NORTH CAROLINA SOLAR CENTER

SOLAR CENTER INFORMATION

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Solar Activities for Students

Energy is an inseparable part of our lives. Energy provides for our basic survival and gives shape to our aspirations and dreams. Our resources of energy, like fossil fuel reserves and natural gas, are decreasing day by day; while at the same time, the demand for energy in our country and across the globe is increasing. Therefore, it is extremely important to understand, develop and explore other forms of energy resources.

Renewable energy resources like the sun and wind play a major role in the development of a sustainable future. The younger generation, especially, have to understand that the issue of energy has a major impact on their future lives. For this reason, there is a great need for education about renewable energy options, such as solar energy. As well, many of the environmental concerns of the earth are due to pollution from the burning of fossil fuels. The "Greenhouse Effect" is an important example of an environmental problem caused by pollution.

Solar energy is an excellent form of renewable energy available to us, *today*. The objective of this factsheet is to provide information about solar energy activities that demonstrate how solar energy can be integrated as a part of our everyday lives.

SOLAR HEATING

Solar heating is an important and very practical step towards a sustainable future. The objective of the activities in this section is to design and build devices that utilize the sun's energy as heat.

Solar heating starts with solar collectors which are divided into two basic groups: flat plate and focusing collectors. The flat plate collector absorbs the sun's energy and converts it into heat, while the focusing collector concentrates the sunlight either by reflecting or refracting to achieve higher temperatures.

Solar Cookers

Cooking with the sun can be fun by building your own solar cooker. A solar box cooker works on the same principle as all solar heating systems; by absorbing the sun's radiant energy directly through glazed surfaces, or indirectly from reflectors.

A solar cooker usually consists of a well-insulated box for storing energy, a glazing surface of plastic or glass for collecting energy, and reflectors, like aluminum foil or a mirror, to increase the amount of heat energy collected. To increase the absorption of the solar radiation, the box is painted a dark color on the inside. Solar absorption can also be increased by using dark-colored pots for cooking.

A solar cooker is a good example of the "greenhouse effect" at work. Short wave radiation from the sun passes easily through the glazing and is absorbed by the dark surfaces inside the cooker. As these dark surfaces get hot from the sun's radiation, they transfer heat energy to the air by convection. They also radiate energy back through the air as long wave radiation. The cooker glazing prevents the escape of a portion of this long wavelength radiation; therefore, the air inside the cooker gets hotter and hotter as more and more energy is trapped and convected to the air.

The temperature inside the cooker is a balance of the energy gained through the glazing versus energy losses through all sides of the cooker. Therefore, if the cooker is well insulated, higher temperatures can be achieved. Food is cooked by heat energy transferring from the absorbing surfaces to the food by conduction and convection. Reflectors increase the energy collected by concentrating the heat energy inside the box.

You are strongly encouraged to design your own solar cooker by using the one given below as an example. Try different material and design options and, using the testing procedure, determine why they increased or decreased the cooker performance.

Materials Required

- Two cardboard boxes with covers (e.g. copy paper box, packing box, cardboard file boxes)

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- Insulation for the box (e.g. fiberglass insulation, foam insulated sheathing, or other kind of insulation)
- Reflecting mirror-like material or tin foil, for reflector, and corrugated cardboard
- Glass, plexiglass or plastic food wrap
- Sticks for props
- Scissors and tape
- Black paint
- String or cord

Procedure
(1) Cut down the cardboard boxes so that the smaller box fits inside the larger one.

(2) Paint the inside of the small box black, for greater heat absorption.

(3) Insulate the box on the bottom and sides by placing insulating material in the gap between the two boxes.

(4) Cut a large hole in the cover of the larger box. Cover the hole with plastic food wrap or place glass in the cut-out portion. The escape of longer wavelengths of heat energy is prevented by the glazing.

(5) Glue the tin foil or mirror to a big piece of recycled corrugated cardboard. It should be approximately the same size as the cover of the box.

(6) Hinge the reflector to the box with tape.

(7) Hold up the reflector with the help of props and string (see Figure 2).

Using the Solar Cooker
Place the solar cooker facing the sun without any shade falling over it. Move the box until the shadow of the prop falls directly behind, parallel to the edge of the box. Adjust the position of the reflector, until the reflected sunlight lights up the inside bottom and front of the solar cooker. Tighten the strings in this position and adjust the props to hold the reflector in this position.

