# Snap Circuits®

STEM
Science Technology Engineering Mathematics

## Instruction Manual

AGES 8-108


Project 3

## Projects 1 - 93

Copyright © 2017 by Elenco® Electronics, Inc. All rights reserved. No part of this book shall be reproduced by any means; electronic, photocopying, or otherwise without written permission from the publisher.

753136
U.S. Patents: 7,144,255; 7,273,377, & patents pending

# Table of Contents



**WARNING: SHOCK HAZARD** - Never connect Snap Circuits® to the electrical outlets in your home in any way!

**WARNING: CHOKING HAZARD** - Small parts. Not for children under 3 years.

Conforms to all applicable U.S. government requirements and CAN ICES-3 (B)/NMB-3 (B).

**WARNING:** Moving parts. Do not touch the fan while it is spinning.

## Basic Troubleshooting

1. Most circuit problems are due to incorrect assembly, always double-check that your circuit exactly matches the drawing for it.
2. Be sure that parts with positive/negative markings are positioned as per the drawing.
3. Be sure that all connections are securely snapped.
4. Try replacing the batteries.

**Elenco® is not responsible for parts damaged due to incorrect wiring.**

**Note:** If you suspect you have damaged parts, you can follow the Advanced Troubleshooting procedure on page 11 to determine which ones need replacing.

**WARNING:** Always check your wiring before turning on a circuit. Never leave a circuit unattended while the batteries are installed. Never connect additional batteries or any other power sources to your circuits. Discard any cracked or broken parts.

**Adult Supervision:** Because children's abilities vary so much, even with age groups, adults should exercise discretion as to which experiments are suitable and safe (the instructions should enable supervising adults to establish the experiment's suitability for the child). Make sure your child reads and follows all of the relevant instructions and safety procedures, and keeps them at hand for reference.

This product is intended for use by adults and children who have attained sufficient maturity to read and follow directions and warnings.

Never modify your parts, as doing so may disable important safety features in them, and could put your child at risk of injury.

## Batteries:

- Use only 1.5V AA type, alkaline batteries (not included).
- Insert batteries with correct polarity.
- Non-rechargeable batteries should not be recharged. Rechargeable batteries should only be charged under adult supervision, and should not be recharged while in the product.
- Do not mix old and new batteries.
- Do not connect batteries or battery holders in parallel.
- Do not mix alkaline, standard (carbon-zinc), or rechargeable (nickel-cadmium) batteries.
- Remove batteries when they are used up.
- Do not short circuit the battery terminals.
- Never throw batteries in a fire or attempt to open its outer casing.
- Batteries are harmful if swallowed, so keep away from small children.

# Parts List (Colors and styles may vary) Symbols and Numbers

**Important:** If any parts are missing or damaged, **DO NOT RETURN TO RETAILER**. Call toll-free (800) 533-2441 or e-mail us at: help@elenco.com.
Customer Service ● 150 Carpenter Ave. ● Wheeling, IL 60090 U.S.A.

| Qty. | ID | Name | Symbol | Part # | Qty. | ID | Name | Symbol | Part # |
|---|---|---|---|---|---|---|---|---|---|
| ❒ 3 | 1 | 1-Snap Wire | | 6SC01 | ❒ 1 | | String | | 6SCM1S |
| ❒ 6 | 2 | 2-Snap Wire | | 6SC02 | ❒ 1 | | Spare Motor Top | | 6SCM1T |
| ❒ 3 | 3 | 3-Snap Wire | | 6SC03 | ❒ 1 | M3 | Electromagnet | | 6SCM3 |
| ❒ 1 | 4 | 4-Snap Wire | | 6SC04 | ❒ 2 | | Iron Core Rod (46mm) | | 6SCM3C |
| ❒ 1 | 5 | 5-Snap Wire | | 6SC05 | ❒ 1 | | Bag of Paper Clips | | 6SCM3P |
| ❒ 1 | 6 | 6-Snap Wire | | 6SC06 | ❒ 1 | M5 | Meter | | 6SCM5 |
| ❒ 1 | B3 | Battery Holder - uses 3 1.5V type AA (not included) | | 6SCB3 | ❒ 1 | | Magnet | | 6SCMAG |
| ❒ 1 | | Base Grid (11.0” x 7.7”) | | 6SCBG | ❒ 1 | | Nut Snap | | 6SCNS |
| ❒ 1 | | Compass | | 6SCCOM | ❒ 1 | ?1 | Two Spring Socket | | 6SCPY1 |
| ❒ 1 | D6 | White LED | | 6SCD6 | ❒ 1 | S1 | Slide Switch | | 6SCS1 |
| ❒ 1 | | Copper Electrode with Snap | | 6SCECS | ❒ 1 | S2 | Press Switch | | 6SCS2 |
| ❒ 1 | | Zinc Electrode with Snap | | 6SCEZS | ❒ 1 | S3 | Relay | | 6SCS3 |
| ❒ 1 | | Iron Fillings | | 6SCIF | ❒ 1 | S6 | Switcher | | 6SCS6 |
| ❒ 1 | | Jumper Wire (Black) | | 6SCJ1 | ❒ 1 | S9 | Reed Switch | | 6SCS9 |
| ❒ 1 | | Jumper Wire (Red) | | 6SCJ2 | ❒ 1 | | Coil | | 6SCWIRE1 |
| ❒ 3 | L4 | Lamp | | 6SCL4 | ❒ 2 | | Grommet | | 662510 |
| ❒ 1 | M1 | Motor | | 6SCM1 | ❒ 1 | | Thin Rod | | MWK01P5 |
| ❒ 1 | | Glow Fan Blade | | 6SCM1FG | You may order additional / replacement parts at our website: www.snapcircuits.net | | | | |

# How to Use Snap Circuits®

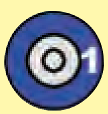
Snap Circuits® uses building blocks with snaps to build the different electrical and electronic circuits in the projects. Each block has a function: there are switch blocks, light blocks, battery blocks, different length wire blocks, etc. These blocks are different colors and have numbers on them so that you can easily identify them. The blocks you will be using are shown as color symbols with level numbers next to them, allowing you to easily snap them together to form a circuit.

### *For Example:*

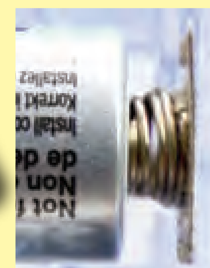
This is the switch block which is green and has the marking (S2) on it. The part symbols in this booklet may not exactly match the appearance of the actual parts, but will clearly identify them.


This is a wire block which is blue and comes in different wire lengths.
This one has the number (2), (3), (4), or (5) on it depending on the length of the wire connection required.


There is also a 1-snap wire that is used as a spacer or for interconnection between different layers.




You need a power source to build each circuit. This is labeled (B3) and requires three (3) 1.5V "AA" batteries (not included).

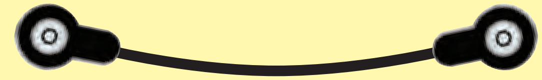


When installing a battery, be sure the spring is compressed straight back, and not bent up, down, or to one side.

A large clear plastic base grid is included with this kit to help keep the circuit blocks properly spaced. You will see evenly spaced posts that the different blocks snap into. The base has rows labeled A-G and columns labeled 1-10.

Next to each part in every circuit drawing is a small number in black. This tells you which level the component is placed at. Place all parts on level 1 first, then all of the parts on level 2, then all of the parts on level 3, etc.

Some circuits use the jumper wires to make unusual connections. Just clip them to the metal snaps or as indicated.



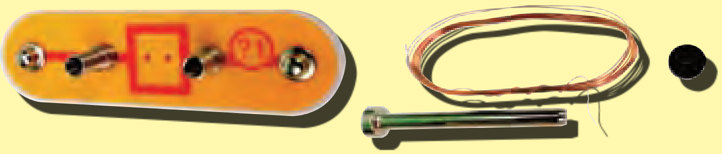
Usually when the motor (M1) is used, the glow fan will usually be placed on it. On top of the motor shaft is a black plastic piece (the motor top) with three little tabs. Lay the fan on the black piece so the slots in its bottom "fall into place" around the three tabs in the motor top. If not placed properly, the fan will fall off when the motor starts to spin.

**Note:** While building the projects, be careful not to accidentally make a direct connection across the battery holder (a "short circuit"), as this may damage and/or quickly drain the batteries.

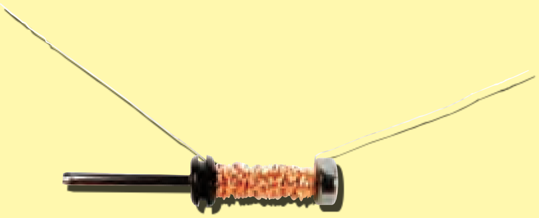
# How to Use Snap Circuits®

## Assembling the build-your-own electromagnet:

You need the coil, an iron core rod, a grommet, and the 2-spring socket (?1).



Wrap the coil around one of the iron core rods, leaving about 3 inches free at both ends. Place a grommet on the end of the rod to help keep the coil wire from coming off it.



Check that some of the protective coating has been removed at each end, leaving about half an inch of bare wire. If the coil wire is broken (or later gets broken) then use sandpaper or steel wool to scrape off the protective coating for about half an inch at each end.

Connect the bare wire ends to the springs on the 2-spring socket (the springs must connect to the wire where the varnish has been removed, otherwise it won't make electrical contact).

## GUIDELINES FOR USE IN CLASSROOMS OR HOME SCHOOLING:

This product is a tool for opening the exciting world of electronics, and its relationship to magnetism. Following the Learn by Doing® concept, electronics & magnetism will be easy for students to understand by using Snap Circuits® to build circuits as they learn about them. This kit emphasizes the practical applications of electronics, without bogging down in mathematics. This course is as much about science as about electronics & magnetism.

Why should students learn about electronics? Electronics plays an important and increasing role in their everyday lives, and so some basic knowledge of it is good for all of them. Learning about it teaches how to do scientific investigation, and the projects develop basic skills needed in today's world.

This product is intended for ages 8 and up. The only prerequisite is basic reading skills.

It should take about 6 hours to do this entire book, or about 2 hours to read the Introduction to Electricity (page 9) and do just the educational summary projects (shown on page 12). Teachers should review the Project Listing (page 12) and decide what is best.

## INSTRUCTOR PREPARATION/ORGANIZATION

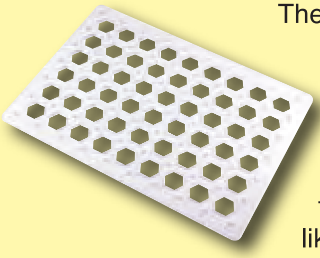
- Determine what the learning environment will be. Will the students be learning independently or in small groups? How much teacher instruction will there be for each section? Will the students be reading the lesson as homework and then have limited teacher instruction before performing the experiments? Decide when quizzes will be given and how they will be organized.
- Allocate time within the session as needed for:
    - Teacher instruction about the topics being covered during the session.
    - Getting the Snap Circuits® components into the workspace.
    - Teacher instruction about the specific projects to be performed during that session.
    - Building and testing the circuits.
    - Performing experiments (and teacher verification if desired).
    - Dismantling the circuits and returning Snap Circuits® components to storage area.
    - Reassembling the class for review.
- Make sure the students know their objectives for the day, how much time they will need for cleanup, and where the materials are being stored.
- Students must understand that there are usually many ways of making the same circuit, and that the instructor may not know all the answers. They are doing scientific investigation, and many circuit projects suggest variations to experiment with.
- Have students review the DO's and DON'Ts of Building Circuits on page 10 at the beginning of each session.

**Answers to quiz questions are at www.snapcircuits.net/scstem1.**

# About Your Snap Circuits® Parts

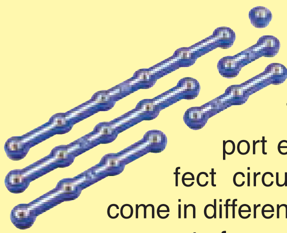
(Part designs are subject to change without notice).

## BASE GRID



The base grid is a platform for mounting parts and wires. It functions like the printed circuit boards used in most electronic products, or like how the walls are used for mounting the electrical wiring in your home.

## SNAP WIRES & JUMPER WIRES



The blue **snap wires** are wires used to connect components. They are used to transport electricity and do not affect circuit performance. They come in different lengths to allow orderly arrangement of connections on the base grid.

The red and black **jumper wires** make flexible connections for times when using the snap wires would be difficult. They also are used to make connections off the base grid.

Wires transport electricity just like pipes are used to transport water. The colorful plastic coating protects them and prevents electricity from getting in or out.

## BATTERY HOLDER

The **batteries (B3)** produce an electrical **voltage** using a chemical reaction. This "voltage" can be thought of as electrical pressure, pushing electricity through a circuit just like a pump pushes water through pipes. This voltage is much lower and much safer than that used in your house wiring. Using more batteries increases the "pressure", therefore, more electricity flows.

The funny marking on the battery holder is the standard battery symbol used in electrical wiring diagrams. These wiring diagrams are called **schematics**, and are used in everything from house wiring to complex radios.

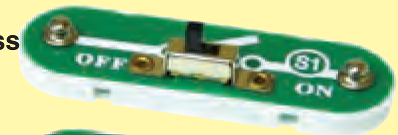

Battery Symbol


Battery Holder (B3)

## SWITCHES

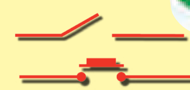
The **slide & press switches (S1 & S2)** connect (pressed or "ON") or disconnect (not pressed or "OFF") the wires in a circuit. When ON they have no effect on circuit performance. Switches turn on electricity just like a faucet turns on water from a pipe.

**Slide & Press Switches (S1 & S2)**



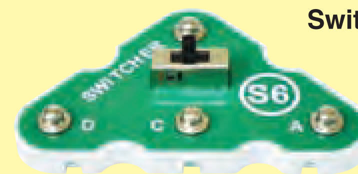


**Symbols**

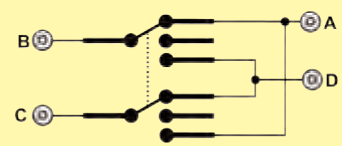


The **switcher (S6)** is a more complex switch used to reverse the wires to a component or circuit. See project 2 for an example of connections.

**Switcher (S6)**




Its symbol & connections look like this:




The **reed switch (S9)** is an electrical switch that can be controlled by a magnet. It has two metal contacts close together. The magnetic field from the magnet makes the contacts come together, completing a circuit just like other switches do.

**Reed Switch (S9)**


**Symbol**

# About Your Snap Circuits® Parts

## METER

The **meter (M5)** is an important measuring device. You will use it to measure the voltage (electrical pressure) and **current** (how fast electricity is flowing) in a circuit.


**Meter (M5)**

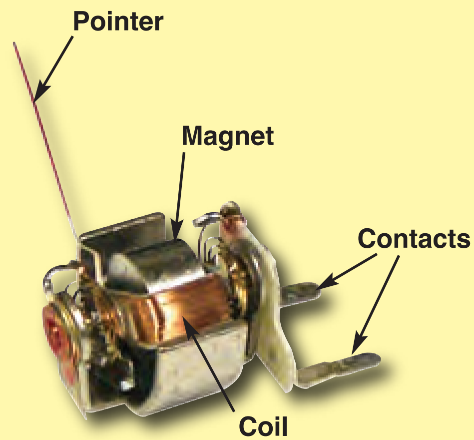
The electrical symbol for a meter is shown below.

**Meter Symbol**

The meter measures voltage when connected in parallel to a circuit and measures the current when connected in series in a circuit.

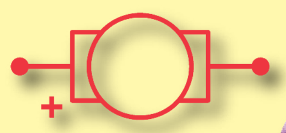
This meter has one voltage scale (5V) and two current scales (1mA and 1A). These use the same meter but with internal components that scale the measurement into the desired range. This will be explained more later. **Note:** Your M5 meter is a simple meter. Don't expect it to be as accurate as normal electronic test instruments.

Inside the meter there is a fixed magnet and a moveable coil around it. As current flows through the coil, it creates a magnetic field. The interaction of the two magnetic fields causes the coil (connected to the pointer) to move (deflect).



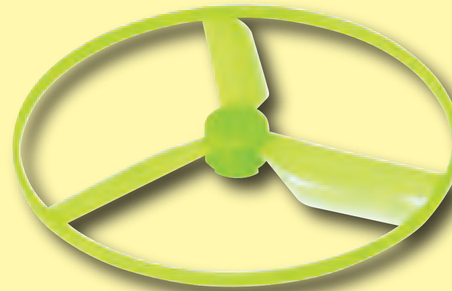

## MOTOR

The **motor (M1)** converts electricity into mechanical motion. An electric current in the motor will turn the shaft and the motor blades, and the fan blade if it is on the motor. The electrical symbol for a motor is also shown here.



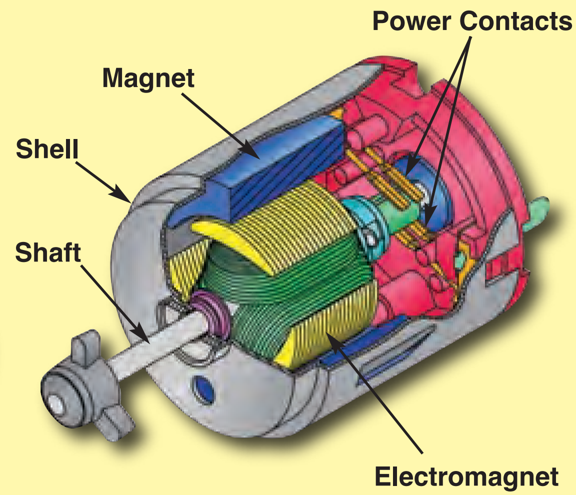
**Motor Symbol**

**Motor (M1)**



**Glow-in-the-dark Fan**

How does electricity turn the shaft in the motor? The answer is magnetism. Electricity is closely related to magnetism, and an electric current flowing in a wire has a magnetic field similar to that of a very, very tiny magnet. Inside the motor is a coil of wire with many loops wrapped around metal plates. This is called an electromagnet. If a large electric current flows through the loops, it will turn ordinary metal into a magnet. The motor shell also has a magnet on it. When electricity flows through the electromagnet, it repels from the magnet on the motor shell and the shaft spins. If the fan is on the motor shaft, then its blades will create airflow.

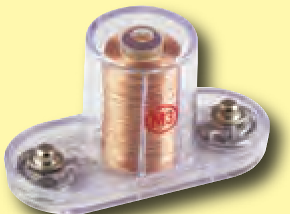


# About Your Snap Circuits® Parts

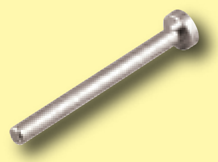
## ELECTROMAGNET

The **electromagnet (M3)** is a large coil of wire, which acts like a magnet when electricity flows through it. Placing an iron bar  inside increases the magnetic effects. The electromagnet can store electrical energy in a magnetic field.

The properties of the electromagnet will be explained in the projects.  Note that magnets can erase magnetic media like computer disks.




**Electromagnet (M3)**



**Iron Core Rod (usually placed in electromagnet)**

The grommet will be used to hold the iron core rod on the electromagnet.

**Grommet**

**Electromagnet Symbol with Rod Inside**

**Electromagnet Symbol without Rod (a coil of wire)**

## LAMP

A light bulb, such as in the **4.5V lamps (L4)**, contains a special thin high-resistance wire. When a lot of electricity flows through, this wire gets so hot it glows bright.  Voltages above the bulb's rating can burn out the wire.


**Lamp (L4)**

The electrical symbol for a lamp is shown here, though other symbols are also used in the industry.

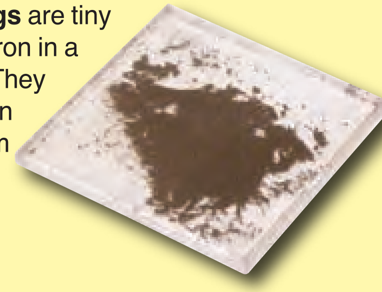
**Lamp Symbol**

## OTHER PARTS

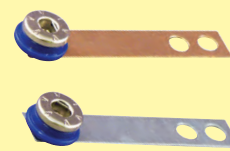
The **magnet** is an ordinary magnet like those in your home.

The **compass** is a standard compass. The red needle will point toward the strongest magnetic field around it, usually the north pole of the earth.

The **iron filings** are tiny fragments of iron in a sealed case. They will be used in magnetism projects.

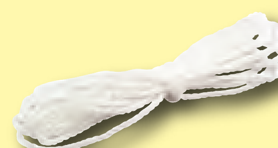


The **copper and zinc electrodes** are just metals that will be used for electro-chemical projects. They have snaps attached for easy connection.

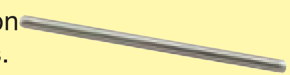


The **nut-snap** is an iron nut mounted on a snap for special projects.

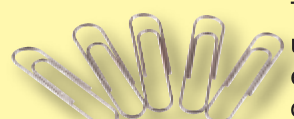
The **string** will be used in special projects. You can use your own string if you need more.



The **thin rod** is an iron bar for special projects.



The **Paper Clips** will be used for special projects. You can use your own if you need more, but they must be metal.



The **spare motor top** is provided in case you break the one on the motor. Use a screwdriver to pry the broken one off the motor, then push the spare one on.

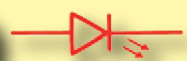
# About Your Snap Circuits® Parts

## LED

The **white LED (D6)** is a light emitting diode, and may be thought of as a special one-way light bulb. In the “forward” direction, (indicated by the “arrow” in the symbol) electricity flows if the voltage exceeds a turn-on threshold brightness then increases. A high current will burn out an LED, so the current must be limited by other components in the circuit (Snap Circuits® LEDs have internal resistors added, to protect them in case you make wiring mistakes). LEDs block electricity in the “reverse” direction.

**White LED (D6)**


**LED Symbol**



## Two Spring Socket

The **two-spring socket (?1)** just has two springs, and won’t do anything by itself. In this set it is used to make the build-your-own electromagnet, as per page 5. It can also be used by advanced users to connect other electronic components to Snap Circuits® for creating your own circuits.

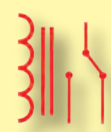
**Two Spring Socket (?1)**


## RELAY

The **relay (S3)** is an electronic switch with contacts that can be closed or opened. It contains a coil that generates a magnetic field when current flows through it. The magnetic field attracts an iron armature, which switches the contacts. See project 69 for further explanation.

**Relay (S3)**


**Relay Symbol**



**Relay:**

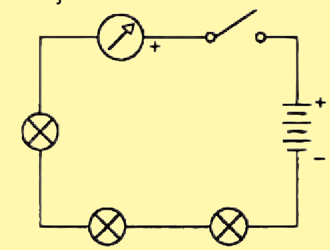
Coil - connection to coil
Coil - connection to coil
NC - normally closed contact
NO - normally open contact
COM - common

See project 69 for an example of proper connections.

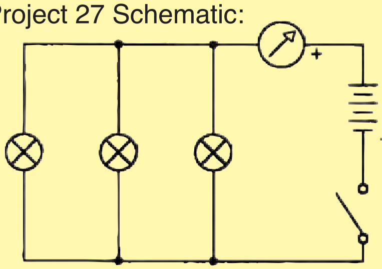
## SCHEMATICS

The symbols for the parts shown in this section are used by engineers in drawings of their circuits, called schematics. Wires connecting components are shown as lines, with a dot indicating a connection between lines that cross. Here are schematics of some of the circuits you will build:

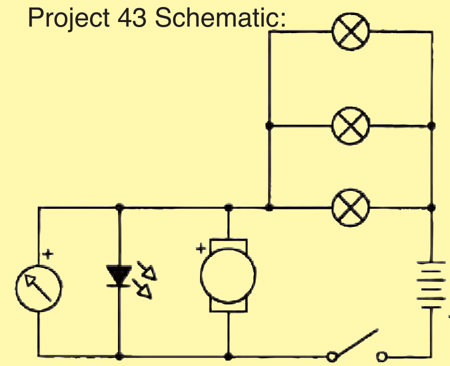
Project 14 Schematic:



Project 27 Schematic:



Project 43 Schematic:



# Introduction to Electricity

What is electricity? Nobody really knows. We only know how to produce it, understand its properties, and how to control it. Electricity is the movement of sub-atomic charged particles (called **electrons**) through a material due to electrical pressure across the material, such as from a battery.

Power sources, such as batteries, push electricity through a circuit, like a pump pushes water through pipes. Wires carry electricity, like pipes carry water. Devices like LEDs, motors, and speakers use the energy in electricity to do things. Switches and transistors control the flow of electricity like valves and faucets control water. Resistors limit the flow of electricity.

The electrical pressure exerted by a battery or other power source is called **voltage** and is measured in **volts** (V). Notice the "+" and "–" signs on the battery; these indicate which direction the battery will "pump" the electricity.

The **electric current** is a measure of how fast electricity is flowing in a wire, just as the water current describes how fast water is flowing in a pipe. It is expressed in **amperes** (A) or **milliamps** (mA, 1/1000 of an ampere).

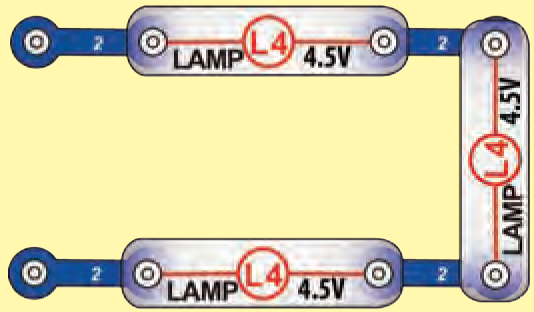
The "**power**" of electricity is a measure of how fast energy is moving through a wire. It is a combination of the voltage and current (Power = Voltage x Current). It is expressed in **watts** (W).

The **resistance** of a component or circuit represents how much it resists the electrical pressure (voltage) and limits the flow of electric current. The relationship is Voltage = Current x Resistance. When the resistance increases, less current flows. Resistance is measured in **ohms** (Ω), or **kilo ohms** (kΩ, 1000 ohms).

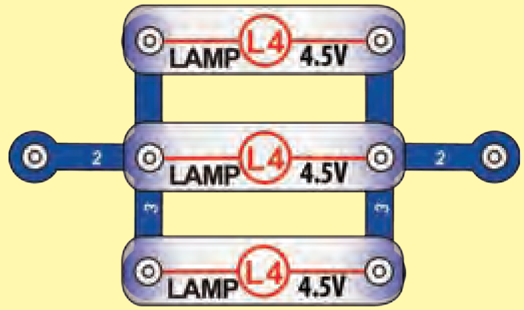
Nearly all of the electricity used in our world is produced at enormous generators driven by steam or water pressure. Wires are used to efficiently transport this energy to homes and businesses where it is used. Motors convert the electricity back into mechanical form to drive machinery and appliances. The most important aspect of electricity in our society is that it allows energy to be easily transported over distances.

Note that "distances" includes not just large distances but also tiny distances. Try to imagine a plumbing structure of the same complexity as the circuitry inside a portable radio - it would have to be large because we can't make water pipes so small. Electricity allows complex designs to be made very small.

There are two ways of arranging parts in a circuit, in series or in parallel. Here are examples:




**Series Circuit**




**Parallel Circuit**

Placing components in series increases the resistance; highest value dominates. Placing components in parallel decreases the resistance; lowest value dominates.

The parts within these series and parallel sub-circuits may be arranged in different ways without changing what the circuit does. Large circuits are made of combinations of smaller series and parallel circuits.

# DO's and DON'Ts of Building Circuits

After building the circuits given in this booklet, you may wish to experiment on your own. Use the projects in this booklet as a guide, as many important design concepts are introduced throughout them. Every circuit will include a power source (the batteries), a resistance (which might be a lamp, motor, electromagnet, etc.), and wiring paths between them and back. You must be careful not to create "short circuits" (very low-resistance paths across the batteries, see examples below) as this will damage components and/or quickly drain your batteries. **ELENCO® is not responsible for parts damaged due to incorrect wiring**.

## *Here are some important guidelines:*

***ALWAYS*** **USE EYE PROTECTION WHEN EXPERIMENTING ON YOUR OWN.**

***ALWAYS*** include at least one component that will limit the current through a circuit, such as a lamp, motor, or electromagnet.

***ALWAYS*** use the meter and switches in conjunction with other components that will limit the current through them. Failure to do so will create a short circuit and/or damage those parts.

***ALWAYS*** disconnect your batteries immediately and check your wiring if something appears to be getting hot.

***ALWAYS*** check your wiring before turning on a circuit.

***NEVER*** connect to an electrical outlet in your home in any way.

***NEVER*** leave a circuit unattended when it is turned on.

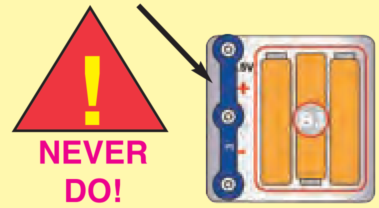
***NEVER*** touch the motor when it is spinning at high speed.

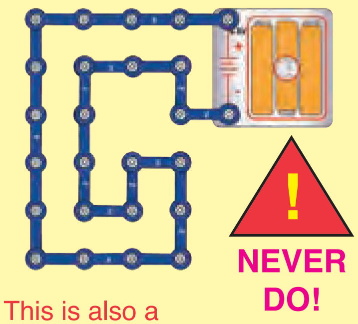
For all of the projects given in this book, the parts may be arranged in different ways without changing the circuit. For example, the order of parts connected in series or in parallel does not matter — what matters is how combinations of these sub-circuits are arranged together.

**Warning to Snap Circuits® owners:** Do not connect additional voltage sources from other sets, or you may damage your parts. Contact ELENCO® if you have questions or need guidance.

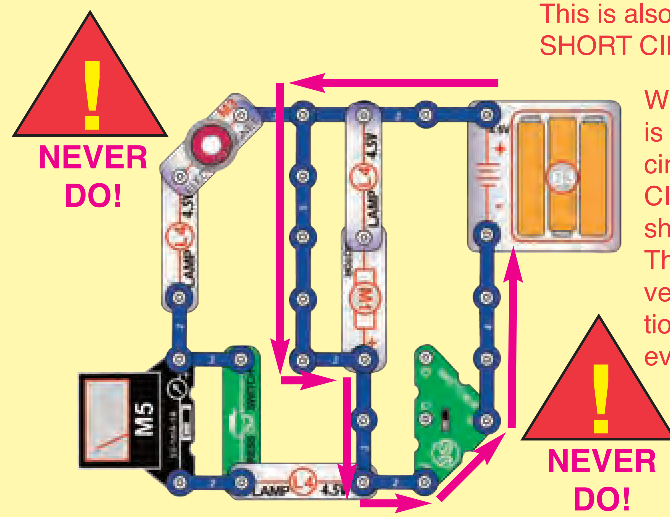
### Examples of SHORT CIRCUITS - NEVER DO THESE!!!

Placing a 3-snap wire directly across the batteries is a SHORT CIRCUIT.




This is also a SHORT CIRCUIT.




When the switch (S6) is turned on, this large circuit has a SHORT CIRCUIT path (as shown by the arrows). The short circuit prevents any other portions of the circuit from ever working.

You are encouraged to tell us about new programs and circuits you create. If they are unique, we will post them with your name and state on our website at: **www.snapcircuits.net/learning_center/kids_creation**. Send your suggestions to ELENCO®: **elenco@elenco.com**.

ELENCO® provides a circuit designer so that you can make your own Snap Circuits® drawings. This Microsoft® Word document can be downloaded from: **www.snapcircuits.net/learning_center/kids_creation** or through the **www.snapcircuits.net** website.

**WARNING: SHOCK HAZARD** - Never connect your Snaptricity® set to the electrical outlets in your home in any way!

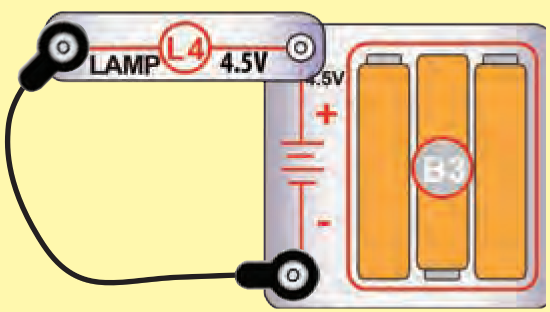
# Advanced Troubleshooting (Adult supervision recommended)

**ELENCO® is not responsible for parts damaged due to incorrect wiring.**

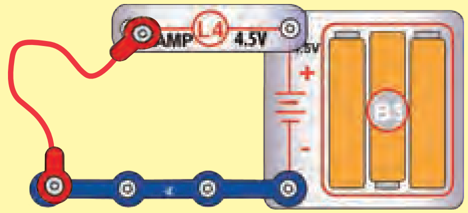
**If you suspect you have damaged parts, you can follow this procedure to systematically determine which ones need replacing:**

1. **White LED (D6), 4.5V lamps (L4), motor (M1), and battery holder (B3):** Place batteries in holder. Place each 4.5V lamp directly across the battery holder, it should light. Place the white LED directly across the battery holder (LED + to battery +), it should light. Do the same with the motor, it should spin. If none work then replace your batteries and repeat, if still bad then the battery holder is damaged.
   If the Motor (M1) does not balance the fan evenly: Inspect the black plastic piece at the top of the motor shaft, it should have 3 prongs. If missing or broken, replace it with the spare that is included with this kit (a broken one can be removed with a screwdriver). If the motor is fine, then inspect the fan.

3. **Jumper wires:** Use this mini-circuit to test each jumper wire, the lamp should light.

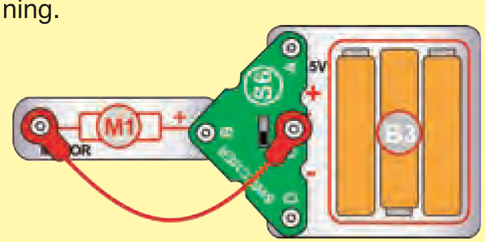



4. **Snap wires:** Use the mini-circuit below to test each of the snap wires, one at a time. The lamp should light.




5. **Two-spring socket (?1) and coil (the build-your-own electromagnet):** use the mini-circuit in test step 4 but replace the 4-snap wire with ?1, with the coil connected between its springs; the lamp should light. If the lamp does not light be sure the protective coating has been removed from the ends of the coil wire where it attaches to the springs; if necessary use sandpaper or steel wool to scrape off the protective coating at each end.

**Switcher (S6):** Build this mini-circuit. With the switch in the middle position the motor (M1) should be off; in the top position the motor should spin counter-clockwise, and in the bottom position the motor should spin clockwise. Do not touch the motor while it is spinning.




6. **Slide switch (S1), press switch (S2), & reed switch (S9):** Build project 85. When you press the switch, the white LED should light. Replace the press switch with the slide switch to test it. Replace the slide switch with the reed switch, and hold a magnet next to the switch to turn on the LED.

7. **Meter (M5):** Build project 85, but replace the 3-snap wire with the meter.
   a. Set the meter to the 5V scale and push the press switch. The meter should read at least 2.5V.
   b. Set the meter to the 1mA scale and push the switch. The reading should be over maximum.
   c. Set the meter to the 1A scale and push the switch. The meter should show a small current.

8. **Electromagnet (M3):** Build project 47 and place the iron core rod in the electromagnet. When you press the switch (S2), the rod in the electromagnet should act like a magnet.

9. **Iron filings:** Sometimes the filings may stick to the case, making it appear cloudy. Move a magnet (the one in this kit or a stronger one in your home) across the case to clean them off.

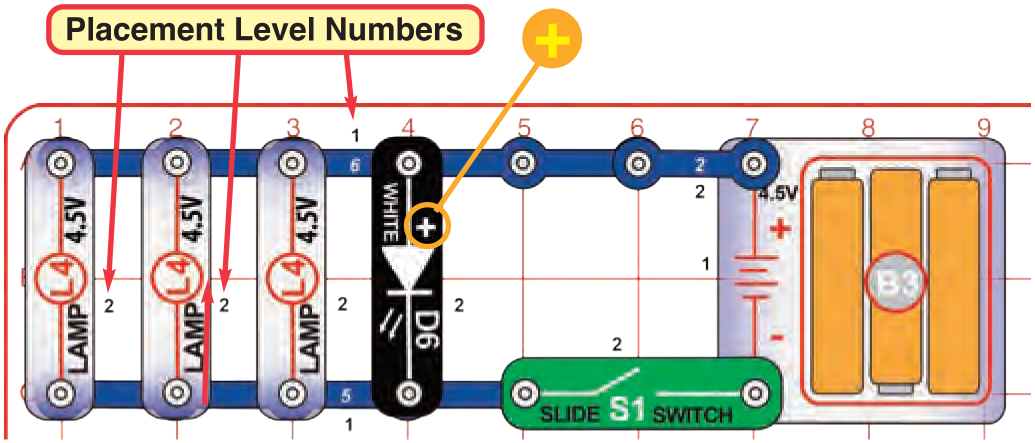
10. **Relay (S3):** Build project 69. Turn on the slide switch (S1); the lamp (L4) should be on. Push the press switch (S2) to turn off the lamp and turn on the white LED (D6).


