DOCUMENT RESUME

ED 170 132 SE 027 579

TITLE Science Activities in Energy: Solar Energy II.
INSTITUTION Oak Ridge Associated Universities, Tenn.
SPONS AGENCY Department of Energy, Washington, D.C.
PUB DATE [78]
NOTE 29p.; For related documents, see SE 027 580 and ED 152 529-532; not available in hard copy due to marginal reproducibility

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS Activity Units; *Earth Science; *Energy; Energy Conservation; Environmental Education; *Meteorology; *Science Activities; Science Education; Secondary Education; *Secondary School Science; *Solar Radiation

ABSTRACT

Included in this science activities energy package are 14 activities related to solar energy for secondary students. Each activity is outlined on a single card and is introduced by a question such as: (1) how much solar heat comes from the sun? or (2) how many times do you have to run water through a flat-plate collector to get a 10 degree rise in temperature? (BB)

SCIENCE ACTIVITIES IN ENERGY—SOLAR II

Science Activities in Energy is a series of concrete, revealing experiments developed by the American Museum of Science & Energy. The series is divided into two levels: elementary and secondary. This set, SOLAR II, was designed primarily for secondary students, but may also be quite useful for a variety of community programs.

The purpose of the series is to illustrate certain principles and problems related to various forms of energy and to their development, use, and conservation.

More important, it is an effort to help you and other teachers involve students directly in exploring intriguing questions—in making discoveries on their own.

While the elementary set, SOLAR, does not require any scientific background on the part of the instructor, SOLAR II does assume that the teacher will have some familiarity with certain scientific principles. However, the experiments do vary in the amount of background required and many of those developed for the secondary level can be conducted by an instructor with limited training in science.

Each unit in the series forms a coherent program of instruction on a single topic: solar energy, electricity, conservation, and the like.

Most activities in the series can be completed in the classroom with materials readily available in any community: pots and pans, paper cups, water, salt, thermometers, and cardboard boxes. A few require purchases from local or national suppliers.

Each project is introduced as a question: How much warmer do objects get in the sun than in the shade? What is the best color to paint a house to keep it cool in the summer? Which stores solar energy better—water or rock?

At the outset of an experiment, try to get your students to predict outcomes, even when they have no experience to justify their projections. Urge them to make a guess. They'll become more interested, feel more involved, if they do.

In order to answer each question, a student (or the class as a group) follows instructions on an activity card that lead him or her through a specific experiment.

This kind of direct student participation leads easily to other related questions—some suggested on the activity cards themselves, others generated by the students and their teacher—and to further exploration by the experimenters on their own.

The American Museum of Science & Energy has purposely used metric measurements throughout the experiments, believing that this would be part of the learning process for many young people and for some adults as well.

Because the activities are outlined on single cards, you can easily photocopy them for distribution or project them on a screen or wall.

As the developers of the series, we are anxious to learn how you and your students use the materials, what variations you develop, and any results you find extraordinary. Please let us know your reactions to the materials, and feel free to ask for more information on any energy-related topic.

This series, Science Activities in Energy, was developed by Oak Ridge Associated Universities under contract from the U.S. Department of Energy, with a staff under the direction of Mr. Mauri Gould. This publication was prepared as an account of work sponsored by the United States Government. Neither the United States nor the U.S. Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

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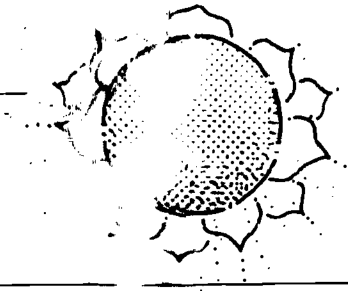


How much solar heat comes from the sun to you?

SOLAR 1

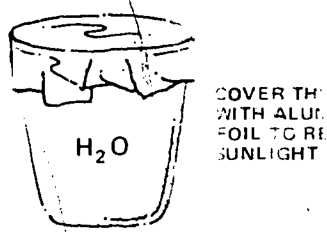
Materials

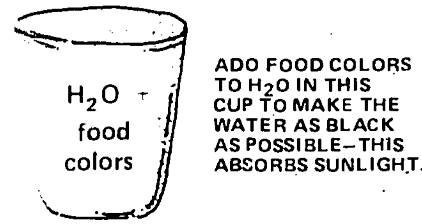
2 Foam cups
2 Thermometers
Food colors; aluminum foil
Graduated cylinder
Metric ruler, watch
Insulation material (packing foam, crumpled newspaper, etc.)
Cardboard box (should be same height as cups: trim if necessary.)

Set Up Your Experiment

Fill the foam cups with a measured amount of cold water.

Add food colors to one cup



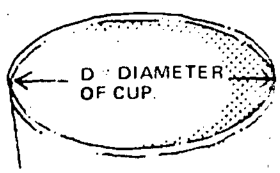


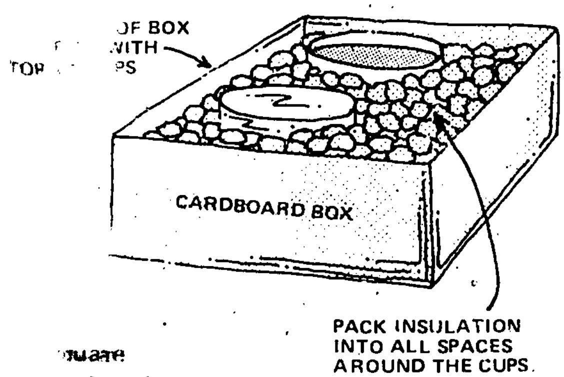
Trim a cardboard box to the ... height as the cups.

Put the cups in the box and add the insulation material.

Put the box in the sun for 10 minutes (Noon to 1 p.m. is usually hottest.)

Stir the water in the cups with the thermometers and record the temperatures.





Do This Calculation

Area $= \frac{\pi d}{4} =$ ________ square centimeters

$$\text{Calories} = \frac{\text{ml of } H_2O \text{ in cup} \times \text{Difference in temperatures of both cups after being in the sun for 10 minutes.}}{\text{Area (square centimeters) of water} \times 10}$$

The "calories" calculated is the amount of solar heat received on 1 square centimeter in 1 minute at your location.

Multiply x 10,000 to get results for 1 square meter!.

Note:
Scientists have measured the amount of solar energy beyond our atmosphere at about 2.0 calories per square centimeter per minute. About 1.5 calories per square centimeter per minute reaches earth after passing through our atmosphere. This is called the Solar Constant.

Other Ideas to Explore

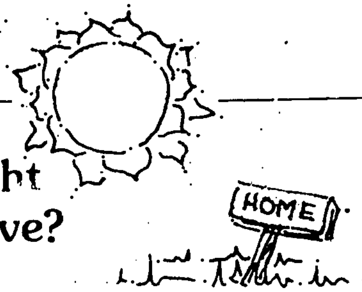
What percentage of the total amount of solar energy is available at your location?

Would you have enough energy to heat your house if the south side of your roof was covered with solar collectors?

Can you think of a more accurate way to do this experiment?

Where do you think most of the errors exist in this experiment?

What is the total amount of solar light received during the day where you live?



SOLAR 2

Materials

0–50 Milliammeter (local electronics hobby shop)

Silicon solar cell, Edmund Electro J4 800 (local electronics hobby shop)

145cm No. 30 enameled copper magnet wire

Sandpaper

Rosin core solder (small diameter)

Soldering iron

2-watt resistor, 100,000 ohms (local electronics hobby shop)

5 pieces 1/4" wood, each 12cm square

Glue (airplane glue, epoxy, etc.)

Hammer and small nails

Keyhole saw

Cartesian graph paper

Hookup wire

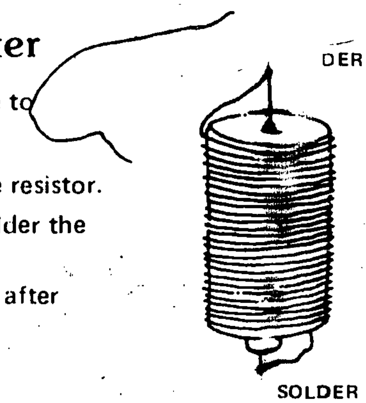
Set Up a Solar Radiometer

Sand the ends of the copper magnet wire to remove enamel.

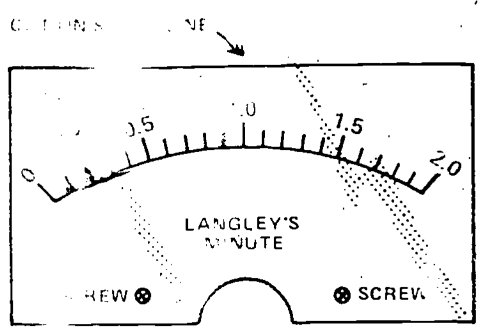
Solder one end of magnet wire to the resistor.

Wrap the wire around the resistor and solder the other end.

Coat the wire-wrapped resistor with glue after soldering.



Calibrate Your Milliammeter



1. Cut out new faceplate.
2. Snap cover off milliameter.
3. Remove 2 small Phillips screws.
4. Remove plate.
5. Glue new plate in place.
6. Screw plate back on meter.
7. Snap cover back on.

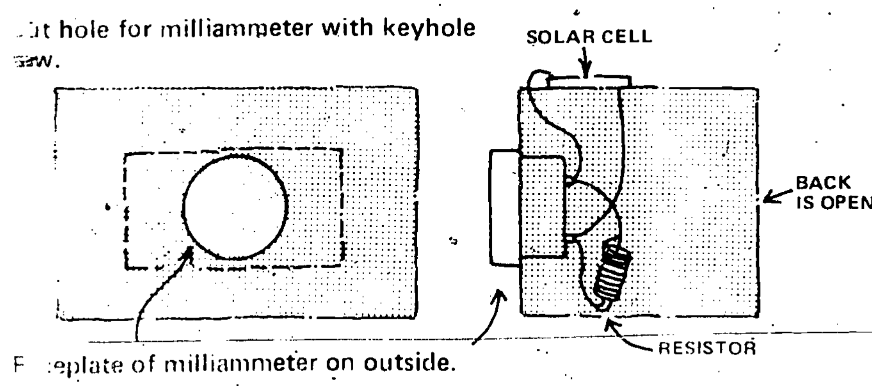
Maximum insolation at sea level has been measured at 1.6 L/min

$$\frac{1 \text{ Langley}}{\text{minute}} = \frac{1 \text{ gr calorie}}{\text{cm}^2/\text{minute}} = \frac{221 \text{ BTU}}{\text{ft}^2/\text{hr}} = \frac{0.0698 \text{ watt}}{\text{cm}^2}$$

Build a Housing for Your Solar Radiometer

FRONT VIEW

SIDE VIEW



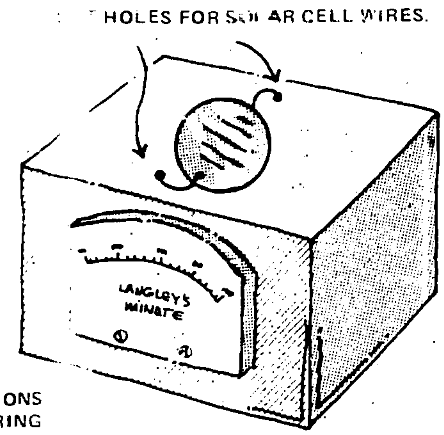
Conduct Your Experiment Like This:

Place the solar radiometer where sunlight can strike the face all day and record the milliammeter reading on the table below for one full day. (Make a larger table!)

