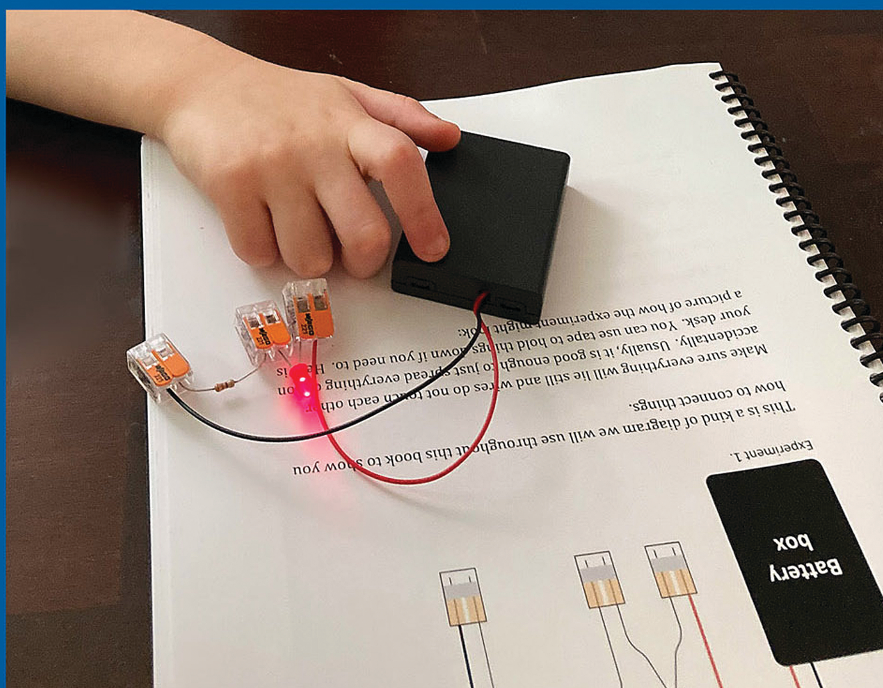
Electronic Experiments for Young Learners



Michael A. Covington
and the 6 Barrett children

Electronic Experiments for Young Learners

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To parents and teachers

This is a book for learners of all ages. It is designed to appeal to young people from about fourth grade on, but adults also enjoy working through it. If you're interested, don't let your age be an obstacle. Nobody is too old. Much younger children can appreciate the experiments as they watch someone else do them.

This is an electrical experiment book for the 21st Century. It focuses on using electricity for signaling and information, not just power. That is one reason you will not find electromagnets and motors here. Instead, I introduce light-emitting diodes right at the beginning, and transistors later.

The other reason for not featuring high-power projects such as electromagnets and motors is safety. The experiments in this book use small amounts of electric current. Sources of heavy current are not needed. The tall "dry cell" batteries of 1950s science books, able to set wires on fire, are no longer with us, thank goodness; this is a book for a new century.

I have also avoided newer hazards. Lithium batteries can overheat and burst when short-circuited. Coin-cell batteries and pill-sized neodymium magnets are very dangerous if swallowed. None of those are used here. None of the experiments involve burning, and none involve electric shocks.

Every experiment is designed to teach something. There is no point in following instructions blindly to see something work without understanding it. If it works, you won't learn much, and if it doesn't work, you won't know why. Also, the experiments often show the learners what would happen if the parts were connected together in different ways.

If you want a shorter course, just do Experiments 1 to 9; in that case, you won't need the switches or transistor. Experiment 14 is particularly complex, and many people may choose to skip it even if they do all the others.

Physics experts will notice that most of the experiments demonstrate some aspect of Kirchhoff's Voltage Law, and that when I say "energy" I mean potential energy per electron, measurable in volts. But I avoid technical vocabulary as much as possible. In a "Going further" chapter at the end, I define volts and amps. Ohm's Law is mentioned briefly, but we do not do calculations.