Use dark-colored cookware for cooking. This helps increase the heat absorption. This solar cooker should be able to reach temperatures between 200º and 300º F. Place a thermometer inside to read the temperature. Preheat the cooker for about half an hour.

Testing Procedure
(1) Place your solar cooker in the sun.

(2) Use an oven thermometer and record the temperature at regular time periods (e.g. every 5 minutes).

(3) Calculate the amount of heat energy gained in one hour by using the formula:

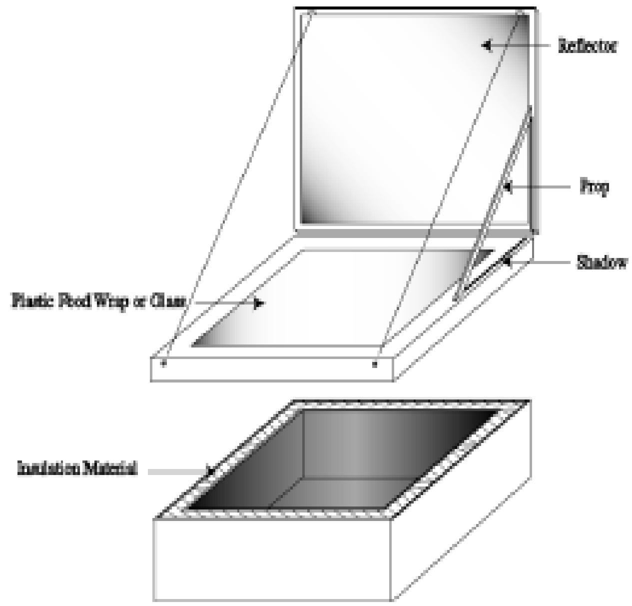


Fig 1. Solar Cooker

Heat (joules) = $m \times c \times \Delta T$

where: m = mass in grams
c = specific heat (4.2 joules/g/°c for water)
ΔT = increase in temperature, °c
(final temperature - initial temperature)

Listed below are some interesting variations that you can experiment with to find out which cooker design results in the highest temperature. Determine the reason why the changes increased or decreased the performance of the cooker.

Experimental Options

- Use only one box lined with foil-faced insulated sheathing inside.
- Paint the inside of the foil-faced sheathing black.
- Use glass instead of plastic wrap for the glazing.
- Use plexiglass instead of plastic wrap.
- Try using the cooker without a reflector.

Precautions
Be sure the cookware is fully covered; otherwise, the escaping moisture will condense on the glass and block the sunlight. Be careful when removing food from the cooker. It's hot inside!

Solar Water Heaters
Solar water heating is an important area for renewable energy development. Heating water is one of the basic needs in our everyday life. Solar hot water systems can be used to heat swimming pools and to provide hot water in homes and industry. You are strongly urged to design your own models by using the one given below as an example.

The procedure described above for building a solar cooker is also very similar for solar water heating. Instead of cooking food, you can heat water. The only additional material required is a large zip-lock bag filled with one gallon of water and laid flat in the bottom of the box.

For a simple solar water heater, start off with a single cardboard box, painted black on the inside. The box should be shallower than the cooker, but tall enough so that the plastic wrap does not touch the zip-lock bag.

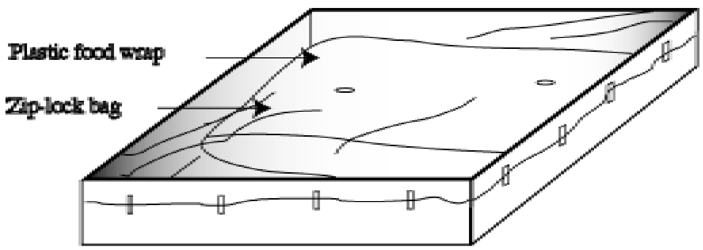


Fig 2. Simple Solar Water Heater

Testing Procedure
Place a gallon of cold water in your solar water heater. The testing procedure is the same as that described for the solar cooker. Think about any improvements that would increase the efficiency of your solar heater.

