Capacitors and Generators

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

1 – 2 class periods, depending on experiments completed

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

- Use a generator to charge a capacitor
- Use the capacitor to power a motor
- Make calculations based on data

Background

During the mid-1700s, the gentlemen scientists of Europe and America were fascinated with a device called a Leyden Jar, which they would use to electrically shock each other at parties. Ben Franklin actually nearly killed himself while trying to electrocute a turkey with one.

People at the time already knew, as any child does today, that you can generate a static electric charge through friction. Rubbing your feet on carpet and approaching your victim with a finger pointed at them delivers a small electric shock. But the Leyden jar's shock was so large that Pieter van Musschenbroek, who invented it, declared after receiving a shock, "I would not take a second shock for the kingdom of France."

Aside from shocking famed scientists, there wasn't much that could be done with the Leyden jar. But todays technology wouldn't be possible without it because it led to the development of a device called a capacitor.

A capacitor is a device that stores electric charge in an electric field. Working on the same principles as the Leyden jar, it prevents current from flowing through it, causing a buildup of positive charge on one side and negative charge on the other. It can store electrical charge and release it at a steady rate, making it vital for any pieces of electronics that depend on getting just the right amounts of electricity.

Capacitors are found in nearly every electronic device today, from phones and computers to cars and airplanes. Our modern way of life owes much to those brave (and sometimes foolish) people who shocked each other in the name of science.

To charge our capacitor, we will use a hand-crank generator. A generator is basically a backwards electric motor: while an electric motor takes electrical energy and turns it to mechanical energy, a generator does the opposite. That means it's possible to use an electric motor to generate electricity by physically turning the motor.

This is the basic idea behind the hand-crank generator in your equipment. The motor is visible as a metal cylinder inside the plastic casing. By turning the crank, you rotate a set of magnets and coils of wire in the motor, generating electricity.

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?

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2. Once you've got wires attached to the super capacitor, you'll connect the other end of those wires to the potentiometer (po-ten-ti-OM-et-er). That's the dial with red, yellow, and green sections. Where do you think you'll attach the red and black wires? Will it matter which plugs you use?

3. 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?

4. 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?

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

6. 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. 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):	Time (sec):	Observations:
1			
2			
3			
4			

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2. Does charging the capacitor require the same number of turns of the generator every time?

Trial:	Turns:	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. The energy stored in a capacitor is equal to ½CV2 where C is the capacitance in farads and V is the voltage in volts. How many Joules of energy does your capacitor store?

Energy: _______________ J

Analysis

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

Claim should reference the generator or capacitor's electrical capabilities.
Example: "The generator produces the same amount of charge on each turn."

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

Evidence should cite data in Observations and/or Experimentation sections.
Example: "The first trial we turned the generator 108 times to fill the capacitor and it ran for 78 seconds. In all of our other trials, we were within 3 turns to fill the capacitor, and within 5 seconds of running time."

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

Reasoning can draw from Background section and/or other materials used in class.
Example: "Roughly the same number of turns of the generator provided roughly the same amount of electrical energy to run the motor."

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4. Design an experiment that compares the energy produced by the generator to the energy discharged by the capacitor. Describe your experiment below.

There are many acceptable responses, but students should be sure to include how they will measure the electrical energy produced by the generator and capacitor. There should be distinct control and experimental trials described.

Conclusions

1. Why do you think there is a limit to how much charge can be stored on a capacitor?

Answers should mention the physical dimensions of the capacitor in some way.

2. How could the amount of charge that a capacitor can store be increased?

Answers could include making the capacitor physically larger, increasing surface area, separating the capacitor's plates, changing the dielectric material, or others depending on students' familiarity with capacitors in general.

3. 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.

4. Do you think the generator was an efficient way to charge the capacitor? Why or why not?

Once again, "Yes" or "No" are both acceptable answers as long as students can justify their responses with data.