Solar Education for NY
SchoolPower ...Naturally

Junior Solar Sprint Series: Electrical Power

SPN LESSON #11

TEACHER INFORMATION

LEARNING OUTCOME: Students are able to describe how photovoltaic cells produce electricity, what voltage and amperage are, and how each relates to electric power. They know how to arrange PV cells in series and parallel circuits and show how doing so changes the voltage and amperage output.

LESSON OVERVIEW: Students read about how photovoltaic cells produce electricity. After using parallel and series electrical circuits to see how to increase the electrical power of solar cells, they develop testable hypotheses and design laboratory investigations. They use instruments (ammeters and voltmeters) and mathematical formulas as they explore what *electrical power* means. Finally, they examine their school's solar collector to determine how the solar cells are arranged to produce electrical output.

GRADE-LEVEL APPROPRIATENESS: This Level II Physical Setting, technology education lesson is intended for students in grades 5–8.

MATERIALS

2 photocells (about 5V each)
1 small motor (1.5V)
1 milliammeter
1 voltmeter
Junior Solar Sprint solar cell
School solar array

SAFETY

There are no safety concerns for this lesson.

TEACHING THE LESSON

Ask students to describe their ideas of how solar cells work. Engage them in a discussion of the ideas without judging the validity of their comments. Then give them the introduction to read and have them respond to the questions in it. You might want students to start responding to the questions in class and then finish them for homework. Review and clarify responses and elicit questions in the following class period.

After the initial discussion, ask:

- whether the arrangement of solar cells in series compared to parallel circuits has an effect on solar power, and
- how their solar car's electrical energy might be increased.

After these initial discussion sessions, prepare the cells (if not already prepared) by soldering the red wire to the backside or positive pole. Solder the black wire to the front or negative pole.

ACCEPTABLE RESPONSES FOR DEVELOP YOUR UNDERSTANDING SECTION

Part A:

1. Raising the height of the waterwheel (making it bigger) and increasing the amount of water falling through the wheel.
2. By increasing either the voltage or the amperage of the solar cells. [Since we would have to rebuild the waterwheel to increase its potential energy, we would have to do the same with the solar cell. So our only feasible way to increase the power of the solar cell is to increase the electron flow and that can be done by increasing the amount of sunlight energy focused on the cell.] Part B:

Procedure Sections: Lab data will vary according to the equipment used and the sunlight available. Voltage produced by the series circuit should be greater. Amperage should be greater for the parallel circuit. Wattage should be approximately the same for both circuits.

Develop Your Understanding Section:

1. Series circuit
2. Parallel circuit
3. They should be the same.
4. In parallel
5. In series
6. No, because changing circuitry would not change the power produced.
7. Yes. The panels must be wired in series with one another.
8. Higher voltage indicates series circuitry.

ADDITIONAL SUPPORT FOR TEACHERS

SOURCE FOR THIS ADAPTED ACTIVITY

This lesson was adapted from materials developed for Junior Solar Sprint by the Northeast Sustainable Energy Association and NREL and the Minnesota Renewable Energy Society.

BACKGROUND INFORMATION

This lesson is one of several preliminary classroom investigations leading to an understanding of the scientific phenomena underlying the operation of, and the eventual building of, a competitive model solar car. This competition is sponsored by the Junior Solar Sprint (JSS) Program, developed originally under the auspices of the U.S. Department of Energy and currently sponsored by the Northeast Sustainable Energy

Association (NESEA) and the U.S. Army. Visit NESEA at www.nesea.org for complete information and more learning activities.

Cells wired in series produce a higher voltage (charge) but lower current (amperage). Cells wired in parallel produce a greater current but lower voltage. No more electrical energy is produced in either wiring method, if the same amount of sunlight energy collected remains constant during the comparison.

REFERENCES FOR BACKGROUND INFORMATION

nesea@nesea.org
Northeast Sustainable Energy Association, 50 Miles Street, Greenfield, MA 01301, phone 413-774-6051

R. Brown: brownrw@tcfreenet.org
Minnesota Renewable Energy Society

LINKS TO MST LEARNING STANDARDS AND CORE CURRICULA

NYS Intermediate Level Science Core Curriculum Grades 5-8

Standard 1—Analysis, Inquiry, and Design: Students will use mathematical analysis, scientific inquiry, and engineering design, as appropriate, to pose questions, seek answers, and develop solutions.