**ELENCO®**
150 Carpenter Avenue
Wheeling, IL 60090 U.S.A.
Phone: (847) 541-3800
Fax: (847) 520-0085
e-mail: help@elenco.com
Website: www.elenco.com


**You may order additional / replacement parts at:**
**www.snapcircuits.net**

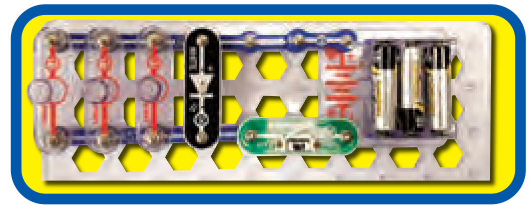
# Project Listings (circuits with gold project numbers are the educational summary projects mentioned on page 4)

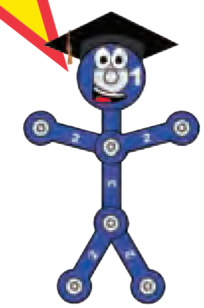
# ☐ Project 1 — Lots of Lights



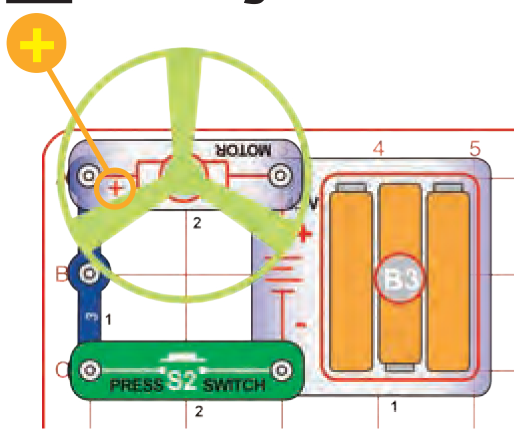

Build the circuit shown by placing all the parts with a black **1** next to them on the board first. Then, assemble parts marked with a **2**. Install three (3) “AA” batteries (not included) into the battery holder (B3). Turn on the slide switch (S1); the lamps (L4) and white LED (D6) light.

NOTE: this circuit (and many others in this book) have an LED being used without a resistor or other component to limit the electric current through it. Normally this could damage an LED but your Snap Circuits® LEDs include internal protection resistors, and will not be damaged. Be careful if you later use other electrical sets with unprotected LEDs.





# ☐ Project 2 — Flying Saucer



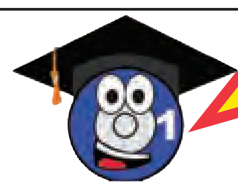

Build the circuit as shown and place the fan on the motor (M1). Be sure the “+” side of the motor is on the left.

Push the press switch (S2) until the motor reaches full speed, then release it. The fan blade should rise and float through the air like a flying saucer. Be careful not to look directly down on fan blade when it is spinning.

If the fan doesn’t fly off, then turn the switch on and off several times rapidly when it is at full speed. New alkaline batteries work best.

**WARNING:** Do not lean over the motor.

**WARNING:** Moving parts. Do not touch the fan or motor during operation.

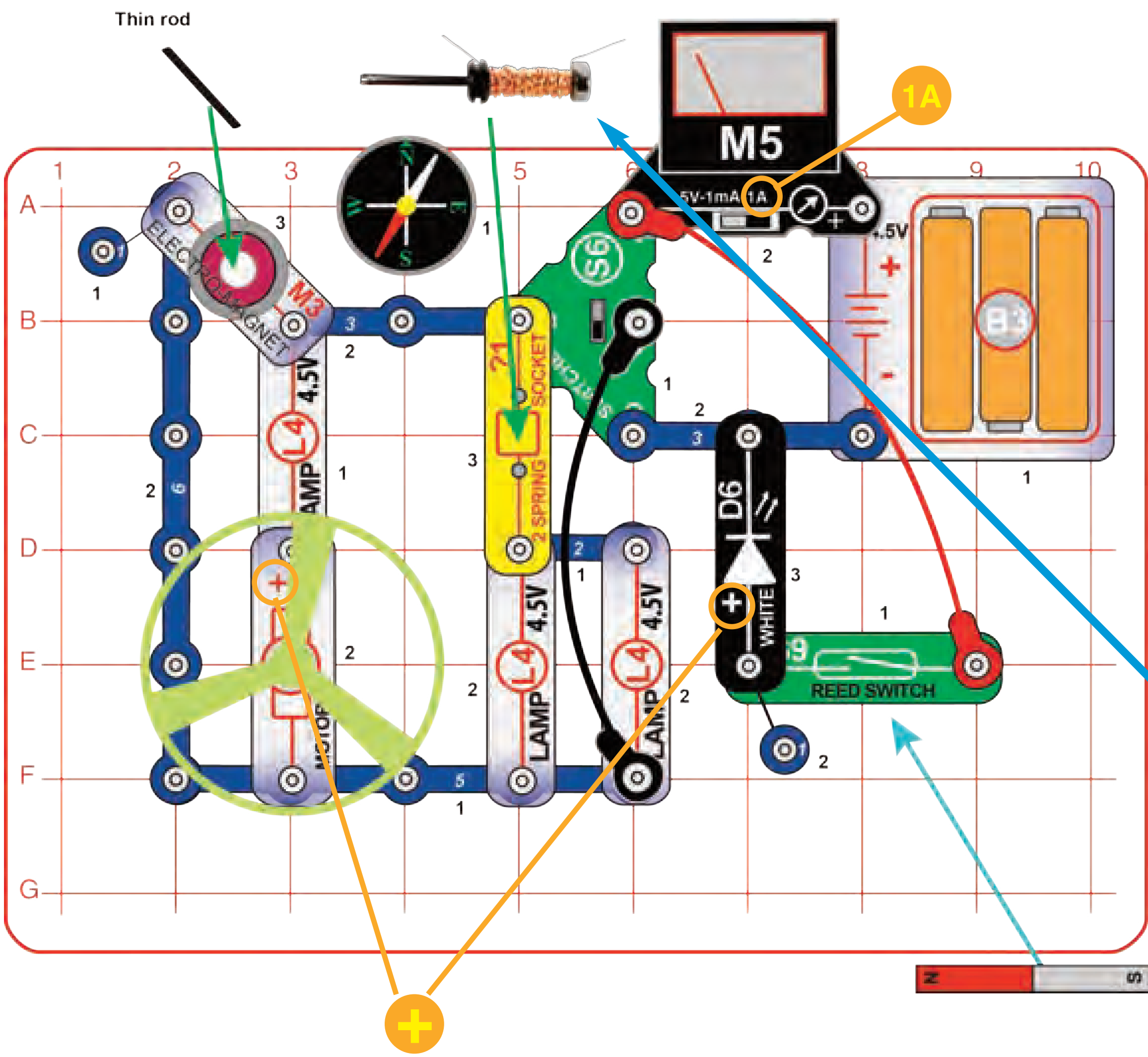


The air is being blown down through the blade and the motor rotation locks the fan on the shaft. When the motor is turned off, the blade unlocks from the shaft and is free to act as a propeller and fly through the air. If speed of rotation is too slow, the fan will remain on the motor shaft because it does not have enough lift to propel it. The motor will spin faster when the batteries are new.

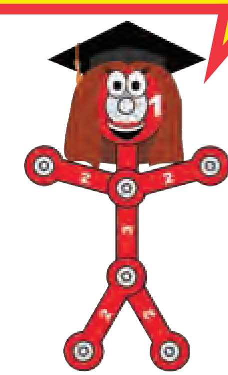
How does the fan rise? Think first about how you swim. When your arms or legs push water behind you, your body moves ahead. A similar effect occurs in a helicopter - the spinning blades push air down, and create an upward force on the blades. If the blades are spinning fast enough, the upward force will be strong enough to lift the helicopter off the ground.

While the switch is pressed, the motor rotation locks the fan on the motor shaft. The fan does not spin fast enough to lift the entire circuit off the ground. When the motor is turned off, the fan unlocks from the shaft. The fan rises into the air like a helicopter, since it is no longer held down by the weight of the full circuit.

# Project 3 — Electronic Playground




Electronics is the science of working with and controlling electricity. This circuit is shown on the front of the Snap Circuits® STEM box, use that picture to help in building it.



Build the circuit as shown. Set the meter (M5) to the 1A setting. Place the thin rod in the electromagnet (M3). Place the glow fan on the motor (M1). Assemble the build-your-own electromagnet as per the instructions on page 5 (or you can assemble it later and replace the 2-spring socket (?1) with a 3-snap wire).

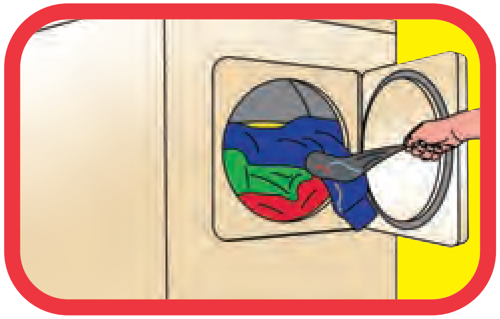
Set the switcher (S6) to either side to light the lamps (L4), spin the motor & fan, suck the thin rod up into the electromagnet (M3), and activate the build-your-own electromagnet. When activated, hold the build-your-own electromagnet near the compass to attract the needle. The meter measures the current.

Hold the magnet near the reed switch (S9) to light the white LED (D6).

**WARNING:** Do not lean over the motor.

**WARNING:** Moving parts. Do not touch the fan during operation.

# Project 4 Static Electricity



Find some clothes that cling together in the dryer, and try to uncling them.

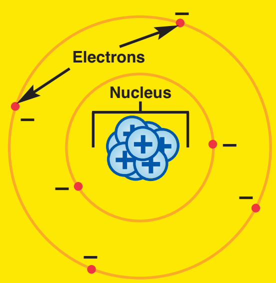
Rub a sweater (wool is best) and see how it clings to other clothes.

Take off a sweater (wool is best) and listen for crackling noises. Try it in a dark room and see if you see sparks. Compare the effects with different fabrics (wool, cotton, etc.).

These effects are caused by electricity. We call this **static electricity** because the electrical charges are not moving, although pulling clothes apart sounds like static on a radio. When electricity is moving (usually through wires) to do something in another place, we call it an **electric current**.

**Electricity** is an attraction and repulsion of particles in a material. All materials are made up of **atoms**, which are really, really tiny. Atoms have a nucleus (which has positive electrical charges), which is surrounded by tiny **electrons** (negative electrical charges). When you rub a material, electrons can move on or off the atoms, giving them an electrical charge.

Electricity exists everywhere, but is so well balanced, that you seldom notice it. But, sometimes differences in electrical charges build up between materials, and sparks can fly. Lightning is the same effect as the sparks between clothes, but on a much greater scale. A cloud holds static electricity just like a sweater.

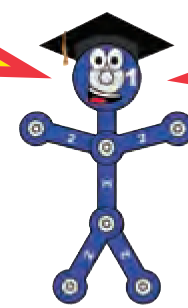

This diagram shows the structure of an atom, except that the nucleus and electrons are actually much farther apart.

Photo courtesy of: NOAA Photo Library, NOAA Central Library; OAR/ERL/National Severe Storms Laboratory (NSSL) [via pingnews].

**Note:** This project works best on a cold dry day. If the weather is humid, the water vapor in the air allows the static electric charge to dissipate, and this project may not work.

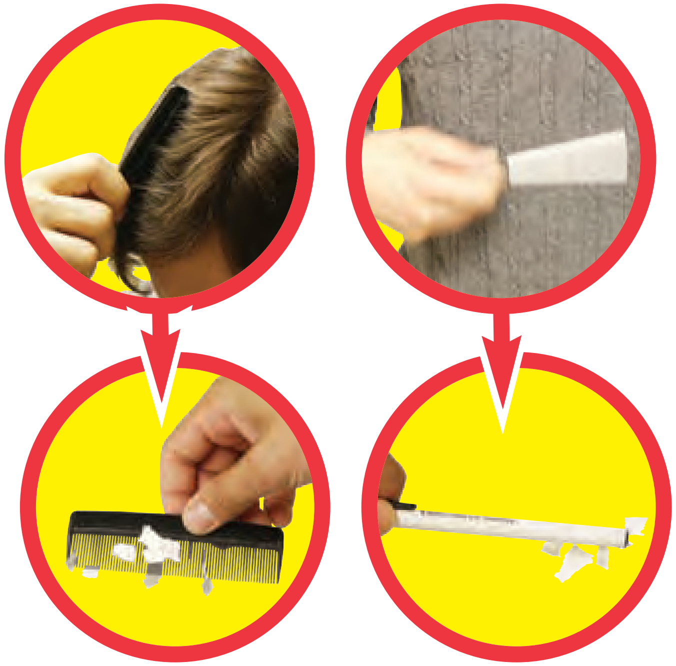
If you wet the clothes then the static charge should mostly dissipate. (Try it.)

You need a comb (or plastic ruler) and a water faucet for this part. Run the comb through your hair several times then hold it next to a slow, thin stream of water from a faucet. The water will bend towards it. You can also use a plastic ruler. Rub it on your clothes (wool works best).



Rubbing the comb through your hair builds up a static electrical charge on it, which attracts the water.

Find a comb (or a plastic ruler) and some paper. Rip up the paper into small pieces. Run the comb through your hair several times then hold it near the paper pieces to pick them up. You can also use a pen or plastic ruler, rub it on your clothes (wool works best).



Notice how your hair can "stand up" or be attracted to the comb when the air is dry. How will this change if you wet your hair? (Try it.)

Electricity is immensely more powerful than gravity (gravity is what causes things to fall to the ground when you drop them). However electrical attraction is so completely balanced out that you don't notice it, while gravity's effects are always apparent because they are not balanced out.

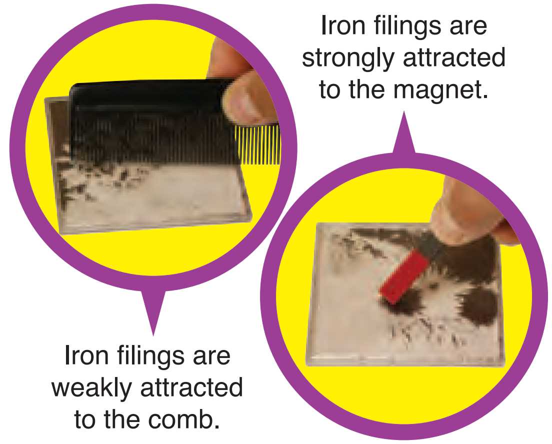
Gravity is actually the attraction between objects due to their weight (or technically, their mass). This effect is extremely small and can be ignored unless one of the objects is as big as a planet (like the earth). Gravity attraction never goes away and is seen every time you drop something. Electrical charge, though usually balanced out perfectly, can move around and change quickly.

For example, you have seen how clothes can cling together in the dryer due to static electricity. There is also a gravity attraction between the sweaters, but it is always extremely small.

Next, hold your magnet near the paper pieces; nothing happens.

Run the comb in your hair again and place it next to the iron filings case; not much happens (there may be a weak attraction). Now hold the magnet near the iron filings; they jump to it easily.

What's happening?



Iron filings are strongly attracted to the magnet.

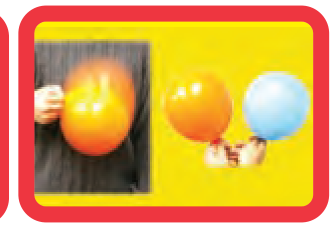
Iron filings are weakly attracted to the comb.

Running the comb through your hair builds up an electric charge in it, which is different from the magnetic charge in the magnet. The paper pieces are attracted to an electric charge, while the iron filings are attracted to a magnetic charge.

You will learn more about the differences between electricity and magnetism later.

Take a piece of newspaper or other thin paper and rub it vigorously with a sweater or pencil. It will stick to a wall.

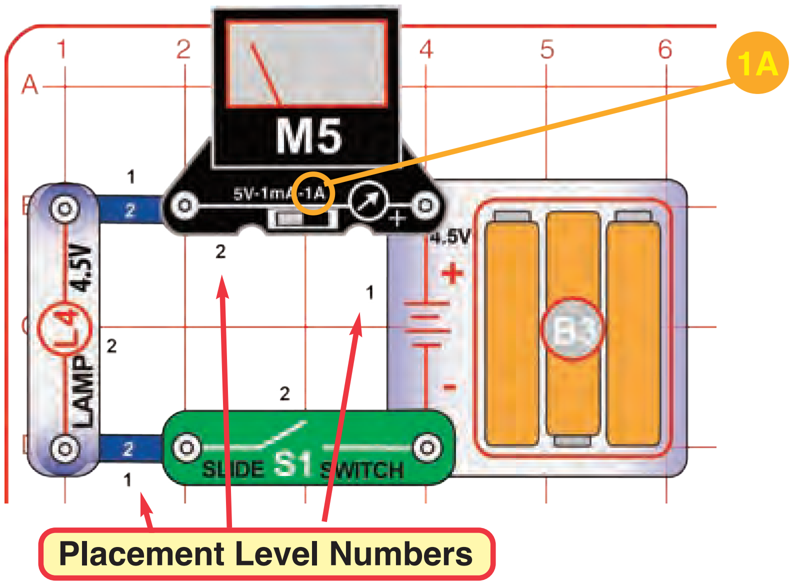
Cut the paper into two long strips, rub them, then hang them next to each other. See if they attract or repel each other.



If you have two balloons, rub them to a sweater and then hang the rubbed sides next to each other. They repel away. You could also use the balloons to pick up tiny pieces of paper.

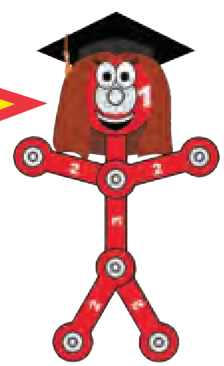
Rubbing the comb through your hair pulls extremely tiny charged particles from your hair onto the comb. These give the comb a static electrical charge, which attracts the paper pieces.

# ☐ Project 5 Light the Way



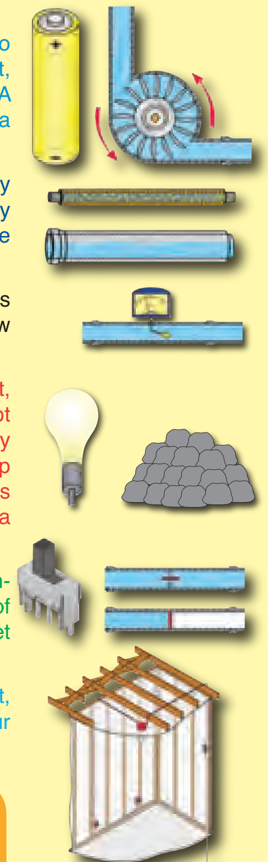

Build the circuit shown by placing all the parts with a black **1** next to them on the board first. Then, assemble parts marked with a **2**. Install three (3) “AA” batteries (not included) into the battery holder (B3). Set the meter (M5) to the 1A setting. Turn on the slide switch (S1); the lamp (L4) lights and the meter measures the current.

Touch the lamp after it has been on for a while; it should feel it little warm (especially if you cover the venting holes). In an incandescent light bulb, only about 5% of the electricity is converted into light, the rest becomes heat. Don’t touch incandescent bulbs in your home because they can be very hot.

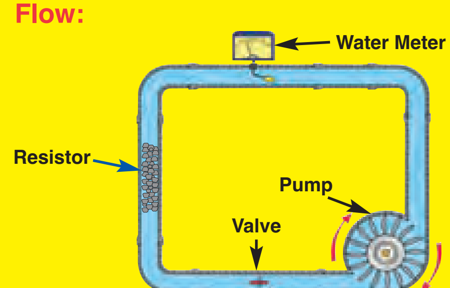


## What is really happening here?

1. The batteries (B3) convert chemical energy into electrical energy and “push” it through the circuit, just like the electricity from your power company. A battery pushes electricity through a circuit just like a pump pushes water through a pipe.
2. The snap wires (the blue pieces) carry the electricity around the circuit, just like wires carry electricity around your home. Wires carry electricity just like pipes carry water.
3. The meter (M5) measures how much electricity is flowing in a circuit, like a water meter shows how fast water flows in a pipe.
4. The lamp (L4) converts electrical energy into light, it is the same as a lamp in your home except smaller. In an incandescent light bulb, electricity heats up a high-resistance wire until it glows. A lamp uses the energy carried by electricity, resisting its flow like a pile of rocks resists the flow of water in a pipe.
5. The slide switch (S1) controls the electricity by turning it on or off, just like a light switch on the wall of your home. A switch controls electricity like a faucet controls water.
6. The base grid is a platform for mounting the circuit, just like how wires are mounted in the walls of your home to control the lights.



### Comparing Electric Flow to Water Flow:



# Project 6
## Light Bulbs of the Future

Use the preceding circuit but replace the lamp (L4) with the white LED (D6, "+" on top). Turn on the slide switch (S1); the LED lights.

LEDs are much more efficient than incandescent light bulbs and last longer. LEDs are also more expensive, but their cost has been declining, so LEDs are increasingly being used for home lighting.

LEDs are like one-way, low-current meters. LEDs have a "turn-on" voltage threshold (about 3V for your white LED) that must be exceeded to turn them on, then quickly get bright. LEDs can be made to product light in different colors.

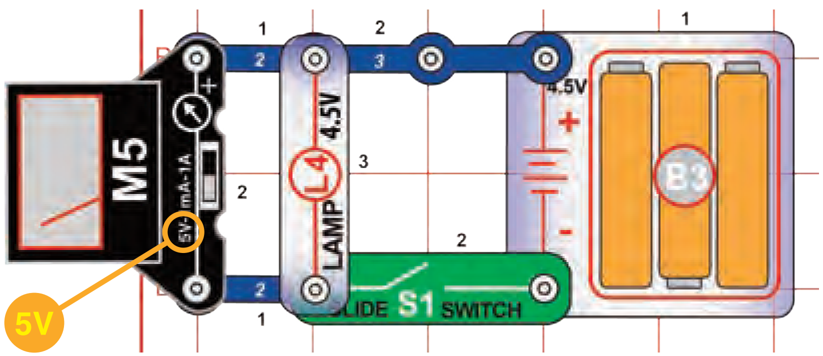
Compare the LED current (measured on the meter) to the current with the lamp (you can also try it with the meter on the 1mA setting instead of the 1A setting). How do they compare?

Would you rather use incandescent light bulbs or LEDs to light your home?

Notice that white LED has a "+" polarity marking, but the lamp does not. What do you think would happen if you flipped the LED or lamp around in this circuit? (Try it.)

**Answers are at www.snapcircuits.net/scstem1.**

# Project 7 Ohm's Law




Build the circuit, set the meter (M5) to the 5V setting, and turn on the slide switch (S1). The lamp (L4) lights and the meter measures the voltage.

You can swap the location of the lamp with the 3-snap wire or slide switch in this circuit, then measure the voltage across each of those parts and calculate their resistance using Ohm's law. What do you think their resistance will be?

Measurements from this circuit and the project 5 circuit can be used to measure the lamp resistance using Ohm's Law.

1. Measure the voltage using this circuit.
2. Measure the current using the project 5 circuit (remove the 3-snap wire, connect the meter where the 3-snap was, and set the meter to the 1A setting).
3. Calculate the lamp resistance using Ohm's Law:

$$\text{Resistance} = \frac{\text{Voltage}}{\text{Current}}$$

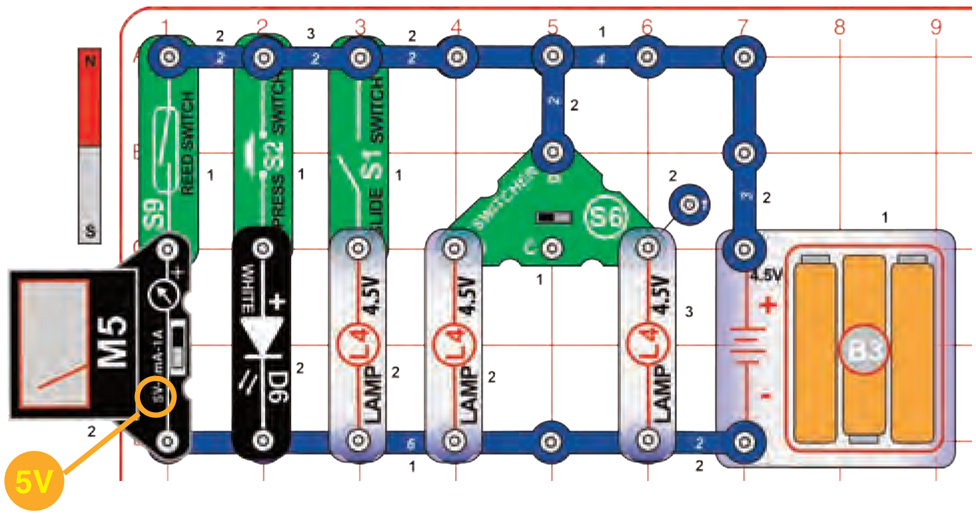
Your calculation:

The lamp resistance is usually 15-30 ohms, when used at 4.5V. The other parts in the circuit (switch, meter on 1A scale, blue snap wires, and batteries) also have resistance but these are much smaller.

**Note:** Your actual results may vary. Your M5 meter is a simple meter; don't expect it to be as accurate as normal electronic test instruments.

You can also calculate the power of the lamp: using: Power = Voltage x Current.
It should be about 1 watt. Compare this to incandescent light bulbs in your home, which are usually about 40-100 watts.

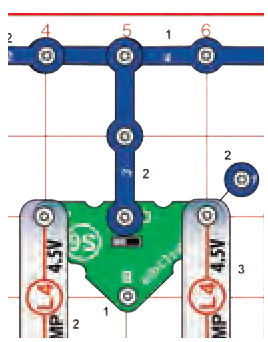
☐ # Project 8 Switches



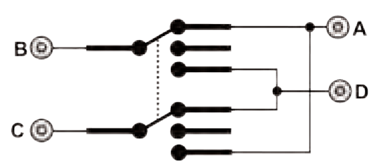

Build the circuit, set the meter (M5) to the 5V setting, and initially set the switcher (S6) to the middle position. Turn on each of the switches:

A. Hold the magnet near the reed switch (S9) to turn on the meter.
B. Push the press switch (S2) to turn on the white LED (D6).
C. Turn on the slide switch (S1) to turn on the left lamp (L4).
D. Set the switcher to the left position to turn on the center lamp.
E. Set the switcher to the right position to turn on the right lamp.

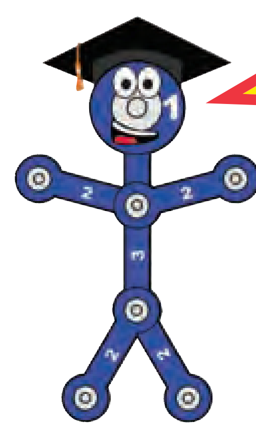
if you flip the switcher (S6) around (as shown below), how will it change the circuit? (Try it.)



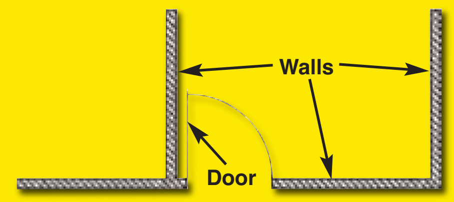
Note that the switcher's connections look like this:




Name at least 10 things in your home that use switches.



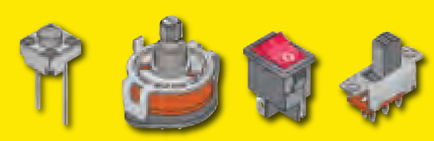
The "on" position of a switch is also called the "closed" position. Similarly, the "off" position is also called the "open" position. This is because the symbol for a slide switch is similar to the symbol for a door in an architect's drawing of a room:




The electronics symbol for a simple slide switch should be thought of as a door to a circuit, which swings open when the switch is off. The "door" to the circuit is closed when the switch is on. This is shown here:

**Open Switch (turned off)** **Closed Switch (turned on)**

Switches come in almost every shape and size imaginable. There are membrane, rocker, rotary, DIP, push button, magnetic, and momentary types just to name a few.



**Push Button** Computer Keyboards

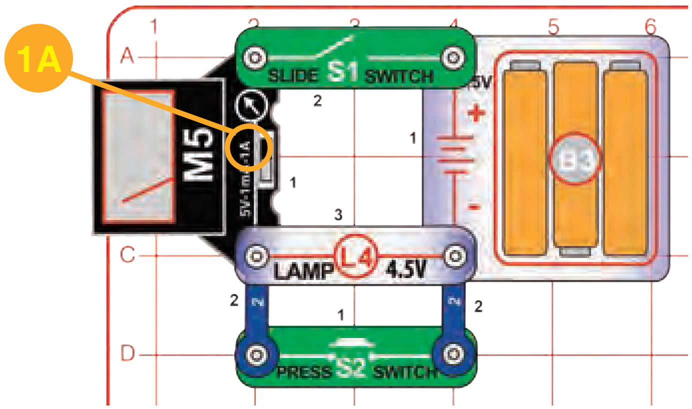
**Rotary** Selector Switch on Appliances

**Rocker** Tools

**Slide** Toys, Household Items

he current carrying capacity of a switch depends on the contact material, size, and the pressure between the contacts.

# Project 9 Fuse

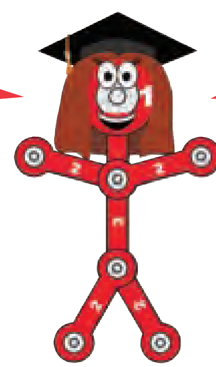



Build the circuit, set the meter (M5) to the 1A setting, and turn on the slide switch (S1). The lamp (L4) lights.

What do you think would happen if you push the press switch (S2) for a moment? Try it.

What do you think would happen if you pushed the press switch for a while? Try it. You should see the current increase, then drop down after a few seconds.

When wires from different parts of a circuit connect accidentally then we have a “short circuit”. A short circuit is a wiring path that bypasses the circuit resistance, creating a no-resistance path across the batteries. It is the “easiest” path through the circuit, it is not always the “shortest”. A short circuit will activate the fuse in your battery holder and/or quickly drain your batteries. Be careful not to make short circuits when building your circuits. Always check your wiring before turning on a circuit. See page 10 for examples of short circuits.

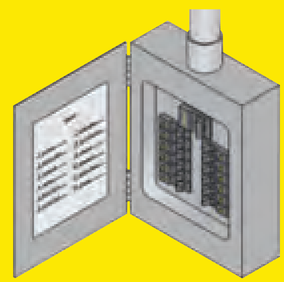


Name some devices in your home that have a fuse.

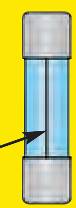
Pushing the press switch bypasses the lamp, making the meter the only resistance in the circuit. The meter has very low resistance on its 1A setting, so there is nothing in the circuit to limit the current. When you push the press switch, the high current (>1A) activates a safety fuse in the battery holder (B3) after a few seconds, which lowers the current enough to protect the batteries and other components from being overloaded. The fuse shuts off shortly after the circuit problem it had detected is corrected. The fuse is the small yellow component inside the battery holder.

Fuses are designed to shut down a circuit when the current is abnormally high (indicating something is wrong, such as a component failure, bad design, or a person using it improperly). This shutdown prevents further damage to the circuit, and can prevent explosions or fires. Fuses are important for safety and most electrical products have one, especially if they use electricity supplied by your local electric company.

Some fuses need to be replaced after they “blow”, but others can be reset by flipping a switch, and some (like the one in your battery holder) can reset automatically. Every home has an electrical box of resettable fuses, it may look like this:

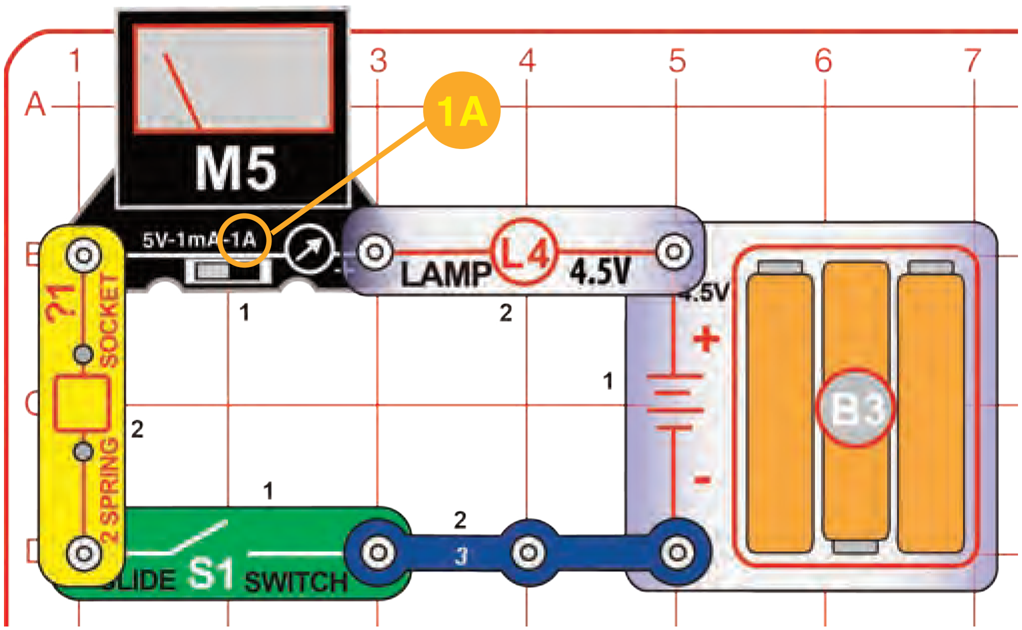


Some fuses have special wires designed to break when an unexpectedly high current flows through them.



*This wire melts to break the circuit.*

# Project 10 Materials Tester




If you have the build-your-own electromagnet connected to the two-Spring socket (?1), disconnect its wires for this project. Build the circuit and set the meter (M5) to the 1A setting.

Turn on the slide switch (S1) and touch (or connect) various materials between the springs on the two--spring socket See which materials are good at transporting electricity by watching the meter current and lamp (L4) brightness. Try string, the electrodes, a shirt, plastic, paper, two of your fingers, wood, or anything in your home.

If the meter reads zero, switch it to the 1mA setting to see if there is just a very small current. To help protect the meter, always switch back to the 1A scale before testing a new circuit.

Which materials gave the highest reading on the meter, and which gave the lowest?

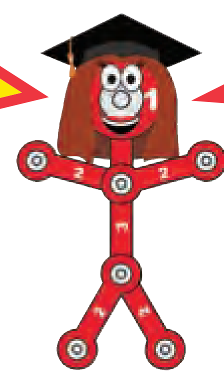
Some materials, such as metals, have very low resistance to electricity will make the lamp bright and give a large current measurement on the meter. These materials are called **conductors**. Conductors have electrons that are loosely held to the nucleus and can move easily.

Other materials, such as paper, air, and plastic, have very high resistance to electricity. These will turn off the lamp and give a zero current measurement on the meter even in the 1mA setting. These materials are called **insulators**. Insulators have their electrons locked in tight and have no room for more.

The best conductor ever discovered is silver, which is very expensive. Copper is the second best conductor, and it is used in almost all electrical wires.

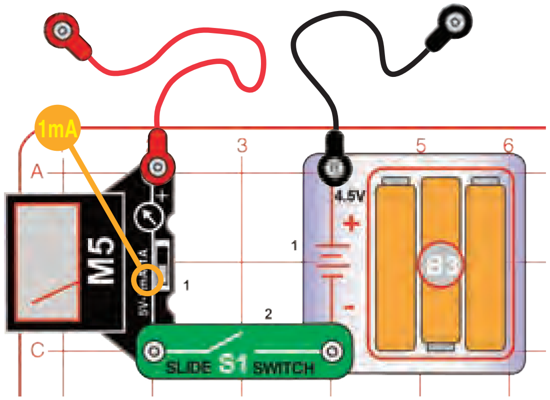
You can use Ohm's Law to measure the resistance of the materials you tested. The voltage is about 4.5V, and use the current measured on the meter.

$$\text{Resistance} = \frac{\text{Voltage}}{\text{Current}}$$



**What is Resistance?** Take your hands and rub them together very fast. Your hands should feel warm. The **friction** between your hands converts your effort into heat. Resistance is the electrical friction between an electric current and the material it is flowing through; it is the loss of energy from electrons as they move through the material.

# Project 11 — Make Your Own Parts




You can use Ohm's Law to measure the resistance of your puddles and drawings. The voltage is about 4.5V, and use the current measured on the meter.

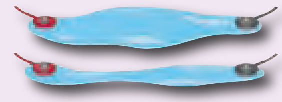
$$\text{Resistance} = \frac{\text{Voltage}}{\text{Current}}$$

The black core of pencils is graphite, the same material used in resistor components throughout the electronics industry.

