# Voltage and Current

## Goals:

- Build a complete circuit
- Power a light
- Measure voltage and amperage

## Next Generation Science Standards

**NGSS Disciplinary Core Ideas**
– PS3.D: Energy in Chemical Processes and Everyday Life

**NGSS Cross-cutting concepts**
– Cause and effect
– Energy and matter

**NGSS Science and engineering practices**
– Analyzing and interpreting data
– Constructing explanations and designing solutions
– Engaging in argument from evidence
– Obtaining, evaluating, and communicating information

## Introduction

People have been fascinated by the mysterious and invisible phenomenon of electricity for centuries. It is powerful and all around us, but only its effects can be observed by humans without tools. Today, we know that electricity is a flow of electrons. Electrons are found in atoms, which make up all matter. They are smaller and more mobile than atoms, and they have lots of unusual properties.

You can picture electrons in a metal wire like water in a pipe. When water is set in motion by a pump, it starts to flow through the pipe. This flow can be used to drive a small water wheel, for example.

As with pumps in a water pipe, there are things that can cause electrons to flow through a wire — for example, batteries and generators. You can use flowing electrons, called electrical current, to do lots of amazing things. The technology of controlling electrons to perform certain goals is called electrical engineering.

A water pump has two ends: one for suction and one for expulsion. Electrical current sources also have two ends, or terminals. At one, called the positive pole, they create a sort of electron vacuum. At the other end, the negative pole, they produce a sort of electron overload.

Current only flows when the poles, or terminals, are connected. Then, the electrons flow from the negative pole to the positive pole, and the force of their flow is capable of doing things like lighting a light bulb or spinning a motor. If the circuit is broken at any point, the flow of current immediately stops.

You have to distinguish carefully between voltage and current strength. Available voltage doesn't mean that current is actually flowing — just as water won't flow from a closed water tap just because there is pressure in the water line. On the other hand, high pressure can push more water through the tap per second than low pressure can. A high electric voltage, likewise, can make a current flow with more strength than low voltage.

In activity you will be generating electricity using a hand crank.

Today, about 60% of electricity is generated using fossil fuels (coal, oil, and natural gas), which are burned in order to heat water to create steam to turn a turbine. The turbine drives an electromagnet that generates electricity. Nuclear and hydro electric power plants also use turbines. The crank in this kit models these turbines on a smaller scale, using your energy.

**Name** ____________ **Group Members** ____________________ **Date** __________

## Materials

– Crank handle
– Generator/motor, switched to generator (G) mode with the gear ratio set to 35X
– LED
– GEMS device
–Easy wire connector x2

## Procedure

*refer to page 19 of the manual*

1. Connect the crank handle to the shaft of the generator/motor. Make sure that the generator/motor is switched to generator (G) mode.
2. Connect one end of the first easy wire connector to the generator/motor and the other end to the socket on the bottom left of the GEMS device
3. Connect one end of the second easy wire connector to the socket on the top right of the GEMS device and the other end to the LED. Make sure the GEMS device is switched to output mode.
4. Turn the hand crank clockwise and observe the effect on the light and the output readings on the GEMS device.

## Observations

## Experimentation

1. How does the speed with which you turn the crank change the readings?

2. What is the minimum electrical output needed to power the light?

3. The generator has two gear ratio settings. What happens if you change the ratio to 70X?

## Analysis

1. Make a scientific claim about what you observed.

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

3. Explain the reasoning behind your claim.

# Wind Power

## Goals:

- Build a wind power generator
- Compare the efficiency of various configurations
- Make observations based on data

## Next Generation Science Standards

**NGSS Disciplinary Core Ideas**
– PS3.D: Energy in Chemical Processes and Everyday Life

**NGSS Cross-cutting concepts**
– Cause and effect
– Scale, proportion, and quantity
– Energy and matter
– Structure and function
– Stability and change

**NGSS Science and engineering practices**
– Planning and carrying out investigations
– Analyzing and interpreting data
– Constructing explanations and designing solutions
– Engaging in argument from evidence
– Obtaining, evaluating, and communicating information

## Introduction

People have been building wind turbines for centuries to harness the power of the wind. Windmills convert the kinetic energy of the wind into rotary motion. In the past, they were used to grind grain, but today they are used as a major source of renewable energy generation. And now it's your turn to build one.
The shape of the rotor blades is similar to the shape of airplane wings. The physics of how these blades work is complicated, but the basic idea is this: Because of their geometric form, the blades exert a downward force on the air as it flows past. Newton's third law states that for every action, there is an equal and opposite reaction. Thus, the air exerts an upward force on the blades causing them to turn. In the past, turbine blades were rotated so that the wind pushed on their surface and thereby rotated them (which uses a force called drag). But engineers now know that using lift is more efficient.