For classroom use, consider providing all the wires already cut to length, with the insulation stripped (or pre-made breadboard jumpers), and transistors with wires already soldered to them. This keeps learners from needing to clean up tiny scraps of wire left behind after cutting or stripping.

I want to thank all six of my grandchildren, who helped me write this book and are listed as co-authors. They have enjoyed electrical experiments ever since they first saw an LED light up. We thank Douglas Downing and Forrest M. Mims III for valuable suggestions.

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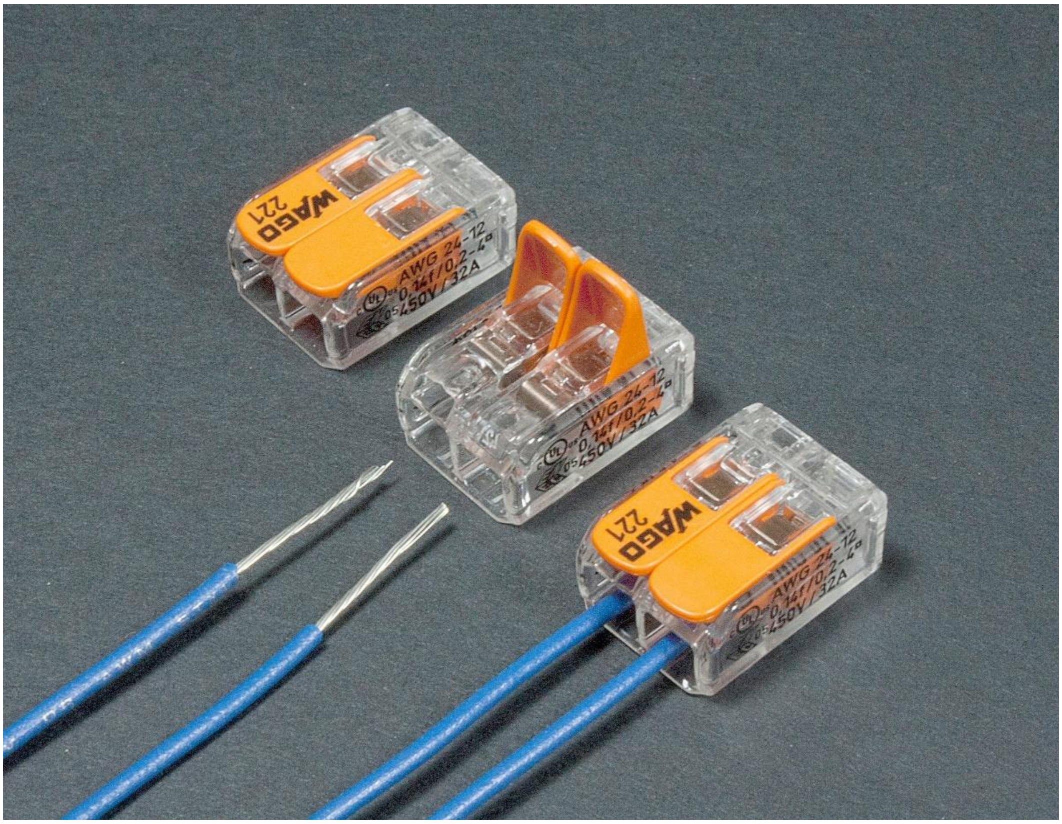
Skill 2: Connecting wires together



Wago connectors.

We need a way to join wires together so that electricity can flow from one of them to the next. In this book, we are using Wago connectors (pronounced WAH-go or WAY-go). In each Wago connector is a piece of metal and two clamps with levers. When you lift up the levers, you can put the wires in, and then when you close each lever, the wire is tightly clamped against the metal. Then electricity can flow from one wire, through the piece of metal, into the other wire.

Experiment 1: Lighting an LED

In this experiment, you will turn electricity into light. You will use an LED, which stands for Light-Emitting Diode.