Pure water has very high resistance because its atoms hold their electrons tightly and have no room for more. Impurities (such as dissolved dirt, minerals, or salt) decrease the resistance because their atoms have loose electrons, which make it easier for other electrons to move through.

**Method A (easy):** Spread some water on the table into puddles of different shapes, perhaps like the ones shown below. Touch the jumper wires to points at the ends of the puddles.

**Method B (challenging):** Use a SHARP pencil (No. 2 lead is best) and draw shapes, such as the ones here. Draw them on a hard, flat surface. Press hard and fill in several times until you have a thick, even layer of pencil lead. Touch the jumper wires to points at the ends of the drawings. You may get better electrical contact if you wet the metal with a few drops of water. Wash your hands when finished.



**Method C (adult supervision and permission required):** Change the setting on the meter to the 1A scale. Use some double-sided pencils if available, or VERY CAREFULLY break some pencils in half. Touch the jumper wires to the black core of the pencil at both ends.

Build the circuit shown, and set the meter (M5) to the 1mA setting. Make your parts using either the water puddles method (A), the drawn parts method (B), or the pencil parts method (C), and turn on the slide switch (S1). Touch the metal in the jumper wires to your parts and read the current in milliamps.

**Part B:**

Place the ends of the wires in a cup of water, making sure the metal parts aren't touching each other. Turn on the slide switch and read the current on the meter.

Add salt to the water and stir to dissolve it. The current should be higher now (if not already at full scale), since salt water has less resistance than plain water.

Now add more water to the cup and watch the current.

If you have some distilled water, place the jumper wires in it and measure the current. You should measure close to zero current, since distilled (pure) water has very high resistance. Normal water has impurities which lower its resistance. Now add salt to the distilled water and watch the current increase as the salt dissolves!

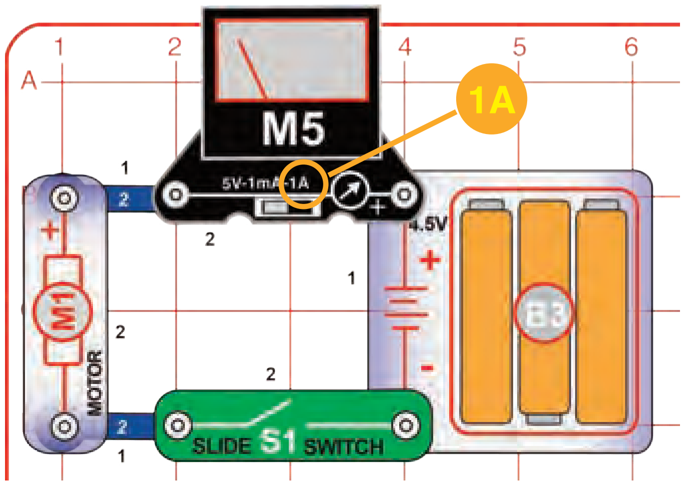
You can also measure the current through other liquids.

Don't drink any water or liquids used here.

Note: Depending on your local water supply, your current measurement may exceed the 1mA scale. You can switch the meter to the 5V scale to get a better comparison, though it isn't really a voltage measurement. (In the 5V setting, the water resistance is compared to the internal resistance of the meter. A low reading means the water has relatively high resistance, and a high reading means the water has relatively low resistance.)

Which gave a higher reading on the meter, long narrow shapes or short wide shapes?

# ☐ Project 12 Motor Resistance




Build the circuit, set the meter (M5) to the 1A setting, and turn on the slide switch (S1). The motor (M1) spins and the meter measures the current. Do this with and without the fan on the motor.

The battery voltage is 4.5V, so use your current measurements to determine the motor resistance using Ohm's Law.

$$\text{Resistance} = \frac{\text{Voltage}}{\text{Current}}$$

The motor resistance is typically 5-20 ohms with the fan and 25-100 ohms without the fan.

**Note:** Your actual results may vary. Your M5 meter is a simple meter; don't expect it to be as accurate as normal electronic test instruments.

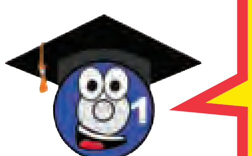
Calculate the power of the motor using: Power = Voltage x Current.

Calculate the resistance of the motor, with and without the fan. How does your calculation of the motor's resistance compare with its typical resistance? What factors could have caused the difference?

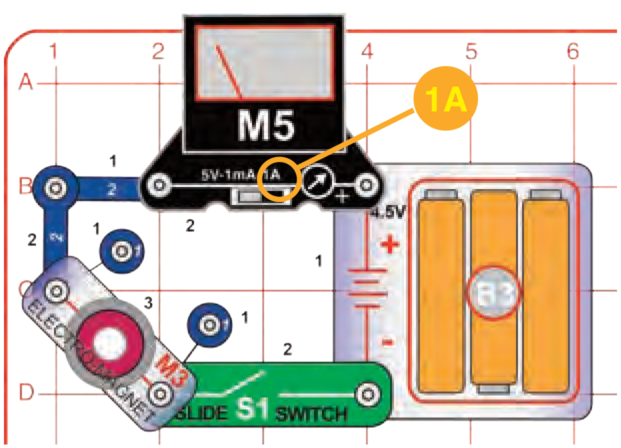
Calculate the power of the motor, with and without the fan. Does the motor use more power when the fan is on it? Why?

**WARNING:** Do not lean over the motor.

**WARNING:** Moving parts. Do not touch the fan during operation.



# ☐ Project 13 Electromagnet Resistance



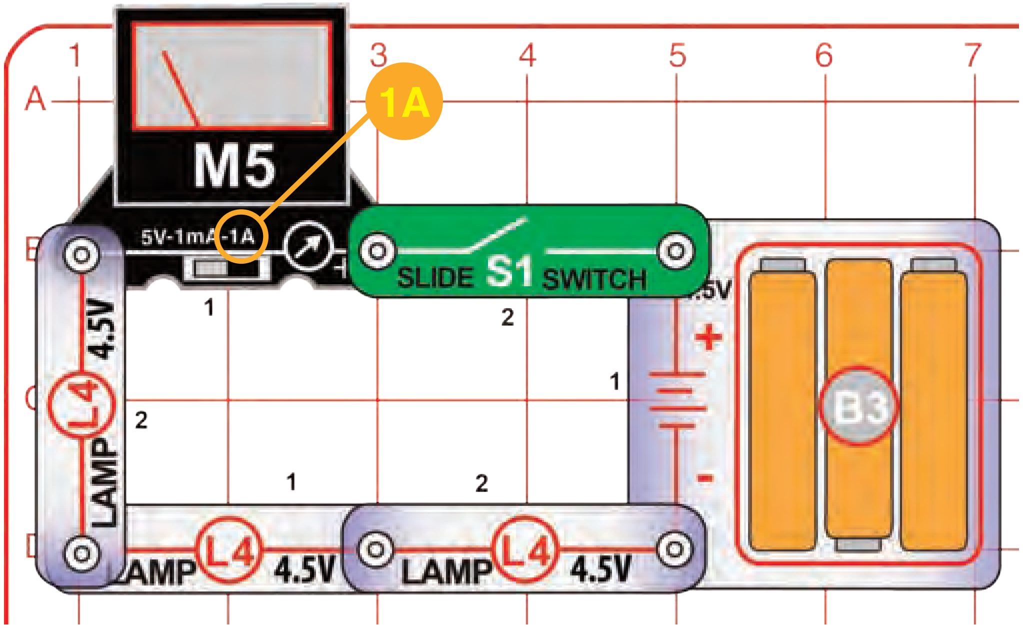

Build the circuit, set the meter (M5) to the 1A setting, and turn on the slide switch (S1). The meter measures the current through the electromagnet. Drop the thin rod into the electromagnet; it will be suspended in mid-air.

Use Ohm's Law to calculate the resistance of the electromagnet's resistance, and compare with its typical resistance.

Wires can generally be as long as desired without affecting performance, just as using garden hoses of different lengths has little effect on the water pressure as you water your garden. However there are cases where the length and size of a pipe does matter, such as in the water lines for your city. Similarly, wire length and size are important for electric power lines transporting electricity from a power plant in a remote area to a city.

The electromagnet is just a large coil of wire, its resistance is about 30 ohms.

# ☐ Project 14 — Series Circuit




Build the circuit, set the meter to the 1A setting, and turn on the slide switch (S1). The three lamps (L4) are dimly lit, and the meter measures the current.

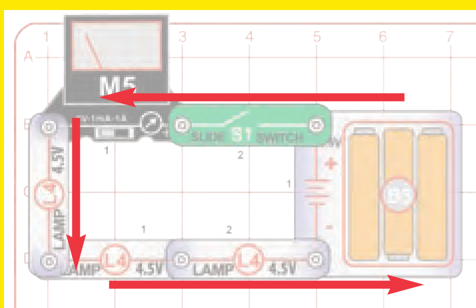
How would the current change if you replaced one of the lamps with a 3-snap wire? (Try it.)

How would the current change if you replaced two of the lamps with 3-snap wires? (Try it.)

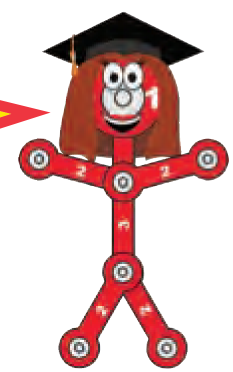
How would the current change if you replaced one of the lamps with the white LED (D6)? (Try it, oriented in both directions.)

How will the circuit performance change if you re-arranged the parts in the circuit? (Try it, but note that the meter and battery holder only fit one way.)

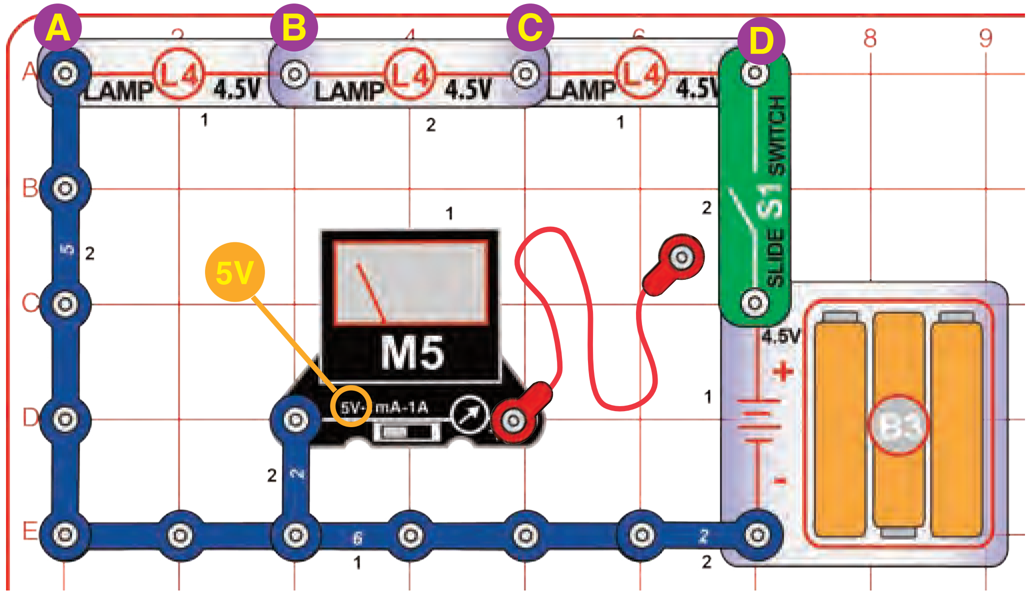
The three lamps are connected in a series, and all the electric current from the batteries flows through each component in the circuit. The lamps are dim because the voltage from the batteries (B3) is divided between them.



Connecting parts in series is one way of arranging them in a circuit. The advantage of it is that wiring them together is simple. The disadvantage is that if one lamp breaks, all three will be off.



# ☐ Project 15 Series Circuit - Voltage

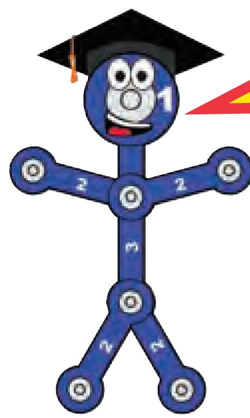



This circuit is similar to the preceding one, but measures the voltage instead of the current. Build the circuit, set the meter to the 5V setting, and turn on the slide switch (S1). The three lamps (L4) are dimly lit. Snap the loose end of the red jumper wire to points A, B, C, or D to measure the voltage at that point using the meter.

You can also connect the red jumper anywhere in the circuit to measure the voltage there.

How would the voltage change if you replaced one of the lamps with a 3-snap wire? (Try it.)

How would the voltage change if you replaced one of the lamps with the white LED (D6, "+" on the right)? (Try it.)



This circuit shows how the total voltage from the batteries gets divided among the components in the circuit, which are resisting the flow of electricity.

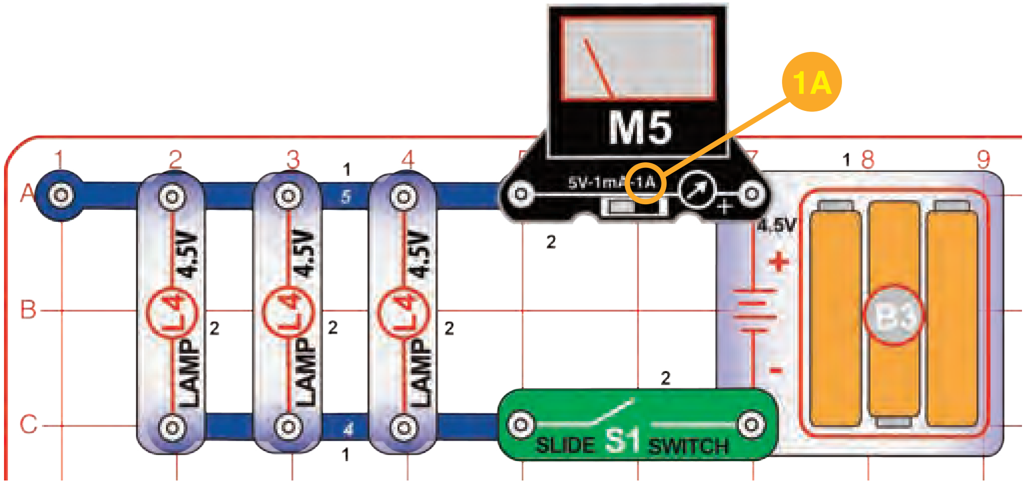
In this circuit the lamps are the resistances which are limiting the flow of electricity. Placing resistances in series increases the total resistance. Advanced users can compute the total resistance as follows:

$$R_{series} = R1 + R2 + R3 + \dots$$

The current is the same through all the resistances in a series circuit. Ohm's Law says that Voltage equals Current times Resistance, so the highest resistances in a series circuit will have the largest voltage drop across them. Equal resistances will have the same voltage drop. In other words:

$$\underset{\text{(across one resistor)}}{\text{Voltage}} = \frac{\text{Resistance (of that resistor)}}{\underset{\text{(total of resistors in the circuit)}}{\text{Resistance}}} \times \underset{\text{(total applied to the series circuit)}}{\text{Voltage}}$$

# ☐ Project 16 Parallel Circuit

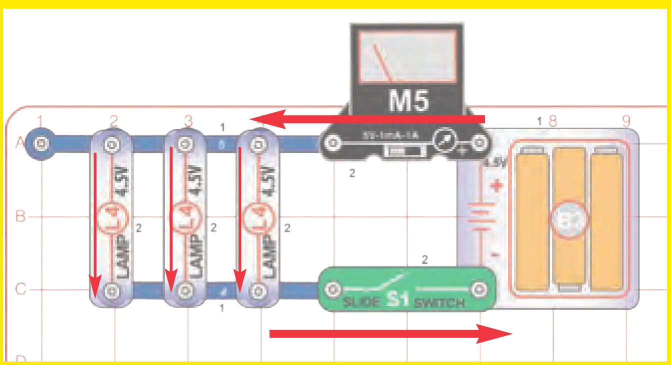



Build the circuit, set the meter (M5) to the 1A setting, and turn on the slide switch (S1). The lamps (L4) are bright and the meter measures the current.

How would the current change if you removed one or two lamps? (Try it.)

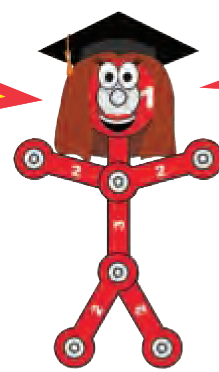
How would the current change if you replaced one of the lamps with the white LED (D6)? (Try it.)

In this circuit the batteries produce an electric current, which flows through the meter, then divides between the 3 lamps, then re-combines and flows through the switch, and back into the batteries.



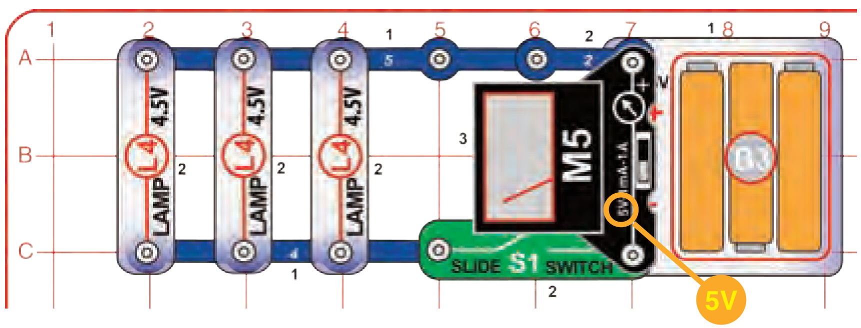

The three lamps are connected in parallel with one another. They are bright because each lamp gets the full battery voltage. The voltage pushes the current with equal force, because all are 4.5V, down each path.

Most of the lights in your house are connected in parallel; so if one bulb burns out then the others are not affected.



**Which way does electricity really flow?** In the above drawing electricity is shown flowing from the "+" battery terminal, through the circuit, and back to the "–" battery terminal. This is how electricity was presumed to flow beginning with discoveries by Benjamin Franklin in 1747. Later discoveries in sub-atomic physics showed that the charged particles that were moving (electrons) had a "–" charge, and that they were moving from "–" to "+" charged materials. However, understanding circuits is easier if you assume electricity flows from "+" to "–", and all circuit analysis is done this way.

# ☐ Project 17 Parallel Circuit - Voltage




Build the circuit, set the meter (M5) to the 5V setting, but leave the slide switch (S1) off. The meter measures the voltage on the batteries. The lamps (L4) will be off, because the switch is off.

Now turn on the slide switch to light the lamps, and see if the voltage changes.

How would the voltage change if you replaced your batteries with ones that are weaker or stronger? (Try it if you have different batteries available.)

How would the voltage change if you left the switch (and lamps) on for a long time?

How would the voltage change if you removed one or two lamps? (Try it.)

How would the voltage change if you replaced one of the lamps with the white LED (D6)? (Try it.)

Batteries produce electricity using a chemical reaction, but they have a limited supply of the chemicals, and not all of them can react at once. If the batteries cannot produce as much electricity as a circuit wants, the voltage drops.


Some batteries, called rechargeable batteries (such as the batteries in your cell phone), allow you to reverse the chemical reaction using another electric source.

Connecting parts in parallel is another way of arranging them in a circuit. The advantage of it is that if one burns out, the others will still work (remove one of the lamps to prove this). The disadvantage is that wiring the parts together is more complex than with series circuits.

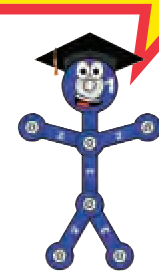
All large circuits are made of combinations of series and parallel circuits.

In this circuit the lamps are the resistances which are limiting the flow of electricity. Placing resistances in parallel decreases the total resistance. Advanced users can compute the total resistance as follows:

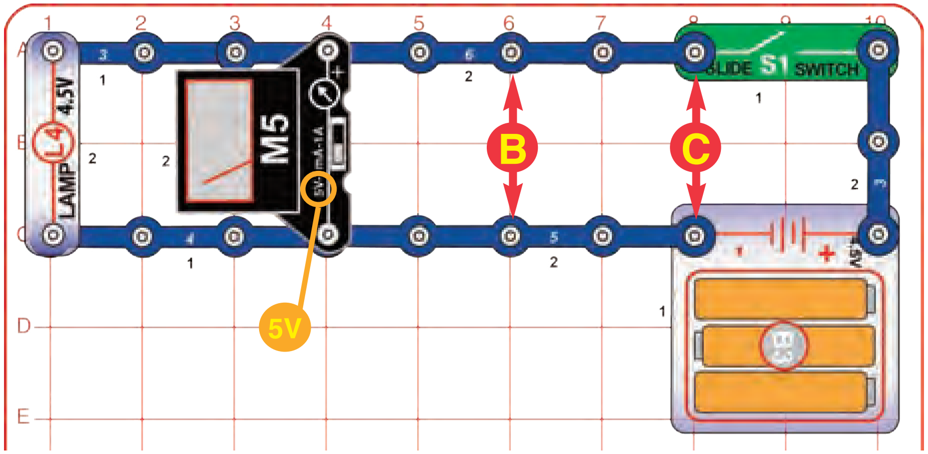
$$\frac{1}{R_{parallel}} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} + \ldots$$

The voltage is the same across all the resistances in a parallel circuit. Ohm's Law says that Voltage equals Current times Resistance, so the lowest resistances in a parallel circuit will have the most current through them. Equal resistances will have the same current. In other words:

$$\text{Current}_{\text{(through one branch)}} = \frac{\text{Resistance}_{\text{(total in all OTHER parallel branches)}}}{\text{Resistance}_{\text{(total of resistors in all branches)}}} \times \text{Current}_{\text{(total applied to the parallel circuit)}}$$



□ **Project 18** # Parallel Swapping

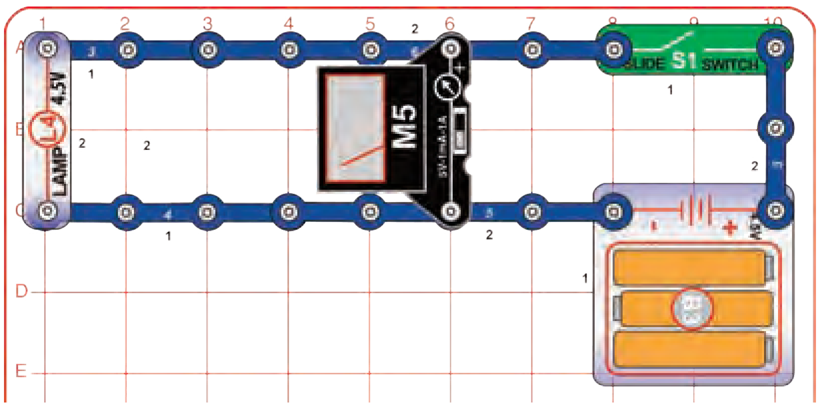



Build the main circuit and set the meter (M5) on the 5V setting. Turn on the slide switch (S1); the lamp (L4) lights and the meter (M5) measures the voltage from the batteries (B3).

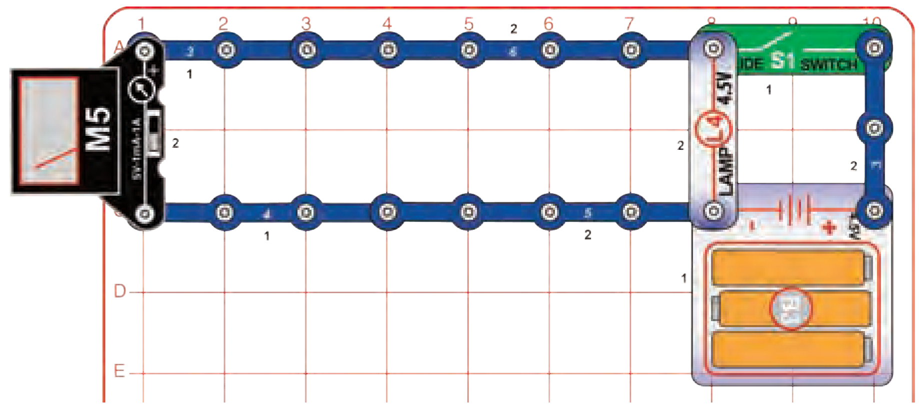
**Part B**: move the meter so it's across location "B" and then location "C". Measure the voltage at each location, is it the same?

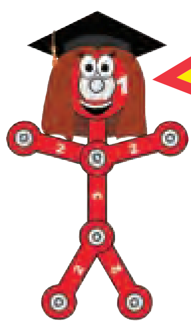
**Part C**: swap the locations of the meter and lamp. Does the meter still measure the same voltage?

## Part B



## Part C

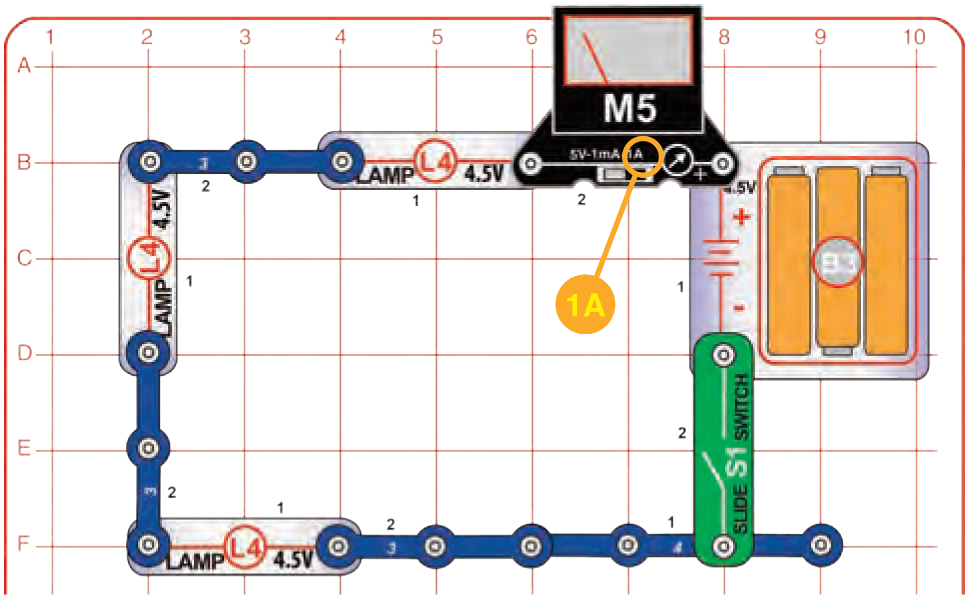




This circuit shows that rearranging parts that are connected in parallel does not change the circuit, because the meter measured the same voltage for each arrangement.

Give some examples of parallel circuits in your home.

# ☐ Project 19 Series Swapping



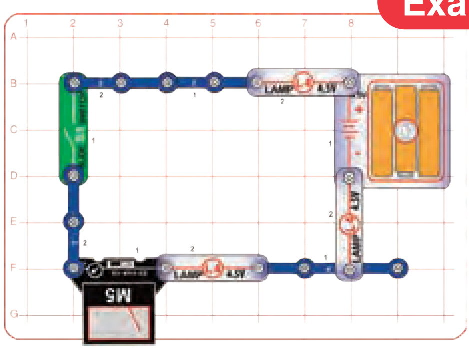

Build the main circuit and set the meter (M5) on the 1A setting. Turn on the slide switch (S1); the lamps (L4) light dimly and the meter (M5) measures the current through the circuit.

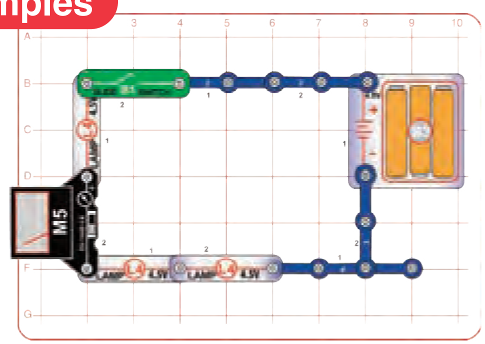
Now swap the positions of any of the lamps, 3-snap wires, the slide switch and the meter (the meter should always be placed so it hangs out of the circuit). Read the current on the meter; does it read the same for each arrangement?

When you turn on the switch, does the meter measure a higher current initially than it does after a few seconds? Why?

**Note:** Your M5 meter is a simple meter. It may read zero on this scale even though a small current is flowing.

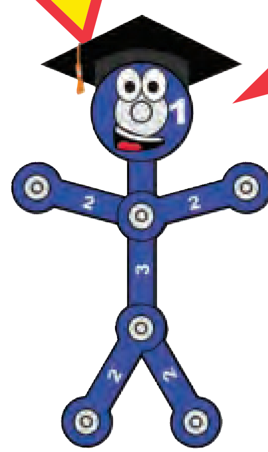
## Examples




The order of parts connected in series or in parallel does not matter - what matters is how combinations of these sub-circuits are arranged together.

The choice of whether to use a series or parallel configuration in a circuit depends on the application, but will usually be obvious. For example the overhead lights in the rooms of your home are all connected in parallel so that you can have lights on in some rooms and off in others, but within each room the light and switch are connected in series so the switch can control the light.



In the first moment after you press the switch, the meter will show a higher “surge” current. Light bulbs have less resistance when you first turn them on, then increase resistance as they get bright.

Give some examples of series circuits in your home.

# Project 20 Batteries in Series

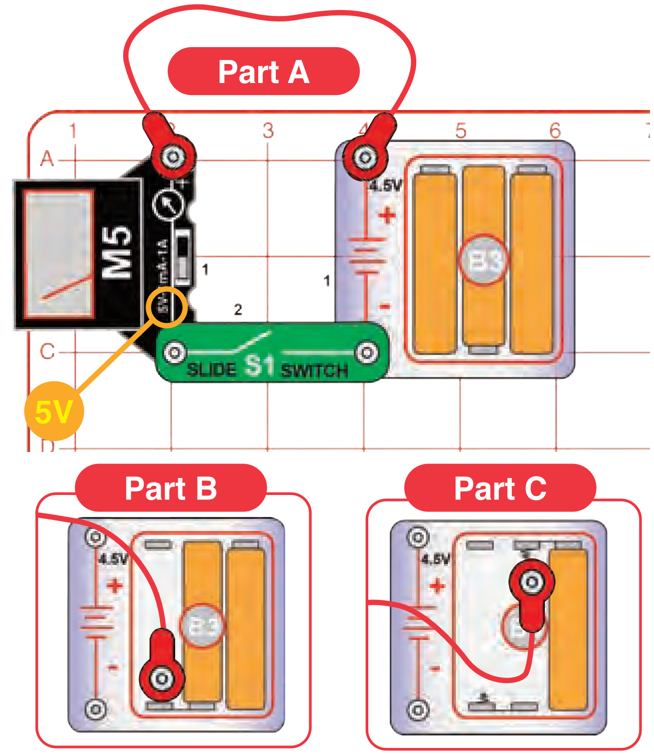
Build the circuit, set the meter (M5) to the 5V setting, and turn on the slide switch (S1).

**Part A:** Read the battery voltage on the meter. If your batteries are new then it should be about 4.5V.

**Part B:** Remove the left battery in the holder (B3) and move the end of the red jumper wire to touch the left spring in the holder. Read the voltage on the meter; measuring 2 batteries.

**Part C:** Now also remove the center battery and move the end of the red jumper wire to touch the center spring in the holder. Read the voltage on the meter; measuring 1 battery.

**NOTE:** The accuracy of your meter may vary.




If a circuit is given too much voltage then its components will be damaged. It is like having the water in your faucet come out at higher pressure than you need, and it splashes all over the room. If water in a pipe is at too high of pressure then the pipe may burst.

What voltage did you measure in Part A?

What voltage did you measure in Part B?

What voltage did you measure in Part C?

When batteries are connected in series, they add together, making the total voltage higher. An AA type battery is rated at 1.5V, but brand new ones will be up to 1.6V, and they get weaker as they are used up.

In Part A, the battery holder (B3) has three 1.5V type AA batteries in series, so the battery voltage is about 4.5V (1.5V + 1.5V + 1.5V = 4.5V).

In Part B, you are measuring two 1.5V type AA batteries in series, so the voltage is about 3V (1.5V + 1.5V = 3V).

In part C, you are measuring one 1.5V type AA battery, so the voltage is about 1.5V.

# Project 21 Lamp at Different Voltages

Use the preceding circuit, but replace the meter (M5) with the lamp (L4). Compare the lamp brightness with 3 batteries (Part A), 2 batteries (Part B), or 1 battery (Part C).

Does the lamp brightness change like the voltage does (are they proportional)?

Your L4 lamp is designed to be used at 4.5V; lower voltages like 1.5V or 3V do not get the bulb's filament hot enough to produce light as well. See project 29 for further explanation of this.

# Project 22
## Motor at Different Voltages

Use the preceding circuit, but replace the lamp (L4) with the motor (M1, “+” on top), with or without the fan. Compare the motor speed with 3 batteries (Part A), 2 batteries (Part B), or 1 battery (Part C). Try it with the fan and without the fan.

Does the motor speed change like the voltage does (are they proportional)?

**WARNING:** Do not lean over the motor.

**WARNING:** Moving parts. Do not touch the fan during operation.

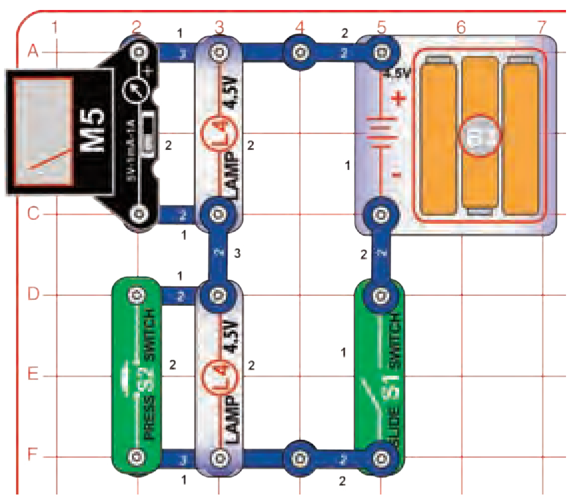
# Project 23
## LED at Different Voltages

Use the preceding circuit, but replace the motor (M1), with the white LED (D6, “+” on top). Compare the LED brightness with 3 batteries (Part A), 2 batteries (Part B), or 1 battery (Part C). The LED may not light with 1 or 2 batteries.

LEDs have a turn-on voltage threshold that must be exceeded before the LED produces any light, then brightness increases quickly. The LED’s threshold depends on the LED color and characteristics but is typically 1.5V for red LEDs, and about 3V for white LEDs.

Does the LED brightness change like the voltage does (are they proportional)?

# Project 24 Voltage Shifter




Build the circuit, and set the meter (M5) to the 5V setting. Turn on the slide switch (S1); the lamps (L4) are on and the meter measures the voltage across the top lamp. Push the press switch (S2) to turn off the bottom lamp.

One of the most basic rules for analyzing circuits is **Kirchhoff’s Voltage Law**: the total voltage driving a circuit must equal the voltage drops within it.

This project proves it because the total voltage across both lamps equals the voltage from the batteries: ($V_{batteries} = V_{lamp1} + V_{lamp2}$)

Since the battery voltage driving the circuit is the same, bypassing the bottom lamp shifts all the voltage to the top lamp. This follows Kirchhoff’s Voltage Law.

With both lamps on, what is the voltage measured across the top lamp?

With both lamps on, what do you think the voltage across the bottom lamp is? Swap the locations of the meter and press switch to see if you are right, then swap them back.

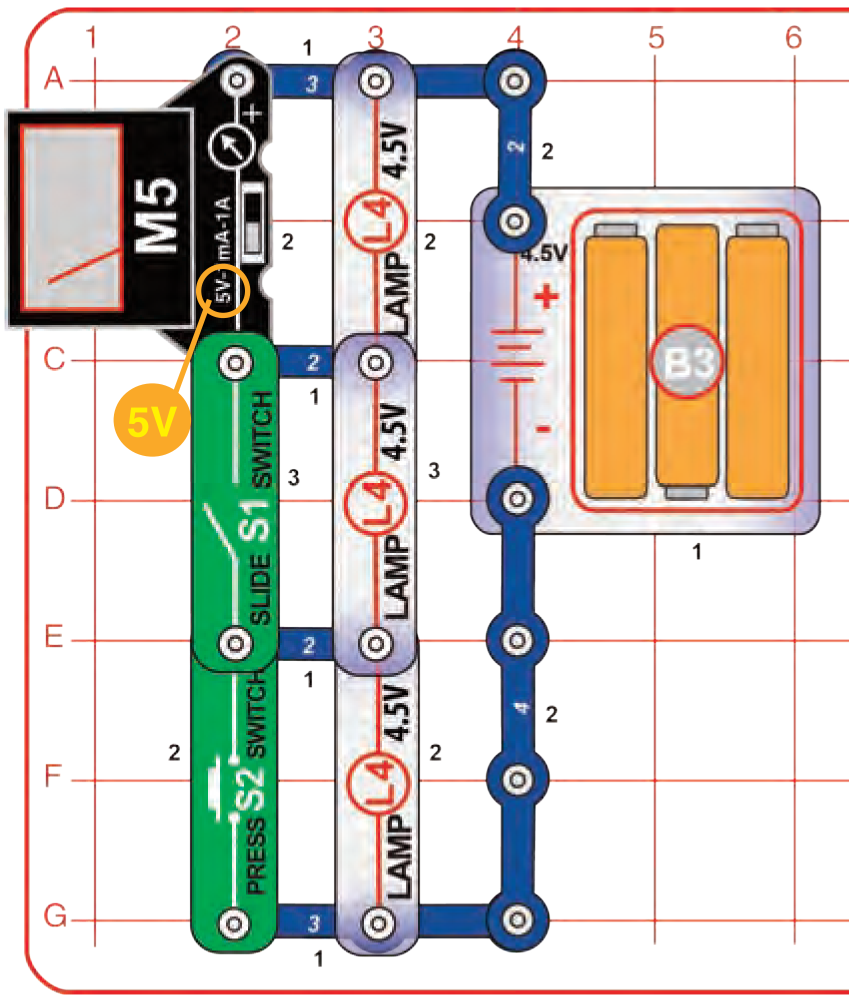
With the press switch pushed, what is the voltage measured across the top lamp?

