Electric Circuits

Next Generation Science Standards

NGSS Science and Engineering Practices:

- ☐ Asking questions and defining problems
- ☐ Developing and using models
- ☑ Planning and carrying out investigations
- ☑ Analyzing and interpreting data
- ☑ Using mathematics and computational thinking
- ☑ Constructing explanations and designing solutions
- ☑ Engaging in argument from evidence
- ☑ Obtaining, evaluating, and communicating information

NGSS Cross-cutting Concepts:

- ☐ Patterns
- ☑ Cause and effect
- ☐ Scale, proportion, and quantity
- ☐ Systems and system models
- ☑ Energy and matter
- ☐ Structure and function
- ☐ Stability and change

NGSS Disciplinary Core Ideas:

- ☑ PS3.D: Energy in Chemical Processes and Everyday Life

Initial Prep Time

Approx. 5-10 min. per apparatus

Lesson Time

1 – 2 class periods, depending on experiments completed

Assembly Requirements

- Scissors

Materials (for each lab group):

- Horizon Renewable Energy Science Kit
- Distilled water
- AA batteries
- Protractor
- Stopwatch
- Horizon Renewable Energy Monitor or multimeter (optional)

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Lab Setup

- We recommend completing step 1 in Experiment 2 and steps 1 and 2 in Experiment 3 in the Assembly Guide for each electrolyzer so your students do not have to assemble the fan, cut tubing, or fill the electrolyzer initially.
- For this activity, your students will not need the wind turbine parts of the lab kit.
- Lab includes small parts that can go missing easily. Set up a resource area for each lab table or for the entire class to minimize lost pieces.
- If you don't have access to a multimeter or Horizon Renewable Energy Monitor, omit the Measurements section of this activity.

Safety

- Battery packs can short out and heat up if the red and black contacts touch each other while the unit is in the on position. Be sure to keep them off when not in use.
- Using regular tap water instead of distilled water will severely shorten the lifespan of the fuel cells. Distilled water can be found at most pharmacies or drug stores.
- Running electric current through dry fuel cells or attaching the battery packs backwards can destroy the fuel cells. Be sure to always connect red to red and black to black.
- Beware of water spills, and don't be surprised if someone tries to start a syringe water fight.

Notes on the Renewable Energy Science Kit:

- Direct sunlight, or a strong electric light, is necessary for operation. Overcast and indirect sunlight may not provide sufficient energy. Be sure any artificial light source is close to the solar panel.
- Be sure to line up the gaps on the inner cylinders of the H2 and O2 tanks so that bubbles can escape.
- You may need to inject more water into the O2 side of the cell if the electrolysis reaction is being sluggish. Wait 3 minutes and then try again.

Common Problems

- The motor's fan sometimes needs a little push to get started.
- If there's hydrogen left but the motor doesn't run, you may have to purge the fuel cell. Unplug the black plug and then quickly replace it to purge impure gases.
- If the water level doesn't change after purging the cells, make sure the gaps on the base of the inner cylinders are open so that water can fill them.

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Goals

- Build a complete circuit with a solar panel
- Power a motor and electrolyzer with a solar panel
- Measure voltage and amperage in different circuits

Background

Electricity has fundamentally changed the history of humanity. Steam may have powered the industrial age, but electricity has powered every age since. It would be impossible to eat, work, travel, communicate, or create music or art like we do today without electricity.

Electricity is nothing more than the movement of electrons. Within the right materials, called conductors, electrons are no longer attached to single atoms but can move freely between them. Metals are the best conductors, and copper is one of the best conducting metals. Silver is even better, but it's much more expensive, so most electrical wires are made of copper.

For an electric current to move through wires, though, it needs to be pumped. Just like water through a pipe, there must be pressure that pushes the electrons in one direction or the other. We could fill a pipe with water, just as the copper atoms still have their electrons all around them, but without a pressure to move them they won't go anywhere. In electrical circuits, we call this pressure a voltage. Voltage is measured in volts.

When a voltage is applied to an electric circuit, electrons begin to move in one direction. This produces an electric current. We measure current, the amount of moving electrons, in amperes or amps for short. Some electric current moves in just one direction, and we call that direct current (DC). Other currents move back and forth very quickly, many times a second, and we call that alternating current (AC).

There are two ways that two or more devices can be hooked up to an electric current: in series and

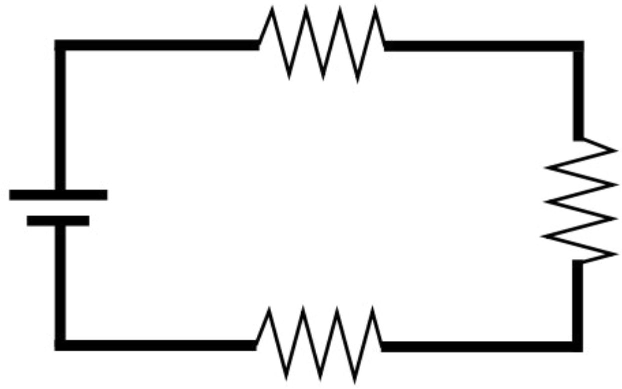

Fig. 1 Series circuit (with 3 resistors)

in parallel. When devices are attached in series, there's only one complete circuit and the devices are attached next to each other like lights on a Christmas tree. (See Fig. 1)

