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ABSTRACT

Presented in this teacher's manual are more than 40 energy-related discussions and projects for use in conjunction with secondary school courses in mathematics, science, social studies, and language arts. Designed to help students discover ways to study and conserve energy, the activities also stress alternate energy sources and their applications. Lessons are organized under four categories: (1) energy conservation, (2) solar energy concepts, (3) solar energy applications, and (4) alternate energy sources. Typical among these activities are constructing a solar collector, debating offshore drilling proposals, tracking the sun by computer, and investigating the effects of thermal pollution. Included in the lesson plans are teacher background material, suggestions for lesson preparation, lists of related activities, student handouts, and step-by-step procedures for conducting the activities. (WB)

STATE OF CONNECTICUT

STATE BOARD OF EDUCATION

ENERGYWATCH VOLUME II CURRICULUM GUIDE

The national interest demands that we conserve energy and use our resources wisely. We must educate young people about the special circumstances they will face in the years ahead. It is a test of our national character which demands creativity, resourcefulness and determination. For this reason, the commitment to deal with energy choices must begin now in our schools. This far-reaching subject must be addressed in every classroom, so that we may prepare our young people to deal successfully with a challenge which they will inherit.

Energywatch Volume II Curriculum Guide reflects the increasing demand for programs that teach our young people the value of conserving energy and respecting our environment. Secondary school teachers will find that this guide offers a practical approach to interesting topics including the use of alternative energy sources and home and school conservation practices.

The State Board of Education is committed to long-term programs within our schools which will complement immediate conservation measures.

This curriculum guide provides the teacher with a variety of topics and "hands-on" projects, which students are sure to enjoy. The classroom can now become a major resource for creative discussion of our energy future.

By stimulating our young people to find a solution to our energy shortage, we are setting a most hopeful tone for our state's future.

Mark R. Shedd
Commissioner of Education

Box 2219 • Hartford, Connecticut 06115

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ENERGYWATCH

DESIGNING ENERGY EDUCATION INTO THE CURRICULUM

VOLUME 2

grades 7 - 12

produced for

CONNECTICUT STATE DEPARTMENT OF EDUCATION

by the

Talcott Mountain Science Center

for Student Development

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November 1980

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ENERGY GRADES 7 - 9

TOPIC / SUBJECT	ENERGY CONCEPTS	ENERGY SOURCES	ENERGY USES	ENERGY CONSERVATION	ENERGY AND ECONOMICS	ENERGY AND ENVIRONMENT
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SUBJECT \ ENERGY TOPIC	ENERGY CONCEPTS	ENERGY SOURCES	ENERGY USES	ENERGY CONSERVATION	ENERGY AND ECONOMICS	ENERGY AND ENVIRONMENT
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SOCIAL STUDIES	130, 204, 211, 216, 222, 234, 246, 251, 257, 267, 272.	56, 63, 130, 211, 216, 222, 234, 246, 251, 257, 267, 272.	2, 6, 211, 216, 222, 234, 251, 257, 267, 272.	2, 6, 56, 59, 211, 216, 222, 234.	2, 6, 56, 59, 63, 211, 216, 222, 234, 267.	59, 211, 216, 222, 234, 251, 257, 262, 267, 272.
LANGUAGE ARTS		56, 63.	6, 46, 52.	6, 46, 52, 56.	6, 52, 56, 59, 63, 251, 257.	
MATH	92, 104, 109, 114, 119, 130, 138, 149, 154, 173, 179, 185, 191, 204, 211, 234.	92, 104, 109, 114, 119, 154, 173, 179, 185, 191, 204, 211, 234, 251, 257.	2, 6, 104, 109, 114, 119, 154, 173, 179, 191, 204, 234, 251, 257.	2, 6, 11, 23, 34, 173, 179, 234, 272.	2, 6, 11, 23, 34, 204, 234, 257.	130, 138, 234, 246, 251, 257, 272.

Introduction

The Energywatch Volume II Curriculum Guide has been compiled to meet an ever increasing demand for energy education in secondary schools. Our depletion of resources and the effects of rising fuel costs are being felt by students and educators alike. Many individuals are now beginning to take steps to conserve and pursue alternate energy forms. Schools are also doing their part to limit energy expenditures but the high price of fuel continually cuts into funds needed for special school programs. This curriculum guide can be a practical teaching tool to help students discover effective ways to identify, calculate cost, and conserve the energy they use in their daily lives. The activities in this guide also stress basic concepts and practical applications of solar energy and other appropriate energy sources in order to help initiate new ideas for easing the high cost of energy at home and at school.

How To Use This Guide

The activities in this guide have been set up to provide the teacher with a variety of topics and "hands-on" projects. Each one is laid out in an easy to follow format. The activities are indexed according to related subject matter, areas of study and relative complexity.

The first portion of each activity provides skills objectives and background information To The Teacher. The grade level for each activity is only suggested and may be modified to fit the students' background in science. Under the heading Before You Begin are some suggestions for preparation and organization of each activity. Related Activities may be incorporated into the activity to provide greater depth or may be used as a follow up project for those students who wish to go further. A list of vocabulary words and a short resource list is provided with each activity, but many more resources can be found in the "Energy Resources Inventory for Connecticut Educators." The Student Pages are set up to provide the pupil with a list of materials, a step-by-step method and often a record page. The majority of the activities involve a session of preparation, a hands-on activity followed by an analysis and discussion of the results. The student pages are intended as a handout but are certainly not the only approach.

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Curriculum Topic

ELECTRIC AND GAS METER READING

Energy Topic

ENERGY USES
ENERGY CONSERVATION
ENERGY ECONOMICS

Grade Level(s) 7 - 12

Site School and home

Skills

- Evaluating information
- Simple math skills
- Read an electric or gas meter

Credit

"Energy Conservation in the Home"
The University of Tennessee Environmental Center and College of Home Economics.

Objective

At the completion of this activity you should be able to:

1. Demonstrate how to read electric and gas meters, and how to determine consumption over a period of time.
2. Calculate approximately and exactly the wattage used.

To The Teacher

Wattage refers to the amount of energy an appliance uses. Household power is measured in kilowatt hours (kwh): wattage multiplied by hours used, divide by 1000. For example, in four hours a 100-watt appliance uses .40 kwh of energy.

$$\frac{\text{Wattage x hrs.}}{1000} = \text{kwh}$$

Before You Begin

1. Locate the electric or gas meter at your school and use this as an introductory demonstration.

Words To Know

watts, kilowatt hours (kwh), odometer, clockwise, counter-clockwise, cubic feet.

Related Activities

- Follow this activity with the lesson "Thermostat Setback".

Notes To Myself

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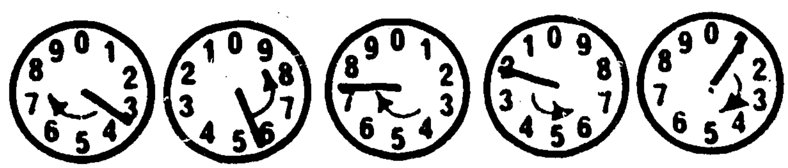
STUDENT PAGE

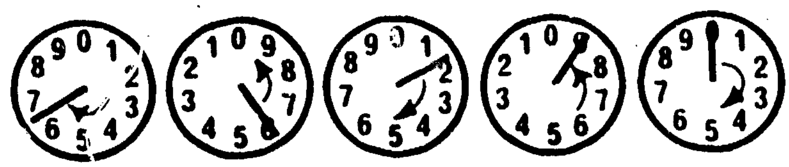
METHOD

In order to determine the effectiveness of your energy-conservation efforts you must be able to tell how much energy is being consumed at your house. The easiest way to do this is by taking meter readings. Electric and gas meters give the total, or cumulative, energy consumption. They operate much like the odometer on a car. You must compare beginning and end readings to find out how much energy your family used over a given period of time (one day, one week, one month). For example, if your meter read 35721 kilowatt-hours on Monday morning and 35731 on Tuesday morning, it means your home consumed 10 kilowatt-hours of electricity for that day or 24-hour period.

Most electric meters have five dials organized from right to left: the rightmost indicates kilowatt-hours; the next dial, tens of kilowatt-hours; then hundreds; and so on. But the dials alternately rotate clockwise and counterclockwise. You should record the digit the indicator has just passed. Study the illustrations and readings below:

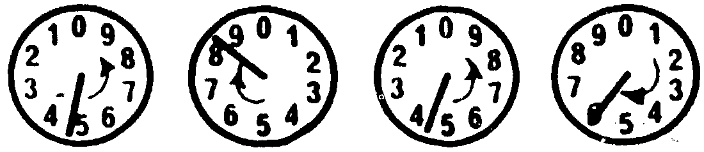


READING=35721



READING=66190

The dials of a gas meter pictured below, are much like that of an electric meter except that there are usually only four dials with markings representing 100 cubic feet on the rightmost dial.



READING=4846

If, after one day, the reading were 4876, then the comsumption that 24-hour period would have been 3,000 cubic feet of gas.

$$\begin{array}{r} 487600 \\ -484600 \\ \hline 3000 \end{array} \text{ cubic feet of gas}$$

Now calculate the amount of electricity being used by recording the following information:

1. Initial reading: __________
2. Final reading: __________
3. Consumption is: __________ for _____ hours.

QUESTIONS

1. What kinds of actions could be taken to conserve electrical or gas energy in this building?

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Curriculum Topic

ELECTRIC APPLIANCE CUT-BACK

Energy Topic

ENERGY ECONOMICS
ENERGY CONSERVATION

Grade Level(s) 7 - 12

Site School or home

Skills

- Locating and obtaining information
- Simple mathematics

Credit

Earthwatch
Environmental Education Center
A program of area cooperative education services

Objective

At the end of this activity the students will be able to:

1. Calculate the amount of electricity saved by conserving the use of electrical appliances.

To The Teacher

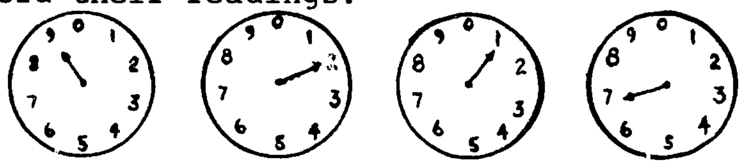
Different appliances use different amounts of power. Even different models of the same appliance vary considerably. When electrical energy is changed to heat, such as the heating element on a stove, power is used at a high rate. To conserve electrical energy in the home, therefore, every conservation effort helps.

Approximate wattage information can be obtained by reading the information listed on the student page. The actual wattage information is usually printed on the appliance. The following formula may be helpful if the wattage is not listed but the amperes and voltage are known:

volts x amps = watts

Before You Begin

1. Place the following examples of dials on the board and have students record their readings:



= 9217

2. Assign students to bring in readings taken in their homes at 8:00 p.m. Record time, date and wattage for each student on a wall chart.

3. Assign a second reading to be taken exactly one week later to the time and day.

4. Subtract and record kwh used for each family.

5. Give students copies of the appliance chart included here. Ask each student to list appliances used in his/her family. List appliances using the greatest wattage and those using the least wattage.

6. Beside each appliance listing, ask students to estimate in hours (using fractions or decimals, if necessary) how much each is used per week. (Example: hairdryer 1.1 hours)

7. Calculate the kilowatt-hours (kwh) for each appliance a student uses.

$$\frac{\text{wattage}}{1000} \times \text{hours used} = \text{kwh}$$

8. Which appliances use the most energy? Do appliances with the highest wattage have the highest energy use (kwh)? Why or why not?

9. Challenge students to cut back on electrical energy consumption. Have a contest to see who can cut back the most during the following week.

10. One week later, have students take a third reading at the same hour.

11. Have students with the greatest reduction in electrical energy use explain how they persuaded their families to decrease electrical use and appliances they were most able to restrict.

12. Discuss ways to conserve energy. The following will help start the discussion:

   a) take shorter, cooler showers

   b) skip drying cycle in dishwasher, air-dry

   c) hang clothes outside to dry whenever possible

   d) keep thermostat set low

13. Conduct a discussion on the reasons for conserving energy:

a) save money for the family

b) save natural resources

c) reduce pollution

d) make the United States more energy independent

e) make energy available for industry

Words To Know

wattage, killowatt (kwh), electric meter, energy conservation.

Related Activities

- How to read an electric or gas meter
- Thermostat setback
- Select a student to call the electric company to learn the rates charged per kwh. Determine the amount of money saved from the energy conserved during the week.

Resources

- HOUSEHOLD ENERGY, Individualized Science Instructional System, Ginn & Co., 1976.

Notes To Myself

STUDENT PAGE

METHOD

1. In Column 1, check all the appliances your family used last week.

2. In Column 3, estimate the number of hours your family used each appliance last week.

3. In Column 4, calculate the kilowatt house (kwh) or the energy used by each appliance in a week. Use the formula below:

$$\frac{\text{WATTAGE}}{1000} \times \text{HOURS USED} = \text{KWH}$$

APPLIANCE	COL. 1 (✓)	COL. 2 WATTAGE	COL. 3 HOURS USED	COL. 4 KWH USED
HOME HEATING UNIT		12,000		
OVEN (STOVE)		12,000		
CLOTHES DRYER		5,000		
WATER HEATER (QUICK)		4,500		
WATER HEATER (STANDARD)		2,500		
AIR CONDITIONER		1,500		
BROILER		1,500		
DEEP FAT FRYER		1,500		
PORTABLE HEATER		1,300		
DISHWASHER		1,200		
FRYING PAN		1,200		
TOASTER		1,200		
IRON		1,000		
COFFEE MAKER		900		
VACUUM CLEANER		650		
FROSTLESS REF/ FREEZER		600		
FOOD DISPOSAL		500		
HAIR DRYER		400		
T.V. (COLOR)		350		
T.V. (B & W)		250		
FLOOR POLISHER		300		
INFRARED HEAT LAMP		250		
WINDOW FAN		200		
CARVING KNIFE		100		

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STUDENT PAGE, CONT'D.

FOOD BLENDER		400		
STEREO		100		
SEWING MACHINE		75		
RADIO		70		
SHAVER		15		
TOOTHBRUSH		7		
CLOCK		2		

Curriculum Topic

THERMOSTAT SETBACK

Energy Topic

ENERGY ECONOMICS
ENERGY CONSERVATION

Grade Level(s) 7 - 12

Site School or home

Skills

- Reading a meter and recording data
- Simple mathematics

Credit

"Energy Conservation in the Home"
The University of Tennessee
Environmental Center and
College of Home Economics

Objective

At the completion of this activity you should be able to:

1. Demonstrate the effect thermostat setback has on energy consumption.

To The Teacher

This activity can be used for students who use electricity and/or natural gas to heat their homes.

Before You Begin

1. Refer to the activity "How to Read an Electric or Gas Meter" if students are unfamiliar with this skill.
2. Do this investigation when mechanical heating or cooling is certain to be needed.
3. Make certain no one adjusts the thermostat during the two weeks of the investigation.

Words To Know

Thermostat, residence, kilowatt-hour (kwh), consumption

Related Activities

- "How to Read an Electric or Gas Meter"
- "Electrical Appliance Cut-back"

Resources

- Contact your local public utility company for more information.

Notes To Myself

STUDENT PAGE

Now that you can read your meter, you can investigate the effects of thermostat setback on the energy consumption at your residence. During the cooling season, thermostats should be set up to 78°F to reduce the use of mechanical air conditioning and during the heating season, set down to 65°F. For additional savings, the thermostat can be set back to 60°F during the night. The effect of these thermostat setbacks will vary from residence to residence, but should be significant.

To test the impact of thermostat setback at your home, first determine the weekly consumption of energy prior to the setback. Read your gas, oil, or electric meter one week before the setback and read it a second time exactly seven days (to the hour) later.

For example:

First Reading	Second Reading
Meter Reading: 14276 kwh	Meter Reading: 15101 kwh
Date: 9/8/77	Date: 9/15/77
Time: 8:00 a.m.	Time: 8:00 a.m.

The energy consumed by the example home for the week was 925 kwh (15101 kwh - 14276 kwh = 925 kwh).