Is it double the voltage measured across the top lamp when both lamps were on?

Why did the voltage change?

Is the top lamp brighter now?

# ☐ Project 25 Double Voltage Shifter



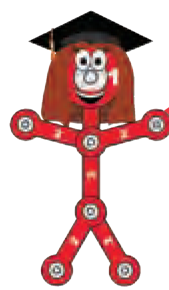

This project is similar to the preceding one, but uses three lamps. Build the circuit, and set the meter (M5) to the 5V setting. The lamps (L4) are on dimly and the meter measures the voltage across the top lamp. Push the press switch (S2) to turn off the bottom lamp. Turn on the slide switch (S1) to turn off the middle lamp. Disconnect the battery holder when you are finished with this project.

With all three lamps on (both switches off), what is the voltage measured across the top lamp?

With all lamps on, what do you think the voltage across each other lamp is? Swap the location of the meter with either switch to see if you are right, then swap them back.

Turn on one or both switches, and compare the voltage measured with one, two, or all three lamps on.

Why did the voltage change?

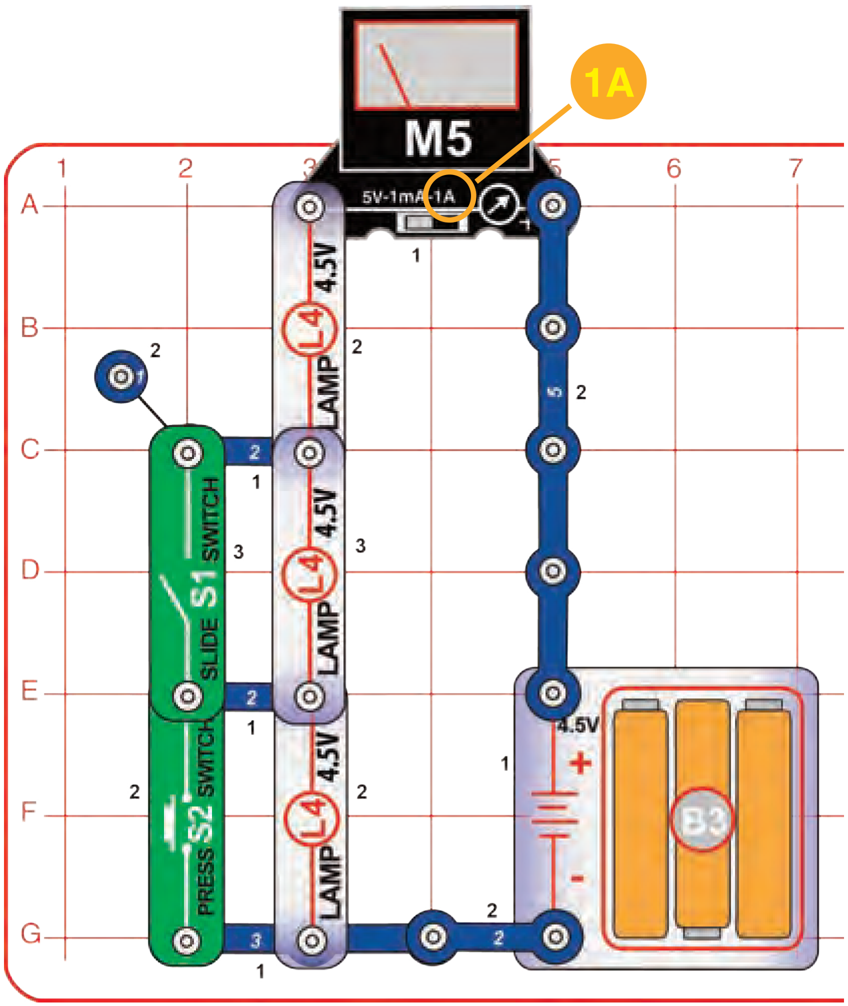


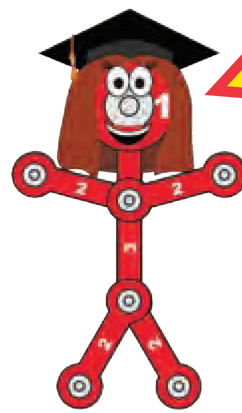
The voltage you measure with only one lamp on should be double the voltage with two lamps on, and triple the voltage with three lamps on. The voltage divides evenly, because the lamps all have the same characteristics.

This is another example of how voltage divides as parts are added in series. The lamps are acting as resistors, because they limit the flow of electricity in the circuit. As resistances are added in series, they add together to reduce the current.

# ☐ Project 26 Double Switching Ammeter

This project is similar to the preceding one, but measures current instead of voltage. Build the circuit, and set the meter (M5) to the 1A setting. The lamps (L4) are on dimly and the meter measures the current through the circuit. Push the press switch (S2) to turn off the bottom lamp. Turn on the slide switch (S1) to turn off the middle lamp. Compare the current with one, two, or all three lamps on. Disconnect the battery holder when you are finished with this project.



This circuit is an example of how current decreases as parts are added in series. If more than one lamp is on, the voltage from the batteries is split among them, and less current will flow through the circuit.

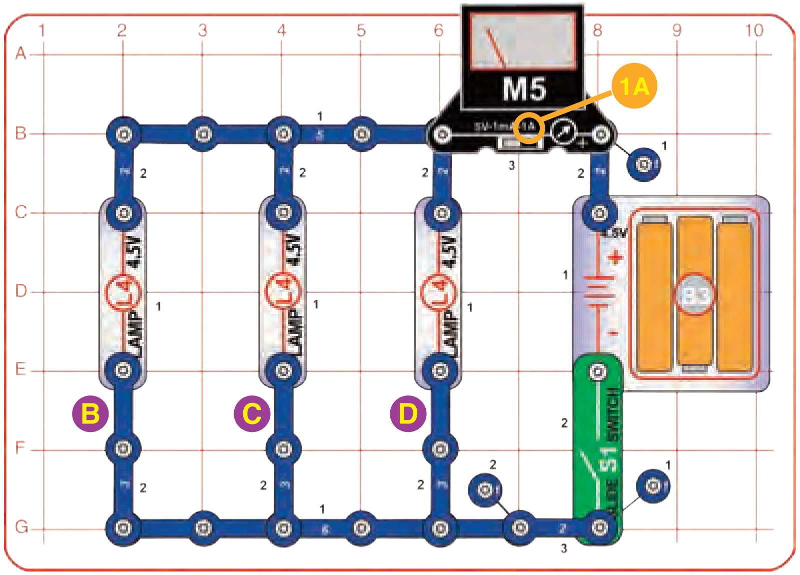
In theory the current with one lamp on should be twice as much as when two lamps are on and triple as much as when three lamps are on, but your results will be different because incandescent lamps like these have more resistance when they are brighter, and because your M5 meter is a simple meter with limited accuracy.

With all three lamps on (both switches off), what is the current?

Turn on one or both switches, and compare the current measured with one, two, or all three lamps on.

Why did the current change?

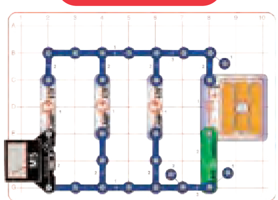
# ☐ Project 27 Current Divider



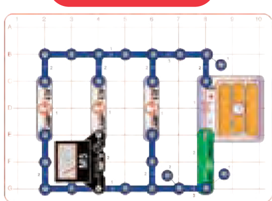

Are the currents through circuit branches B, C, and D the same or different?

Add up the currents through circuit branches B, C, and D. How does the total compare to the main circuit current (part A)?

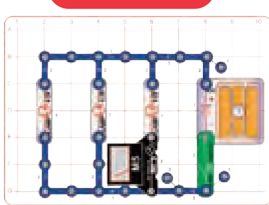
**Part B**



**Part C**



**Part D**

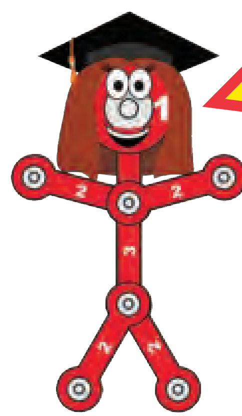


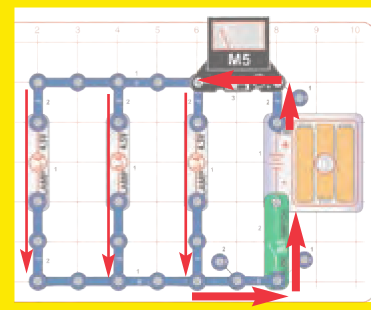
**Part A:** Build the main circuit, and set the meter (M5) to the 1A setting. Turn on the slide switch (S1); the lamps (L4) are all bright and the meter measures the current through the circuit.

**Part B:** Swap the location of the meter with the 3-snap wire marked "B" ("+" side towards the lamp). The meter shows the current through circuit branch "B".

**Part C:** Swap the "B" location of the meter with the "C" 3-snap. The meter shows the current through circuit branch "C".

**Part D:** Swap the "C" location of the meter with the "D" 3-snap. The meter shows the current through circuit branch "D".





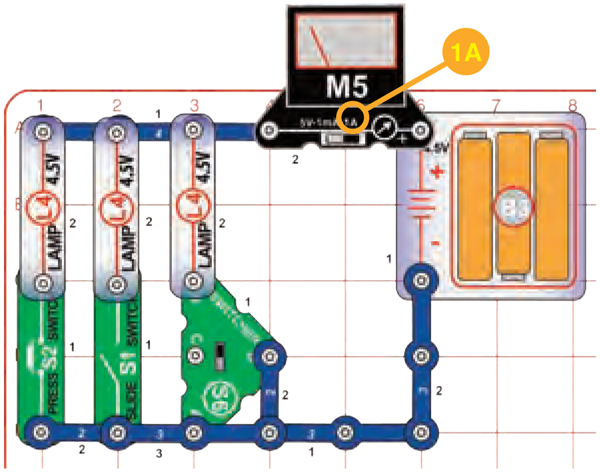

The current from the batteries splits up between the three lamps, because they are connected in parallel. Connecting parts in parallel allows more current to flow, so it decreases the overall circuit resistance.

If you add up the current you measured through circuit branches B, C, and D, it should be the same as the current you measured from the batteries. (Your result may be a little different, because M5 is a simple meter with limited accuracy.)

**Kirchhoff's Current Law**, an important rule for analyzing circuits, says that all current flowing into a point must flow out of it.

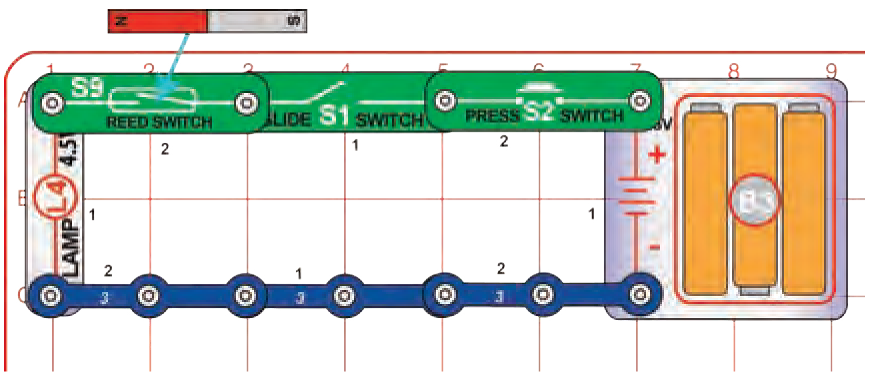
$(Current_{batteries} = Current_{lampB} + Current_{lampC} + Current_{LampD})$

## ☐ Project 28 — 3 Currents




Build the main circuit, and set the meter (M5) to the 1A setting. Push the press switch (S2), turn on the slide switch (S1), or set the switcher to the top position (turning it on). Turn on the switches one at a time and in combinations, comparing the current on the meter.

## ☐ Project 29 — AND Circuit




Are the three switches connected in series or in parallel?

Give an example of an AND circuit in your home.

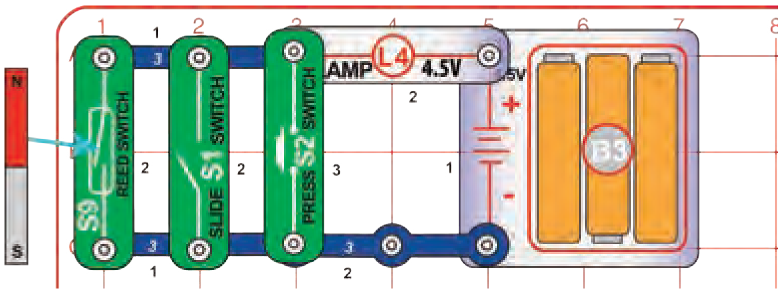
Place the magnet next to the reed switch (S9) to turn it on, push the press switch (S2), and turn on the slide switch (S1) in different combinations while seeing if the lamp (L4) lights. Fill out this table with the results:

| S9 | S1 | S2 | L4 |
|---|---|---|---|
| OFF | OFF | OFF | |
| OFF | OFF | ON | |
| OFF | ON | OFF | |
| OFF | ON | ON | |
| ON | OFF | OFF | |
| ON | OFF | ON | |
| ON | ON | OFF | |
| ON | ON | ON | |

If switch S9, switch S1, AND switch S2 are on then the lamp will be on. Engineers refer to this switching combination as an AND sub-circuit (short for "this AND that").

Having to turn on several switches just to turn on a lamp seems simple but is very important. The press switch could represent an on/off switch on an electric saw, one of the slide switches could be a safety switch on the saw, and the reed switch could be a fuse box in your basement. Safety is very important in electrical wiring.

# Project 30 OR Circuit



Are the three switches connected in series or in parallel?

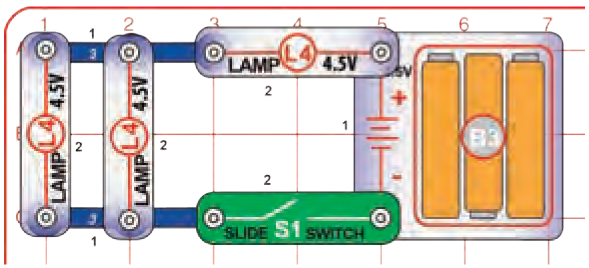
Give an example of an OR circuit in your home.

Place the magnet next to the reed switch (S9) to turn it on, push the press switch (S2), and turn on the slide switch (S1) in different combinations while seeing if the lamp (L4) lights. Fill out this table with the results:

| S9 | S1 | S2 | L4 |
|---|---|---|---|
| OFF | OFF | OFF | |
| OFF | OFF | ON | |
| OFF | ON | OFF | |
| OFF | ON | ON | |
| ON | OFF | OFF | |
| ON | OFF | ON | |
| ON | ON | OFF | |
| ON | ON | ON | |

if switch S9, switch S1 **OR** switch S2 is on then the lamp will be on. Engineers refer to this switching combination as an OR sub-circuit (short for "this OR that"). The same type of circuit is used throughout your home, such as having several sensors controlling a security light.

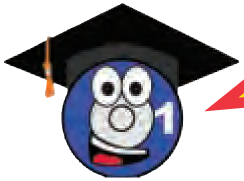
# Project 31 Light Bulb

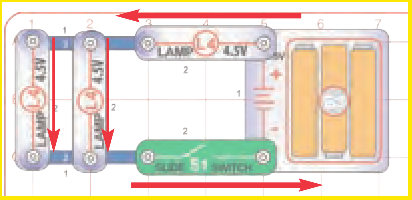


Build the circuit. Turn on the slide switch (S1) on and off several times, watching the brightness of each lamp (L4). Compare the brightness of each lamp, and how quickly each turns on.

How much brighter is the right lamp compared to the others?

Why do the two lamps on the left turn on slowly?



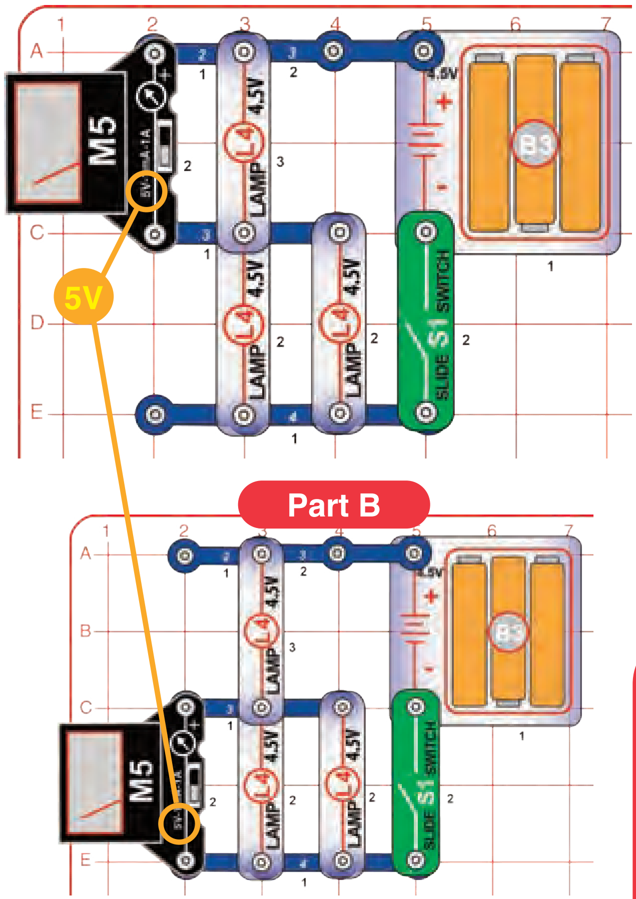


All the electric current flows through the right lamp, then divides between the two lamps on the left. The right lamp is much brighter than the others because it has twice as much electricity flowing through it, but that is not the only reason for the difference in brightness.

Why is the top lamp so much brighter than the others, even though it only has twice as much electricity through it? And why do the left bulbs take a few seconds before they make any light?

This happens because a dim light bulb has less resistance than a bright one. Incandescent bulbs like these make light by passing a big electric current through a special high-resistance wire, the filament. The high current heats up the filament, which gets so hot that it glows. The left bulbs get less current than the top one so they take longer to heat up and don't get as hot, barely getting hot enough to light their filaments.

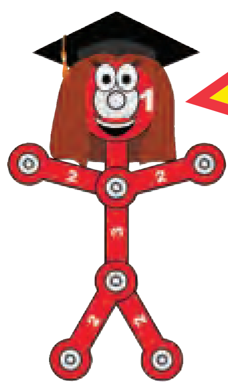
☐ # Project 32 Light Bulb with Meter




This circuit is like the preceding one, but adds a meter so you can compare the voltages across the lamps. Build the circuit, set the meter (M5) to the 5V setting, and turn on the slide switch (S1). The meter measures the voltage across the top lamp, which is bright.

**Part B:** Move the meter so it is across the lower lamps, as shown. Now the meter measure the voltage across the lower lamps, which are very dim. Watch the lower lamps and the meter closely; initially the lamps are dark, but slowly become dimly lit.

**Note:** The voltage in Part B will be much smaller; in some cases it may even be too small to measure with your M5 meter. M5 is a simple meter, don't expect it to be as accurate as normal electronic test instruments.



The resistance of the lower lamps is typically about triple that of the top lamp, but your results may vary. All wires have higher resistance when they are very hot.

Incandescent bulbs produce lots of heat, and the glass bulb prevents the filament from reacting with oxygen in the air and burning. When the voltage rating of an incandescent bulb is exceeded, the filament gets so hot it burns out. Filaments are usually made of tungsten, since ordinary copper would melt.

Most of the electrical energy used by incandescent light bulbs becomes heat, not light. Only about 5% of the electricity used by incandescent bulbs is converted into light. Without the more efficient fluorescent bulbs (and increasingly LEDs bulbs), our society of office buildings might have been much different.

What is the voltage across the top lamp?

What is the voltage across the lower lamps?

Remove the top 3-snap wire (which connects to the battery holder) and place the meter there. Set the meter to the 1A setting and measure the circuit current.

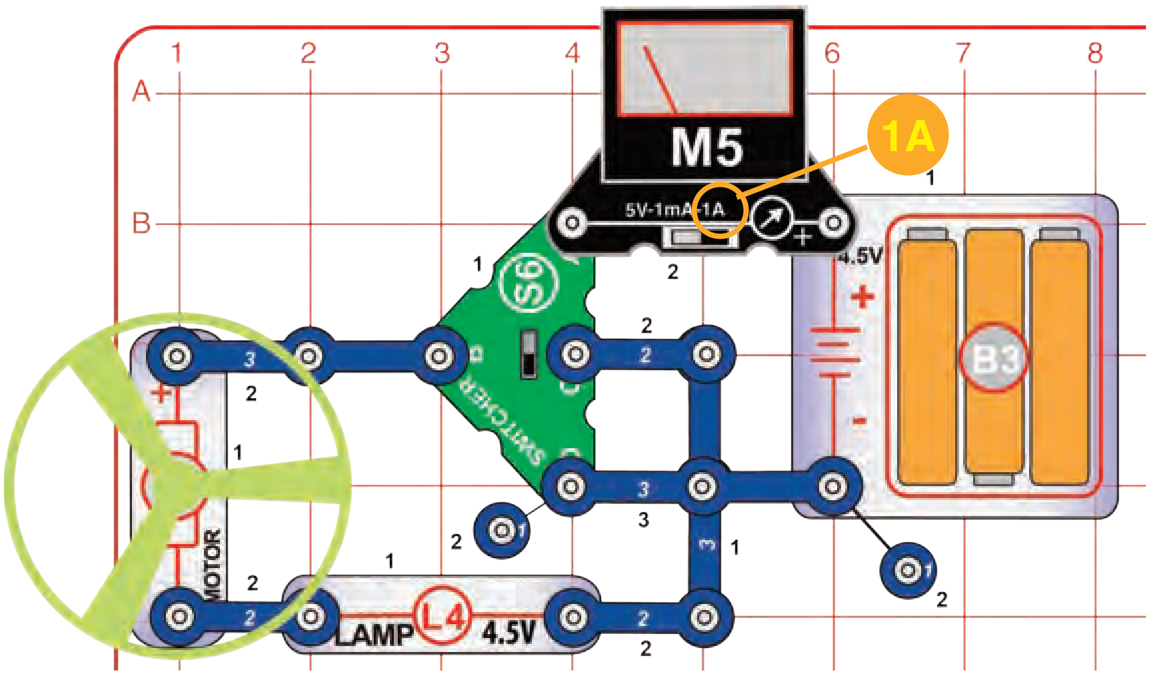
With the above measurements, use Ohm's Law ( ) to calculate the resistance of the lamps:

Resistance (top lamp) = Voltage (top lamp) / Current (as measured) =

Resistance (each lower lamp) = Voltage (lower lamps) / half of Current (since split between 2 lamps) =

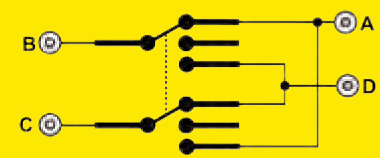
Find a fluorescent or LED bulb and feel the heat coming off it; you won't feel much. Find an incandescent lamp THAT HAS BEEN OFF FOR A WHILE and turn it on. Feel the heat it produces; it soon becomes too hot to touch. How much hotter is the incandescent bulb?

# ☐ Project 33 — 2 Direction Motor

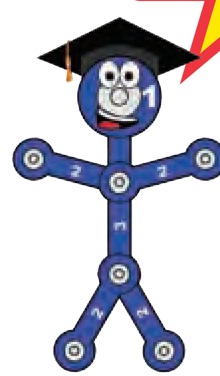



Build the circuit. Set the switcher (S6) to the middle position (off), set the meter (M5) to the 1A setting, and place the fan on the motor (M1). Now set the switcher to the top position; the motor spins, the lamp (L4) lights, and the meter measures the current. Set the switcher back to the middle position to turn off the circuit.

The switcher's connections look like this:




The switcher is used to reverse the battery connections (from snap A & D) to snaps B & C, which reverses the voltage across the motor and lamp. In the top position, battery "+" is connected to snap B, and in the bottom position battery "+" is connected to snap C.

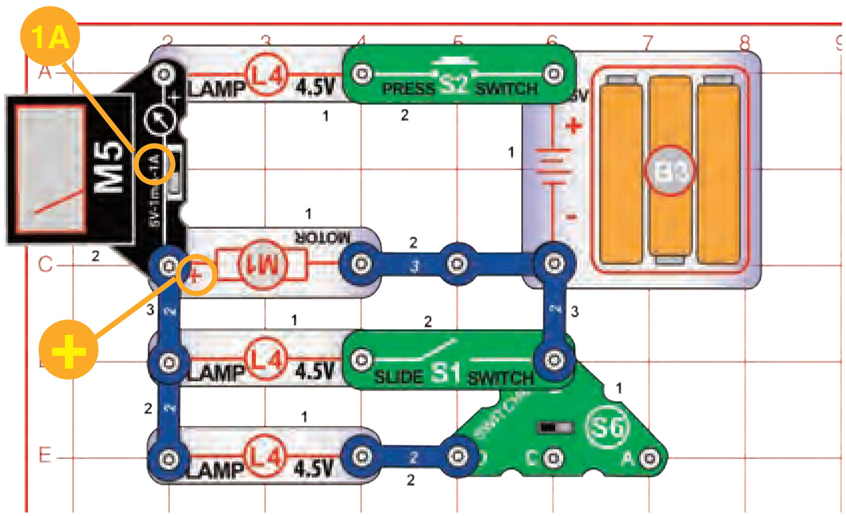


Study the circuit. What will happen to the motor, lamp, and meter if you change the switcher to the bottom position? (Try it.)

**WARNING:** Moving parts. Do not touch the fan during operation.

**WARNING:** Do not lean over the motor.

# ☐ Project 34 3-Speed Motor




Build the circuit, set the switcher (S6) to the middle position (off), set the meter (M5) to the 1A setting, and leave the fan off the motor (M1). Push switch (S2); the motor spins, and the meter measures the current. Turn on the slide switch (S1) or set the switcher to the left position to adjust the motor speed. You may need to give the motor a push to get it started, but do not touch it while it is spinning. Sometimes the lamps may not light.

**WARNING:** Moving parts. Do not touch the fan during operation.

**WARNING:** Do not lean over the motor.

When S1 and S6 are off the top lamp should be dim or off, why?

Here you control the motor speed by diverting some of the current to the lamps.

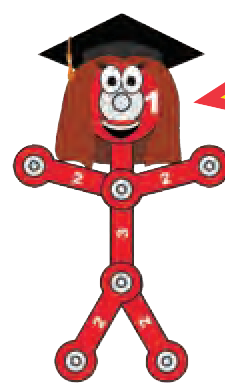
---

Now place the fan on the motor. Turn on the slide switch and set the switcher to the left (so both switches are on), and push the press switch. The motor will not spin.

Now turn off the slide switch and set the switcher to the middle position (so both switches are off), push S2 to get the motor spinning, then set the slide switches back (so both are on) while still pushing S2.

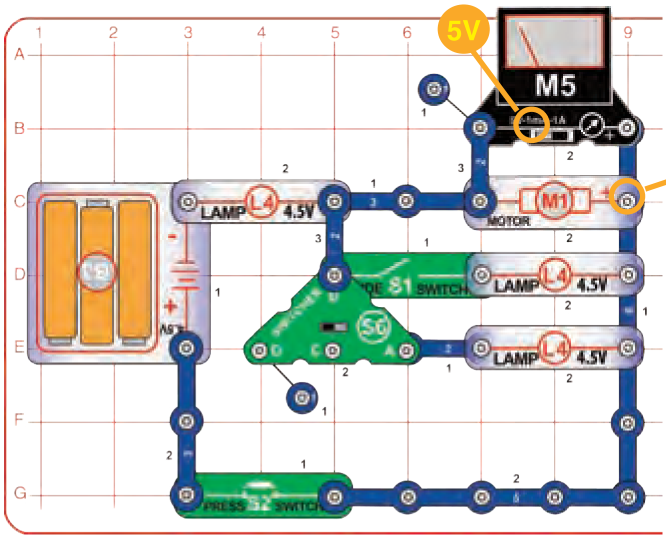
Note: Motor performance may vary, in rare cases it may spin in all switch settings.

The motor could not start spinning with the other lamps on, but it will keep spinning as long as you keep pushing S2. Why?



The surfaces touched by the motor shaft offer some resistance to motion, called friction. Once the initial friction is overcome, it doesn't take much effort to keep the motor spinning. This is especially important when the motor is trying to start the fan, due to the fan weight.

# ☐ Project 35 — 3-Speed Motor - Voltage




This circuit is just like the preceding one, except the meter measures the voltage instead of the current. Build the circuit, set the switcher (S6) to the middle position (off), set the meter (M5) to the 5V setting, and leave the fan off the motor (M1). Push switch (S2); the motor spins, and the meter measures the voltage. Turn on the slide switch (S1) or set the switcher to the right position to adjust the motor speed. You may need to give the motor a push to get it started, but do not touch it while it is spinning. Sometimes the lamps may not light.

Now place the fan on the motor and try the different switch combinations again.

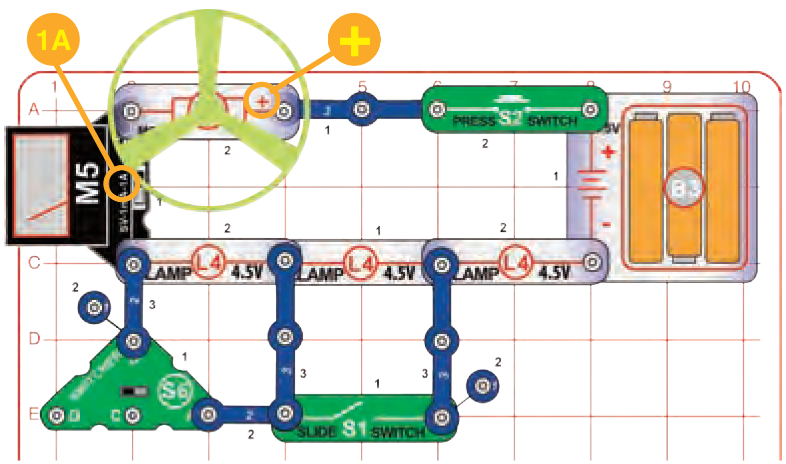
Compare the voltage measurements with out the fan to those with the fan.

Turning on the other lamps diverts current away from the motor, reducing the voltage across it and slowing it down.

**WARNING:** Moving parts. Do not touch the fan during operation.

**WARNING:** Do not lean over the motor.

# ☐ Project 36 — 3-Speed Motor with Fan




Build the circuit, set the switcher (S6) to the middle position (off), set the meter (M5) to the 1A setting, and place the fan on the motor (M1). Push switch (S2); the motor spins, and the meter measures the current. Turn on the slide switch (S1) or set the switcher to the right position to adjust the motor speed. You may need to give the motor a push to get it started, but do not touch it while it is spinning. Sometimes the lamps may not light.

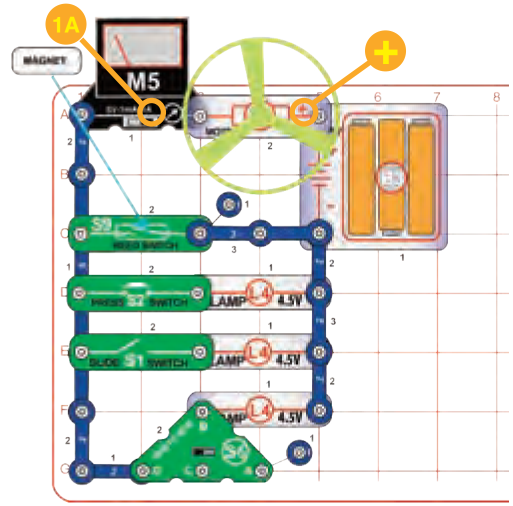
Turn on the slide switch and set the switcher to the right (so both switches are on), and push the press switch to get the fan spinning fast. Now turn off the slide switch and watch how long it takes to light the middle lamp; how long does it take to light, and why?

**WARNING:** Moving parts. Do not touch the fan during operation.

**WARNING:** Do not lean over the motor.

# Project 37 4-Speed Motor

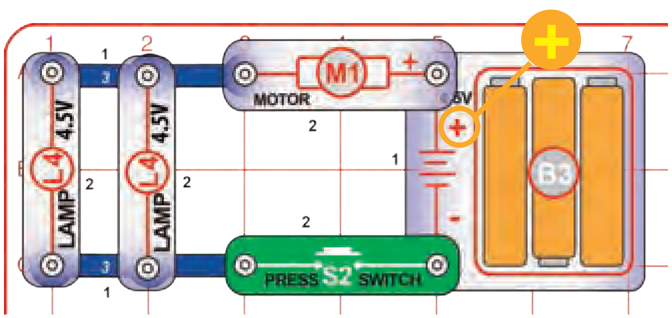
Build the circuit, set the switcher (S6) to the middle position (off), set the meter (M5) to the 1A setting, and place the fan on the motor (M1). First, set the switcher to the left position to start the motor. Then turn on the slide switch (S1) to increase the speed. Then push the press switch (S2) to increase the speed again. Then hold the magnet next to the reed switch (S9) to turn it on, further increasing the motor speed. Try different combinations of those switches. The meter measures the current.




**WARNING:** Moving parts. Do not touch the fan during operation.

**WARNING:** Do not lean over the motor.

# Project 38 Back EMF

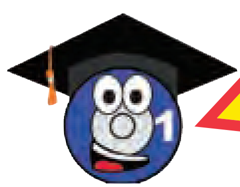



Build the circuit as shown, leave the fan off the motor (M1).

Place your finger on the top of the motor shaft to prevent it from spinning, then push the press switch (S2) - the lamps (L4) are bright. Now release the motor shaft and press the switch again - the lamps get dim or go out as the motor speeds up. DO NOT TOUCH THE MOTOR WHILE IT SPINS.

Next, place the fan on the motor and push the press switch again - the lamps stay bright as the fan speeds up.

Why does the fan affect the lamp brightness?

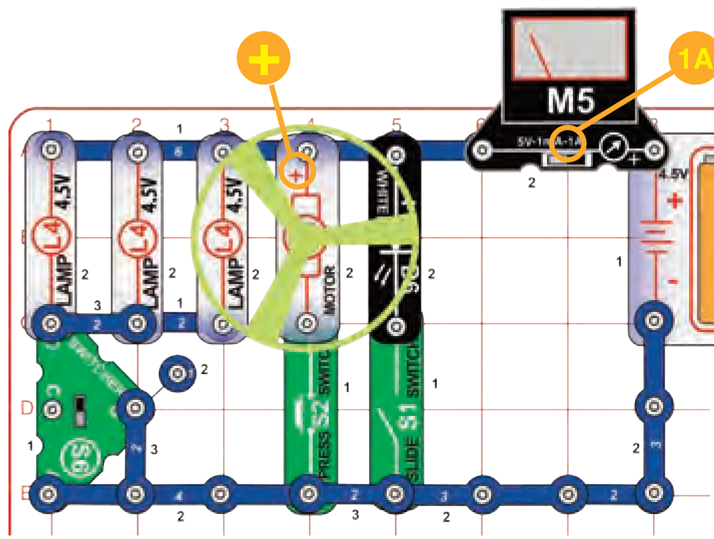


The voltage from the batteries (B3) pushes an electric current through a coil in the motor, which spins the shaft using magnetism. But the spinning shaft also uses magnetism to produce a current in the coil, which opposes the current from the batteries.

The result is that the motor has low resistance when the shaft isn't spinning fast, allowing a higher current to make the lamps bright. When the shaft is spinning really fast without the fan, the motor has high resistance, limiting the current and keeping the lamps dim.