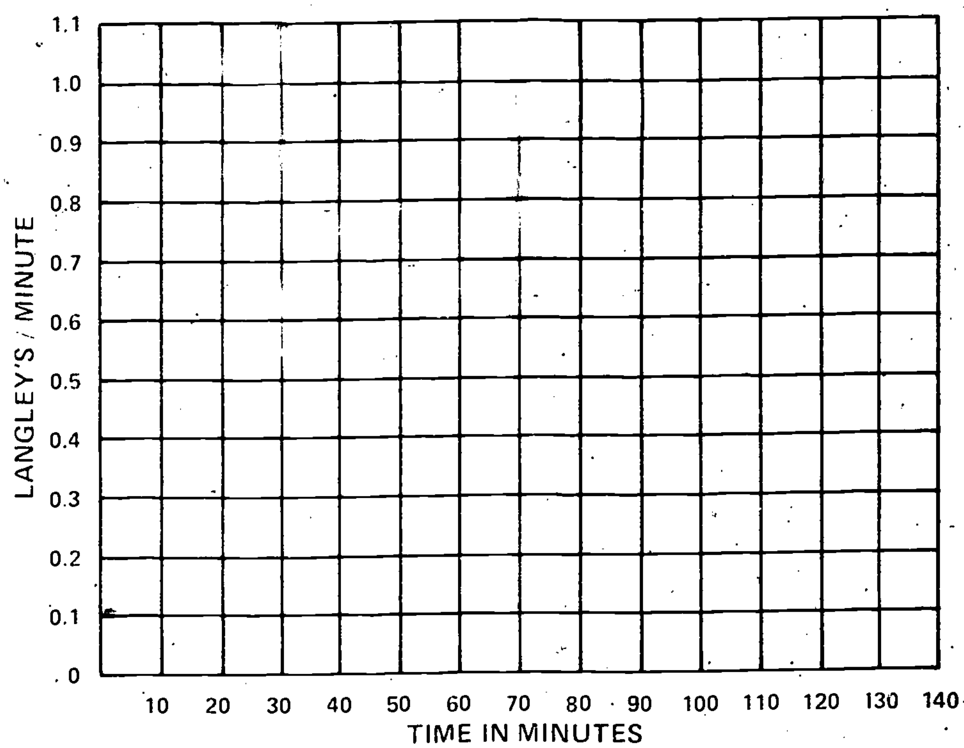
Calculate the total solar insolation: number of blocks under the curve you draw x area of the solar cell in cm².

Wire milliamme solar cells, and resistor as indica

Nail the pieces o together to make an open ed box



SEE ACTIVITY 3 FOR DIRECTIONS FOR WIRING SOLAR CELLS.



This material is adapted from "Measure the Sun's Energy with a Solar Radiometer" by Warren Jochem, Popular Electronics 10(6):45-47.

Other Ideas to Explore

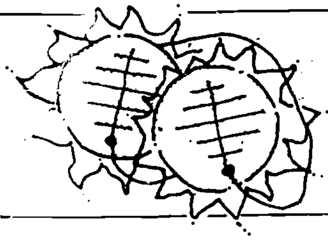
Which reflects more light: a white car or a red one?

How much light comes through a clear window? A tinted window?

Do all sunglasses block the same amount of light?

Which gives off more light: incandescent or fluorescent bulbs?

Which delivers more power to a motor, 2 solar cells in series or in parallel?



SOLAR 3

Materials

2 photocells, about .5 volts, 50-100 milliamps (local electronics hobby shop)

1 small motor, 1.5 volt low current type (available from the American Museum of Science & Energy)

1 Milliammeter, 0-500 ma

1 Voltmeter, 0-1 volt

Rosin core solder, fine (small diameter)

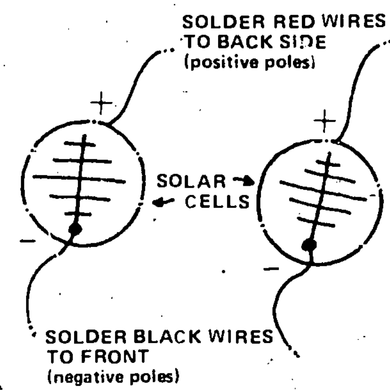
Small soldering iron

Black and red hookup wire (local electronics hobby shop or hardware store)

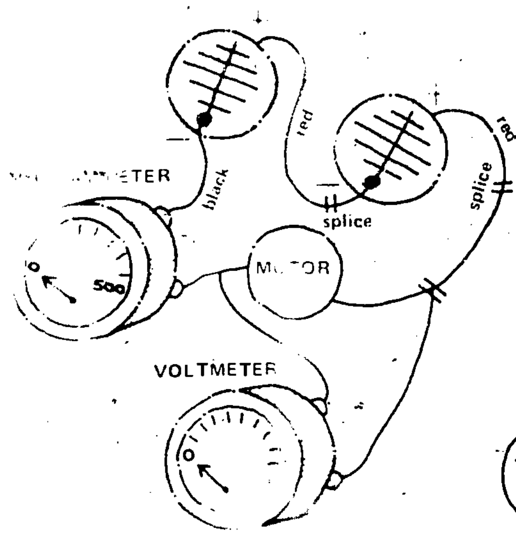
Note:
If the meter needle goes the wrong way, reverse the leads to the meter!

Wire the Solar Cell

First wire the solar cells, unless wires are already attached.



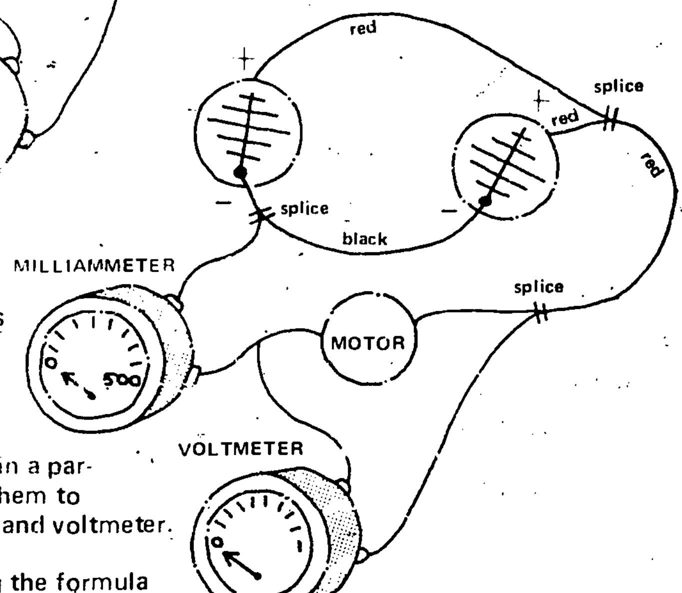
Following the diagram below wire the solar cells into a series circuit.



Place the solar cells in full sun and measure milliamps and volts.

Compute the power generated:

$$\text{Power in watts} = \text{volts} \times \frac{\text{milliamps}}{1000}$$



Reconnect the solar cells in a parallel circuit and connect them to the motor, milliammeter, and voltmeter.

Compute the power using the formula above.

Other Ideas to Explore

Would the results be the same if you wired a flashlight bulb instead of a motor into the circuits?
How much is the electricity you produced worth at the rates your local electric company charges?
How much would it cost to produce electricity for your home if you had to buy enough solar cells to do the job?

What is the minimum number of photocells required to operate a sound generator?

SOLAR 4

Materials

- D cell
- Small soldering iron
- Rosin-core solder (small diameter)
- 1 block of wood, about 10cm square
- 2 small wood screws

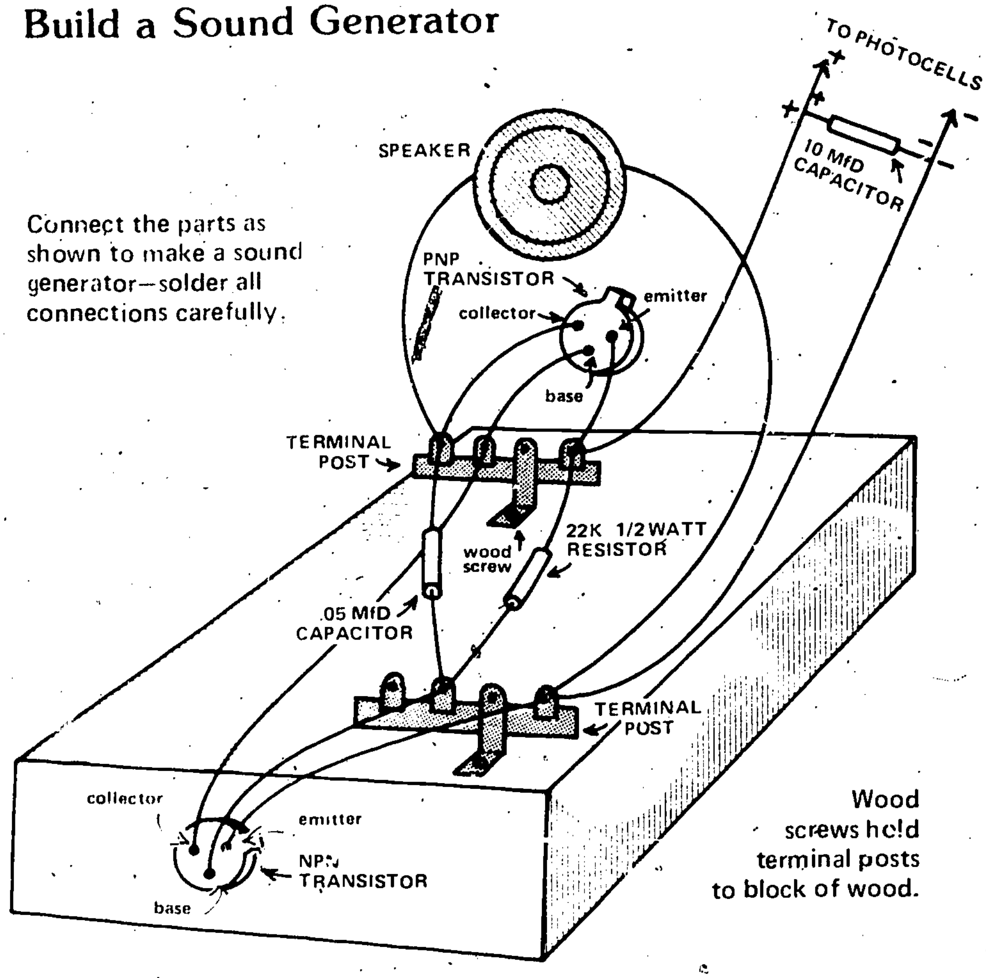
Note: Try a local electronics hobby shop for the supplies below.

- A number of photocells
- NPN and PNP germanium transistors (bargain basement type will do)
- .05 MfD capacitor, electrolytic, 6-12 volt
- Small speaker
- 2 terminal strips (at least 3 posts)
- 10 MfD capacitor, electrolytic, 6-12 volt
- 1 22K ½ watt resistor
- Hookup wire (local electronic hobby shop or hardware store)

Note:
If you don't hear a tone, check connections or check for a faulty transistor.

Build a Sound Generator

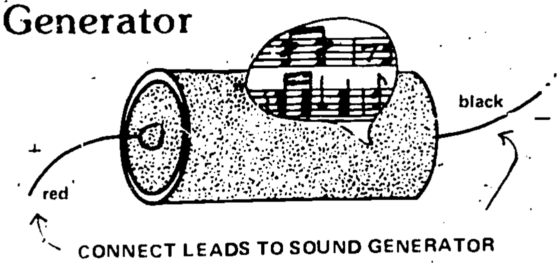
Connect the parts as shown to make a sound generator—solder all connections carefully.

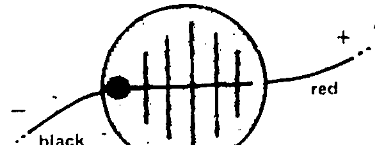


Wood screws hold terminal posts to block of wood.

Test Your Sound Generator

To test the sound generator, connect a D cell to the photocell leads and place the sound generator in direct sun—you should hear a tone!

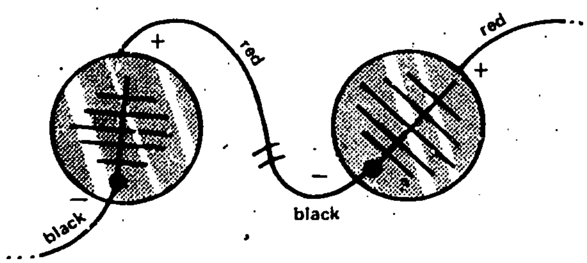




Remove the battery and connect a photocell to the sound generator.

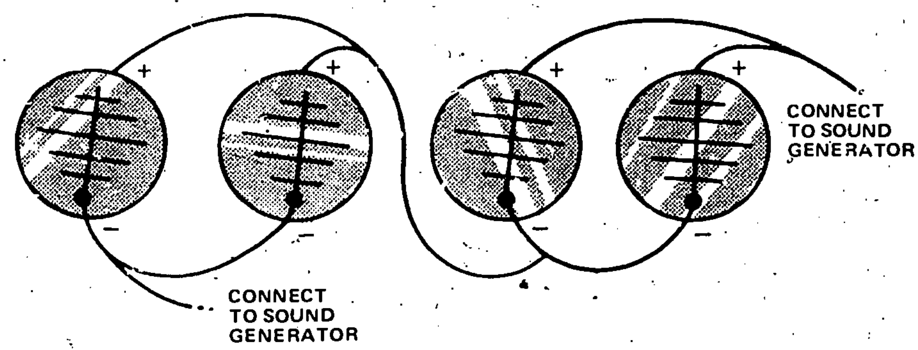
Does it work?