Experimental Options
You can experiment with your own designs, using various options like:

- Use a black metal box instead of cardboard.
- Use a different material for reflectors.
- Use glass instead of plastic wrap for the glazing (or try it with no glazing).
- Use the box without the reflector.
- Use various other containers like dark cookware, a plastic garbage bag, soda bottle or hot water bottle instead of plastic zip-lock.
- Try coloring the water with food coloring or ink.
- You can be creative and experiment to find out which design and material is most effective!

SOLAR ELECTRICITY
Solar energy can be converted directly into electricity, which can then be used in many applications such as powering houses, offices, satellites, solar cars and charging batteries. Because fuel is not burned while using solar energy, pollution is eliminated. A photovoltaic cell is the basic component of a solar electric system.

A photovoltaic cell is made up of thin semiconductor material, like silicon wafers. The actual silicon wafer is negatively charged. When light shines upon it, photons strike the solar cell and electrons are knocked loose from the deeper layer to the surface layer from the atoms in the semiconductor material. The electrons can be captured in the form of an electric current by attaching the positive and negative wires from the photovoltaic panel to your application.

The power or wattage of the electric current is determined by the equation: *Power* (watts) = *Voltage* (volts) x *Current* (amperes). Voltage is the potential or pressure of the electricity being produced, and current is the rate of flow of the electrons. Current is measured in Amperes.

Individual silicon-based PV cells have a characteristic potential of about half a volt. The amount of current delivered by a cell is directly proportional to the intensity of light (the number of photons arriving per unit area per unit time). In bright noon sunshine, the solar cell listed in this activity produces approximately 1.5 watts of electricity.

Shadows and angle of incidence are important factors affecting the intensity of light. On a cloudy day, the rate of arrival of photons is greatly reduced. The light intensity is also affected by the angle of incidence of light striking the surface of the solar cell. By adjusting the angle of the cell so that it faces the sun directly, the light intensity can be increased.

A number of solar cells can be connected together to form a module. The cells can be connected in series or parallel arrangements, to achieve the required combination of current and voltage. To produce more voltage, the cells are connected in series and, to produce more current, the cells are connected in parallel.

The photovoltaic modules produce direct current (DC) electricity. By using a voltmeter or millimeter, the electric output of the cell can be measured directly.

Solar Battery Charger
You can build a solar battery charger using photovoltaic cells as an experiment to understand the basic principles of photovoltaic power. It is an effective way of conserving energy, as well as saving money required for new batteries! The example given below is a basic design for a solar battery charger.

You can experiment using more solar cells, or using other types of batteries like “AAA” or “D” or “C”. Find out what happens if the cells are connected in parallel versus series.

Materials Required
- Silicon Solar Cells (3)
- Two “AA” rechargeable batteries
- 2 Single Battery Holders for “AA” battery

- Wire for connecting the cells and holder (preferably #26 gauge or less)
- Small soldering iron (less then 50 watts)
- Solder material (e.g. Rosin Core solder)
- Flat board for mounting the cells and battery holder (e.g. perfboard)
- Self-sticking fasteners like Velcro

Procedure

(1) Solder the three solar cells in series with the help of connecting wire, as shown in the diagram. When the cells are connected in series, the voltage is increased by three times, which is sufficient to charge the battery (the voltage of a single battery is 1.25V). The current remains the same. Each 2x4 cm solar cell will produce about 0.45 volt and 0.275 amp of usable current.

(2) Mount the cell on a board with the help of Velcro or any other material you can think of (e.g. Self-sticking Hoop-And-Loop Fasteners).

(3) Connect the battery holders in parallel.

(4) Connect the battery holder to the solar cells.

(5) Mount the battery holders with the rechargeable batteries, on the board.

(6) Place the board with the cells and battery holder in direct sunlight. It can be laid horizontal, but it is better to tip up the board towards the direction of the sun. This increases the efficiency of the solar cells.

(7) Use rechargeable batteries that are dead.

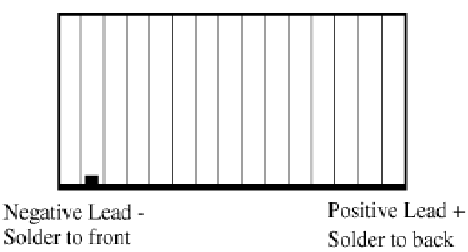
(8) If you have a voltmeter at home, you can check the voltage in the batteries, at intervals.