Immediately after the second reading set back the thermostat 5°F lower if heating and 5°F higher if cooling. Then take a third meter reading exactly seven days later.

For example:

<u>Third Reading</u>

Meter Reading: 15897 kwh
Date: 9/22/77
Time: 8:00 a.m.

The energy consumed by the example home for the week with the setback is 796 kwh. To determine the possible savings, find the difference between the first week's consumption and the setback week's consumption.

Using the example home:

<u>925 kwh</u> - <u>796 kwh</u> = <u>129 kwh</u>

Now try the test at your residence.

First Reading		Second Reading		Third Reading	
Meter Reading:	_____	Meter Reading:	_____	Meter Reading:	_____
Date:	_____	Date:	_____	Date:	_____
Time:	_____	Time:	_____	Time:	_____

First week's consumption:

_______________ - _______________ = _____________

meter reading 2 — meter reading 1 — consumption

Setback week's consumption:

_______________ - _______________ = _____________

meter reading 3 — meter reading 2 — consumption

Savings

_________________________ - ___________________________ = _______

First week's consumption — Setback week's consumption — savings

QUESTIONS

1. Why is it better to use a week's consumption for comparison rather than a day or an hour?

2. What could be possible reasons for finding no savings or possibly an increase in consumption during the week with the setback?

3. How much money could be saved in a year if you could realize the savings you found (if you found one) during the setback week?

Curriculum Topic

ENERGY CHECKLIST FOR THE HOME

Energy Topic

ENERGY CONSERVATION

Grade Level(s) 7 - 8

Site Home and Classroom

Skills

- Locating and obtaining information.

Credit

Earthwatch
Environmental Education Center
A program of Area Cooperative Educational Services (ACES)

Objective

At the end of this activity the students will be able to:

1. generalize from the data their own habits in the use of energy,
2. identify areas where energy savings could be accomplished.

To The Teacher

This activity is to identify, for students, areas of their own lifestyles where energy-conservation practices could be instituted. It does not quantify energy-loss nor estimate the cost of alleviating the problem, but rather, gives students an overall picture of their energy-consumption practices. One way to use this activity is to assign it as homework during and energy study unit.

1. Energy from the sun: How is your house insulated/heated?
2. The 2nd law of thermodynamics: Energy wasted in the home is energy and money permanently lost.
3. Sea and Land breezes: Heating and cooling the home.

Americans use more energy per person than any other people in the world. We have only 6 percent of the world's population, but we use about one-third of all the energy consumed on this globe. Our total national energy cost in 1975 amounted to about $170 billion, and each year this cost is steadily rising.

Where does all this energy go?

Our industry takes about 36 percent. Our commerce uses about 11 percent for enterprises including stores, offices, schools and hospitals. Our residences take about 26 percent. And transportation accounts for another 29 percent or so.

Most of the energy we use in the United States comes from petroleum (crude oil). Because domestic production falls short of our needs, we have to import almost half of it, at a cost of $45 billion a year (at 1977 rates).

Expert estimates of our known and potential domestic reserves vary, but most likely we have somewhere between a 25 to 30 year supply of oil, if we keep our energy-use growth rate at about 2 percent per year.

However, if we continue using energy as we have become accustomed to, we could run out of domestic oil supplies in the year 2007, and we may run out of natural gas even sooner. The severe winter of 1976-1977 painfully dramatized the natural gas situation with its complex supply and economic problems.

The overall enrgy situation in the United States is not rosy: Energy demand keeps rising; energy prices keep going up; the availability and future costs of supplies remains uncertain.

What can we do about it?

Without personal hardship, we could easily cut our energy use by an estimated 30 percent or more-- saving energy for our country and money for ourselves.

Conserve energy. This will help us extend our supplies and reduce our import burdens until we develop new energy technologies and resources.

The energy we use for our homes and automobiles -- gas, oil, electricity -- draws on all of our energy resources. Cutting back on these uses is the simplest, most effective way to make our resources last longer. And each individual conservation effort, multiplied by millions, can serve as an "energy bank" -- a supply that can be used to help balance our energy accounts. (From "Tips for Energy Savers")

Before You Begin

1. Hand out the "Residential Energy Checklist" as a homework assignment.

2. On the next day, tabulate the class res s and discuss. Students can make a list of key areas of energy waste and compare it to corresponding lists of energy-saving procedures.

Words To Know

energy conservation, insulation

Resources

- Energy Conservation in the Home, U.S. Department of Energy, "Tips for Energy Savers", Federal Energy Administration 77/212, August, 1977.

Notes To Myself

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STUDENT PAGE

RESIDENTIAL ENERGY CHECKLIST

House: The Shell	yes	no
1. Are plants properly located around the house to provide a break against wind and shade against unwanted sun?		
2. Are drapes and furniture located so they do not obstruct heating, air-conditioning or ventilation?		
3. Are draperies insulated?		
4. Do draperies fit snugly around the window?		
5. Are exterior house doors closed quickly after use?		
6. Are lights and appliances turned off after use?		
7. Do you have storm windows and doors?		
8. Are all doors and windows properly caulked and weatherstripped?		
9. Are draperies and shades closed at night and on cloudy, windy days during the heating season?		
10. Are draperies opened to admit sunlight on sunny days in the heating season?		
11. Are draperies and shades closed on sunny days during the cooling season?		
12. Is the attic ventilated?		
13. Is the attic insulated to 6-8"?		
14. Are the walls insulated?		
15. Do floors exposed to unheated or cooled air have from 2-3½" of insulation?		
16. Is the fireplace damper closed when not in use?		
17. Is the den, gameroom or family room oriented to the south?		
18. Is the house shaded from the western sun?		

	yes	no
19. Does your home have window area equivalent to 10% or less of its square footage?		
20. Is your home sealed from drafts? Is it free from cracks and holes?		
21. Does your home have fluorescent lighting where appropriate?		
22. Does your home have wall-to-wall carpeting?		
23. Do all windows have drapery, shades, blinds, shutters or other covering?		
Environmental Control		
24. Are ducts, radiators or air-conditioners closed off in unused rooms or closets?		
25. Are hot water pipes insulated in unheated and uncooled spaces?		
26. Are air ducts insulated in unheated and uncooled spaces?		
27. Is the thermostat set at 68°F or below during the heating season?		
28. Is the thermostat set at 78°F or above during the cooling season?		
29. Are heating and cooling filters clean?		
30. Is the thermostat turned back at night?		
31. Are windows and doors tightly closed while mechanically heating or cooling?		
32. Is an attic fan used in the summer?		
33. Do thermostats indicate correct temperature settings?		
34. Is an outside air-conditioning unit located on the shady (north) side of the house?		
35. Is the water heater insulated?		
36. Is the water heater temperature setting at 140°F or less?		

	yes	no
37. Is the air-conditioning unit properly sized for your needs?		
38. Do you have a heat pump?		
39. Do you use natural ventilation as much as possible?		
40. Are radiators and other heating or cooling equipment clean and dust free?		
41. Is the water heater located in a heated space?		
Housing Selection		
42. If you live in an apartment, is it an "inside" apartment?		
43. If you live in a mobile home, does it have a "skirt"?		
44. If you live in an older home, have its plumbing, wiring, insulation and chimneys been checked by "experts"?		
Food		
45. Is the frost on the refrigerator and freezer less than ¼ inch thick?		
46. Is the refrigerator set at 40°F?		
47. Is the freezer set at 10°F?		
48. Are gaskets around refrigerators and freezers tight?		
49. Is the oven used to bake more than one food at a time?		
50. Is the gasket around ovens tight?		
51. Are frozen foods thawed completely before cooking?		
52. Is the cooking range turned off immediately after use?		

	yes	no
53. Are dishes washed only when there is a full load?		
54. Are dishes allowed to air dry?		
55. Are appliances clean and dust free (particularly cooling coils)?		
56. Is the oven never used as a dryer or heater?		
57. Are flat bottom pots and pans used?		
58. Is a timer used to avoid over-cooking?		
59. Are pots covered during cooking?		
60. Is as little water used as possible during cooking?		
61. Is the heated dry cycle on the dishwasher not used?		
<u>Clothing</u>		
62. Does your family dress warmer in cool weather to avoid mechanical heating?		
63. Does your family dress cooler in warm weather to avoid mechanical cooling?		
64. Are clothes washed only when there is a full load?		
65. When washing is cold or warm water used when possible?		
66. Are clothes line dried when possible?		
67. Are most of your family's clothes wash-and-wear, permanent press to avoid dry cleaning and ironing?		
68. Are clothes always rinsed with cold water?		
69. Is the washer located near the water heater?		
70. Is the dryer lint screen cleaned after each load?		

Personal Care	yes	no
71. Do the members of your family take short showers or use only small amounts of water for tub baths?		
72. Are all water faucets repaired and not leaking?		
73. For washing, shaving or make-up is the lavatory filled rather than allowing water to run?		
Entertainment		
74. Are entertainment devices turned off when not in use?		
75. Do members of your family try to entertain themselves rather than rely on devices?		

--If you answered with 65 or more yes's, you are truly an energy conserver and will make a good conservation advocate.

--If you answered with 55 to 65 yes's, you are energy conscious but lack will-power or drive.

--If you answered with 45 to 54 yes's, you are wasting energy but with minor changes could make a conserver.

--If you answered with 35 to 44 yes's, you are an energy waster and should make an all-out effort to reform!

--If you answered with less than 35 yes's, you are making an effort to waste energy and should consider the long range and immediate effects!!

Curriculum Topic

THE EFFECTS OF INSULATION
ON HOME HEATING COSTS

Energy Topic

ENERGY CONSERVATION
ENERGY AND ECONOMICS

Grade Level(s) 10 - 12

Site School and Home

Skills

- How to collect and organize data
- How to graph data
- How to read tables

Credit

U.S. Department of Energy
Solar Energy Education Project

Objective

At the completion of this activity you should be able to:

1. Determine the total annual heat loss from a home.
2. Calculate the amount of fuel used and determine the cost to heat the house per year.
3. Compare the cost of heating a home when different thicknessess of insulation are used.

To The Teacher

Detailed backgound information is given in the student section of this activity. Additional information is available in the references.

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Before You Begin

1. Graph paper and a calculator are needed.

2. Heating degree days data for your area can be obtained from local heating fuel dealers.

3. Costs of insulation can be obtained from local home insulators or building supply stores.

4. Two or three days of 42 minute class periods are appropriate, depending on how far in-depth the teacher wishes to go with the questions. Some of the GOING FURTHER activities would require using additional time.

5. This activity could be part of a unit on solar energy or part of any unit in a course which studies energy conservation.

6. Time spent on the activity could be reduced by assigning different groups of students to complete the data for different insulating conditions, and then allowing them to share their data. But each student should make his own graphs in order to see the various relationships for himself.

7. The topic if insulation offers a unique opportunity to infuse career education into the classroom, since it is a good example of the new kinds of career opportunities suddenly opening up in the energy-environment field. Insulation contracting has sprung up overnight in the face of energy cost increases. Insulation contractors and experts could be brought into the classroom to discuss their new lines of work, or students could go out into the community to interview them and observe their jobs. Power company consumer representatives could be brought in to discuss their jobs, as well as their companies; recommendations for home insulation.

This activity could be done as a student project or taken home.

Words To Know

British Thermal Unit (BTU),mean temperature-factor, degree day, infiltration, convection, conduction.

Related Activities

- This activity could be shortened by omitting some of the categories in Data Sheet 2. The category of 0" wall and 0" ceiling insulation should not be excluded since it dramatically indicates the large heating costs that result.

- An additional project could be assigned to evaluate a student's home, classroom or school building. (Refer to Project Retrotech under RESOURCES.)

- Using the costs of insulation for your area, determine how long it would take to pay back the cost of adding additional insulation through savings in oil heating bills. This can be done for any number of situations. For example:

  a. A house with 3" wall insulation and 3" ceiling insulation has 6" insulation added to the ceiling.
  b. A house with 3" wall insulation and 6" ceiling insulation has 6" insulation added to the ceiling.
  c. A house with 0" wall insulation and 3" ceiling insulation has 3" wall insulation added.

- You are constructing a new house with the same dimensions as the house in the activity with 6" insulation in the ceiling and want to use 2" x 6" wood rather than conventional 2" x 4" S to build your walls. This type of construction would allow you to put 6" insulation in the walls rather than 3" insulation. How long would it take to pay back the cost of the additional insulation in the walls through savings in oil heating bills? Remember to include the additional costs of 2" x 6" s vs. 2" x 4" s in your calculations. You can assume that on the average 2" x 4" x are 16" apart and 2" x 6" s are 24" apart.

- New types of insulation have been designed with an R value of roughly 38. These rigid materials can be used to make the walls and also provide support. If our typical house were constructed of this type of material, what would be its annual oil heating cost?

- Determine the annual heating costs for varying thicknesses of insulation if our typical home were heated by gas or electricity. Which type of fuel seems most economical? Consult power companies in your area to find the cost of gas or electricity. (See table in step 2.)

- Try using your own home as a model and determine its annual heating cost. Compare your computations to the actual heating bills. If you live in a two story home or a home with a basement, the values for heat loss will vary.

Resources

- HEATING DEGREE DAYS. Ray Falconer, (Atmospheric Sciences Research Center, State University of New York at Albany, Publication No. 432).

- OTHER HOMES AND GARBAGE: DESIGNS FOR SELF-SUFFICIENT LIVING. Jim Lackie, Gil Master, Harry Whitehouse and Lily Young, (Sierra Book Club, San Francisco) 1975.

- PROJECT RETROTECH HOME WEATHERIZATION MANUAL AND HOME WEATHERIZATION JOB BOOK. (Conservation Paper 28C) Federal Energy Administration, Washington, DC, 1976.

Notes To Myself

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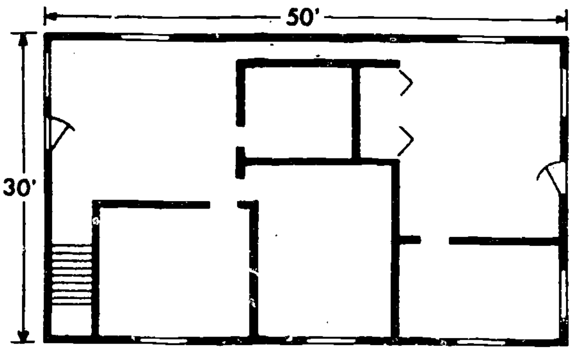
STUDENT PAGE

MATERIALS

- A calculator is most helpful.
- Graph paper.
- Heating degree days data for your areas. Contact your local weather station, local oil dealer, or your gas and electric company.



METHOD

You are to consider the house illustrated above.

The house is a one-floor ranch resting on an unheated concrete floor with a completely exposed perimeter. The two doors are each 3' x 7'. The eight double-paned windows are each 2' x 5'. The walls are eight feet high. In order to calculate the hourly loss of heat per degree Fahrenheit and eventually the annual cost of heat for this house, use the following steps and record the results in the appropriate tables and data sheets.

1. Calculate the area of windows, doors and walls. Use the following formulas and place your answers in the appropriate column of Table 1: Calculation of Area.

   a. Windows = Number of windows x length x width.
   b. Doors = Number of doors x length x width.
   c. Walls = Total wall area - door area - window area.
   d. Ceiling = Length x width.

Table I

Calculation of Area

	AREA (FT^2)
WINDOWS	________
DOORS	________
WALLS	________
CEILING	________

2. Computation of Total R values.

The resistance of a material to heat transmission is known as its thermal resistance, or R value. R values for various materials are given below in Table 2.

Table 2

R Values for Various Thicknesses of Blanket-Type Fiberglass Insulation and Other Building Materials

MATERIALS	R VALUE
Ceiling Material	1.7
3" Insulation	11.1
6" Insulation	22.2
12" Insulation	44.4
18" Insulation	66.6
Double Paned Windows	2.0
Exterior Door	2.0
Wall Materials	2.5

To find the Total R for a given building structure, the R values of the individual materials composing that structure must be given without insulation. Table 2 indicated the R value for ceiling materials to be 1.7 and for wall material to be 2.5. Therefore, a ceiling with 3 inches of insulation would have a Total R value of 1.7 + 11.1 (R for 3" insulation) or 12.8. A wall with the same insulation would have a Total R value of 2.5 + 11.1 or 13.6.

