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:

- ☑ PS1.A: Structure and Properties of Matter
- ☑ 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 Super Capacitor Science Education Kit
- Stopwatch
- Horizon Renewable Energy Monitor or multimeter (optional)

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Lab Setup

- Before the lab starts, you should assemble the fan motor, and attach the super capacitor to its base.
- 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.
- The fan motor sometimes needs a quick tap or flick to get it to start spinning.

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Goals

- Generate an electric current
- Add electric charge to a capacitor
- Create an electric current using a 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 a small motor.

Procedure

1. Look at the super capacitor. It's the long cylinder with one red and one black plug on one end. What wires do you think you should attach to it?

2. Once you've got wires attached to the super capacitor, you'll connect the other end of those wires to the

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potentiometer (po-ten-ti-OM-et-er). That's the dial with red, yellow,

3. and green sections. Where do you think you'll attach the red and black wires? Will it matter which plugs you use?

4. The potentiometer will tell you when you've filled the super capacitor with energy, but you'll need the hand-crank generator to do that. Looking at the generator, how do you think you should attach it to the potentiometer?

5. If you've got your generator hooked up to the potentiometer, turn the hand-crank in a clockwise direction to transfer power to the super capacitor. (WARNING: Do not spin it in a counter-clockwise direction or you will damage the super capacitor!) What do you observe as you spin the hand-crank?

6. As you fill the super capacitor, you'll notice the dial on the potentiometer moving. How will you know when it's full?

7. When you've filled the super capacitor, disconnect the potentiometer from the super capacitor and connect the fan to the super capacitor using the red and black wires. The fan should start moving as soon as it's connected.

Observations

Experimentation

1. Does the capacitor hold the same amount of charge each time you fill it? Use a stopwatch to measure the amount of time the motor runs each time you connect it to the supercapacitor. Record your results below:

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

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2. Will the capacitor keep its charge when disconnected, or does it lose charge over time? After charging the capacitor, wait before hooking it up to the motor and record what happens:

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. 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.

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 fan ran for 90 seconds. When we left it alone for 120 seconds, the fan ran for 67 seconds. The longer we left the capacitor, the shorter the fan 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 fan 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 fan 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.

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