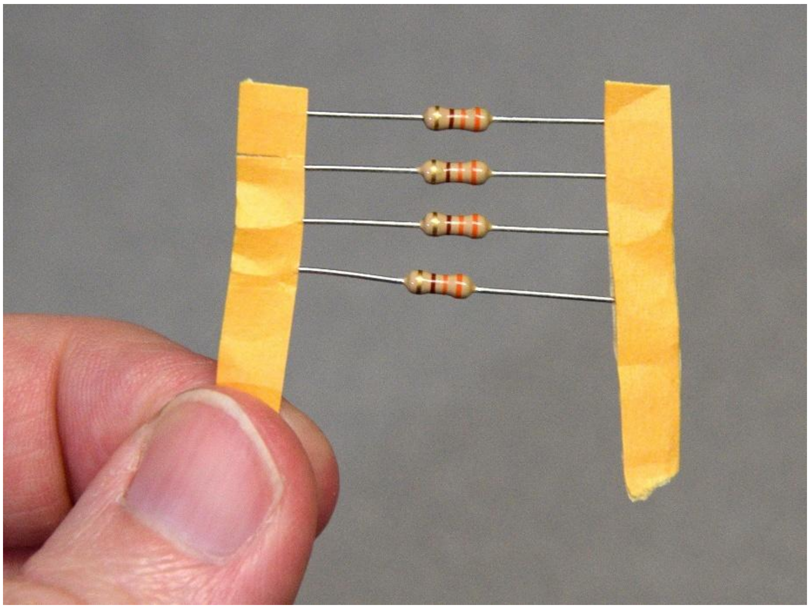
Working with resistors

This experiment uses a resistor. That is a part that limits the flow of electricity; electricity has a harder time flowing through it than through a wire.

A resistor.

The colored stripes on the resistor indicate how much resistance it has. This one is 330 ohms. For our experiments, anything from 200 to 1000 ohms will work.

Your resistors may arrive with heavy paper tape across the ends of the wires. When you remove the tape, it leaves behind a residue that does not conduct electricity well. Clean off the residue with a solvent such as Goo Gone or cut off the part of the wire that is not clean.



If resistors have paper tape on them, remove it, either by cutting the wires or by cleaning them until no residue is left.

How to build it

You will need:

The battery box

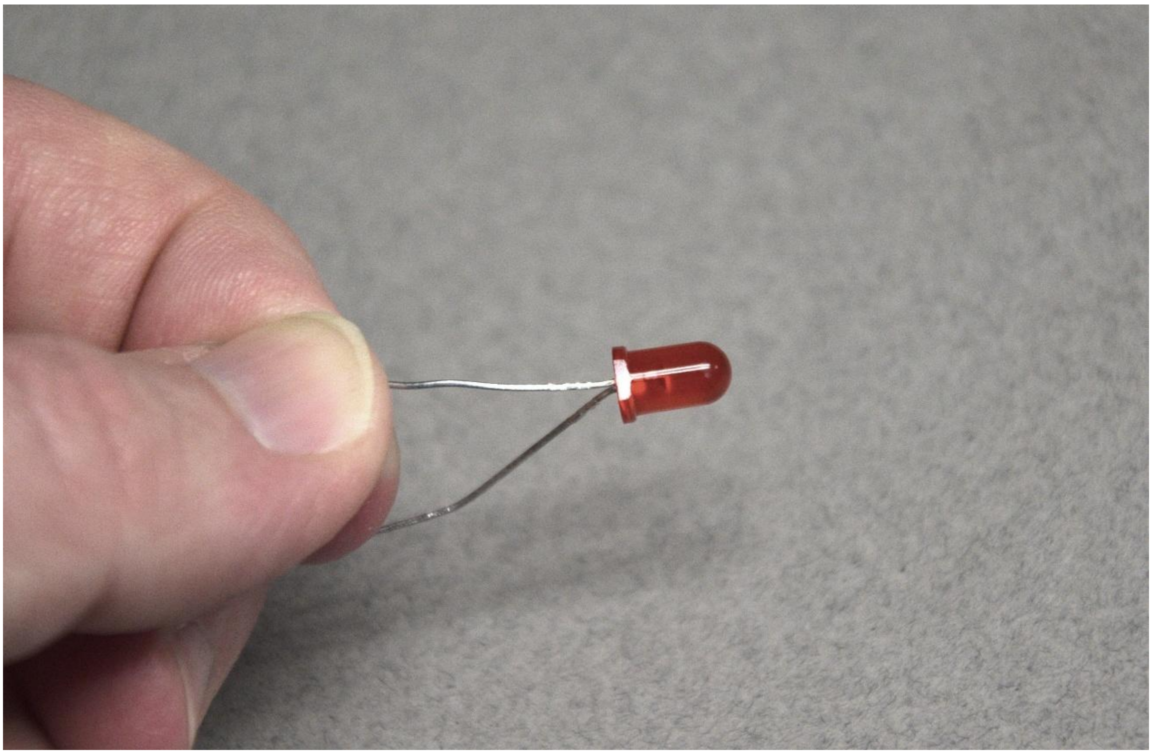
1 red LED

1 resistor

3 Wago connectors for 2 wires

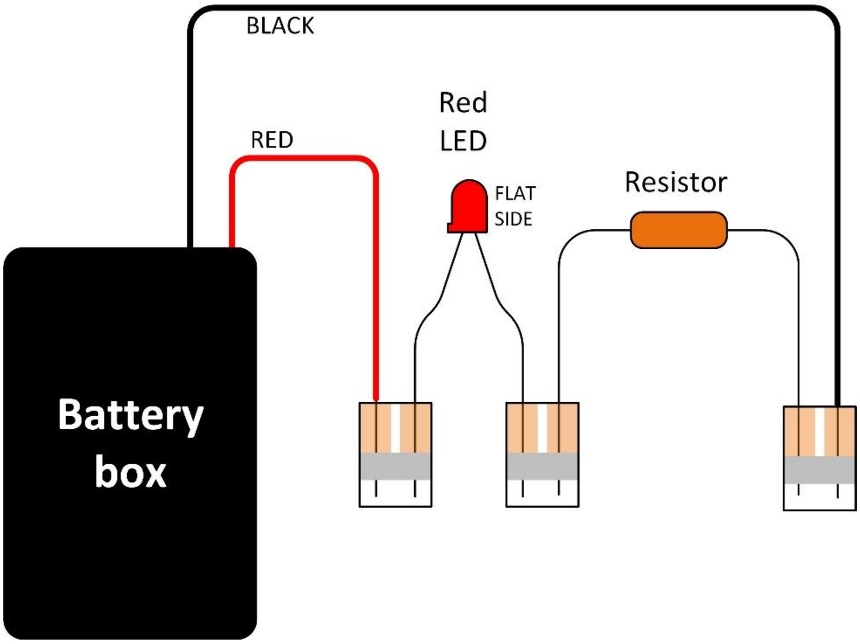
The battery box should be switched off. If you have not figured out how to switch it off, take out one of the batteries so that it will not deliver electricity.

Look closely at the LED. You will see that one side of it has a flat spot; also, the wire coming out of that side is probably shorter. That is the wire through which the electrons go into the LED. They come out through the other one. You can probably find the flat spot more easily by feeling for it rather than looking for it. If you cannot find the flat side of your LED, try connecting the LED one way, then the other.



An LED. One side is flat to mark where the electrons go in.

Now lay out the parts on the table and connect them together like this:



Experiment 1.

This is a kind of diagram we will use throughout this book to show you how to connect things.