(9) It should take approximately a day to charge the batteries.

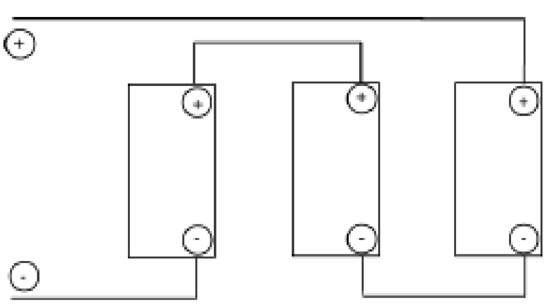
Precautions

Make sure that the solar cells are placed in full sunlight with no shadows falling over them. Be careful while handling the soldering gun. Wear safety glasses! If you want to avoid the soldering, an enclosed solar module could also be used for this experiment. *Note*: The battery holders have batteries connected in parallel; therefore, the voltage remains the same and the current is divided.

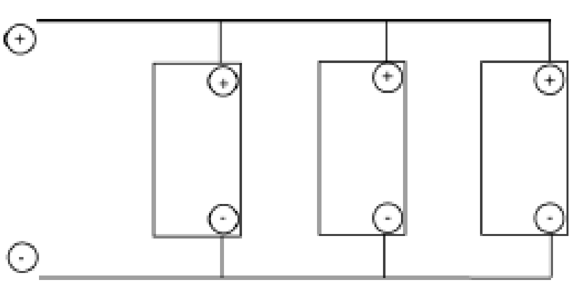
You can find most of the material required around the house, like the wire or board. However, for your convenience, listed below are all of the items required for the experiment, which are available at Radio Shack.



SOLAR CELL



SERIES ARRANGEMENT



PARALLEL ARRANGEMENT

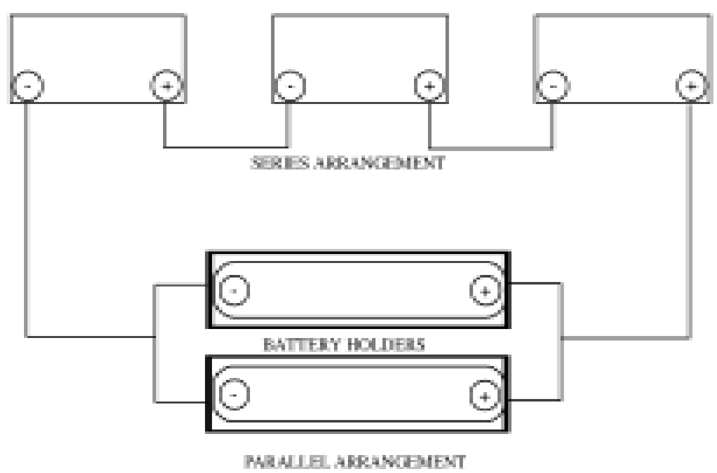


Fig 3. Solar Battery Charger

Item	Number	Price $
Silicon Solar Cell (3)	276-124	4.49
Or Enclosed Solar Module (1.5V, 200mA)	RSU 11903085	10.99
2 "AA" Batteries (1 pack) Rechargeable Ni-Cds	23-125	5.49
2 Single Battery Holders (For 1 "AA" no.26)	270-401	0.79
Prepunched Perfboard (41/2 x 6")	276-1394	2.39
Hook-And-Loop Fasteners (self-sticking 3-inch Strips)	64-2345	2.69
Rosin core solder (0.062", 0.5 oz)	64-001	1.19
Wire (#26 gauge or less)		

Solar Cars

Powering a car with solar energy is one of many rapidly developing ideas for using alternative forms of energy. A panel of solar cells, instead of gasoline, is used to run the car. An electrical charge generated from the solar panel is stored in a battery; this stored energy is used for driving the vehicle. Energy can be stored and drawn from batteries at night or on cloudy days.

This following activity will illustrate various concepts such as speed, friction, inertia, gravity, momentum and drive and propulsion mechanisms. It also gives the experience of using hand tools for different applications.