The voltage/current produced by a motor when it is spinning is called its *Back Electro-Motive-Force* (Back EMF); this may be thought of as the motor's electrical resistance. The motor's *Front Electro-Motive-Force* is the force it exerts in trying to spin the shaft. This circuit demonstrates how the Back EMF increases and the overall current decreases as the motor speeds up.

# Project 39 Big Load

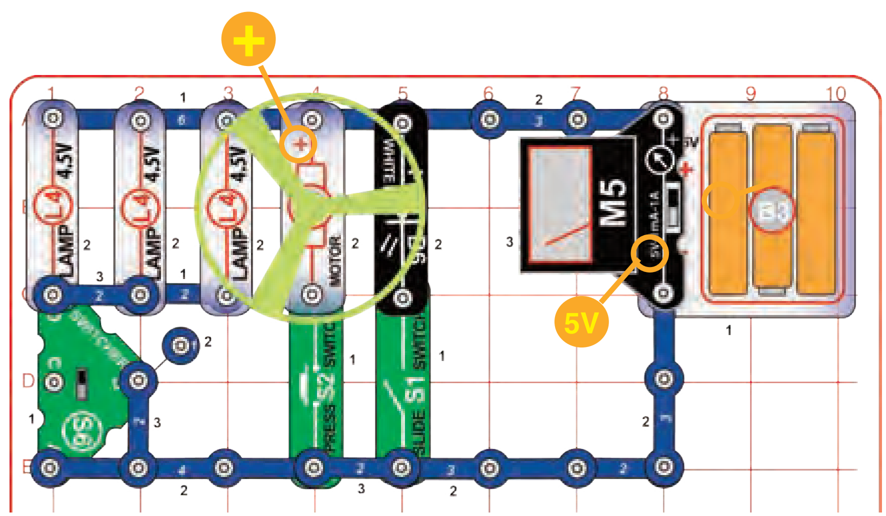



Build the circuit, set the switcher (S6) to the middle or lower position (off), set the meter (M5) to the 1A setting, and place the fan on the motor (M1). Set the switcher to the top position to light the lamps (L4), push the press switch (S2) to spin the motor, and turn on the slide switch (S1) to light the white LED (D6). Try each switch separately and in different combinations, and compare the current measured on the meter.

The higher the current, the more the lights and motor are "loading" the batteries, making the batteries work harder. Removing the fan from the motor makes the motor shaft easier to spin, lightening its load.

Remove the fan from the motor and compare the current. Why is it higher or lower?

# Project 40 Big Load - Voltage

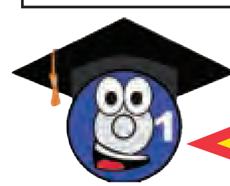



Use the preceding circuit but replace the meter (M5) with a 3-snap wire, then set the meter to the 5V setting and place it across the battery holder, as shown. With all the switches off, the meter measures the battery voltage. Turn on the switches to light the lights and spin the motor, comparing how much the voltage changes for each. If available, compare different batteries (such as old and new, or alkaline and non-alkaline) to see how much the voltage changes.

Using this and the preceding circuit, compare the current and voltage for each switch. Does the voltage drop more when the current is higher?

**WARNING:** Moving parts. Do not touch the fan during operation.

**WARNING:** Do not lean over the motor.



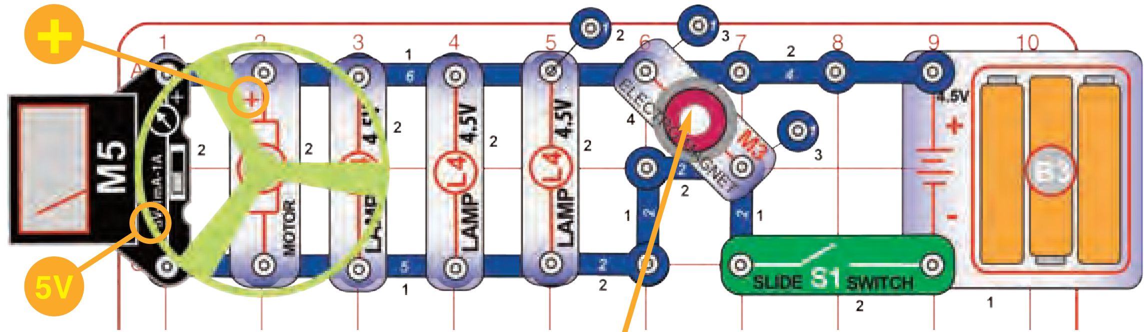
The battery voltage (electrical pressure) may drop as the current increases, because the batteries may not be able to supply all the current the circuit needs. This effect is more noticeable when the batteries are weaker.

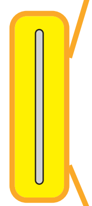
# ☐ Project 41 Holding Down

Build the circuit. Set the meter (M5) to the 5V scale, place the fan on the motor (M1), and drop the thin rod into the electromagnet (M3).

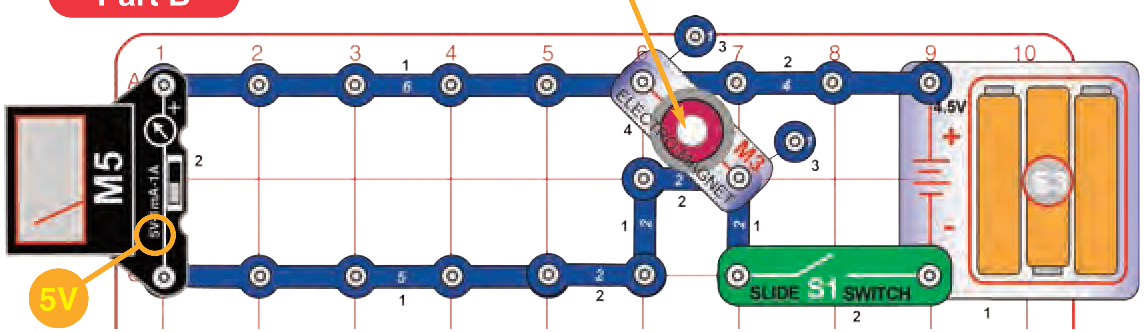
Turn on the slide switch (S1). The fan spins, the lamps (L4) light, and the meter measures the voltage. Nothing happens to the thin rod. Notice that the voltage is much lower then the normal 4.5V; the motor and lamps are overloading the batteries (B3), so the voltage drops.

**Part B:** Turn off the circuit, remove the motor and lamps, then turn the circuit back on. Now the measured voltage is much higher, and the thin rod gets sucked up by the electromagnet.

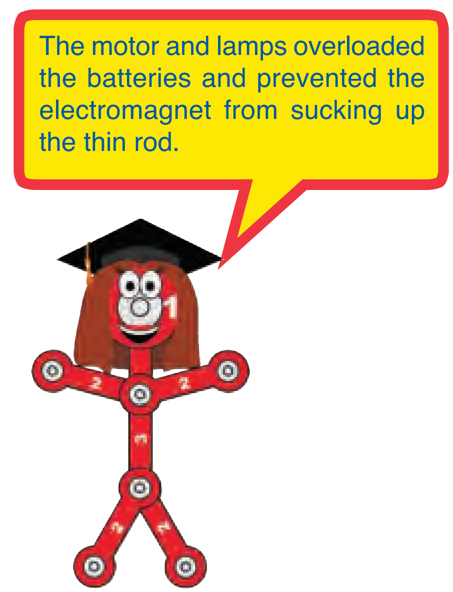


Part B



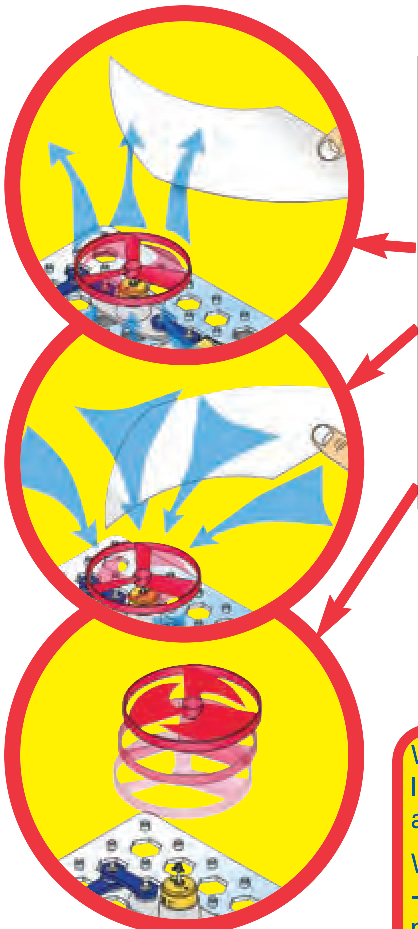

How do you think the measured voltage in the top circuit would be affected if you added 100 more lamps to the circuit?




**WARNING:** Moving parts. Do not touch the fan during operation.

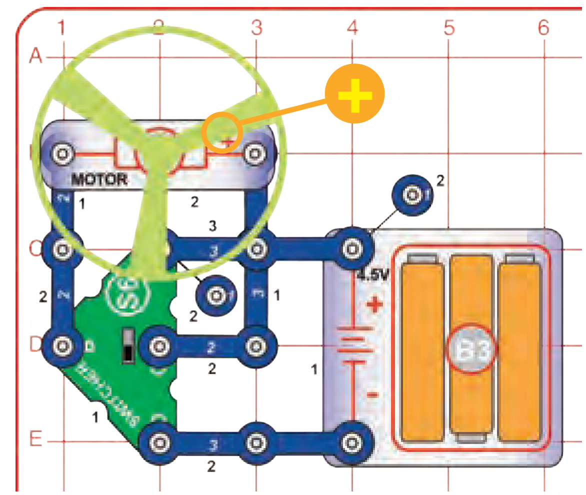
**WARNING:** Do not lean over the motor.

# Project 42 Propellor and Fan



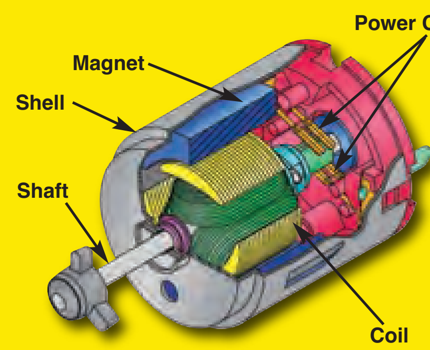
Build the circuit as shown, and set the switcher (S6) to the middle position at first, then set it to the bottom position to spin the fan. The fan blades suck in air around the motor (M1) and push it straight up. Hold a sheet of paper above the motor, it will get pushed up and away from the fan.

Flip the switcher to the top position now. The fan spins the other direction and sucks in air from above and pushes it down to the table. If the fan is spinning fast enough, then it will rise into the air when you turn off the switcher (sometimes it may fly off sooner due to vibrations). If you hold a sheet of paper near the motor, it will get sucked into the fan. If the fan doesn't fly off, then turn the switcher on and off several times rapidly when it is at full speed.




How does electricity turn the shaft in the motor? The answer is magnetism. The motor is the opposite of an electromagnet. Moving a magnet near a coil of wire can make a current flow in it (like the electromagnet), but a current flowing can move a magnet.

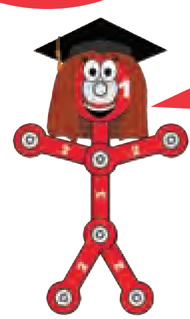
Inside the motor is a coil of wire mounted on a shaft. The motor shell has a magnet on it. When electricity flows through the coil of wire, it repels from the magnet on the motor shell and the shaft spins. If the fan is on the motor shaft then its blades will create airflow.




To prove the motor has a magnet inside, move your compass around it. The red needle will be attracted to one side but repelled from the other.

When the motor is blowing air up, it is a fan - just like the ones in your home. It will cool you off on a hot day.

When the motor is sucking air in, it is a propeller - just like the ones on helicopters or small airplanes.



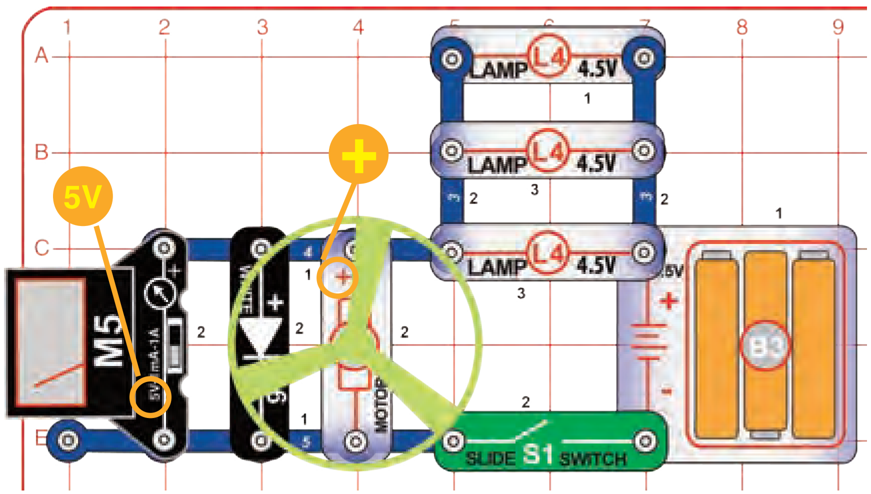
Switching circuits like this are commonly used to control motors in products like remote-controlled cars. Electronic controlled transistors are used in place of the switches, and the motor drives the wheels in the car.

Motors are used throughout our society to convert electricity into mechanical motion.

**WARNING:** Moving parts. Do not touch the fan during operation.

**WARNING:** Do not lean over the motor.

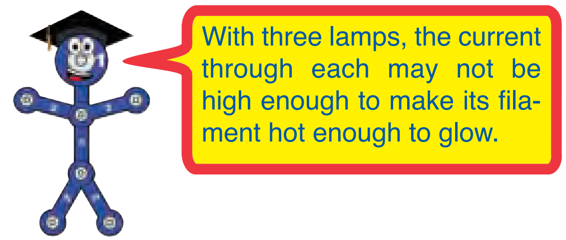
# Project 43 Motor & Lights




Build the circuit, set the meter (M5) to the 5V scale, and turn on the slide switch (S1). The meter measures the voltage across the white LED (D6) and motor (M1). Notice how fast the fan spins, and how bright the lights are. The lamps (L4) may be off.

Remove one lamp and compare the motor speed and brightness of the lights. Then remove a second lamp and compare again.

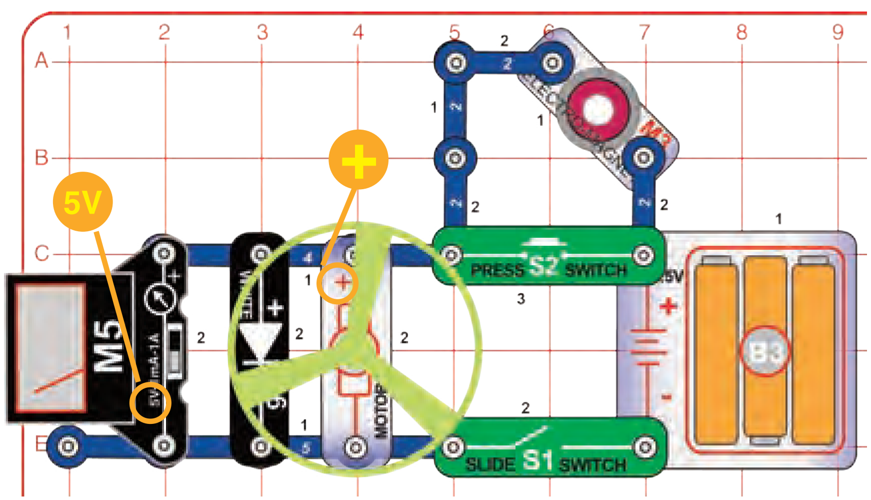
Lastly, turn off the switch, remove the fan from the motor, then turn the switch back on and compare the voltage measured and brightness of the lights. Do this with one, two, or three lamps in the circuit.



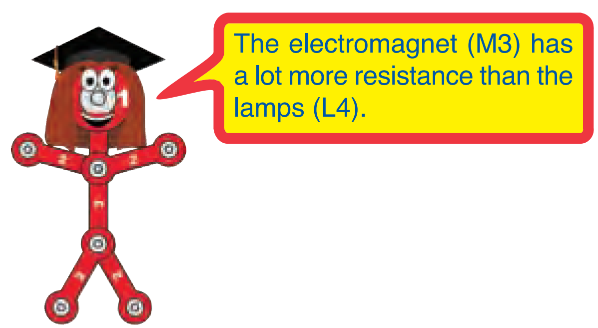

**WARNING:** Moving parts. Do not touch the fan during operation.

**WARNING:** Do not lean over the motor.

# Project 44 Slow Motor & Lights




Modify the preceding circuit to be this one. Keep the meter (M5) on the 5V scale. Turn on the slide switch (S1), then push the press switch (S2) if the white LED (D6) is off or the motor (M1) is not spinning. Compare the results to the preceding circuit. Try it with and without the fan on the motor.




**WARNING:** Moving parts. Do not touch the fan during operation.

**WARNING:** Do not lean over the motor.

# ☐ Project 45 Compass

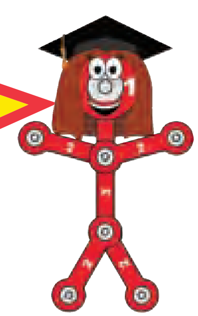

1. Hold your compass away from everything, notice that the red arrow always points north. Spin it around, the red arrow will adjust and resume pointing north.
   The earth's core is made of iron, which has a magnetic field. The compass points north because it is attracted to this magnetic field. This allows compasses to be used for navigation.
2. Now place the compass next to a large iron object, such as a refrigerator or car. If the object is heavy enough, the red arrow will point toward it.
   Large iron objects also exert a small magnetic field, which may attract a nearby compass. The magnetic field is much weaker than the earth's, but much closer to the compass.
3. Now place your magnet near the compass. The red arrow will immediately point toward the black "S" side of the magnet, ignoring a nearby refrigerator.
   Magnets have been induced to have a concentrated magnetic field at either end. This magnetic field is much stronger than ordinary iron objects that may be nearby.
4. Tie the magnet to a string and hold it near the compass. Gently spin the magnet, and see how the compass needle moves.
5. Pull out a 2-snap wire, a paper clip, the electrodes, the iron core rod, and the thin bar. Decide which of these you think the magnet will pick up, then try it and see if you were right. Do the same for other materials in your home.
   The physical properties of iron make it easy to induce a magnetic attraction in. This doesn't work for other metals or other materials.

All materials have tiny particles with electric charges, but these are so well balanced that you do not notice them unless an outside voltage disturbs them. The same tiny particles also have magnetic charges, which are usually so well balanced that you do not notice them unless a magnetic field disturbs them.

Magnets are materials that concentrate their magnetic charges at opposite ends. One side attracts while the other repels, but the overall material is neutral. Most magnets are made of iron.

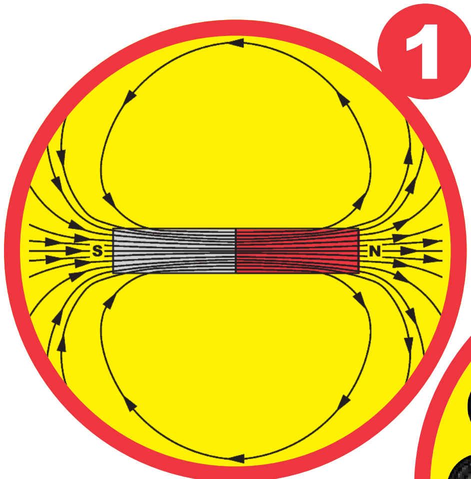
The name "magnet" comes from magnetite, an iron ore that magnetism was first seen in.

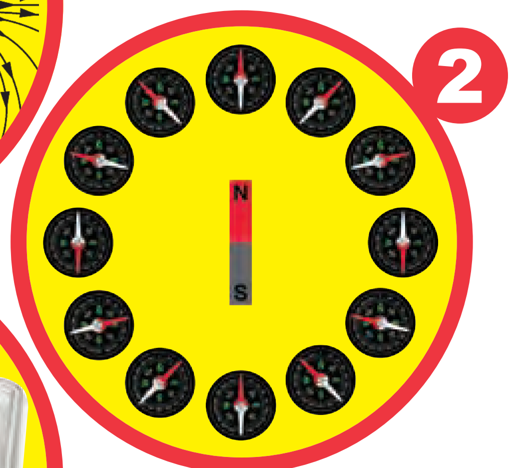
The earth we live on is a giant magnet, due to its iron core. A compass needle always points north because it is attracted to the earth's magnetic field. The opposite ends of a magnet are often labeled north and south, representing the north and south poles of the earth. A compass actually points to the earth's magnetic north pole (which is in the Arctic Ocean just north of Canada), not the geographic north pole.



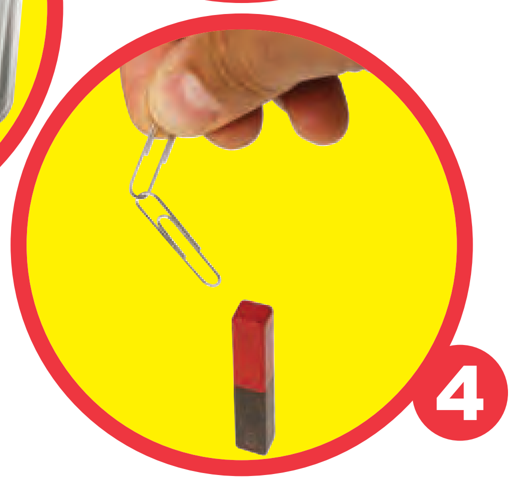
☐ # Project 46 Magnetic Fields

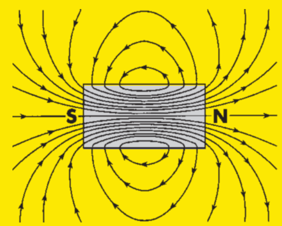
1. There is an area around a magnet where it can affect other objects, called a magnetic field. It is strongest at the ends of the magnet.
2. Slowly move your compass around the magnet and watch its pointer to see the magnetic field.
3. Shake the iron filings pack to spread the filings evenly. Move the magnet over the filings and you can see the magnetic field in them.
4. Loop two paper clips together. Hold them near the magnet and move them around it to see the magnetic field.





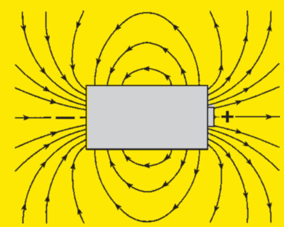



Magnet - magnetic field

A magnet has a magnetic field, and a battery has an electric field. The north and south poles of a magnet are comparable to the positive and negative terminals of a battery.

Electric and magnetic fields affect each other. If you place a magnet next to a radio your reception can be disturbed.

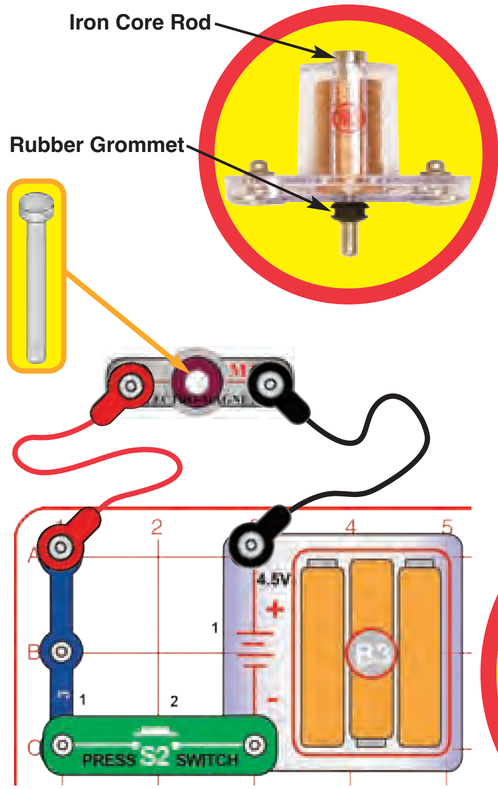


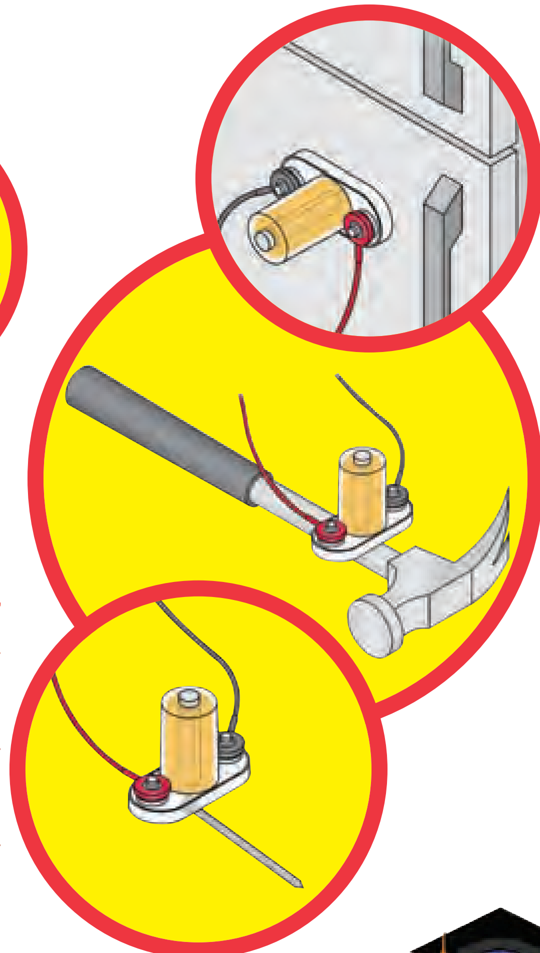

Battery - electric field


Permanent magnets are made by exposing iron (or other metals) to a much stronger magnetic field, usually from an electromagnet. Magnets can magnetize other materials (usually iron), concentrating their magnetic charges at opposite ends. This causes the magnetic attraction/ repulsion that you see. Magnetization can be temporary or long-lasting, depending on the materials and magnetic force used. For example, Paper Clips attracted to a magnet sometimes stick together after the magnet is removed. Most magnets can be demagnetized using heat or vibration.

Name some items that use magnets:

# Project 47 Electronic Magnet



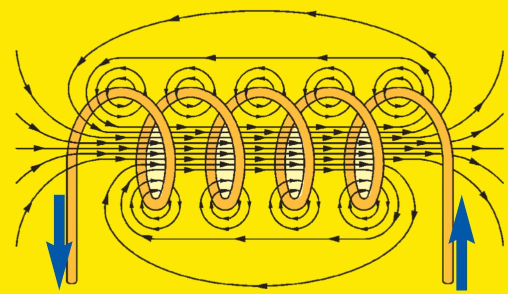



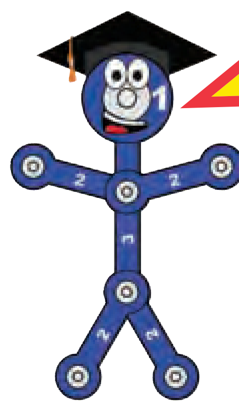
Build the circuit shown. Place the iron core rod inside the electromagnet (M3) and secure it with the rubber grommet. This project works best if you have new alkaline batteries.

Hold the electromagnet near something made of iron and push the switch (S2). While pressed, the electromagnet will attract small metal parts like nails or will stick to a hammer or refrigerator. Release the switch and the attraction disappears.

Pressing the switch turns on an electric current which transforms the electromagnet from an ordinary coil of copper wire into a magnet. An electronic magnet is much better than an ordinary magnet because you can turn it on or off with a switch!

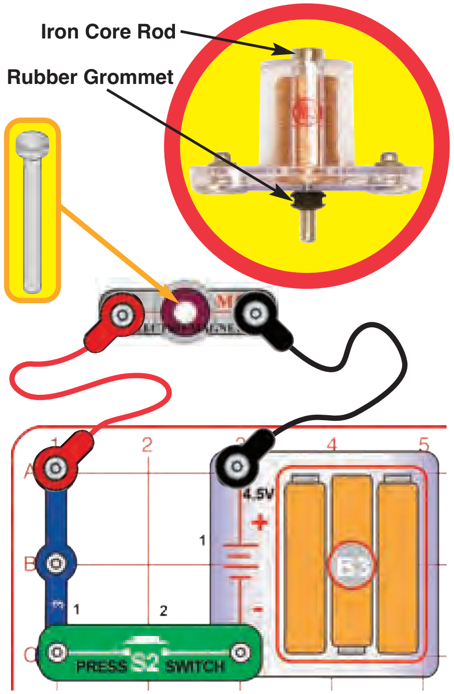
An electron current flowing in a wire has a tiny magnetic field. By looping a long wire into a coil the tiny magnetic field is concentrated into a large one. The strength of the magnetic field depends on how much current is flowing in the wire and how many loops of wire.

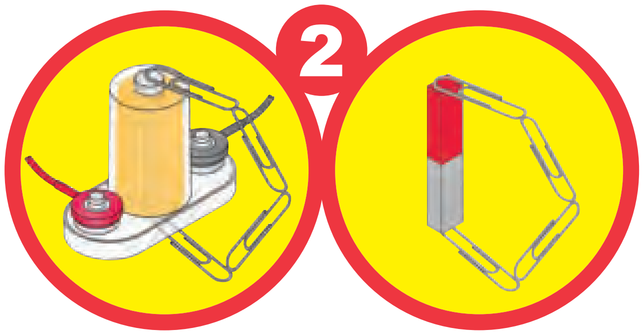


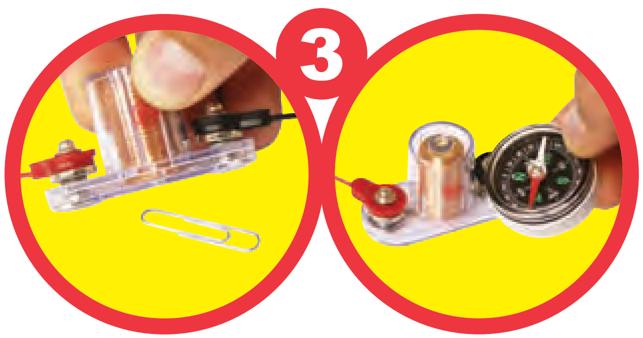


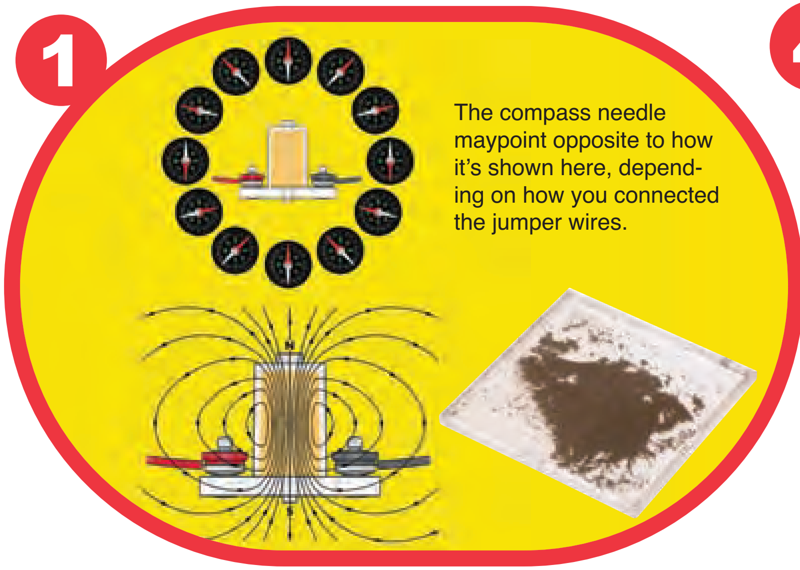
Names some advantages and disadvantages of electronic magnets compared to permanent magnets.

# ☐ Project 48 Electromagnet Magnetic Field

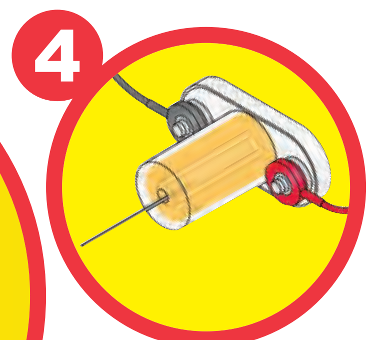



The compass needle maypoint opposite to how it's shown here, depending on how you connected the jumper wires.

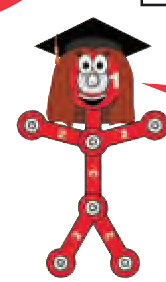



1. Use the circuit from the preceding project, with the iron core rod in the electromagnet (M3). An electronic magnet has a magnetic field just like an ordinary magnet. Hold your compass next to the electromagnet and push the press switch (S2). Move the compass all around the electromagnet and watch where the compass points.
2. The magnetic field created by a magnet occurs in a loop. You can see this using paper clips.
3. Remove the iron core rod from the electromagnet. Now push the press switch again and try to pick up things with the electromagnet. The attraction is now very weak.

   The iron core rod concentrated the magnetic effects of the electromagnet. You can use the compass to see that electronic field is now much weaker.
4. Materials made of iron concentrate their magnetic effects at both ends. The center of the material is magnetically neutral because the attraction from each end is the same.

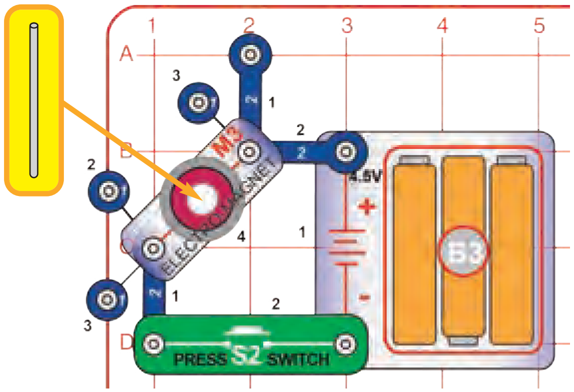
   The magnetic field created by the electromagnet works the same way. It is strongest at both ends but neutral in the center. But the electromagnet is hollow - so iron at one end will be sucked into the middle.

   Lay the electromagnet on its side. Hold the thin rod next to the center hole and push the press switch to suck it inside. Hold the switch and gently pull the rod to see how much suction the electromagnet has.

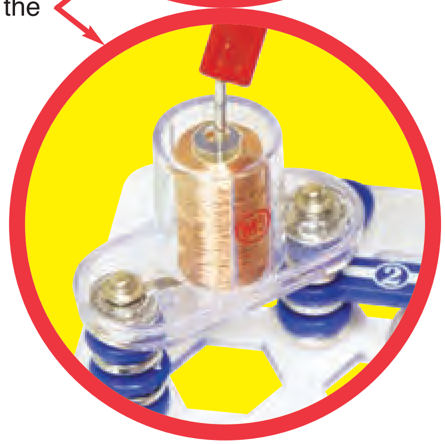


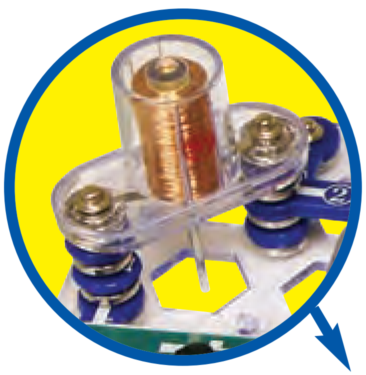
You can turn on the switch to pick up things with the electromagnet, then release the switch to drop them. This is done with large magnets at factories or junk yards.

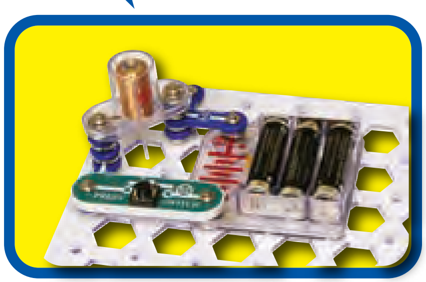
# ☐ Project 49 Electromagnet Tower




**Note:** the magnet poles may be opposite of how it's shown here, depending on how you connected the electromagnet (M3).



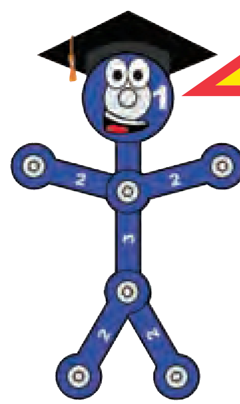




Build the circuit as shown and drop the thin rod into the electromagnet (M3). Push the press switch (S2) several times. The thin rod gets sucked into the electromagnet and can be suspended there, or you can bounce it up and down.

When you push the press switch, the thin rod gets sucked up and wiggles up and down until settling in position just below center. Measure how high you get the thin rod to go, then try with old and brand new batteries. Remove a 1-snap from under each side of the electromagnet, then see how high the thin rod will go.