Make sure everything will lie still and wires do not touch each other accidentally. Usually, it is good enough to just spread everything out on your desk. You can use tape to hold things down if you need to. Here is a picture of how the experiment might look:

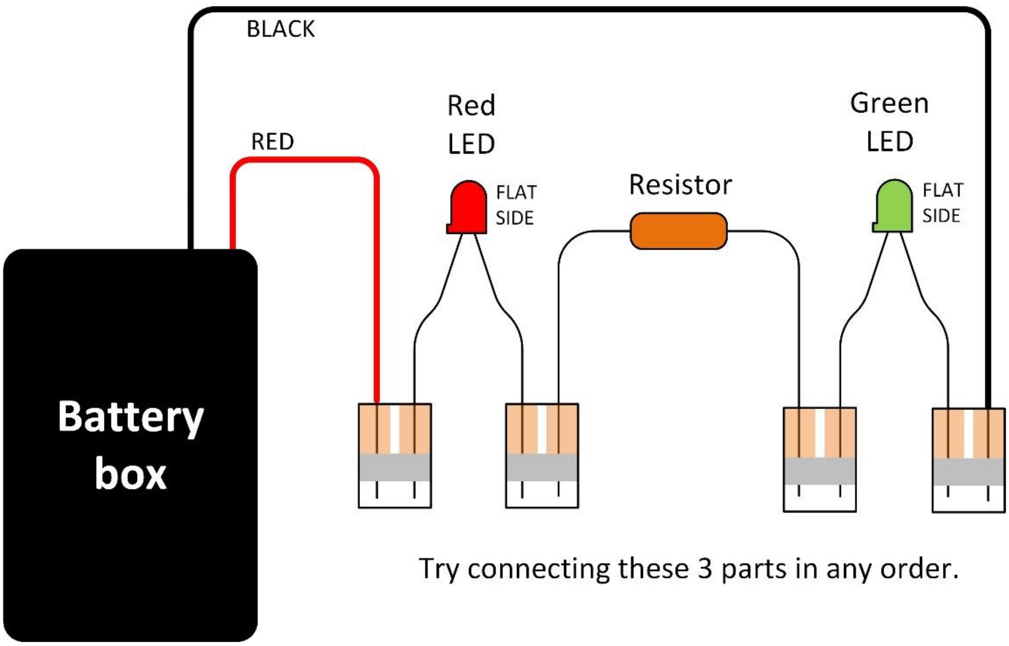
Experiment 5: Order doesn't matter

In this experiment we see that if the same electrons pass through all the parts of a circuit, it doesn't matter which part they pass through first.

How to build it

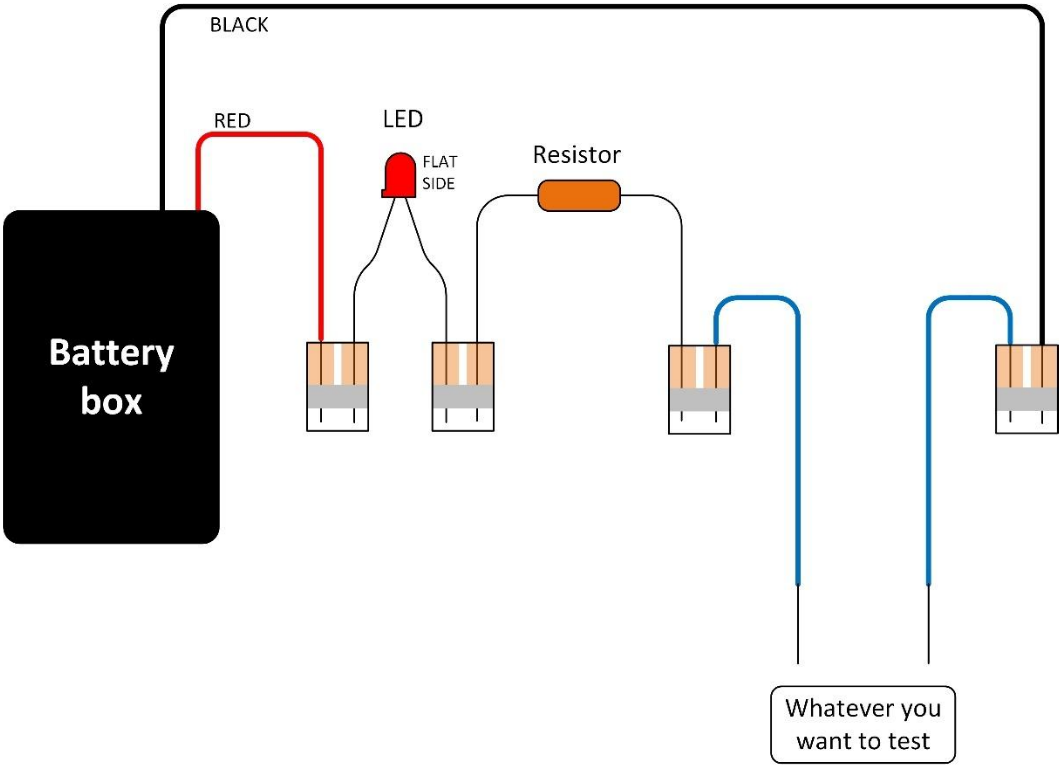
Build Experiment 4 and get it working.