Try These Other Combinations



Now try connecting 2, then 3 photocells to the sound generator.

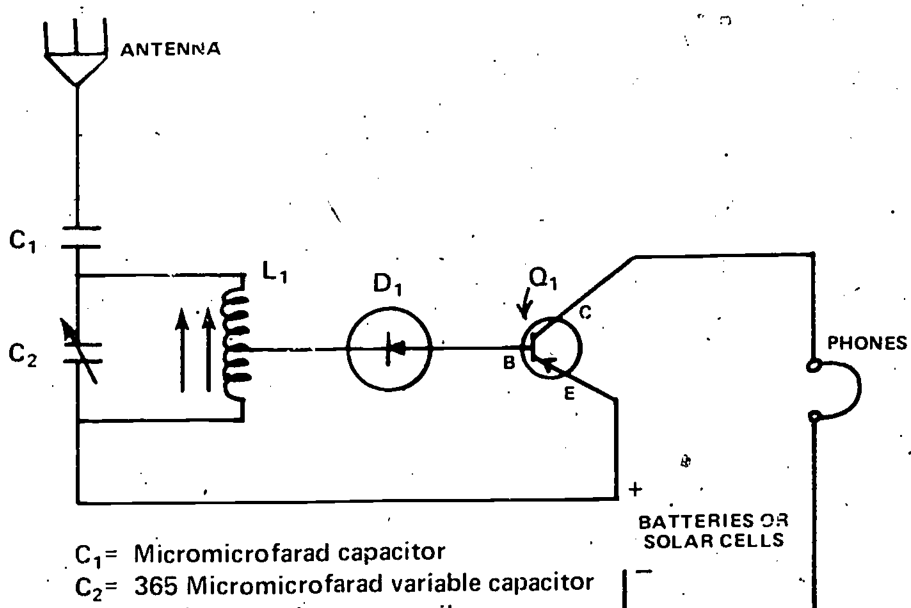
Compare the results.



Try connecting 4 cells in this parallel series. Which connection gives the best results?

Other Ideas to Explore

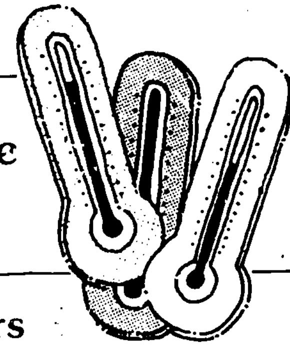
Try constructing a simple light-powered receiver—follow the schematic below.



C_1= Micromicrofarad capacitor
C_2= 365 Micromicrofarad variable capacitor
L_1= Ferrite-tapped antenna coil
D_1= IN34A Diode (or equivalent)
Q_1= 2N107 PNP transistor (or equivalent)
(B = base; C = collector; E = emitter)
Phones = 2000 Ohm earphones

Note:
Solar cells in the appropriate series or parallel connections can be substituted for batteries.

Which batch-type solar collector gets the hottest after 15 minutes in the sun?



SOLAR 5

Materials

Plastic trash bags; one each white, green, and black (local grocery store)

Insulating material (styrofoam, cardboard, newspaper, etc.)

Aluminum foil

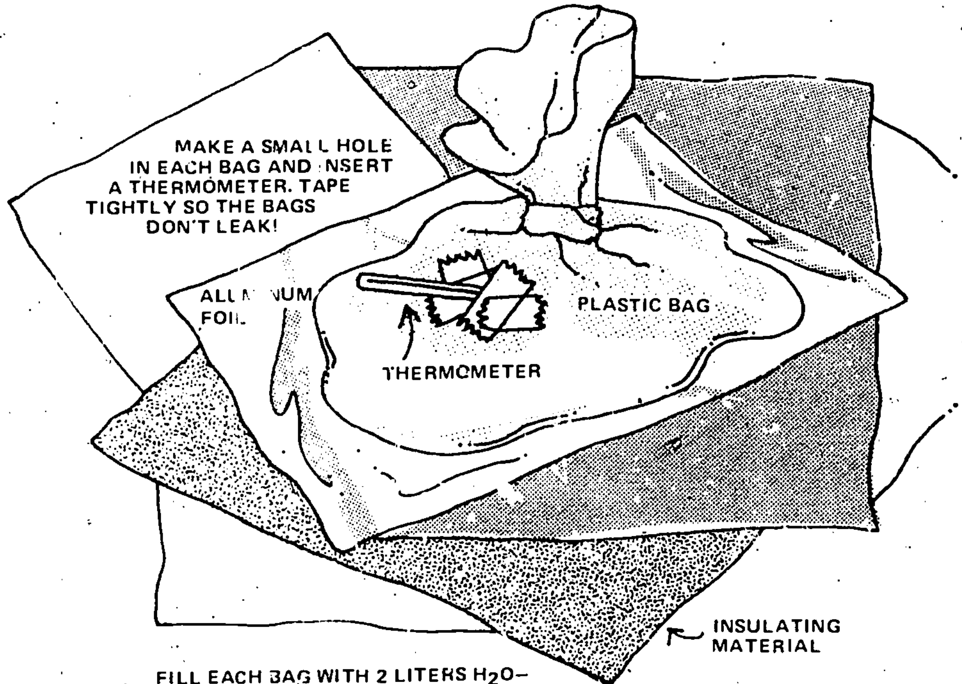
3 thermometers

Tape

Prepare the Collectors

Make 3 plastic trash bag solar collectors by following the drawing below.

On the ground outside, put down insulating material, and then aluminum foil. The bags go on top in a row.



Record the temperatures of the 3 collectors, and place the collectors on the foil in the sun.

Record the temperatures again in 15 minutes.

What causes the differences in temperatures recorded?

How could this affect other solar experiments?

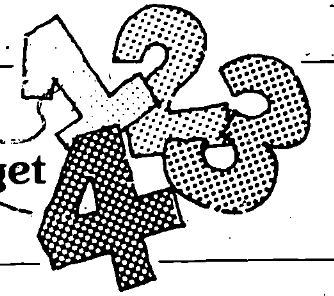
	TEMP. BEFORE	TEMP. AFTER
GREEN		
WHITE		
BLACK		

Other Ideas to Explore

Try this experiment with 2 bags of the same color. Prepare these solar collectors in the same way and place them in full sun, one on insulation material and foil and the other directly on the ground.

Record the temperatures as above and compare the results.

How many times do you have to run water through a flat-plate collector to get a 10^0 rise in temperature?



SOLAR 6

Materials

1 25cm square pi[illegible] galvanized sheet [illegible]tal (thinnest sheet available) (local hardware store or building supply)

[illegible]n square piece [illegible]board

[illegible]ack spray paint

I[illegible]ation material, 7cm th[illegible]k x 25cm square (styrofoam, cardboard, newspaper, etc.)

1 meter soft copper tubing, 3/8" to 1/2" diameter (local hardware store or building supply)

Plastic funnel to fit inside plastic tubing

100-200 watt soldering iron and acid flux solder

30cm clear plastic tubing, 3/8" to 1/2" diameter (local hardware store or building supply)

Razor blade or knife

Tape or stapler

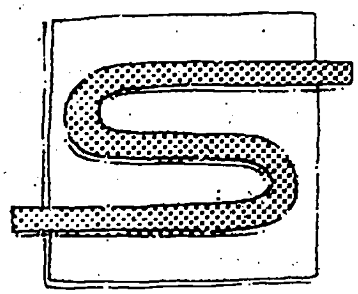
2 styrofoam cups

2 40cm square pieces 3- or 4-mil clear plastic (local hardware or garden stores)

Thermometer

Note:
Copper tubing must be bent with a tubing bender (about $1.50) or tubing can be bent at the hardware store when purchased.

Build a Flat-plate Metal Collector



Bend the tubing carefully with a tubing bender to avoid kinks!

Solder soft copper tubing to galvanized sheet metal.

Spray plate and tubing flat black after construction.

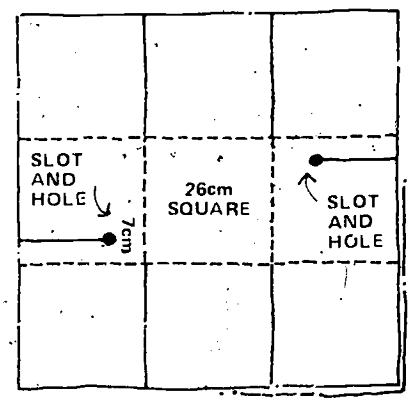
Construct a Box

Using a 52cm square piece of cardboard, construct a box to house your flat plate collectors.

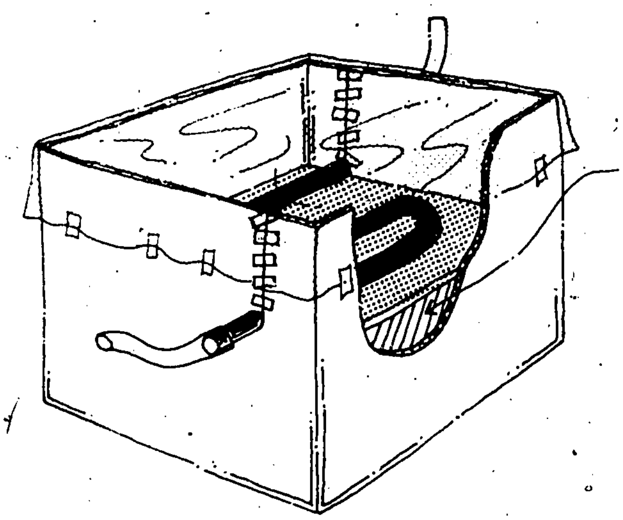
Cut on solid lines.

Fold on dotted lines.

Cut slot and hole to insert flat-plate collector.



Assemble the Collector



Fold and staple or tape cardboard to make a box.

Insert the 7cm of insulation.

Fit the collector into the box. Tape the slots tightly closed.

Fold and tape the plastic to make a tight but removable cover.

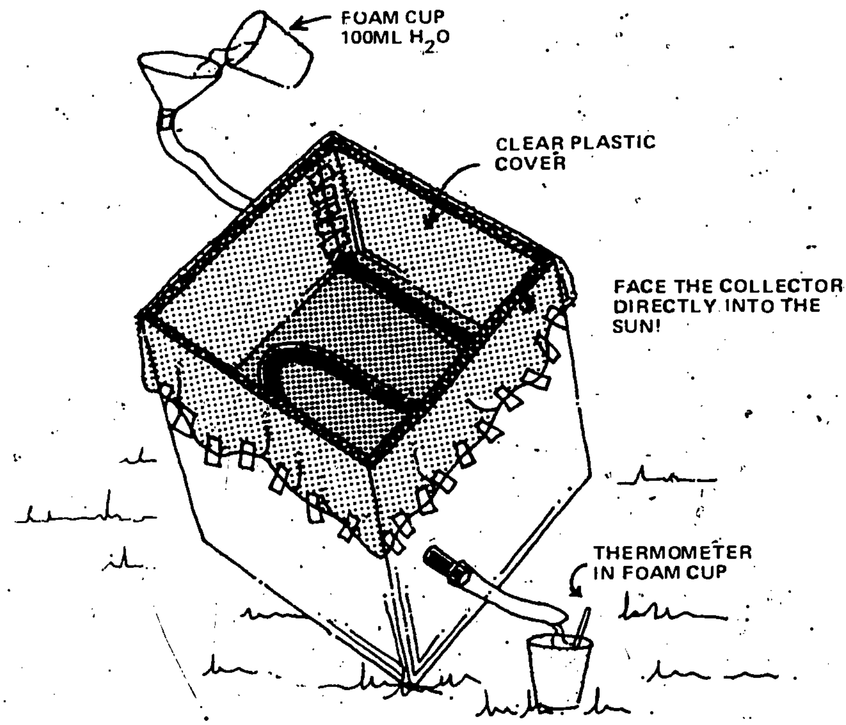
Fit 15 cm clear plastic tubing over ends of copper tubing.

Conduct Your Experiment Like This:

Measure and record the temperature of 100ml of H_2O, then pour it through the flat-plate collector until the temperature rises 10° (allow 5 seconds between pourings).

How many pourings does it take?

Now the Experiment:



Check the box to be sure all cracks and holes are tightly sealed!

