Here Comes the Sun

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Lesson Focus

Lesson focuses on solar panel design, and its application in the standard calculator. It explores how both solar panels and calculators operate and explores simple circuits using solar power.

Lesson Synopsis

The Here Comes the Sun activity explores the concept of how solar energy is gathered by solar panels and adapted to provide power to a variety of machines, from calculators to spacecraft. Students disassemble a solar powered calculator and explore the component parts. Students work in teams to suggest design enhancements to the calculator to improve performance.

Age Levels

8-18.

Objectives

- Learn about solar power and solar panel design and operation.
- Learn about how calculators work and how the product is comprised of many different component parts.
- Learn about teamwork and the engineering problem solving/design process.

Anticipated Learner Outcomes

As a result of this activity, students should develop an understanding of:

- solar power and solar panel engineering
- calculator design and operations
- impact of engineering and technology on society
- engineering problem solving
- teamwork

Lesson Activities

Students learn about how solar energy is gathered and transferred to electrical energy in solar panels. Topics examined include solar panels, simple circuits, and the inner workings of a simple calculator. Students work in teams to disassemble a calculator, evaluate the design and operation of its component parts, recommend changes to improve functionality through redesign and/or material selection, and present to class.

Resources / Materials

- Teacher Resource Documents (attached)
- Student Resource Sheets (attached)
- Student Worksheets (attached)

Alignment to Curriculum Frameworks

See attached curriculum alignment sheet.

Internet Connections

- TryEngineering (www.tryengineering.org)
- U.S. Department of Energy, Solar Energy Technologies Program (www1.eere.energy.gov/solar)
- National Renewable Energy Laboratory (www.nrel.gov)
- NREL Video: "Photovoltaics: Turning Sunlight Into Electricity" (www1.eere.energy.gov/solar/video/pv4.mov)
- IEEE Global History Network - Solar Power Satellites (www.ieeeghn.org/wiki/index.php/Solar_Power_from_Satellites)
- History of Solar Energy (www1.eere.energy.gov/solar/pdfs/solar_timeline.pdf)
- Curriculum Links (www.acara.edu.au)

Recommended Reading

- Solar Electricity Handbook, 2010 Edition: A Simple Practical Guide to Solar Energy - Designing and Installing Photovoltaic Solar Electric Systems by Michael Boxwell (ISBN: 978-1907670008)
- Power from the Sun: A Practical Guide to Solar Electricity by Dan Chiras (ISBN: 978-0865716216)

Optional Writing Activities

- Write an essay or a paragraph describing how solar panels have been engineered into a product you find in your home or school. Explain why solar energy is a good choice for powering this product.

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For Teachers:
Teacher Resources

◆ Lesson Goal
Explore solar power and how solar panels operate. Students learn about engineering design by taking apart a solar powered calculator and examining the component parts, how they interact, and determine a design improvement which they present to the class.

◆ Lesson Objectives
- ✦ Students learn about solar power and solar panel design and operation.
- ✦ Students learn about how calculators work and how the product is comprised of many different component parts.
- ✦ Students learn about teamwork and the engineering problem solving/design process.

◆ Materials
- Student Resource Sheets
- Student Worksheets
- One set of materials for each group of students:
  - o One old or new calculator (many less than $5) -- look for ones with screws on back for easy disassembly
  - o Eyeglass Repair Kit or mini screwdriver (must be very small gauge)
  - o scotch tape

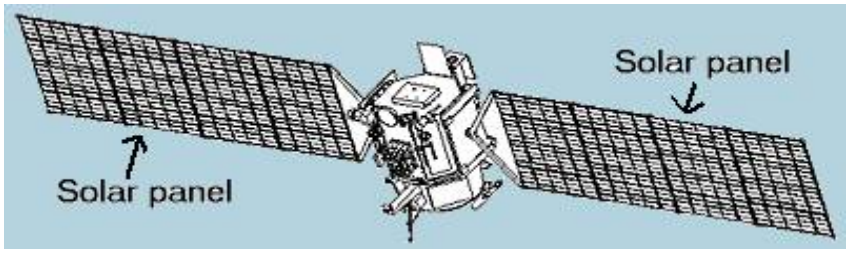
◆ Procedure
1. Show students the various Student Reference Sheets. These may be read in class or provided as reading material for the prior night's homework.
2. Divide students into groups of 3-4 students; provide one set of materials per group.
3. Ask students to complete the student worksheet. As part of the process, the students work in teams to dissect a calculator, evaluate the component parts including the solar panel, and in teams of "engineers" to design a new enhancement to the calculator. They plan and present their ideas to the class.