Then change the order of the parts. For example, make the electrons go through the green LED first, then the resistor, then the red LED, like this:

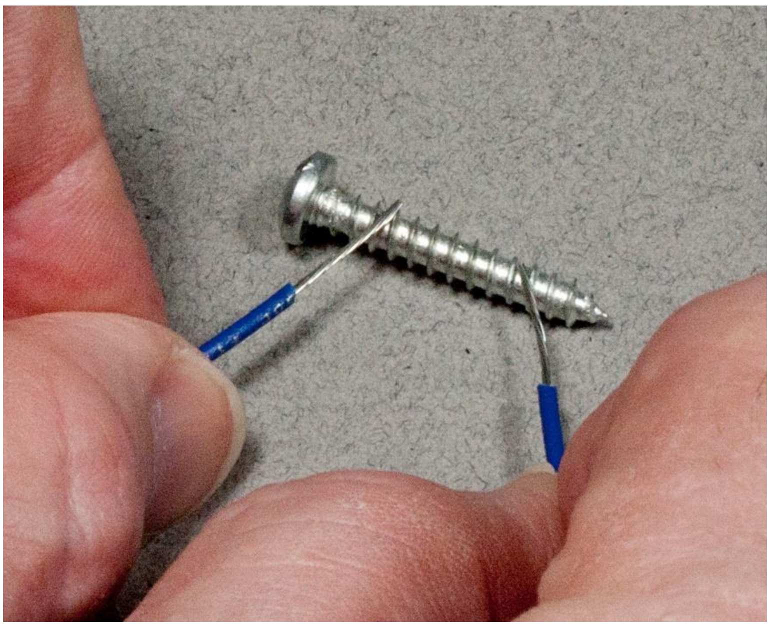


Experiment 5.

The LEDs light up the same as before.



Experiment 9.



Testing whether a screw conducts electricity.

Experiment 15: A switch made of silicon

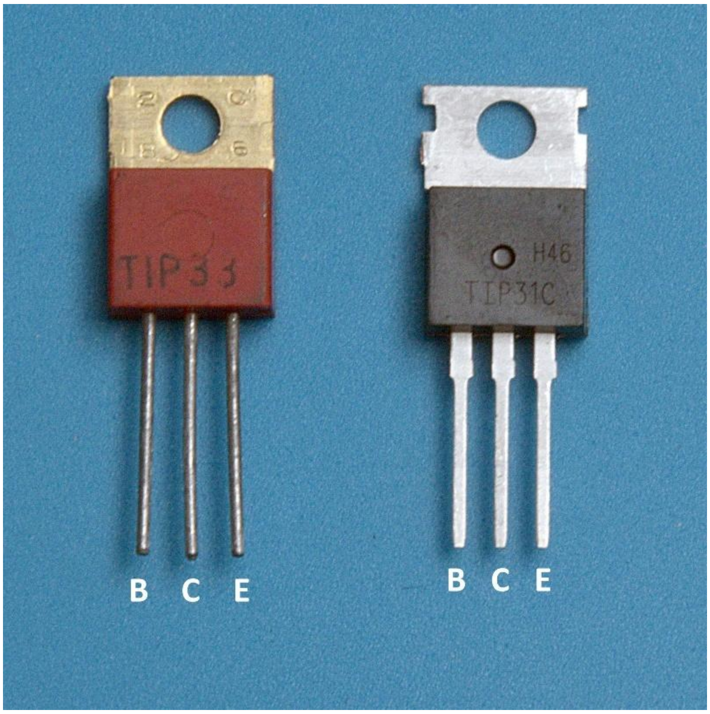
In this experiment, you will use a **transistor**, which is a switch with no moving parts. It is made of a block of silicon that conducts electricity when a few electrons are pulled into it or out of it. Transistors are very important in modern electronics.

