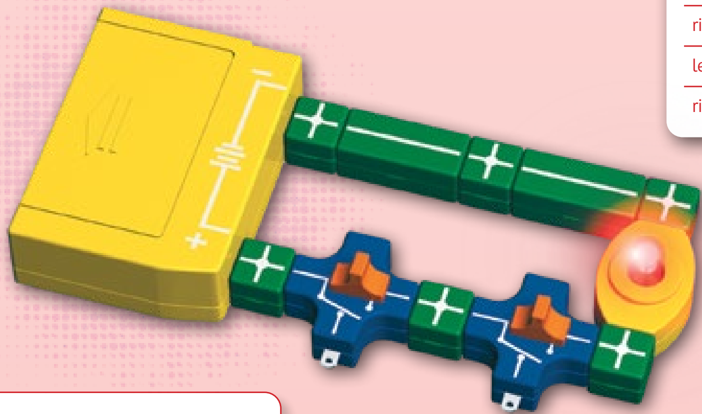
Switches in lockstep

If you can arrange lights in a series, you should also be able to do that with switches. See how the current behaves when you do that.

HERE'S HOW

Insert the two switches into the circuit directly behind one another in series. This way, you can more easily compare their settings.

Try different settings for the two switch buttons. How many different possible combinations are there? And with how many of them does the bulb light up?



SWITCH SETTINGS

Switch 1	Switch 2	Light
left	left	off
right	right	lights up
left	right	off
right	left	off

WHAT'S HAPPENING?

The table shows that there are four possible combinations in all, and the bulb will only light up with one of them.

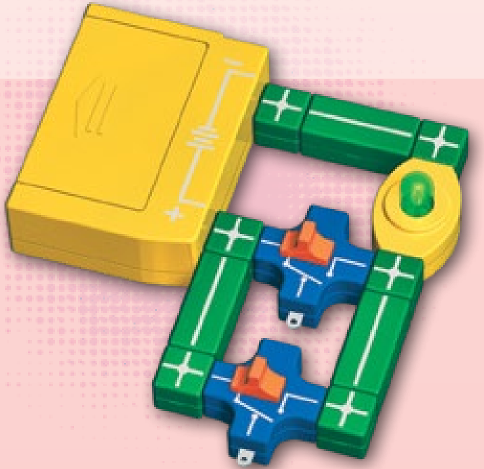
Electrical engineers call this kind of arrangement of switches an **AND circuit.** That's because the light will only shine when switch 1 AND switch 2 are turned on.

A lot of MP3 players will only work when their main switch is set to "On" and you also press the start button — this is an AND circuit too.

SWITCH SETTINGS

Switch 1	Switch 2	Light
left	left	off
right	right	lights up
left	right	lights up
right	left	lights up

1



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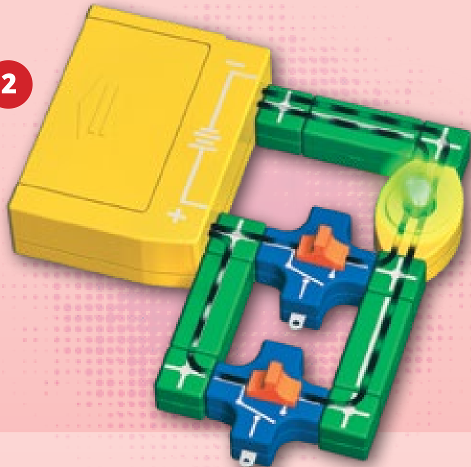


One or the other

Of course, you can also hook up the two switches in parallel. How does the current behave when you do that?

HERE'S HOW

Assemble the illustrated circuit (figure 1).

Try all the different switch settings again. With which ones will the bulb light up now?

Trace the course of the current with the help of figure 2.

WHAT'S HAPPENING?

Once again, there are four possible combinations. But this time, the bulb lights up with three of them and stays off with just one.

This kind of parallel arrangement of switches is called an **OR circuit.** The bulb lights up when switch 1 OR switch 2 is turned on. Only when both are switched off will it fail to shine (figure 1).

EXPERIMENT 12

Morse code with light

Would you like to send secret messages to your brother or sister or a friend next door?

One way to do that is by Morse code. This is a code consisting of short and long signals that you can send by radio or as pulses of light. Each letter and each number is transmitted as a certain sequence of short and long signals.

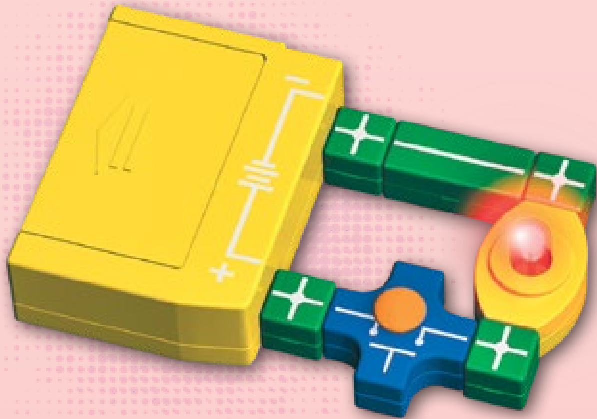
HERE'S HOW

Assemble a circuit with push button and light.

By pressing briefly or longer, you can make the bulb light up accordingly. This is how you transmit the Morse code signals.

MORSE CODE

A	· —	K	— · —	U	· · —	1	· — — — —
B	— · · ·	L	· — · ·	V	· · · —	2	· · — — —
C	— · — ·	M	— —	W	· — —	3	· · · — —
D	— · ·	N	— ·	X	— · · —	4	· · · · —
E	·	O	— — —	Y	— · — —	5	· · · · ·
F	· · — ·	P	· — — ·	Z	— — · ·	6	— · · · ·
G	— — ·	Q	— — · —			7	— — · · ·
H	· · · ·	R	· — ·			8	— — — · ·
I	· ·	S	· · ·			9	— — — — ·
J	· — — —	T	—			0	— — — — —



WHAT'S HAPPENING?

The push button closes the circuit so the bulb lights up in matching rhythm.

TIP!

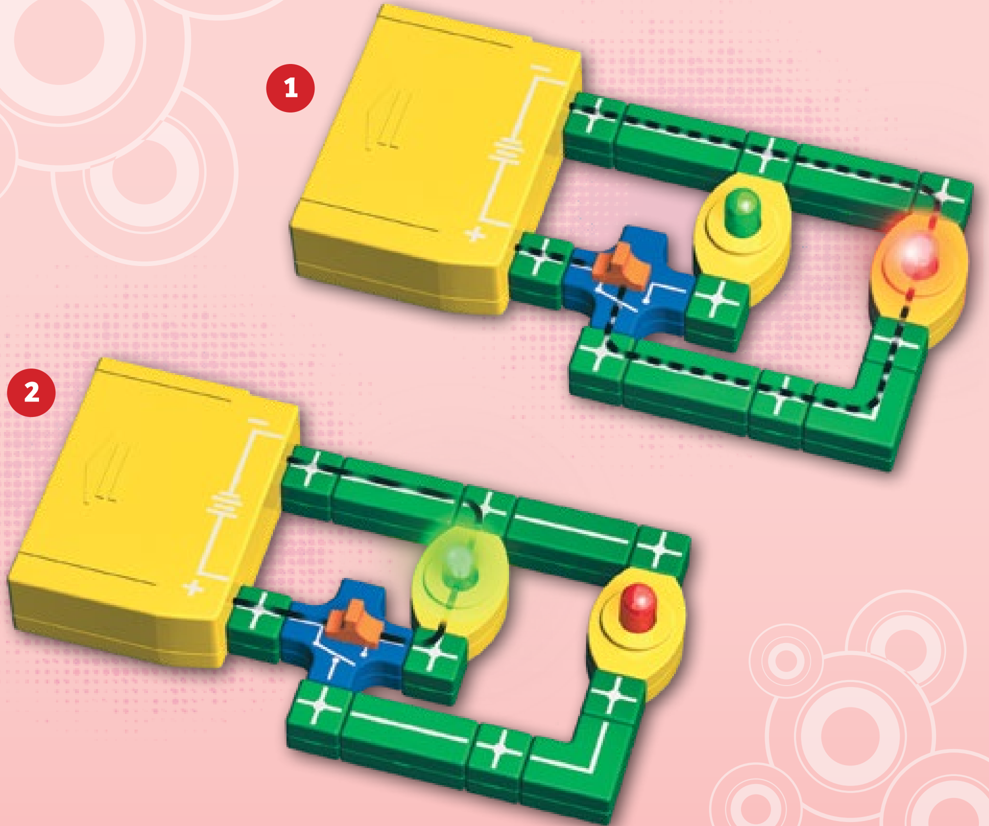
Only let the current flow for a brief time (a few seconds), or the battery will quickly get used up.

TIP!

If you really want to use the circuit to send messages, you should get yourself a few meters of double-cable wire. Use the alligator wires to hook up the circuit so that the push button and battery are next to you but the light is in another room (wherever your friend is).

Another possibility is to hold the light up to a window so your friend can see the light signals.

In the Morse telegraph experiment, you will build a Morse station that will also let you hear the signals.



Choice between red and green

You have probably been asking yourself what you can use the switch's third terminal for. Now you'll find out.

HERE'S HOW

Try the illustrated circuit. Turn on the switch — what do you see?

WHAT'S HAPPENING ?

Depending on the position of the switch, the red or the green bulb will light up.

When you activate the switch, one of the two lights goes out while the other comes on.

The setup contains two circuits — one with the red (figure 1) and the other with the green light (figure 2). Both are connected at one end to the upper battery contact. Depending on its setting, the switch connects first one and then the other light to the lower battery terminal.

This kind of red-green switch is very useful. If you have a model train set, you can use it as a railway signal. Or you can use it as a signal to tell visitors whether they are allowed to enter your room or not.

EXPERIMENT 14

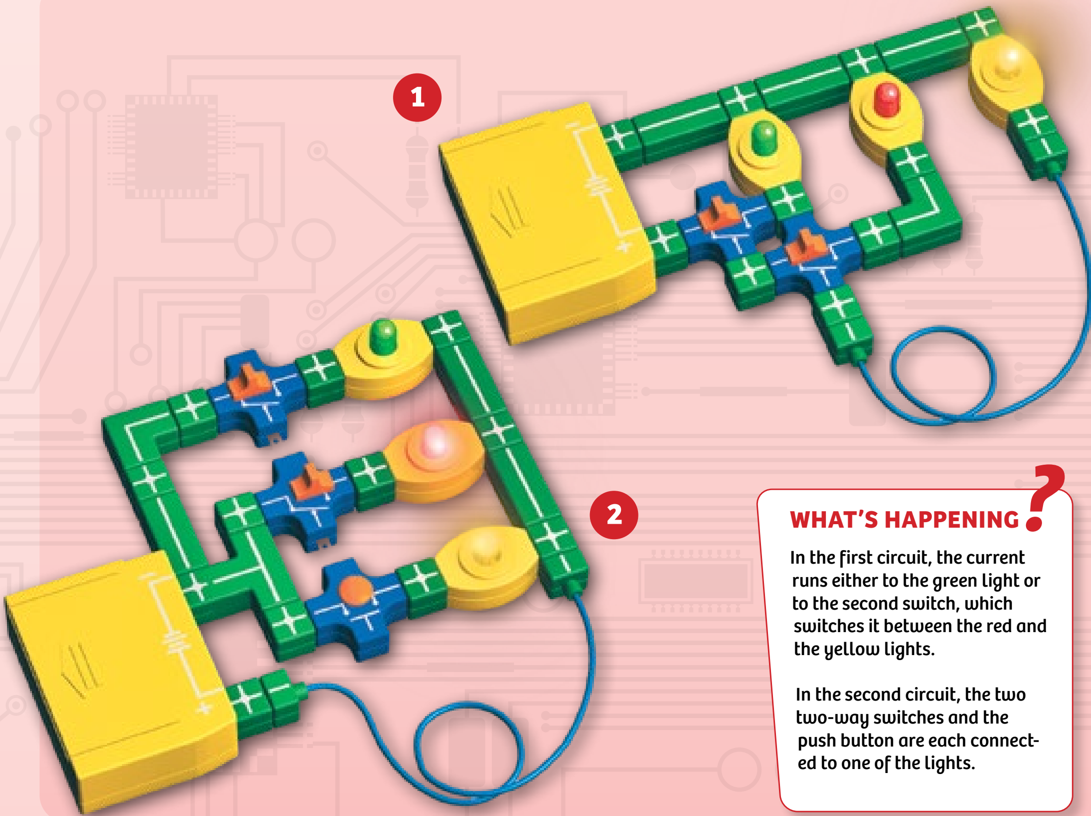
Your own traffic light

Of course, red and green are also the colors that traffic signals use to tell drivers or pedestrians whether they are allowed to proceed through an intersection or cross the street. Traffic lights also use the color yellow. Would you like to be able to control three different lights?

HERE'S HOW

Assemble the circuit exactly as shown in figure 1. If you do it right, you can choose whether to have the green, red, or yellow bulb light up. Trace the course of the current with your finger.

In the traffic lights used in some countries, the yellow light can shine at the same time as the red one, or at the same time as the green one. This setup can't do that, but the one shown in figure 2 can. In this one, the first switch provides current to the green light, while the other controls the red light, and you can use the push button to switch on the yellow light whenever you want.



WHAT'S HAPPENING

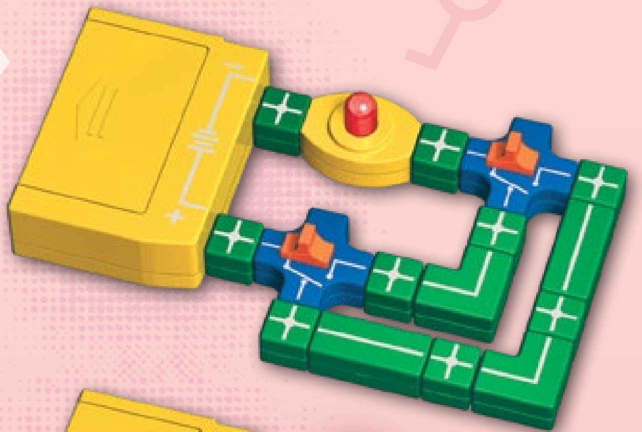
In the first circuit, the current runs either to the green light or to the second switch, which switches it between the red and the yellow lights.

In the second circuit, the two two-way switches and the push button are each connected to one of the lights.

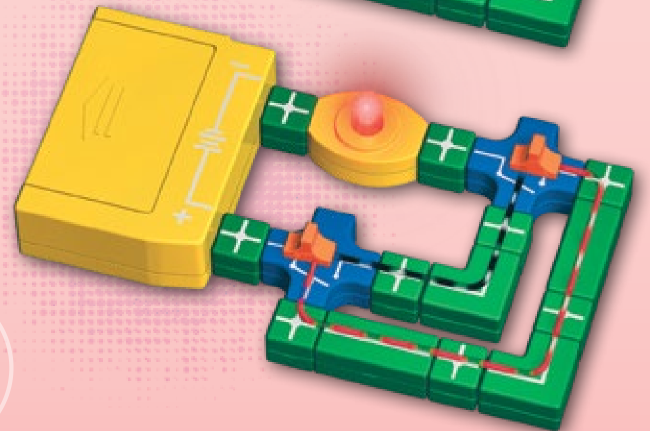
Light from the end of the hallway

In long hallways or in apartment building stairways, you can usually turn the light on or off from two different places. That isn't as easy to do as you might think. But here's a trick you can use.

1



2



HERE'S HOW

Assemble the circuit shown in figure 1.

Now you can turn the light on or off from either switch.

WHAT'S HAPPENING ?

Follow the path of current for each of the four switch position combinations. Each switch can close the circuit in one of its two possible settings — regardless of the setting of the other switch.

When it is connected to the red path, the current then chooses the black or the red route (figure 2).

