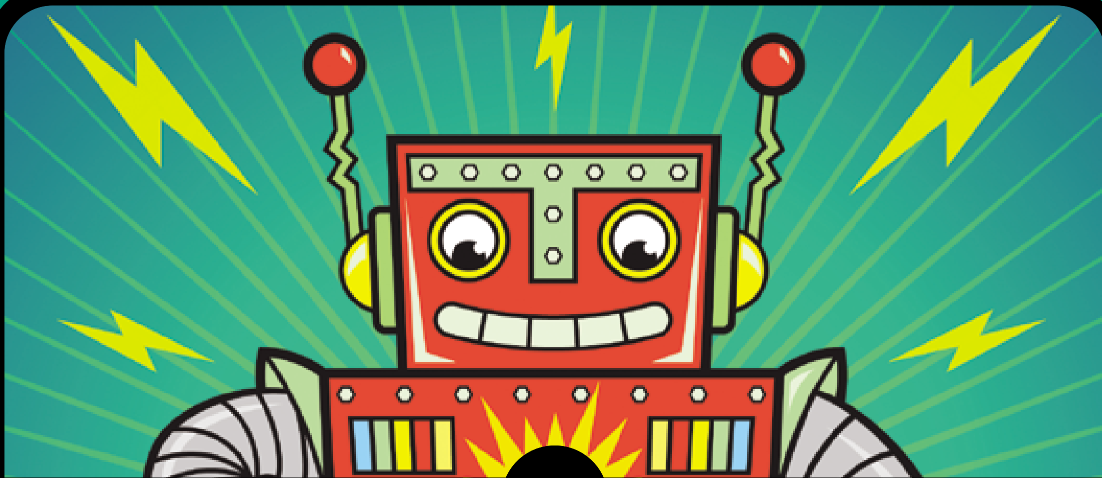


3

HOW TO GENERATE ELECTRICITY

Chapter 1 described why you need a closed loop to get current flowing through a circuit, and Chapter 2 showed you how to build your own electromagnet and motor. The projects in those chapters used electricity from a battery, but in this chapter, you'll make your own electricity sources!

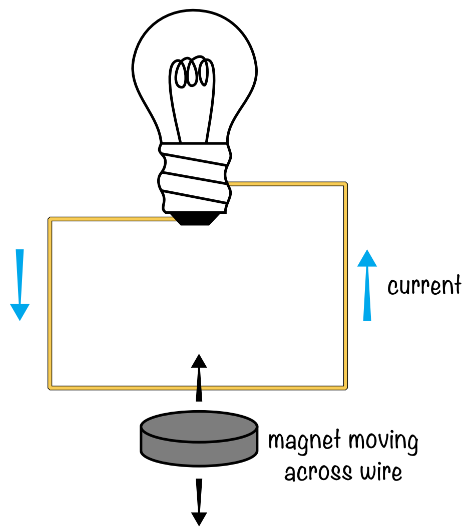
Specifically, you'll learn how to build your own generator, which creates electricity from movement, and your own battery, which creates electricity through chemical reactions. These are two of the most common ways to obtain electricity.

GENERATING ELECTRICITY WITH MAGNETS

When you run current through a wire, it creates a magnetic field around the wire, but there's another connection between electricity and magnetism. You can also create electricity using a wire and a magnet!

A Changing Magnetic Field Creates Electricity

If you move a magnet back and forth over a wire connected in a closed loop, you'll create a current in the wire. Moving the magnet changes the magnetic field around the wire, and the changing magnetic field pushes the electrons through the wire.

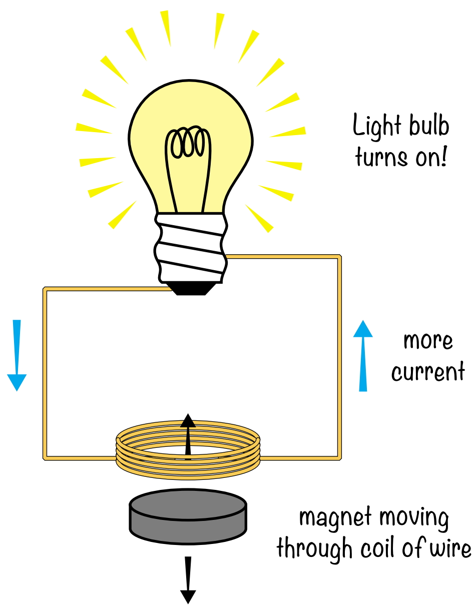


If you stop moving the magnet, the current also stops—even if the wire is still within the magnetic field—because the magnetic field is no longer changing.

If you connect the two ends of the wire to a light bulb and create a closed loop, then the current can flow. Unfortunately, however, the current created by moving a magnet over a single wire doesn't provide enough energy quickly enough to actually light the bulb. To light a bulb, or to power anything else, you need to find a way to generate more *power*, which is the amount of energy produced in a certain time.