Working with the transistor

Every transistor has a type number. Many types of transistors are made by more than one company, using the same type number. The one specified for this experiment is type TIP31C, but several other types will substitute for it. One good substitute is type TIP33.

But not everything that looks like this transistor is actually the same thing. The same kind of package with three pins coming out of it is used for other kinds of transistors and even other kinds of electronic parts. When in doubt, make sure you have the right kind.

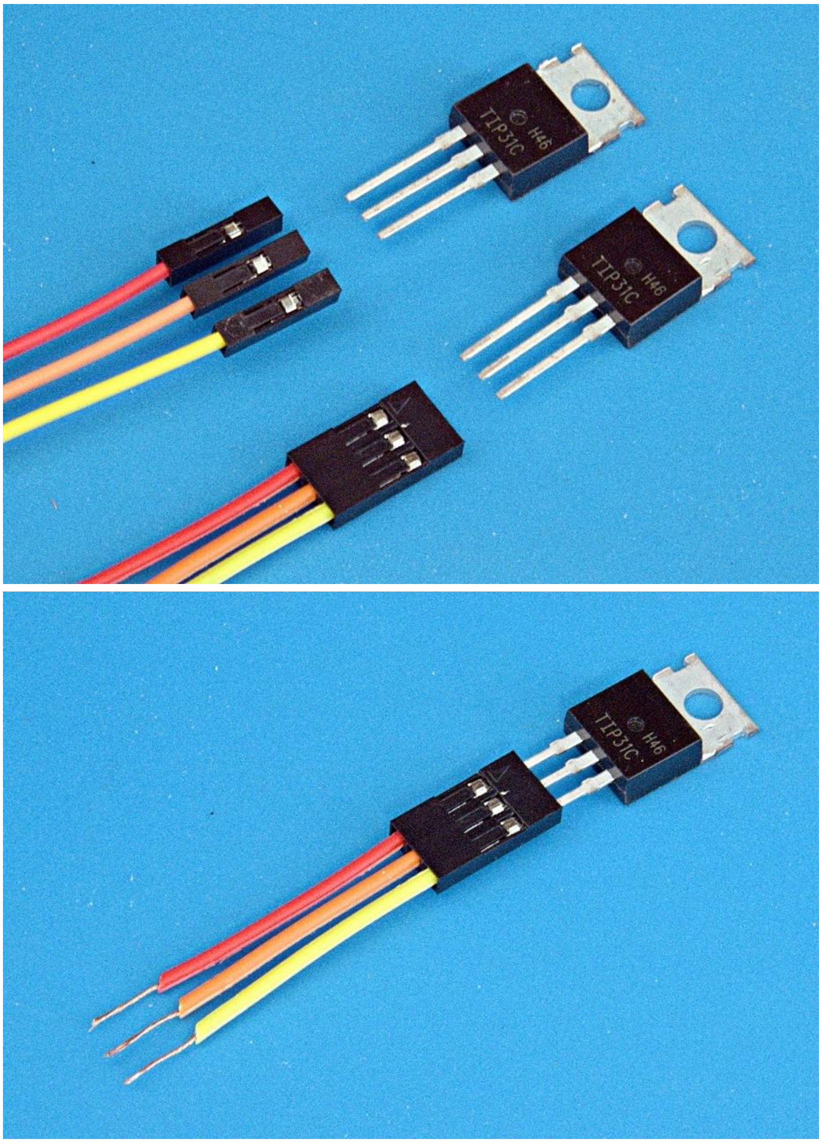
The three pins connect to parts of the transistor called the **base**, **emitter**, and **collector** (B, C, and E). The picture shows you which is which. (They are not the same on all transistors of different types.) To keep from getting them mixed up, make sure you are looking at the front of the transistor, which has writing on it, not the back.