This method of connecting two switches in a house or apartment is known as a **three-way switch.**

EXPERIMENT 16

Conductors and insulators

Up to now, you have used the wires and green connectors to conduct electricity from the battery case to the lights without really thinking about it. But what kinds of materials will conduct electricity, anyway? One thing you already know is that air will not conduct electricity — otherwise, you wouldn't need any connectors at all!

HERE'S HOW

Clamp the red alligator wire to one of the battery terminals. Attach the light to the other terminal using the X-connector.

Clamp the blue alligator wire to the free prong of the light. When you press the two free alligator clips together, the bulb will light up.

Now, you can try connecting the two alligator clips to all sorts of objects. If the bulb lights up, you know that they conduct electricity.

Try it, for example, with a metal pot, a wooden spoon, aluminum foil, a metal fork, coins, teacups, paper, plastic, nails and glass.

WHAT'S HAPPENING?

Only objects made of metal will make the bulb light up. The connectors also contain metal wire so that the current can flow through them.

CONDUCTORS AND INSULATORS

Materials that conduct electricity well are called **conductors.**

Materials such as plastic, which will not conduct electricity, are called **insulators.**

Your wires contain copper inside them. The plastic covering prevents the current from jumping from one wire to another if they happen to touch — which would cause a **short circuit.**

Red light alarm

Do you know what an alarm system is? It's a device that sends a signal whenever an intruder opens a door or a window. You can build your own simple alarm system with a red light that comes on if someone opens your window, for example.

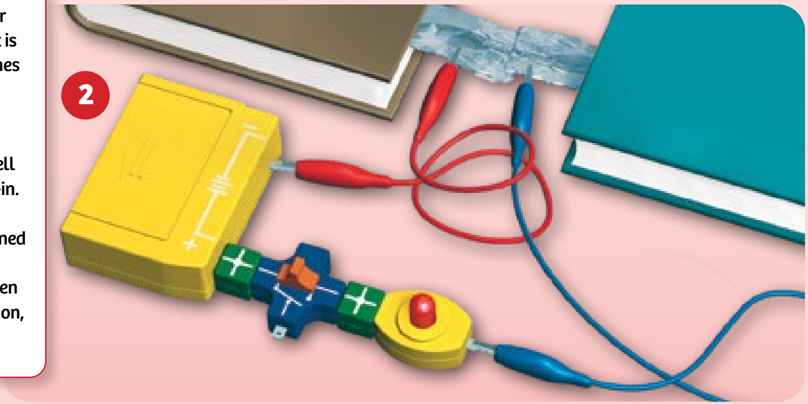
HERE'S HOW

Make two solid strips of aluminum foil. Clamp each inside a book in such a way that it projects out. One book will represent the window frame, while the other represents the window sash (the window itself).

Clamp an alligator wire to each of the aluminum strips. Lead one wire to a battery terminal, and the other to the red light connected to the other battery terminal (image 1).

Position the books in such a way that the aluminum strips are close to each other without quite touching. Now push one book (the window sash) against the other, so the strips briefly touch. What happens?

What if you want to be able to open the window during the day without setting off the alarm? In that case, install another switch between the light and the battery (image 2). That way, you can turn the system on and off.



TIP!

If you can get a few meters of dual-cable wire from an electronics or hardware store, you will be able to install this alarm system on your door or window.

WHAT'S HAPPENING?

If a burglar opens the window, the strips slide past each other and make contact. The circuit is then closed and the light comes on briefly.

Real alarm systems usually have an audible sound as well as lights to indicate a break-in.

Most alarm systems are turned off during the daytime, and then turned on at night. When the alarm system is turned on, it is said to be "armed."

EXPERIMENT 18

Alarm when the windowpane is broken

What if an intruder breaks the window instead of opening it? Or what if he breaks in a plate glass window to steal the window display from a store? What would an alarm system look like that was designed to set off an alarm in that kind of situation?

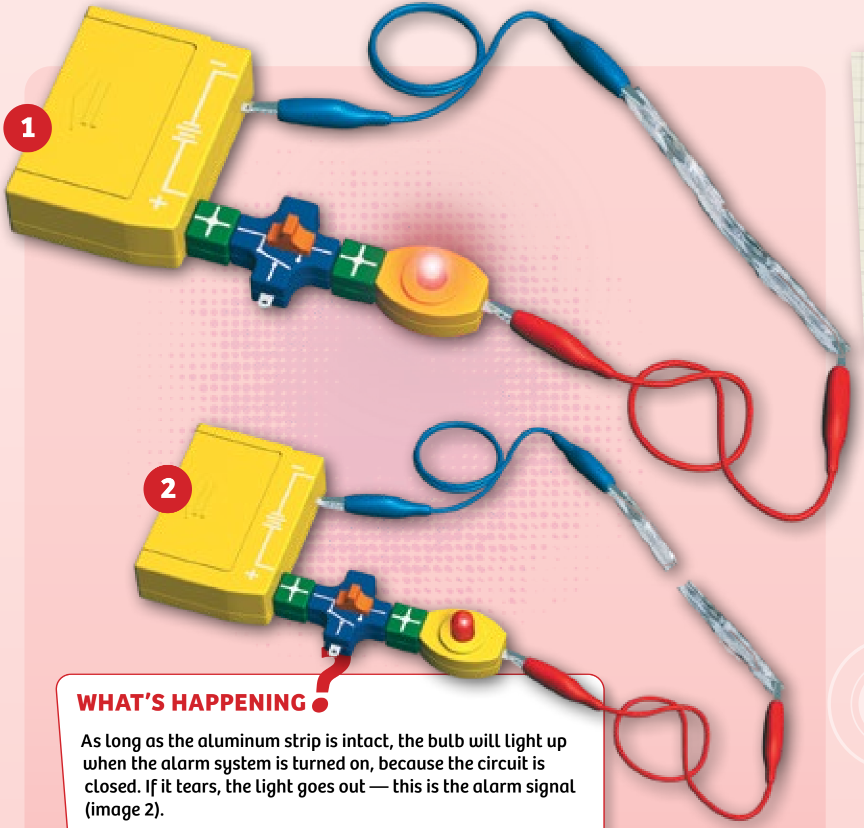
HERE'S HOW

Assemble a circuit like the one shown in image 1, with battery, light, two-way switch, and alligator wire.

Cut a narrow, 20 cm-long strip of aluminum foil and clamp the free end of each alligator wire to each end of the strip.

Switch on the alarm system: The red bulb will light up.

Now imagine that a razor-thin aluminum strip is attached to a windowpane. Then, if the pane were broken, the strip would tear. Try it with your strip — tear it. What do you notice?



TIP!

You can cut this kind of thin aluminum strip from the roll, secretly install it and connect it to the alarm system to secure your windows, doors, and drawers.

WHAT'S HAPPENING?

As long as the aluminum strip is intact, the bulb will light up when the alarm system is turned on, because the circuit is closed. If it tears, the light goes out — this is the alarm signal (image 2).

Alarm systems like this are actually in use. In their case, however, when the aluminum tears it sets off an audible alarm or a releases a silent call to a security company.

Electrical network

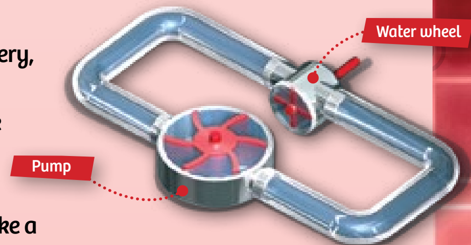
This is what an electrician calls an arrangement of electronic components connected together.

Electrical load

A load is something like an appliance that uses the electricity supplied by a circuit. Small loads are things such as light bulbs. An electric oven would be a somewhat larger electrical load, and really big loads are such things as the powerful engines in electric trains and streetcars.

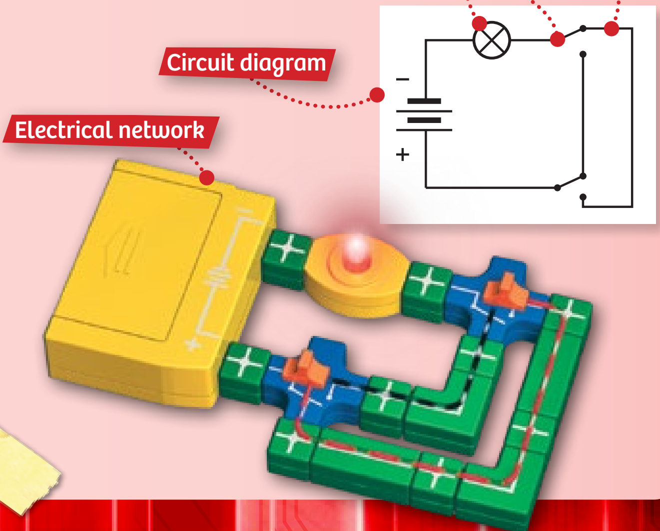
Electrical circuit

Picture an enclosed water-filled pipe arranged in the shape of a circle. A pump is installed in one part of the pipe. If the pump is turned on, it sets the water into motion so that it flows around in a circle through the pipe. In another location, there is a small water wheel that is turned by the flowing water, and imagine further that this water wheel drives, say, a propeller on the outside of the pipe. In this model of a circuit, the pump corresponds to your battery, which makes electrons flow. The electrons move through the wires, which correspond to the pipes. And the water wheel is like a light or a motor — a device or appliance that takes the electrical energy supplied by the battery and converts it into light or movement. If you block the pipe at a certain location, the pump cannot pump water any longer — the entire process stops. In the same way, the flow of electrons will stop when the electrical circuit is broken in any location.

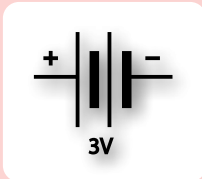


Circuit diagram

Electrical engineers have developed something known as a **circuit diagram,** which offers a clear and simple way of representing components and their connections. Each component is shown as a symbol, or circuit symbol. The symbol for an electrical wire is particularly easy — a single line. When a wire is thickened with a dot, it represents a place where two wires are joined or connected.

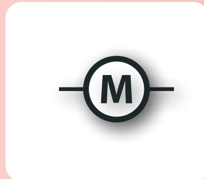


Important circuit symbols

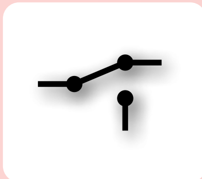


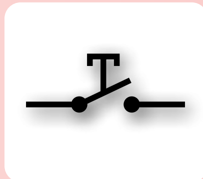
Battery

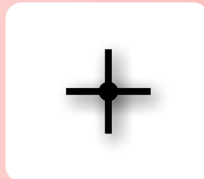

Lamp



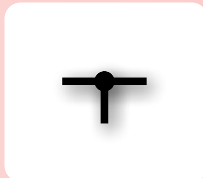
Motor


Two-way switch


Push button


X-connector


L-connector


T-connector

I-connector

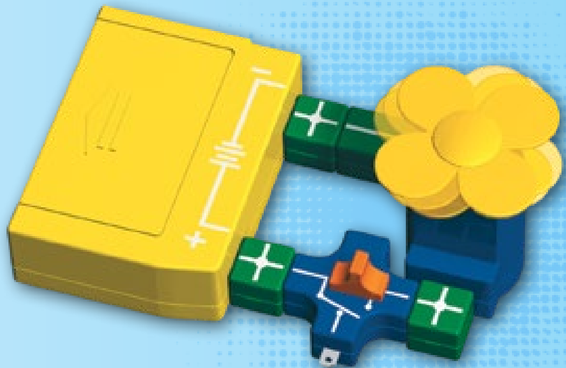
Electric Motor

In all sorts of places in our homes, in factories, and in vehicles, we use devices that produce rotation from electrical current. These kinds of **electric motors** provide power and movement wherever and whenever they are needed. They are at work, for example, in mixers and drills, vacuum cleaners and ventilators, CD players and computer hard drives, lathes and countless other machines, and they power subway cars and streetcars, locomotives and submarines. Even in a gasoline-powered car, all kinds of electric motors are at work in fans, power windows, and windshield wipers. Electric cars, of course, even use an electric motor as their main drive source. You have an electric motor inside your kit too.

EXPERIMENT 19

Sent spinning

If it's called an electric motor, then electrical current should be able to make it turn. Try it!



HERE'S HOW

Assemble a circuit with a switch. This time, instead of a light, try installing the motor with the fan mounted on top.

Turn on the motor with the switch.

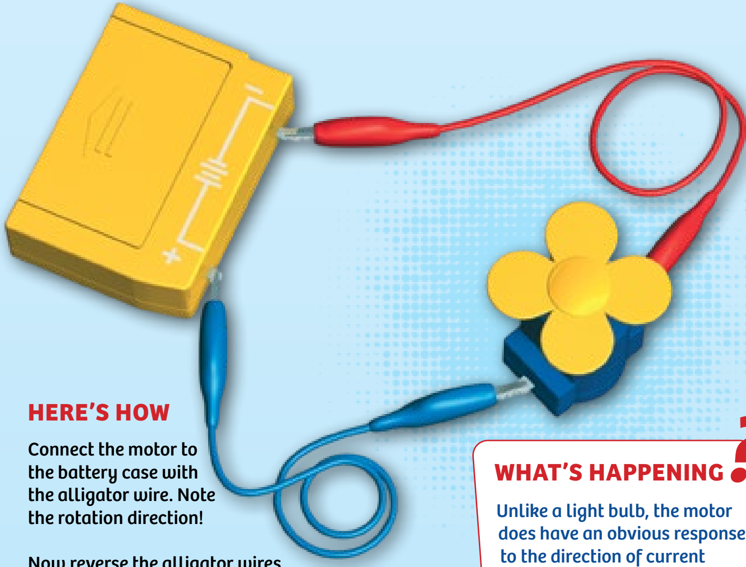
WHAT'S HAPPENING?

The electric motor converts the electrical current into a rotational movement — the fan spins quickly.

EXPERIMENT 20

Opposite direction

It made no difference to the light what direction the current flowed through it. Does it make a difference to the motor?



HERE'S HOW

Connect the motor to the battery case with the alligator wire. Note the rotation direction!

Now reverse the alligator wires at the battery case. This will make the current flow the opposite direction through the motor. How does it turn?

Now switch the wires at the motor terminals. What direction of rotation does the fan have now?

WHAT'S HAPPENING?

Unlike a light bulb, the motor does have an obvious response to the direction of current flowing through it: If you reverse the direction of flow, the fan's rotation reverses as well.

BATTERY POLES

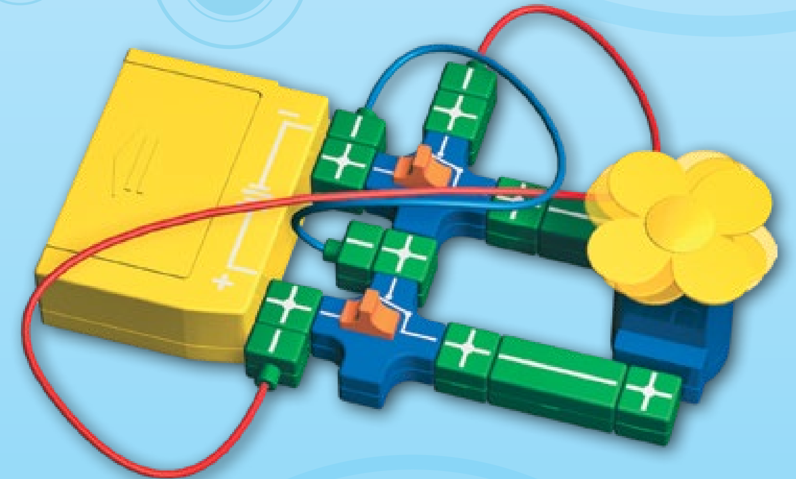
Each of your batteries has two different-shaped terminals.

One of them is the source from which the current will flow out into a circuit, while the other is where the current flows back in.

These two terminals are known as **poles**. One is the called positive pole (+) while the other is called the negative pole (-).

The battery case is marked with these plus and minus symbols as well.

If you reverse the connections, the current flows in the opposite direction through the circuit.