Mathematics Key Idea 1: Abstraction and symbolic representation are used to communicate mathematically.

M1.1: Extend mathematical notation and symbolism to include variables and algebraic expressions in order to describe and compare quantities and express mathematical relationships.

M1.1b: Identify relationships among variables including: direct, indirect, cyclic, constant; identify non-related material.

M1.1c: Apply mathematical equations to describe relationships among variables in the natural world.

Key Idea 2: Deductive and inductive reasoning are used to reach mathematical conclusions.

M2.1: Use inductive reasoning to construct, evaluate, and validate conjectures and arguments, recognizing that patterns and relationships can assist in explaining and extending mathematical phenomena.

M2.1b: Quantify patterns and trends.

Key Idea 3: Critical thinking skills are used in the solution of mathematical problems.

M3.1: Apply mathematical knowledge to solve real-world problems and problems that arise from the investigation of mathematical ideas, using representations such as pictures, charts, and tables.

M3.1a: Use appropriate scientific tools to solve problems about the natural world.

Science Key Idea 2: Beyond the use of reasoning and consensus, scientific inquiry involves the testing of proposed explanations involving the use of conventional techniques and procedures and usually requiring considerable ingenuity.

S2.1: Use conventional techniques and those of their own design to make further observations and refine their explanations, guided by a need for more information.

S2.1b: Conduct an experiment designed by others.

S2.1d: Use appropriate tools and conventional techniques to solve problems about the natural world, including:

- measuring
- observing

S2.2: Develop, present, and defend formal research proposals for testing their own explanations of common phenomena, including ways of obtaining needed observations and ways of conducting simple controlled experiments.

S2.2b: Design scientific investigations (e.g., observing, describing, and comparing; collecting samples; seeking more information, conducting a controlled experiment; discovering new objects or phenomena; making models).

S2.2c: Design a simple controlled experiment.

S2.2d: Identify independent variables (manipulated), dependent variables (responding), and constants in a simple controlled experiment.

S2.3: Carry out their research proposals, recording observations and measurements (e.g., lab notes, audiotape, computer disk, videotape) to help assess the explanation.

S2.3c: Collect quantitative and qualitative data.

Key Idea 3: The observations made while testing proposed explanations, when analyzed using conventional and invented methods, provide new insights into phenomena.

S3.1a: Organize results, using appropriate graphs, diagrams, data tables, and other models to show relationships.

S3.1b: Generate and use scales, create legends, and appropriately label axes.

S3.2: Interpret the organized data to answer the research question or hypothesis and to gain insight into the problem.

S3.2a: Accurately describe the procedures used and the data gathered.

S3.2b: Identify sources of error and the limitations of data collected.

S3.2c: Evaluate the original hypothesis in light of the data.

S3.2d: Formulate and defend explanations and conclusions as they relate to scientific phenomena.

S3.2e: Form and defend a logical argument about cause-and-effect relationships in an investigation.

S3.2f: Make predictions based on experimental data.

S3.2g: Suggest improvements and recommendations for further studying.

S3.3: Modify their personal understanding of phenomena based on evaluation of their hypothesis.

Engineering Design Key Idea 1: Engineering design is an iterative process involving modeling and optimization (finding the best solution within given constraints); this process is used to develop technological solutions to problems within given constraints.

T1.3: Consider constraints and generate several ideas for alternative solutions, using group and individual ideation techniques (group discussion, brainstorming, forced connections, role play); defer judgment until a number of ideas have been generated; evaluate (critique) ideas; and explain why the chosen solution is optimal.

T1.3a: Generate ideas for alternative solutions.

T1.3b: Evaluate alternatives based on the constraints of design.

T1.4: Develop plans, including drawings with measurements and details of construction, and construct a model of the solution, exhibiting a degree of craftsmanship.

T1.4a: Design and construct a model of the product or process.