Using the R values in Table 2, calculate the total R value for each structure in Table 3.

Table 3

Total R and U Values

Structure	Total R Value					1/R = U Value
CEILING MATERIAL + NO INSULATION	1.7	+	0	=	____	____
CEILING MATERIAL + 3" INSULATION	1.7	+	11.1	=	12.8	____
CEILING MATERIAL + 6" INSULATION	____	+	____	=	____	____
CEILING MATERIAL + 12" INSULATION	____	+	____	=	____	____
CEILING MATERIAL + 18" INSULATION	____	+	____	=	____	____
WALL MATERIAL + NO INSULATION	2.5	+	____	=	____	____
WALL MATERIAL + 3" INSULATION	2.5	+	11.1	=	13.6	____
WALL MATERIAL + 6" INSULATION	____	+	____	=	____	____
DOUBLE PANED WINDOWS				=	2.0	.5
EXTERIOR DOOR				=	2.0	.5

3. Computation of U Values.

The reciprocal of R is the U value. This is the amount of heat transferred in one hour through one square foot of wall or ceiling for each degree Fahrenheit of temperature difference between the air on the warm side and the air on the cold side of the building.

U is expressed in BTU's/(hr.) (ft.^{2}) (^{o}F).

Using the formula U = 1/R, calculate the U value for each structure in Table 3. (U values may be rounded to the nearest tenth.)

4. Total Heat Loss per Hour x ^{o}F.

You can now calculate the total heat loss per hour ^{o}F of this house by using the formula:

Heat loss (q) = U x area

On Data Sheet 1, calculate the total heat loss in BTU's/hr. ^{o}F for the windows, doors, walls, and ceiling if the house had no insulation in either the walls or ceiling. Enter this calculation in the appropriate column of Data Sheet 2.

Now calculate the heat loss per hour ^{o}F for the other combinations of insulation given in Data Sheet 2. Use the remaining spaces in Data Sheet 1 for your calculations. Remember to enter this calculation in Data Sheet 2.

5. Floor

Due to the numerous computations necessary to compute the heat loss of an unheated concrete slab floor, it will be assumed to be 43 BTU/hr. ^{o}F.

6. Infiltration

A house will lose heat by infiltration, the process of heat losses by cold air coming in and warm air going out. The rate of infiltration for this house has been determined to be approximately 92 BTU/hr. ^{o}F. If you lived in a windy area, (top of mountain, etc.), the infiltration rate would be greater.

7. Completion of Data Sheet 2.

To show corrected heat loss- it is a good practice to add 10% to the total heat loss (BTU/hr. ^{o}F) to account for error. (For example, a total heat loss of 384 BTU/hr. ^{o}F + a 10% error of 38.4 = Corrected heat loss of 422.4 BTU/hr. ^{o}F.) Calculate the corrected heat loss for each category in Data Sheet 2 and enter the results in the appropriate column.

8. Heat Loss per Day ^{o}F.

Convert the total corrected heat loss per hour ^{o}F to heat loss per day ^{o}F by multiplying by 24. (For example, total heat loss of 422.4 BTU/hr. ^{o}F x 24 hours = 10,138 BTU/day ^{o}F.) Enter the results in the appropriate column on Data Sheet 2.

9. Total Heat Loss per Year.

This depends on the yearly total of heating degree days for your area. This information can be obtained from your teacher or from a local energy supplier. (i.e., fuel oil dealer, natural gas dealer).

Heating degree days accumulate only when the outside temperature drops below 65°F. It is implied that heat for a house is only required when the outside temperatures are below 65°F. Heating degree days can b determined by using the following method. Take the high and low temperature for a given day and determine the mean temperature.

High temperature	70°
Low temperature	+30°

$$2\overline{)100} = 50^{\circ}$$

Mean temperature is 50°F

Next subtract the mean temperature for that day from the base of 65°F.

$$\begin{array}{r} 65^{\circ} \\ -50^{\circ} \\ \hline \end{array}$$

15 heating degree days

This can be calculated for every day of the year.

Total BTU heat loss per year = BTU/day °F x total heating degree days for the year.

For example:

10,138 BTU/day °F x 7223 heating degree days = 73,226,774

Total heat loss of 1976 = 73,226,774 BTU

Now calculate the total heat loss per year for the various combinations. THIS SHOULD BE DONE FOR YOUR AREA AND FOR ANY OTHERS THAT YOU CHOOSE. PLACE YOUR DATA IN THE APPROPRIATE COLUMN ON DATA SHEET 2.

10. Gallons of Oil Consumed per Year.

The BTU equivalents for the most common fuels are given in the following chart.

145,000 BTU = 1 gallon oil
1,000 BTU = 1 cubic foot natural gas
3,412 BTU = 1 kilowatt hour of electricity

Calculate how many gallons of oil are needed to heat this house for a year for each combination of insulation on Data Sheet 2. Place your calculations in the appropriate column on Data Sheet 2.

11. Yearly Heating Costs.

Using the present price for oil, calculate the yearly cost of heating the house for each combination of insulation. Place these calculations in the appropriate column on Data Sheet 2.

> Oil price/gal. x gallons of oil consumed per year = yearly cost of heating.

12. Graphing the Data.

So far you have accumulated large amounts of data. By graphing these data, you can observe some relationships and trends. Graph the amount of ceiling insulation against the yearly heating cost for each thickness of wall insulation. The graph should consist of three lines: one line for 0" wall insulation, one for 3" wall insulation and one for 6" wall insulation.

QUESTIONS

1a. What would be the annual cost of heating this typical house when it has 3" insulation in the walls and 3" insulation in the ceiling?

b. If you added 3 more inches of insulation to the ceiling, how much money would you save annually in oil heating bills?

c. If you added 3 more inches to that, so that you now have 9" insulation in the ceiling, how much would you save in annual oil heating bills as opposed to having 6" insulation in the ceiling?

2. According to your graphs what would be the annual heating costs of the home with no insulation? With maximum insulation in walls and ceiling?

3. If you could only insulate <u>either</u> the ceiling <u>or</u> the walls with the same thickness of insulation (disregarding the cost of insulation); which would save you more money on your heating bill? Why?

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SAMPLE

DATA SHEET #1

AMOUNT OF INSULATION

CEILING ________ WALLS ________

COMPUTATION OF HEAT LOSS IN BTU/HR°F

(HEAT LOSS = AREA X U)

	AREA (FT^2) (TABLE #1)	X	U VALUE (1/R) (TABLE #3)	HEAT LOSS
WINDOWS				
DOORS				
WALLS				
CEILING				
FLOOR	X		X	43
INFILTRATION	X		X	92
			TOTAL:	

SAMPLE DATA SHEET #2

Inches of Insulation Wall	Inches of Insulation Ceiling	Total Heat Loss Rate in BTU/Hr °F (from Data Sheet #1)	Corrected Heat Loss (+ 10% Error)	Heat Loss Per Day °F (X 24 hours)	Total BTU Heat Loss Per Year (X total HDD)	Gallons of Oil Consumed Per Year (÷ by 145,000 BTU's/gallon)	Yearly Cost of Heating (X price/gal.)
0"	0"						
0"	3"						
0"	6"						
0"	12"						
0"	18"						
3"	0"						
3"	3"						
3"	6"						
3"	12"						
3"	18"						
6"	0"						
6"	3"						
6"	6"						
6"	12"						
6"	18"						

Curriculum Topic

PEOPLE WHO LIVE IN GLASS HOUSES SHOULDN'T...

Energy Topic

ENERGY CONSERVATION
ENERGY AND ECONOMICS

Grade Level(s) 7 - 12

Site School building or home

Skills

- Collecting and compiling data, interpreting data, measuring

Credit

Earthwatch
Environmental Education Center
Area Cooperative Educational Services (ACES)

Objective

At the completion of this activity students will be able to:

1. determine the percentage of square footage of window area to total wall area and total floor area in various rooms of school or home.

To The Teacher

Openings in a home (windows or doors) allow heat to escape in winter and enter in summer. Eight times as much heat will pass through one square foor of window area as will pass through one square foot of insulated wall area. Heat loss and gain through windows can be reduced by storm panels, weather stripping, insulating and shading devices, and wise placement. Double glazed windows with a southern placement may account for a net heat gain in winter months.

Before You Begin

1. Review with students the method for computing. Also review the method for changing a fraction into a percentage.

2. Divide class into teams of 2 - 3 students.

3. Distribute meter sticks, worksheets and directions.

4. Before they measure the windows, students will note whether windows have storms. Discuss ways to better insulate existing glassed areas to conserve more energy. Make a list of recommendations for improvements.

5. Teams will measure the classroom windows. Students will then compute the ratio of window area to floor and wall area. Convert to percentage.

6. When the percentage of square footage of window area to total wall area is computed, teams will repeat the procedure for other rooms in the school: cafeteria, library, other classrooms, laboratory, office, etc. and report back to the class. Record the information on a chart.

7. Using a compass outside determine the directional exposure of each room to prevailing weather north and northwest lose the most heat, southern exposures of glass gain more heat than lose.

8. Present the chart to the school principal with an explanation of whether the building conforms to the building code restrictions and guidelines for the amount of glassed area.

Words To Know

insulator, area, percent

Related Activities

- As a homework activity, have students compute ratio of wall area to window area in their homes.

Resources

- "Energy Conservation in the Home," University of Tennessee Environment Center and College of Home Economics, Knoxville, TN, 1977, p. 191.

Notes To Myself

STUDENT PAGE

MATERIALS

- 1 meter stick per group
- 1 compass per group

METHOD

1. Check windows and doors for storm weather stripping and air leakage. If problems exist, how would you improve them?

2. Measure glass areas with a meter stick for a room in your school.

3. Measure floor area and finally total wall area for the exterior wall.

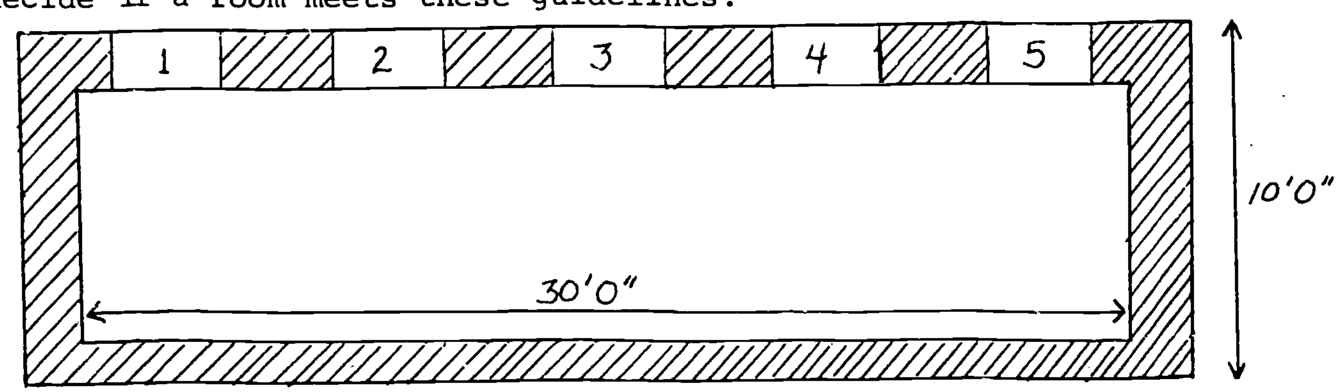
4. Compute a ratio of window to floor (method 1) and window to exterior wall (method 2).

5. Convert these figures to percentages.

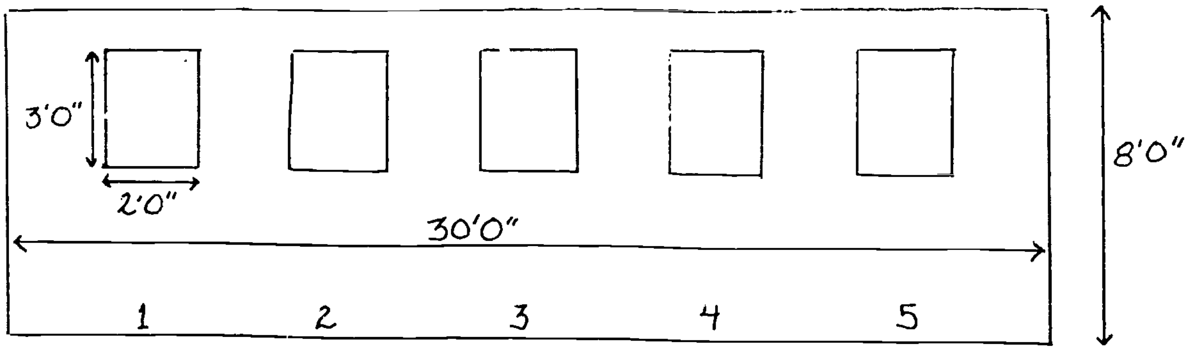
6. Repeat steps 1 - 5 for other rooms in your building and record the information on your chart.

7. As a group, go outside. With a compass determine the exposure (north, south, east or west) of the walls measured. Windows on north and northwest walls would account for greater amounts of heat loss since windows to the south gain heat from the sun.

Because glass is a much poorer insulator than walls, less glassed areas in a building mean greater possibility of conserving energy for cooling and heating. There are building code restrictions and guidelines for the amount of glassed area: 10% of the total area of the floor and less than 20% of the exterior wall area are generally accepted standards. We will use the following calculations to decide if a room meets these guidelines.



This is an elevated view of a room looking down at the floor: The area of the floor, then, is 10' x 30' = 300 square feet.



This is an exterior wall.

The total window area is 3' x 2' (each window) x 5 (number of windows) = 30 square feet.

Calculation 1:

Divide - $\frac{\text{total glassed area}}{\text{total floor area}}$ or $\frac{\text{30 sq. ft.}}{\text{300 sq. ft.}}$ x 100 = 10%

We find this room meets the standard of 10% of floor area. In the example, the total exterior wall area is

8' x 30' = 240 sq. ft.

Calculation 2:

Divide - $\frac{\text{total glassed area}}{\text{total exterior wall area}}$ or $\frac{\text{30 sq. ft.}}{\text{240 sq. ft.}}$ x 100 = 12.5%

Using either method, this room is within these guidelines. Now use these methods to see if your classroom meets the guidelines. Use the worksheet to record measurements.

School Building Check: Percentage Glassed Area

ROOM	METHOD 1: 10% of FLOOR AREA				METHOD 2: 20% of WALL AREA			
Exposure N, S, E, or W	Total sq. ft. floor area	Total sq. ft. glassed area	% glass	check if acceptable	Total wall area sq. ft.	Total glass	% glass	check

Curriculum Topic

ABCs OF BTU CONDITIONING

Energy Topic

ENERGY USES
ENERGY AND CONSERVATION

Grade Level(s) 7-8

Site Classroom

Skills

- Computing skills
- Ability to use and read measuring devices

Credit

Earthwatch
Environmental Education Center
A program of Area Cooperative Educational Services (ACES)

Objective

At the end of this activity the students will be able to:

1. compute the number of BTU's needed to cool a designated area.

To The Teacher

"Energy, though not easily defined, is not easily ignored. Man's senses respond to a variety of energy forms. The eyes respond to light energy. The ears detect sound energy. Other nerves indicate contact with thermal and electrical energy. These energy forms are interconnected and exchangeable; different forms of energy can be used for the same purpose; energy can be stored or transformed. But probably the most common and important characteristic of energy is its capacity for doing work.