Quick change

Changing the direction of rotation by reversing the wire clamps is a little clumsy, of course. It would be great to be able to do it with two simple flicks of a switch.

HERE'S HOW

Assemble the circuit with eight X-connectors.

Try different switch settings and compare the motor's direction of rotation for each one.

Trace the current path for each switch setting.

WHAT'S HAPPENING

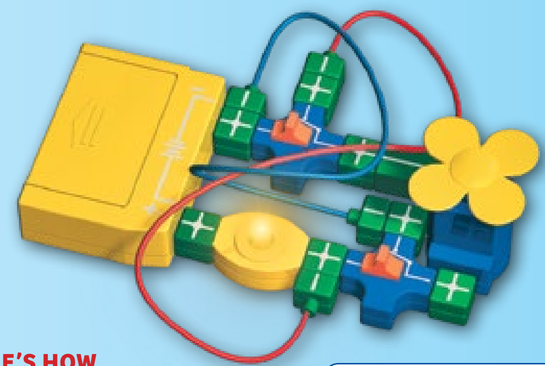
You can see how, for each switch setting, the current flows in one direction, in the opposite direction — or not at all.

Accordingly, the fan rotates clockwise, or counter-clockwise — or not at all.

EXPERIMENT 22

Current control

How can you check and make sure that a certain switch setting won't result in a short-circuit — that is, a direct connection between the two battery terminals? The simplest way is to monitor the current flow with a light bulb.



HERE'S HOW

You can see that the circuit matches the one in Experiment 21 ("Quick change"), except in this case a light is attached directly to one of the battery terminals.

On the other side, you will insert an I-connector to make the components fit together again.

Try all the switch settings. When does the bulb light up? Does anything occur to you as you watch the brightness of the light when the motor comes on?

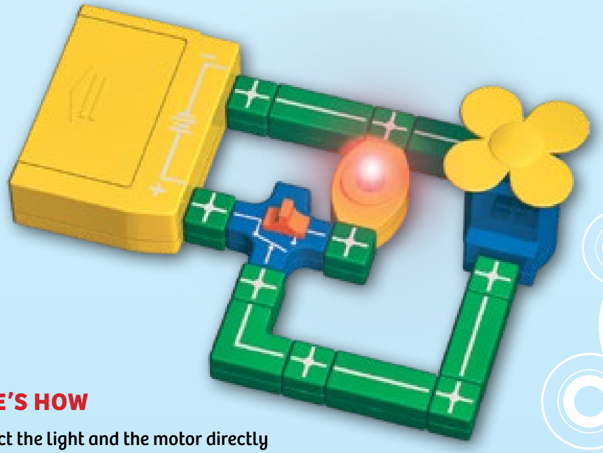
WHAT'S HAPPENING ?

By lighting up, the bulb shows you when current is flowing. So you can be sure that when it doesn't light up, there's no circuit. At the moment that the motor starts up, the bulb is dimmer than it is after that point. This shows that the motor is consuming more current at that moment. Only once it's running at full speed does its electricity requirement drop again.

EXPERIMENT 23

Motor or light

You can use the two-way switch to switch the current back and forth between different loads. Try it with the light and the motor.



HERE'S HOW

Connect the light and the motor directly to one of the battery terminals on one side, and connect the other side of each component to a different terminal of the two-way switch.

Now you can choose whether to make the bulb light up or the motor run.

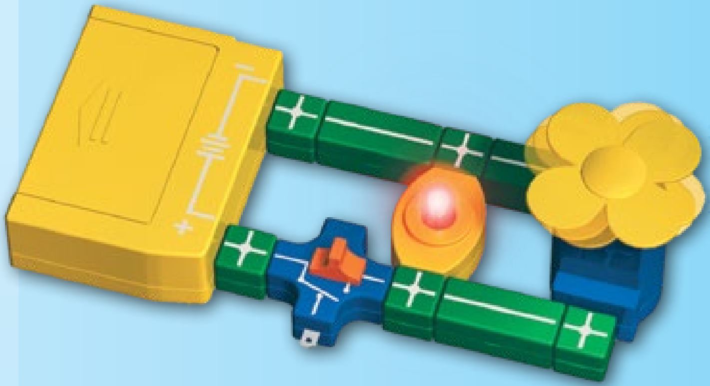
WHAT'S HAPPENING ?

Depending on the setting of the switch, the current will run through the light or through the motor.

EXPERIMENT 24

Motor plus light

You can also supply both the motor and the light with current at the same time. You already tried a series connection in Experiment 22 ("Current control"), and you found out that the light doesn't light up very brightly with that circuit type. But you know about a second wiring option — the parallel connection.



HERE'S HOW

This circuit is quite simple: Connect both the motor and the light directly to the battery terminals via the switch.

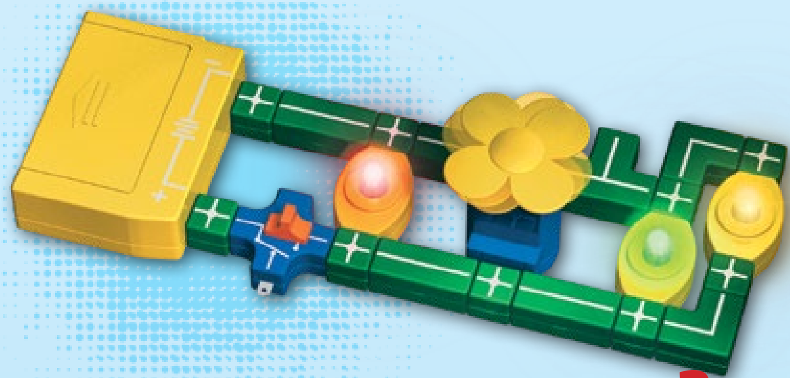
WHAT'S HAPPENING

With the parallel connection, both loads get enough current. So the bulb shines with its full brightness, and the motor turns fast.

EXPERIMENT 25

Motor at full brightness

Now the battery really has its work cut out for it. It will have to supply all three lights as well as run the motor. Do you think it can handle all that?



HERE'S HOW

This circuit is just an extension of the parallel circuit from Experiment 24 ("Motor plus light"), with the two extra lights connected up with two extra connectors.

Turn on the current with the switch. Do the bulbs light up? Does the fan turn?

WHAT'S HAPPENING

Apparently, the battery has no problem supplying all four loads at the same time.

All three bulbs light up and the motor turns. Of course, the battery would get used up much more quickly under this kind of load than when it has just one light to power.

EXPERIMENT 26

Motor with double switch

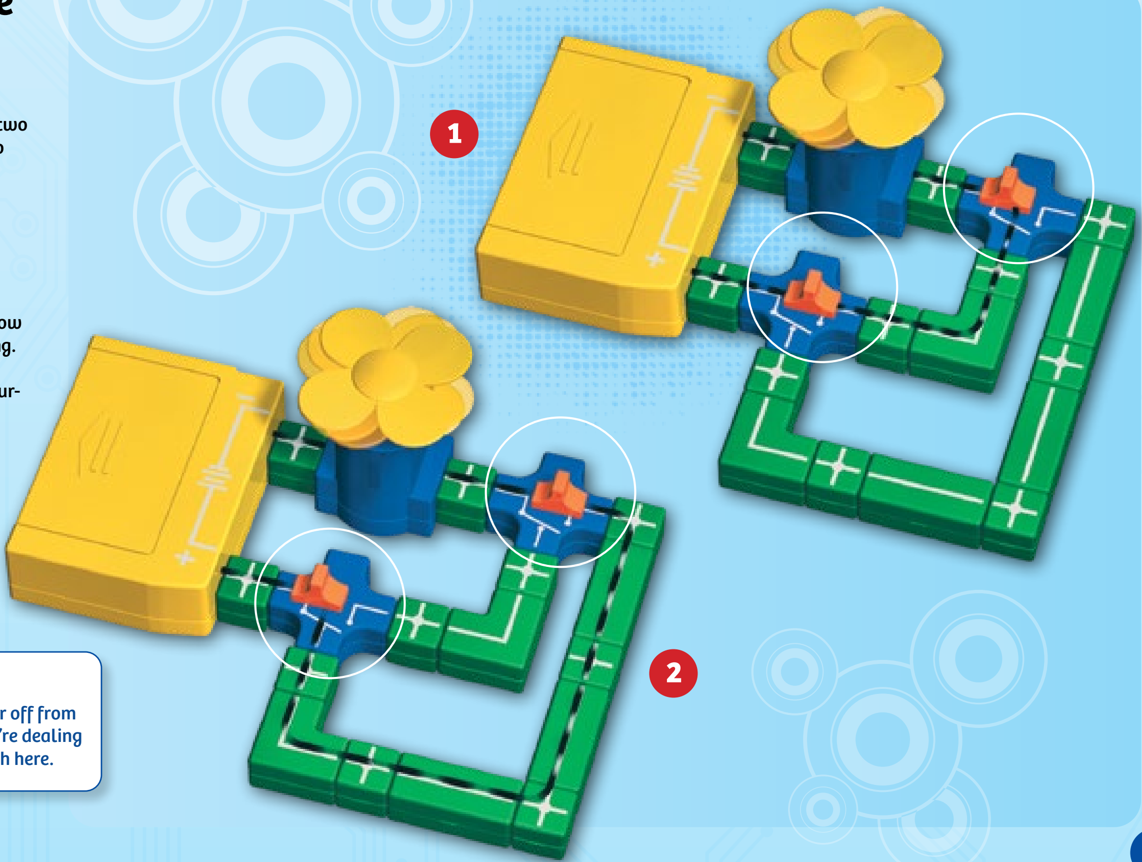
Sometimes, you might also like to be able to turn a motor on and off from two different locations. This circuit can do that.

HERE'S HOW

Assemble the circuit.

Try the different switch settings. Follow the path of the current for each setting.

Figures 1 and 2, with their different current paths indicated by broken lines, should help you here.



WHAT'S HAPPENING

It's possible to turn the motor on or off from either switch. You can see that we're dealing with yet another three-way switch here.

CHECK IT OUT

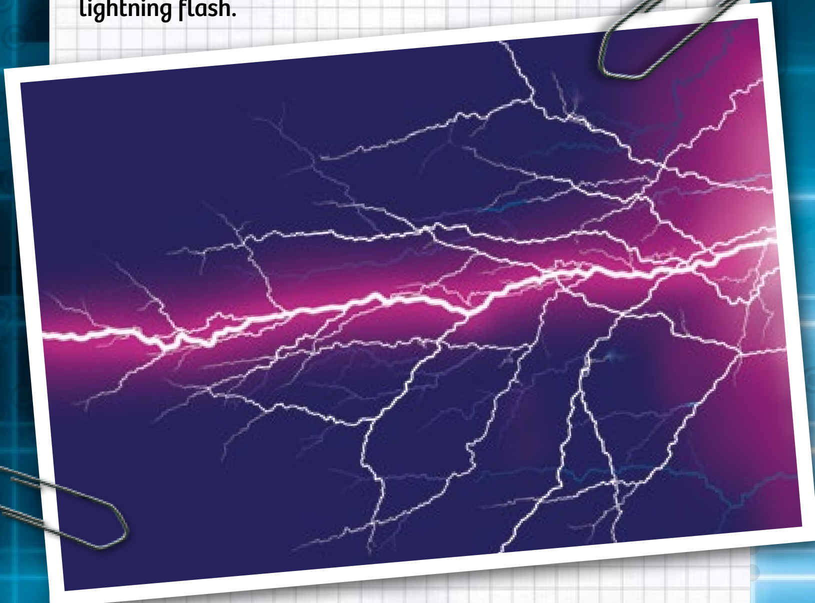
Electricity in nature

Electricity is a fundamental force of nature. Without it, our world would not exist at all. After all, the atoms and molecules out of which all the world's materials are composed are held together by electrical forces. Without electricity, there would be no stars or planets, no rocks, no living creatures. Even electrons, those particles that make up electrical current, can be found everywhere in nature:

All atoms are made of tiny nuclei around which electrons (usually a lot of them) are orbiting.

Lightning

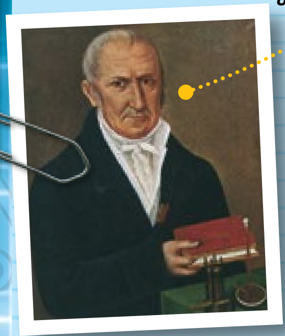
Lightning bolts are probably the showiest electrical phenomena in nature. Inside a thundercloud, there are areas with a huge excess of electrons, and other areas where there are too few. So, just like between the poles of a battery, there exists electrical tension, or voltage, between these areas. In a thundercloud, though, the voltage doesn't amount to just a few volts. Often, it will be over 100 million volts. So it discharges itself over and over again in the form of lightning bolts, which are the means by which the excess electrons leave the cloud. In the process, the air along the lightning channel gets heated explosively — to around 300,000 degrees Celsius, or six times hotter than the surface of the sun! That's what produces the rolling thunder that accompanies the lightning flash.



How does a battery produce electrical current?

You have been carrying out your electronic experiments using current from the two batteries in the battery case. But where exactly is the energy in the batteries coming from?

Over 200 years ago, the physicist Alessandro Volta observed that an electrical voltage is produced when two different types of metal, such as copper and zinc, are immersed together into a salt solution.

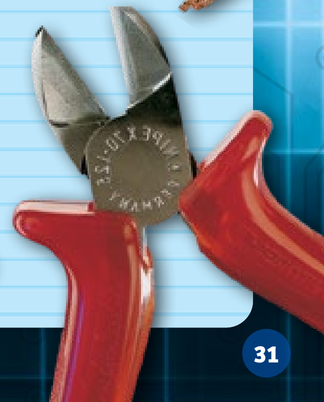


Even today, batteries are usually made of two metals connected via an electrically conductive liquid or paste. In this kind of battery, complicated chemical reactions take place while the current is flowing, with one of the metals gradually dissolving in the process. The dissolution of the metal is what supplies the energy from the battery. And that's also why the battery becomes used up, or "dead," after a while.

Why is it that electricity can be dangerous?

If electrical current flows through your body and blood, it decomposes the blood, with heat and toxic substances produced in the process. On top of that, our nervous system (including brain cells) works by the use of weak electrical signals. A strong electrical current wreaks havoc on that system.

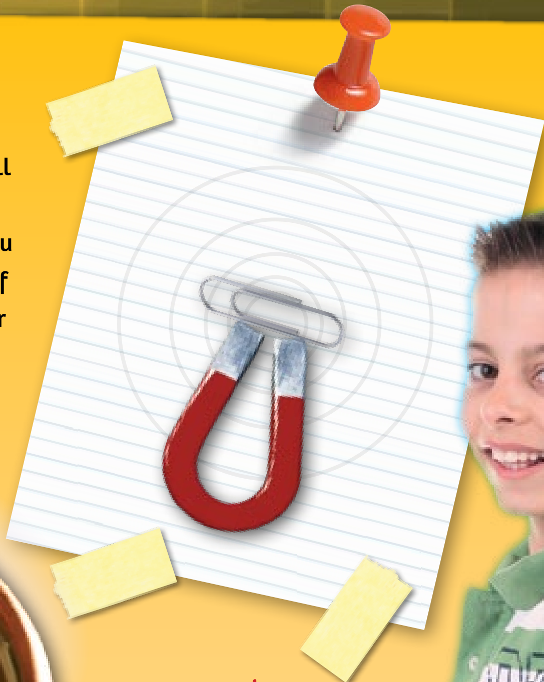
Because the body is a rather poor conductor of electricity, electrical current only becomes dangerous above a certain minimum voltage. A current of 3 volts, which is what your battery case supplies, is harmless.



The 110 volts coming out of the wall socket is quite another matter, though. That can kill you!