T1.4b: Construct a model of the product or process.

T1.5: In a group setting, test their solution against design specifications, present and evaluate results, describe how the solution might have been modified for different or better results, and discuss trade-offs that might have to be made.

T1.5a: Test a design.

T1.5b: Evaluate a design.

Standard 6—Interconnectedness: Common Themes. Students will understand the relationships and common themes that connect mathematics, science, and technology and apply the themes to these and other areas of learning.

Key Idea 6: In order to arrive at the best solution that meets criteria within constraints, it is often necessary to make trade-offs.

6.1: Determine the criteria and constraints and make trade-offs to determine the best decision.

6.2: Use graphs of information for a decision-making problem to determine the optimum solution.

Standard 7—Interdisciplinary Problem Solving: Students will apply the knowledge and thinking skills of mathematics, science, and technology to address real-life problems and make informed decisions.

Key Idea 1: The knowledge and skills of mathematics, science, and technology are used together to make informed decisions and solve problems, especially those relating to issues of science/technology/society, consumer decision-making, design, and inquiry into phenomena.

1.4: Describe and explain phenomena by designing and conducting investigations involving systematic observations, accurate measurements, and the identification and control of variables; by inquiring into relevant mathematical ideas; and by using mathematical and technological tools and procedures to assist in the investigation.

Key Idea 2: Solving interdisciplinary problems involves a variety of skills and strategies, including effective work habits; gathering and processing information; generating and analyzing ideas; realizing ideas; making connections among the common themes of mathematics, science, and technology; and presenting results.

2.1: Students participate in an extended, culminating mathematics, science, and technology project. The project would require students to:

- Working Effectively: Contributing to the work of a brainstorming group, laboratory partnership, cooperative learning group, or project team; planning procedures; identify and managing responsibilities of team members; and staying on task, whether working alone or as part of a group.
- Gathering and Processing Information: Accessing information from printed media, electronic data bases, and community resources and using the information to develop a definition of the problem and to research possible solutions.
- Generating and Analyzing Ideas: Developing ideas for proposed solutions, investigating ideas, collecting data, and showing relationships and patterns in the data.
- Common Themes: Observing examples of common unifying themes, applying them to the problem, and using them to better understand the dimensions of the problem.
- Realizing Ideas: Constructing components or models, arriving at a solution, and evaluating the result.
- Presenting Results: Using a variety of media to present the solution and to communicate the results.

Standard 4: The Physical Setting: Students will understand and apply scientific concepts, principles, and theories pertaining to the physical setting and living environment and recognize the historical development of ideas in science.

5.1: Describe different patterns of motion of objects.

5.1a: The motion of an object is always judged with respect to some other object or point. The idea of absolute motion or rest is misleading.

5.1b: The motion of an object can be described by its position, direction of motion, and speed.

5.1c: An object's motion is the result of the combined effect of all forces acting on the object. A moving object that is not subjected to a force will continue to move at a constant speed in a straight line. An object at rest will remain at rest.

5.1d: Force is directly related to an object's mass and acceleration. The greater the force, the greater the change in motion.

5.1e: For every action there is an equal and opposite reaction.

5.2: Observe, describe, and compare effects of forces (gravity, electric current, and magnetism) on the motion of objects.

5.2a: Every object exerts gravitational force on every other object. Gravitational force depends on how much mass the objects have and on how far apart they are. Gravity is one of the forces acting on orbiting objects and projectiles.

5.2b: Electric currents and magnets can exert a force on each other.

5.2c: Machines transfer mechanical energy from one object to another.

5.2f: Machines can change the direction or amount of force, or the distance or speed of force required to do work.

5.2g: Simple machines include a lever, a pulley, a wheel and axle, and an inclined plane. A complex machine uses a combination of interacting simple machines, e.g., a bicycle.