**Part B:** With the switch pressed and the thin rod suspended in mid-air, hold the magnet near the thin rod. Notice that the red (N) side of the magnet repels the thin rod but the black (S) side attracts it.



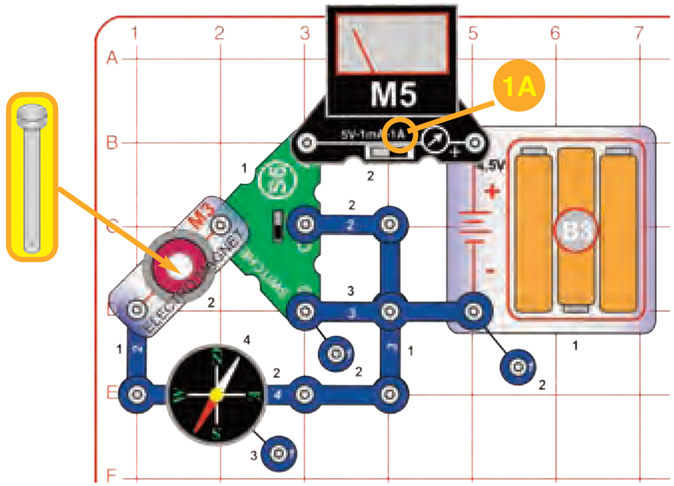
Coils of wire store energy in a magnetic field, while static electricity stores energy in an electric charge across a material (an electric field).

Magnets concentrate their magnetic effects at both ends. The magnetic field is strongest at both ends but neutral in the center, because the attraction from each end is the same. But the electromagnet is hollow - so iron at one end will be sucked into the middle.

The magnetic field produced by the electromagnet has direction just like a normal magnet. Opposite ends of magnets attract, while like ends repel each other.

Find two magnets in your home. Try putting them together, then flip one around. They will attract one way but repel the other way.

# Project 50 — Electromagnet Direction

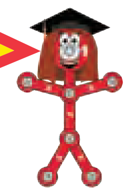



Build the circuit shown. Place the iron core rod in the electromagnet (M3), and set the meter (M5) to the 1A scale. Set the switcher (S6) to the top or bottom position. The meter shows a current is flowing and the compass needle is attracted to the electromagnet.

Now set the switcher to the opposite side (left or right). The other side of the compass needed is attracted to the electromagnet (magnetic field is reversed). In some cases you may need to hold the compass closer to the electromagnet for the needle to change sides.

If you remove the iron core rod from the electromagnet, the compass needle attraction will be much weaker. Try moving the rod in and out while watching the compass.

The direction of a magnetic field from a current flowing in a wire (or coil of wire) depends on the direction of the electric current.

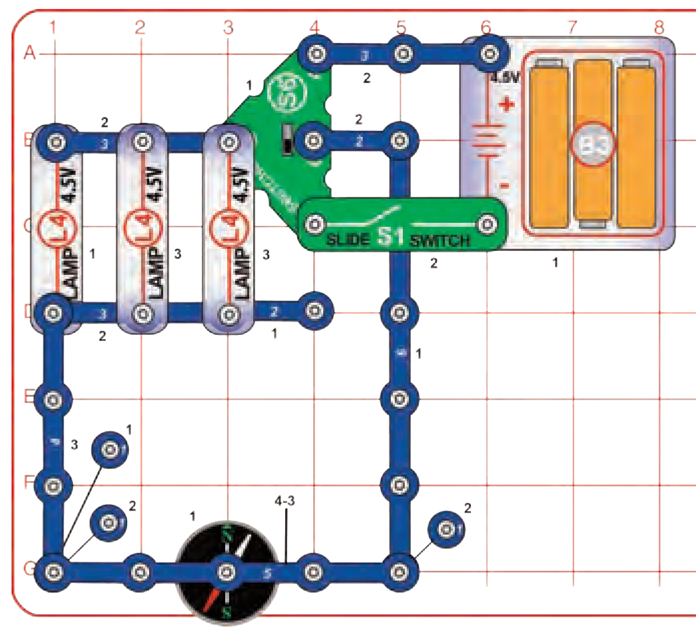


# Project 51 — Wire Magnet

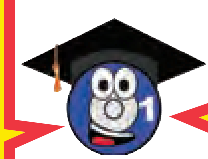
Build the circuit as shown. Note that the 5-snap wire is connected on level 4 on the left side and at level 3 on the right side, over the compass; make sure it is securely snapped. This circuit works best with new alkaline batteries. Keep the circuit away from any iron objects.

Turn on the slide switch (S1) and switch the switcher (S6) between the top and bottom positions repeatedly while watching the compass. You should see the compass needle move a little - indicating a change in the magnetic field from the 5-snap wire (the "wire magnet"").

**Note:** The magnetic field produced by the wire is very small. If the compass needle does not move, check your batteries (B3) and make sure you are not close to any iron objects.



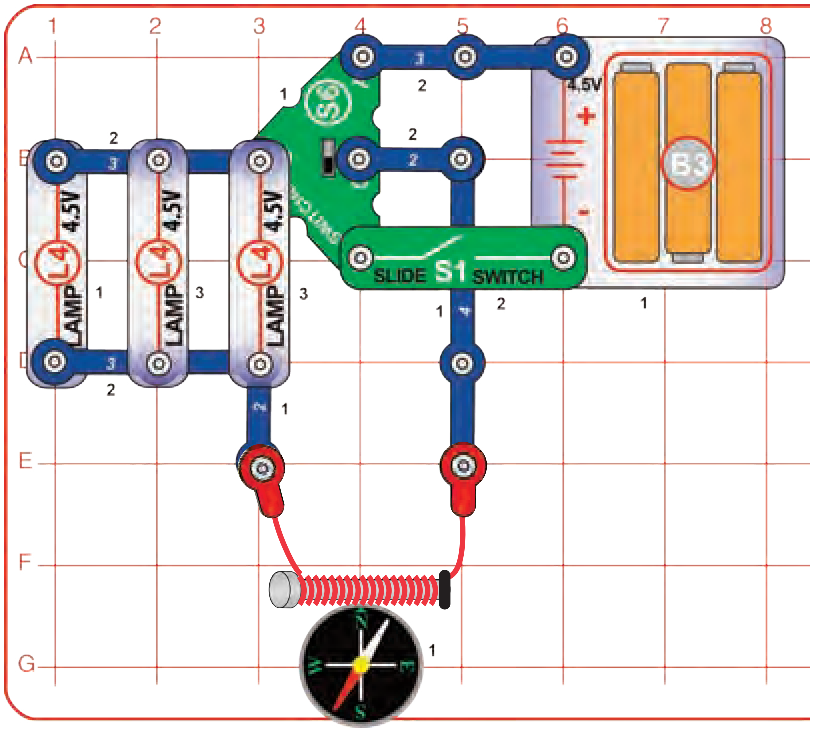

Any electric current flowing in a wire has a magnetic field, but it is usually very small. An electromagnet creates a noticeable magnetic field by looping the wire very many times to concentrate the magnetic field from it.



The three lamps (L4) are in this circuit to limit the current; without them the circuit would have almost no resistance (since the only components would be switches and wires). Then the "wire magnet" would have a stronger magnetic field, but the higher current would trigger a safety fuse in your battery holder, which would quickly shut down the circuit.

# ☐ Project 52 Better Wire Magnet

**FOR ADVANCED USERS - ADULT SUPERVISION RECOMMENDED**



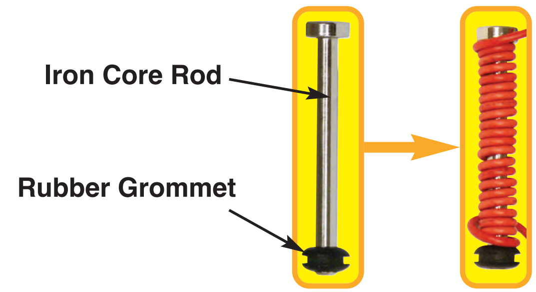

Build the circuit. Place the rubber grommet on one end of the iron core rod and wrap the red jumper wire tightly around it, as shown. Connect the red jumper wire to the circuit.

Turn on the slide switch (S1) and set the switcher (S6) to the top or bottom position. Move the iron core rod (with the red wire around it) around the compass and watch how it attracts the compass needle.

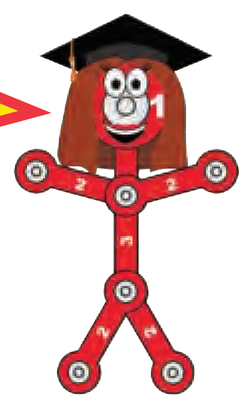
Switch the switcher between the top and bottom positions and watch the compass to see how the magnetic field has changed.

**Part B:** Now take off the rubber grommet and remove the iron core rod, but keep the red wire wound in a coil and connected to the circuit. Push the press switch and watch the compass while moving the coiled red wire around it. Now the compass needle has much less attraction to the red wire.

Part B

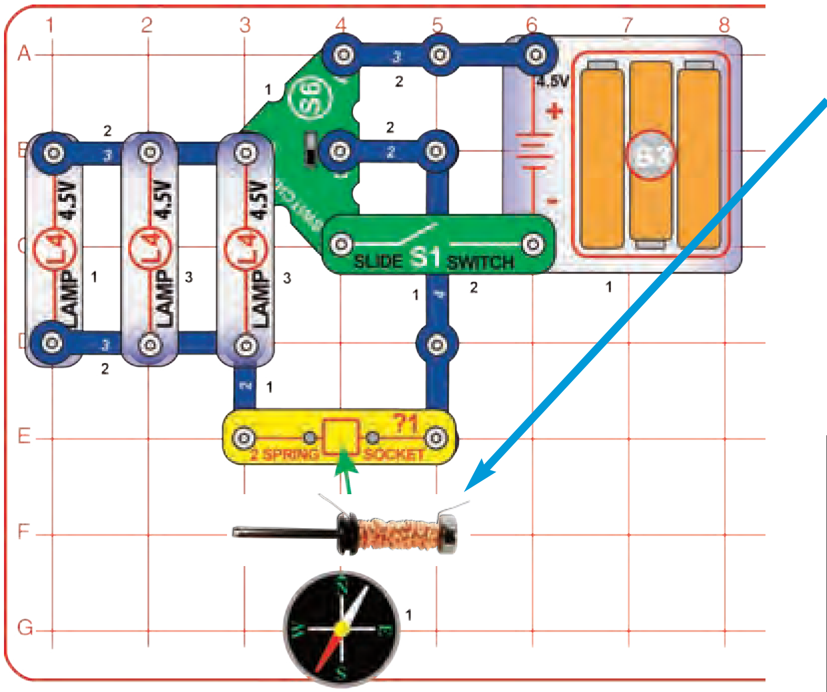



This circuit shows how wrapping a wire into a coil concentrates the magnetic field from the wire. The more loops of wire a coil has, the stronger the magnetic field produced. So if you only loop the jumper wire around the iron core rod a few times, the magnetic field will not be nearly as strong. You can also see how looping the wire around an iron core increases the magnetic field produced. Your M3 electromagnet is just like the coiled red wire except that it has many more loops, giving it a stronger magnetic field.



How could you make this electromagnet more powerful?

# Project 53 Build-Your-Own Electromagnet




The wire magnet in the preceding circuit is not very powerful because it only has a few loops of wire, but you can make a better one. Assemble the build-your-own electromagnet (the thin wire wrapped around an iron core rod, with the ends connected to the 2-spring socket (?1)) using the instructions on page 5.

Connect the build-your-own electromagnet to the preceding circuit as shown here. Turn on the slide switch (S1) and set the switcher (S6) to the top or bottom position. Move the compass around the build-your-own electromagnet and watch how its needle is attracted.

Switch the switcher between the top and bottom positions and watch the compass to see how the magnetic field has changed.

How does the build-your-own electromagnet used here compare with the wire magnet used in the preceding project? Which is more powerful?

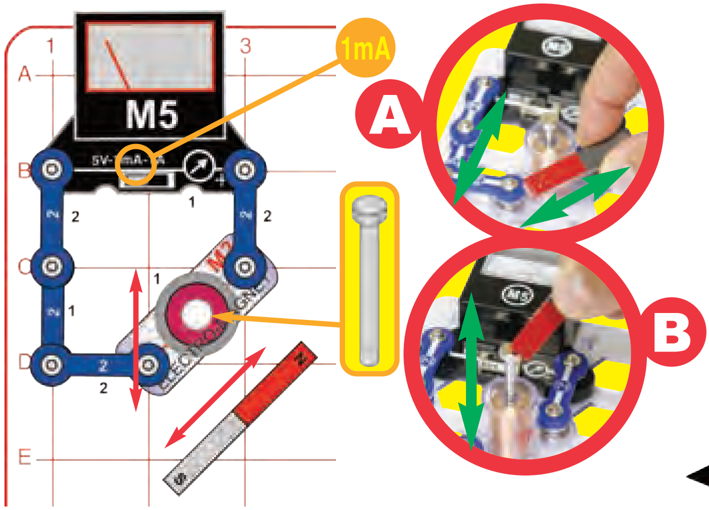
How does it compare to the M3 electromagnet used in project 49?

# Project 54 Build-Your-Own Electromagnet (II)

Use the preceding circuit. Connect several paperclips into a chain and hold near the build-your-own electromagnet, studying the attraction. See if the electromagnet can pick up paperclips. Lay the iron fillings case on top of your electromagnet and change the magnetic field using the switcher (S6).

Your can also try these tests with the wire magnet from project 52.

# Project 55 Magnetic Induction



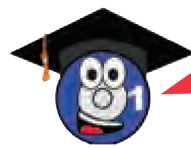

Build the circuit as shown. Place the iron core rod into the electromagnet (M3) and set the meter (M5) to the 1mA scale.

A. Move the magnet left-right or up-down near the electromagnet. You may see the meter pointer wiggle, which indicates a small current.

B. Place the magnet on the iron core rod and use it to move the rod up and down IN the electromagnet. The meter pointer should move or wiggle slightly, showing a current is produced.

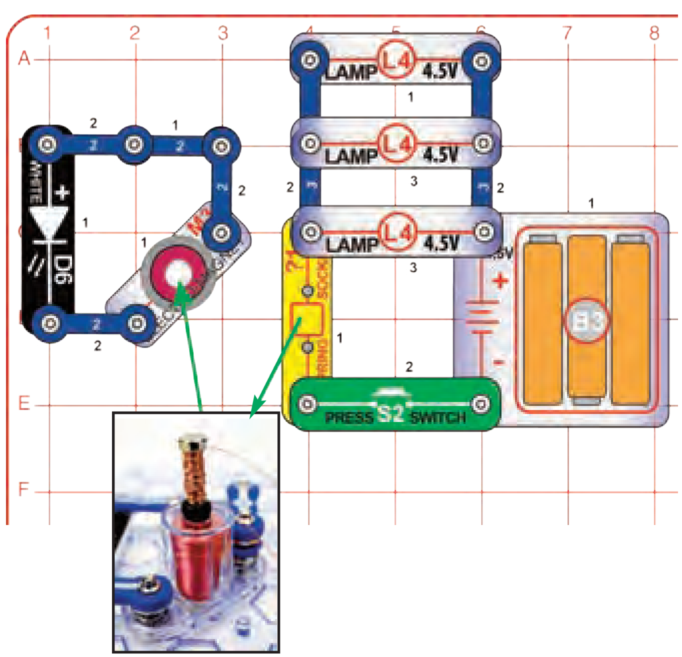
Try removing the iron core rod from the electromagnet and see how the current is affected.

If you have a more powerful magnet in your home, use it in place of the Snap Circuits® STEM magnet. A more powerful magnet will create a larger current and be easier to measure.



The meter shows an electric current even though no batteries are used. By moving the magnet near the coil, you have induced (created) a current in the circuit. You have made electricity from magnetism - an electric generator! This simple concept is very important to our society. High pressure water from dams or steam (often heated by burning oil or coal) spins large magnets in coils to produce much of the electricity that runs our cities.

# Project 56 Electromagnetic Induction




Build the circuit as shown. Assemble the build-your-own electromagnet as per the instructions on page 5. Push the wire on the build-your-own electromagnet to one side and insert its iron rod into the top of the electromagnet (M3), as shown.

Push the press switch (S2) and watch the white LED (D6) when you press or release the switch; you should see a flash. The flash on the LED is easier to see if you look directly into the LED and block the light from the lamps with your hand. If you don't see any flash on the LED then you may need to push the iron rod further into the M3 electromagnet.

Pull the iron rod out the M3 electromagnet. The LED should no longer light when you press the switch, because the magnetic connection between the circuits is broken now.

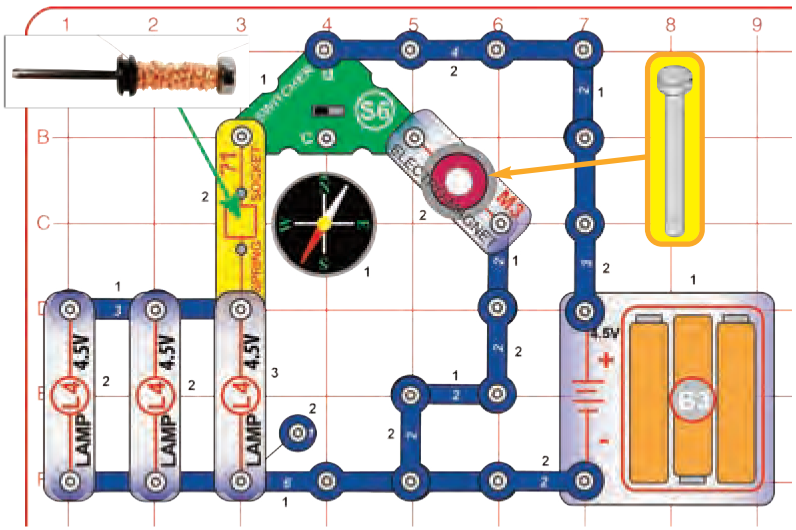
You can replace the build-your-own electromagnet with the one made with the red jumper wire in project 52 (wind the red wire on one side of the rod), but it will not work as well because it has less windings.

You can also replace the white LED with the meter (M5, on the 1mA setting).

Notice that this only works when the magnetic field is changing due to you pressing or releasing the switch. If you keep the switch pressed the magnetic field is constant, and no current is induced in the electromagnet to light the LED.

**Note:** The lamps (L4) are in the circuit to limit the current through the build-your-own electromagnet. If you replace one of the lamps with a 3-snap wire then the LED may flash a little brighter, but you should only press the switch briefly because pressing it makes a short circuit and may activate the fuse (see project 9 for more details).

# Project 57 Electromagnet Challenge



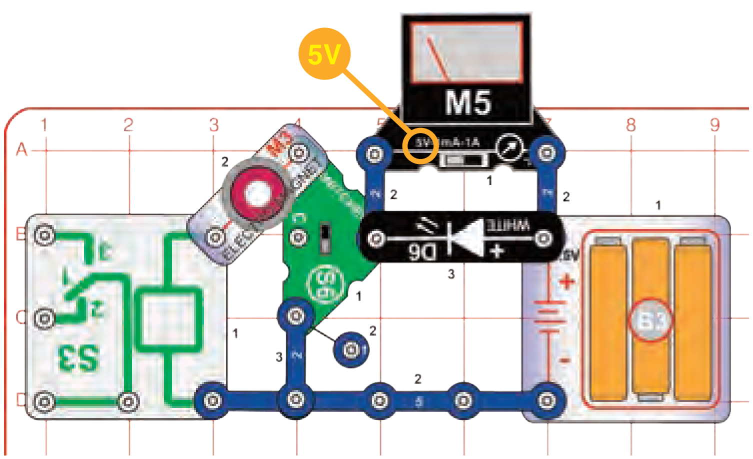

Assemble the build-your-own electromagnet (the thin wire wrapped around an iron core rod, with the ends connected to the 2-spring socket (?1)) using the instructions on page 5. Build the circuit, place the iron core rod in the electromagnet (M3).

Set the switcher (S6) to the left position to turn on the build-your-own electromagnet, set it to the right position to turn on the M3 electromagnet, or set it to the middle position to turn off the circuit. Move the compass around to compare the magnetic fields from the two electromagnets. Connect several paperclips into a chain and hold near each electromagnet, comparing them.

To turn on both electromagnets at the same time, connect a 3-snap wire between the 2-spring socket and the M3 electromagnet (over the switcher), and set the switcher to either the left or right position.

This circuit isn't really a fair comparison between the build-your-own and M3 electromagnets, because the build-your-own electromagnet is in series with the lamps (L4). The lamps limit the current through the build-your-own electromagnet (to avoid triggering the safety fuse), but also lower its power. The M3 electromagnet has enough resistance to avoid triggering the safety fuse.

# Project 58 Coil Resistance




Build the circuit shown and set the meter (M5) to the 5V setting. Set the switcher (S6) to the bottom position; the meter shows that the full battery voltage is across the white LED (D6, and the LED is very bright.

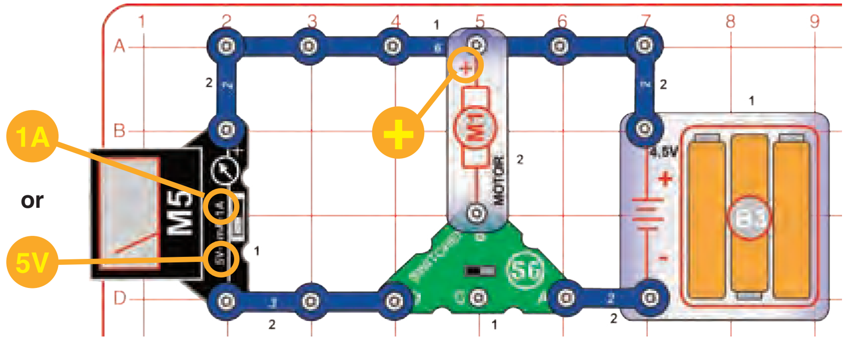
Now set the switcher to the top position to place the electromagnet (M3) and relay (S3) in series with the white LED. The voltage is a little lower now, and the LED is not as bright.

Next, replace the white LED with a lamp (L4). Compare the difference in lamp brightness with the switcher in the top and bottom positions.

The wire in the coils of the electromagnet and relay is long enough to have noticeable resistance; this resistance makes the white LED a little less bright, and prevents the lamp from lighting at all.

☐ 

# Project 59 Generator




SET THE SWITCHER (S6) TO THE MIDDLE POSITION BEFORE COMPLETING THE CIRCUIT. Build the circuit as shown, leave the fan off the motor (M1). Set the meter (M5) to the 5V scale for now.

Set the switcher to the right position to get the motor spinning, then set it to the left position and watch the meter to see how much voltage is produced.

Next, set the meter to the 1A scale and set the switcher to the right for a few seconds, then set it to the left and watch the current produced.

**Part B:** Put the fan on the motor and repeat the above tests to see what voltage and current are produced with the fan on the motor.

This circuit uses the batteries (B3) to get the motor spinning, then disconnects the batteries and uses the motor as a generator. A **generator** uses mechanical motion (here the spinning motor shaft) to create electricity (a current in a coil in the motor). The meter shows how much current and voltage are produced by the spinning shaft, with and without the fan.

**WARNING:** Do not lean over the motor.

**WARNING:** Moving parts. Do not touch the fan or motor during operation.

Compare the electrical energy produced by the generator (the motor): Is the voltage higher with or without the fan?

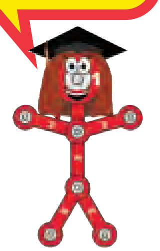
Is the current higher with or without the fan?

Does the voltage/current last longer with or without the fan?

☐ 

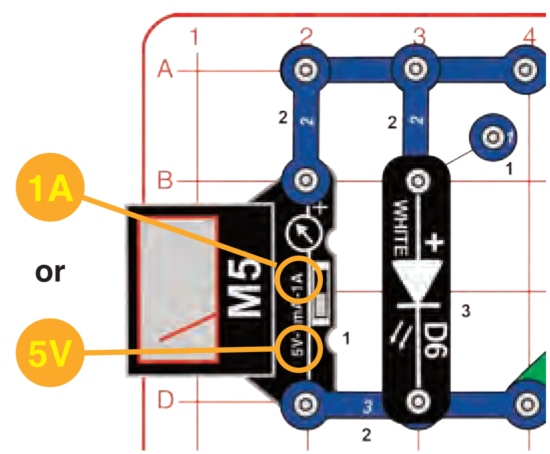
# Project 60 Generator with Light

The white LED needs about 3V to turn on, so should get bright without the fan, but may not light at all with the fan. The lamp needs a sustained high current to heat up its filament enough to produce light.

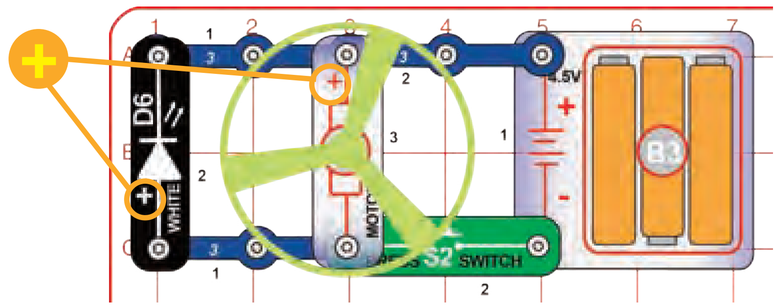


Add the white LED (D6) to the preceding circuit, as shown. Set the switcher to the right to get the motor spinning, then set it to the left and watch the white LED. Do it both with and without the fan on the motor, comparing the light from the LED.

If you replace the white LED with the lamp (L4), how bright will the lamp get? (Try it, both with and without the fan.)



☐ # Project 61 Motor with Flashes




Build the circuit shown and watch the white LED (D6) as you push and release the press switch (S2). Notice that even though the LED is connected backwards, it is flashing dimly while the fan is spinning, and then flashes brightly when you release the press switch.

You can also try this without the fan, or holding the motor top so it can't spin (but don't touch the motor top while it is spinning).

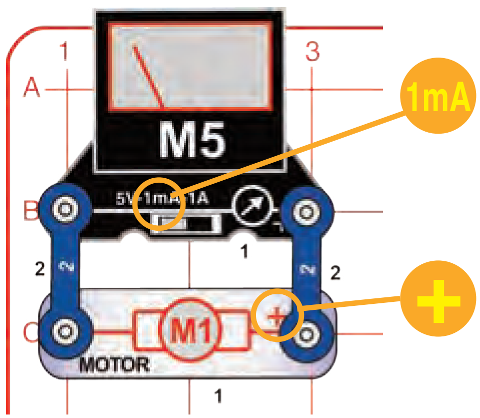
As the motor shafts spins it produces small voltage spikes (both positive and negative), which can be enough to dimly light the LED.

When you release the switch (turning off power to the motor), a magnetic field in it collapses, releasing energy that lights the white LED.

**WARNING:** Moving parts. Do not touch the fan during operation.

**WARNING:** Do not lean over the motor.

☐ # Project 62 Make Your Own Generator

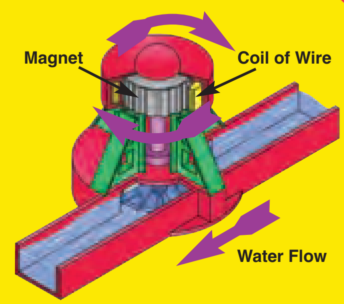



Build the circuit and set the meter (M5) to the 1mA scale. Spin the motor (M1) top clockwise with your fingers and watch how much current is produced. (Clockwise means in the direction in which the hands of a clock rotate.)

Now spin the motor in the other direction (counter-clockwise). You won't see much current produced now because it is produced in the other direction - the meter needs to be flipped around. Instead of flipping the meter around, flip the motor around to see this.

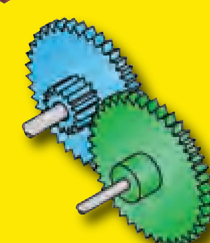
Name some products in your home that have a generator.

This circuit is a true generator, using motion (and magnetism) to make an electric current.In electric power plants, the same thing happens but on a much larger scale. High-pressure steam or water spins a shaft, which uses magnetism to make an electric current in a coil of wire.




Notice that this circuit used the 1mA meter setting while the preceding circuit used the 1A setting (1000 times greater). You can produce a much higher current by spinning the shaft much faster.

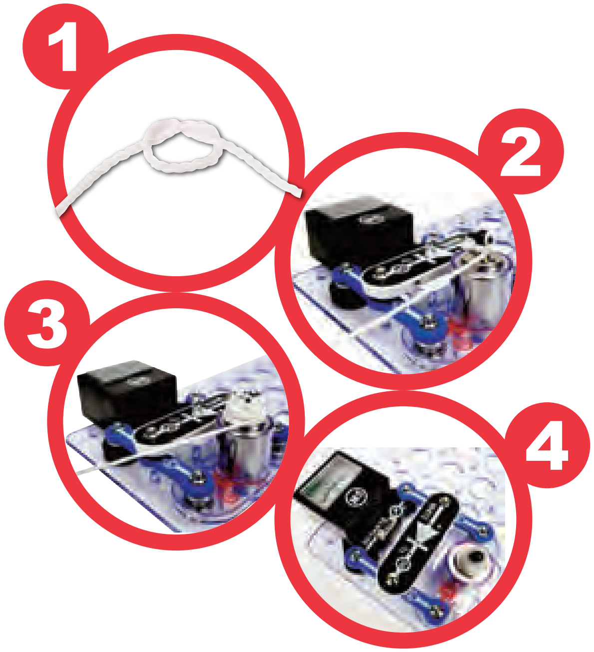
Hand-cranked generators like this are used in some flashlights instead of batteries. They use gears to spin the shaft much faster.

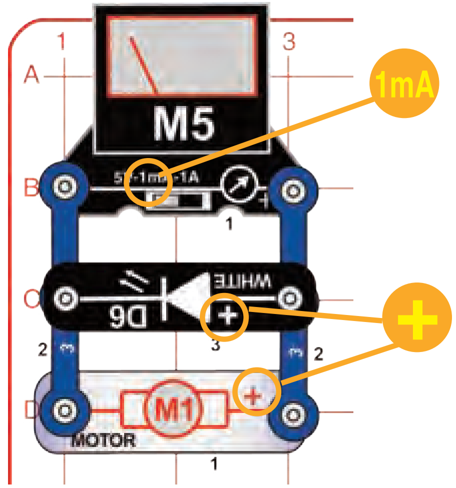


Gears are used between two wheels or shafts. One wheel spins at low speed but with great force, while the other wheel spins at high speed but with much less force. This can increase efficiency or give greater control.

# ☐ Project 63 — High Speed Generator

**FOR ADVANCED USERS - ADULT SUPERVISION RECOMMENDED**




Build the circuit and set the meter (M5) to the 1mA scale. Using the string, make a small loop at one end and put it on a prong of the motor (M1) top. Wind a few feet of the string around the motor shaft (wind it so that pulling the string will spin the motor shaft clockwise).

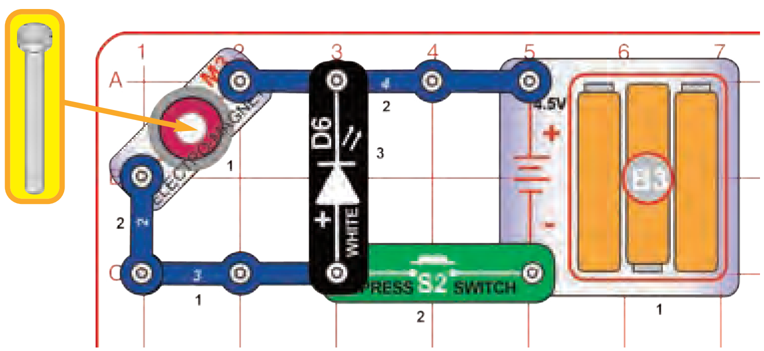
Pull the string gently but fast, watching the white LED (D6) and the current produced in the meter. If you wind the string well and pull it fast, you can briefly light the LED. Get an adult to help with this if needed.

The LED will light more easily if you remove the meter and connect the LED where the meter was.

A spare motor top is included with this kit in case you break any of the prongs on the motor top. Use a screwdriver to pry off the broken piece, then push the new one on.

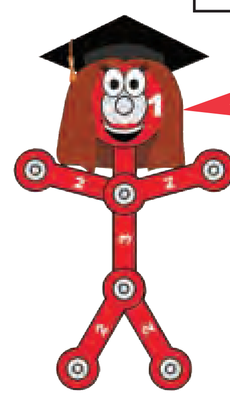
This circuit shows how much more current is produced when you spin the motor shaft faster.

# ☐ Project 64 — Magnetic Energy Released



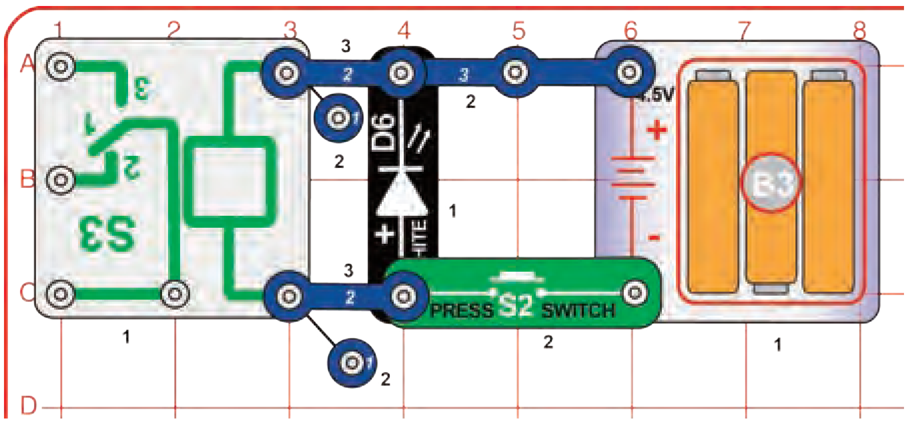

Build the circuit, and place the iron core rod into the electromagnet (M3). Push and release the press switch (S2) while watching the white LED (D6). Try it with and without the iron core rod in the electromagnet.

How bright will the white LED flash if you remove the 2-snap wire from the circuit (to disconnect the electromagnet)? (Try it.)

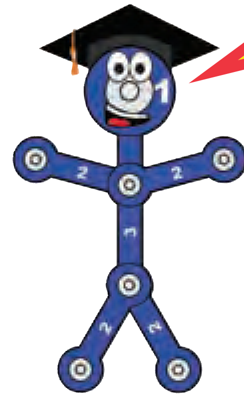


When you release the switch (turning off power to the electromagnet), the magnetic field collapses, releasing energy that lights the white LED. The magnetic field is stronger when the iron core rod is in the electromagnet. There is also a small flash in the LED when the circuit is turned on, setting up the magnetic field.

# Project 65 Relay Magnetic Energy Released




Build the circuit, then push and release the press switch (S2) while watching the white LED (D6).



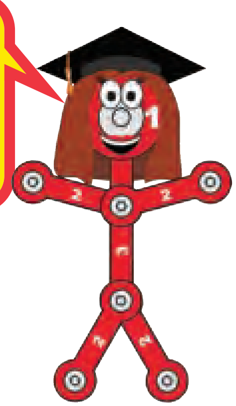
The relay (S3) has a coil with a magnetic field, just like the electromagnet (M3). The lamp does not have a coil or a magnetic field. so the white LED will not light with the lamp in the circuit.

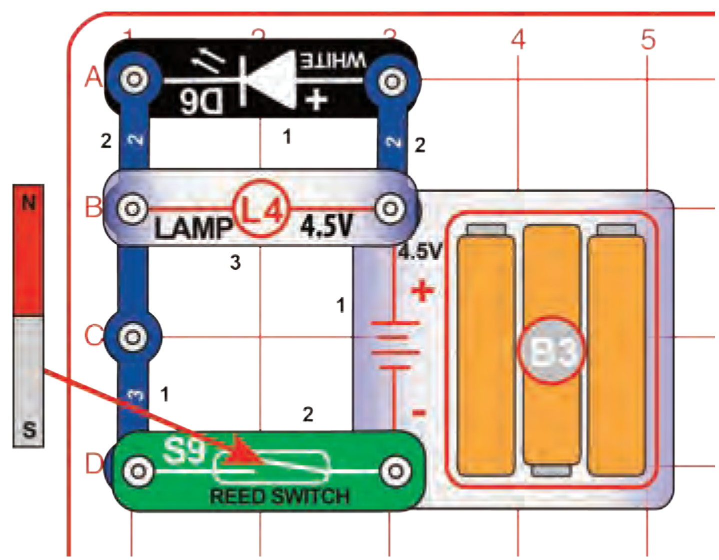
Replace the relay (S3) with the lamp (L4). Does the white LED flash?

# Project 66 Reed Switch

Place the magnet next to the reed switch (S9) to activate it, turning on the lights (D6 & L4).