B, C, and E are the 3 terminals of a transistor.
The metal tab is also connected to C.

Attaching wires to the transistor

The best way to connect wires to the transistor is to use jumper wires that have pin sockets on the ends, either three single pin sockets, or one triple pin socket with holes 0.1 inch (2.5 mm) apart, as shown in the pictures. If your jumper wire has something else on the other end, simply cut it and strip the wires.



Jumper wires with pin sockets are the best way to connect to the transistor. (Your wires should be longer than these, if possible.)

If you cannot get jumper wires with pin sockets, you can connect wires to the transistor by twisting them carefully around the pins, then crimping them tight with pliers. They can still come loose, so be careful.

Going further: Volts and amps

We have not said anything about how electricity is measured. There are two things to measure, how many electrons are flowing and how much energy they carry.

The flow of electrons is called **current** and is measured in **amps**, which is short for **amperes**.

A flow of 1 amp is about 6,240,000,000,000,000,000 electrons per second. That is a lot of electrons, but not a lot of electricity, because electrons are very tiny.

Many circuits use a lot less than 1 amp, so we also measure current in **milliamps** (**milliamperes**), abbreviated **mA**, where 1000 mA make 1 amp.

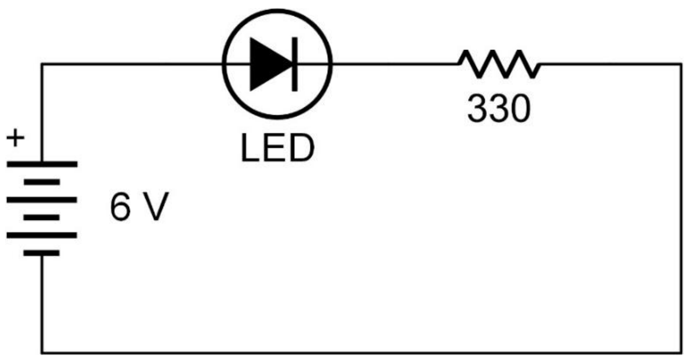
In Experiment 1, the current through the resistor and LED is about 12 mA. In Experiment 15, the current through the LED is also about 12 mA, coming out the collector of the transistor, but the flow through the base of the transistor, which turns it on, is only 4 mA, and the circuit would still work even if it were a lot less. The transistor allows a small current to control a larger one.

The energy that electrons carry is measured in **volts**, abbreviated **V**. Your battery box supplies 6 volts. That is four 1½-volt batteries in series; 1½ + 1½ + 1½ + 1½ = 6.

In Experiment 1, the LED takes about 2 volts and the resistor takes up the rest of the energy, about 4 volts. Notice that 4 + 2 = 6. This is an example of Kirchhoff's Voltage Law –

Going further: Circuit diagrams

In this book, we have drawn circuits the way they actually look, with pictures of the parts. Electronic engineers usually use a different kind of diagram with symbols for the parts instead of pictures of them. These are called **circuit diagrams** or **schematic diagrams**. Here is a schematic diagram of Experiment 1:



Experiment 1 (circuit diagram).

The 6-volt battery box is shown by a symbol that is marked "6 V," with the red wire marked "+" for positive. That symbol means "battery" in any circuit diagram, anywhere. The LED and resistor have symbols of their own. The resistor is marked 330 because it is a 330-ohm resistor – that is how much it resists the flow of electrons.

Compared to the drawing of Experiment 1, the diagram seems to be upside down. The reason is that it is traditional to draw diagrams with the positive voltage at the top. Many years ago, scientists didn't know which way the electrons were