Magnetism

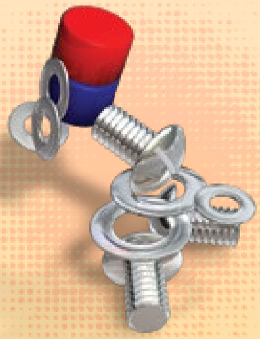
In the experiments in this section, you will be investigating the mysterious invisible forces emanating from a magnet. And you will learn how seafarers in earlier ages of exploration used these forces to find their way over seemingly endless expanses of ocean.



EXPERIMENT 27

Mysterious force of attraction

See how the magnets in the kit interact with the metal pieces.



HERE'S HOW

Spread out all the pieces from the kit's small parts pouch on the table.

Hold one of the cylindrical red-and-blue bar magnets above them. Pay attention to the distance between them and the magnet. When do the metal parts jump up and stick to the magnet?

Repeat the experiment with a ring magnet.

Now place the magnets on the table and hold a screw a few millimeters first above the bar magnet, and then above the ring magnet.

WHAT'S HAPPENING

Apparently, magnets and iron pieces can somehow sense each other's presence. If they get close enough, they can attract each other. Still, there are differences among different magnets: The bar magnet, for example, is stronger than the ring magnet.

EXPERIMENT 28

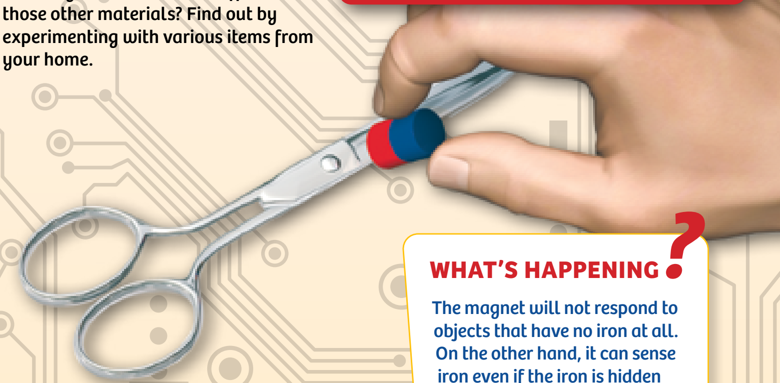
A love for iron

We are surrounded by all kinds of materials — glass, wood, paper, porcelain, aluminum, and so on.

Will magnets also have an effect on all those other materials? Find out by experimenting with various items from your home.

CAUTION!

Do not touch diskettes, compact disks, audio or video tapes, credit cards with magnetic strips, computers, or mechanical watches with your magnets. The sounds, images, or other data stored on them would be irretrievably erased, and the watch might not work properly any longer.



HERE'S HOW

Walk around your house with the bar magnet and test it on various objects to see if it attracts them.

In particular, try testing pots, nails, glass, cups, aluminum bottle caps, paper, baking sheets, coins, cutlery or silverware, furniture, needles, and paper clips.

WHAT'S HAPPENING

The magnet will not respond to objects that have no iron at all. On the other hand, it can sense iron even if the iron is hidden under a layer of plastic.

So you can use a magnet as an "iron detector." If you have a wire or paper clip coated in plastic, for example, you can use the magnet to tell whether there is iron inside.

EXPERIMENT 29

Scrap metal separator

Iron and steel are important raw materials that are hidden inside all sorts of everyday things. Still, a lot of iron-containing objects end up in the trash. With the help of a magnet, you can separate those objects from the rest of the trash in order to recycle the iron.

HERE'S HOW

Pour a handful of sand into a bowl. Mix the small metal pieces into the sand.

The sand will represent the non-magnetic trash. Now, try digging around in the sand with the bar magnet.

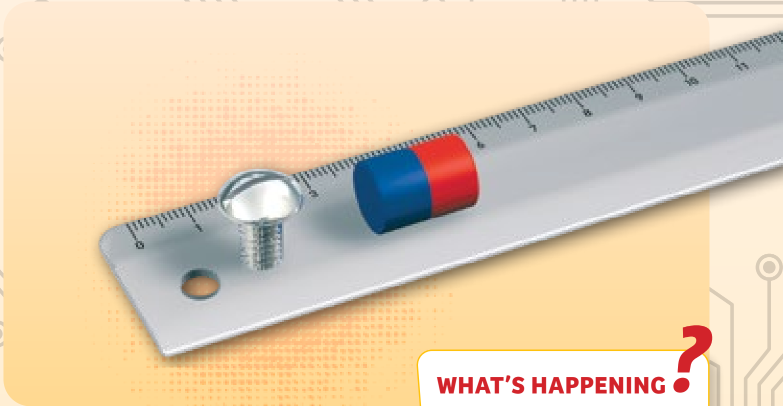
WHAT'S HAPPENING?

Piece by piece, the metal objects will get stuck to the bar magnet. In fact, powerful magnets really are used at trash collection facilities to separate iron and steel parts from other trash. Then they are melted down again and reprocessed into new iron parts.

EXPERIMENT 30

Intimate attraction

Apparently, magnets are capable of monitoring their surroundings, sensing the presence of iron, and pulling it close with invisible arms. How far do you think those arms might reach?



HERE'S HOW

Lay a 30-cm ruler on the table, and place a screw precisely on the zero mark.

Now slowly slide the bar magnet toward the screw, blue end in front, starting from around the 10-cm mark. At what distance (in millimeters) does the screw tip over due to the magnet's force of attraction and stick to the magnet?

Try performing this experiment with the ring magnet as well.

WHAT'S HAPPENING?

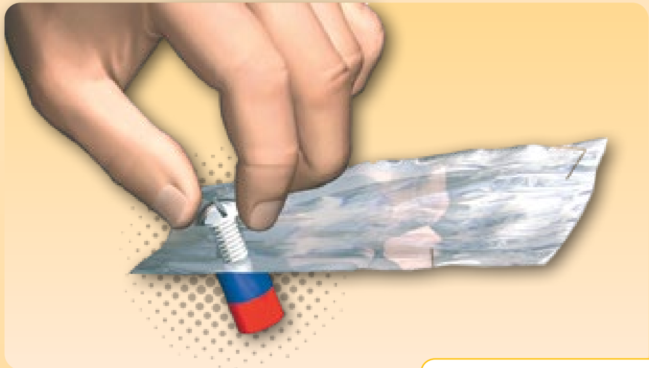
The strength of the magnetic force depends a lot on the distance. At a greater distance, the force is weak, but as you get close it quickly increases.

You can use the screw and the ruler to compare the strength of various magnets and their different sides. The ring magnet will be weaker overall.

EXPERIMENT 31

Penetrating effect

The force of a magnet can evidently penetrate air, because otherwise it wouldn't have been able to sense the screw in Experiment 30 (Intimate attraction). But can a magnet also "see" through other materials?



HERE'S HOW

Move various objects between the magnet and the screw to test whether you can still feel the force of attraction.

Of course, the objects shouldn't be thicker than a few millimeters, since otherwise the distance alone might prevent you from feeling anything.

Try it with plastic wrap, aluminum foil, a thin-sided cup, cardboard, paper, fabric, and an iron baking sheet.

WHAT'S HAPPENING

The magnetic force apparently penetrates all these materials without any problem, even the metal ones. The only exception is the iron baking sheet.

EXPERIMENT 32

Contagious magnetism

Is a magnet capable of altering the iron that it attracts? It may look no different from the outside, but do you think it might have acquired special properties?

HERE'S HOW

Take a screw in your hand and see if you can use it to attract any of the other iron pieces from the pouch. In fact, you won't feel any effect.

Suspend the screw from the bar magnet and then touch it against other iron pieces from the pouch. They will be attracted to it.

If you remove the magnet from the screw, the other pieces will fall off again.

See how many of the little pieces the screw can hold!

WHAT'S HAPPENING

The magnet does in fact change the iron in the screw, by turning it into its own little magnet. But this change is only sustained as long as the magnet sticks around. As soon as the magnet has moved far enough away, the magnetic power of the screw disappears as well.

EXPERIMENT 33

Magnetic flowers

You can put magnetic forces to use by having them make parts stick to each other temporarily — without using any glue. Of course, the parts will have to have something made of iron, such as the rings around these plastic disks.

HERE'S HOW

Here's where your imagination has to get in on the act. Try composing interesting shapes out of the four magnets and the colorful disks. How about a flower, for example?

WHAT'S HAPPENING?

By using their force of attraction to hold the iron tight, the magnets keep the shapes from falling apart.

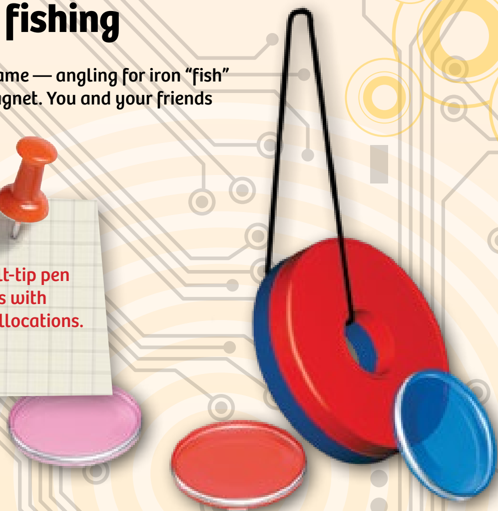
EXPERIMENT 34

Magnetic fishing

Here's an age-old game — angling for iron "fish" with the use of a magnet. You and your friends will enjoy this.

TIP!

You can use a felt-tip pen to mark the disks with different point allocations.



HERE'S HOW

Take a 50-cm piece of twine, and tie one end tightly to a ring magnet and the other end to the handle of a cooking spoon. This will be your fishing rod.

Spread the plastic disks across the bottom of a box. Now, without looking into the box, take turns fishing. If you lift up the fishing rod without having caught anything, you have to pass it to your neighbor. If you catch something, take another turn.

The winner is the one who has the most plastic disks at the end of the game, or the most points.

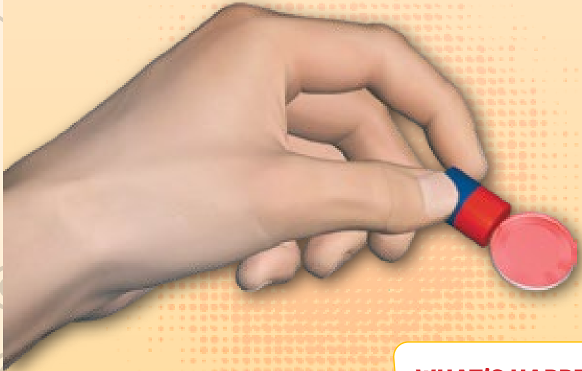
WHAT'S HAPPENING?

The magnet attracts the iron rings around the disks. But because the ring magnet is not very strong, the disks can easily fall off again, which makes the game more challenging and more fun.

EXPERIMENT 35

Centers of force

You have probably noticed that the magnetic force is not equally strong in all parts of the magnet. Now it's time to investigate this a little more closely, using a plastic disk with an iron ring as your test object.



HERE'S HOW

Bring the disk close to the bar magnet and move it slowly around the magnet. Where do you feel the force of attraction most strongly?

Let the disk be attracted by the magnet. Where does it stick to the magnet?

Repeat the experiment with the ring magnet.

WHAT'S HAPPENING?

In fact, any magnet has two locations where its magnetic force is greatest. These are called the "magnetic poles." With the bar magnet, the poles are at the ends, and the magnetic force is much weaker in the middle. With the ring magnet, it's the ring-shaped surfaces that represent the poles.

Magnets...

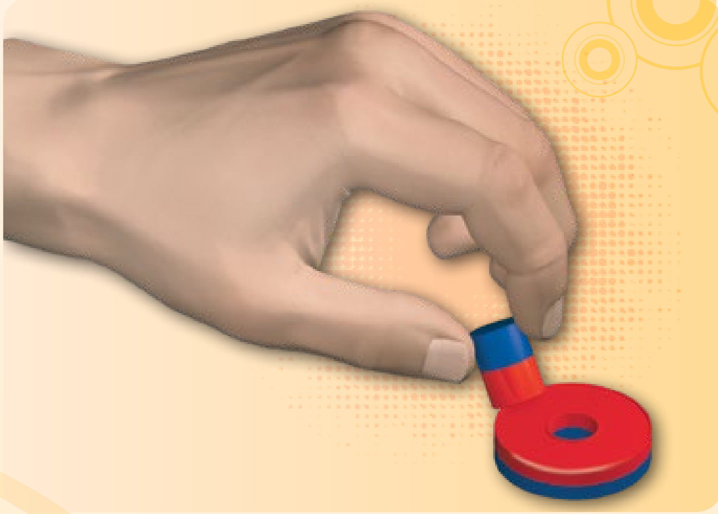
...can be made in all kinds of shapes. There are bar and ring magnets like the ones in your kit, but magnets also exist as tubes, disks, powders, flexible films, and as lots of other types as well, depending on how they are to be used.

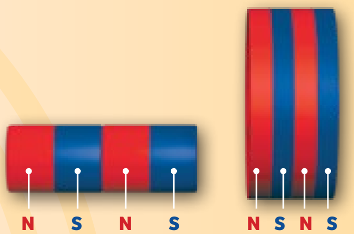
But you can always tell a magnet apart from similarly shaped iron pieces, simply by bringing another magnet close to it. Start by turning one of the magnet's ends toward the unknown object, then turn it around and bring the other end close. If the object in question is a piece of iron, you will feel a force of attraction with both ends. If the object is itself a magnet, it will be pushed away when one of the ends of the first magnet is moved close to it. You will investigate this phenomenon in the next experiment.

THE POLE COLORS

The red and blue colors are just for purposes of identification, of course.

The reason the poles behave differently has to do with certain properties of their atoms, which are the smallest particles in the magnetic material.





Magnetic friends and foes

You have already tested a lot of materials to see how they behave in response to magnets. But how do magnets behave with each other?

HERE'S HOW

Hold the two bar magnets close to each other. What do you feel?

Turn one of the magnets around. What do you notice? Pay attention to the colors of the ends!

Repeat this experiment with the ring magnets. Then try seeing how a ring and a bar magnet respond to each other.

WHAT'S HAPPENING?

While the two poles of a magnet will behave identically toward pieces of iron, they do not behave identically toward other magnetic poles. Two poles of the same color will repel each other, while different-colored poles will attract each other.

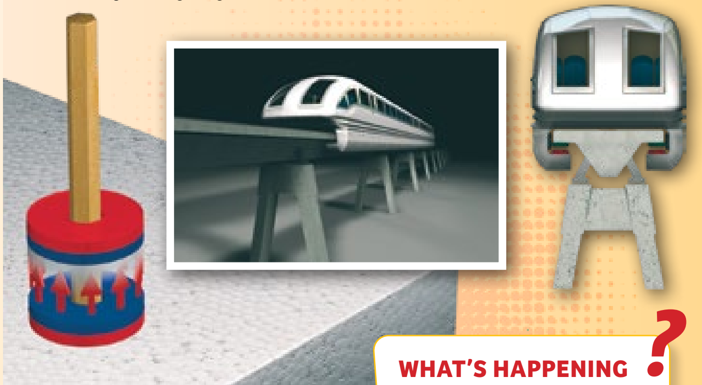
To tell them apart, one pole is called the **north pole,** while the other is called the **south pole.** Two north poles or two south poles will repel each other, while unlike poles will attract.

In your magnets, the red end is the north pole, while the blue end is the south pole.

EXPERIMENT 37

Floating on magnetic pillows

Instead of moving on wheels, magnetic levitation trains float a few millimeters above the track. That helps them stay quiet and vibration-free even as they reach speeds of over 500 kilometers per hour. The secret lies in using the repelling forces of magnets to help them float on a cushion of air. Can you do the same trick with your ring magnet?



HERE'S HOW

Stick a pencil pointed-end-first into the kit box's Styrofoam.

Drop one of the ring magnets onto the pencil.

Place another ring magnet on top of it, with two surfaces of the same color facing each other.