"The British thermal unit (Btu) is the amount of heat energy required to raise the temperature of one pound of water one degree Fahrenheit. The Btu is commonly used by engineers to specify the total amount of energy used for some specific purpose; for example, an air conditioner may have a cooling capacity of 8,000 Btu's per hour. The Btu is also used to specify the energy content of primary fuels or energy resources; for example:

'Each gallon of gasoline has a heating value of about 136,000 Btu. (Heating value is the maximum amount of energy released when fuel combines with oxygen in a combustion process.) If an automobile gets ten miles per gallon of gasoline, then it takes about 13,600 Btu to drive the car each mile.'" (Weast, p. 81)

from Energy Conservation in the Home, U.S. Dept. of Energy

This activity will relate the concept of energy as the ability to do work to a typical energy task - the cooling of a room via air conditioning.

Before You Begin

1. Preparation: Be sure students understand the meaning of Btu (see To The Teacher) and EER. The EER, Energy Efficiency Ratio, is obtained by measuring in Btu's the capacity of an energy-user (e.g. air conditioner) and then dividing this number by the number of watts the unit uses. (e.g. 4000 Btu ÷ 780 watts = EER of 5.1) The higher the EER, the more efficient the unit. Maximum efficiency of an air conditioner is approximately 11.5 to a low of 5.4. High efficiency units must have an EER of at least 7.5. An 11.5 EER unit is more than 2 times as efficient as a 5.4 EER unit and uses less than ½ the electrical energy.

2. One class period will be needed to do this activity.

Words To Know

BTU, EER, watts, volts, amperage, conduction, combustion

Related Activities

- Determine if your home air conditioners are adequate for the cooling requirements of the rooms.

Resources

- Consumer Reports 1978, pp. 279-286.

- Energy Conservation in the Home, EDM 1028, U.S. Dept. of Energy, October 1977, Technical Information Center, P.O. Box 62, Oak Ridge TN 37830

Notes To Myself

STUDENT PAGE

MATERIALS

- Tape measure or yardstick
- Step ladder (optional)

METHOD

- You will be taking measurements of doors, windows, floor space and ceiling space for an area you wish to cool using an air conditioner. These measurements will help you determine the number of Btu's per hour which are admitted to the room. This figure will indicate the cooling capacity of an air conditioner necessary to adequately cool the room.

COOLING LOAD ESTIMATE FORM

1. Heat gained from doors and arches.
   A. Multiply by 300 the width of a door or arch between rooms to be cooled. Do this for each door or arch in the room. If the rooms are connected by a door or an arch greater than 5' wide, treat the two rooms as one. Record your answer on your record sheet.

2. Sun through windows.
   Multiply window area (ft^2) for each exposure using the factors listed below. Hint: Use the factor "inside shades" if the window has blinds/shades. If a window has an awning, use the factor listed "awning". Factors are for single pane glass. If windows are double paned or storm windowed, multiply each factor by .8.

If the window faces:	multiply ft^2 of window by	NO SHADES	INSIDE SHADES/DRAPES	AWNING	ANSWER
NE		60	25	20	______
E		80	40	25	______
SE		75	30	20	______
S		75	35	20	______
SW		110	45	30	______
W		150	65	45	______
NW		120	50	35	______
N		0	0	0	______

On your Student Record Sheet record only the largest answer you obtain. Do not total the answers.

3. Conduction through windows.
   Calculate the total area (ft^2) of all windo[illegible]. Multiply this total by 14, if [illegible]ndows are single paned [illegible] other types of windows, mult[illegible] total area of win[illegible] by 7.

4. Heat gained through walls.
Calculate the area of the wall by multiplying the length of the wall by its height and subtracting from that total the square footage of any windows or doors in that wall. If the wall is insulated or made of masonry, multiply the total area (ft^2) by the appropriate numbers from Column B. If the wall is not insulated, multiply the total area (ft^2) by the number in Column A. Total your results for all walls and record on answer sheet.

	(No Insulation) A	(Insulation) B
Walls of a Northern Exposure	30	20
Walls of all other Exposures	60	30

5. Heat gained through the ceiling.
Calculate the area (ft^2) of the ceiling and multiply this figure by:

19 if uninsulated with no space above
8 if insulated with no space above
12 if uninsulated with attic space above
5 if insulated with attic space above
3 if space above is occcupied

Record answer.

6. Heat gained through the floor.
Calculate the area (ft^2) of the floor. Multiply this number by 3. Record your answer.

7. Now add together answers 1-6 and record.

8. Multiply the answer in #7 by a climate correction factor. For our area of the U.S., New England, this number is 1.0.

9. People.
Multiply the number of people who use the cooled space by 600 and add this number to the total in #8.

10. The total number in #10 is the number of Btu's of heat admitted into the room per hour. The Btu cooling capacity of an air conditioner should come within 10% of the total Btu's of heat admitted into the room.

Check the Btu cooling cpacity of the air conditioner in the room you are measuring. You may need the instruction manual that comes with the air conditioner.

RECORD SHEET

1) Heat gained from doors and arches ____________________

2) Sun through windows ____________________

3) Conduction through windows ____________________

4) Heat gained through walls ____________________

5) Heat gained through ceiling ____________________

6) Heat gained through the floor ____________________

7) Total of numbers 1 - 6 ____________________

8) Climate correction factor (1.0) x total ____________________

9) Number of people x 600 ____________________

10) Total of #8 and #9 ____________________

Your answer is the number of Btu's of heat admitted to the room per hour.

60

Curriculum Topic

TRANSPORTATION PROBLEMS
THE AUTOMOBILE

Grade Level(s) 7 - 9

Site Classroom

Skills

- Simple mathematics

Energy Topic

ENERGY USES
ENERGY ECONOMICS
ENERGY CONSERVATION

Credit

U.S. Department of Energy
Your Energy World

Objective

At the completion of this activity you should be able to:

1. Calculate passenger miles per gallon for various vehicles carrying different loads.

2. Explain the difference between miles per gallon (mpg) and passenger miles per gallon (pmpg).

3. Discover some of the advantages of urban mass transportation systems and predict some trends for these systems and the single-passenger automobile.

To The Teacher

Transportation, the conveying of someone or something from one place to another, is now recognized as an enormous drain on the world's energy resources. Yet we cannot do without it. Throughout history, animals have trod and wheels have turned from horse to horsepower, from wagon to automobile. This evolution has been taken for granted because most of us considered the supply of inexpensive fossil fuel energy limitless.

Still, there is a limit to this energy supply, and we must find ways to conserve it. Because transportation is an "energy eater," strategies to encourage conservation in the transportation sector are especially important. The key to success is cooperation and careful planning. A world on the move has to know where it's going.

Transportation patterns throughout the world have changed dramatically during the past 200 years since the first steam engine was developed by James Watt in 1776. From foot power and horse and other animal power we have moved to energy-intensive two-ton automobiles, jet airplanes, even space vehicles. Little more than a hundred years ago, we depended entirely on human and animal energy, wood, and coal to move people and goods from one place to another. However, two events that happened within two years of each other changed the course of the world.

In 1859, the first oil well was put down in Pennsylvania and in 1860, Etienne Lenoir of France produced the first practical internal combustion engine. By the early years of the twentieth century, trains, automobiles, and airplanes were powered by petroleum.

Today, the transportation sector accounts for one-quarter of the total U.S. energy consumption and 60 percent of the total U.S. petroleum consumption. These are direct costs only for gasoline, diesel and jet fuel, and motor oil. If all the indirect costs--which include vehicle manufacturing, fuel refining, road building, extraction of metals and other raw materials--were added, the total U.S. energy consumption for transportation would be much greater than 25 percent.

For the last decade it has been increasingly easier to get from one place to another. One result is sprawling suburbs with millions of commuters pouring in and out of our major cities every day. Traffic problems and insufficient parking spaces plague city governments while increasing fuel costs plague the commuter. This activity is designed to make students aware of these problems and to help them make intelligent choices for their future. This activity may be concluded by discussing possible solutions to our energy consumption and urban transportation problems.

Before You Begin

1. Introduce a familiar topic--'Your family car'. Discuss pros and cons of different models of cars.

2. Suppose you could buy any new car or van you like. Money is no object. What kind would you pick? Keep one thing in mind, however. After you "buy" your dream car, you have to be able to pay for the gas, oil, and all repairs.

3. Let the student now take on the role as a commuter to school. Have each student choose his or her dream car. (Each should stick to their choice) Using the table provided for M.P.G. current gas prices and the number of miles used in traveling to school and back for each student calculate an annual cost.

4. Conclude this part of the lesson by suggesting the following question: "Can you afford your dream car?" Many students will be reluctant to give up their dream. Use this opportunity to introduce students to a consideration of alternate transportation systems. Should we begin to think of a car as transportation rather than a "dream machine?" Why are there so few mass transportation systems in American cities? What are some advantages in using buses, commuter trains, and airplanes? How might more automobiles cause more city problems?

5. Perhaps some families have already made conscious efforts to conserve. Ask for this information and discuss these alternatives as a class.

Answer the questions at the end and evaluate these answers and their relative importance to our changing society.

Words To Know

MPG (miles per gallon), commuter district, mass transit.

Related Activities

If your town has a bus system, contact the company and find out how many people can ride on one bus at one time, the kind of energy used to power the buses (gasoline, diesel fuel, electricity), and how many miles per gallon the gasoline-powered buses get.

Assuming that the average car gets 20 miles per gallon and the average automobile trip is 5 miles, figure out how much energy would be saved if the bus were filled to capacity and individual cars were not used for the five-mile trip. Suppose you find that the average bus holds 40 people and gets 5 miles per gallon; figure the problem this way:

car: $\frac{5 \text{ mi.}}{20 \text{ mpg}} \times 40$ trips = 10 gallons used

bus: $\frac{5 \text{ mi.}}{5 \text{ mpg}} \times 1$ trip = 1 gallon used

Nine gallons of gasoline are saved

STUDENT PAGE

Motor vehicles use about three-fourths of all the transportation energy. There are 100 million automobiles in the U.S. and more licensed drivers than there are registered voters. Statistically, two new cars are produced for every American baby born each day.

What features on an auto are the most important to you? Choose your "dream machine" taking into account style, performance, safety, reliability, economy. Which feature is most important to you?

1. Rate these categories in order from 1 - 10:

____ Good-looking paint job

____ Sporty lines

____ Whitewalls

____ Air conditioning

____ Good gas mileage

____ Powerful engine

____ Convertible

____ Big size

____ Standard four-speed transmission

____ Designer interiors (customized vans, denim upholstery, Pucci, etc.)

2. Choose your dream car from list on next page. Using the numbers for M.P.G., figure the number of miles you might travel in a year, to school, errands and dates and calculate your annual costs.

Example:
Suppose your car gets 20 MPG. Divide the number of miles traveled -- 250 divided by 20. This result will be the number of gallons used. Then multiply that figure by the current price of gasoline (250 divided by 20 multiplied by current price) What will your "dream" car gasoline costs be?

QUESTIONS

1. Henry Ford did not make the first automobile. What was the important first that he did do? What contribution did he make to the American auto industry?

2. How did the Model T change the kinds of entertainment people once enjoyed in small towns?

3. How did school change with the advent of better vehicles and roads?

4. What advantages did larger towns offer over small villages and towns?

5. How did the automobile have advantages over train travel?

6. How did the automobile make more leisure time available?

7. It has been said that the automobile has made people less dependent on each other. How would you explain this statement?

YOUR DREAM MACHINE
Student Activity Sheet

Model	Manufacturer	MPG
Chevette	GM-Chevrolet	36
Civic CVCC	Honda	44
Corolla Sedan	Toyota	32
Datsun B-210	Nissan	42
Datsun 200SX	Nissan	26
Accord CVCC	Honda	42
Celica GT	Toyota	26
Rabbit	Volkswagen	34
Fiat 128	Fiat	27
VW Station Wagon	Volkswagen	28
Opel (Isuzu)	Isuzu	27
Vega	GM-Chevrolet	28
Dodge Colt	Mitsubishi	35
Pinto	Ford	30
Mazda GLC	Toyo Kogyo	38
Mustang II	Ford	26
Datsun 280Z	Nissan	21
Volvo 244	Volvo	22
Gremlin	American Motors	23
Maverick	Ford	24
Volare	Chrysler-Plymouth	20
Nova	GM-Chevrolet	22
LTD II	Ford	17
GTO	GM-Pontiac	17
Trans Am	GM-Pontiac	17
Matador	American Motors	15
Cutlass Supreme	GM-Oldsmobile	18
Cougar	Ford	16
Ford	Ford	15
Buick Electra 225	GM-Buick	18
Plymouth	Chrysler-Plymouth	15
Silver Shadow	Rolls Royce	12
Chrysler	Chrysler-Plymouth	13
Bonneville	GM-Pontiac	17
Eldorado	GM-Cadillac	14
Buick Wagon	GM-Buick	18
Ford Wagon	Ford	13
Chrysler Wagon	Chrysler-Plymouth	12
Continental Mark V	Ford	13
Toronado	GM-Oldsmobile	15
Grand Prix	GM-Pontiac	17
Thunderbird	Ford	17
Mercedes 280 SE	Dailler-Benz	16
Seville	GM-Cadillac	16
Chevy Van V-8	GM-Chevrolet	18
Dodge Van V-8	Chrysler-Dodge	16
Ford Van V-8	Ford	16
VW Bus	Volkswagen	23

*January 1977 Gas Mileage from EPA City/Highway Test Cycle.
Source: "1977 Gas Mileage Guide for New Car Buyers," U.S. Environmental Protect[illegible] Agency, January 1977 (Second Edition) Fuel Economy, Pueblo, Colorado 81009 -- Single Copies; Fuel Economy, FEA, DPM Room 6500, Washington, D.C. 20461 -- Bulk Copies.

Curriculum Topic

REPORTER ON THE STREET CORNER

Energy Topic

ENERGY USES
ENERGY ECONOMICS
ENERGY CONSERVATION

Grade Level(s) 7 - 9

Site School, home, town

Skills

- Writing
- Conducting an interview

Credit

U.S. Department of Energy
Your Energy World

Objective

Upon completion of this activity you should be able to:

1. Improve reporting and observational skills while performing an activity on transportation and energy.

2. Discover energy waste and application of conservation in your community.

To The Teacher

This activity requires students, in the role of reporters, to research information on energy use in their communities, to interview family and friends, and to write a "newspaper" article based on the facts they have gathered. The master itself is a survey form used for gathering the data.

Before You Begin

Divide the students into small groups, and arrange to have an adult leader accompany each group on a "field trip" into the neighborhood adjacent to the school. Each group should find a busy corner and observe traffic there for 10 minutes. Have the students count how many big 4-door cars pass, how many small ones, how many new cars, how many cars with only one person and how many buses and trucks. Designate some students to take note of the approximate number of passengers on the buses and the kinds of goods the trucks carry. Another student could count screeching tires and rough stops or starts. If an actual adult-accompanied field trip is impractical, assign this activity to be done with a parent after school. If your school is located on a busy street corner, you may be able to do the survey from the schoolyard or a window.

Students will also interview three drivers of both large and small cars. They will first identify the type of car by "large" or "small". They will ask why the drivers purchased the kinds of cars they did, how many miles they drive each week, and how many miles per gallon of gasoline their cars get.

Finally, the students will ask all drivers if they believe there really is an energy shortage in this country. From this part of the activity, students will learn first-hand how attitudes may vary and how difficult it may be to get nationwide agreement about the energy situation.

When the students return to the classroom, have them share their information. Discuss community transportation characteristics and consider their impact on energy use and conservation. What do people like and dislike about both large and small cars? Which are more energy-efficient? What is the average number of miles people in your community drive each week? How might drivers cut down number of miles driven each week? Do most people in your community think there is an energy shortage? If they do not, discuss with students why they think this is so.

Armed with their data, your students can then take their survey forms home and ask their parents to guess what the results were in every survey category. Comparing parent estimates with actual figures can be both a learning and motivating experience for those at home. The survey can also serve as a convenient device for doing further "research" informally when the family is riding around town in the car, at a shopping center, or on the highway. The driving tips on the survey can also function as reminders for the family to conserve gasoline and save wear and tear on engine and tires.

As a final step in this activity, students can write an article based on their field trip experience for a classroom energy newspaper or booklet.

Related Activities

Have some students write about their solutions to some of the energy problems they may have discovered.