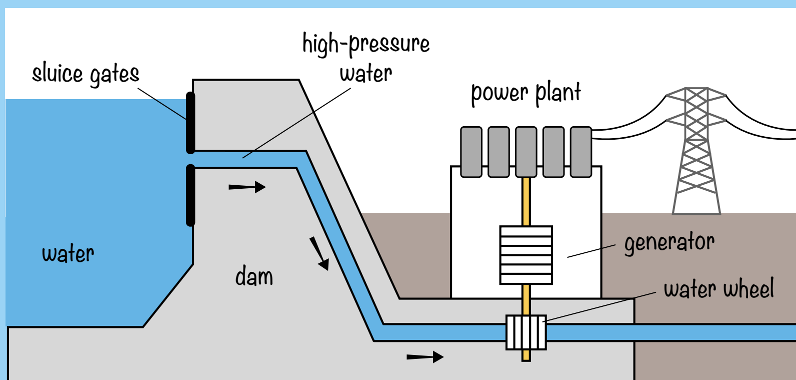
How Does a Generator Work?

A *generator* is a device that turns movement—such as the movement of a magnet over a wire—into electricity. To create more power with a wire and a magnet, you can wind that wire into a coil. The coiled wire acts like a group of wires, and when the magnetic field passes through it, a current flows through each coil, creating more power than you could with a straight wire.



CREATING ELECTRICITY FROM WATER OR WIND

If you place a coil in a magnetic field and rotate the coil with a handle, you're converting your own movement into electricity. If you replaced the handle with a water wheel and placed it into a stream of water, the water would push the wheel so that the coil would rotate in the magnetic field and create a current. This is how some power plants generate electricity! The power plant just lets water run through a wheel that's connected to a generator. Then this electricity is transferred, through power lines, to the power outlets in people's houses.



You can make electricity out of other natural forces in the same way. For example, to create electricity out of wind, you can connect the coil to a windmill so that when the wind blows, it rotates the coil.

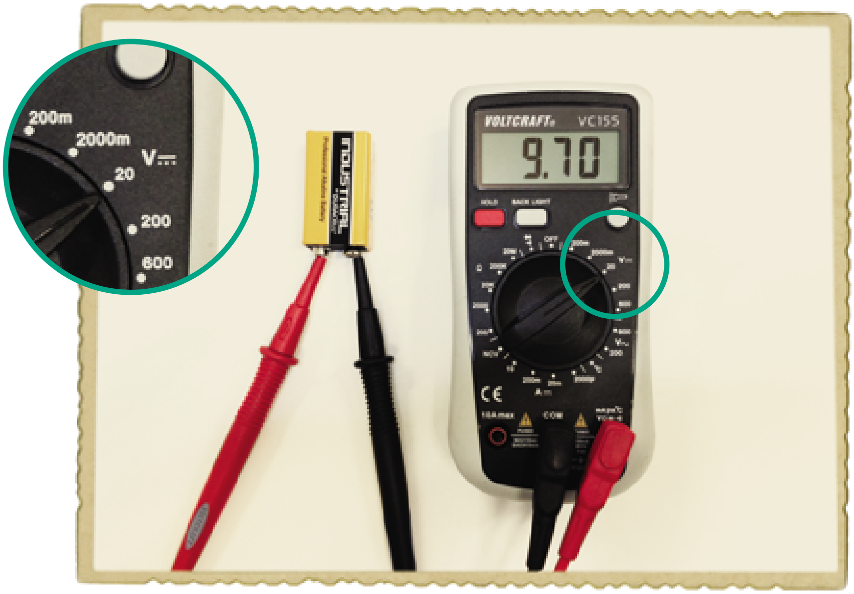
MEET THE MULTIMETER

You can measure exactly how much energy a simple generator creates with a basic *multimeter*. Multimeters are handy when building any circuit because they can measure a lot of different values, including resistance, current, and voltage.

The red lead is the positive lead, the black lead is the negative lead, and the big dial in the middle lets you tell the multimeter what to measure. If you're having problems with a circuit, measuring the voltage at key points in your circuit is one practical way to figure out what's wrong.

How to Measure Voltage

To measure voltage with a multimeter, first turn the dial to one of the V options. (In this book, I'll tell you which setting to choose, but in your own projects, pick one that has a number higher than the highest voltage you expect to see in your circuit.) Then, at the bottom of the multimeter, connect the black lead to the COM socket and the red lead to the V socket. Finally, place one lead on each side of the part you want to measure the voltage across.



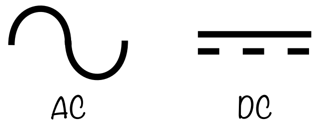
In this example, the meter is measuring the voltage between the positive and negative terminals of a 9 V battery. Notice that my dial is turned to 20 V, in the range showing a V with a straight-line symbol. But there's another V on the multimeter with a wavy line next to it. Let's look at what these symbols mean.

What Are AC and DC?

How you set your multimeter depends on whether you want to measure the voltage from a battery or a generator. A battery has a positive and a negative side, but a generator doesn't! A generator has two wires that alternate between being positive and negative. This is because when one side of the magnet moves past the coil, current in the coil flows in one direction, and when the other side of the magnet moves past the coil, current flows in the other direction.

When the current direction switches like that, we call it *alternating current (AC)*; when the direction of the current stays the same all the time, we call it *direct current (DC)*.