WHAT'S HAPPENING

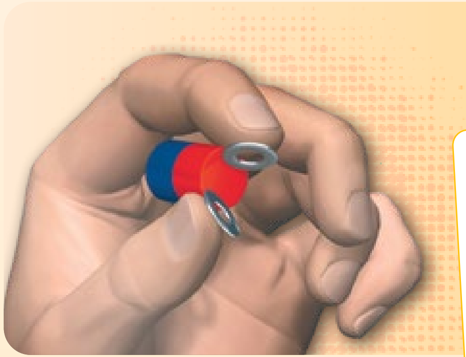
The magnets don't touch each other at all. The upper one floats above the one below it as if held up by the hand of a ghost.

That's because the two ring magnets will repel each other when two poles of the same type are facing each other. The pencil keeps the upper magnet from slipping to the side.

EXPERIMENT 38

Insufferable twins

In Experiment 32 (Contagious magnetism), you turned a piece of iron into a magnet. Now that you have learned something about magnetic poles, it's time to investigate this a little more closely. What happens when you bring two similar pieces of iron, such as the two disks with a hole in them, up to one of the poles of the magnet?



HERE'S HOW

Place the two washers next to each other on the red north pole surface of the bar magnet.

Hold them tight against each other with your fingers. What do you feel?

You can perform the same experiment with the same result on the blue south pole.

WHAT'S HAPPENING

The two washers will immediately tip away in opposite directions as soon as they touch the bar magnet. The bar magnet is transforming the washers into magnets. But they have their like poles turned toward each other — north pole (N) toward north pole, south pole (S) toward south. And like poles repel each other.

So when you hold them tight, you can easily feel the forces of repulsion between them.

Disappearing poles

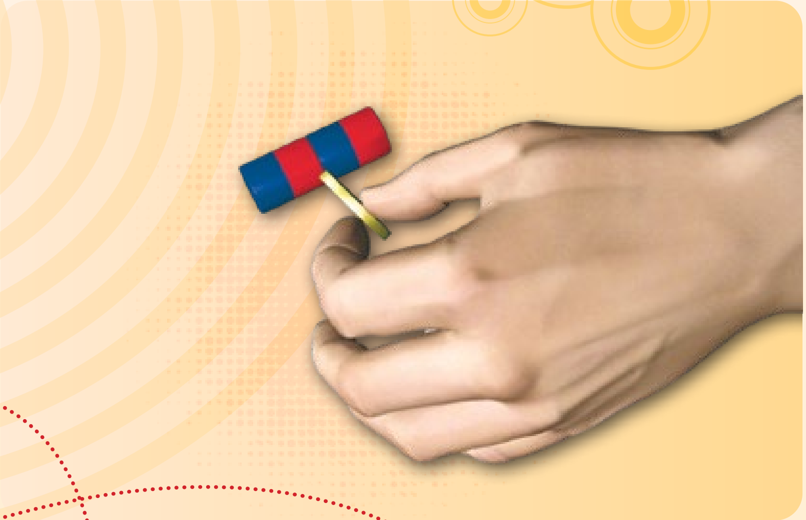
Each of your magnets has a north pole and a south pole. Do you think you could ever find just a north or a south pole by itself, or do they only come in pairs?

HERE'S HOW

Attach the two bar magnets to each other by bringing the opposite poles together.

Now test to see where the areas of strongest magnetic force are. What can you determine?

Pull the magnets apart and test them again. Repeat the experiment with the ring magnets.



WHAT'S HAPPENING?

Two magnets connected together behave just like one single magnet with two poles. In the area where they touch, on the other hand, their magnetic force disappears.

When you pull them apart, though, it reappears. The same thing happens when you actually saw a magnet in half: You get smaller and smaller magnets, each with two poles.

WHY DOES A MAGNET ATTRACT IRON, OF ALL THINGS?

It's because iron consists of countless tiny magnets, due to its special atomic structure.

These so-called molecular magnets are normally all jumbled up, so their individual magnetic forces cancel each other out.

When they happen to get close to another magnet, they all line up in the same direction.

That's how a piece of iron will temporarily turn into a magnet as well — and these two magnets will attract each other.

EXPERIMENT 40

Magnetic force made visible

It's kind of a shame that you can't see magnetic forces. But there's a trick for making them visible — by using the iron powder from the plastic box.

HERE'S HOW

Place the two touching bar magnets flat on the table. Spread out the iron powder fairly evenly in the box and hold the box a few millimeters above the magnets (which creates clearer patterns than when you hold the magnet directly against the box).

Tap gently on the box. The iron particles will form a picture, as if painted by the hand of a ghost (figure 1).

You might have to perform this experiment a few times before you get the hang of making a really nice-looking pattern.

Stand the bar magnet upright (figure 2) and repeat the experiment. How does the picture look now?

Also try seeing what kinds of patterns the ring magnet makes (figure 3).

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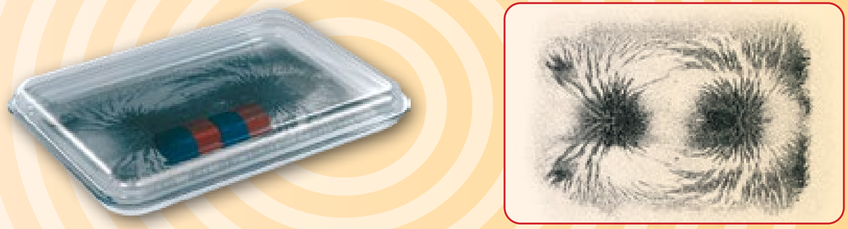

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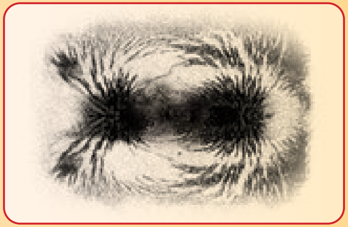


HERE'S HOW IT CONTINUES

Secure the bar magnets a few millimeters apart on the table and see what kinds of patterns they form (figure 4).

Now hold the two bar magnets against the top of the box (figure 5). Of course, they will attract some of the iron powder.

WHAT'S HAPPENING?

As the iron particles show, the magnetic force seems to pour out of the poles and follow an arching path back to the opposite pole, with that path reaching a few millimeters out into the surrounding area.

That is because the iron particles themselves turn into little magnets when they are close to another magnet.

You already know about this from Experiment 32 (Contagious magnetism). The particles orient themselves according to the poles of the magnet, and stick together in chains. That's how the pattern is created out of thousands of tiny magnets.

TIP!

When unlike poles are facing each other, you can create an actual bridge of iron powder from one to the other. That won't work with equal poles.

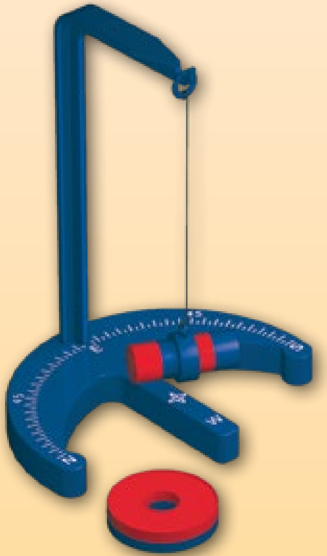
MAGNET FIELD

You can picture magnetic force as lines projecting out from one magnetic pole, running through the surrounding space, and then re-entering the other pole. These so-called **magnetic lines of force** are just a simple conceptual model, of course. In reality, a magnet is altering the space around it by giving it the property of being able to exert force on pieces of iron. Physicists call this kind of altered space a field. So there's a **magnetic field** all around the magnet, with the strength of the field falling as you get farther away from the magnet.

EXPERIMENT 41

Hanging magnets

As you have already seen in several experiments, magnets have a definite response to other magnets. You can use this knowledge to build a very sensitive detection device for magnetic forces.



TIP!

Keep your other magnets at least one meter away, so they don't interfere with your experiments!

HERE'S HOW

Mount the hanger arm on the base. Hang the cord with rings from the hook by the small ring. Insert the two bar magnets into the large ring so they stick tightly to each other.

Wait for the bar magnet to stop swinging. Now you can move one of the ring magnets toward it and test the sensitivity of your device.

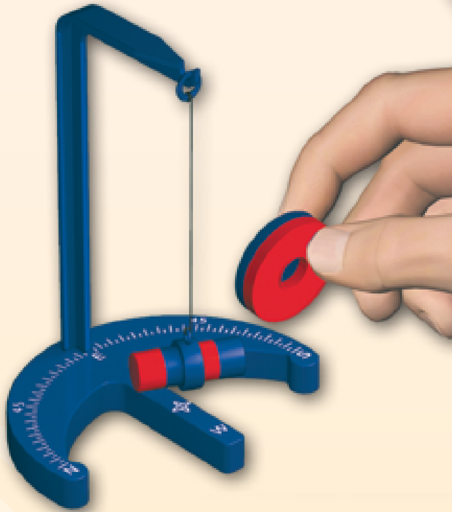
WHAT'S HAPPENING

Because the magnets are suspended in a way that lets them move freely, they can even react to weak magnetic forces by turning their attractive pole toward the other magnet.

EXPERIMENT 42

Dancing magnets

The bar magnet dangling on the string is extraordinarily mobile. That makes it handy for this fun experiment.



HERE'S HOW

As you did in the last experiment, suspend the two bar magnets with the cord from the hanger arm.

Now move the ring magnet past the suspended bar magnet from a certain distance away.

If you coordinate the movements of the ring magnet and the pair of bar magnets skillfully enough, you will be able to get the bar magnets to rotate rapidly.

WHAT'S HAPPENING

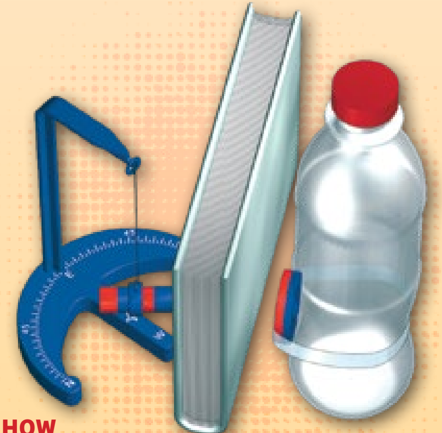
The sideways movement of the ring magnet is transferred to the bar magnet via the magnetic field, and makes the bar magnet start rotating. If you keep giving it a push with the ring magnet at just the right moment, the rotation gets faster.

This is the same principle by which electric motors work: They contain magnets that are set into a spinning motion by other magnets.

EXPERIMENT 43

Improved penetration test

In Experiment 31 (Penetrating effect), you tested various materials for their ability to let magnetic force pass through them. Now, with your sensitive detection device, you can perform this test much more accurately.



HERE'S HOW

Tape the ring magnet to a bottle and guide it close enough to the bar magnet pair hanging from the hanger arm to make the bar magnets turn noticeably toward it.

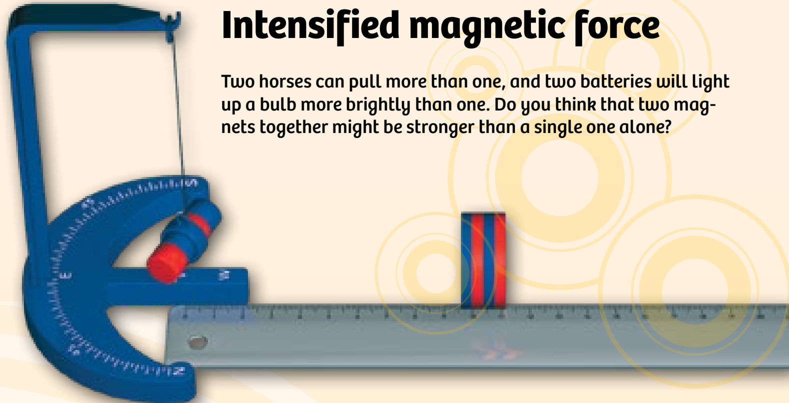
Leave the bottle in this position and move various materials between the magnets — glass, porcelain, wood, plastic, your hand, metals, and so on. Even fairly large objects will be able to fit between them now.

WHAT'S HAPPENING?

Thanks to the high sensitivity of your device, the test is much more convincing than the first experiment with the screw. Still, the result is pretty much the same: All the materials except for iron will let the magnetic force pass through unhindered.

EXPERIMENT 44

Intensified magnetic force



Two horses can pull more than one, and two batteries will light up a bulb more brightly than one. Do you think that two magnets together might be stronger than a single one alone?

HERE'S HOW

Push the zero marker of a ruler (30 cm) under the pair of bar magnets. Wait for the magnets to stop moving.

Slide a ring magnet slowly along the ruler toward the bar magnets. Note the distance at which the magnets react.

Now stick the two ring magnets together with their unequal poles facing each other. Slide them toward the bar magnets again. When do the bar magnets react?

Repeat the experiment, except this time push the ring magnets together with their equal poles facing each other.

WHAT'S HAPPENING?

Two magnets stuck together are noticeably stronger than one, and they will make the bar magnets move from a greater distance away.

On the other hand, the magnetic force is greatly reduced when you push the ring magnets together with their equal poles facing each other. Then, you can bring the ring magnets quite close before the bar magnets respond.

EXPERIMENT 45

Magnets in competition

You can also use your sensitive hanging magnet device to compare the strengths of two magnets.

HERE'S HOW

Assemble the hanger device with cord and bar magnets, and wait until the "long" bar magnet stops moving.

Now set down two rulers (30 cm) so that they form a right angle. The bar magnet should point to the exact center of this angle.

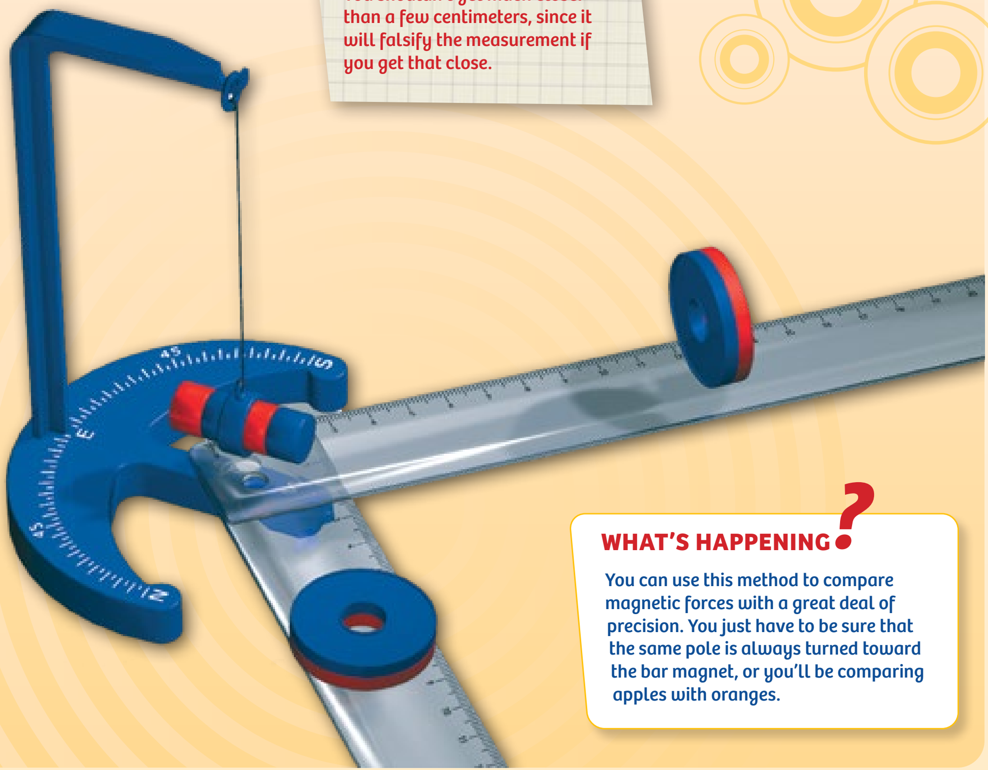
To be able to see this position easily, rotate the hanger base so that the magnet is suspended exactly in the middle of it.