REPORTER-ON-THE-STREET CORNER

1. SURVEY:

DIRECTIONS: Either with a group from your class or with a parent after school, you are going to observe traffic "where it's happening." Take this form along, spend 10 minutes at a busy corner, and count the items and events on this sheet. Later, you will put your figures together with those of others in your class to determine some action you can take. Use a checkmark (✓) for each of the following you see in 10 minutes.

HOW MANY:

large cars with 4 or more doors: ____________________

small "compact" cars: ____________________

cars less than 2 years old: ____________________

"driver only" cars: ____________________

buses: ____________________

trucks: ____________________

2. INTERVIEW:

DIRECTIONS: Interview three people you know who own cars. First, describe the car as *large* (8-cylinder, 4-door, van or truck) or *small* (6-cylinder, compact or sub-compact.) Then ask them their reasons for purchasing the kind of car they did, how many miles a week they drive, and how many miles per gallon of gasoline they get. As a final question, ask them if they believe there is in fact an energy shortage in this country.

	TYPE OF CAR	WHY THAT SIZE PURCHASED?	MILES PER WEEK	MILES PER GALLON
Owner 1 Energy shortage? ☐ yes ☐ no				
Owner 2 Energy shortage? ☐ yes ☐ no				
Owner 3 Energy shortage? ☐ yes ☐ no				

DRIVING TIPS:

1. Observe the 55 mph speed limit.
2. Avoid sudden starts and sudden stops.
3. Follow a program of regular car maintenance: oil changes, tune-ups, and so forth.
4. Use your air-conditioning sparingly.
5. Avoid idling the motor for long periods of time.
6. Form car pools if possible; bicycle and walk.
7. Use public transportation for commuting.
8. Purchase energy-efficient cars.

Curriculum Topic

THE GREAT ENERGY DEBATE
BLACK GOLD

Energy Topic

ENERGY AND ENVIRONMENT
ENERGY AND ECONOMICS

Grade Level(s) 7 - 12

Site Classroom

Skills

- Library research
- Speaking before a group
- Group decision making

Credit

U.S. Department of Energy
Award Winning Energy Education Activities

Objective

At the completion of this activity the student should be able to:

1. Become proficient in research and decision making processes through group presentations and involvement using role playing.

To The Teacher

Modification of existing teaching materials in any subject can allow for exposure of basic energy information. Whether the unit under consideration deals specifically with an energy problem, or uses energy facts as a vehicle for teaching other material, the significance of the information will usually be obvious. Students are generally aware of the energy crisis, and any unit which involves all class members can provide many teachable moments.

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Before You Begin

1. In developing a unit on "The Ocean in Danger," I used a role-playing activity to dramatize the problem of securing new oil supplies. Students considered the growth and variety of oil related products, the rising costs of these products, and the location and richness of known oil reserves. They also considered whether other resources could be substituted for oil products, and how some costs could be lowered. They debated ways to reduce their use of oil. Students used the newspapers as a resource and found much information in the publications of Shell and Exxon Oil Companies. Reprints from the Social Issues Resources series and written informational packets from the Environmental Protection Agency and Energy Offices in many states were other valuable supplementary resource outlets.

2. The games could easily take two weeks of class time if it is preceeded by in-group discussions and individual to group research. The class might spend several days researching and discussing the effects of oil spills and performing experiments in removing oil from water. However, the duration of the active participation in the role-playing activity requires only three days.

3. Becoming part of a decision-making process can pep up a class atmosphere. In this game, the players become aware of the gentle and not-so-gentle means of persuasion that come into play when such things as politics, personal concerns, and environmental preferences become enjoined. The Coastal Problems Committee is called to consider the Petro Oil Company's request to drill for oil on the continental shelf. Company representatives come to the meeting prepared to offer alternatives to drilling, including the offer to construct onshore refineries and deepwater ports to serve super-tankers.

4. Consultants in energy and marine scientists testify and offer opinions in opposition to the Oil Company. After hearing the questioning of all witnesses, the Committee must make a decision to 1) allow the oil company to begin its search for oil, or 2) permit super-tankers to bring overseas' oil to onshore refineries, or 3) seek other sources of energy and deny requests.

5. Students with leadership qualities will indoubtedly claim the six witnesses' roles. Other class members take the roles of Committee members, but do not have specific roles assigned. In reaching a decision, students become interested in a common problem and see the need for evaluating all aspects of the issue at hand. They take from the simulation the idea of establishing priorities, which is a valuable step in their becoming active, informed citizens in the future.

Words To Know

environmental impact, refinery, offshore drilling, continental shelf

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Resources

- Rosanne Fortner, Hidden Valley Intermediate School, Roanoke, VA.

Notes To Myself

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Curriculum Topic

SAVE ENERGY: RECYCLE

Energy Topic

ENERGY CONSERVATION
ENERGY ECONOMICS

Grade Level(s) 7 - 8

Site Classroom

Skills

- Information gathering

Credit

Ecology Action Pack
MacDonald's Corporation
Oakbrook, Illinois

Objective

At the completion of this activity students will be able to:

1. Describe the method by which paper is recycled.
2. Understand the importance of recycling to energy conservation.

To The Teacher

Recycling is the reuse of partially-used, discarded materials. By recycling, resources are used over and over again in a manner similar to the cycle of natural elements such as carbon, nitrogen and oxygen. Reuse of matter is in contrast to flow of material from earth to home to garbage such as our present production system requires.

Recycling is important for two reasons:

1. America is running out of the raw materials required to make products. Fuel , timber and mineral supplies are not without limits.
2. Non or semi-disposable products are not recycled, they remain as useless waste. We are then faced with the increasingly

difficult problem of disposal.

In the recycling of paper, the first step is the collection of waste paper from the homes, businesses, or industrial sites. Next, the paper is separated according to "grades": newsprint, stationery, magazines, cartons and cardboard. Each grade is recycled separately to avoid contamination with other grades. When sorted, the paper is "de-inked" a step which removes coatings, clays, inks and binders. The cleansed paper is put into a huge vat, the hydropulper, where it is stirred and mixed with water and acids. The paper is now pulp: tiny wood fibers suspended in water. A pipe in the bottom of the hydropulper drains the pulp and pumps it onto a screen which vibrates, pressing the pulp into a flat mass. Heated drums then squeeze dry the pulp into new paper. Your students will use a simplified technique to recycle their own paper.

Before You Begin

1. Materials: For each group of students: an old newspaper, 1 qt. mixing bowl, egg beater, wood block about 2" x 3" (cut from a 2 x 4), a piece of window screen 4" x 4", a plastic sandwich bag, wallpaper paste or cornstarch, water, table spoon, copy of Directions for Students.

2. Before students begin the activity, you might want to discuss with them the importance of recycling and explain briefly how paper is recycled commercially. Also you may want to explain the pulp industry and the paper-making process from tree to newsstand.

3. Divide the students into lab groups of 2 or 3 students.

4. Distribute materials and supervise lab activity. (If class period is short, you may ask students to do Step 1 as preparation on the day before the activity, allowing paper to soak overnight.)

Words To Know

Recycle, pulp

Related Activities

- Assign students to investigate for sites in their areas where paper is collected for recycling.

Resources

"TEACHING ACTIVITIES IN ENVIRONMENTAL EDUCATION", ed. J.H. Wheatley & H.L. Coon, Vol. II, The Eric Center for Science, Mathematics, and Environmental Education Information, p. 86, EEC #60.3

THE ENVIRONMENTAL HANDBOOK, ed. Garret de Bell, Ballantine Books, 1970, pp. 214-215.

The U.S. Department of Agriculture may have some useful bulletins for added information.

The St. Regis Paper Company also provides many interesting and well-illustrated wall charts on the subject of forest products and in manufacturing paper.

Notes To Myself

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STUDENT PAGE

MATERIALS

- 1 egg beater or electric mixer
- 1 mixing bowl
- 1 wood block
- 1 piece of window screen
- 1 plastic sandwich bag
- 1 table spoon
- Cornstarch or wall paper paste will be provided by teacher

METHOD

Follow these steps to recycle your own paper!

1. Fill the bowl ¼ full with water. Tear a half a page of newspaper into tiny pieces. Place the pieces in the bowl and let them soak for at least one hour.

2. When the paper is thoroughly soaked, beat it with an egg beater or electric mixer until the paper is broken into fibers. When the mixture has been beaten enough, it will have the creamy texture of pulp (the moist, soft mass from which paper is made).

3. Dissolve 2 heaping tablespoons of wallpaper paste or cornstarch in a pint of water. Pour into the pulp and stir.

4. Hold the piece of window screen flat as you lower it into the pulp. Repeat until there is a layer of pulp on the screen about 1/16 inch thick.

5. Put the pulp-covered screen on a newspaper and place a plastic bag flat over it. Press down on these with the wood block -- gently at first, then with more pressure. The water will be forced through the screen onto the newspaper.

6. Allow the fibers to dry for about 24 hours.

DAY 2: Peel the fibers from the screen. Here is your recycled paper.

Curriculum Topic

CAREERS IN SOLAR ENERGY

Energy Topic

ENERGY AND ECONOMICS
ENERGY SOURCES

Grade Level(s) 7 - 12

Site School

Skills

- Analyze words and terms for pronunciation and meaning.
- Relate job skills to educations skills.
- Communicate with business personnel.

Credit

U.S. Department of Energy
Solar Energy Education Project

Objective

At the completion of this activity you should be able to:

1. List possible jobs and careers in the solar energy field.
2. Report the results of a literature search for information about solar energy jobs and careers.
3. Determine the skills and education required for a particular solar energy job.
4. Define and discuss technical terms relating to solar energy concepts.
5. Explain the purpose of career education.

To The Teacher

Career education is striving to provide an active relationship between the academic world and the world in which people earn a living. Most high school students do not have adequate knowledge of the career opportunities open to them, especially when there are tens of thousands of job titles in the United States, and especially when the number of these job titles increases almost too rapidly to keep track of them. Consideration of the job opportunities in a new and rapidly expanding field, such as solar technology, should help to bridge the gap.

The United States Office of Education has developed the cluster concept, which groups job titles in the following categories:

Construction	Consumer and Homemaking
Manufacturing	Marketing and Distribution
Agribusiness and Natural Resources	Communications and Media
Marine Science	Hospitality and Recreation
Environment	Personal Service
Business and Office	Public Service
	Health Opportunities
	Fine Arts and Humanities

Before You Begin

1. Information regarding solar energy careers can be obtained from the use of the references listed at the end of this Teacher Information Sheet. Additional information may also be obtained by contacting solar organizations and manufacturers.

2. Announce ahead of time that a notebook will be required for this activity.

3. It would be advisable to let your guidance counselors know ahead of time that this activity is planned so that they can be prepared.

4. Your guidance department may subscribe to the Computerized Guidance Information System (GIS). If so, this will make occupation information easily available through the nearest computer terminal.

5. Time allotment will vary depending on the depth of coverage you desire for this topic, and upon how many of the activities you assign to your class. Assignment of most of the activities would require 1 to 2 weeks for completion.

6. A thorough introduction to the basic concepts and principles of solar energy technology is needed before this activity will be successful. It is suggested that this activity be used near the end of a unit or set of activities on solar energy, so that students already possess basic knowledge of solar energy concepts.

7. Students should be given a basic orientation to the concept of career education before this activity is attempted.

Words To Know

Students will develop their own list.

Related Activities

- A chart may be constructed following the activity showing the connections and relations of the careers listed, (e.g. Dealer -- Installer -- Builder).

Resources

- CAREERS IN ENERGY INDUSTRIES. (Department of Energy, Washington, DC) (Pamphlet - FEA/A - 75/228)

- ENERGY SOURCES AND CAREERS. (Billerica, Massachusetts: Megatech Corp.) (Booklet/transparencies) 1978

- SCHOOL SUBJECTS AND JOBS. (Chicago: Science Research Associates, Inc.) 1971

- SOLAR ENERGY: POTENTIAL POWERHOUSE FOR JOBS. Work Life, August 1976 (Reprinted in Social Issues Resources Series, Energy Vol. 2 - #33.)

- THE DAWN OF AN INDUSTRY. Nation's Business, The Chamber of Commerce of the U.S., September 1974. (Reprinted in Social Issues Resource Series, Energy, Vol. 1, Article #79)

Notes To Myself

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STUDENT PAGE

MATERIALS

- A notebook in which to keep career information
- The Reader's Guide to Periodical Literature
- The employment sections of large circulation newspapers, such as The New York Times or The Hartford Courant
- Periodicals (magazines)
- A word glossary
- Manufacturers' lists
- Career guidance library

METHOD

1. Discuss the concept of career education with your teacher and other members of your class. Then define the term.

2. Using The Reader's Guide to Periodical Literature, and recent magazines and news articles, conduct a literature search for articles and information on solar energy jobs and careers. Also use your career guidance library to obtain additional career information on this topic. Keep a "jobs and careers" notebook containing the information you have obtained, along with any articles or information which you were able to find.

3. Search the employment sections of various newspapers for advertisements relating to solar energy jobs and careers. If possible, cut them out and place them in your notebook.

4. Using the results of your literature search and the employment ads you found, develop a list in your notebook of jobs and careers in the solar energy field. For each, determine what the job is, and what educational levels and skills are required. Both the ad itself and your career guidance library will be helpful for this.

5. Listed below are some of the processes used in the solar energy industry. Working in a small group with 2 or 3 other class members, define the processes in your notebook. A word glossary may be helpful.

collection	circulation	design/construction
conversion	storage	development
transfer	distribution	experimentation

6. Listed below are some of the materials and equipment used in the solar energy field. Working with your group again, explain in your notebook what each refers to.

collector	valves	furnace
system	metal ducts	heat exchanger
storage tank	piping	insulation
pump	gauges	

7. Working with a partner, arrange to go out and interview someone working in the solar energy industry, such as a businessman or an installer of solar systems. Also interview representatives from state, federal and local agencies who would be knowledgeable about jobs and careers in solar energy. Arrange for some class members to interview the school guidance counselor for information on career possibilities in solar energy.

8. Working in a small group, develop a list of jobs and careers which will be affected by solar energy.

9. Working in a small group, develop a list of solar energy jobs and careers which may be in demand ten to twenty years from now. (This will require some creative thinking.)

QUESTIONS

1. How many different jobs and careers did you list in your notebook?

2. Make a list of solar energy jobs which require each of the follow- educational levels:

a. No high school diploma required
b. High school diploma
c. Two years of college or vocational training
d. Four years of college
e. Advanced degree (Master's or Ph.D.)

3. Where are the best places to look for solar energy job and career opportunities?

4. Are there any new, unusual, or interesting job opportunities in solar energy? If so, what are they?

5. Make a list of satellite (indirect) jobs which will be affected by the solar energy industry.

6. Keep an updated list over a period of time of new careers and jobs in solar energy.

Curriculum Topic

A CUP OF SUNLIGHT

Energy Topic

ENERGY THE CONCEPT
ENERGY USE

Grade Level(s) 7 - 9

Site Classroom and Outside

Skills

- Measure Celsius temperature on a thermometer; time; mass and volume in a graduated cylinder
- Plot and interpret graphs

Credit

U.S. Department of Energy
Solar Energy Education Project

Objective

At the completion of this experiment you should be able to:

1. Construct the heat transfer analysis box.
2. Determine by measurement of temperature change, heating as a function of depth of material.
3. Determine by measurement of temperature change, the heating of different substances.
4. Determine the heating of air as a function of duration of sunlight.

To The Teacher

The assembly box is simply a passive support for the cups. In addition to establishing equivalent conditions for them, it also acts to minimize external influences on the heat transfer being analyzed. Double thick cups further minimize the heat transfer and allow the cup to approximate quite well a closed system for absorption of insolation. Since we are analyzing heat accumulation we may not modify the reflectance of the surfaces. In fact, the reflection and reradiation of heat are a significant factor in the procedural analysis. The ventilation holes allow for minimizing the surface contamination below the cups and the geometry of their positioning prevents heat from reaching the cups anywhere but through their tops.

