Electricity

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:

- ☑ PS2.A: Forces and Motion
- ☑ PS3.B: Conservation of Energy and Energy Transfer

Initial Prep Time

Approx. 5 min. per apparatus

Lesson Time

Approx. 1 class period

Assembly Requirements

- None

Materials (for each lab group):

- Horizon Electric Mobility Experiment Set
- Stopwatch
- Horizon Renewable Energy Monitor or multimeter (optional)

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Lab Setup

- Your students will need the chassis, the red and black wires, the capacitor, and the hand-crank generator to build their supercapacitor cars.
- 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

- Students must attach the capacitor to the hand-crank generator correctly and only turn the crank clockwise once it's connected. We recommend close supervision the first time students attempt this part of the procedure.
- Safety goggles should be worn at all times.

Notes on the Super Capacitor Science Kit:

- The hand-crank generator is durable, but not indestructible. Try to discourage students from being too enthusiastic in their cranking to prevent breakage.
- There's not too much current from the generator, but students will usually figure out how to zap themselves and their peers by touching contacts or ends of wires. This isn't really a safety issue, but may quickly become annoying.

Common Problems

- If no electricity is flowing, check that all connections are properly wired and try again.

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Goals

- Use a generator to make an electric current
- Store electric charge in a capacitor
- Power a car with the capacitor

Background

More than any other technological advance, electricity has shaped our modern world. Nearly everything you do in an average day, from turning on a light in the morning, to driving to school or work, to listening to music or watching movies, would be impossible without electricity.

Electricity is actually nothing more than the movement of electrons, the tiny subatomic particles that orbit the nucleus of every atom at almost the speed of light. When large numbers of electrons move in one direction, we call that an electric current. But if large numbers of electrons don't move, but instead pile up in one place, we say that we've built up an electric charge.

If you've ever felt your hairs stand on end from static electricity, you've felt an electric charge building up on your skin. When you get an electric shock from touching metal or another person, that charge moves and turns into a short-lived electric current.

Electricity can move in two ways. It can proceed in a single direction around a circuit, or it can move back and forth many times a second, never moving any one electron far from its origin but transmitting electric energy over long distances.

Alternating current(AC), the movement of electrons back and forth in a circuit, is very useful for generating and transporting electricity. The current that comes out of a wall socket anywhere in the world is an alternating current. But direct current (DC), where electricity travels in one direction, is used in nearly all of our electronic devices such as computers, phones, or tablets.

A capacitor is a perfect tool for exploring electricity because it is capable of storing electric charge, which it will then gradually release as electric current. Capacitors do this by stopping electric current from passing through them. When a current is applied to a capacitor, through a generator or battery, the current is forced to build up in the capacitor instead of flowing through it, as the current would do with a lightbulb, motor, or other electrical device.

All that built-up current sits in the capacitor as electric charge, which can then be released as an electric current in the reverse direction if the capacitor is hooked up to an electric circuit.

During this activity, we will use a hand-crank generator to build up electric charge on a supercapacitor (a capacitor with the ability to hold a large amount of electric charge) and we will use that charge to run an electric car.

Procedure

1. Connect the capacitor to the hand-crank generator using the set of red and black wires.

2. Gently turn the hand-crank clockwise to generate current and charge the capacitor. Charge the capacitor for at least 60 seconds.

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3. Disconnect the hand-crank generator from the capacitor and connect the capacitor to the plugs on the front of the frame. Secure the capacitor in the middle of the frame.

4. Connect the wires from the motor to the red and black plugs nearest to them on the front of the frame and the car will start moving. Record your observations below.

Observations

Experimentation

1. How much time does the car run for each turn of the generator? Count how many times you turn the generator and then use a stopwatch to measure the amount of time the motor runs once you connect it to the supercapacitor. Record your results below:

Trial:	Turns:	Time (sec):	Observations:
1			
2			
3			
4			

According to your data, how many seconds of running time do you get per turn of the generator?

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2. Will the capacitor keep its charge when disconnected, or does it lose charge over time? After charging the capacitor for an equal number of generator turns, disconnect it and wait before hooking it up to the motor. Record what happens below:

Trial:	Idle Time (sec):	Motor Time (sec):	Observations:
1			
2			
3			
4			

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. Raise the front wheels off the ground and record the highest current in amps and highest voltage in volts produced while the capacitor is powering the motor. Record your answers below:

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

Current: _____________ A

Voltage: ___________ V

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

Resistance: ____________ Ω

3. Capacitance (C) is measured in farads. Look closely at your capacitor and you'll find that it lists its capacitance. Record it below:

Capacitance: ____________ F

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4. Since C = q/V where q is the charge and V is the voltage, how many coulombs of charge does your capacitor hold?

Charge: _____________ C

5. One coulomb of charge is equal to approximately 6.242×1018 electrons. How many electrons are stored in your capacitor?

_______________ e-

Analysis

1. Make a scientific claim about what you observed while running your capacitor-powered car.

Claim should reference characteristics of electric current.
Example: "Electric charge slowly drains from the capacitor when it's not being used."

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

Evidence should cite data in Observations and/or Experimentation sections.
Example: "We turned the generator the same amount of times for each trial. When we left the capacitor alone for 60 seconds, the car ran for 30 seconds. When we left it alone for 120 seconds, the car ran for 23 seconds. The longer we left the capacitor, the shorter the car ran."

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

Reasoning can draw from Background section and/or other materials used in class.
Example: "If it ran the car for less time, the capacitor must have contained less electrical energy."

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4. Design an experiment that could test the relationship between the size of the capacitor and the current it produces when discharging. Describe your experiment below:

Many answers are acceptable. Students should include ways to change the size of the capacitor or use different capacitors and indicate how they would measure the current produced. There should be clear control and experimental groups described.

Conclusions

1. Why did the car eventually stop moving? Construct an explanation of what you observed using what you know about electricity.

Students can use the concept of minimum voltage or the idea of finite charge moving over time to explain how the current dissipated.

2. Could a capacitor be a useful source of electricity for an electric car? Why or why not?

“Yes” or “No” are both acceptable answers as long as students can justify their responses with data.

3. Based on your observations, does the capacitor lose its charge over time?

Students should cite their data from the Experiment section to support their answer.

4. Based on your results, do you think fuel cells are a good energy source for cars?

Students may take either position on this question, provided they are able to cite information from their experiments to back up their stance.