Now you can slide both ring magnets along the rulers toward the hanger. To let you see a difference, hold one magnet vertically and the other horizontally. If you have other magnets, of course, you can try them too.

Push the first magnet forward until you see a slight reaction from the bar magnet. Then push the other magnet along until you see the bar magnet regain its earlier position.

TIP!

You shouldn't get much closer than a few centimeters, since it will falsify the measurement if you get that close.



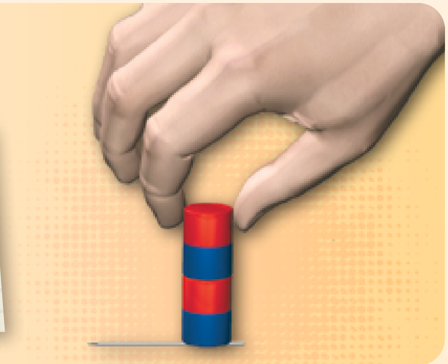
WHAT'S HAPPENING?

You can use this method to compare magnetic forces with a great deal of precision. You just have to be sure that the same pole is always turned toward the bar magnet, or you'll be comparing apples with oranges.

EXPERIMENT 46

Birth of a magnet

In Experiment 32 (Contagious magnetism), you saw how a piece of iron can turn into a magnet when it is touched by a magnet. Unfortunately, the magnetic power disappears as soon as the iron and the magnet are separated. But that isn't true for all iron objects.



TIP!

Be sure to keep the magnetic needle in a safe place, since you'll be needing it for other experiments.

HERE'S HOW

Start by using the iron pieces to test the needle for magnetism. It will presumably be very weak at best.

Now stroke the blue pole of the bar magnet 50 to 100 times across the needle, always in the same direction.

Test the needle again. What do you find?

WHAT'S HAPPENING?

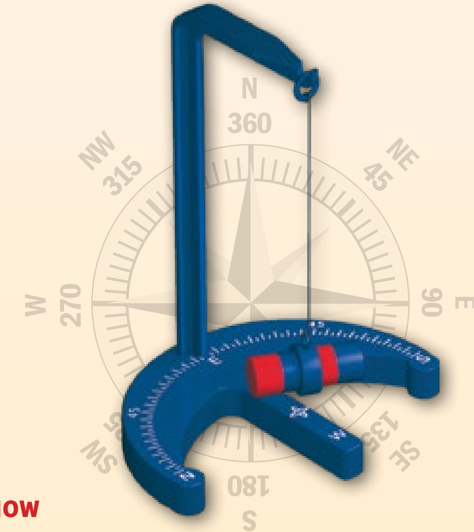
Now the needle really does act like a magnet, even if only a weak one.

The needle is made of steel, which is a kind of iron that has been treated in a special way. When you magnetize steel, it retains its magnetic power.

EXPERIMENT 47

Mysterious behavior

Researchers tend to have excellent powers of observation. Are you a good observer? Let's find out!



HERE'S HOW

Place the hanger device, with the bar magnet suspended from it, in various locations around your home. Wait each time for the magnet to stop moving. Watch carefully. Do you notice anything?

Look for a notable landmark some distance away (say, a tall building or a mountain) in the direction in which the magnet is pointing. Also try going outside to see what direction the magnet points.

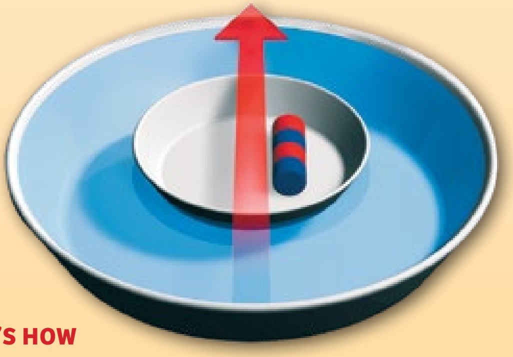
WHAT'S HAPPENING?

Whether you're inside or outside, the magnet always points in the same direction.

EXPERIMENT 48

Floating magnets

Do you think the fact that the bar magnets always point in the same direction might have something to do with the hanger device or maybe the cord? It's easy to check by setting something else up that will still let the magnets move freely. How about having them float on water?



HERE'S HOW

Fill a bowl with water.

Set the stuck-together bar magnets on a saucer and let your "boat" float freely (don't let it get caught against the edge). After a few seconds, the bar magnet, and the saucer along with it, will turn in a certain direction.

Turn the bar magnet in a different direction. What do you notice?

Perform the experiment again with two ring magnets standing upright.

WHAT'S HAPPENING?

Even the floating magnets prefer a certain direction. Apparently, they feel the same external influence as the hanging magnets.

You could test your magnets almost anywhere: They always have the same preferred direction. Why? See the next experiment.

EXPERIMENT 49

Remote-controlled magnet

It would be interesting to figure out what direction this is that seems to be so important to the magnets. To do that, try finding your home's location on a map of your area.

HERE'S HOW

In Experiment 47 (Mysterious behavior), you looked for a notable landmark in the direction in which the magnet was pointing. Look for this landmark on your map, along with your home.

Draw a line with a pencil between the two locations. Do you notice anything?

WHAT'S HAPPENING?

The line should lie parallel to the left and right edges of the map. That's due to the conventional way of representing things on a map: Maps are drawn with the north at the top, south at the bottom, west to the left, and east to the right.

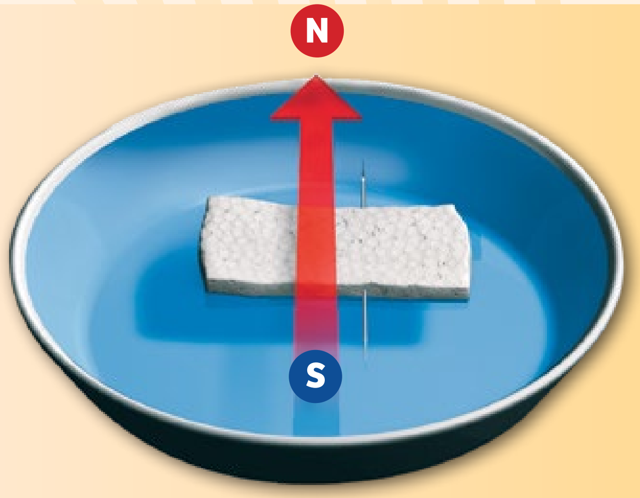
So your line indicates that the bar magnet settles into in a north-south direction. In other words, it is acting like a compass needle.

ALWAYS TO THE NORTH

A compass needle, as you already learned, is a tiny magnet. It orients itself according to the direction of Earth, since Earth itself is a magnet.

Earth behaves as if there were a giant bar magnet wrapped inside its interior, with one end near the North Pole, and the other end near the South Pole.

In reality, of course, it isn't really a gigantic permanent magnet that produces Earth's magnetic field. The field is actually caused by powerful electrical currents flowing through Earth's metallic core.



WHAT'S HAPPENING?

If the polystyrene foam floats freely, the needle always points in a north-south direction.

Slender arrows and needles let you detect a northerly direction more precisely.

In fact, early compasses really were made out of a magnetized needle and cork floating in a bowl of water marked with a scale.

Magnetic needle

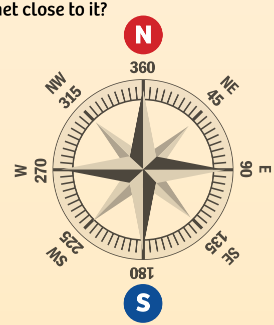
The bar magnet is only somewhat useful as a compass, since its shape won't let you read the direction very precisely. But there's a better option. Try your hand at making a replica of one of the earliest compass models — a floating compass.

HERE'S HOW

Fill a bowl with water. Break off a piece of polystyrene foam, as flat as possible, from the kit's parts tray, and let it float in the bowl.

Once it is floating properly, insert the magnetized needle from Experiment 46 (Birth of a magnet) horizontally through part of the polystyrene foam piece, and let it float freely in the middle of the bowl. What do you notice?

How does your floating compass react when you bring the ring magnet or bar magnet close to it?



CHECK IT OUT

The word magnet …

… comes from the name of the ancient city of Magnesia in Asia Minor. That's where people found chunks of an unusual, heavy material with a strange property of attracting pieces of metallic iron. Today we know that this was the kind of iron ore we call magnetite.

Compass

Thousands of years ago, people realized that magnets orient themselves in north-south directions. They took advantage of this to build compasses — devices that will always show the direction, even at night or when the sky is overcast. Without a compass, the great explorers such as **Christopher Columbus** and **James Cook** would never have been able to cross the world's oceans, since they never would have been able to find their way across the seemingly endless expanses of water.

Christopher Columbus

James Cook

IN EVERYDAY LIFE…

…compasses are incredibly important, even if you can't always see them.

You probably know that magnetic compasses have been guiding ships across the oceans for hundreds of years.

But there are also electrical magnets — magnets, in other words, that get their power from electric current. You can find them inside electric motors and speakers, in bicycle dynamos and in the gigantic electrical generators in power plants.

As you can tell from these examples, electricity and magnetism are very closely related.

You will be exploring both domains in the exciting experiments in the next section.

Electromagnetism

Are electricity and magnetism related? Or are they completely different natural phenomena? In the following experiments, you will be exploring the strange connections between them, and you will learn about some of their useful applications.

EXPERIMENT 51

Astonishing electrical effect

Can electricity influence magnets? Find out with the help of your hanging magnet apparatus.

HERE'S HOW

Assemble your hanger device with base, arm, cord, and the double bar magnet, and let the magnet come to a resting position.

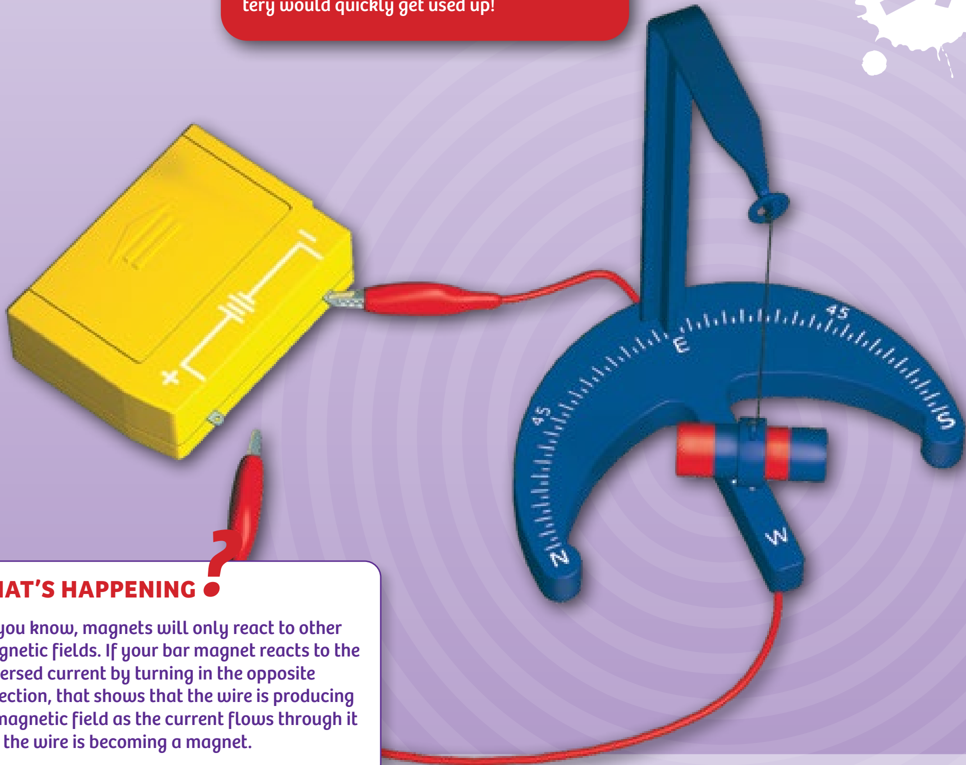
Secure the alligator wire clip to one of the battery case terminals, and then guide the wire under the hanger base in such a way that it runs parallel to the lengthwise direction of the bar magnet. Place the other alligator clip near the second battery terminal.

Tap this other clip briefly against the battery terminal. The magnet will turn a little. After it has turned a little, it will orient itself at right angles to the wire. Note the side to which the red end moves.

Unfasten the clip, turn the battery case around, and attach one of the clips again. Tap briefly against the free battery terminal again. Now the current will be flowing in the opposite direction through the wire. Does that have an effect on the direction that the magnet turns?

CAUTION!

You should only tap the clip very briefly on the battery terminal, one second at most. If the current were to flower longer, the battery and wire might get too hot, and the battery would quickly get used up!



WHAT'S HAPPENING

As you know, magnets will only react to other magnetic fields. If your bar magnet reacts to the reversed current by turning in the opposite direction, that shows that the wire is producing a magnetic field as the current flows through it — the wire is becoming a magnet.

EXPERIMENT 52

Intensified electrical effect

Do you think you might be able to intensify the effect on the bar magnet by using more than one wire? Or maybe it will work to coil a single wire multiple times to form a spool.

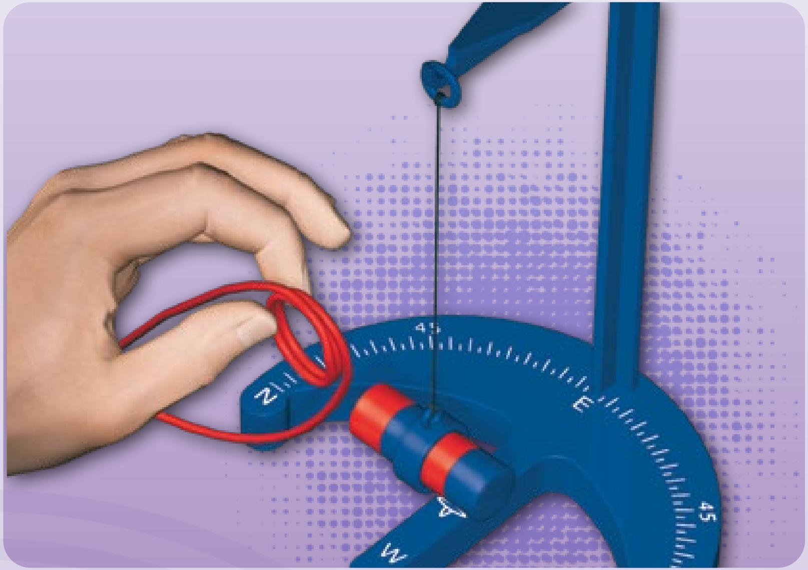
HERE'S HOW

Wind the red plug wire around your finger to form a coil, and secure the coil in place with some tape.

Connect the wire to one of the battery case prongs via an X-connector. Connect the other end to an I-connector via an alligator clip. Place one of the blue alligator wire's clips on the other side of the I-connector.

Hold the spool two to three centimeters away from the red end of the bar magnet, and briefly touch the alligator clip at the free end of the blue wire against the free battery terminal. The red end of the bar magnet will turn toward or away from the spool.

Reverse the direction of current flow and repeat the experiment. In what direction does the magnet turn now?



WHAT'S HAPPENING?

The spool is acting like a bar magnet with a north and a south pole. If you switch the direction of current, the poles will also switch, and the magnet will turn in the exact opposite direction from before.

Of course, the spool is only magnetic while current is flowing through it. So it's an **electromagnet** — unlike bar or ring magnets, which retain their magnetic power permanently and are therefore known as **permanent magnets**.

TIP!

Only let the current flow very briefly (a few seconds), or the battery will quickly get used up.

EXPERIMENT 53

Even stronger electrical effect

A permanent magnet can make iron magnetic. Can an electromagnet do that too?

HERE'S HOW

Use a nut to connect two screws together (figure 1).

Wind the red alligator wire onto the screws to form a spool (which it would be good to tape in place as in figure 2).

Connect the alligator wire to the plug wire as you did in the last experiment, and the blue alligator wire to the battery.

Repeat the "intensified electrical effect" experiment, but this time with the iron piece inside the spool. What do you notice?