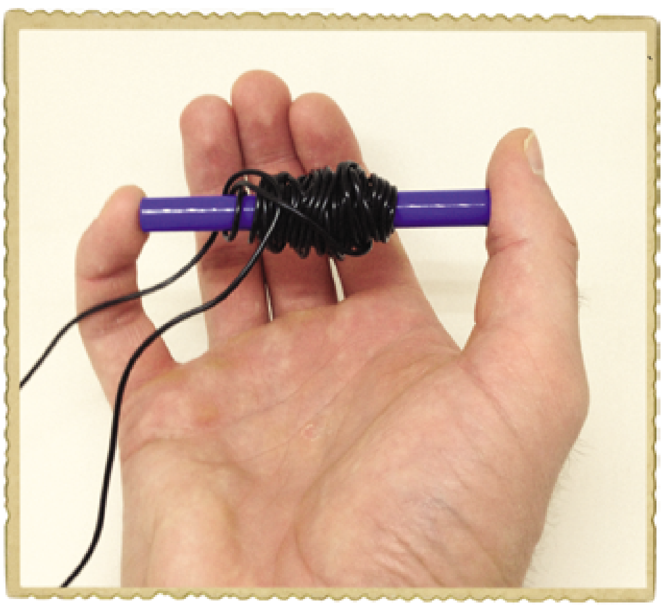
Usually, you'll find these symbols on your multimeter to indicate the AC and DC ranges of measurement:



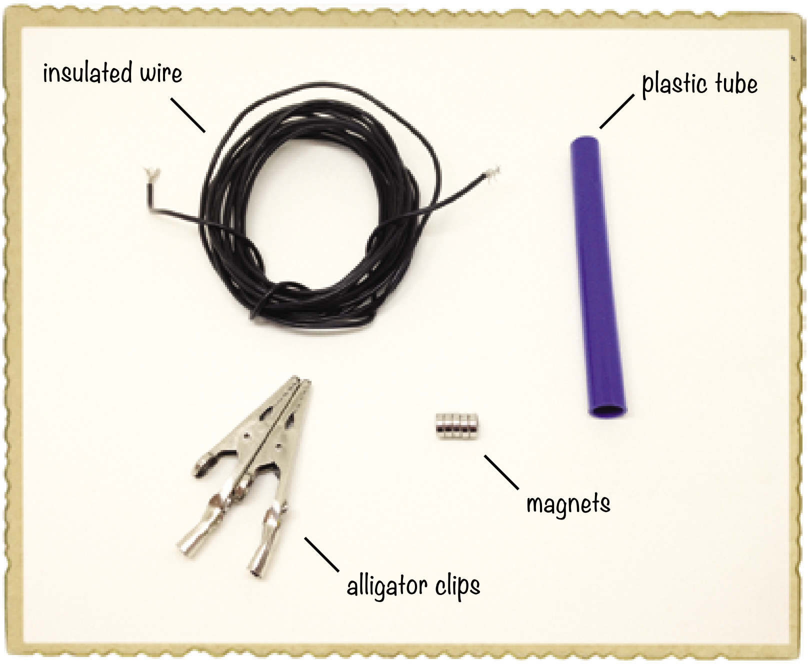
You need to set the multimeter to measure either AC or DC to get the correct reading. For example, batteries have a DC voltage.

PROJECT #5: MAKE A SHAKE GENERATOR

Grab your multimeter—this project will show you how to make a generator and measure its voltage. One quick way to create a simple generator is to manually move a magnet back and forth inside a coil. In this project, you'll put a magnet inside a tube and wind a coil around the tube. When you shake the tube, the magnet should move back and forth inside the coil and create a voltage.



Shopping List



- **Insulated solid-core wire** (Jameco #36792, Bitsbox #W106BK), about 9 feet. Standard hookup wire works fine.
- **A small plastic tube**, such as an old pen.
- **Five disc magnets** (Jameco #2181319, Bitsbox #HW145) stacked to form a magnet rod.
- **Two alligator clips** (Jameco #256525, Bitsbox #CN262) to connect the multimeter to the coil.

Tools

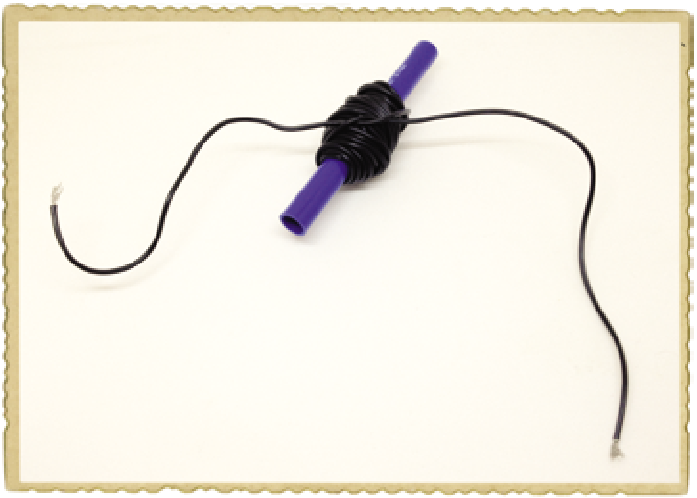
- **A multimeter** to measure the voltage of your generator. The multimeter should be able to measure very low AC voltages, down to 0.01 V or less. Suitable multimeters are Jameco #2206061, Bitsbox #TL057, or Rapid Electronics #55-6662. These multimeters are a bit more expensive than the cheapest ones, but they will serve you for many years to come.