◆ Time Needed
One to two 45 minute sessions.

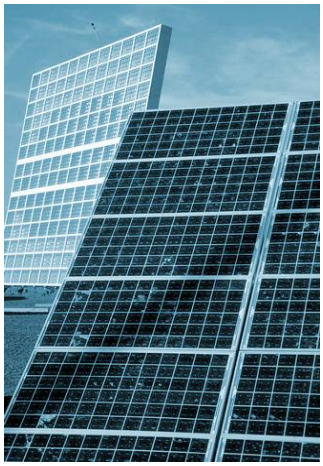
Here Comes the Sun

Student Resource:
How Solar Panels Work

◆ Solar Panel Basics



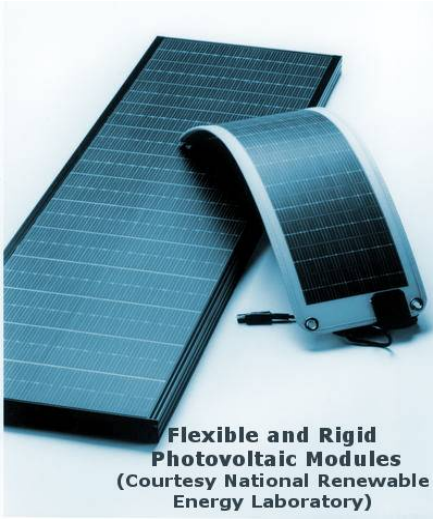
Sunlight is made up of tiny packets called photons. Every minute enough of this energy reaches the world to meet the world's energy demand for the whole world. Solar panels convert the sun's energy into electricity which can be used to power many products from small calculators to spacecraft. Many road and traffic signs along highways are now powered by the sun, and you have likely seen garden or path lights that are solar powered and automatically turn on at night.



Each solar panel is comprised of solar cells or semiconductors attached by wire to a circuit. Light reaching the semiconductor is converted into electricity which then flows through the circuit. Solar cells only operate when light is present. So, solar panels on spacecraft usually move to point toward the sun, regardless of the direction of the spacecraft. The more solar cells that are included in a solar panel, the greater the electricity that can be generated. A small panel is required to power a calculator, while spacecraft require enormous panels for power. Batteries are included in most systems to store energy for use when the sun isn't shining.

◆Solar Concentrators

Some spacecraft use solar concentrators to enhance the available light. It works the same way as a magnifying glass can multiply the power of light to focus the rays of light on kindling to start a fire. Solar concentrators use Fresnel lenses to take a large expanse of sunlight and point it toward the solar panels to boost the amount of energy that can be derived from the sun by a spacecraft in orbit.


Flexible and Rigid Photovoltaic Modules (Courtesy National Renewable Energy Laboratory)

◆Solar Panel Components

Some photovoltaics used on spacecraft are made out of gallium arsenide (GaAs). GaAs is made into a cylinder that is then sliced into cells. The solar cells are connected to the rest of the power network. Solar concentrators, made of clear plastic, are placed above them to focus the Sun's rays. More common in commercial, Earth-bound systems are crystalline silicon wafers, which are grown into cylinders and sliced to make cells. These are less efficient than GaAs cells, but are much less expensive to manufacture.

(Some content/images courtesy of NASA and the National Renewable Energy Laboratory.)

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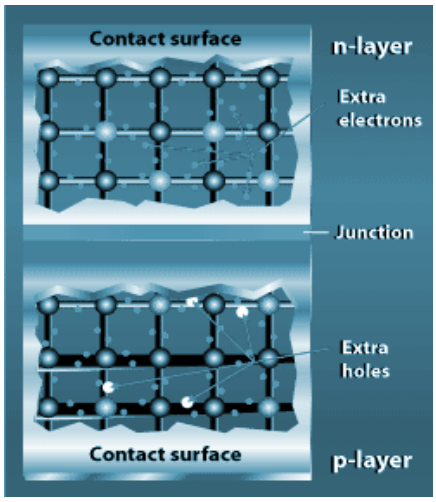
Student Resource:
Solar Power History and Innovation

In 1839, Edmond Becquerel discovered the process of using sunlight to produce an electric current in a solid material. But it took more than another century to truly understand this process. Scientists eventually learned that the photoelectric or photovoltaic (PV) effect caused certain materials to convert light energy into electrical energy at the atomic level.