PROCESS SKILLS BASED ON STANDARD 4

General Skills

1. follow safety procedures in the classroom and laboratory
2. safely and accurately use the following measurement tools:
    - voltmeter
3. use appropriate units for measured or calculated values
4. recognize and analyze patterns and trends
5. classify objects according to an established scheme and a student-generated scheme
8. identify cause-and-effect relationships

Physical Setting Skills

16. determine the speed and acceleration of a moving object

Produced by the Research Foundation of the State University of New York with funding from the New York State Energy Research and Development Authority (NYSERDA)
www.nyserda.org

Should you have questions about this activity or suggestions for improvement, please contact Bill Peruzzi at billperuz@aol.com

(STUDENT HANDOUT SECTION FOLLOWS)

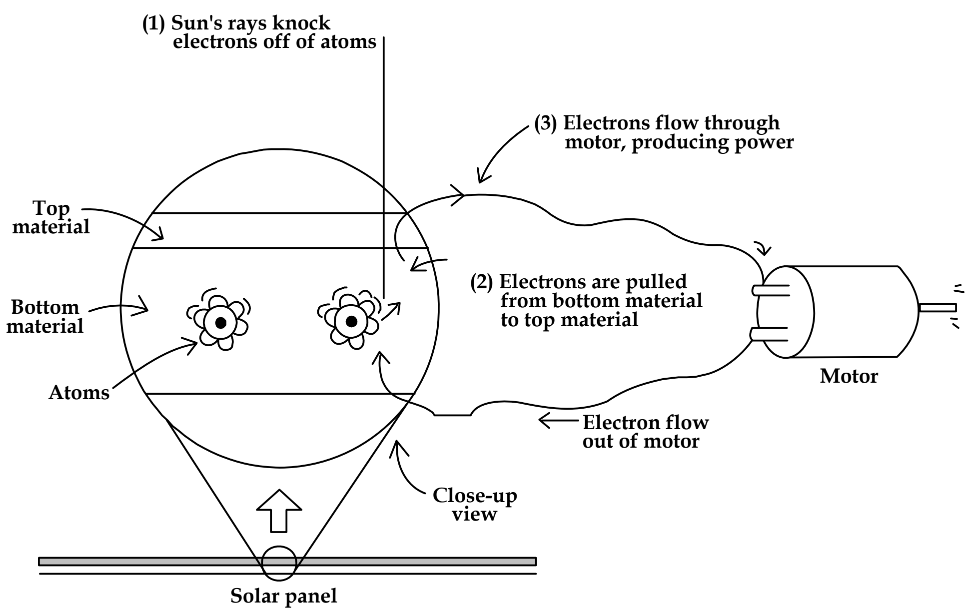
Name ___________________________________