Step 1: Prepare Your Tube

Find a tube that's big enough to let the magnets slide easily back and forth. If you're using a pen, disassemble the pen and make sure your magnets fit inside the tube.

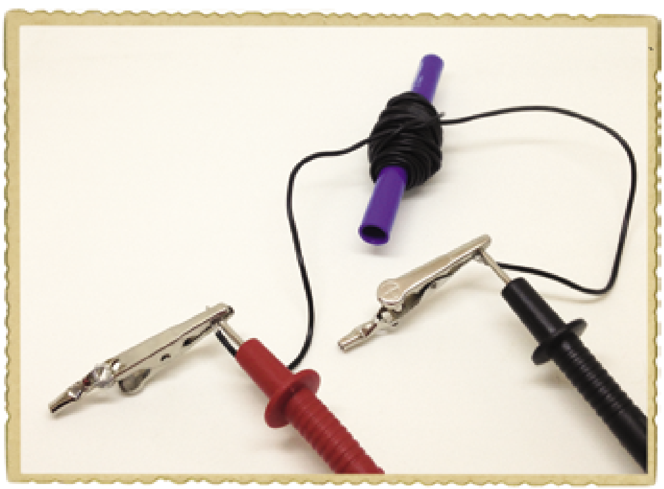
Step 2: Wind Your Coil

Wind about 50 turns of wire around the middle of your tube. After winding, make a simple knot with the two ends to keep your coil together. Then, strip the insulation from the two wire ends, as shown.



Step 3: Connect the Multimeter

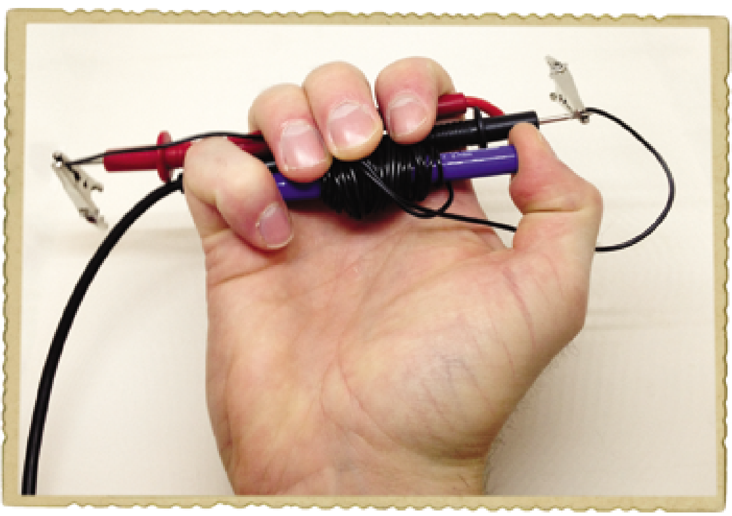
Connect the multimeter to both ends of the coil using alligator clips and set the multimeter to measure AC. Choose the lowest AC voltage setting available.



Step 4: Shake That Thing!

Next, put the magnets inside the tube. They should fit inside without coming apart.

Holding the tube and multimeter leads in your hand, place one finger on each side of the tube so that the magnets don't fall out. Then, shake it like you mean it!



Observe the voltage value on the multimeter. How much voltage do you get? I was able to get only 0.02 V from my generator, so it's not very powerful.

Step 5: What If There's No Voltage?

If you can't measure any voltage from your generator, first check that your multimeter leads are connected well to the exposed coil wires. If you still don't see a voltage higher than 0 V, make sure your multimeter is set to measure really low voltages; my dial was turned to 2 V AC. You won't get a high voltage from this simple generator, so if the multimeter isn't on the lowest setting possible, it will keep reading 0 V. Note that not all multimeters are able to measure such low voltages.

This generator isn't very powerful right now. How can you make it more powerful? Try to increase the voltage from the generator by shaking it faster, adding more loops of wire to the coil, or using a more powerful magnet.

NOTE *Standard hookup wire is a bit bulky; even 50 turns take up a lot of space! If you want to get a lot more turns, try using* magnet wire *instead. It's really thin wire with a thin layer of insulating coating.*

TRY IT OUT: USING A MOTOR AS A GENERATOR

A motor already has a magnet and a coil of wire that can rotate in the magnet's magnetic field. If you rotate the rotor with your hand, you can generate a voltage on the motor's wires.

You could create a generator by reversing the motor you built in Chapter 2, but the power you'd get from it would be too small to measure. Instead, try to find an old motor from a computer fan or a radio-controlled toy car that you don't want to play with anymore. Then, set your multimeter to a low-voltage DC range, such as 2 V DC. Attach the multimeter leads to the motor wires, just as you did with the shake generator, and turn the rotor with your fingers. Some motors have internal circuits that control the motor, and those circuits can prevent the electricity generated inside the motor from going out to the wires. But if you're lucky and find a motor that doesn't have such circuits, you should see a reading on the multimeter. Try a low-voltage AC range on your multimeter if you see nothing with DC.

HOW DO BATTERIES WORK?

I've shown you how to generate electricity manually, but that doesn't explain how you've powered circuits up to this point in the book. You've been using batteries, and in this section, we'll look at what lets those batteries create electricity.