◆ So, How Does it Work?

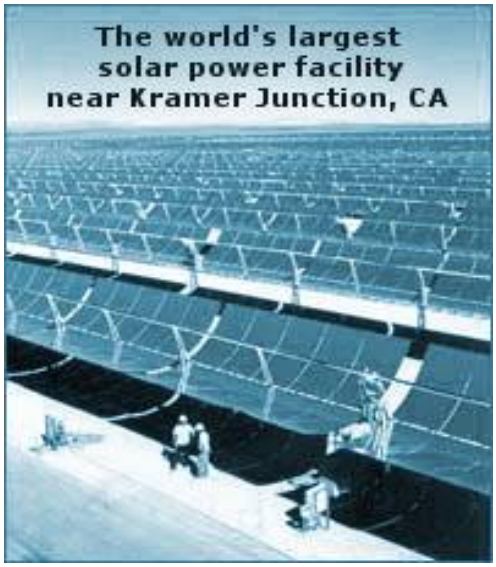
To induce the built-in electric field within a photovoltaic cell, two layers of somewhat differing semiconductor materials are placed in contact with one another. One layer is an "n-type" semiconductor with an abundance of electrons, which have a negative electrical charge. The other layer is a "p-type" semiconductor with an abundance of "holes," which have a positive electrical charge.



Although both materials are electrically neutral, n-type silicon has excess electrons and p-type silicon has excess holes. Sandwiching these together creates a p/n junction at their interface, thereby creating an electric field.

When n- and p-type silicon come into contact, excess electrons move from the n-type side to the p-type side. The result is a buildup of positive charge along the n-type side of the interface and a buildup of negative charge along the p-type side.

Because of the flow of electrons and holes, the two semiconductors behave like a battery, creating an electric field at the surface where they meet -- called the p/n junction. The electrical field causes the electrons to move from the semiconductor toward the negative surface, where they become available to the electrical circuit. At the same time, the holes move in the opposite direction, toward the positive surface, where they await incoming electrons.



To make the p-type ("positive") and n-type ("negative") silicon materials that will eventually become the photovoltaic (PV) cells that produce solar electricity, an element is added to the silicon that either has an extra electron or lacks an electron. This process of adding another element is called doping.

(Some content/images courtesy of the U.S. Department of Energy, Office of Energy Efficiency and

Renewable Energy.)

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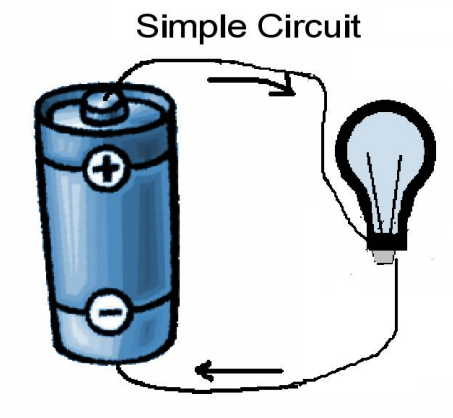
Student Resource: What is a Simple Circuit?

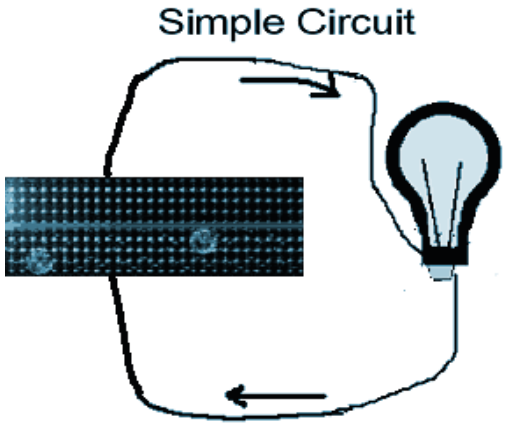
◆ Simple Circuit

A simple circuit consists of three minimum elements that are required to complete a functioning electric circuit: a source of electricity (battery), a path or conductor on which electricity flows (wire) and an electrical resistor (lamp) which is any device that requires electricity to operate. The illustration below shows a simple circuit containing, one battery, two wires, and a bulb. The flow of electricity is from the high potential (+) terminal of the battery through the bulb (lighting it up), and back to the negative (-) terminal, in a continual flow.