Other Ideas to Explore

What happens if you try 50ml of H_2O?

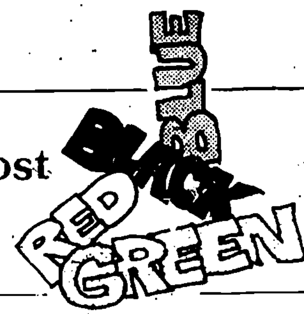
Try varying the angle at which the collector faces the sun. What effect does this have on your experiment?

Make a second box cover of the remaining 3- or 4-mil plastic and place it about 1.25cm above or below the first. Does this have any effect?

What is the highest temperature you can reach with your flat-plate collector? How many pourings does it take?

Fill the collector tubing with H_2O and allow it to stand instead of flowing out. How hot does the H_2O get after 10 minutes in full sun?

Which color liquid absorbs the most solar energy?



SOLAR 7

Materials

Flat-plate metal collector box, plastic cover, and insulation from Solar Activity 6

1 25cm square piece clear plastic (1/8" or thicker) or cardboard

2 meters clear plastic tubing, 3/8" to 1/2" diameter
(local hardware store or building supply)

Glue or tape

Food colors

Thermometer

2 styrofoam cups

Funnel

Conduct Your Experiment Like This:

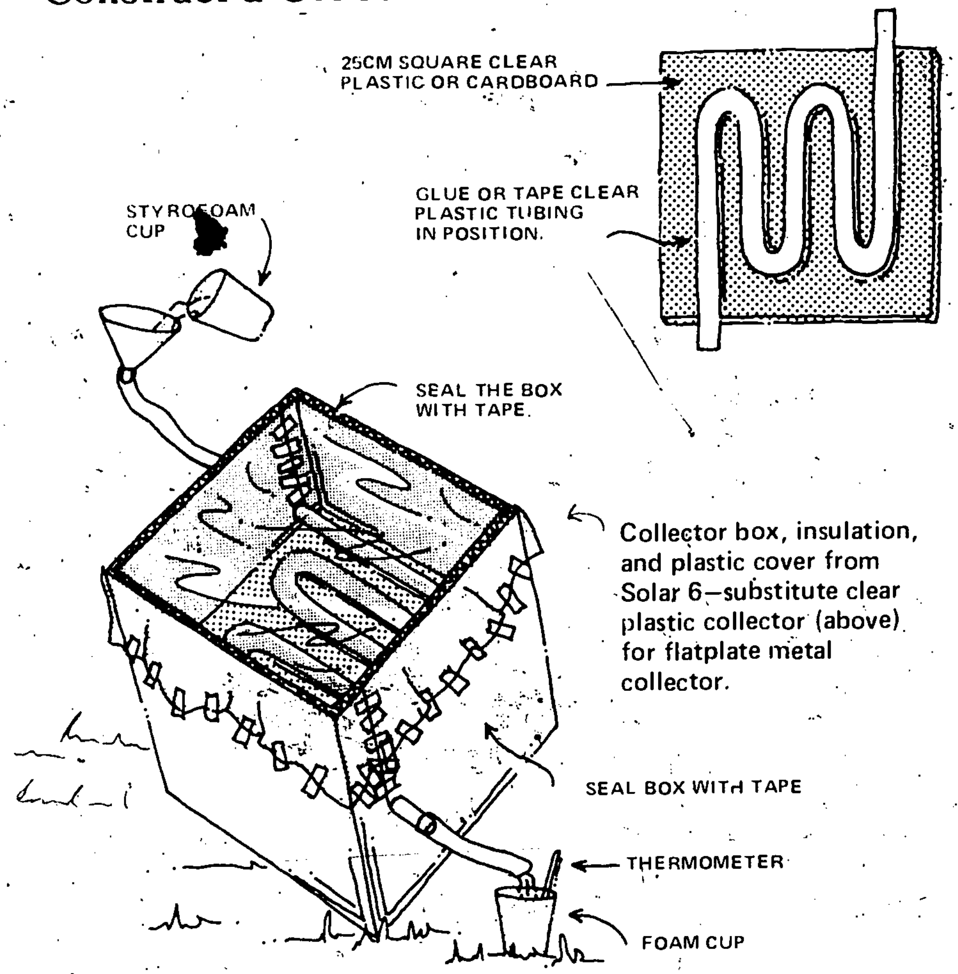
Measure and record the temperature of 100ml H_2O. Pour through the collector 10 times, allowing 5 seconds between pourings. Record the final temperature.

Add 2-5 drops red food color to 100ml H_2O and run through the collector 10 times. What happens?

Try other food colors mixed with 100ml H_2O and compare the results with those of the earlier experiments.

Make a 100ml mixture of H_2O combining 2-5 drops of each different food color. Pour through the collector 10 times and compare the results.

Construct a Collector Plate

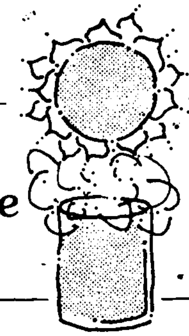


Put the clear plastic collector plate in the box from Activity 6, and face the collector directly into the sun.

Other Ideas to Explore

Try substituting colored salts, such as copper sulfate, chromium chloride, potassium permanganate, etc., for food colors in your 100ml H_2O mixtures. How do the results compare with those of earlier experiments?

How hot will the water get in a solar water heater after 20 minutes of exposure to the sun?



SOLAR 8

Materials

Flat-plate metal collector, insulation and cover from Solar Activity 6

1 or 2 pound coffee can with plastic lid

2 5cm pieces soft copper tubing, 3/8" to 1/2" diameter
(local hardware store or building supply)

Soldering iron and acid-flux solder

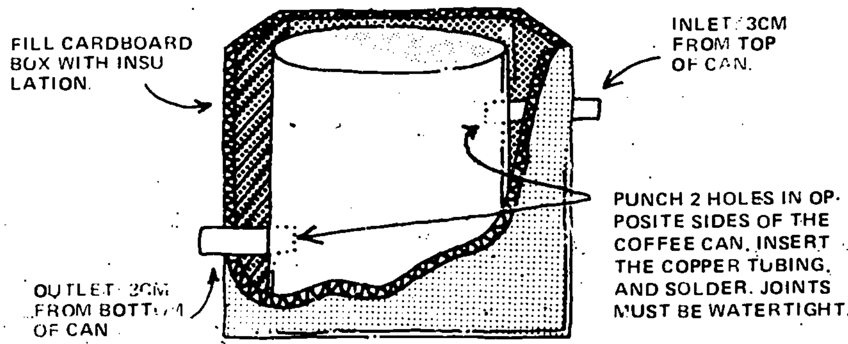
1 meter clear plastic tubing, 3/8" to 1/2" diameter
(local hardware store or building supply)

Celsius thermometer

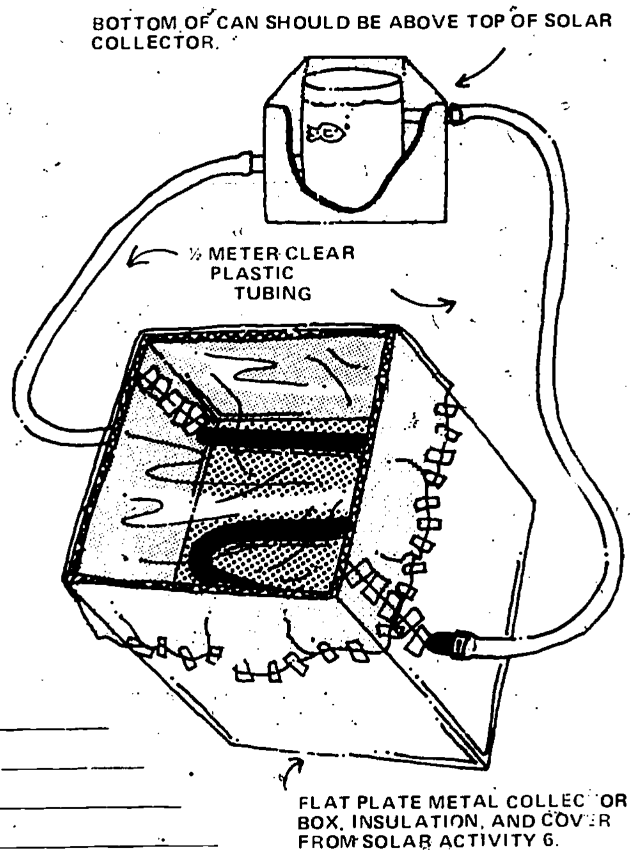
Cardboard box, slightly larger than coffee can

Insulation material (styrofoam, cardboard, newspaper, etc.)

Construct a Hot Water Heater



After you construct your hot water heater, hook it up to the solar collector as illustrated.



Record This Data:

Weight of can only: __________

Weight of H_2O in can: __________

H_2O temp before: __________

H_2O temp after: __________

Weight of H_2O and can after: __________

Conduct Your Experiment Like This:

Disconnect the tubing from the inlet.

Run H_2O through the tubes and the collector until all air is expelled.

Reconnect the tubing to the inlet and fill the can to above the level of the inlet with H_2O.

Record the temperature and replace the lid.

Face the collector directly into the sun.

Record the temperature again after 20 minutes.

How hot did the water get?

Compute the Calories of Heat

Using the formula below, compute the number of calories of heat produced in the solar water heater:

$$\text{Calories} = (\text{Final temperature} - \text{starting temperature}) \times \text{weight of water} + (\text{Final temperature} - \text{starting temperature}) \times 1/20 \text{ wt. of can}$$

Other Ideas to Explore

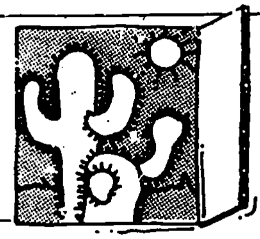
Would the solar water heater work if the storage container was placed lower than the collector?

Will the solar water heater work in reverse on a cold night?

Can you detect the water flow in the system using chalk dust or food coloring?

What is the maximum temperature you can record?

How hot does a box get with a convection-type solar collector in 5, 10, and 15 minutes?



SOLAR 9

Materials

2 white or white-painted boxes, at least 35cm high x 45cm long x 30cm wide (dimensions may vary, but boxes should be about the same size)

Duct tape (local hardware store or building supply)

Tape or stapler

Knife or scissors

About 40cm square piece 3- or 4-mil clear plastic (local hardware or garden stores)

4 thermometers

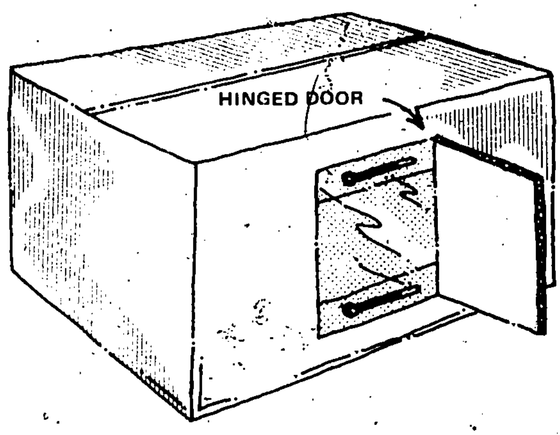
Flat black spray paint

Galvanized sheet metal (dimensions based on size of cardboard box—see instructions) (local hardware store or building supply)

Cardboard (See instructions for amount required)

Insulation material (styrofoam, cardboard, newspaper, etc.)

Construct a Control Box



CUT A HINGED DOOR.

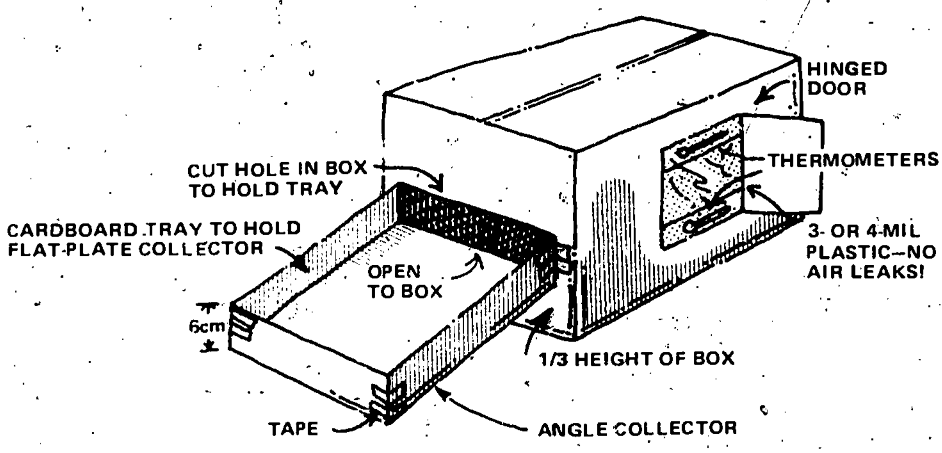
TAPE 3- or 4-MIL PLASTIC TIGHTLY TO INSIDE OF BOX—NO AIR LEAKS!