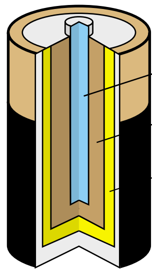
What's Inside a Battery?

To create a battery, you need three things:

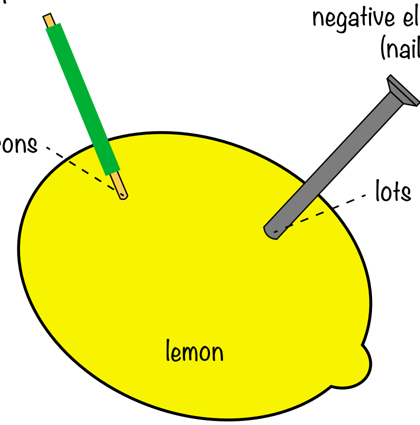
- A positive electrode
- A negative electrode
- An electrolyte

An *electrode* is a wire that is used to make contact with something nonmetallic, like the inside of a battery. An *electrolyte* is a substance that can release or gain electrons.

Here's how these three pieces fit inside a typical battery:



You can actually make your own battery by using a simple nail for one electrode and a copper wire for the other. Stick both into a lemon, and the lemon juice is your electrolyte.



The copper wire becomes the positive terminal of the battery, and the nail becomes the negative terminal.

The Chemistry Behind Batteries

When you combine the lemon, the copper wire, and the nail, two chemical reactions happen: one between the lemon juice and the nail, and another between the lemon juice and the copper wire. In the first reaction, electrons build up on the nail; in the second, electrons leave the copper wire. The nail gets too crowded with electrons, and the copper wire ends up with too few. Electrons don't like to be in crowded places, so the electrons on the nail want to go over to the copper wire to even things out. But the chemical reactions with the lemon juice are pushing the electrons the other way.

Now, what do you think will happen if you connect a light bulb between the nail and the copper wire? The electrons on the nail really want to get to the copper wire, so they'll take the easiest path they can find, and when you create this closed-loop circuit, they flow from the nail to the copper wire through the light bulb. Recall that current is just electrons flowing in a wire; if you have enough current flowing through the light bulb, it lights up!

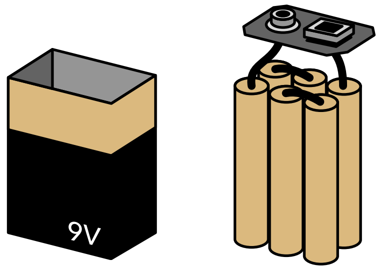
After a while, the chemical reactions in the battery stop. When this happens, the battery is dead. Some batteries can be recharged when they die, while others must be thrown away. The materials chosen for the electrodes and electrolyte determine whether the battery can be recharged or not.

The batteries you buy in the store are not made of lemons, of course! Modern batteries are made from different materials, and scientists are always looking for new ways to create batteries that have more energy, while being small and lightweight.

What Determines a Battery's Voltage?

The materials used for the electrodes and electrolyte determine the voltage you get from a battery, but the size of the electrodes and the amount of electrolyte don't matter when it comes to voltage.

To create higher battery voltages, several battery cells are connected in *series*. Connecting two battery cells in series means that you connect the positive side of one battery to the negative side of the other. The two unconnected terminals become the bigger battery's new positive and negative terminals, and the resulting voltage is the sum of the voltages from the two batteries. For example, in a standard 9 V battery, you have six 1.5 V battery cells, as shown. Notice that the connectors on the outside are attached to just two terminals.



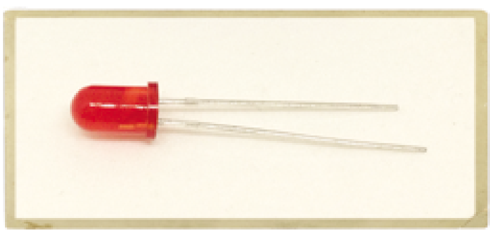
PROJECT #6: TURN ON A LIGHT WITH LEMON POWER

You can make a battery out of many different things; for example, in "What's Inside a Battery?" on page 55, I showed you how a lemon battery might work. In this project, you'll learn how to build a lemon battery of your own and power a light with it.

WARNING *When you're finished with this project, throw the lemons away. The chemical reactions that happen with the nail and copper wire will leave the lemons unsuitable for eating.*