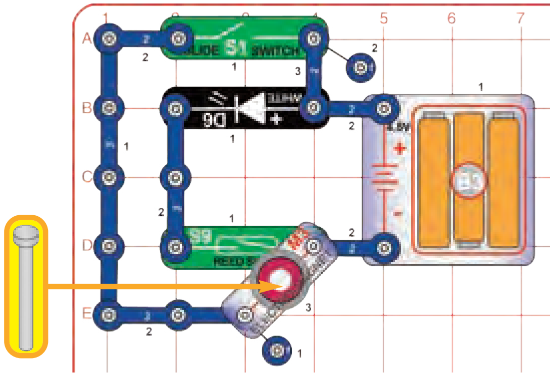
The reed switch is an electrical switch that can be controlled by a magnet. It has two metal contacts close together inside a glass tube. The magnetic field from the magnet makes the contacts come together, completing a circuit just like other switches do.






What could you use a reed switch for?

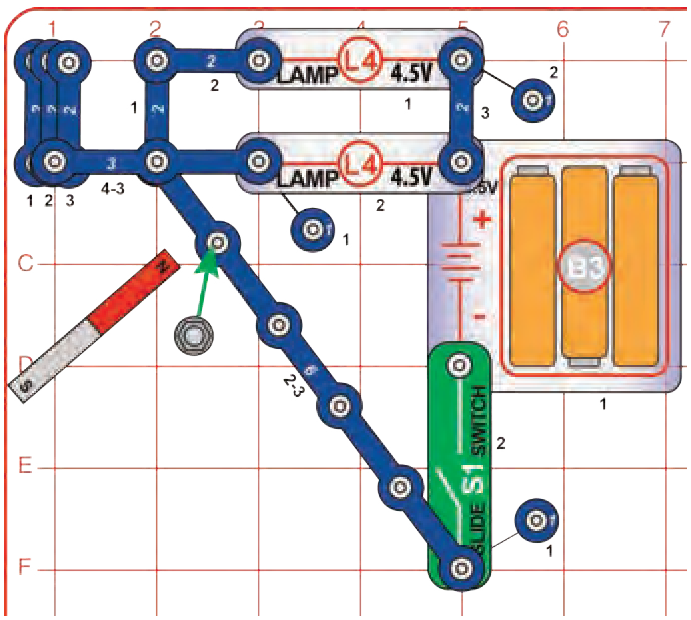
# ☐ Project 67 Reed Switch with Electromagnet




Build the circuit as shown, and turn on the slide switch (S1). The electromagnet (M3) should be activating the reed switch (S9), which turns on the white LED (D6). Raise the iron core rod in the electromagnet (or remove the rod) to turn off the LED.

You can also remove the electromagnet and instead connect it to the circuit using the red & black jumper wires, then hold it near the reed switch to turn on the LED.

# ☐ Project 68 Build-Your-Own Reed Switch

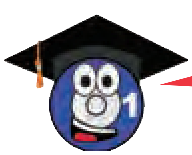



Build the circuit as shown. There are three 2-snap wires at base grid locations A1-B1. Snap the 6-snap wire at base grid location F5, then place it so it lays on the snap at grid location B2 (DO NOT SNAP IT ON). A 3-snap wire is placed across grid locations B1-B3, with the left side on lever 4 and the right side on level 3; sure it is securely snapped. Place the nut snap on the 6-snap wire.

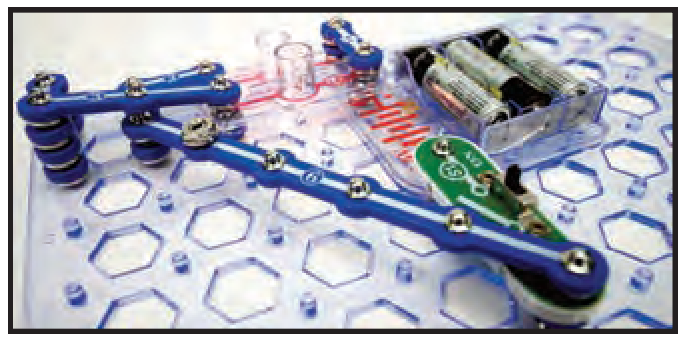
Turn on the slide switch (S1); the top lamp (L4) lights.

Now hold the magnet just above the nut snap to attract it; this should turn off the top lamp. Use the magnet to raise the 6-snap wire until its loose end contacts the bottom of the 3-snap wire, which should turn on the bottom lamp.

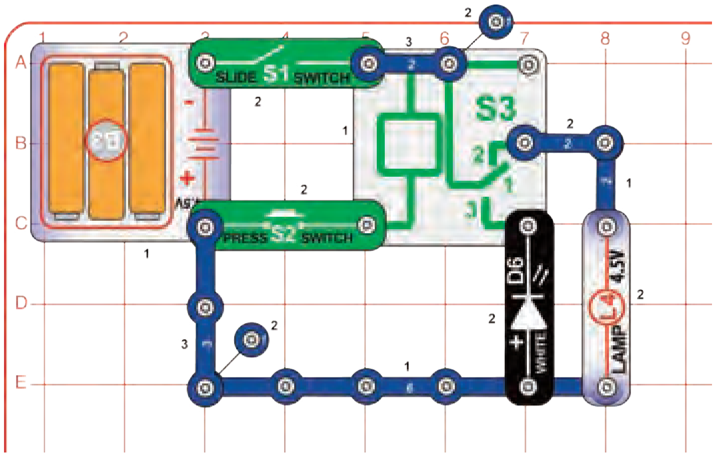
Moving the magnet up and down above the nut snap should attract and release it, raising and lowering the 6-snap wire, flipping the lamps on and off.



Reed switches are used as proximity switches and in door and window sensors for burglar alarms. Speed sensors on bicycles use a reed switch to detect when a magnet on the wheel passes the sensor.



# Project 69 Relay

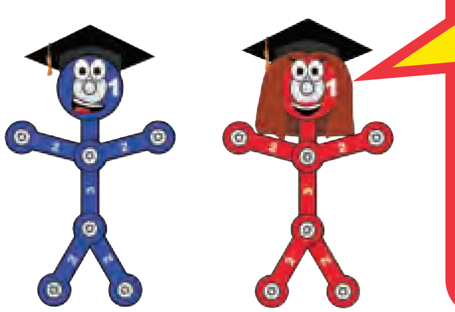



Build the circuit and turn on the slide switch (S1); the lamp (L4) is on. Now push the press switch (S2) to activate the relay (S3); you hear a click as the relay switches power from the lamp to the white LED (D6).

You can replace the white LED with the motor (M1) and fan if you like.

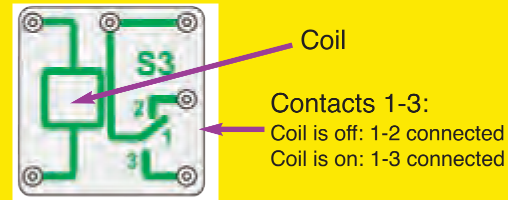
List some devices in your home that use relays.

What is the main reason to use a relay?

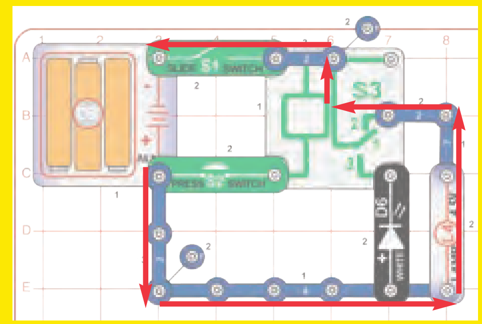


**Relays** are electronically controlled switches, which allow a low-voltage circuit to control a high-voltage or high-current circuit.

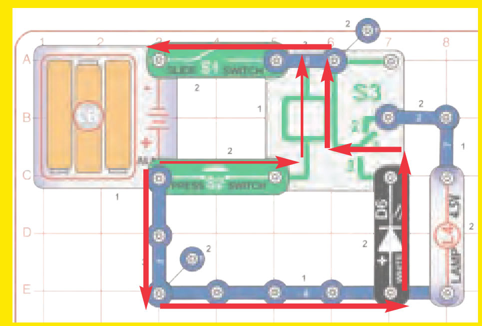
Relays use magnetism to open or close a mechanical switch. Look at the relay symbol in the drawing. The relay contains a coil, and a set of contacts that are switched when the coil is activated.




With the press switch off, the relay is off, so the 1 and 2 contacts are on the relay are connected, and current flows through the lamp.



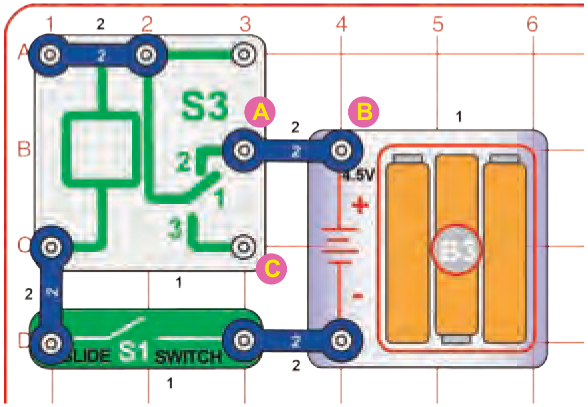
With the press switch on, current flows through a coil in the relay, which magnetically switches the relay's contacts. Now the relay's 1 and 3 contacts are connected, and current instead flows through the white LED.



The current through the press switch activates the coil in the relay, which changes the relay connection from contacts 1-2 to contacts 1-3. There is no electrical connection between the relay's coil and 1-2-3 contacts, so those circuits do not affect each other, and can operate at different voltages. In this way a low-voltage circuit can control a high-voltage or high-current circuit.

Most industrial machinery and home appliances operate at voltages of 120V or higher. However, the circuits used to control them (either automatically or by interfacing with people) operate at low voltages. These voltages are usually less than 6V and very rarely higher than 50V. Relays allow these low voltage devices to control high voltage machinery and appliances.

# ☐ Project 70 Relay Buzzer



Build the circuit and turn on the slide switch (S1). The relay (S3) makes a buzzing sound.

What will happen if you remove the 2-snap wire that connects the points marked A & B, and instead connected the red jumper wire between points B & C? (Try it.)

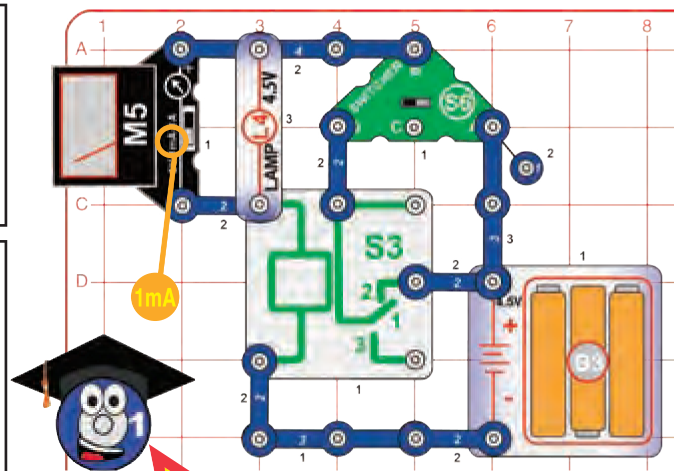
The sound is caused by the relay's contacts opening and closing at a fast rate. Look at the "1-2-3" marking on the relay symbol in the drawing. What's happening is this: when the switch is turned on, current flows through the relay's coil, causing contact 1 to disconnect from contact 2 and connect to contact 3. This opens the circuit and stops current from flowing through the coil, which causes contact 1 to move back to contact 2. This closes the circuit and current flows through the coil again, and the cycle repeats continuously.

# ☐ Project 71 Relay Buzzer Meter

This circuit is similar to the preceding one, but adds the meter (M5) to measure the current. Set the meter to the 1mA setting. Set the switcher (S6) to the right position to turn the relay (S3) on, set the switcher to the left position to make the relay turn on and off continuously (producing a buzzing sound), and set the switcher to the middle position to turn the circuit off. Compare the meter current for each switcher position. The lamp (L4) will not light.

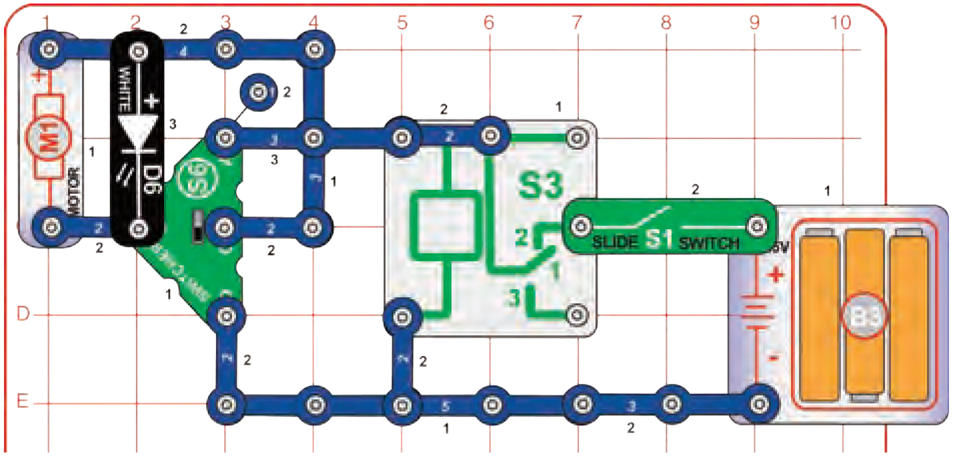
Why is the meter current lower when the relay is buzzing?

Use Ohm's Law (Resistance = Voltage / Current) to determine the resistance of the relay's coil when the relay is on continuously. The voltage is about 4.5V, and see Snappy's note about the meter current. (The resistance should be 50-100 ohms, but your results will vary due to the limited accuracy of your meter, and the battery voltage may not be exactly 4.5V.)



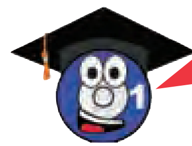
The current is actually more than 1mA (about 50mA when the relay is on continuously), but the lamp is used here to adjust the current to be within the 1mA range on the meter. To see the actual current, remove the lamp and set the meter to the 1A setting; it should be slightly above 0.

# Project 72 Alternating Voltage




Build the circuit as shown (leave the fan off the motor), and turn on the slide switch (S1); you hear a buzzing sound as the relay (S3) turns on and off rapidly. Set the switcher (S6) to the top or bottom position to turn on the motor (M1) and white LED (D6).

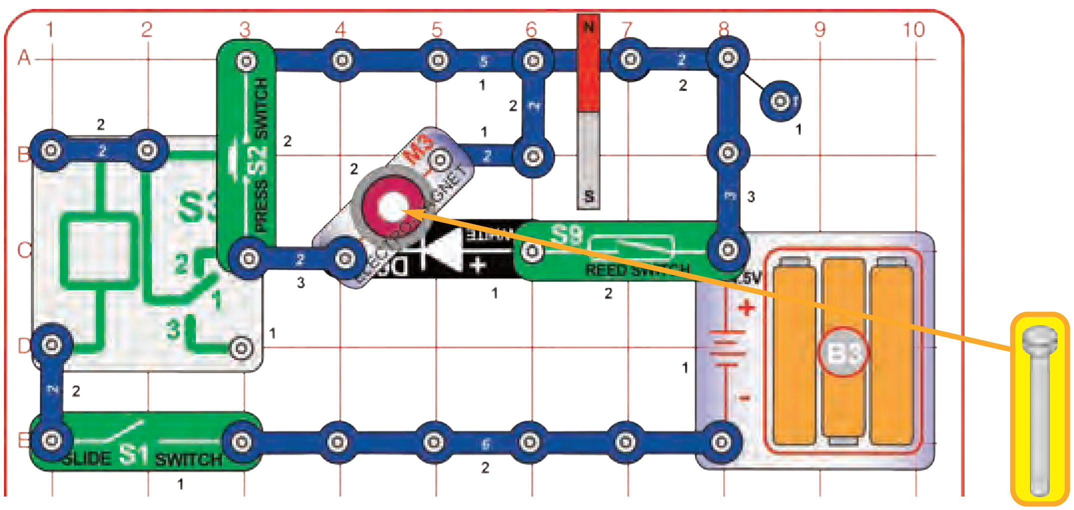
In project 85 and others the LED only works in one of the switcher (S6) settings, but in this circuit it works in either the top or bottom S6 setting. Why?



The electricity supplied to your home and school by your local electric company is not a constant voltage like that from a battery. It averages about 120V but is constantly changing, due to the design of the generators that produce it. This is not a problem, since all equipment that uses it accounts for this change. Its frequency is 60 Hz.

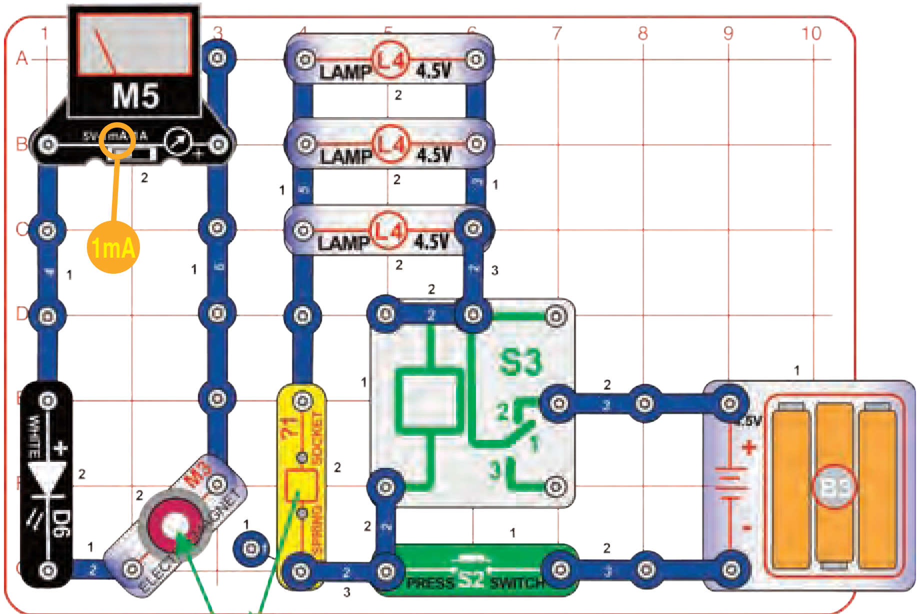
An electrical current that is changing is called an **alternating current**, or **AC**. Because of this, the power from the electric company is also called AC power. An electrical signal that is constant and unchanging is called a **direct current**, or **DC**. The power from a battery is also called DC power.

# Project 73 Super Buzzer




Build the circuit as shown, and turn on the slide switch (S1); you may hear a buzzing sound as the relay (S3) turns on and off rapidly. Adjust the sound by pushing the press switch (S3), raising and lowering the iron core rod in the electromagnet (M3), or by placing the magnet near the reed switch (S9) to activate it and the white LED (D6); try combinations of these and see how the sound changes.

# ☐ Project 74 Transformer




Build the circuit as shown. Assemble the build-your-own electromagnet as per the instructions on page 5. Push the wire on the build-your-own electromagnet to one side and insert its iron rod into the top of the electromagnet (M3), as shown. Set the meter (M5) to the 1mA setting.

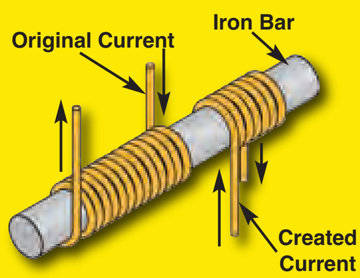
Push the press switch (S2) and hold it down for a few seconds; the relay (S3) makes a buzzing sound as its contacts open and close quickly. Watch the white LED (D6) and meter, then reverse the directions of the LED and meter and push the switch again (it works better in one direction, depending on how you wired the build-your-own electromagnet). If the LED does not light in either position then you may need to push the iron rod further into the M3 electromagnet.

Pull the iron rod out the M3 electromagnet. The LED should no longer light when you press the switch, because the magnetic connection between the circuits is broken now.

You can replace the build-your-own electromagnet with the one made with the red jumper wire in project 52 (wind the red wire on one side of the rod), but it will not work as well because it has less windings.

The buzzing sound produced by the relay is used to create a constantly changing magnetic field in the build-your-own electromagnet, which induces a current in the M3 electromagnet, which is seen on the LED and meter.

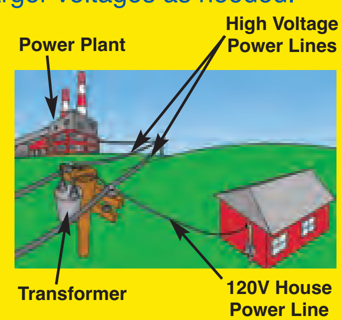
If a current through a coil can magnetize an iron bar, what if you had another coil from a different circuit wrapped around the same iron bar? The magnetization of the iron bar would create a current in the other circuit. This is a **transformer**, which allows one circuit to create a current in another circuit using magnetic fields.




Transformers allow circuits to be isolated from each other, since the connection between them is magnetic and not electrical. Transformers can also change the voltage by using coils with more or less loops of wire.

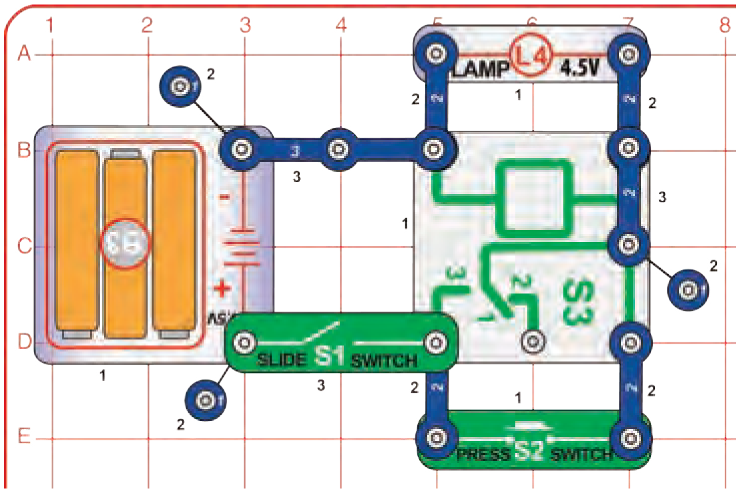
Typical Transformer

When electric power companies transport electricity across great distances (like between power generating plants and cities), they use very high voltages and low currents since this reduces power loss in the wires. Large transformers convert this to 120V, which is supplied to homes and offices. Many products (like computers) then use small transformers to convert this to smaller or larger voltages as needed.




A transformer is a magnetic bridge, since we use magnetism to cross an air gap that electricity cannot cross by itself.

# Project 75 Relay Memory

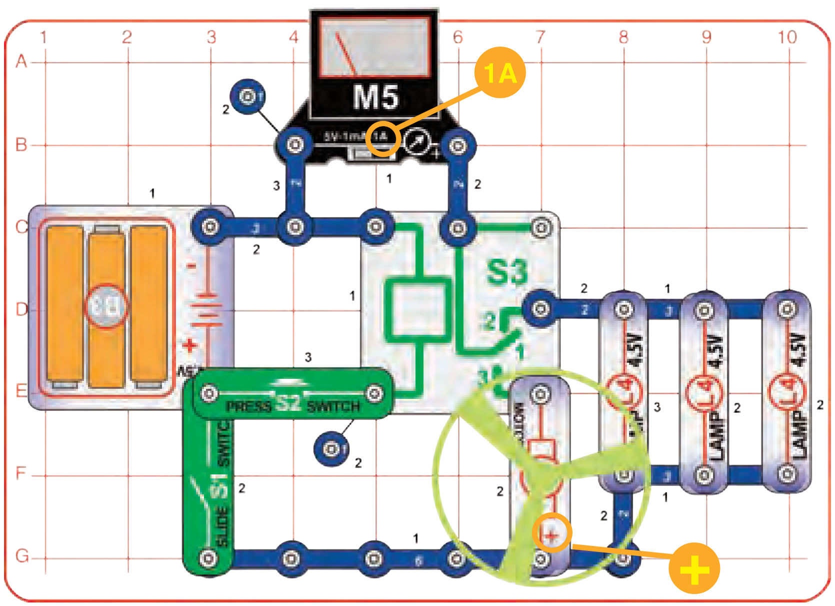


Build the circuit and turn on the slide switch (S1). Nothing happens. Now push the press switch (S2). The lamp (L4) comes on and stays on even after you release the press switch (the circuit "remembers" that you pushed the press switch). Turn off the slide switch to turn off the lamp.

Why is the lamp off until you push the press switch?

Why does the lamp stay on after you release the press switch? (Look at the explanation of how the relay works in project 8, and note that when the relay is on contacts 1 and 3 on the relay symbol in the drawing are connected.)

# Project 76 Relay Circuit



Build the circuit, place the glow fan on the motor (M1), and set the meter (M5) to the 1A setting. Turn on the slide switch (S1); the three lamps (L4) light and the meter measures the current.

Push the press switch (S2) to activate the relay (S3). The lamps turn off and the motor (M1) spins the fan.

Name an appliance in your home that uses a relay to switch lights or motors on and off.

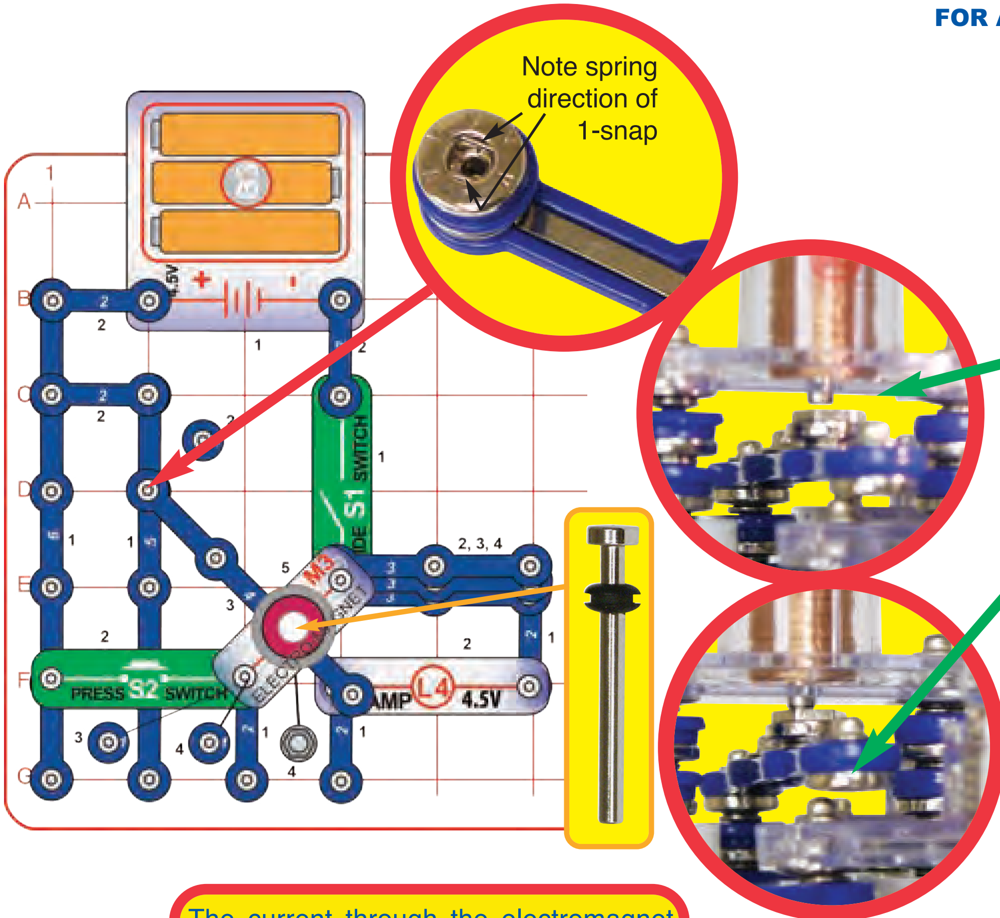
**WARNING:** Moving parts. Do not touch the fan during operation.

**WARNING:** Do not lean over the motor.

# Project 77

# Build Your Own Relay

**FOR ADVANCED USERS - ADULT SUPERVISION RECOMMENDED**



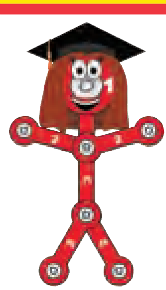

Build the circuit shown. Three 3-snaps are stacked together at base grid location E4-E6. Snap the 4-snap onto the 1-snap at grid location D2, then place it so it lays on the snap at F4 (DO NOT SNAP IT ON). Place the nut-snap on the 4-snap so it will be under the electromagnet (M3). This circuit works best with new alkaline batteries.

Place the rubber grommet on the iron core rod and push the rod into the electromagnet until it is just barely above the nut-snap without touching it (0.025 inches).

Turn on the slide switch (S1). The lamp (L4) should be on (if off, make sure the 4-snap is touching the 2-snap at F4 without being snapped there).

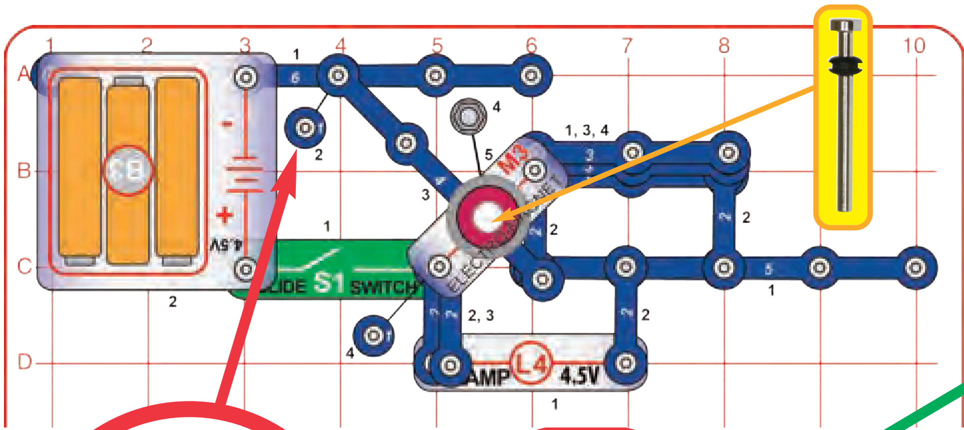
Push the press switch (S2) to turn on the electromagnet. This should raise the 4-snap slightly and turn off the lamp (adjust the position of the grommet on the rod if it does not). If you still can't get it to work, rotate the 1-snap at location D2 to the proper spring direction as shown, this may make the 4-snap move more easily.

The current through the electromagnet makes a magnetic field that attracts the nut-snap, which breaks the circuit to the lamp.

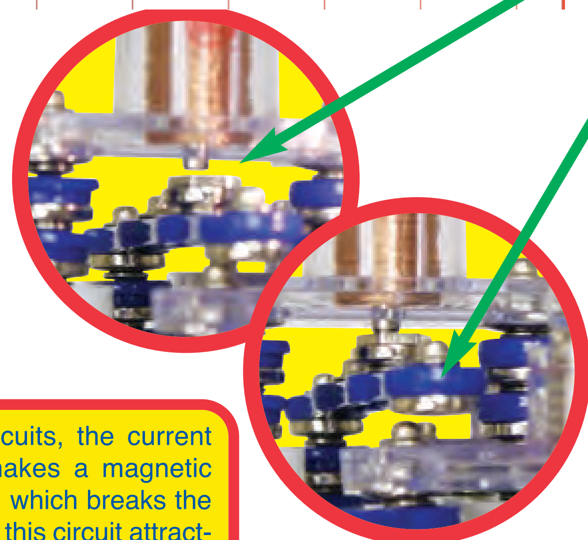


# ☐ Project 78 — Build Your Own Buzzer

**FOR ADVANCED USERS -**
**ADULT SUPERVISION RECOMMENDED**







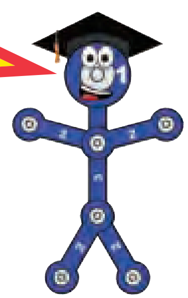
Build the circuit shown. At base grid location B6-B8, 3-snaps are on levels 1, 3 and 4. Snap the 4-snap onto the 1-snap at A4, then place it so it lays on the snap at C6 (DO NOT SNAP IT ON). Snap the nut-snap on the 4-snap so it will be under the electromagnet (M3). This circuit works best with new alkaline batteries.

Place the rubber grommet on the iron core rod and push the rod into the electromagnet until it is just barely above the nut-snap without touching it (0.025 inches).

Turn on the slide switch (S1). The lamp (L4) should be on; adjust the position of the grommet until you hear a buzzing sound. If the lamp is off, make sure the 4-snap is touching the lamp snap at C6 without being snapped there. Make sure the 4-snap lays centered on the snap at C6 (vibration tends to move it off-center).

This circuit requires precise adjustment; if it doesn't work then make sure the grommet and 4-snap are positioned as described above and start over. If you still can't get it to work, rotate the 1-snap at location A4 by 90 degrees, this may make the 4-snap move more easily.

As in the preceding relay circuits, the current through the electromagnet makes a magnetic field that attracts the nut-snap, which breaks the circuit to the lamp. However in this circuit attracting the nut-snap also breaks the circuit to the electromagnet, which then releases the nut-snap. This creates a feedback loop which raises and releases the nut-snap in a repeating cycle. The buzzing sound you hear is from raising and releasing the nut-snap many times a second.



# ☐ Project 79 — Build Your Own Vibrating Circuit

Use the preceding circuit, but replace the lamp (L4) with the meter (M5), set to the 5V scale. Since the circuit is sometimes on and sometimes off, the meter pointer will be vibrating.

# ☐ Project 80 Cola Power


Set the meter (M5) to the 1mA scale and connect the jumper wires to it. Connect the other ends of the jumper wires to the snap electrodes (red to copper), and place them in a cup of cola soda.

Read the current on the meter. You may switch the meter to the 5V scale to also measure the voltage produced, but the voltage may be too small to measure accurately with a simple meter like M5.

Try replacing the cola with other flavors and compare them.

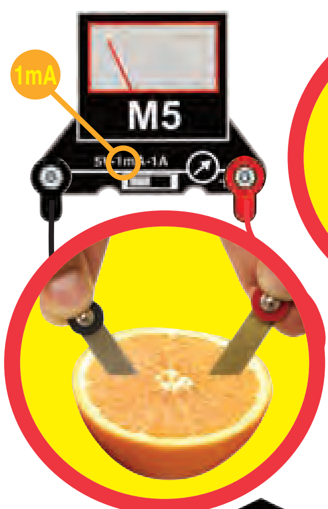
Throw away the soda used in this project. Wash off the electrodes.

Cola-flavored soda is lightly acidic. The acid is similar to the material used in some types of batteries, though not nearly as strong.

The acid in the cola will react with the copper and zinc electrodes to make an electric current, just like the AA batteries or the larger battery in your family car. As some of the acid in the soda is neutralized, the current produced drops.

You can buy a cola-powered clock.


# ☐ Project 81 Fruit Power




Squish or roll a lemon a few times to break up some of the cells inside (tomatoes or grapefruit also work). Stick the copper and zinc snap electrodes into the lemon. Set the meter (M5) to the 1mA scale and connect the jumper wires to it, then connect the other ends of the jumper wires to the snap electrodes (red to copper).

Read the current from your “lemon battery” on the meter. Try placing the electrodes in different parts of the lemon to see how the current changes. You may switch the meter to the 5V scale to also measure the voltage produced, but the voltage may be too small to measure accurately with a simple meter like M5. You may see the current/voltage slowly drop as the “lemon battery” is used up.

If you don’t measure any current, move the electrodes closer together or to a different place on the fruit.