Date ____________________________________

Junior Solar Sprint Series: Electrical Power

Part A: How the Solar Panel Works

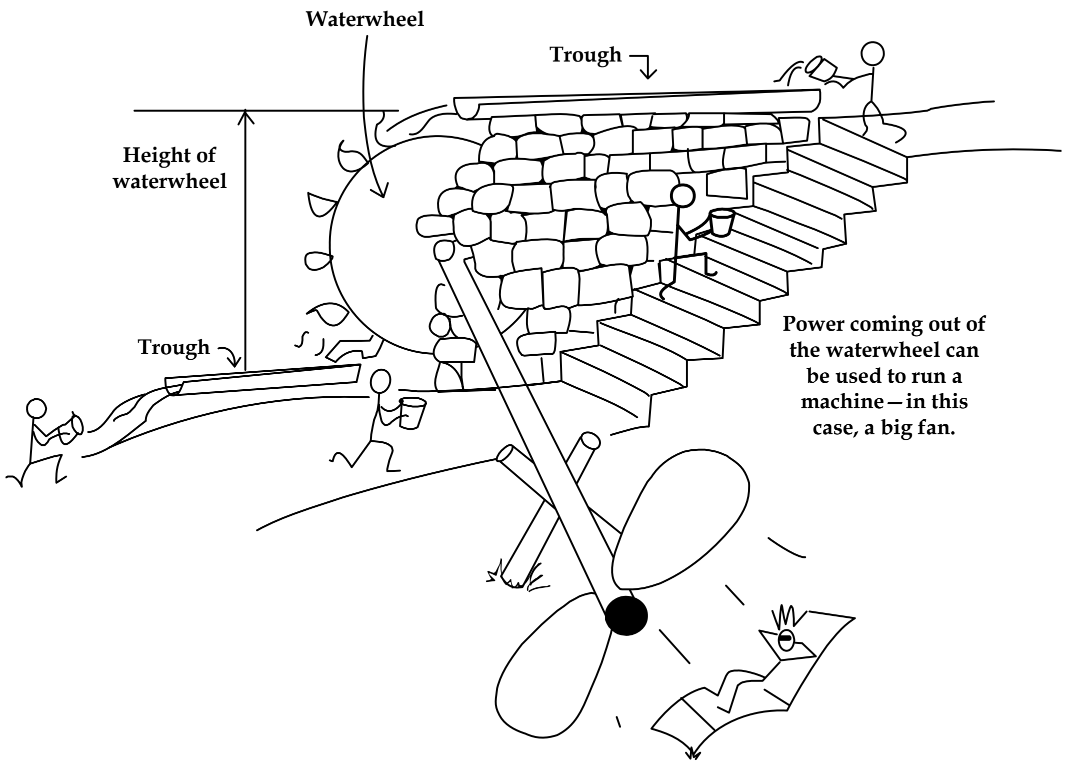
A solar cell is made of a “sandwich” of two materials known as semiconductors. [Each is made of millions of atoms. Atoms have a positively charged nucleus, and moving around the nucleus are negatively charged electrons.] When this sandwich is placed in sunlight, electrons are pulled from the bottom half of the sandwich to the top half. The sunlight energy knocks the electrons off the atoms of the lower layer and they are pulled to the top of the sandwich as shown in the diagram below.



If wires from each layer are connected to a motor, the free electrons will flow from the top layer through the wire into the motor (making it spin) and then back through the wire connected to the bottom layer of the solar panel.

Power

How does a solar panel create electrical power, and how is power related to this flow of electrons? A mechanical graphic can demonstrate this relationship. Study the drawing of the waterwheel model (The Minnesota Renewable Energy Society) on the next page.



In this model, people climb stairs carrying buckets of water from the bottom trough of the waterwheel, and then they pour the water into the upper trough. The water flows down over the waterwheel, which has buckets attached to it that catch the water. The weight of the water in the waterwheel buckets makes the wheel spin. The power of the spinning wheel makes a machine such as the big fan spin.

For the waterwheel, the *power* coming out depends on two things:

1) How *high* the water falls and
2) How *much* water (how many buckets) is poured over the wheel.

The power produced by the wheel is represented by:

Power = Height x Amount of water

1. What could be done to increase the power of the waterwheel model?

How is the waterwheel model like a solar panel and motor? The water molecules are the electrons, the troughs are the wires, and the waterwheel is the electric motor. The

Sun's energy is used to carry the electrons up an electric "stairway" inside the solar panel, and then the electrons are "poured" down a wire and through the motor.

The solar panel uses a very similar equation to the waterwheel's equation for mechanical power to determine its electrical power. The "height," or electrical potential, of the solar panel is called ***voltage***, and the buckets of water are the number of electrons flowing through the circuit, which is called the ***electric current***. The electrical ***power*** of the solar panel is the product of the voltage and the number of electrons flowing (the current):

Power = Voltage x Current

2. How can the power produced by solar panels be increased?

Part B: Activity: Can the power of two solar cells be increased by wiring them into a series circuit or a parallel circuit?

Materials Needed:
2 photocells (about 5V each)
1 small motor (1.5V)
1 milliammeter
1 voltmeter
Junior Solar Sprint solar cell
School solar array

Procedure:
1. Wire the solar cells into a parallel circuit, and connect the voltmeter and the ammeter into the circuit. (See the diagram.)
2. Place in full sunlight and measure the amperes and the volts. Record these values.
   Amperes = Voltage =