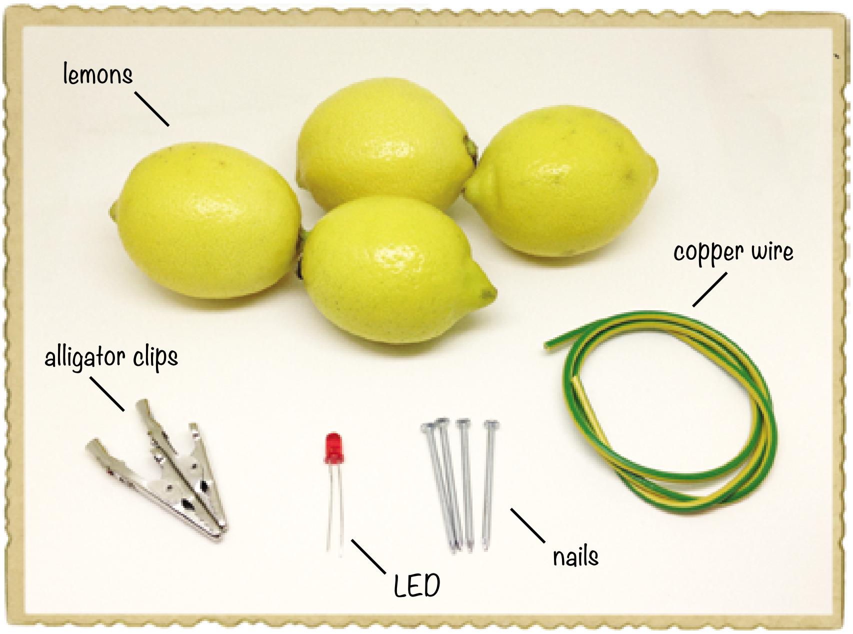
Meet the LED

A lemon battery can't create a lot of electricity, so you need to connect the battery to something that needs very little power to see the effect. Most light bulbs need more power than you'll generate in this project, so let me introduce a component called a *light-emitting diode*, or *LED*.



This little electronic component gives off, or *emits*, light when you apply a little bit of power to it. LEDs come in many colors: red, green, yellow, blue, and more. You'll learn more about this component in Chapter 4, and you'll use LEDs a lot in this book. For now, you're just going to use an LED to see the power generated by your lemon battery.

Shopping List



- **Four lemons** or one lemon cut into four pieces.
- **24 inches of copper wire** (any copper wire will do, but it's important that the wire be copper).
- **Four galvanized nails** (most common nails for outdoor projects are galvanized).
- **Two alligator clips** (Jameco #256525, Bitsbox #CN262) for connecting the LED.
- **A standard LED** (Jameco #333973, Bitsbox #OP002 for just this one, or Jameco #18041, Bitsbox #K033 for a variety pack). You'll need several LEDs for the projects in this book, so order at least 10 or a variety pack.

Tools

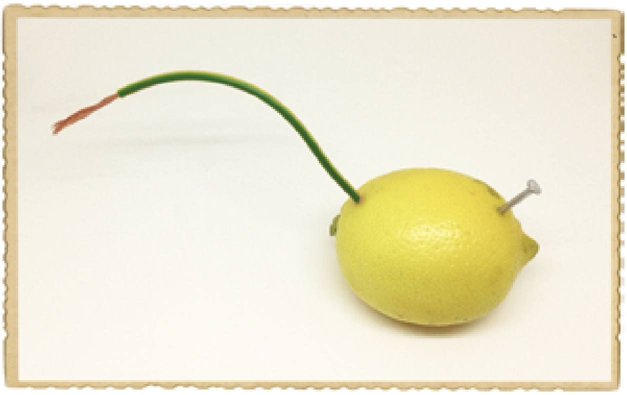
- **A wire cutter** (Jameco #35482, Bitsbox #TL008) to prepare the copper wire.
- **A multimeter** (Jameco #2206061, Bitsbox #TL057, Rapid Electronics #55-6662) to see whether your battery is working correctly.

Step 1: Prepare Your Wires

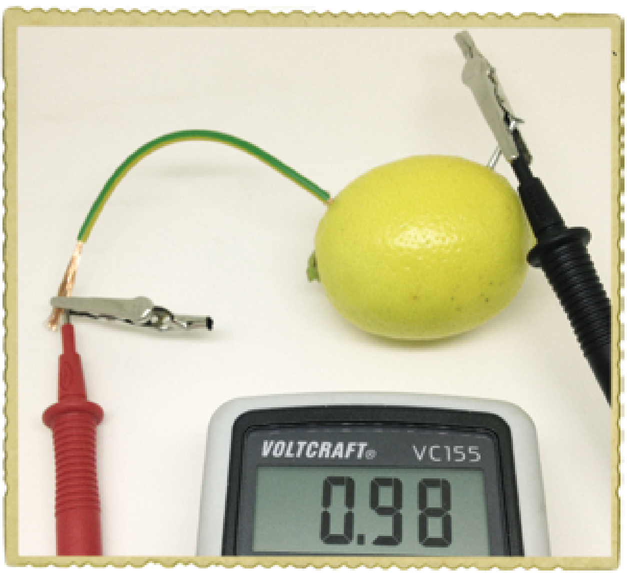
First, cut your copper wire into four 6-inch lengths. Strip about 1 inch of insulation from both ends of each wire. These will become the electrodes.

Step 2: Insert Electrodes into a Lemon

Roll and squeeze a lemon so that you break up the small juice packets inside it, but not enough to break the skin. Then, use a nail to make one hole in one end, push a copper wire into that hole, and push the nail into the other end, as shown. This is the first lemon battery!