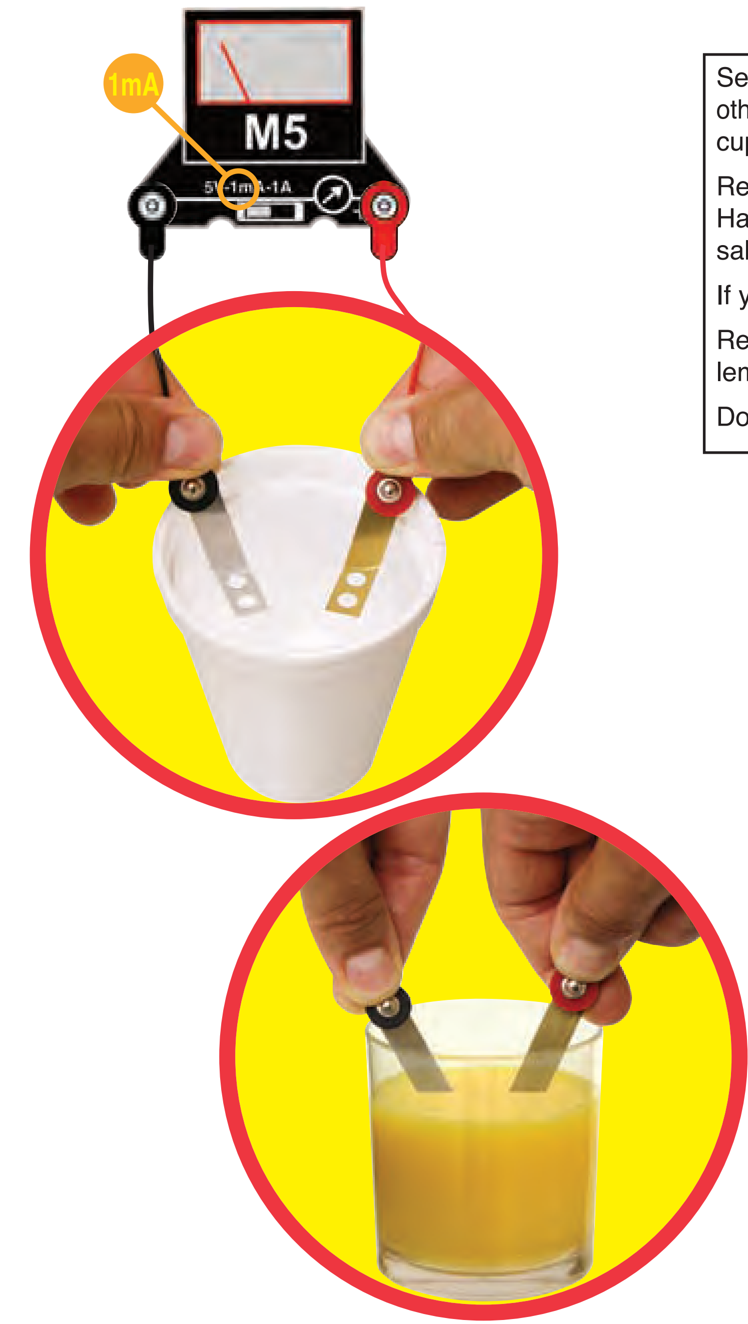
Replace the lemon with other fruits or vegetables such as a tomato, grapefruit, orange, carrot, or onion; see how much current they produce.

Throw away the fruits and vegetables when you are finished with this project. Wash off the electrodes.

Some fruits and vegetables have a sour taste because they are lightly acidic. The acid in them is similar to the material used in some types of batteries, though not nearly as strong.

The acid in the fruit will react with the copper and zinc electrodes to make an electric current. As some of the acid in the fruit is neutralized, the current produced drops.

# ☐ Project 82 Water Impurity Detector



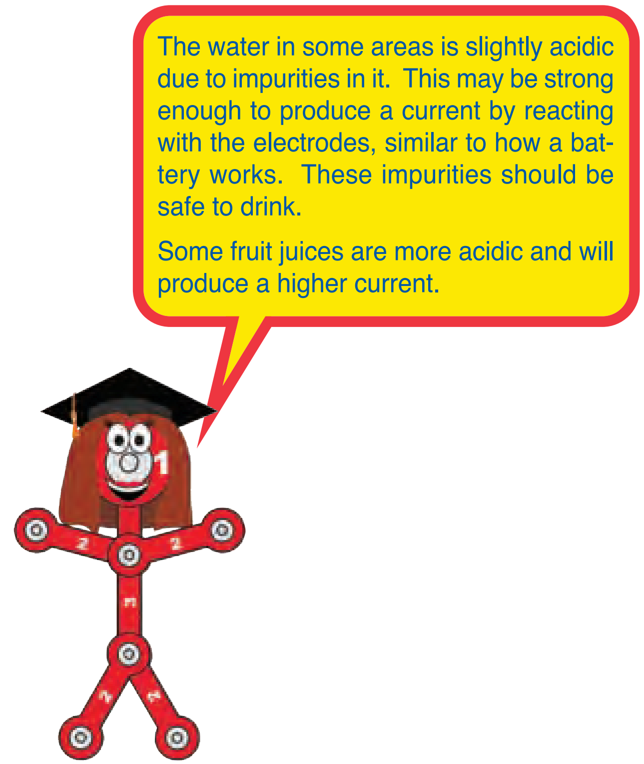

Set the meter (M5) to the 1mA scale and connect the jumper wires to it. Connect the other ends of the jumper wires to the snap electrodes (red to copper), and place them in a cup of water.

Read the current on the meter, if it is zero then your water is relatively free of impurities. Having impurities does not mean your water is unsafe to drink. You can try dissolving salt in the water and see if the current changes.

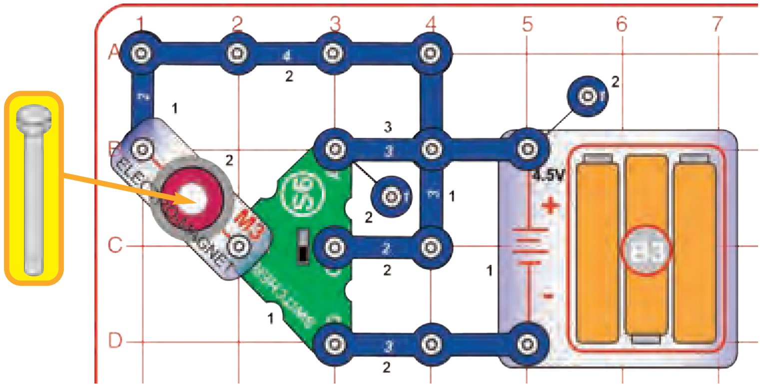
If you have some distilled water, test it. It should have zero current.

Replace the water with fruit juices and see how they compare. Sour tasting juices like lemon or grapefruit juice usually produce the most current.

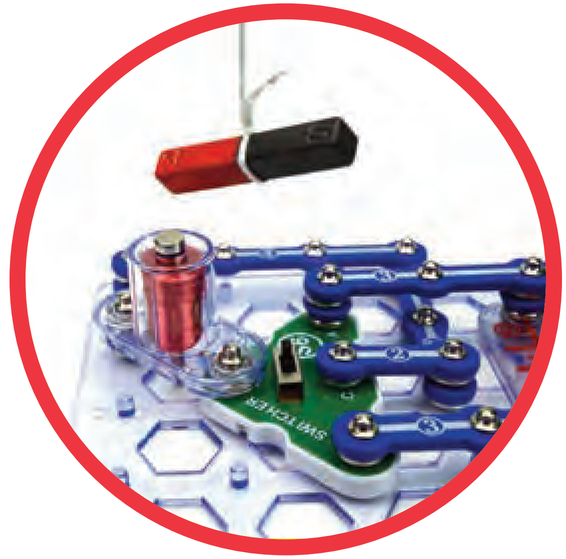
Don't drink any water or juice used in this project. Wash any juice off the electrodes.



## Project 83 — Swing the Magnet



Build the circuit shown and place the iron core rod in the electromagnet (M3). Tie the magnet to a string and hold it just above the electromagnet, so that the magnet is attracted to the iron core rod without touching it. Flip the switcher (S6) back and forth between its top and bottom positions to reverse the electromagnet's magnetic field; the magnet flip around each time.

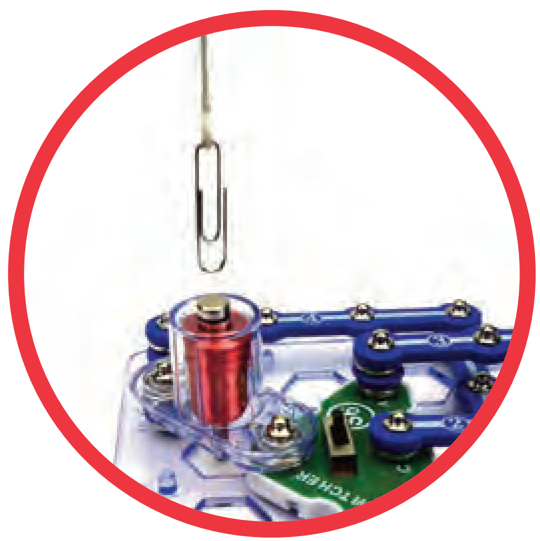


## Project 84 — Magic Rope Trick

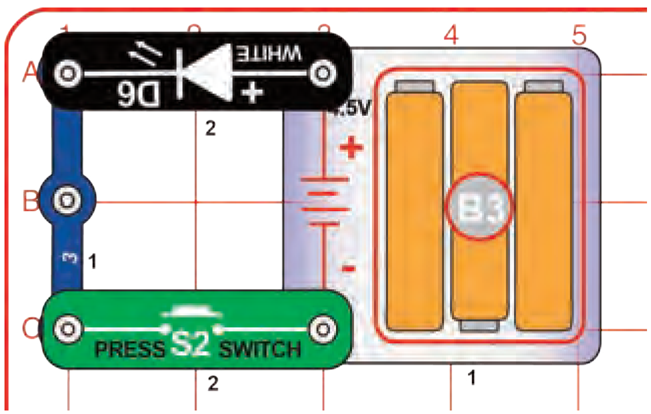
**Part A:** Use the preceding circuit. Secure the paper clip-string with a weight above the circuit, as shown. Set the switcher (S6) to the top or bottom position to pull the paper clip towards the electromagnet. Attract and release the paper clip using the switcher (top and bottom positions are on, middle position is off).

**Part B:** Secure the magnet in place with nothing beneath it. Tie a paper clip to the string and place it on the magnet. Slowly pull the string away so the paper clip is suspended in air. Hold the paper clip in place with a weight, as shown.

Next, hold the magnet near the paper clip and lift it off the ground, without it touching the magnet. Move it around in mid-air.



# ☐ Project 85 Morse Code




This simple circuit can be used for communication.

Push the press switch (S2) in long and short bursts to make a pattern of light flashes representing the dots and dashes shown in the Morse Code table shown. You can use Morse Code and this circuit to send secret messages to some friends in the room without others knowing what you're saying.

If you have a strong flashlight or searchlight then you can send messages to friends far away at night. During World War II Navy ships sometimes communicated by flashing Morse Code messages between ships using searchlights (because radio transmissions might reveal their presence to the enemy).

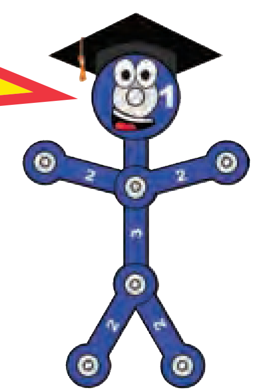
Decode this Morse Code message:

. . . .   .   . _ . .   . _ _ .      _ _   .

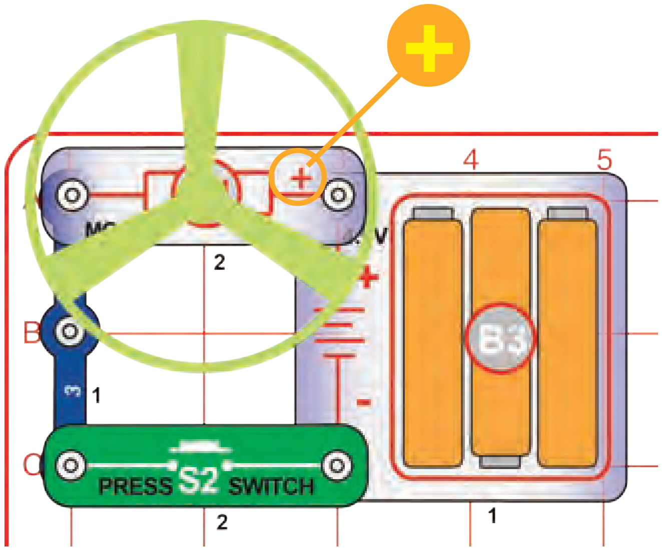
**Morse Code:** The forerunner of today's telephone system was the telegraph, which was widely used in the latter half of the 19th century. It only had two states - on or off (that is, transmitting or not transmitting), and could not send the range of frequencies contained in human voices or music. A code was developed to send information over long distances using this system and a sequence of dots and dashes (short or long transmit bursts). It was named Morse Code after its inventor. It was also used extensively in the early days of radio communications, though it isn't in wide use today. It is sometimes referred to in Hollywood movies, especially Westerns.

## MORSE CODE

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



# ☐ Project 86 — Hypnotic Discs




**Part A**
Build the circuit as shown. Cut out the red spiral pattern shown and tape it on the fan. Spin the pattern by briefly pushing the press switch (S2). You will see the most interesting effects when the pattern is spinning slowly.

**Part B**
Replace the pattern with the colored lines pattern shown. When the switch is pressed, the arcs turn into colored rings with a black background. Notice how the color drops when it is stretched to make a complete circle.

**Part C**
Place the circuit under a fluorescent light with a T12 bulb (1.5” diameter) that runs on normal house current. and spin the disc slowly. As the speed changes, you may notice the lines first seem to move in one direction, then they start moving in another direction. This effect is because the lights are blinking 120 times a second and the changing speed of the motor is acting like a strobe light to catch the motion at certain speeds.

**WARNING:** Do not lean over the motor.

**WARNING:** Moving parts. Do not touch the fan or motor during operation.

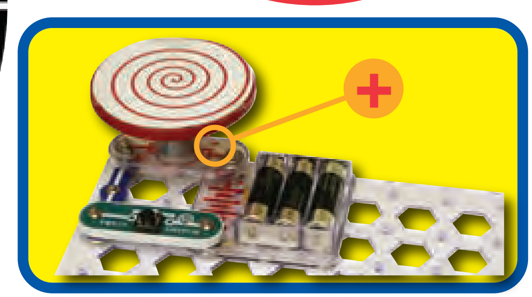
□ # Project 87 Spin Draw

Use the preceding circuit. Using the fan as a guide, draw a circle on a piece of cardboard or paper. Cut the circle out with scissors and tape it to the fan blade so it can be easily removed later. Obtain some thin and thick marking pens to use as drawing tools.

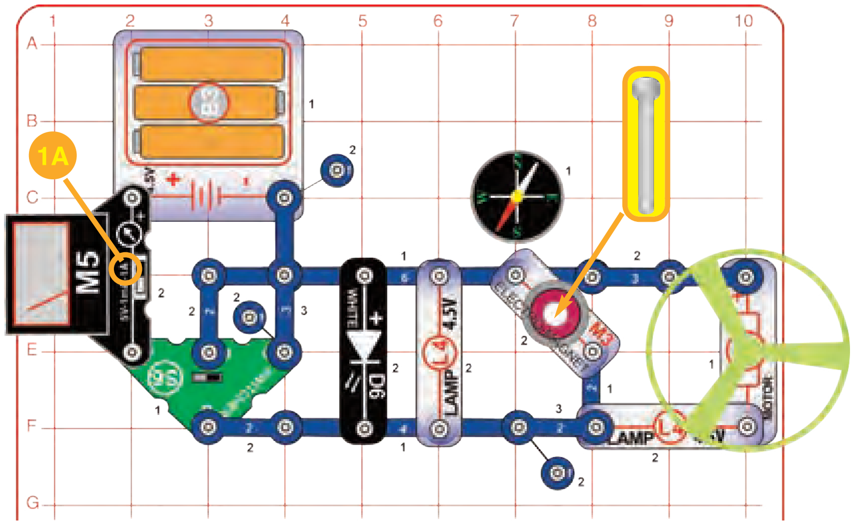
Spin the paper by pressing and holding the press switch (S2) down. Gently press the marker on the paper to form rings. To make spiral drawings, release the press switch and as the motor approaches a slow speed, move the marker from the inside outward quickly.

Change the colors often and avoid using too much black to get hypnotic effects. Another method is to make colorful shapes on the disc then spin the disc and watch them blend into each other.

Spin Draw is an old toy that your parents may have played with when they were young.



# Project 88 — 2-Way Circuit



Build the circuit, set the meter (M5) to the 1A setting, place the iron core rod in the electromagnet (M3), and place the fan on the motor (M1). Set the switcher (S6) to the left or right to make electricity flow through the lights, motor, and electromagnet in opposite directions. The compass measures the magnetic field from the electromagnet and the meter measures the current from the batteries. Set the switcher to the middle position to shut off the circuit.

A lamp is connected in series with the motor to slow down the motor; if you replace the lamp with a 3-snap wire then the fan may fly off.

For each component, select how they work when the electricity is reversed:

LED: A. 1 direction only B. effects unchanged C. effects reversed

Lamp: A. 1 direction only B. effects unchanged C. effects reversed

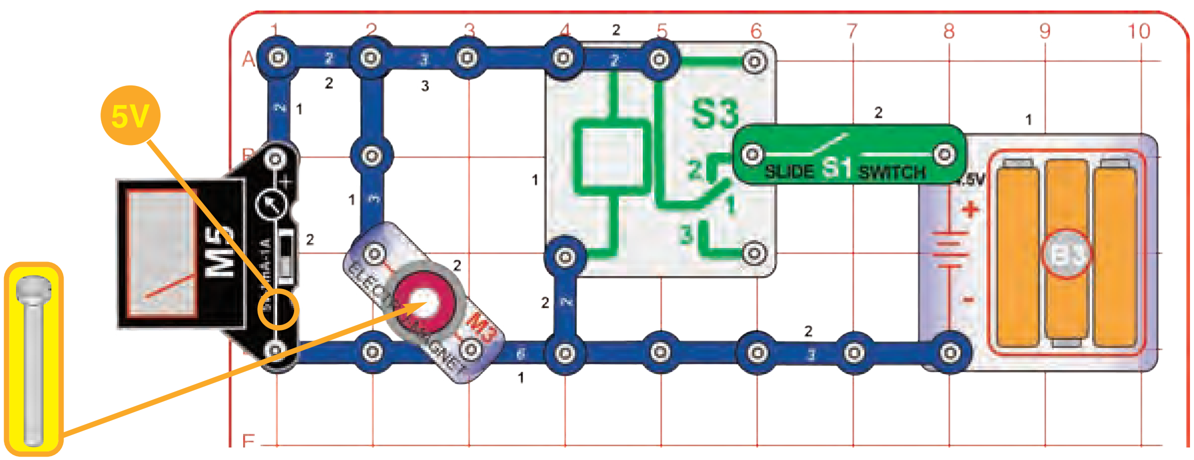
Motor: A. 1 direction only B. effects unchanged C. effects reversed

Electromagnet: A. 1 direction only B. effects unchanged C. effects reversed

**WARNING:** Moving parts. Do not touch the fan during operation.

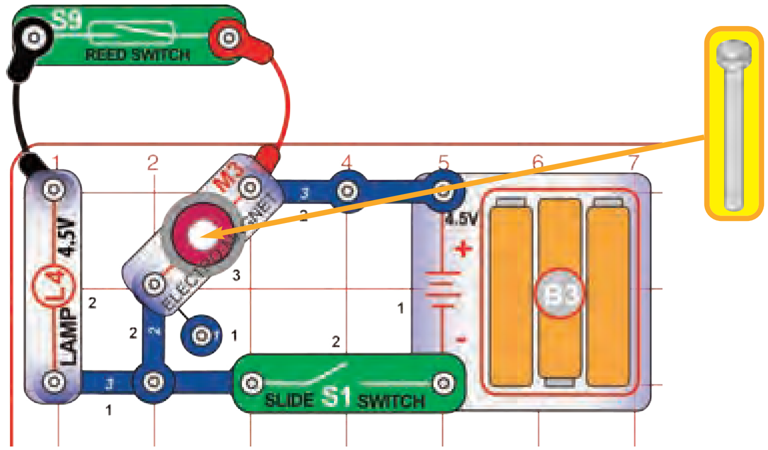
**WARNING:** Do not lean over the motor.

# Project 89 — Electromagnet Music



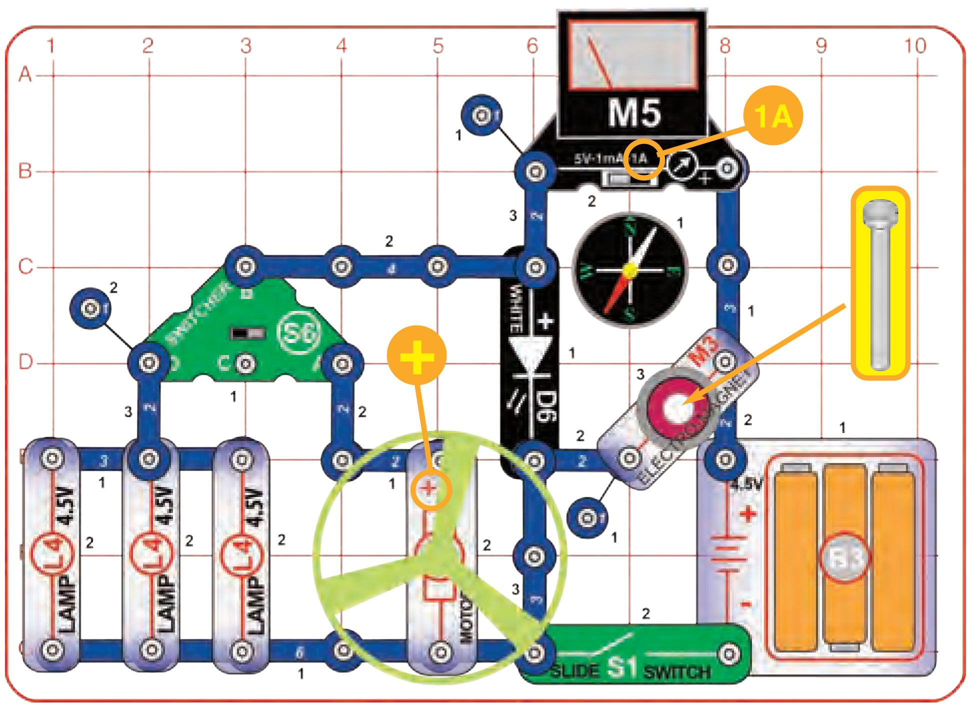
Build the circuit, set the meter (M5) to the 5V setting, and turn on the slide switch (S1); you hear a buzzing sound as the relay (S3) turns on and off rapidly. Adjust the sound by raising and lowering the iron core rod to different heights in the electromagnet (M3), to make music. The meter shows how the voltage is changing.

# Project 90 Electromagnetic Controlled Switch




Build the circuit, place the iron core rod in the electromagnet (M3), and turn on the slide switch (S1). Use the red & black jumper wires to hold the reed switch (S9) over the electromagnet to turn on the lamp (L4). You can also activate the reed switch by holding the magnet close to it.

# Project 91 Electromagnetic Playground

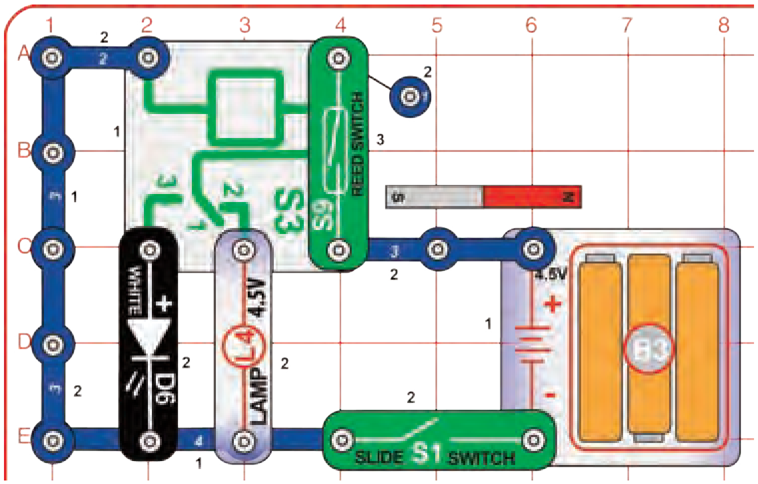



Build the circuit, set the meter (M5) to the 1A setting, place the iron core rod in the electromagnet (M3), and place the fan on the motor (M1). Turn on the slide switch (S1); the white LED (D6) lights, the meter measures the current, and the electromagnet attracts the compass needle. Set the switcher (S6) to the left to the left to light the lamps, to the right to spin the motor & fan, or the middle to do neither.

**WARNING:** Do not lean over the motor.

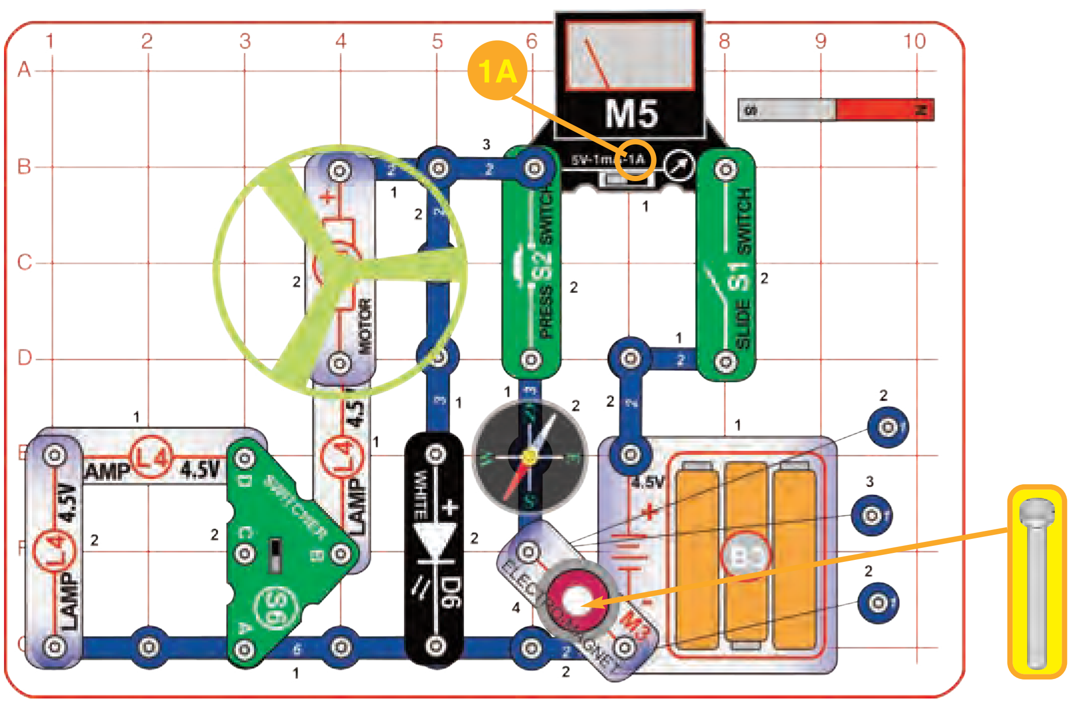
**WARNING:** Moving parts. Do not touch the fan during operation.

## ☐ Project 92 Magnetic Switcher




Build the circuit and turn on the slide switch (S1); the lamp (L4) should be on. Hold the magnet near the reed switch (S9) to activate the relay (S3), which turns the white LED (D6) on and the lamp off.

## ☐ Project 93 Circuits Fun




Build the circuit as shown, set the meter (M5) to the 1A setting, and place the magnet as shown. Turn on the slide switch (S1); the white LED (D6) lights and the meter measures the current. Set the switcher (S6) to the top position to make the fan spin, set it to the bottom position to make the fan spin faster, or set it to the middle position to turn off the fan. The compass is attached to the magnet; push the press switch (S2) to make the compass be attracted to the electromagnet (M3).

**WARNING:** Do not lean over the motor.

**WARNING:** Moving parts. Do not touch the fan during operation.

# TEST YOUR KNOWLEDGE

**Answers are at www.snapcircuits.net/scstem1.**

1. Electric current is the movement of sub-atomic charged particles through a material due to electrical pressure across the material.
   TRUE or FALSE?
2. Voltage is a measure of the electrical pressure to push electric current through a circuit.
   TRUE or FALSE?
3. Voltage is measured in watts.
   TRUE or FALSE?
4. An advantage of electricity is that it makes it easier to transport energy over distances.
   TRUE or FALSE?
5. Resistance can be thought of as electrical friction, resisting the flow of electricity through a circuit.
   TRUE or FALSE?
6. Resistance is measured in ohms.
   TRUE or FALSE?
7. Resistance is calculated as voltage divided by current.
   TRUE or FALSE?
8. Electrical Power is a measure of how fast energy is moving through a wire.
   TRUE or FALSE?
9. When clothes cling together in the dryer, it is because they have an electric current flowing through them.
   TRUE or FALSE?
10. A switch turns a circuit on or off by connecting or disconnecting wires in a circuit.
    TRUE or FALSE?
11. Batteries produce electricity using a biological or nuclear reaction.
    TRUE or FALSE?
12. The electric current from a battery is alternating current.
    TRUE or FALSE?
13. A short circuit is better than a normal circuit because it takes up less space.
    TRUE or FALSE?
14. A fuse shuts down a circuit if the current is abnormally high.
    TRUE or FALSE?
15. Insulators have very low resistance to the flow of electricity.
    TRUE or FALSE?
16. An incandescent light bulb makes light by heating a filament to be glowing hot.
    TRUE or FALSE?
17. Incandescent light bulbs are more energy efficient than LED bulbs.
    TRUE or FALSE?
18. An incandescent light bulb filament has more resistance when it is cold than when it is hot.
    TRUE or FALSE?
19. When several lamps are connected in series, if one burns out then the others will still light.
    TRUE or FALSE?
20. The two basic ways of connecting parts in a circuit are in series and in parallel; all large circuits are made of combinations of these.
    TRUE or FALSE?
21. In a parallel circuit, the circuit branch with the lowest resistance will have the most current flowing through it.
    TRUE or FALSE?
22. If you want a switch to turn a lamp on and off, you should connect the switch and lamp in parallel.
    TRUE or FALSE?
23. The voltage is the same across all components that are connected in parallel.
    TRUE or FALSE?
24. An LED works the same when connected in either direction.
    TRUE or FALSE?
25. The current through an LED is always proportional to the voltage across it.
    TRUE or FALSE?
26. Connecting several batteries in series reduces the total voltage.
    TRUE or FALSE?
27. Connecting several components in parallel increases the total resistance.
    TRUE or FALSE?
28. Reducing the resistance of a circuit will reduce the current through it.
    TRUE or FALSE?
29. When several components are wired in series with each other, all will have the same electric current flowing through them.
    TRUE or FALSE?
30. Reversing the current to an electromagnet does not change the direction of its magnetic field.
    TRUE or FALSE?
31. If a battery cannot supply as much current as a circuit needs, the voltage produced drops.
    TRUE or FALSE?
32. The faster a motor's shaft is spinning, the higher its electrical resistance.
    TRUE or FALSE?
33. A motor has the same electrical resistance when its shaft turns in either direction.
    TRUE or FALSE?
34. Decreasing the number of windings in an electromagnet increases the power of its magnetic field.
    TRUE or FALSE?
35. Electricity and magnetism do not affect each other.
    TRUE or FALSE?
36. A small electric current flowing in a wire has a magnetic field.
    TRUE or FALSE?
37. The magnetic field of a magnet is weakest at the ends of the magnet.
    TRUE or FALSE?
38. Most magnets are made of copper.
    TRUE or FALSE?
39. Placing an iron rod inside a coil of wire with an electric current through it increases the magnetic field produced.
    TRUE or FALSE?
40. You can reverse the direction of the magnetic field from an electromagnet by reversing the direction of the electric current through it.
    TRUE or FALSE?
41. If you want to be able to turn a magnetic field on and off, you should use an electronic magnet instead of an ordinary magnet.
    TRUE or FALSE?
42. An electronic magnet stores energy in an electric field.
    TRUE or FALSE?
43. In a generator, electricity is used to produce mechanical motion.
    TRUE or FALSE?
44. It takes more energy to spin the motor shaft when the fan is not on it.
    TRUE or FALSE?
45. A reed switch is a magnetic switch controlled by an electric current.
    TRUE or FALSE?
46. Distilled water can power a clock better than cola soda.
    TRUE or FALSE?
47. A relay allows a low-voltage to control a high-voltage circuit.
    TRUE or FALSE?
48. A relay uses magnetism to open or close a mechanical switch.
    TRUE or FALSE?
49. Transformers allow circuits to be electrically isolated from each other.
    TRUE or FALSE?
50. Snap Circuits® is fun.
    TRUE or FALSE?

# Other Snap Circuits® Products!

For a listing of local toy retailers who carry Snap Circuits® visit **www.elenco.com** or call us toll-free at 800-533-2441. For Snap Circuits® accessories, additional parts, and more information about your parts visit **www.snapcircuits.net**.

## Snapino – MAKING CODING A SNAP

### Model SC-SNAPINO

**with over 20 projects**

Snapino is an introduction to the open source Arduino Hardware-Software environment. Learn to code and utilize your Snap Circuits modules at the same time!

A great general introduction to Coding and the Arduino platform Arduino is a microcontroller used in robotics and other applications Learn coding basics with this kit and then further expand into the Arduino world using other Snap Circuit kits!

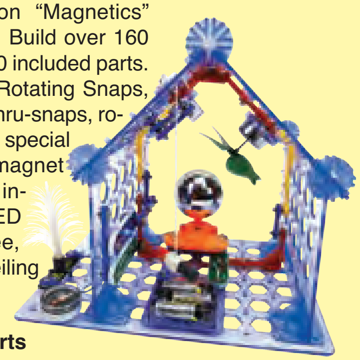
**Contains over 15 parts**

## 3D M.E.G – MAGNETICS – ELECTRONICS – GEARS

### Model SC-3MEG

**with over 160 projects**

Snap Circuits 3D M.E.G. is a new kit with fun and focus on "Magnetics" "Electronics" "Gears". Build over 160 projects with the over 60 included parts. New parts include 3D Rotating Snaps, 2-sided base grid with thru-snaps, rotating mirror ball, gears, special LEDs, melody IC, magnet switch. New features include Rotating LED Lights, Fiber Optic Tree, Rotating Mirror Ball, Ceiling Fan and more.



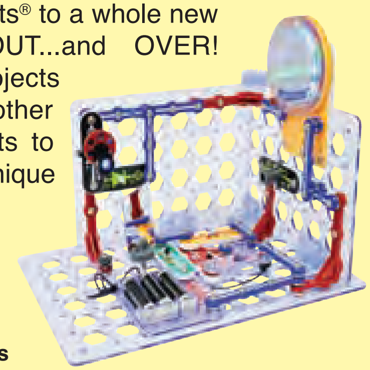
**Contains over 60 parts**

## 3D ILLUMINATION

### Model SC-3DI

**with over 150 projects**

Taking Snap Circuits® to a whole new dimension UP...OUT...and OVER! Build over 150 projects or combine with other Snap Circuits® sets to build even more unique structures.



**Contains over 60 parts**

## Snap Circuits® ARCADE

### Model SCA-200

**with over 200 projects including 20+ games**

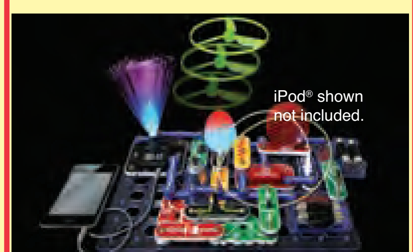
Snap Circuits® ARCADE **contains over 35 parts** along with over 200 projects including 20+ games to complete. Create your own message to display on the programmable word fan using the microcontroller. Check out the cool dual LED display, change it up with the bi-color LED, and get the party started with the colorful disco ball! Clear and concise colorful illustrated manual includes explanations for different snap modules and concepts needed to build ARCADE projects.

## Snap Circuits® LIGHT

### Model SCL-175

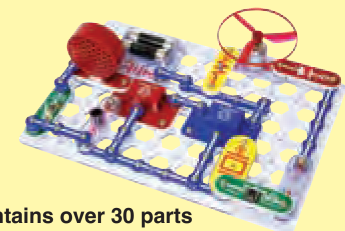
**with over 175 projects**

Snap Circuits® LIGHT **contains over 55 parts** and over 175 projects to complete. Connect your iPod® or any MP3 player and enjoy your music as the lights change to the beat. The strobe light with spinning patterns will amaze you with its visual effects. Features include: Infrared detector, color changing LED, glow-in-the-dark fan, fiber optic communication, and color organ controlled by iPod®/MP3 player, voice, and fingers.




## Snap Circuits® JR

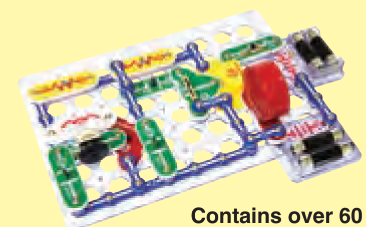
**Model SC-100** with over 100 projects



**Contains over 30 parts**

## Snap Circuits®

**Model SC-300** with over 300 projects



**Contains over 60 parts**

## Snap Circuits® Pro

**Model SC-500** with over 500 projects

**Contains over 75 parts**

## Snap Circuits® Extreme

**Model SC-750** with over 750 projects

**Contains over 80 parts**

# SC-STEM1 SELECT Block Layout

**Important:** If any parts are missing or damaged, **DO NOT RETURN TO RETAILER**.
Call toll-free (800) 533-2441 or e-mail us at: help@elenco.com. Customer Service • 150 Carpenter Ave. Wheeling, IL 60090 U.S.A. **Note:** A complete parts list is on page 2 in this manual.