Inclination of the plane of the surface of the frame to create rays normal to the surface is not significant unless the rays are far from vertical. In that case a significant portion of the cup will not be illuminated or heated. In the case of the full day trials this effect will accentuate the reduced value of insolation at near sunrise and sunset positions.

Most thermometers have a sufficiently long barrel to allow for tape to mark the penetration depth for that part of the procedure.

The many factors influencing heat flow in the substances may all be considered qualitatively. Quantitative approaches will be unsatisfying due to lack of precision of experimental materials.

Before You Begin

1. Check the mimeo room several weeks before the lab data and take up a collection of boxes. Corrugated boxes work the best.

2. Styrofoam cups in sleeves of 25 or 50 are low in cost and may be obtained easily.

3. In the pre-lab session you may solicit suggestions from students for substances to use in the cups but it is suggested that you provide basic items such as sand, gravel, loam and water for use. The sand used by highway departments is readily graded by sifting it through a screen window.

4. Thermocouples can be used by some students if they are available.

5. Remember that saturating the cup contents renders that cup useless for trial until it is again evaporated dry. Have enough materials to cover that contingency.

6. X-Acto knives must be used with care and it is suggested that you do the cutting yourself from a master template.

7. One period to construct the frame and explain the purpose and procedure of the lab.

8. One to three days to gather data.

9. Establish the qualitative perspective and open-ended philosophy of the procedure and hypotheses.

10. Try to get at least two sets of all data to check for correspondence but strive for a variety of setups as outlined in the procedures.

11. Note the dependence of your data on uniform atmospheric conditions and be prepared with alternative lessons if the heavens do not smile on you.

12. Emphasis on the RELATED ACTIVITIES section will give valuable information to increase the relevance of the procedure and data.

Words To Know

insolation
reradiation
inclination
thermocouple

Related Activities

- Try the experiment in a place near a highly reflective wall surface.

- By use of thermal energy equations, calculate the heat gain by each sample and speculate on the reasons for any differences. (Heat gain = mass of sample x change in temperature x specific heat of substance). Ask your teacher for data on specific heat values.

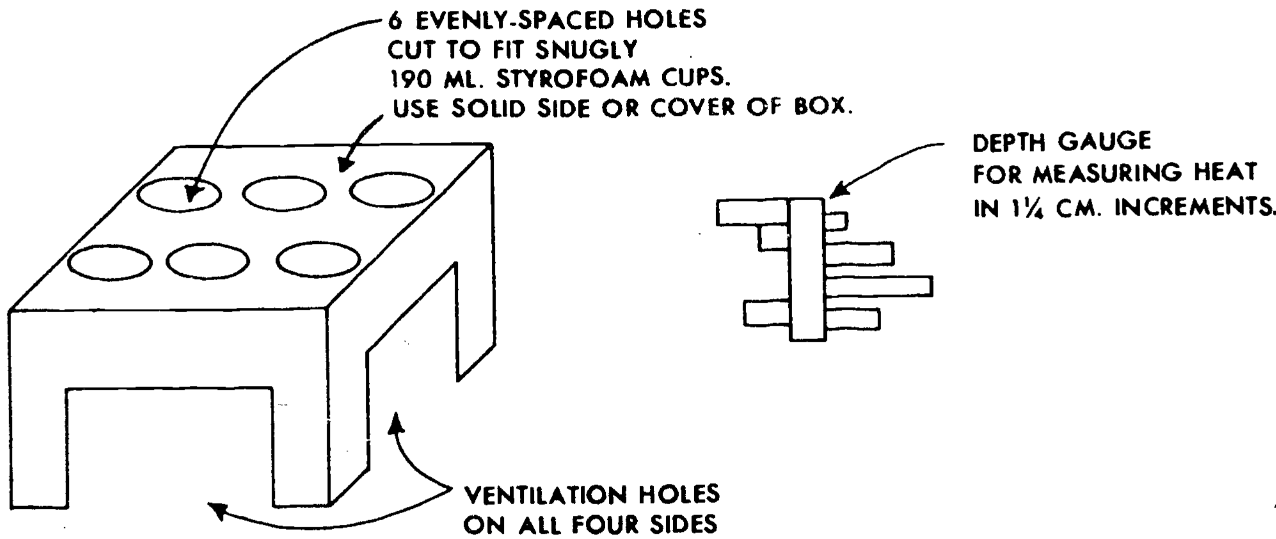
- Try the lab procedure with substances such as canning wax (melting point is quite low), alcohol (evaporates rapidly), wood samples with holes drilled into the blocks at depth intervals (try both soft and hard woods), foam samples, metal pellets or anything that seems promising. BE SURE TO CHECK WITH YOUR TEACHER BEFORE TRYING ANY SUBSTANCES THAT HAVE ANY POSSIBILITY OF BEING DANGEROUS WHEN HEATED.

Resources

- CIRCUS OF PHYSICS WITH ANSWERS, Jearl Walker, Wiley, 1977.

Notes To Myself

STUDENT PAGE



MATERIALS

- Approximately one dozen (12) styrofoam cups (190ml work well).
- Celsius thermometers (one is adequate but 3-6 are better).
- One cardboard box from the mimeo room paper supply (The 12 ream box is approximately 20xm x 20cm x 40cm and works very well).
- X-Acto or other sharp knife, masking tape or heavy duty paper fasteners.
- Testing samples (may include loose topsoil, clay, fine sand, coarse sand, fine gravel, coarse gravel, water, styrofoam blocks, or any permeable materials).
- Timing device.
- Ruler or other measuring stick for depth determination.
- Graduated cylinder.
- Balance.

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METHOD

1. Cut into the box on a single ply solid side six evenly-spaced holes. Make them large enough to snugly contain the styrofoam cups.

2. Letting the six-hole face be the top, cut ventilation holes in the four sides. Make them as large as possible without weakening the frame too much. The holes should not extend so high that sunlight will strike the sides of the cups.

3. Fill the styrofoam cups to the level of the rim bulge of each cup. Use various substances to gather data. All samples should be of equal and uniform temperatures throughout when the timing starts. Measure the mass of each cup and the cup plus contents. By subtraction determine mass of the contents. Describe the contents as precisely as possible for your data.

4. Place the framework in direct sunlight, tilting it to get as vertical as possible illumination of the cups. This cannot be done if you choose to use liquids and you should comment on how failure to do it will affect your data.

5. Measure the air temperature with a shielded thermometer. After 15 minutes, 30 minutes and 45 minutes, record the surface temperatures of each sample by carefully placing the tip of the thermometer into it. In the same fashion either carefully dig the thermometer deeper into each sample, approximately 1.25cm per trial to get four other temperature readings, or drill a hole using a nail or dowel rod of the same size as the thermometer and then place the thermometer into the sample. Try not to distrub the material as the thermometer is put into it. If the sun is constant and time is available the data may be extended to several hours of observation even from sunrise to sunset. If the full day data is taken the air temperature may be measured hourly as well as substance temperatures and it is also recommended that the box surface be left horizontal for all readings.

6. After taking data of temperature, time and depth, plot a first graph as follows:

   a. Surface temperature vs. time for each substance.

   b. On the same axes plot air temperature vs. time.

   For each substance and depth prepare another graph of temperature vs. time.

7. After the data are gathered, add a measured amount of water to each cup until it is full. Stir to allow for full absorption. From the water volume and cup size determine the percentage air space in each cup and the densities of each substance (D = Mass/Volume).

QUESTIONS

1. Does the nature of the substance seem to influence the rate of heating at its surface? From your data specifically quote the rate of temperature change and comment on characteristics of the substance that might influence this rate. (NOTE: You have data for the particle size, density of the substance, percentage of air space in sample, descriptive properties as well as the temperature vs. time evidence. Try to put all this into a set of speculations.)

2. How, if at all, does depth influence heating? Comment on the temperature change rate as compared to increased depth in a sample. Do all the samples behave the same? Does density, air space percentage, or any physical characteristic of the materials seem to influence heat transfer?

3. If you used a fluid for one sample, how can you explain the data it gave?

4. Why were the instructions so specific about the ventilation holes and their size and placement? What effect would two cup thicknesses instead of one have on the data?

5. For the full day trial, does the time of day influence the temperature change of the substance as well as air temperature? Why? Do the times of peak air temperature correspond to the times of peak substance temperature? How do these temperatures correspond to local solar noon?

6. How may one improve the apparatus of the experiment? Assume that money is no object.

7. If the bottom of the box were cut out and the box then placed over grass, hard-packed dirt, concrete paving, asphalt pavement and a pan of water each in turn to gather data as in the original procedure, what would be expected to happen? Why?

8. Why does the sand on the beach change temperature with depth? Why is the moisture in it also influenced by depth?

9. Why in the arctic is there ice below swamps, even in midsummer?

10. Why is perspiration less evident on windy days?

11. Why does perspiration cool objects? Why does condensation form on iced drinks in hot places?

Curriculum Topic

CHANGING PHYSICAL PROPERTIES WITH THE SUN

Energy Topic

ENERGY USES

ENERGY SOURCES

Grade Level(s) 7 - 8

Site Classroom or outside

Skills

- Set up a solar collector to effectively capture the sun's rays.
- Graph data
- Perform controlled experiment

Credit

U.S. Department of Energy

Solar Energy Education Project

Objective

At the completion of this activity, you should be able to:

1. Use a flat plate solar collector.

2. Determine if enough energy can be collected over a two hour period to change the physical properties of a) water, b) chocolate bars, and c) tea bags in water.

To The Teacher

On the sun, hydrogen nuclei unite to form helium. During this process the sun gives off energy and tranmits it to the earth at a rate of 1.94 cal/cm^2/min. As this energy is transmitted, 15% is absorbed by the atmosphere, 42% is reflected by clouds, snow, water, or land and 43% is absorbed by the earth's surface. The total solar energy falling upon the earth is very much greater than current or projected demands for energy. (The energy the sun sends the earth each year is equivalent to 120 trillion tons of coal.)

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At the present time, the problem is how to effectively collect and store this energy at a reasonable cost. A solar collector itself is simple to operate and relatively easy to install.

In this experiment, the students will see solar energy used to heat water, melt chocolate and make tea. They should then be able to conclude that solar energy has many practical applications including heating their homes, producing hot water for their homes and/or cooking in their homes.

The teacher might also point out that solar energy striking photovoltaic cells has produced electricity which has been used to power such items as radios, watches, spacecraft and remote electronic installations.

Before You Begin

1. A flat plate collector can be made simply by painting a large wooden or cardboard box black both inside and out and covering it with a piece of glass or plastic wrap. Make sure that the flat plate collector you will use or construct is deep enough to accommodate 3 beakers.

2. If beakers are not available, any glass container will suffice.

3. One class period for the basic exercise. (Data should be collected during the school day.) One to two class periods for initial and final discussions.

4. This lesson should be taught as part of a unit on energy with particular emphasis on the energy problem in the world today. Topics such as the sources, uses and waste of energy would be covered. Alternate sources of energy could be introduced and then the class could focus on one viable alternative - solar energy.

5. The teacher could discuss how solar energy is created and how it reaches the earth. The construction and operation of a solar collector could be discussed, followed by the advantages and disadvantages of using solar energy. This experiment could then be tried, followed by a lecture-discussion class on the uses of solar energy with emphasis on its use to heat homes, heat hot water and cook food.

6. In carrying out this exercise, you could divide the class into groups and have each group collect data. Alternatively, you could have the entire class set up the experiment one day in a suitable place and make initial observations. Then the class would be divided into groups and assigned a time to take temperature readings the next day before class. Each group would add its results to a class Data Table kept at the experiment. At the next class, the

students would make final observations of physical appearances and complete their own data on temperature changes. During the remainder of the class period, completion of graphs and answering of questions could be accomplished.

Words To Know

solar collector, hydrogen nuclei, photovoltaic cells

Related Activities

- Students may try styrofoam cups instead of glass beakers. Note the change in results.

- Styrofoam cups may be painted black for a different result.

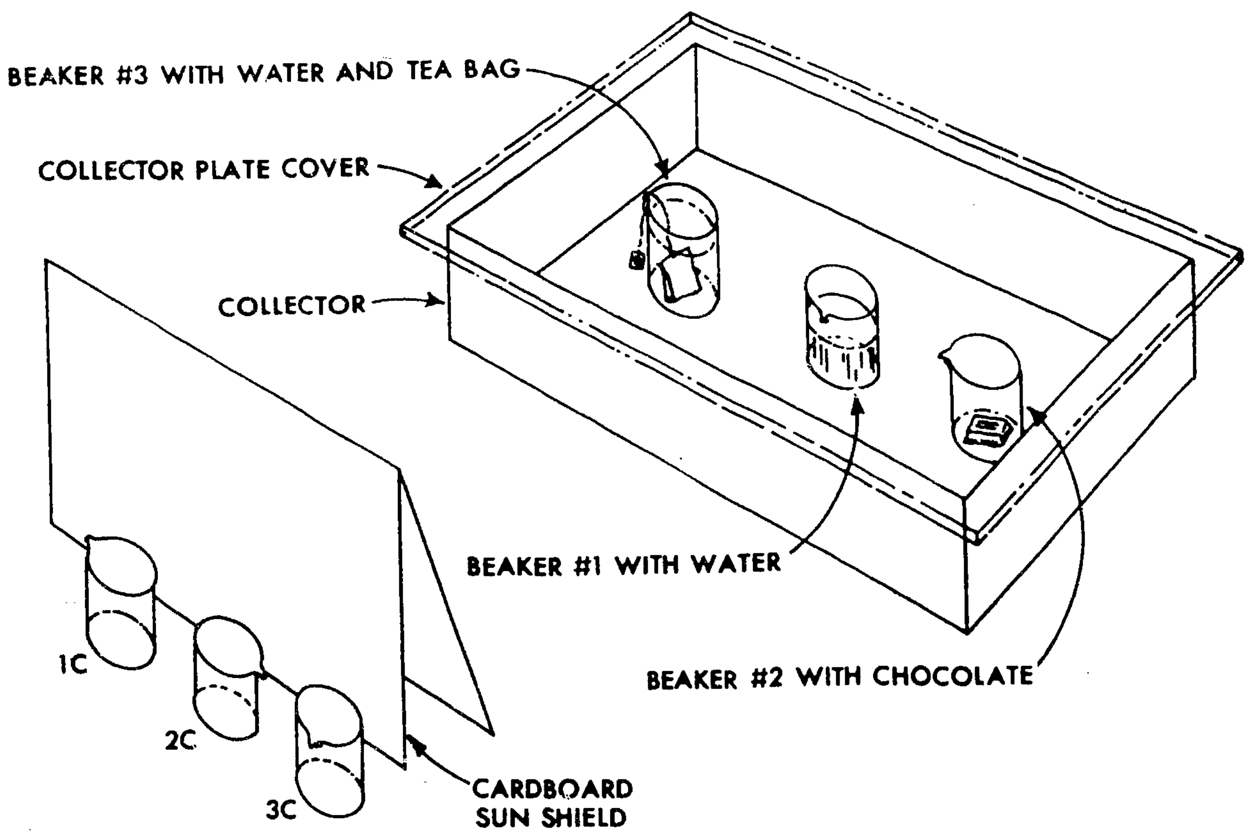
Notes To Myself

STUDENT PAGE

MATERIALS

For each group collect:

- 1 solar collector
- 6 beakers
- Water
- 2 chocolate bars
- 2 tea bags
- 6 standard laboratory thermometers ($-10^{\circ}C$ to $100^{\circ}C$)



METHOD

1. Set up the solar collector so that it effectively catches the sun's rays.

2. Label 6 beakers as follows: 1, 1C, 2, 2C, 3, 3C. The beakers marked C will be our control.

3. Put a thermometer into each beaker.

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4. Place the following substances into the following beakers.

1 & 1C - water
2 & 2C - chocolate bar
3 & 3C - water and tea bag

5. Place beakers 1C, 2C, and 3C in the shade. Place beakers 1, 2, and 3 in the collector.

6. Observe the physical appearance of each substance and record your observations in Data Table 1.

DATA TABLE 1

BEAKER	INITIAL OBSERVATIONS	FINAL OBSERVATIONS
1		
2		
3		
1C		
2C		
3C		

7. Take the temperature of the substance in each of the six beakers every half hour for two hours. Record this information in Data Table 2.