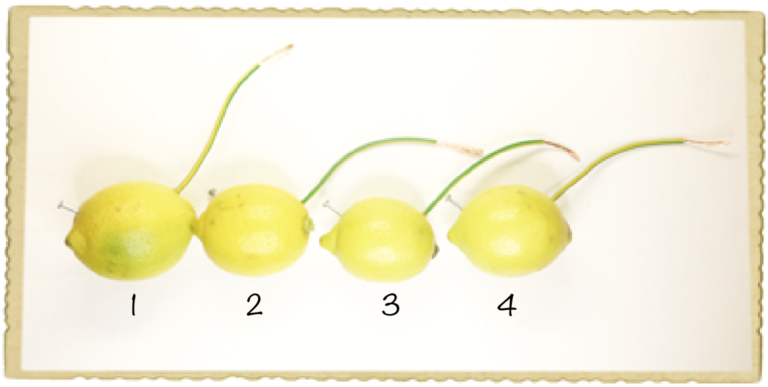
Get your multimeter, set it for DC voltage measurement, and test your lemon battery now. Place the positive test lead on the copper wire and the negative test lead on the nail. If everything works correctly, you should see a voltage of around 1 V on your multimeter.



Step 3: Create Four Lemon Batteries

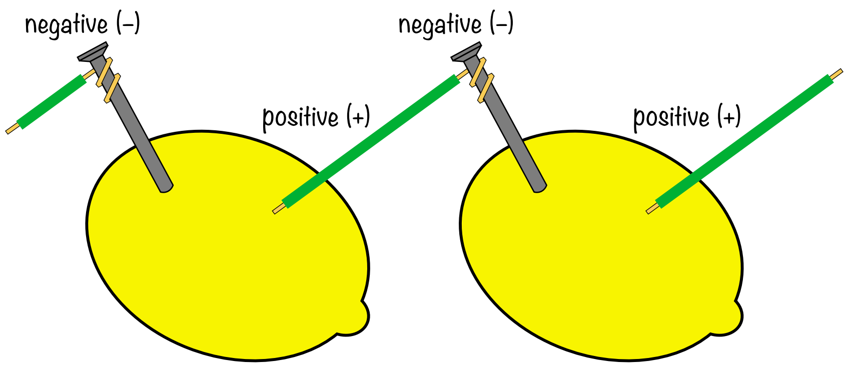
Even if you get 1 V out of your lemon, that's not enough to light an LED. Let's create several lemon batteries so we can get more electricity!

Just repeat the process described in Step 2 for the other lemons; each will become a battery. (If you don't have four lemons to spare, you can cut one lemon into four pieces.) Now you should have four lemon batteries.



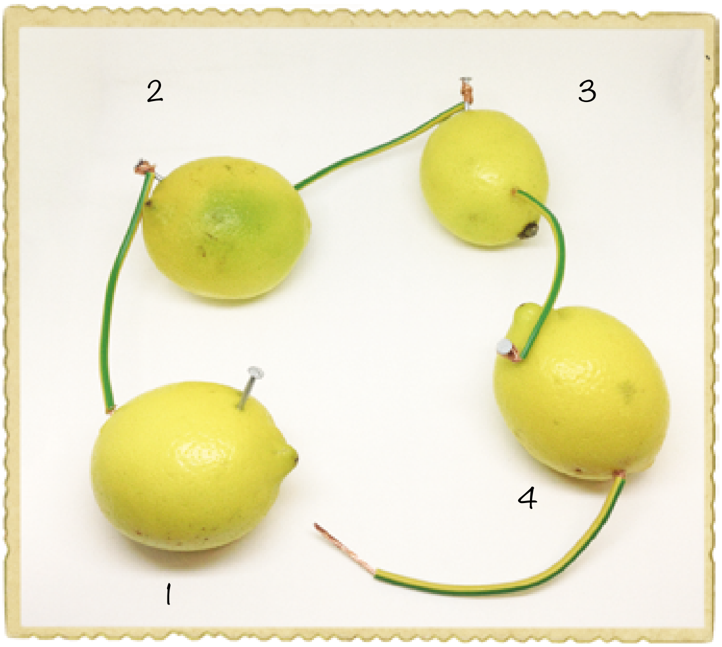
Step 4: Connect the Lemons in Series

To get a higher voltage with your lemon batteries, you'll need to connect them in series. To connect two lemons in series, you just connect the positive side of one lemon to the negative side of another. Remember, the copper wire is positive, and the nail is negative.

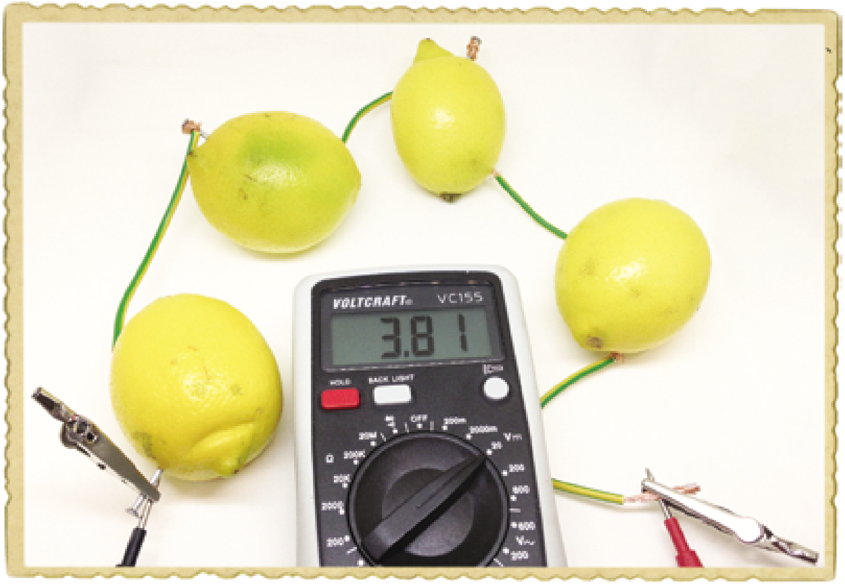


To wire four lemons in series, just repeat that process a couple more times. Line your lemons up in a row with the copper wires pointing to the right and number the lemons from 1 to 4, beginning from the left. Connect the copper wire from lemon 1 to the nail in lemon 2. Twist the wire onto the nail so that the metals connect without coming apart.

