
GENERATE ELECTRICITY WITH A LEMON BATTERY

Can you imagine how your life would change if batteries did not exist? If it were not for this handy storage of electrical energy, the radio in a car would not function, nor would the lights. A pacemaker or hearing device would need to be plugged into a wall outlet in order to function, and do not forget all portable electronic devices like phones, digital music players, or tablets, which are all powered by batteries.

With all the frustration you might have endured coping with dead batteries, it might surprise you how easy it is to make one out of household materials. Try out this activity, and it might just charge up your imagination.

The Battery Test Center at Idaho National Laboratory is the Department of Energy's primary center for battery technology testing. The test facility provides 17,500 square feet of laboratory space equipped with tools that allow testing of several hundred batteries at the same time, ranging from small cells to full-sized battery packs used in today's light-duty vehicles.

GRADE LEVELS: K-5

VOCABULARY

ELECTRICITY- *a form of energy resulting from the existence of charged particles (such as electrons or protons), either statically as an accumulation of charge or dynamically as a current.*

BATTERY- *a container consisting of one or more cells, in which chemical energy is converted into electricity and used as a source of power.*

CHEMICAL REACTION- *a process in which one or more substances are converted to one or more different substances.*

ELECTRICAL CONDUCTOR- *material which electricity, heat or sound can flow through.*

MATERIALS

- Pennies
- Water
- A few drops of dishwashing soap
- Paper towels
- Aluminum foil
- Scissors
- Ruler
- Plate
- Knife
- At least one lemon (preferably with a thin skin)
- Plastic-coated paper clips (2)



INSTRUCTIONS

PREP WORK

1. Wash your pennies in soapy water, then rinse and dry them off with a paper towel. This will remove any dirt sticking to the pennies.
2. Cut out three aluminum foil rectangles, each 3 centimeters (cm) by 20 cm. Fold each strip in thirds, lengthwise, to get three sturdy 1 cm by 20 cm aluminum strips.

PROCEDURE

1. Put the lemon on a plate, on its side, and carefully use the knife to make a small cut near the middle of the lemon (away from either end). Make the cut about 2 cm long and 1 cm deep.
2. Make a second, similar cut, parallel to the first, so the cuts are about 1 cm apart.
3. Push a penny in the first cut until it sits halfway down into the lemon. Part of the penny should be in contact with the lemon juice, as a chemical reaction between the copper from the penny and the lemon juice plays an essential role in generating electricity. The copper penny that is in contact with the lemon juice is called the electrode of your battery. Note: If your lemon has a very thick skin, you might need to cut away some lemon peel.
4. Slide one of the aluminum strips in the second cut until you are sure part of the aluminum is in contact with the lemon juice. The aluminum strip that sits inside the lemon is the second electrode of your battery. It will react with the lemon juice to generate electricity.

Do you think it is important for the aluminum to be in contact with the lemon juice?

5. You just made a battery! It has two electrodes made of different metals (copper and aluminum) and an electrolyte (the lemon juice) separating them.

Do you think this battery is generating electricity or is there still something missing?

6. *Your battery can generate electricity but will only do so when the electrodes relate to something that conducts electricity. To create a connection, attach the second aluminum strip to the part of the penny sticking out of the lemon with a plastic-coated paperclip. Make sure the aluminum touches the penny so electricity can pass between the copper penny and the aluminum foil.*

You used an aluminum strip to create a connection; would you expect a plastic strip to work as well?

7. *As soon as the two aluminum strips touch each other, electricity will be produced in the battery and flow through the aluminum strips, from one electrode to the other. Since you cannot see the electricity flowing, let us try to feel it. Let the two strips of aluminum touch a sensitive area on your body, like your fingertip or tongue, with about 1 cm in between the places where the aluminum touches the body part.*

Can you feel a tingling, created by a small amount of electricity running from one aluminum strip to the other through your body?