DATA TABLE 2

TIME (MIN.)	TEMPERATURE IN BEAKERS °C					
	1	2	3	1C	2C	3C
0						
30						
60						
90						
120						

8. After two hours, make a second observation of the physical appearance of each substance and record it on Data Table 1.

9. On a large piece of paper, graph the data from Data Table 2 using time on the horizontal axis and temperature on the vertical axis.

QUESTIONS

1. What conclusions can be drawn from the graphs?

2. Compare the final temperature and appearance of the water in beaker 1 and 1C.

   a. Was there any difference?
   b. How do you account for any difference observed?
   c. Do you see any way that you could use the information that you gained in this experiment in your home?

3. Compare the final temperature and appearance of the chocolate bar in beaker 2 and 2C.

   a. Was there any difference?
   b. How do you account for any difference observed?
   c. Do you see any way that you could use the information that you gained in this experiment in your home?

4. Compare the final temperature and appearance of the water and tea bag in beaker 3 and beaker 3C?

   a. Was there any difference?
   b. How do you account for any difference observed?
   c. Do you see any way that your could use the information you gained in this experiment in your home?

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Curriculum Topic

EXPLORING BASIC PROPERTIES
OF SOLAR ENERGY: ABSORPTION

Energy Topic

ENERGY SOURCES
ENERGY USES
ENERGY CONCEPTS

Grade Level(s) 7 - 9

Site

School - indoors with heat lamp or outside

Skills

- Data collection
- Graphing of data

Credit

U. S. Department of Energy
Solar Energy Education Project

Objective

At the completion of this activity, you should be able to:

1. Demonstrate that solar energy can be absorbed by materials and changed into heat energy.

2. Demonstrate that all materials do not absorb solar energy at the same rate.

3, Identify and name the variables that might affect this investigation.

To The Teacher

This activity is intended to help students gain the knowledge and insights into the basic characteristics of solar energy. It should help them understand why solar collectors are designed with black collector plates and transparent glazings. This will enable them to select materials and designs for their own solar activity.

The phenomenon of absorption occurs every time light falls on a surface. The light energy is taken into the substance and is changed into heat energy, as is seen in the temperature rise of the soil and sand. This increased heat energy can be explained as an increase in the kinetic energy of the molecules in the substance; light energy in the form of infrared radiation strikes these molecules and causes their motion energy to increase. The color of a substance is also closely related to absorption. Certain wavelengths of light are absorbed, others are reflected. Those which are reflected produce the color of the substance.

Before You Begin

1. Allow one to two class periods to perform the activity and answer the questions, and one-half class period to discuss the activity.

2. If it is impractical to use the sun as a source of solar energy when you plan to do this activity, then a 200 watt incandescent lamp clamped to a ringstand will work just as effectively. Place the containers directly under the lamp so that each one receives an equal amount of light.

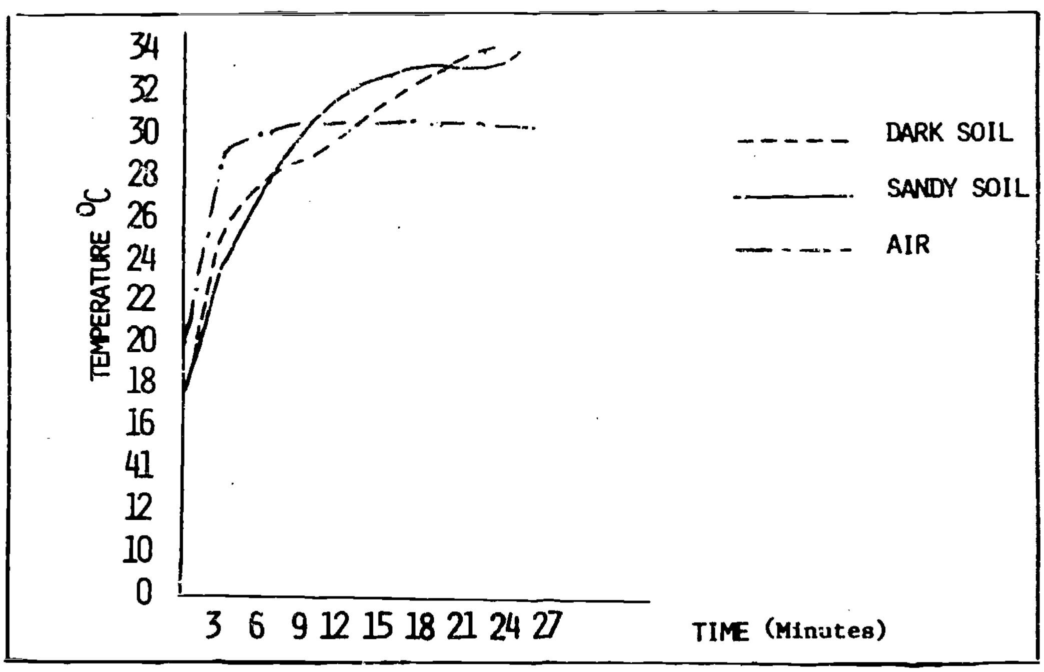
3. Discuss the way the activity will be carried out. Assign students to groups. If possible, use different soil types in the cans.

4. Have the groups carry out the activity and collect their data. After the data is collected each student should prepare the graphs and answer the questions using the graphs.

5. Discuss, as a class, the results. Were there any individual results that clearly stand out from the rest of the data? How are such results explained by the students?

6. Can the students think of any practical application of their findings? Have them describe, in writing, things they think of.

7. Typical results for absorption of solar energy by the dark soil, sandy soil, and the container of air are listed below:



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Words To Know

absorption, infrared, kinetic energy.

Related Activities

- Repeat this activity but use black ink, red ink and clear water. Place the jars in direct sunlight or under the 200 watt incandescent lamp. Record the temperatures at 30 second intervals, as before, for 10 to 25 minutes. Graph the results of each jar. Compare this investigation with the ones in the original activity.

Resources

SOLAR ENERGY EXPERIMENTS, Thomas W. Norton, (Emmaus, Penn: Rodale Press) 1977.

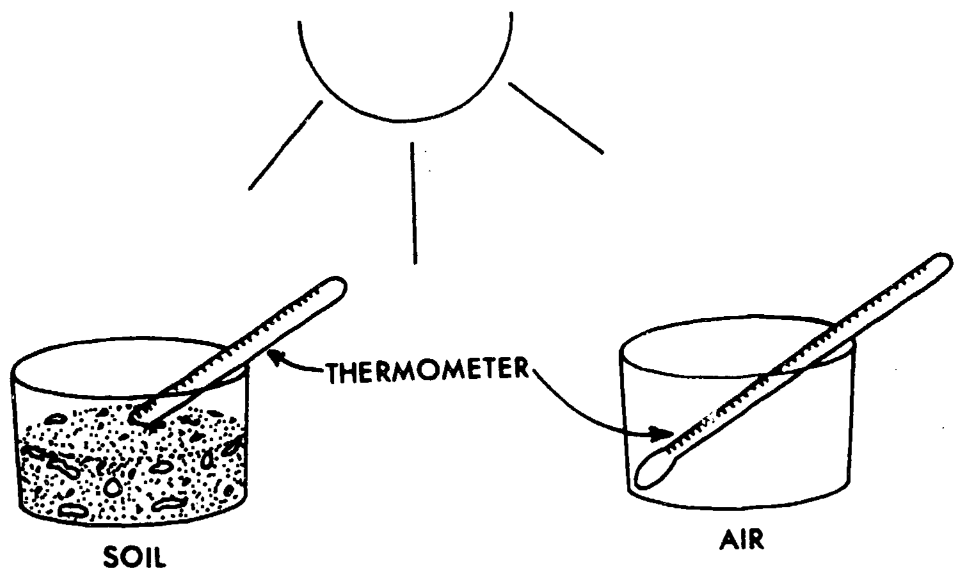
Notes To Myself

STUDENT PAGE

MATERIALS

- 3 glass or plastic dishes about 10 cm in diameter and 5 cm high.
- 3 thermometers, Celsius scale, range -10^{o}C to 110^{o}C.
- Dry, black soil to fill one dish.
- Dry, white sand to fill another dish.
- 200 watt incandescent lamp and reflector with clamp.
- Ringstand.

If unable to do activity in sunlight



METHOD

1. Fill one dish to a depth of about 2.5cm with dry black soil. Fill the second dish to the same depth with dry white sand. Leave the third dish empty.

2. Place a thermometer in each dish. In the dish with the dry black soil, place the bulb of the thermometer just under the surface of the soil, making sure that the bulb is completely covered with the soil. Do the same for the sand.

3. Record the initial temperature of the soil, sand and air.

4. Place the 3 dishes on the table in direct sunlight. (If artificial light is used, place the dishes so that the light from the incandescent lamp shines equally on each dish.

5. Take the temperatures of the soil, sand and air every 30 seconds for at least 25 minutes and record on the data table.

6. When the data taking is done lift the dish of dark soil from the table and place your hand under it. Observe whether any solar energy is transmitted through the dark soil. Do the same with both the dish containing the sand and the dish containing the air. Again observe whether any solar energy is transmitted.

7. Construct a graph using the data collected. Use different colors for plotting the changes in the temperature of the sand, soil and air.

QUESTIONS

1. What happened to the temperature of each container as time passed?

2. What was the greatest difference in temperature between the three containers?

3. Was solar energy transmitted through the container of soil, sand, or air?

4. Was the temperature of the soil-filled or sand-filled containers higher than that of the air-filled containers? Explain.

5. How do you explain the fact that the temperature curves on the graph did not continue to rise but flattened out?

6. On a sunny day, why do dark asphalt type roads get very hot, while concrete type, light colored pavements remain relatively cool?

7. Why were you told to use one container with only air in it?

DATA TABLE

Time min/sec	Dark Soil °C	Light Soil °C	Air °C	Time min/sec	Dark Soil °C	Light Soil °C	Air °C
0 00				13 00			
0 30				13 30			
1 00				14 00			
1 30				14 30			
2 00				15 00			
2 30				15 30			
3 00				16 00			
3 30				16 30			
4 00				17 00			
4 30				17 30			
5 00				18 00			
5 30				18 30			
6 00				19 00			
6 30				19 30			
7 00				20 00			
7 30				20 30			
8 00				21 00			
8 30				21 30			
9 00				22 00			
9 30				22 30			
10 00				23 00			
10 30				23 30			
11 00				24 00			
11 30				24 30			
12 00				25 00			
12 30				25 30			

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Curriculum Topic

HEAT ABSORPTION OF COLORED SURFACES

Energy Topic

ENERGY CONCEPT
ENERGY SOURCES

Grade Level(s) 7 - 9

Site

School in classroom with heat lamps or outside

Skills

- Read a thermometer
- Record data
- Construct a graph

Credit

U.S. Department of Energy
Solar Energy Education Project

Objective

Upon completion of this activity you should be able to:

1. Measure the temperature change of colored substances after absorbing infrared light.

2. Determine which colored substances best absorb infrared radiation.

3. Determine which colored substances best reflect infrared light.

4. Determine why solar collectors are painted black.

To The Teacher

White light comes to earth from the sun. Actually, it contains all colors of light mixed together. Your eyes see this special mixture as white.

Sunlight also contains some wavelengths of radiation which your eyes don't see, including ultra-violet and infrared. Infrared is the light which makes you feel warm when sunlight hits your skin. Even though your eyes can't tell when there is too much infrared or ultra-violet light around, your skin has a very painful way of letting you know when you've had too much.

The infrared lamp that you will be using in this lab is a special lamp that produces infrared light. This is the type of lamp used in restaurants to keep hamburgers and french fries sizzling hot. Possibly you have also seen infrared lamps in the bathrooms of motel rooms. These are used to warm you and the bathroom when you're taking a shower or bath.

In the activity your students will be doing, they should discover that black substances absorb the most heat. They should also see a relationship between the color of the substance and the amount of heat absorbed.

Before You Begin

1. In preparing for this experiment, it may be a valuable time-saving idea to set out the materials in small boxes.

2. An infrared heat lamp works best for the experiment, although a projector flood lamp will also produce observable results.

3. Jars may be used instead of test tubes, as long as they can be made to hold the thermometers with a very small additional hole added to allow for thermal expansion of the air inside.

4. Chairs make excellent holders for the heat lamps and experimental apparatus. The lamp may be clamped onto the back of the chair and the seat may be used as a supporting surface for the test tubes.

5. One class period to set up the experiment and gather data.
   One class period for graphing and discussion of results.

6. Using a prism and a filmstrip projector, break up the projector's white light into colored bands. Discuss the electromagnetic spectrum and include the ideas of white light, colors, infrared light, and ultra-violet light.

7. Discuss the protective function of the earth's atmosphere (especially the ozone layer).

8. Show students how to remember the colors of the visible light spectrum with "ROY G. BIV".

9. Direct students to begin the activity following the method prescribed on the student sheet.

10. Neighboring test tubes should be close enough to receive the same amount of radiant heat from the lamp, but they should be far enough apart from each other that heat from one will not influence the temperature of the other. Another way to compensate for this would be to make sure the tubes are put in this order: White-Red-Orange-Yellow-Green-Blue-Indigo-Violet-Black. The foil covered tube <u>must</u> be kept quite far away from the others, since it tends to reflect heat on its neighbors.

Words To Know

electromagnetic spectrum, infrared light, ultra-violet light, radiant energy, absorption, emission.

Related Activities

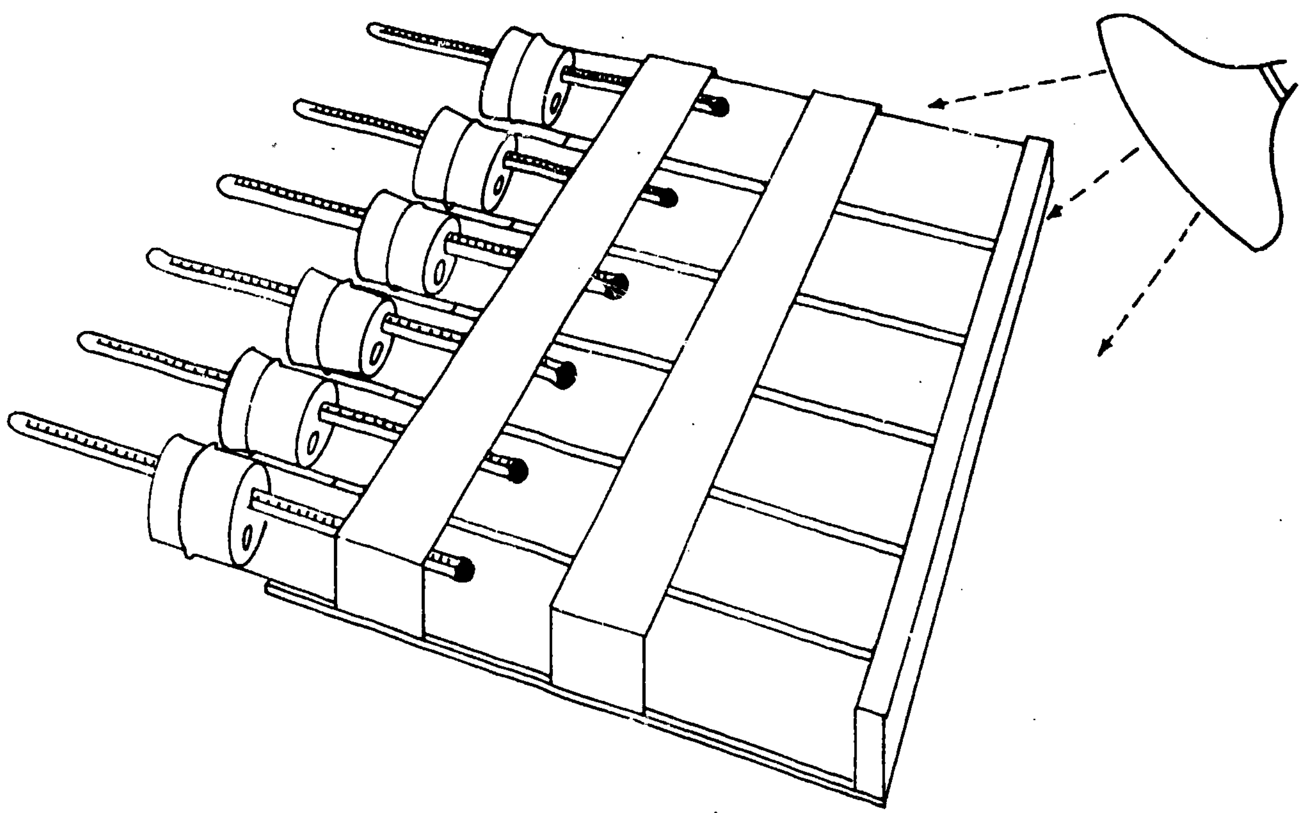
- Investigate the cooling of different colored substances by recording the temperature of each tube after the infrared lamp is turned off. Do this in 2 minute intervals for 20 minutes and again graph your results. Make a generalization about the rate of cooling for different colors. Does this change your opinion about questions 6 and 7?
- Find out how a solar panel is constructed and how it works.
- This activity may be performed in a sunlit window or outside in sunlight. Use a cardboard panel or a book to block the sunlight in place of a light switch.