WHAT'S HAPPENING?

The spool's power is noticeably stronger, since the iron increases the power of the electromagnet quite a bit. It seems to concentrate the power inside itself. So powerful electromagnets always have an iron core.

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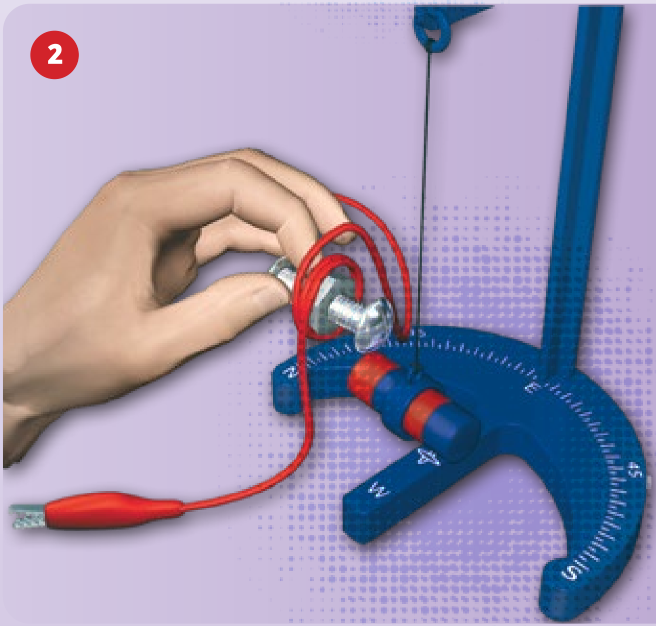


Strength from electricity

Electromagnets have two other distinct advantages over permanent magnets. First: You can turn them on or off whenever you like. Second: You can construct them in such a way that they can handle very strong electrical currents. These currents can, in turn, produce magnetic fields that are much more powerful than anything a permanent magnet can achieve.

TIP!

Only let the current flow very briefly (a few seconds), or the battery will quickly get used up.

EXPERIMENT 54

Electromagnets love iron too

The horseshoe-shaped electromagnet in the kit is even stronger than your homemade electromagnet. But the construction is very similar: two spools mounted on a U-shaped iron core. See how it works!

HERE'S HOW

Connect the horseshoe electromagnet to the battery via the push button switch and two plug wires (figure 1). Before turning it on, hold a few pieces of iron (screws or a nut, for example) in front of the bare metal prongs. You won't feel any pull at all.

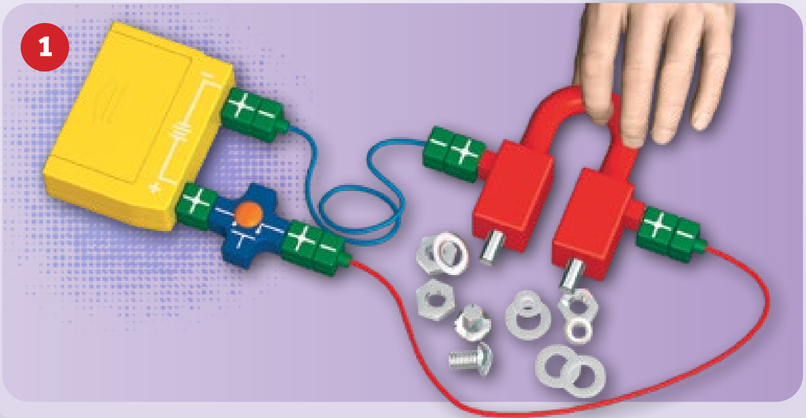
Now press briefly on the button to make current flow through the horseshoe. The pieces of iron will be attracted to it.

What happens to the iron pieces sticking to the magnet when you switch the current off?

Test the strength of the magnet. How close do the iron pieces have to get for them to react? Are both poles equally strong?

Try carrying out the experiment using the colorful disks (figure 2).

1



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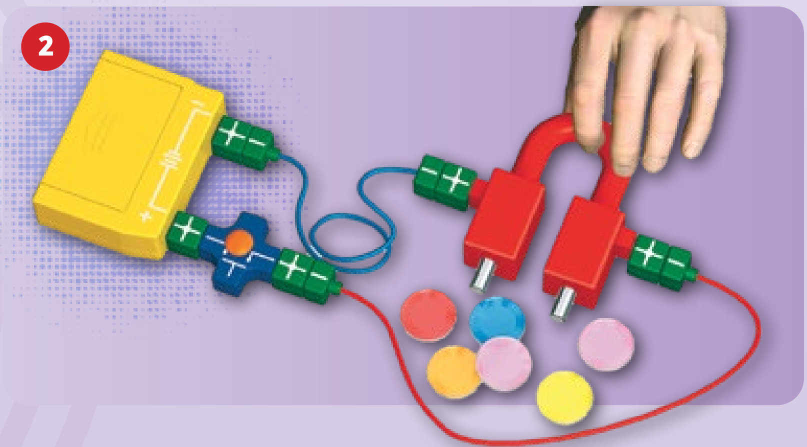

WHAT'S HAPPENING?

The horseshoe electromagnet really does turn into a magnet — an electromagnet — when current flows through it. Then it attracts iron just like a permanent magnet. But it only does so while the current is flowing. Turn it off, and the electromagnet loses its power.

EXPERIMENT 55

Iron arches

If the horseshoe electromagnet really is turning into a magnet, you should be able to make its magnetic lines of force visible. Try it!

HERE'S HOW

Connect the electromagnet to the battery via the push button, two plug wires, and five X-connectors (figure 1).

Spread the iron powder out into a fairly even layer on the floor of the box.

Switch on the electromagnet and hold the box with the iron powder a few millimeters above it. Tap gently on the box several times. What do you see?

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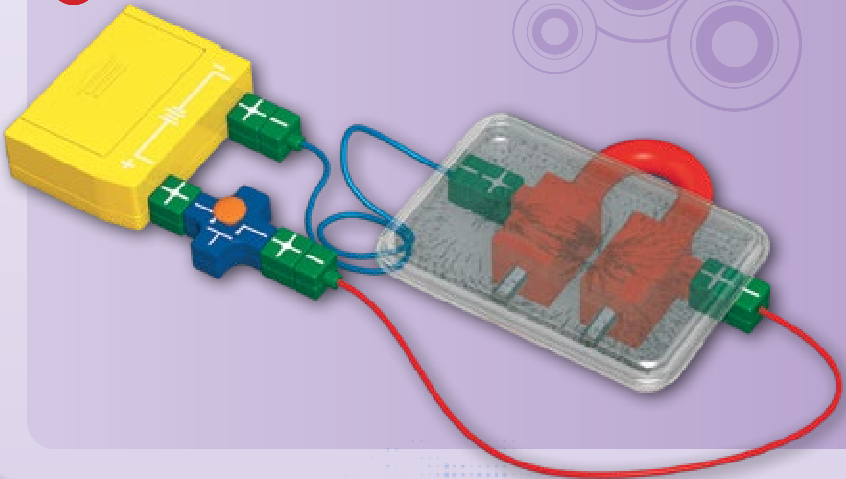

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WHAT'S HAPPENING?

When the magnet is switched on — and only then — you will see the typical pattern, familiar from the bar magnet, form at the poles. The lines arching from one pole to the other should show up particularly clearly once you tap on the box a few times (figure 2).

The names of the poles

You may be wondering why the poles of a magnet are called the north and the south pole. There are historical reasons for it:

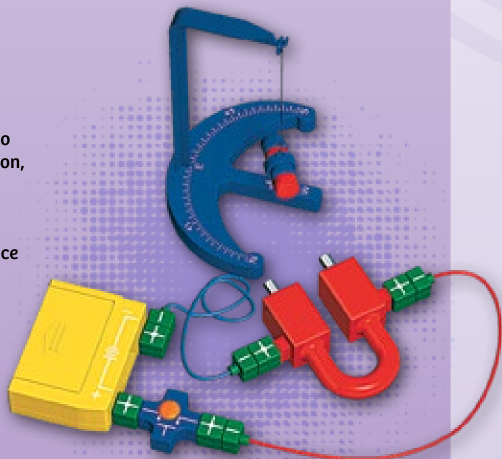
In earlier times, people were familiar with compasses, but didn't know anything else about magnetic forces.

People thought it was Earth's poles, or gigantic magnetic mountains near them, that were attracting the compass's needle. The ends of the compass needle that were pointing in those directions were thus given matching names.

EXPERIMENT 56

Polarity tester

Do you think an electromagnet also has a north and a south pole? You can't tell by touching it with the bar magnet, since the bar magnet will react to the iron inside the electromagnet. But maybe you can use your sensitive hanging magnet tester.



HERE'S HOW

Connect the electromagnet to the battery via the push button, two plug wires, and five X-connectors.

Set it next to the hanger device with one of its poles a few centimeters away from the bar magnet.

Switch on the electromagnet for a few seconds. What happens?

Now push the other pole closer to the bar magnet and briefly switch on the current again. What do you notice? Test the needle again. What does it show?

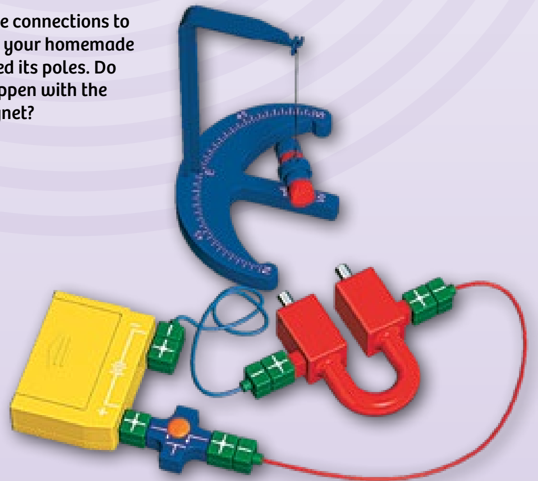
WHAT'S HAPPENING?

The bar magnet reveals that when the current is switched on, one of the arms of the electromagnet becomes the north pole, while the other becomes the south pole.

EXPERIMENT 57

Switching poles

When you switched the connections to the battery terminals, your homemade electromagnet changed its poles. Do you think that will happen with the horseshoe electromagnet?



HERE'S HOW

Place the horseshoe electromagnet next to the hanger device with its left pole considerably closer to the bar magnet than the right pole.

Briefly switch on the current. Note the color of the bar magnet pole that turns toward the horseshoe magnet pole.

Now reverse the connections at the battery case and switch on the current again. Which one of its poles does the bar magnet now turn toward the horseshoe pole?

WHAT'S HAPPENING?

In fact, reversing the current really does reverse the electromagnet's poles as well — the north pole becomes the south pole and vice-versa.

EXPERIMENT 58

Electromagnet's penetrating force

The magnetic powers of your permanent magnets were able to penetrate all kinds of materials, with the exception of iron. Is that true for the powers of the electromagnet as well?

HERE'S HOW

Assemble your hanger device and the horseshoe electromagnet, and place the two a few centimeters apart. The distance should be small enough to make the bar magnet react noticeably when you switch on the current.

Now try holding objects made from a variety of materials — such as glass, porcelain, wood, paper, cardboard, textiles, plastic, your hand, an aluminum pot, an iron baking sheet — between the horseshoe electromagnet and the bar magnet.

Which materials will the magnetic force penetrate, and which materials block it?

WHAT'S HAPPENING?

The electromagnet behaves exactly like a permanent magnet: Its magnetic force penetrates all the materials except iron.

EXPERIMENT 59

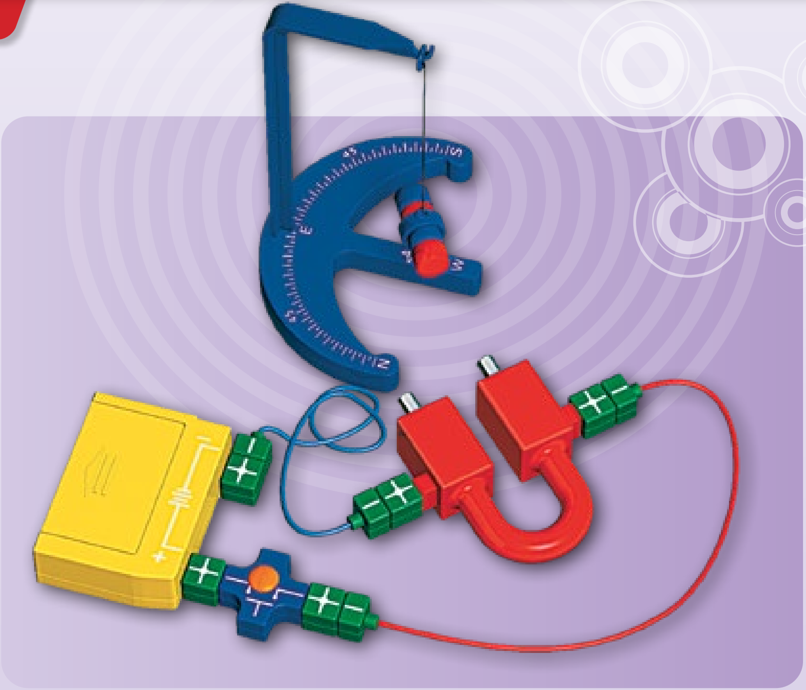
INSIDE AN ELECTRIC MOTOR

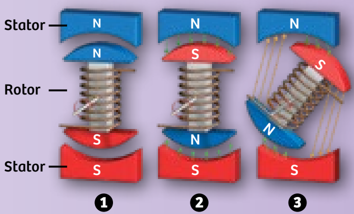
Equal magnetic poles repel each other, while opposite ones attract. That is the basic principle behind an **electric motor.**

An electric motor consists of a **rotor,** electromagnets mounted in such a way that they can spin and turn one of their poles outward, where they will face the poles of fixed electromagnets forming the other part of the motor, called the **stator.**

For the motor to run, some of the rotor magnets' poles have to be attracted by the adjacent stator poles and turn in their direction.

At just the right moment, by switching the flow of current, the stator poles are then repulsed by their neighbors, keeping the rotor turning continuously.





WHAT'S HAPPENING

What you've built here is a very primitive electric motor. It works on the same principle as the small motor in this kit, as well as the huge engines that drive electric trains and all-electric cars.

Electromagnet dance class

In Experiment 42 (Dancing magnets), you were able to send the bar magnet into a rapid spinning motion through skilful manipulation of the ring magnet.

The same idea can work even better with the electromagnet, since all you have to do in this case is turn the current on or off at just the right moment.

HERE'S HOW

Place the horseshoe electromagnet a few centimeters in front of the bar magnet and briefly switch on the current.

When the bar magnet turns, switch off the current again, then switch it back on, and so on.

Try to find the right switching rhythm to match the rotation speed of the bar magnet.

With a little practice, you will be able to send the bar magnet into a rapid spinning motion just by switching the current on and off.

EXPERIMENT 60

Speaker

An electromagnet, with its magnetic force able to be turned on or off at will, can be used to make some very interesting appliances — a very simple speaker, for example.

HERE'S HOW

Tape a sheet of paper over the lid of a cardboard box. Tape an iron disk from the small parts pouch to the center of the paper.

Connect one of the horseshoe electro-magnet's prongs to one of the battery terminals with one of the plug wires. Clamp the red alligator wire to the magnet's second prong.

Place the horseshoe electromagnet on a short stack of books, with one of its arms just far enough away from the iron disk that they will not touch when the current is flowing. Secure it in the desired position with a little tape.