When devices are attached in parallel, the circuit splits current to each individual device and reconnects to the power source. (Fig. 2)

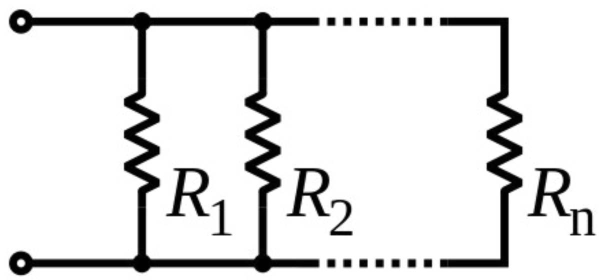

Fig. 2 Parallel circuit (of n resistors)

During this activity, we will use a solar panel to generate DC electricity, see how we can change the amount of current it produces, and attach devices to the circuit in series and in parallel.

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Procedure

1. Use your solar cell to power the small motor that controls the fan. You'll need to connect the solar cell to the fan using wires to carry the electricity. Why do you think you need two wires?
2. When you've connected the solar cell to the motor, you may have to give the fan a little push to get it started. The solar cell will work best in direct sunlight. What happens to the fan if you try the solar cell with other light sources?
3. You can use the electricity from the solar panel to generate hydrogen gas using the electrolyzer. The electrolyzer is the square with "H2" and "O2" printed on either side. What do you think will happen if you connect it to a source of electricity like the solar cell?
4. Your electrolyzer is also a hydrogen fuel cell that can generate electricity from hydrogen and oxygen. It has two small tubes attached to it. Is there anywhere else on the fuel cell that you could attach the longer tubes?
5. Look at the remaining pieces of your kit. If the fuel cell splits water into hydrogen and oxygen gases, what could you use to trap the gases so they don't float away?
6. Connect the tubes of your fuel cell so that you can trap the gases. To generate hydrogen, you'll need to supply an electric current. You can do this with the battery pack or the solar cell. Try both. Which is better at producing hydrogen? How do you know?
7. When you've produced hydrogen, you can use the fuel cell to power the motor just like you did with the solar cell. Plug the motor into the fuel cell and it should start turning. Note in your observations if you see any difference in how the motor works with the fuel cell instead of the solar cell.

Observations

Experimentation

1. With the motor attached, try tilting the solar panel so that it changes the angle of the light that hits it. Can you tilt it far enough that the motor stops running? Does it matter which direction you tilt the panel? Using a protractor, measure the biggest angle at which you can still run the motor.

Maximum angle will change based on type of light source. A powerful light source may be able to keep an almost perpendicular solar cell running. Students should present data to determine whether one direction of tilt is better or worse than another.

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2. Attach both the motor and electrolyzer to the solar panel in series and record your observations below:

Weak light sources might not be able to run both at all, stronger light sources will run both, but visibly slower than each independently.

3. Now attach them both in parallel. How can you split the electricity between the two devices? How does their performance compare to when they were attached in series? Record your observations below:

Students should use the circuit board to attach the devices in parallel. They should note the relative performance of each device compared to the previous configuration

Measurement

For this section, you will need a multimeter or the Horizon Renewable Energy Monitor. For an introduction to using a multimeter, click here.

1. Measure the current in Amps and the voltage in Volts while running the motor. Record your answers below:

(Answers will vary, but check that they are within reason, i.e. not >1A.)

Current: _____________ A

Voltage: ___________ V

2. Measure the current in Amps and the voltage in Volts while running the motor and electrolyzer in series. Record your answers below:

Current: _____________ A

Voltage: ___________ V

3. Voltage is equal to the current multiplied by the resistance (V = IR), so according to your data what is the combined resistance in ohms of the electrolyzer and motor?

Resistance: ____________ Ω

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4. Measure the current in Amps and the voltage in Volts while running the motor and electrolyzer in parallel. Record your answers below:

Current: ____________ A

Voltage: ___________ V

Analysis

1. Make a scientific claim about what you observed while using your circuits.

Claim should reference characteristics of series and/or parallel configurations.
Example: "Series circuits supply less current to each device attached to them."

2. What evidence do you have to back up your scientific claim?

Evidence should cite data in Observations and/or Experimentation sections.
Example: "We measured the current as 0.19 Amps when the devices were in parallel and 0.05 Amps when the devices were in series."

3. What reasoning did you use to support your claim?

Reasoning can draw from Background section and/or other materials used in class.
Example: "We know that a series circuit adds up the resistances of all devices and that V=IR from Ohm's Law."

4. Use your observations to design an experiment you could run to increase the amount of electricity generated by the solar panel. Describe your experiment below.

Many answers are possible, but students should include ways of measuring the electrical output and clear control and experimental groups in the description.

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Conclusions

1. Based on your observations did the electrolyzer and motor get more electric current when they were hooked up in series or in parallel? How do you know?

Be sure that student answers cite data from their observations during the series and parallel experiments.

2. Does hooking up more devices to an electrical circuit in series increase or decrease the electric current in the circuit? Explain your answer.

Students should have observed the decrease in electric current when an additional device in series was connected and answers here should reference those observations.

3. Which is the best way to attach both the motor and electrolyzer with the solar cell at the same time: series or parallel? Explain your answer.

Either is acceptable, as long as students can back up their answer with data from their experiments.