TAPE THERMOMETERS INSIDE WINDOW AT TOP AND BOTTOM—YOU MUST BE ABLE TO READ THEM THROUGH THE WINDOW.

SPRAY THE OUTSIDE OF THE BOX WHITE IF A WHITE BOX IS NOT AVAILABLE.

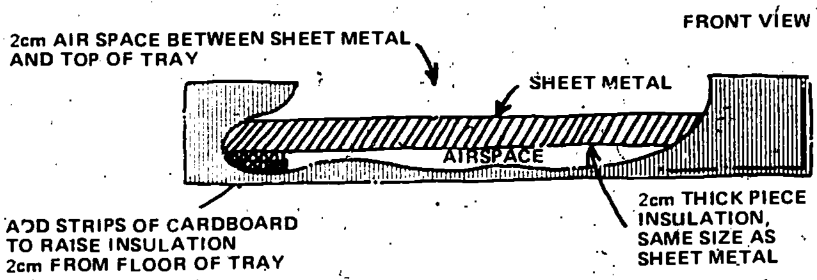
Construct a Solar Collector Box

Make another box like the one above, but add a cardboard tray:



Construct a Flat-plate Collector

Cut galvanized sheet metal to fit snugly into cardboard tray, and spray paint the sheet metal flat black.



Conduct Your Experiment Like This:

Read and record the temperatures of both the thermometers in the control and experimental boxes.

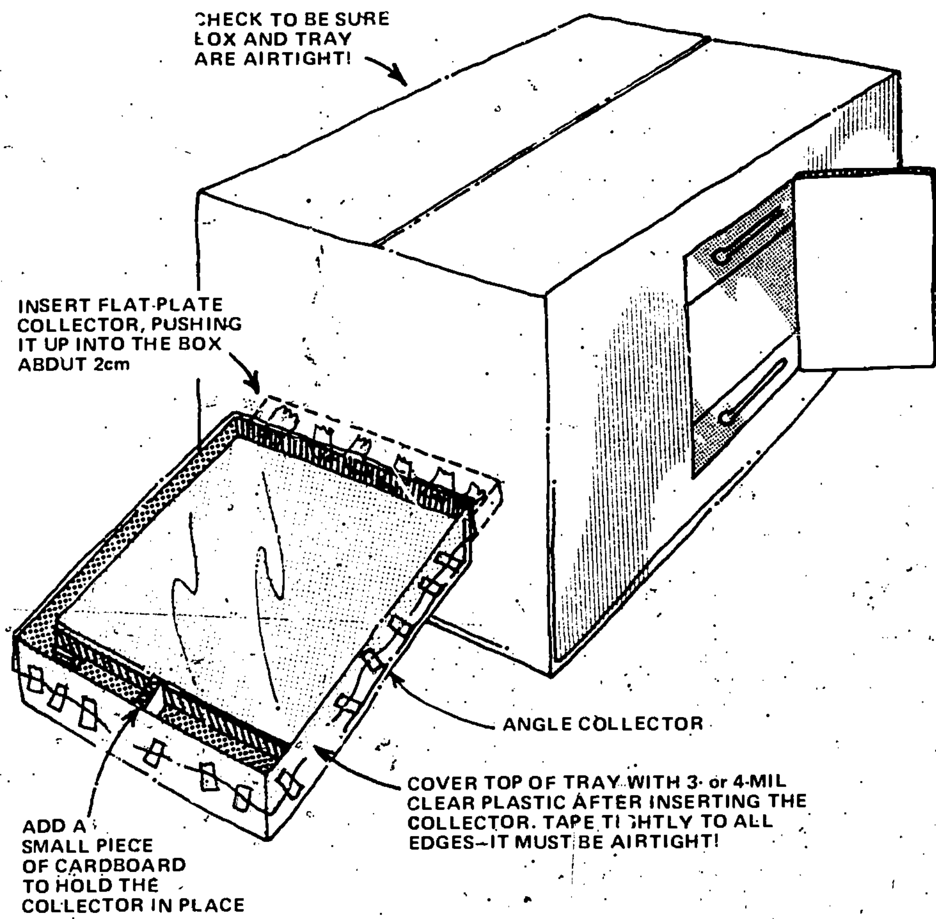
Place the boxes in the sun.

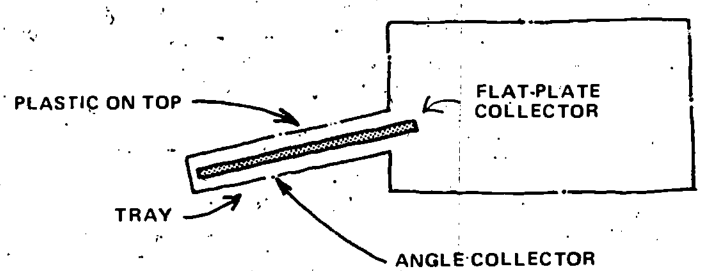
Record the temperature of each thermometer after 5, 10, and 15 minutes.

Compare the results.

Can you describe how the air moves inside the control box? In the experimental box?

Set Up Your Experimental Box

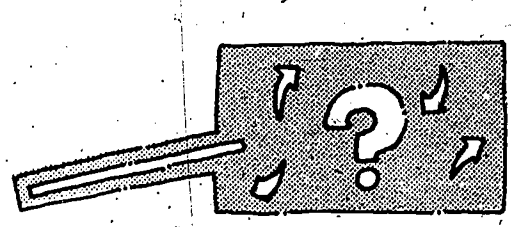




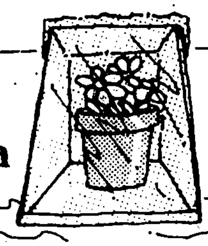
Other Ideas to Explore

Can you make a device that will visually show the air movement inside the box?

NOTE: See elementary Solar Activity 1 for instructions on constructing a draftometer—available from the American Museum of Science & Energy!



How much better is a solar greenhouse than a standard greenhouse at keeping a steady temperature in the winter?



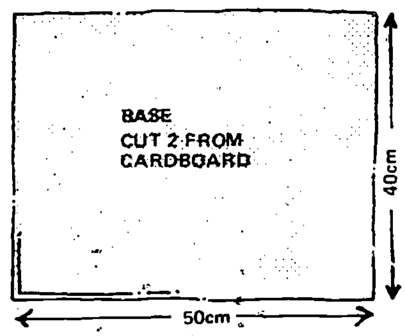
SOLAR 10

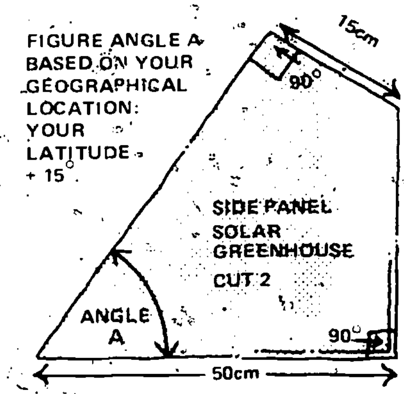
Materials

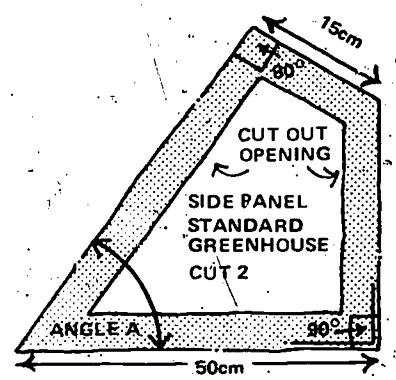
- Corrugated cardboard (figure amount needed based on drawings)
- Clear plastic, 3- or 4-mil, 50cm x 450cm (local hardware or garden stores)
- Flat black spray paint
- White spray paint
- 2 Thermometers
- Plastic wrap (grocery store)
- Tape
- String or thread
- Tin cans
- Rubber bands
- Insulation material (styrofoam, cardboard, newspaper, etc.)

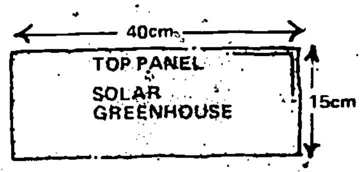
Build a Solar Greenhouse

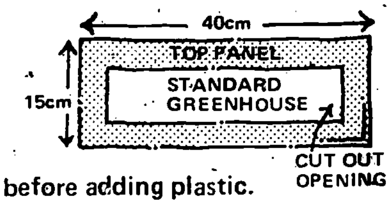
Build a solar greenhouse and a standard greenhouse according to these drawings. (Be sure to cut 2 of each side panel.)



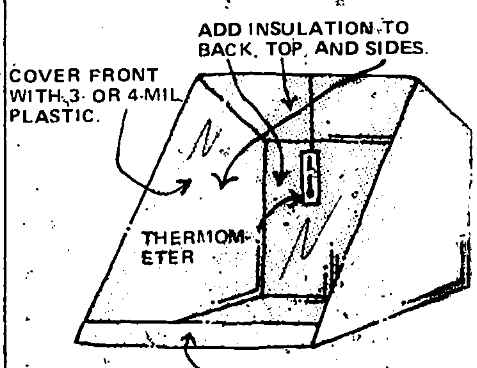


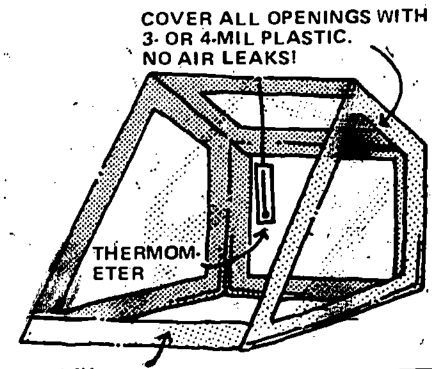






Spray the outside of the greenhouses white before adding plastic.



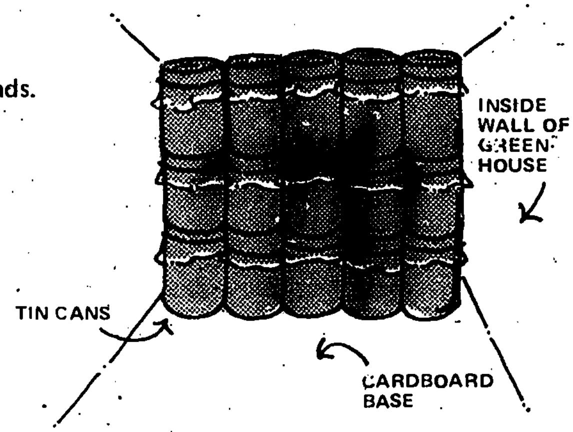


Add 5cm cardboard panel for stability.

Spray the cans flat black.

Fill with H_2O and cover tightly with plastic wrap and rubber bands.

Stack them in the back of the solar greenhouse.