Connect the copper wire of lemon 2 to the nail in lemon 3, and connect the copper wire from lemon 3 to the nail in lemon 4. This should give you a row of four lemons, with an unconnected nail on lemon 1 and an unconnected copper wire on lemon 4. These are the positive and negative terminals for your big lemon battery, respectively.

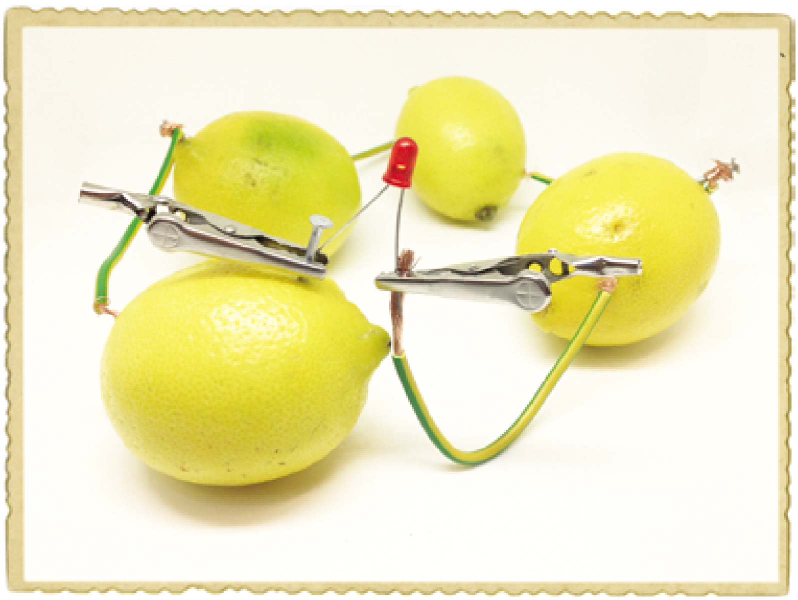


When you connect batteries in series, you can add their voltages to find your total. Four 1 V lemon batteries should give you 4 V. If you have a multimeter, measure the voltage between the two ends to see whether everything is connected. You should get a voltage of around 3.5 to 4 V.



Step 5: Test Your Lemon Battery

Let's connect the LED to the lemons! Connect the long leg from the LED to the copper wire, and connect the short leg to the nail, as shown. The LED should now light up.



Lemons aren't super powerful batteries (you'd never see anyone with a lemon connected to their computer, for example), so your LED will probably be very dim. After you finish building your lemon-powered circuit, turn off the light in your room, and you should see the LED glow.

Remember, when you're finished with your lemon battery, throw the lemons away—don't eat them!

TRY IT OUT: MORE FOOD BATTERIES!

When you're done making lemon batteries, test to see whether you can make batteries out of other fruits or vegetables. For example, what about a potato battery? Are you able to get more voltage, or is it the same as the voltage from the lemon?

Step 6: What If Your Lemon Light Doesn't Work?

If you can't see light from your LED, even in a dark room, check to see whether your LED is connected the right way. The long leg should be connected to the positive side of the battery, which is the copper wire.

Make sure the lemons are connected to each other only through the wires and nails. For example, if your lemons are sitting in a puddle of lemon juice, they could be connected through that. Just dry them off and move them somewhere else. Next, check that the copper wires are properly connected to the nails and that the nails and copper wires are actually touching the juice inside the lemons. Also, check that the nails and copper wires are not touching each other inside any of the lemons.

If the circuit still doesn't work, disconnect all the lemon batteries from each other. Then, use a multimeter to check that each lemon battery has some voltage. Connect two lemons in series, and check that you see a higher voltage. Connect the third lemon, and check that the voltage has increased again. Then, connect the fourth lemon and check that you have even more voltage.

If you see a voltage but the LED doesn't light, then you probably just need some more power. Get another lemon or two, create some more batteries, and connect them in series with the rest.

WHAT'S NEXT?

In this chapter, you learned how to create your own electricity from magnetism and chemical reactions. You made your own shake generator, and you built a lemon battery to power an LED.

If you want to explore generators even more, I suggest trying to find a *dynamo* from an old bike. Unlike the generator you built in this chapter, a dynamo is a generator that gives you a DC voltage, like a battery, and dynamos are commonly used to power headlights on bikes. Cut some windmill blades out of some stiff cardboard or plastic, connect them to the dynamo, and see whether you can harvest energy from the wind.

You've now met a few electronic components, including switches, LEDs, and motors. In the following chapters, you'll learn about even more components and graduate to building some real electronic circuits, like lights that blink, a touch-sensitive switch, and even your own electronic musical instrument!