The basic materials required for building a solar car include:

- A solar panel for generating power to run the car. Make sure that no shadows from the mounting material fall on the solar cell.
- A small DC electric motor to transfer the generated power to the propulsion system.
- A lightweight material, such as balsa wood or foam core, for the body of the car and mounting the solar cell. Use materials that are light and easy to work with. The weight is a very important factor to be considered when designing and building a solar car. Small solar cells do not provide enough power to move heavy car bodies.
- Aerodynamics is also an important factor while building a car. Crosswinds, drag and other forces that act on the body of the car when it is in motion have to be considered while designing the body of the car.
- Propulsion system for rotating the wheels. Options include a system of pulleys and rubberbands, or gears, or a propeller. The electric motor transfers the power generated by the solar panel to the propulsion system, which is then used to rotate the wheels.
- Wheels and axles. You can use parts from old toys or car kits. Use your imagination and find materials around the house. Make sure that there is minimum rolling resistance by choosing the right kind of material for the wheels and watch the wheel alignment. Take care to reduce friction as much as possible. Think of ways to attach the wheel assembly to the car body. For example—using a straw with the axle running through it. Wheels are connected to the axle and the straw can then be glued to the body of the car.

Solar car kits are available from companies like Kelvin Electronics or Fisher Scientific. These kits provide you with the basic materials required for a solar car.

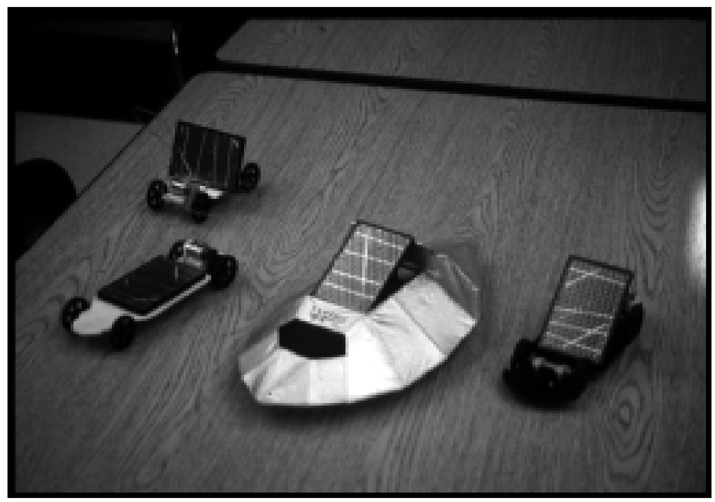


Fig 4. Solar Powered Cars designed by students for the solar car race held at North Carolina's Clayton Middle School in 1996.

Fig 5. Students with solar car models.

Materials

Kelvin Electronics
10 Hub Dr.
Melville, NY 11747
Toll-free: 1-800-KELVIN-9 or (516) 756-1750
Fax: 1-800-756-1025 or (516) 756-1763
E-mail: kelvin@kelvin.com Web: www.kelvin.com

Fisher Scientific
2000 Park Lane
Pittsburgh, PA 15275
Toll-free: 1-800-955-1177 Fax: 1-800-955-0740
E-mail: fisheredu@ix.netcom.com
Web: www.procurenet.com/emd/emdcatal.htm

RadioShack
Tandy Corporation
1800 One Tandy Center
Ft. Worth, TX 76102
Toll-free: 1-800-THE-SHACK
Web: www.radioshack.com

Take advantage of the state tax credit for renewable energy!

North Carolina offers a personal tax credit of 35 percent of the construction, equipment and/or installation costs for renewable energy systems. The maximum credit per year and per system is $10,500 for residential photovoltaic, micro-hydro, biomass, biogas and wind systems; $3,500 for residential passive and active space heating; and $1,400 for solar water heating systems.

For commercial and industrial installations of solar equipment for production of heat or electricity, the corporate tax credit per year and per system is 35 percent, with a maximum credit of $250,000 for all solar, wind, hydro and biomass applications. For solar systems, additional tax incentives also are available from the federal government (10 percent tax credit and 5-year accelerated depreciation). For wind and biomass, there is also a kWh production tax credit. There is also a corporate tax credit for North Carolina of 25 percent for the costs of constructing a renewable energy equipment manufacturing facility, with no maximum credit, which can be carried over to the next year for up to ten years.

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