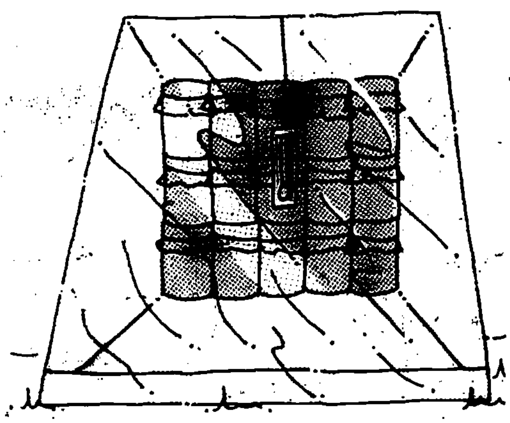


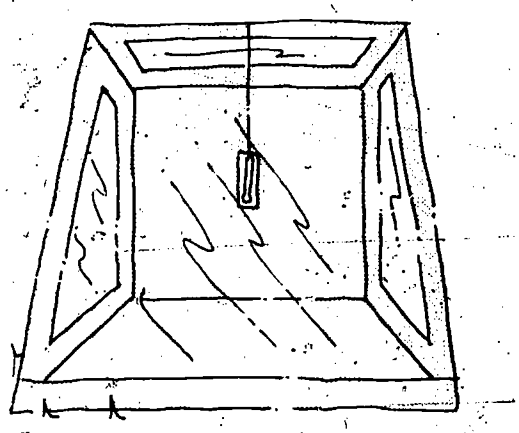
Conduct Your Experiment Like This:

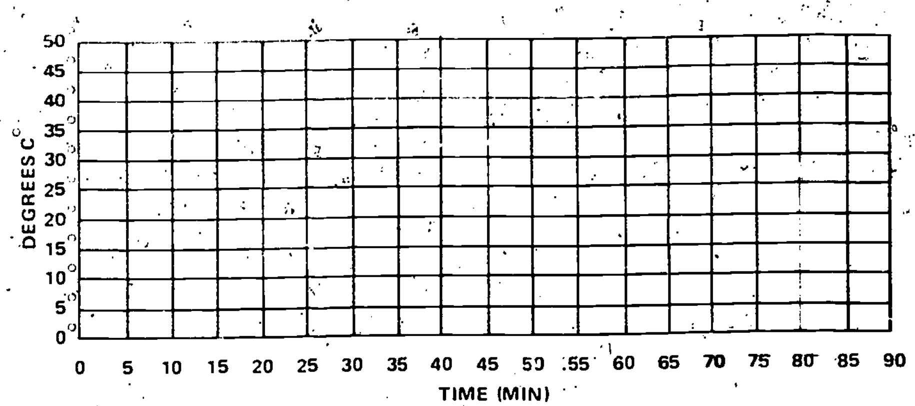
Face both greenhouses directly into the sun.

Measure and record the temperatures in each one as the day progresses.

After they have reached a high temperature place both in the shade—read and record the temperatures as they cool off.







Graph the results of your experiment.

Other Ideas to Explore

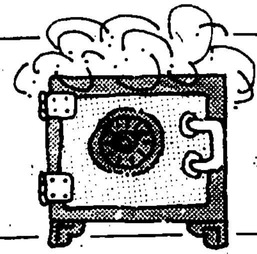
What would happen if you added more insulation material? What if you added 2 layers of plastic to the front?

What are other ways of maintaining and storing heat when there is no sunlight?

Try substituting gravel, sand, and soil for H_2O in the tin cans in the solar greenhouse and try the experiment again.

Would you save energy in your climate by using a solar greenhouse?

Which substance will retain the most heat: H_2O, gravel, or hypo? (sodium thiosulfate)



SOLAR 11

Materials

Hot plate

Pan (same size as hot plate)

3 large test tubes

3 thermometers

3 styrofoam cups

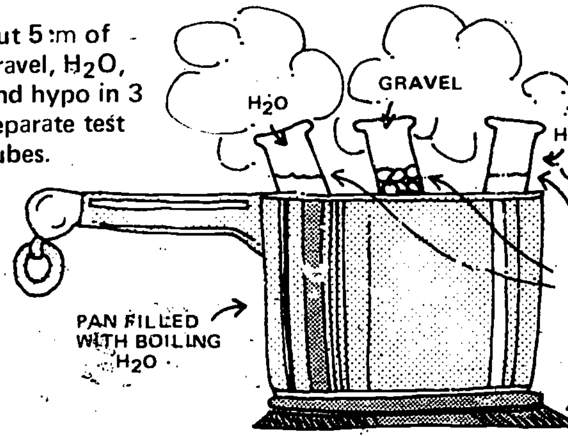
Equal volumes of these materials:

- Gravel
- H_2O
- Plain hypo (hydrated sodium thiosulfate) (local drugstore or photo supply shop)

(Glauber's salt may be substituted for plain Hypo)

Begin Your Experiment

Put 5 cm of gravel, H_2O, and hypo in 3 separate test tubes.

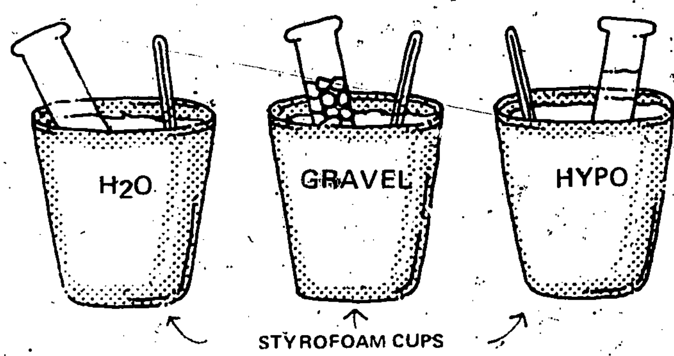


Heat the test tubes in a boiling water bath for 5 minutes.

Fill the styrofoam cups with equal, measured amounts of cold water. Record the water temperatures.

Water temperature before adding test tubes: ______

Add the test tubes, one to each cup. In 15 minutes record the temperatures again. Calculate the number of heat calories gained by the H_2O.



Water temperature after 15 minutes: H_2O _____ Hypo _____ Gravel _____

C = wt. of H_2O x difference in temperatures before and after.

Which substance gives up the most heat?

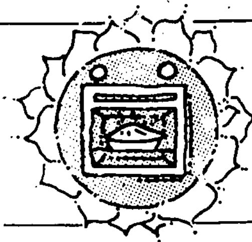
What are the advantages and disadvantages of each storage method?

Other Ideas to Explore

How could each storage method be applied to businesses and homes?

Are there any substances that can be substituted for hypo in this experiment?

What is the average temperature a solar oven produces?



SOLAR 12

Materials

Oven thermometer

Cardboard box, approximately 70cm long x 45cm wide x 35cm high

1 sheet rigid foam insulation, 5cm thick (buy the type with an aluminum foil backing) (local building supply store)

1 pane thermal glass (dimensions depend on size of box—see instructions) (local hardware store or building supply)

Duct tape (local hardware store or building supply)

Flat black spray paint

Glue

Plywood; gypsum board (dimensions depend on size of box; see instructions for base) (local hardware store or building supply)

Weather-stripping (local hardware store or building supply)

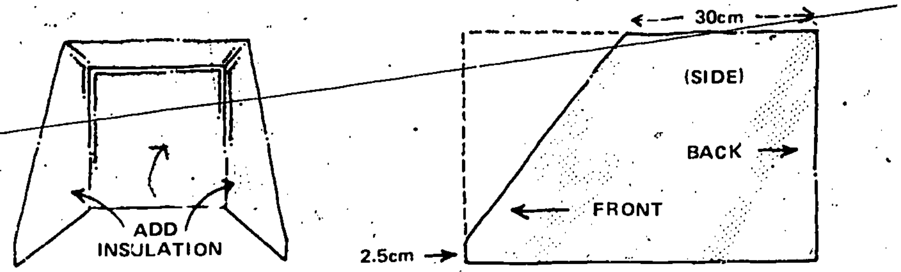
Cardboard pieces

Aluminum foil

4 coat hangers

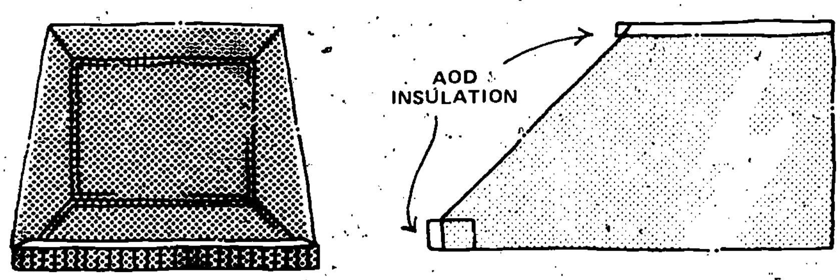
Prepare the Cardboard Box Frame

Remove the bottom and one end from the box. Then cut the top and sides as illustrated below.



Use the sides and back of the box as a pattern to cut insulation that fits the sides and back of the box precisely. Glue them in with the aluminum foil side against the box.

Now add insulation to the top and front of the box: it should extend about 1.25cm beyond the open edge. Again, glue it into place.

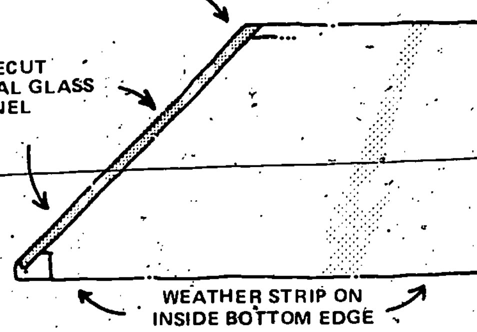


Paint the interior of the box with flat black spray paint to absorb extra heat.

Trim the insulation at an angle so the glass will sit evenly on it.

Add a precut pane of thermal glass to the front of the oven and seal securely with duct tape.

Tape the glass tightly on all edges with duct tape.



Add weather stripping to the cardboard box frame—use duct tape or glue in place.

Conduct Your Experiment Like This:

Use the oven thermometer to see how hot your oven gets.

Log the temperature at 10 minute intervals for 1 hour to find the average temperature.

Turn the oven face to follow the sun while you cook.

Now Build the Oven Base

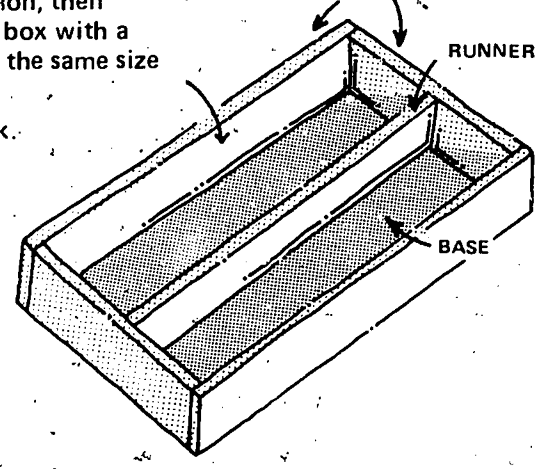
Cut a plywood base 5cm longer and 5cm wider than the base of the oven.

Rim the base with more plywood 5cm high, and add a runner down the center.

Fill the spaces with insulation, then cover the entire top of the box with a piece of gypsum board cut the same size as the plywood base.

Paint the gypsum flat black.

Center the oven on top of the base.

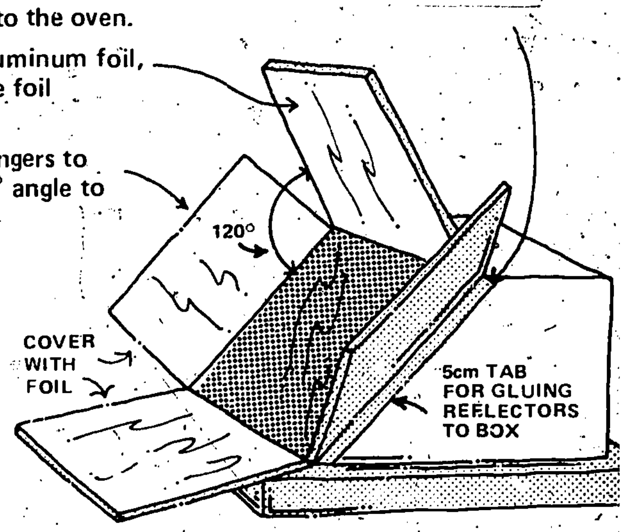


Now Add Reflectors

To make reflectors, cut 4 pieces of cardboard the size of the thermal glass plus 5cm larger on one side. This extra 5cm will be creased to serve as a tab to attach the reflectors to the oven.

Cover the reflectors with aluminum foil, shiny side out, attaching the foil with glue.

Use the straightened coathangers to prop the reflectors at a 120° angle to the face of the oven.



Other Ideas to Explore

How long does it take your oven to cook hamburgers?

Would a second pane of glass and more insulation help you achieve a higher temperature?

How many calories of heat can you generate with a paraboloid solar collector?