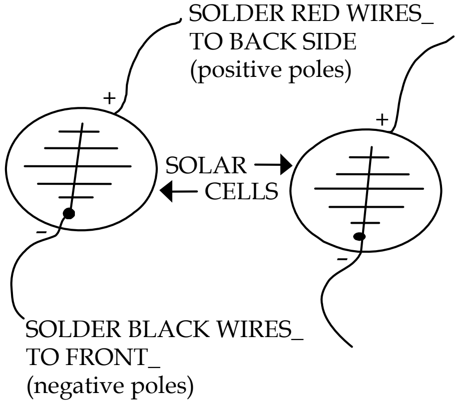
u

3. Wire the solar cells into a series circuit. (See the diagram.)
4. Place in full sunlight and measure the amperes and the volts. Record these values.
   Amperes = Voltage =

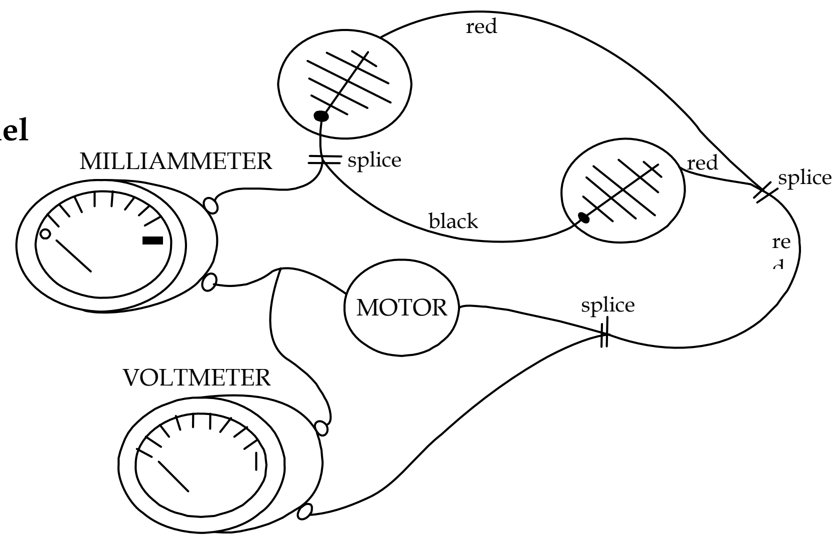
5. Compute the power in watts that was generated in each circuit, using the following formula:
   Volts x amps = Watts

Parallel Circuit/Series Circuit Diagrams

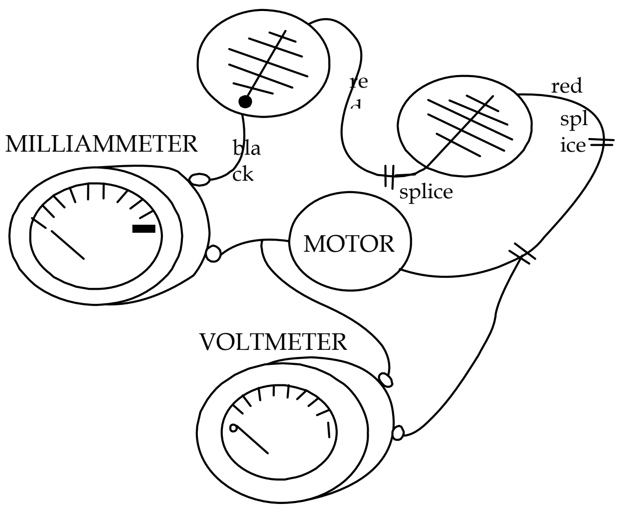
GEAR



Parallel



Series



DEVELOP YOUR UNDERSTANDING

1. Which type of circuit produced a higher voltage?

2. Which type of circuit produced the higher current (amperage)?

3. Which circuit produced the greatest power in watts?

4. How is the voltmeter connected into the solar cell–motor circuit?

5. How is the ammeter connected into the solar cell–motor circuit?

6. Does it matter that you have only a single solar panel to use to power your Junior Solar Sprint car?

7. Is the voltage of the Junior Solar Sprint panel different from that of the smaller panels used in this activity? What does this indicate regarding the circuitry of the Junior Solar Sprint panel?

8. How does the voltage output of your school's solar array compare to the voltage output for the solar cells used in your investigation? What does this indicate regarding the kind of circuitry present in the solar array panels?