◆ Simple Circuit

The following illustration shows a simple circuit using a solar panel as the power source



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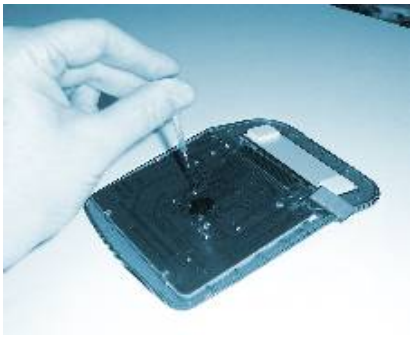
Student Worksheet:
Dissect a Solar Powered Calculator

Step One: As a team, observe whether the calculator operates when you completely block the solar power panel. What happens if you partially block the solar panel? Write you observations, and explanations of what you found below.

Step Two: Suggest five other products you can think of that are either completely or partially powered by solar panels.

Step Three: As a team, disassemble either a new (inexpensive) or old unusable solar powered calculator, using the materials provided to you. Be sure that you remove all the small screws that hold the top and bottom together, some are often hidden under pads or rubber strips. You will need to use a very small screwdriver, such as the type commonly found in eyeglass repair kits. And, you will need to unscrew the circuit board from the front panel of the calculator too -- there are many screws. ***Safety Note:*** Be careful touching the solar panel and the LCD (liquid crystal display) as the glass edges may be sharp.



Step Four: As a team, observe the solar panel and see how it is connected to the other parts of the calculator. Examine all the other parts of the calculator, and discuss what you find. Then answer questions below.

Questions:

1. How many individual parts did you find? Describe them.

2. What surprised you the most about the interior parts of the calculator?

3. How was the solar panel connected to the circuit board?

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Student Worksheet:
Dissect a Calculator (continued)

4. If there was a battery back up for this calculator, how was it connected to the circuit board?

5. Some calculators will still operate in the disassembled state, as long as the wires from the solar panel and battery are still connected to the circuit board. Does your calculator still operate? If you reconnect the wires with scotch tape, does it still work?

6. Why do you think there was a rubber or plastic sheet separating the circuit board from the buttons you press?

7. What type of material do you think is embedded under the plastic or rubber sheet and the circuit board? Why do you think engineers included this sheet in their design?

8. Assuming you could repower your calculator, if you reconstructed your calculator with all the buttons in different positions, would it still work properly? Why, why not?

9. Is there anything you would recommend, as part of an engineering team, to improve the functionality of the calculator you disassembled? Attach a drawing or sketch of your proposed component part or improvement, and answer the questions below:

What new materials will you need (if any)	What materials or parts will you eliminate (if any)	How will this new product improve the functionality of a calculator?	How do you think your new design will impact the cost of this calculator? Why?

5. Present your ideas to class.

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For Teachers:
Alignment to Curriculum Frameworks

Note: All lesson plans in this series are aligned to the Australian Curriculum for both Science and Mathematics.

	Year Level					
	5	**6**	**7**	**8**	**9**	**10**
Science Understandings		Energy from a variety of sources can be used to generate electricity **(ACSSU219)** *Investigating the use of solar panels* *Considering whether an energy source is sustainable*		Energy appears in different forms including movement (kinetic energy, heat and potential energy, and causes change within systems **(ACSSU155)**	Energy transfer through different mediums can be explained using wave and particle models **(ACSSU182)** *Investigating factors that affect the transfer of energy through an electric circuit*	
Science as a human endeavour	Scientific understandings, discoveries and inventions are used to solve problems the directly affect peoples' lives **(ACSHE220)**		Science knowledge can develop through collaboration and connecting ideas across the disciplines of science **(ACSIS226)**		Advances in scientific understandings often rely on developments in technology and technological advances are often linked to scientific discoveries **(ACSHE158)**	
Science Inquiry Skills	Compare data with predictions and use as evidence in developing explanations **(ACSIS221)** Suggest improvements to the methods used to investigated a question or problem **(ACSIS108)** Communicate ideas, explanations and processes in a variety of ways **(ACSIS 110)**		Summarise data, from student's own investigations and secondary sources, and use scientific understandings to identify relationships and draw conclusions **(ACSIS145)** Reflect on the method used to investigate a question or solve a problem, including evaluating the quality of the data collected, and identify improvements to the methods **(ACSIS146)** Communicate ideas, findings and solutions to problems using scientific language and representations using digital technologies as appropriate **(ACSIS148)**		Use knowledge of scientific concepts to draw conclusions that are consistent with evidence **(ACSIS170)** Evaluate conclusions and describe specific ways to improve **(ACSIS171)** Communicate scientific ideas and information for a particular purpose **(ACSIS174)**	