SOLAR 13

Materials

Posterboard of desired dimensions (the larger it is the more solar heat will be collected)

Protractor

25cm wire (any type will do)

Thermometer

Aluminum foil

Tomato paste can

Spray adhesive (try a hobby shop or art supply store)

1 sheet cardboard of desired dimensions (see instructions below)

Adhesive tape

3 coat hangers

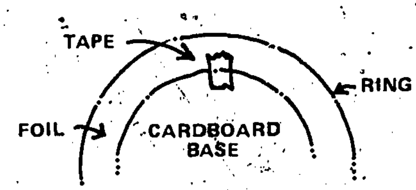
Flat black spray paint

Construct a Paraboloid Solar Collector

1. Decide on a focal length. In our example we chose 25cm. Decide on size of posterboard. In our example we chose 50cm square. (Refer to figure I)
2. Draw horizontal line $\overline{HI}$ across bottom of posterboard.
3. Draw ⊥ line $\overline{PQ}$ from midpoint of $\overline{HI}$ (P) to height of focal distance. (Q)
4. Decide on the size of the focus spot. In our example we chose 5cm. This determines the width of the rings. The smaller the focus spot the hotter the spot will be, but the more difficult the collector is to make.
5. At point Q draw horizontal line $\overline{AC}$ the length of diameter of focus spot. Extend in the other direction, making $\overline{AQ} = \overline{QC}$. Do the same thing at point P with line $\overline{BD}$ so that $\overline{BP} = \overline{PD}$.
6. Draw $\overline{AB}$.
7. Draw $\overline{BC}$.
8. Using B as the center, adjust protractor so that the 90° mark bisects the angle between $\overline{AB}$ and $\overline{BC}$. (Refer to figure 2)
9. Mark point E at 180° at left side. (Refer to figure II)
10. Draw BE and measure ∡b. Record.
11. Place ruler on BE and make point F 10cm (= to $\overline{AC}$) from B.
12. Draw $\overline{B'C}$ through F. Mark B′ where it intersects line HI.
13. Draw ⊥ from B′.
14. Using B′ as a center for the protractor, bisect the angle between ⊥ and $\overline{B'C}$. Make a point E′ at 180° mark. Draw line B′E′.
15. Read $∡b_2$ and record. On $\overline{B'E'}$, measure 10cm (= to $\overline{AC}$) from B′ and mark F′.
16. Repeat until boundary of posterboard prevents further expansion of rings.
17. Measure r_1, r_2, r_3, etc. from your diagram and record.
18. Calculate the values of ∡g and H using the formulas ∡g = 360 sin ∡b;

$$h = \frac{r}{\text{Sin } ∡b}$$

19. Carefully draw rings on reverse side of posterboard. Refer to Figure III. Using the center of the posterboard as the center of the circles, draw a circle of radius h_1. Now draw another circle whose radius is h_1 + w (width of focus).
20. Do the same for all values of h and ∡g.
21. Measure ∡g on all the rings. (Refer to figure IV)
22. Glue aluminum foil to calculation side of posterboard using spray adhesive. Cut out rings and space between angle marks as shown.
23. Join ends of each respective ring evenly. Beginning with the largest ring, attach rings to a piece of cardboard, cut to final collector size. Tape to the cardboard. See drawing at right.



Construct a Paraboloid Solar Collector

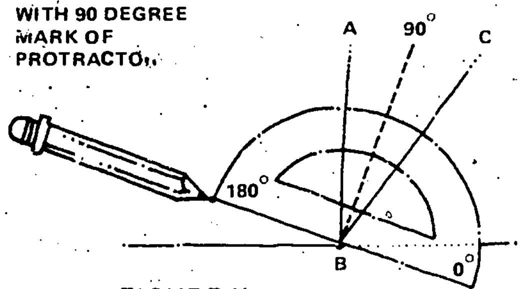
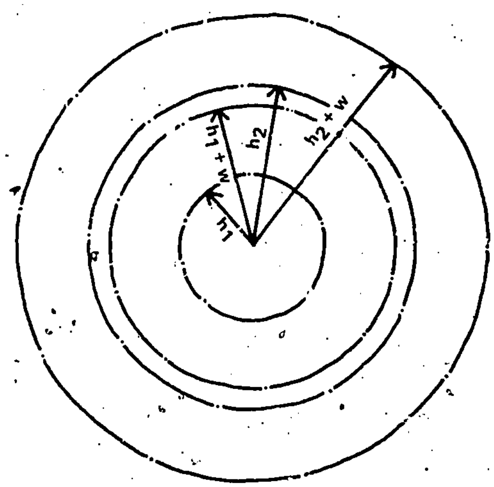


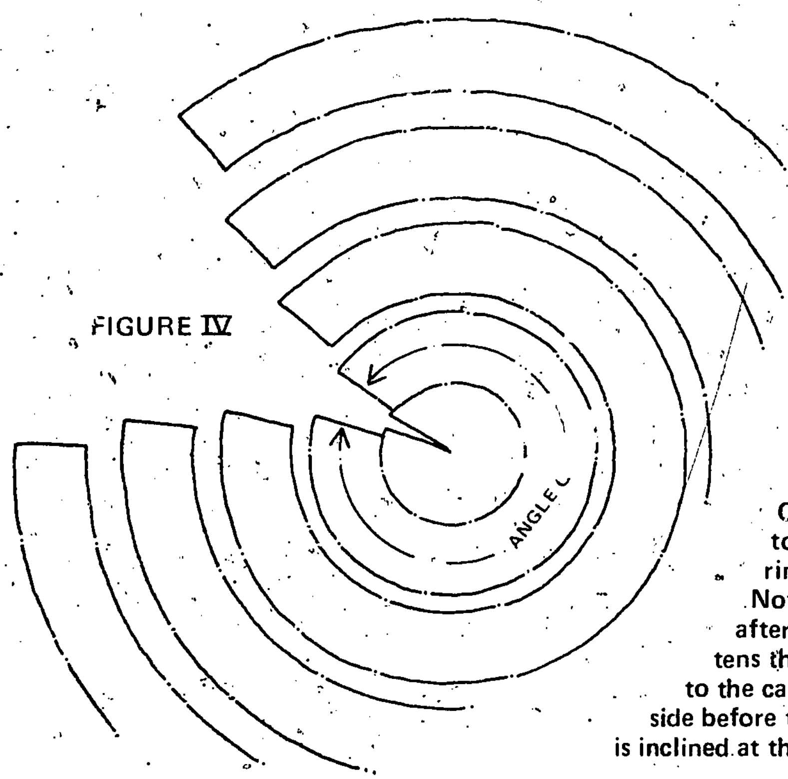
FIGURE II

FIGURE III



W = Width of Focal Spot

FIGURE IV

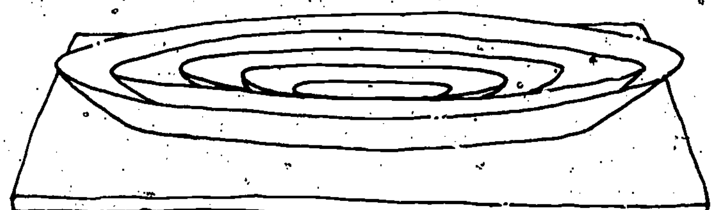


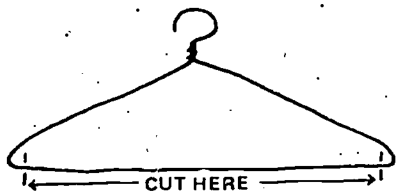
Cut on solid lines, then splice the ends of the ring together. Mark your drawing before cutting out rings.

Note: A ring tends to become slightly elliptical after the cut ends are spliced together. This flattens the angles on two sides. Tape the spliced sides to the cardboard first, then push or pull opposite side before taping. This helps make a good circle which is inclined at the correct angle.

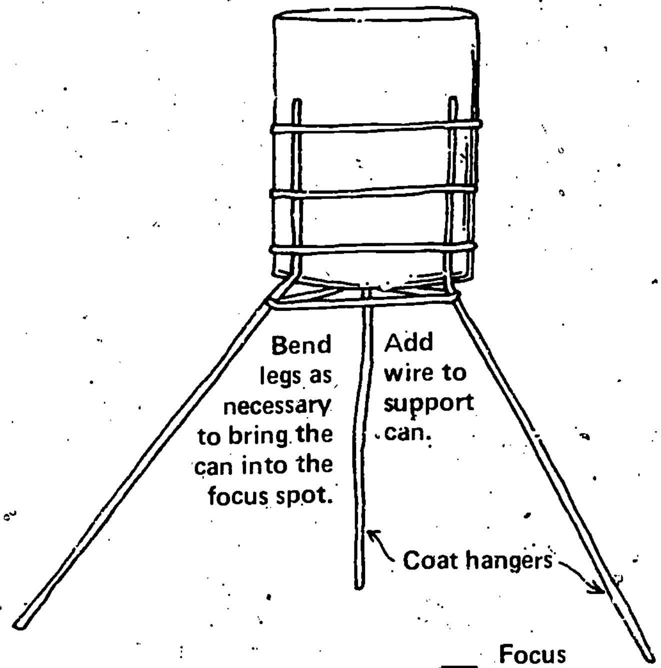
FIGURE V

Finished paraboloid collector





Build a tripod from the 3 coat hangers and wire to the tomato paste can.



Fill the can with a measured amount of cold water, and record the following data:

____

temperature (before)

____

weight of H_2O

Place the collector in direct sun for 15 minutes. Take the water temperature again:

____

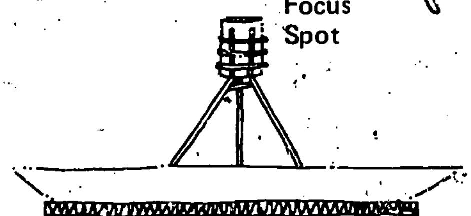
temperature (after)

Calculate the number of heat calories generated:

Calories = wt. of H_2O x difference in temperatures before and after experiment

\+

wt. of can x .1 x difference in temperatures before and after experiment



Paraboloid solar collector

Table 1

Focus length = 25cm
Focus spot = 5cm

	∡b°	Sine ∡b°	∡g°	r_{cm}	h
∡b_1	84	.994	358	2.5	2.5
∡b_2	78	.978	35[illegible]	7.8	8.0
∡b_3	74	.961	346	13.8	14.
∡b_4	69	.934	336	19.6	21.
∡b_5	65	.906	326	26.3	29.

Table 2

Focus length = 25cm
Focus spot = 10cm

	∡b°	Sine ∡b°	∡g°	r_{cm}	h
∡b_1	79	.982	354	5.0	5.1
∡b_2	69	.934	336	16.6	18.0
∡b_3	61	.875	315	31.2	36.0

Other Ideas to Explore

Using your solar meter or the solar constant for your location, calculate the amount of solar heat falling on your collector. What is its efficiency?

What do you expect would happen to the heat and temperature obtained if you doubled the diameter of the collector?

Are there any objections to this method of collecting solar energy compared to a flat-plate type collector?