Name ______________ Group Members ________________________ Date __________

## Materials

– Generator/motor, switched to generator (G) mode with the gear ratio set to 35X
– Assembled wind turbine (see page 9 of the manual)
– Supercapacitor switched to IN
– GEMS device
– Easy wire connector x2
– 7-hole rounded rod
– Static axle connector x6
– A fan
– Clear, lightweight plastic, a clean plastic soda bottle works well

## Procedure

*refer to page 28 of the manual*

1. Connect the generator to the supercapacitor using the 7-hole rounded rod
2. Insert four of the axle connectors into the top of the GEMS device and mount the generator and supercapacitor on top.
3. Using the remaining two axle connectors, attach the wind turbine to the top of the generator.
4. Connect one end of the first easy wire connector to the socket at the top left of the GEMS device and the other end to the generator.
4. Connect one end of the second easy wire connector to the socket on the top right of the GEMS device and the other end to the supercapacitor. Make sure the GEMS device is switched to output mode.
5. Place the wind turbine in front of the fan and turn on the fan. Ideally the center of the fan should align with the center of the turbine. Record the output displayed on the GEMS device on the next page. What do you think would change if you moved the turbine closer or farther from the fan? What if you placed it off center?
6. Adjust the angles of the blades by turning them so that the notches at the base point to a different dot on the hub. What changes? What happens if they are not all adjusted to the same position? Record your findings on the next page.
7. Design and make your own blades using the plastic and record your findings on the next page.
8. Changing one variable each time, test your wind turbine at least 8 more times and record the output on the next page. Can you make the turbine even more efficient?

## Experimentation

| Type of Blade | Blade Angle | Other Adjustments | Voltage (Volts) | Current (Amps) |
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## Additional Observations

## Analysis

1. Make a scientific claim about what you observed.

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

3. Explain the reasoning behind your claim.

# Solar Power

## Goals:

- Build a solar power generator
- Compare the efficiency of various configurations
- Make observations based on data

## Next Generation Science Standards

**NGSS Disciplinary Core Ideas**
– PS3.D: Energy in Chemical Processes and Everyday Life

**NGSS Cross-cutting concepts**
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## Introduction

A solar cell is typically made of silicon semiconductors, which have special properties that allow them to generate electricity from light. A semiconductor is a material that is in between materials that conduct electricity, like metals, and materials that do not conduct electricity, like wood.

To make a semiconductor out of silicon, other elements are added to it. Silicon semiconductors include two types of layers: N-type layers, which have phosphorous atoms added to the silicon, and P-type layers, which have boron atoms added. Phosphorous has one more electron in its outer shell than silicon, so the N-type layer has extra negative charges that are free to roam around. Boron has one fewer electron than is required to bond with the surrounding silicon atoms, so the P-type layer has positively-charged electron vacancies or "holes." When the layers are put next to each other, the free electrons in the N-type layer fill the holes of the P-type layer, and these free electrons become bound. This separation of charges results in an electric potential, or electric field, between the two layers: the side with the boron atoms, which originally had the holes, now is negatively charged, and the side with the phosphorous atoms is now positively charged.

When sunlight strikes a solar cell, the electrons that are bound in the P-type layer absorb energy from the light and become free again. The electric field between the two layers forces the electrons to flow, thus creating an electric current. The flow of electricity will continue as long as the sunlight hits the solar cell.

The solar energy striking Earth's atmosphere each year is an unimaginable 1,500,000,000,000,000,000 kilowatt-hours. This corresponds to about 8,000 times the energy consumption of all of humanity (as of 2023).

A large portion of the solar energy is reflected or absorbed by the atmosphere. The rest of this sunlight hits Earth's surface and can be used to generate electricity.

Name ____________ Group Members ______________________ Date __________

## Materials

– Generator/motor, switched to generator (G) mode with the gear ratio set to 35X
– Solar panel
– Supercapacitor switched to IN
– GEMS device
– Easy wire connector x2
– 7-hole rounded rod x3
– Static axle connector x2

## Procedure

1. Assemble the 7-hole rounded rods, static axle connectors, and solar panel as shown on page 31, steps 14 and 15 of the manual.
2. Connect one end of the first easy wire connector to the socket at the bottom left of the GEMS device and the other end to the solar panel.
3. Connect one end of the second easy wire connector to the socket on the top right of the GEMS device and the other end to the supercapacitor. Make sure the GEMS device is switched to output mode.
5. Place the solar panel in direct sunlight. Angle its surface so that the sunlight hits it perpendicularly (at a 90º angle) to the surface. Record the output displayed on the GEMS device on the next page. What do you think would change if you changed the angle? What if you used a different light source or placed a colored filter in front of the solar panel?
6. Changing one variable each time, test your solar panel at least 8 more times and record the output on the next page. What conditions produce the strongest readings?

## Experimentation

| Light source | Panel Angle | Other Adjustments | Voltage (Volts) | Current (Amps) |
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## Additional Observations

## Analysis

1. Make a scientific claim about what you observed.

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

3. Explain the reasoning behind your claim.