8. *Some of our test persons needed a slightly more powerful battery before they could feel the tingling sensation created by the electricity. To increase the power, build a second battery, identical to the first. Remember a battery consists of two electrodes (the copper penny and the aluminum foil) separated by an electrolyte (the lemon juice). You can choose a different spot on the lemon you just used or use a second lemon to build a second battery. Note that you only need one aluminum strip to build a second battery. You will create connections in the next step.*
9. *To connect the second battery to the first, find the aluminum strip of the first battery that serves as an electrode (it has its end inserted in the lemon). Use a plastic-coated paperclip to attach the other end of this aluminum strip to the penny of the second battery (which if you are using one lemon, is just on another part of your lemon). This connects the aluminum electrode of the first battery to the copper electrode of the second battery.*
10. *Test this set of connected batteries in a similar way as you tested the single battery, bringing the ends of the two aluminum foil strips sticking out of your battery set (those that have a free end) in contact with your fingertip or tongue.*

Can you feel electricity running? If you could feel it the first time, is this any different?

Note that some people can clearly describe the intensity of the electricity running through their fingertip or tongue, while others will only be able say whether they feel it or not.

11. *If you still cannot feel it, check if each electrode (pennies and the aluminum strips stuck in the lemon) are inserted deep enough so they are in contact with lemon juice, make sure there is firm contact between the penny and its attached aluminum strip, and make sure the aluminum strips are not touching each other. If all is correct, you might need slightly more electricity to feel the tingling generated by electricity running through your body. You can test another person to see if he or she can feel the electricity, or you can add one more lemon battery to your set.*
12. *Now that you can detect whether electricity is generated or not, try some different configurations.*

What happens if you let the aluminum strips touch each other and your finger or tongue?

CLEANUP

1. Pull out your pennies and throw away the lemon and aluminum strips.



WHAT HAPPENED?

Did you instantly feel a tingling in your fingertip or tongue, or did you need two or more batteries to feel the electricity run?

The tingly feeling is due to a small amount of electricity running through your body. The electricity was generated by your lemon battery. Connecting the aluminum strips to each other or your body allows the electricity to flow.

As soon as you let the aluminum strips touch each other, the tingly sensation disappeared. The electricity will run through the aluminum back to the battery, which is easier than running through your body.

THE SCIENCE BEHIND IT

Batteries are containers that store chemical energy, which can be converted to electrical energy, or what we call electricity. They depend on a chemical reaction to generate electricity (side note: Chemical reactions that generate electricity are called electrochemical reactions). The reaction typically occurs between two pieces of metal, called electrodes, and a liquid or paste, called an electrolyte. The battery you made has one copper electrode (from the penny) and one aluminum electrode (from the aluminum foil) separated by lemon juice, the electrolyte. It will generate electricity as soon as the electricity has a path to flow from one electrode to the other. You created this path using strips of aluminum, a material that conducts electricity well.

By connecting your battery to a body part, you allow the small amount of electricity it generates to run through that body part. This amount of electricity can create a tingly feeling in a fingertip or tongue, two sensitive areas of the body. Experiences will differ from person to person. Some people might only feel the larger amount of electricity generated by connecting several batteries in a particular way, as described in the project.

Letting the aluminum strips touch creates a very easy way for the electricity to run from one electrode to the other, so almost no electricity will travel through your body and the tingly sensation disappears.

Warning: *Letting large amounts of electricity (like the electricity delivered by a wall outlet) run through a body part can cause serious damage. In general, batteries are safe to use in home electronics projects.*

EXTENSIONS

- See what happens if you replace an aluminum strip with a plastic piece, an unfolded metal paperclip, or a toothpick.
- Try different types of metals as electrodes for your batteries. Do you think a battery with two pennies as electrodes would generate electricity? What about a battery with a penny and a nickel? Note that some combinations might generate electricity, but the amount generated might be below your ability to feel it. Connecting two or more of these batteries might help you identify good combinations.
- You used a lemon to provide the electrolyte for your battery. Do you think other vegetables or fruits would work as well? Would a potato, apple, or onion battery work? Would one particular fruit or vegetable outperform the others?
- Scientists call the way you connected the batteries in this activity connecting batteries in series. Do you think the way you connect two batteries makes a difference in the amount of electricity you feel? Try it out; connect the two copper electrodes with each other and connect the two aluminum electrodes with each other. (Note: You will need an extra strip of aluminum folded three times to do this.) Scientists call these connecting batteries in parallel. Test both ways of connecting batteries and compare; maybe you can feel the difference.
- If you have an LED (light-emitting diode) available, investigate how many lemon batteries are needed to light up the LED.

RESOURCES

<https://www.sciencebuddies.org/stem-activities/lemon-battery#exploremore>

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