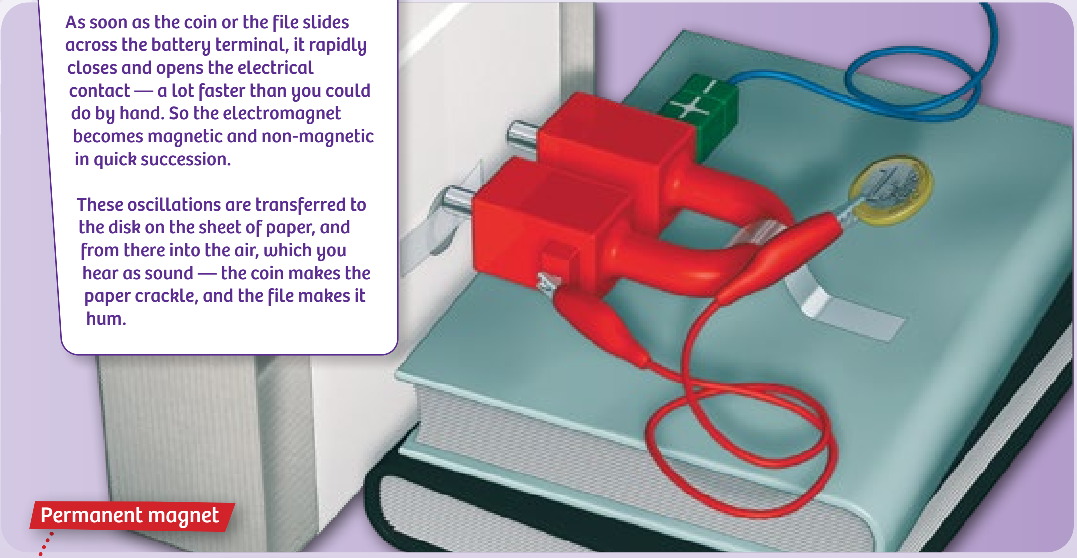
Attach the free clip of the alligator wire to a coin with ribbed edges. Rub the coin several times back and forth across the free battery terminal. What do you hear?

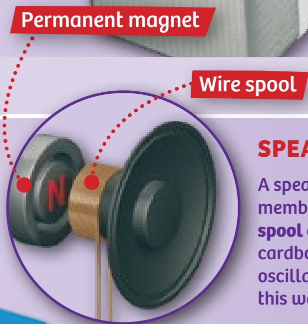
Attach a file to the red alligator clip and move it gently across the battery terminal. What kind of noise comes from the paper?

WHAT'S HAPPENING?

As soon as the coin or the file slides across the battery terminal, it rapidly closes and opens the electrical contact — a lot faster than you could do by hand. So the electromagnet becomes magnetic and non-magnetic in quick succession.

These oscillations are transferred to the disk on the sheet of paper, and from there into the air, which you hear as sound — the coin makes the paper crackle, and the file makes it hum.





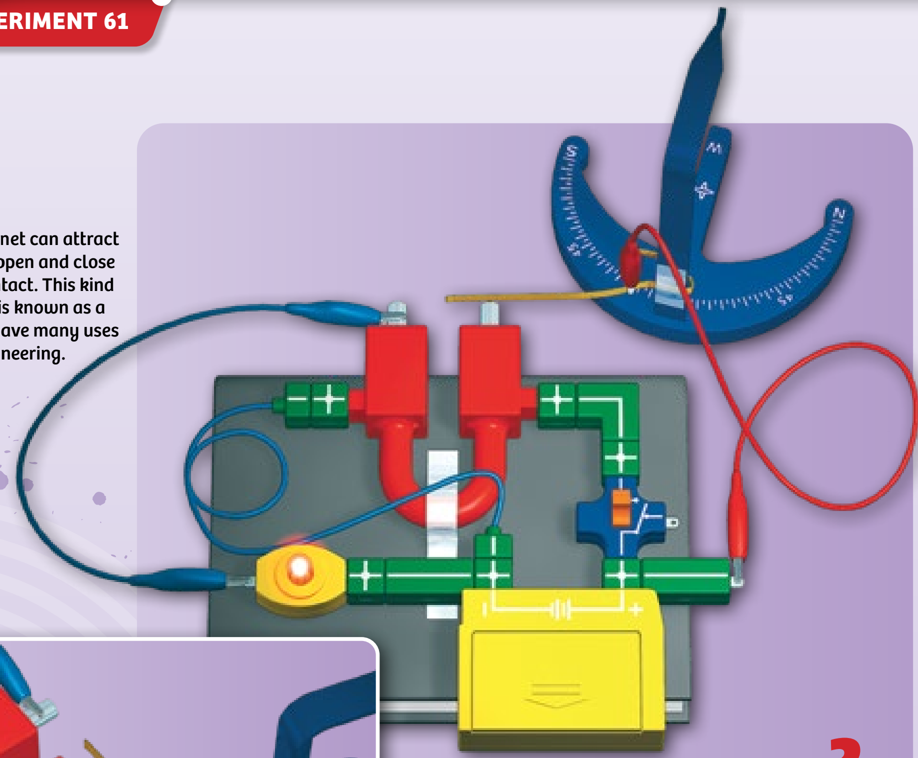
SPEAKER

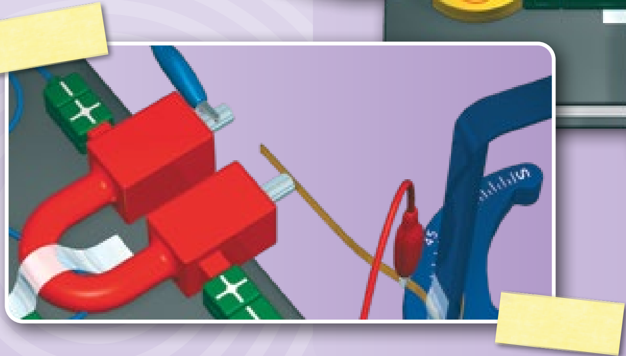
A speaker also contains a cardboard membrane and two magnets. Usually, a tiny **spool of wire** will be attached to the cardboard membrane, into which the oscillations of electrical current will be fed. In this way, the spool is turned into an electromagnet. This spool is surrounded by the magnetic field of a strong permanent magnet. The fluctuations of magnetic force mean that it is more or less strongly attracted by this permanent magnet. It moves in rhythm with the fluctuations in current, and passes these movements on to the membrane.

EXPERIMENT 61

Remote control

If an electromagnet can attract iron, it can also open and close an electrical contact. This kind of arrangement is known as a “relay.” Relays have many uses in electrical engineering.





WHAT’S HAPPENING?

The electromagnet attracts the metal strip to touch its pole. When that happens, the electric circuit is closed and the light shines. When you break the circuit, the light turns off and the strip springs back.

HERE’S HOW

Remove the metal prong fastener strip from a folder, and use a piece of sandpaper to roughen up its surface to about three centimeters from both ends. Attach the fastener strip to the hanger device by partly wrapping the strip around it and then securing it with tape. Its end should be about three centimeters above the table surface when the hanger is standing upright.

Connect the horseshoe electromagnet to the battery case via switch, plug wire, and X- and L-connectors.

Assemble a second circuit with light, I-connectors, and both alligator wires. One of the alligator wires will lead from the light to one of the bare poles of the horseshoe electromagnet. Clamp one end of the other wire to the battery’s second terminal and the other end to the metal fastener strip, near where you attached it.

Arrange the horseshoe electromagnet and the hanger in such a way that the magnetic poles and the strip are at the same height. Place a book under the horseshoe electromagnet if necessary.

The magnet should only touch the metal strip when it is switched on. When that happens, one of the two bare arms of the horseshoe electromagnet should touch a part of the metal strip that you rubbed bare.

Now, when you send current through the electromagnet, the bulb will light up. What do you see when you switch the current off?

EXPERIMENT 62

Morse telegraph

Before the internet or telephone, people sent messages by Morse code through wires running between cities and continents. After radio technology was invented those message were sent wirelessly around the world.

Would you like to build a Morse telegraph to render dots and dashes audible? With a little dexterity, you can certainly build this kind of device. You already know the Morse code symbols from page 15.

HERE'S HOW

Assemble two circuits supplied with electricity from the battery case. One, shown in figure 1, will power the motor and contain the two-way switch and two I-connectors. The other will supply current to the horseshoe electromagnet, and it will have a push button so you can switch the current on and off.

Again, attach the metal prong fastener strip to the hanger device so that it can swing freely, but without slipping, at a height of about three centimeters (figure 2).

Tape the horseshoe electromagnet to the battery case so it's at just the right height (figure 3).

Continued on the next page...

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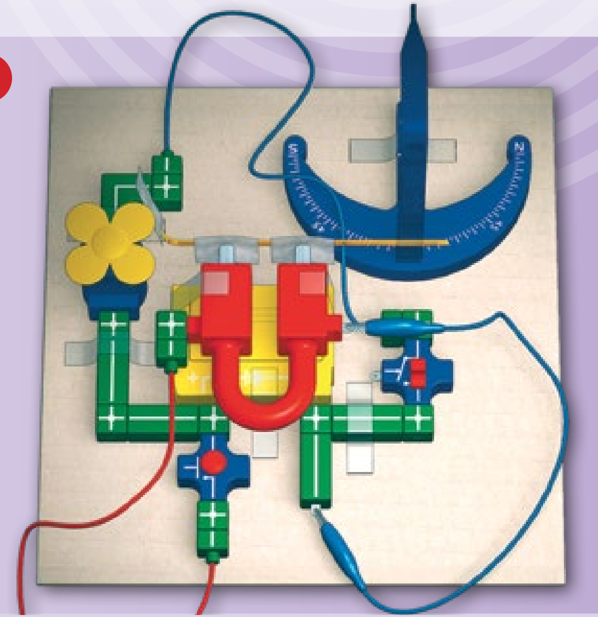

TIP!

If you can get a few meters of dual-cable wire from an electronics or hardware store, you may be able to figure out how to install this system between two different rooms in your house.

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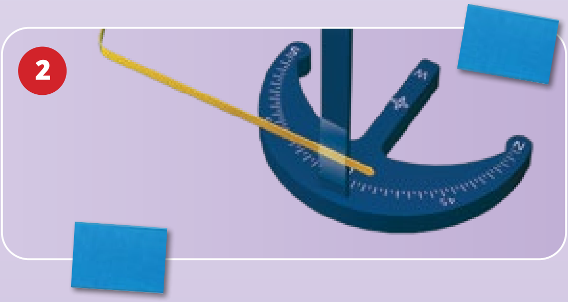

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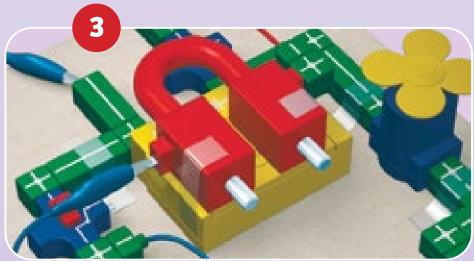

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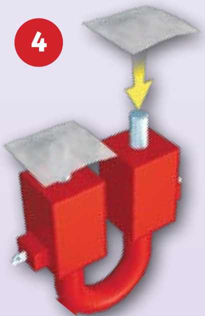

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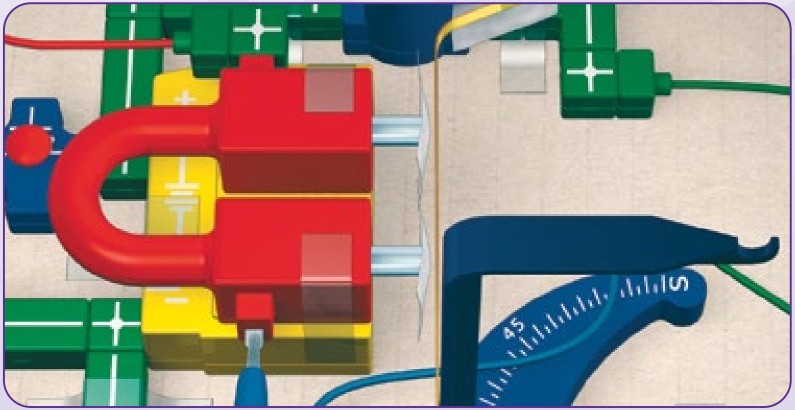

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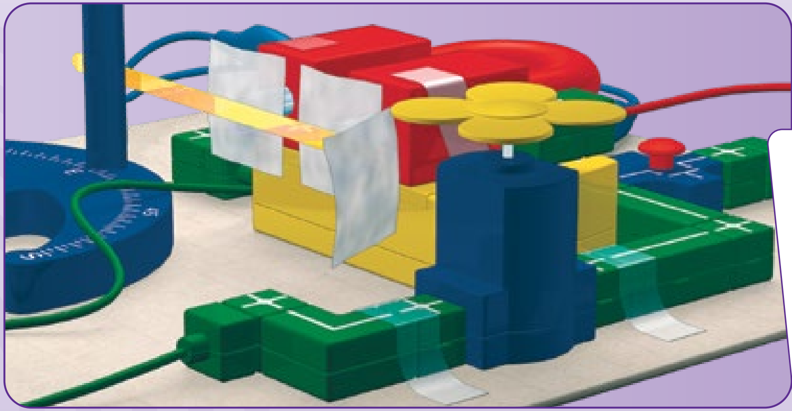


HERE'S HOW IT CONTINUES

Attach a piece of tape to each of the bare surfaces of the horseshoe electromagnet poles (figure 4). This will prevent the metal strip from sticking to them after you switch off the current.

Now mount the hanger base on the cardboard such that the metal strip swings a few millimeters in front of the poles of the horseshoe electromagnet, as shown in figure 5. Test to see if the strip moves toward the magnet when you press the push button, and that it swings back again when you let go.

Secure the motor with its two I-connectors to the cardboard near the end of the metal strip (figure 6). Tape a narrow strip of paper to the end of the metal strip, so that it just barely touches the yellow propeller when attracted by the magnet.

Now switch on the motor and push the button in Morse-code rhythm. What do you hear?

WHAT'S HAPPENING?

The heart of this system is the electromagnet, which attracts the metal strip when the current is flowing. But because that would be hard to hear, the paper contacts the rotating propeller to produce a humming sound. So you hear the dots and dashes as short and long voice-like noises.

Of course, you shouldn't operate this Morse code system too long, since the motor would soon use up the battery.

CHECK IT OUT

A little history

Almost 200 years ago, the Danish physicist **Hans Christian Oersted** discovered that electrical current and magnetism are closely related. His experiment with a compass and a wire with current flowing through it opened the way to countless important practical applications.

In action

Electromagnets are found in electric motors, in **relays**, in electrical generators at power plants, and in power network transformers. They are also used in radios and televisions, record players, microphones, telephones, and speakers, in modern medical exam machinery, as well as in the particle accelerators that physicists are using to explore the world of subatomic building blocks. Without risk of exaggeration, you can truly say that our world would be a very different place without electromagnets.

How is electricity produced on a large scale?

If you wanted to use batteries to power subways, streetlights, electric ovens, or the electric engines in factories, you wouldn't get very far. Fortunately, people discovered another way to produce electricity over 150 years ago — by using an alternating magnetic field to generate electricity in a spool.

That is what a bicycle dynamo uses, and on a much larger scale it is also how large electrical generators work, by rapidly rotating electromagnets past spools. The generators in power plants are driven by turbines whose blades are in turn driven by falling water **(in hydroelectric plants)** or by hot steam (in coal, oil, and nuclear power plants). In wind power plants, the wind turbine propeller drives the generator directly.

How does electricity get to your wall outlet?

Different kinds of power plants produce electricity that feeds into your wall outlet through a gigantic network of wires, including those huge power line towers you sometimes see in open areas. This network distributes the electricity over large areas of the country and ultimately guides it to your house. More wires lead from the house connection all the way to each of the wall outlets.


European wall outlet

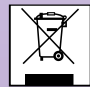

U.S. wall outlet

Solar cells

A small portion of the electricity produced today comes from the blue or black solar cells like the ones you may have seen on roofs. They convert the light of the sun directly into electricity — as long as the sun is shining, of course.

Notes on Disposal of Electrical and Electronic Components:

The electronic components of this product are recyclable. For the sake of the environment, do not throw them into the household trash at the end of their lifespan. They must be delivered to a collection location for electronic waste, as indicated by the following symbol:



Please contact your local authorities for the appropriate disposal location.

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