Mathematics Links

Activity	Concept / Year Level							
	Number and Algebra				Measurement and Geometry		Statistics and Probability	
	Number and place value	Real numbers	Money and financial maths	Linear and non-linear relationships	Using units of measurement	Geometric reasoning	Data and representation and interpretation	Shape
Here comes the sun	Yr 5 - 10	Yr 7 - 10						

Mathematics Links with Science Curriculum (Skills used in this activity)	General Capabilities	Cross-Curriculum Priorities
• Process data using simple tables • Data analysis skills (graphs) • Analysis of patterns and trends • Use of metric units	• Literacy • Numeracy • Critical and creative thinking • Personal and social capacity • ICT capability	• Sustainability

Science Achievement Standards

Year 6

By the end of Year 6, students compare and classify different types of observable changes in materials. They analyse ***requirements for the transfer of electricity and describe how energy can be transformed from one form to another to generate electricity***. They explain how natural events cause rapid changes to the Earth's surface. They decide and predict the effect of environmental changes on individual living things. Students explain how scientific knowledge is used in decision making and identify contributions to the development of science by people from a range of cultures.

Students follow procedures to develop investigable questions and design ***investigations into simple cause-and-effect relationships***. They ***identify variables to be changed and measured and describe potential safety risks when planning methods***. They ***collect, organise and interpret their data, identifying where improvements to their methods*** or research could improve the data. They ***describe and analyse relationships in data using graphic representations*** and construct multi-modal texts ***to communicate ideas, methods and findings***.

Year 8

By the end of Year 8, students compare physical and chemical changes and use the particle model to explain and predict the properties and behaviours of substances. ***They identify different forms of energy and describe how energy transfers and transformations cause change in simple systems***. They compare processes of rock formation, including the time scales involved. They analyse the relationship between structure and function at cell, organ and body system levels. Students examine the different science knowledge used in occupations. ***They explain how evidence has led to an improved understanding of a scientific idea and describe situations in which scientists collaborate to generate solutions to contemporary problems***.

Students identify and construct questions and problems that they can investigate scientifically. They ***consider safety and ethics when planning investigations, including designing field or experimental methods. They identify variables to be changed, measured and controlled. Students construct representations of their data to reveal and analyse patterns and trends, and use these when justifying their conclusions. They explain how modifications to methods could improve the quality of their data and apply their own scientific knowledge and investigation findings to evaluate claims made by others. They use appropriate language and representations to communicate science ideas, methods and findings in a range of texts types.***

Year 9

By the end of Year 9, students explain chemical processes and natural radioactivity in terms of atoms and energy transfers and describe examples of important chemical reactions. They ***describe models of energy transfer and apply these to explain phenomena***. They explain global features and events in terms of geological processes and timescales. They analyse how biological systems function and respond to external changes with reference to interdependencies, energy transfers and flows of matter. They ***describe social and technological factors that have influenced scientific developments and predict how future applications of science and technology may affect people's lives***.

Students design questions that can be investigated using a range of inquiry skills. They design ***methods that include the control and accurate measurement of variables and systematic collection of data and describe how they considered ethics and safety***. They analyse ***trend in data, identify relationships between variables and reveal inconsistencies in results***. They ***analyse their methods and the quality of their data, and explain specific actions to improve the quality of their evidence***. They ***evaluate others 'methods and explanations from a scientific perspective and use appropriate language and representations when communicating their findings and ideas to specific audiences.***