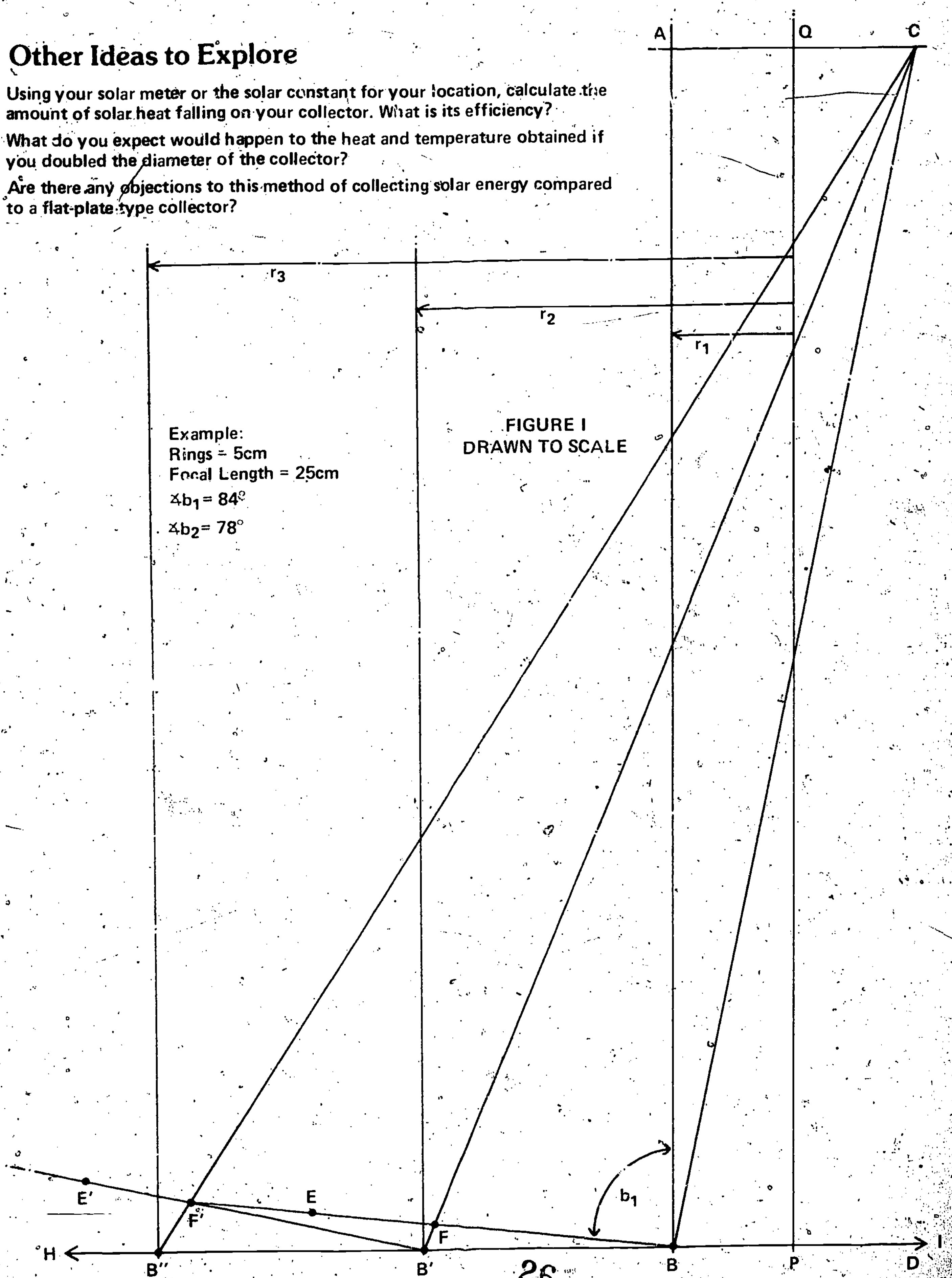


FIGURE I
DRAWN TO SCALE

What percent of solar energy falling on your Fresnel lens (optical paraboloid reflector) is changed to heat?

SOLAR 14

Materials

Fresnel lens (any Fresnel lens will do) (information available from the American Museum of Science & Energy)

Two 1" long + 1/8" diameter bolts and wing nuts to fit (local hard ware store)

Coat hanger

Tin can (bottom 1/3)

Tin snips or hacksaw

Cardboard (see instructions for amount required)

Tape

Tomato paste can

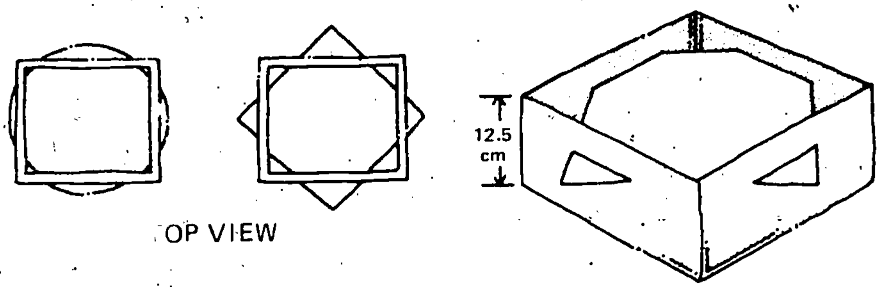
Flat black spray paint.

Food colors

Note:
The design for this Fresnel furnace can be modified to hold any Fresnel lens you have, whether it's round or rectangular. Best results will be obtained by using a Fresnel lens at least 25cm across.

WARNING:
Don't look at the focal point for long without wearing very dark glasses! The bright light could damage your eyes.

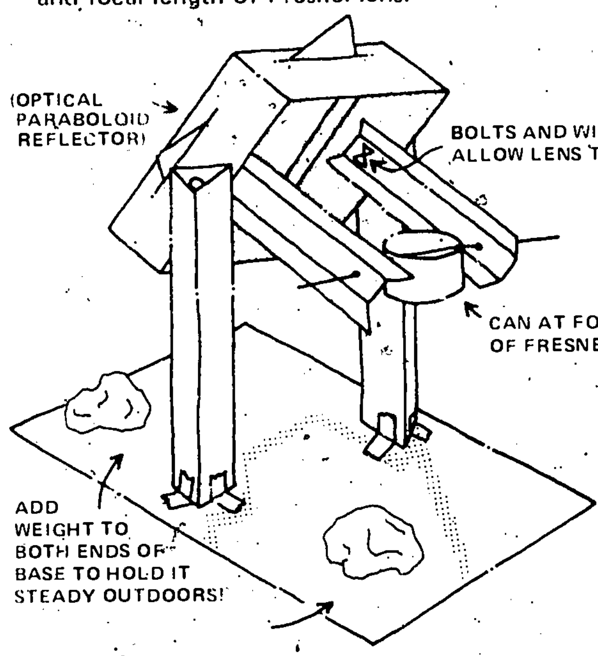
Make a Frame for Your Fresnel Lens



Construct the Solar Furnace

*Dimensions of solar furnace depend on size and focal length of Fresnel lens.

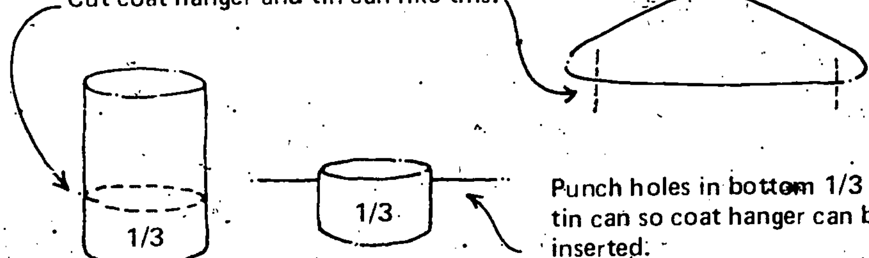
Cut a 12.5cm wide strip of cardboard.
Wrap it around the lens, cutting slits to hold it in position.



*THE FOCAL LENGTH OF YOUR LENS SHOULD BE LISTED ON THE INSTRUCTION SHEET THAT COMES WITH IT. ANOTHER WAY TO FIND THE FOCAL LENGTH IS WITH A SHEET OF WHITE PAPER: MOVE THE PAPER BELOW THE LENS UNTIL YOU LOCATE THE SMALLEST PINPOINT OF LIGHT COMING THROUGH IT. THE PAPER SHOULD IGNITE AND BURN.

Cut the Large Tin Can

Cut coat hanger and tin can like this.



Punch holes in bottom 1/3 of tin can so coat hanger can be inserted.

Conduct Your Experiment Like This:

Using the solar constant or solar radiometer from solar experiment # 1 or # 2, calculate the amount of solar energy falling on your Fresnel lens.

Prepare tomato paste can and record the following data:

Wt. of can only: _____

Wt. of H_2O: ________

Temperature of H_2O: ____________

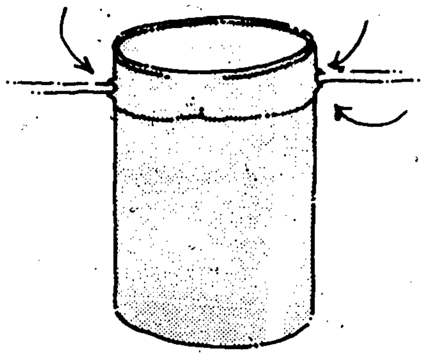
Place the filled can in the focal point of your solar furnace and measure the temperature rise after 2 minutes.

Temperature of H_2O after experiment: ____

Compute the calories of heat attained.

Prepare Tomato Paste Can

Punch holes to insert coat hanger on opposite sides of can.



Paint can flat black.

Weigh the can empty.

Fill with cold H_2O to just below the holes you punched and add 15-20 drops of food color to make the water good and black.

Weigh the can again.

Compute the Calories of Heat

Compute the number of calories of heat attained and compare with the total energy coming in through the lens:

Calories received = wt. of can x .1 x temp change + wt. of H_2O x temp change.

Using the solar constant (solar activity No. 1), calculate the amount of solar energy falling on your lens:

Solar Energy = Solar Constant x Area of lens (calories/minute)

The percentage of solar energy changed to heat is calculated this way:

$$\text{\% of solar changed to heat} = \frac{\text{Calories received by water \& can}}{\text{Calories received by lens x 2}} \times 100$$

Other Ideas to Explore

Using the bottom half of the large tin can you prepare first, try the following experiments:

See if the solar furnace will melt solder.

See how long it will take to boil 25 ml of H_2O.

Which produces steam faster? Clear water in a black can or black liquid in a glass jar? (Wire and rubber band the jar in position: a baby food jar works well.)

Calibrating a Thermometer

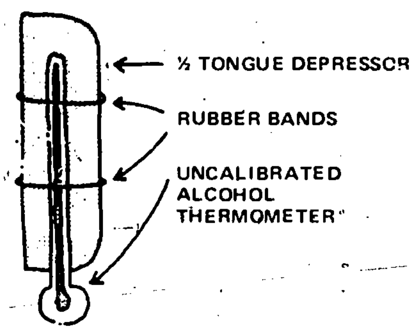
Thermometers are fragile, and can be relatively expensive to replace on a regular basis. In addition, most students do not understand the meaning of the calibrated scales. To remedy both problems, purchase inexpensive uncalibrated alcohol thermometers and permit each student to calibrate one.

Materials

Uncalibrated alcohol thermometers (available from the American Museum of Science & Energy).

Tongue depressors, split lengthwise.

Small rubber bands.

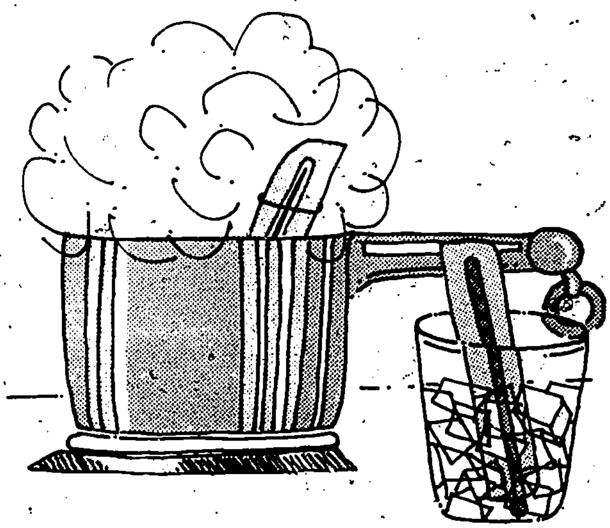


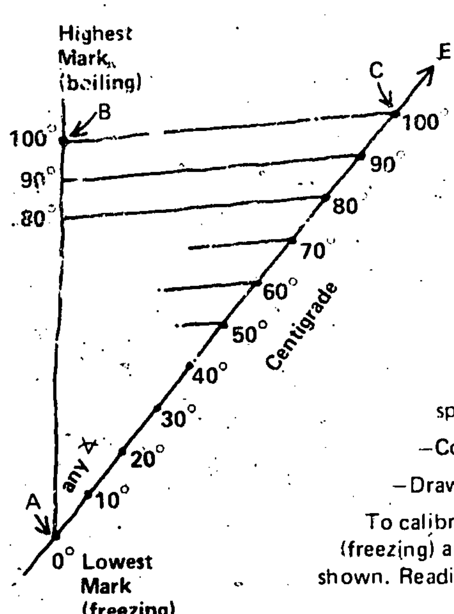
Place the thermometer on the stick as shown:

Note: Mark the placement of the thermometer on the tongue depressor so it can be replaced if it slips or the rubber band breaks.

Note: The space between boiling and freezing marks will not be the same for different thermometers!

Place the thermometer in a mixture of cracked ice and water. Make a mark at the lowest position of the red liquid. Then, place the thermometer in boiling water and mark the highest position of the red liquid. Don't let the thermometer touch the bottom of the pan—suspend it by attaching a pencil to the tongue depressor.





Divide the space between the boiling and freezing marks on your thermometer into 10 equal spaces—an easy way to do this follows:

Draw a line any length at any angle from point A to E.

Divide part of this line into 10 equal parts starting at A. Any unit of space will do: 1cm, 1 paper clip, etc. Mark the 10th dot C.

—Connect points B and C with a straight line.

—Draw parallel lines from the other 9 points on AC to AB.

To calibrate your thermometer on a Celsius scale, point A should be 0°C (freezing) and point B should be 100°C (boiling). Label the rest of the scale as shown. Readings on the scale can be estimated to within 1° accuracy quite easily.