Notes To Myself

STUDENT PAGE

MATERIALS

- Infrared heat lamp, 250 watts.
- Clip on socket or other holder for lamp.
- 6 test tubes, 200mm x 25mm.
- 6 double-hole stoppers, to fit test tubes.
- 6 Celsius thermometers.
- Large test tube rack.
- Aluminum foil.
- Colored paper: white, red, green, violet, and black.
- Scissors.
- Tape.
- Watch or clock with second hand.



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METHOD

1. Insert a thermometer into each of the six stoppers using glycerin to make the thermometer slide more easily. Adjust all the thermometers so the top of the stopper is at the zero mark of the thermometer.

2. Wrap each of the test tubes in a colored paper jacket. Also wrap one test tube in aluminum foil.

3. Fit each test tube with a stopper and thermometer.

4. Lay all six test tubes on the test tube rack and set up the infrared lamp about 50cm above them.

5. Record the initial temperature in the correct blank on the data table. Make sure the test tubes are arranged in the same order you will be reading them.

6. Turn on the lamp. CAUTION: FROM NOW UNTIL ABOUT FIVE MINUTES AFTER THE LAMP IS TURNED OFF, DO NOT TOUCH THE LAMP. IT WILL BE EXTREMELY HOT AND CAN BURN YOUR HAND.

7. Record the temperature of each tube every 2 minutes for the next 20 minutes. Always read the thermometer and record the data in order, starting with white.

8. Make a graph of your results for each tube. Put time in minutes on the horizontal axis. Put temperature in degrees, Celsius on the vertical axis.

DATA TABLE

TIME MINUTES	TEMPERATURE (^{0} C)					
	WHITE	RED	GREEN	VIOLET	BLACK	ALUMINUM FOIL

QUESTIONS

1. Which color absorbs the most heat? How can you tell?

2. Which color absorbs the least heat? How can you tell?

3. List the colors you used in order from the one which absorbed the least heat to the one that absorbed the most heat.

4. Why do people usually wear light clothes in the summer and dark clothes in the winter?

5. Suppose you are building a house in Alaska, and you don't want to use too much oil when you heat it. Based on your data, what color roof would you choose?

6. Would you use the same color roof if you decided to build your house in a desert? Explain.

7. Solar collectors are designed to capture the sun's heat. What color are they usually painted? Why?

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Curriculum Topic

RADIATION OF SOLAR ENERGY

Energy Topic

ENERGY CONCEPT
ENERGY SOURCES

Grade Level(s) 7 - 10

Site

School, outside, classroom (with heat lamp)

Skills

- Read a thermometer
- Graph data

Credit

U.S. Department of Energy
Solar Energy Education Project

Objective

At the completion of this activity you should be able to:

1. Compare the rates at which two cans, one black and the other shiny, absorb and radiate heat energy.

2. Select a color that would be best to use as a solar energy absorber in a solar collector.

To The Teacher

Radiation is a method of heat transfer in which the heat travels in the form of electromagnetic waves. Heat can travel through a vacuum by radiation only. The light coming from the sun is an example of radiation. All warm objects radiate heat energy, and at the same time receive this energy from other objects in their surroundings. When an object absorbs energy its temperature rises, and when it emits energy its temperature drops.

Various substances radiate energy more rapidly than others. For example, if a silvered container were filled with hot water the heat would not escape very quickly because radiated heat is reflected by smooth surfaces such as shiny metals. In comparison, a black container would emit more heat since black substances do not reflect this energy as well.

Black is known as the super-absorber. This is because it absorbs light of all wavelengths. When it absorbs the light energy, the molecules composing the black material speed up. The increase in the speed of these molecules leads to a rise in temperature. Therefore, light energy absorbed by this black substance becomes heat energy. On the other hand, shiny or white substances reflect almost all colors of the electromagnetic spectrum, and therefore do not experience such a large temperature change.

This is the reason black is best worn in cold weather, since it takes in more light energy and changes it to heat, and white is best worn in hot weather, since it reflects light energy. This phenomenon also explains the use of black in the construction of solar collectors. The top is covered by a transparent plate of glass or plastic, which allows the solar radiation to pass through, and the back is blackened in order to absorb as much solar radiation as possible.

Before You Begin

1. Several weeks before the activity is to be done, collect aluminum soda cans. Remove the paint from the ones which are to be shiny, and use flat black paint on the dark cans.

2. One class period (45 minutes) to do the first part of the activity on measuring the rate of absorption of radiant energy.

One class period to do the second part of the experiment on measuring the rate of radiation of heat energy.

One class period to discuss the results.

3. Divide the class into groups of two or three. One student should be responsible for timing, while the other one or two are responsible for reading the temperatures and recording them.

4. Unless the period is more than an hour long, it would be best to have students do the activity on absorption one day and the activity on radiation the next.

5. If there is difficulty in obtaining an adequate number of heat sources, have half the class do the activity, measuring the rate of radiation, while the other half measures the rate of absorption. The next day the students should then do the opposite activity.

6. A demonstration of the apparatus will facilitate the activity.

7. This activity could be done using different substances in the cans or using different colored cans.

Words To Know

radiation (as applies to solar energy), super absorber

Related Activities

- Repeat the experiment using empty cans. Give reasons for any differences in results that you might observe.
- Repeat the experiment using different distances from the heat source.
- Follow by using the sun as a radiant energy source.

Notes To Myself

STUDENT PAGE

MATERIALS

- A source of radiant energy, such as a high wattage lamp.
- Two thermometers (-10°C to 110°C)
- Two cans of the same size and substance with some type of cover, one painted black and the other left shiny
- Corrugated cardboard
- A clock with a second hand
- Water at room temperature
- Hot water at least 50°C

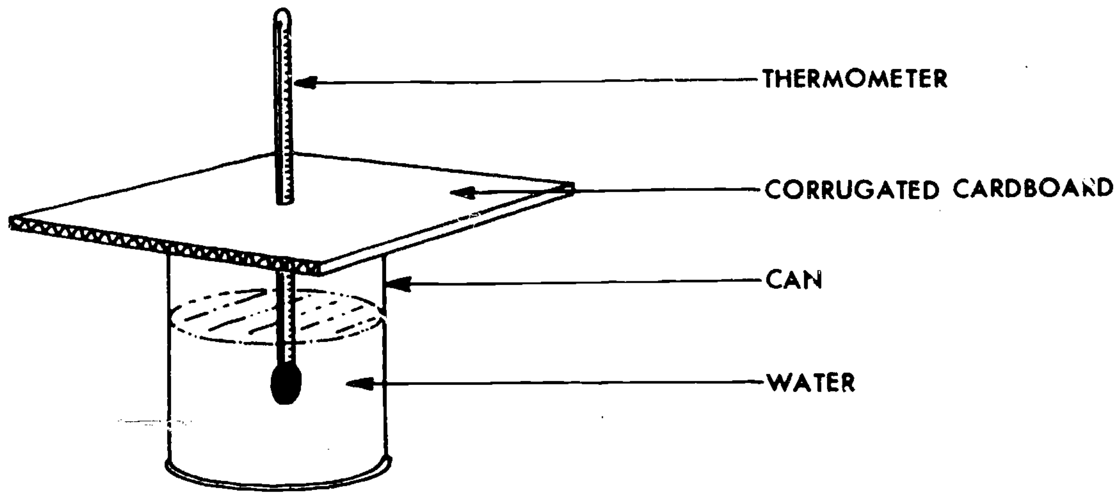

FIGURE 1

METHOD

1. Fill the two cans with equal amounts of water at room temperature.

2. Obtain a piece of corrugated cardboard cut slightly larger than the can top. Make a hole in the center of the cardboard with a pencil point slightly smaller than the diameter of the thermometer. Carefully insert the thermometer in the hole so that there is a snug fit. Repeat for the second thermometer.

3. Place the thermometer and cardboard lid arrangement on each can. Adjust the thermometer so that the bulb of the thermometer does not touch the sides or bottom of the can. See diagram 1.

4. Place each can 20cm from the heat source. See diagram 2.

5. Record in data table 1 the temperature of the water in each can.

6. Turn on the heat source and record the temperature of the water in the cans every two minutes for about thirty minutes. Record this information in data table 1.

7. At the end of thirty minutes remove the heat source, and graph your results.

8. Next, empty both cans and then fill each of them with equal amounts of hot water.

9. Using the same thermometer arrangement as before, record the temperature of the water in each can every 2 minutes for 40 minutes as the water cools. See diagram 3.

10. Graph the results for the cooling of the water.

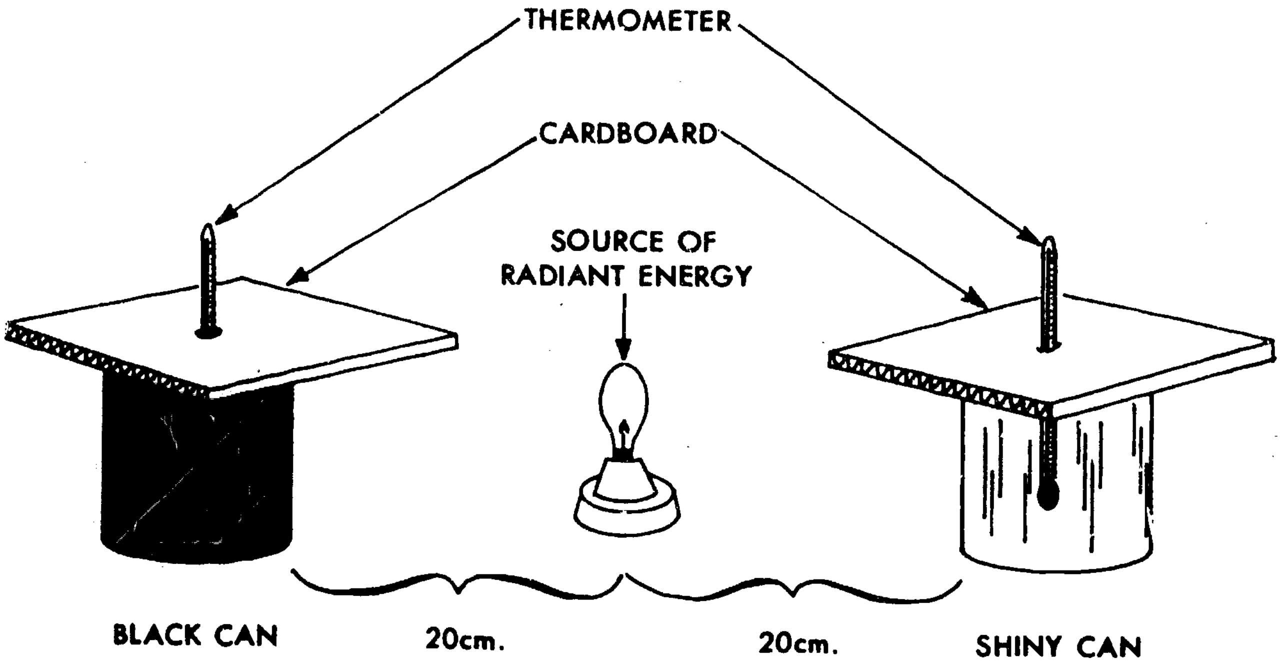

FIGURE 2

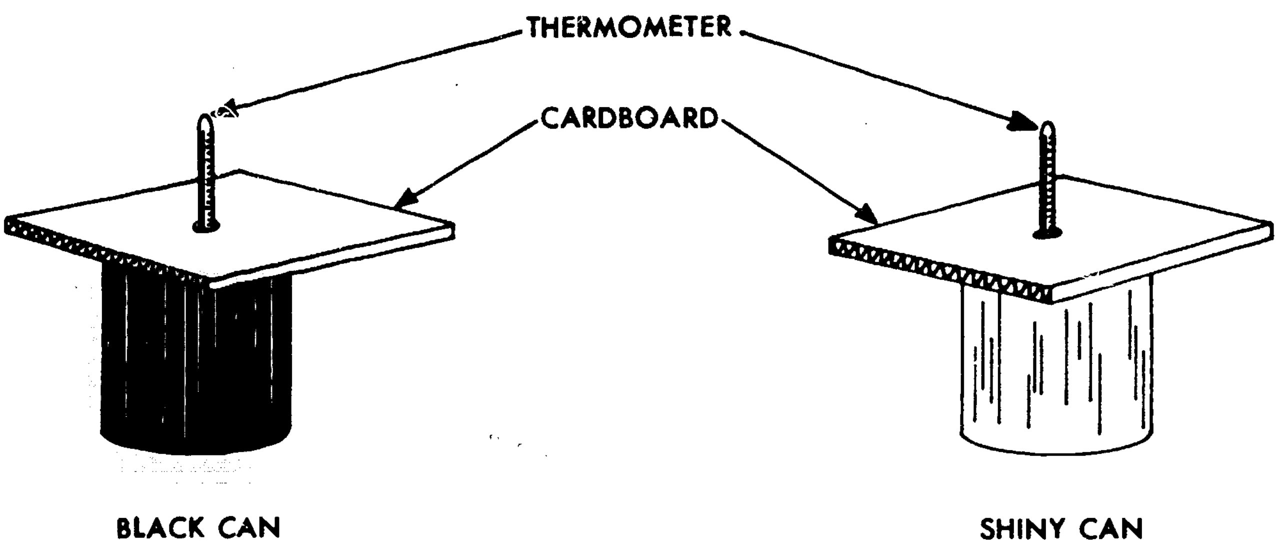

FIGURE 3

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Curriculum Topic

INSULATION: CAN IT KEEP HEAT IN AND OUT?

Energy Topic

ENERGY CONSERVATION
ENERGY AND ECONOMICS
ENERGY: THE CONCEPT

Grade Level(s) 7 - 8

Site Classroom

Skills

- Read a thermometer
- Graph data

Credit

U.S. Department of Energy
Solar Energy Education Project

Objective

At the completion of this experiment you should be able to:

1. Compare insulating materials to keep heat out using temperature data collected.
2. Use this information to determine the best insulating material to keep heat out.
3. Compare insulating materials to keep heat in using temperature data collected.
4. Use this information to determine the best material to insulate against heat loss.

To The Teacher

Insulators are materials used to reduce heat transfer. They prevent heat leakage through building walls and windows. It is estimated that a 20% savings could be realized by insulating attics. According to John Fowler, "most homes built before 1965 had only 1½" of insulating materials in the ceiling, none in the walls and floors, and plain windows (only about half of all single family homes currently have storm windows.) Current practices call for 2" - 3" of insulation in the walls; 4" - 6" in the ceiling. An EPA report estimated that complete retrofitting of one third of the existing homes would save 0.5×10^{15} BTU's. A BTU, British Thermal Unit, is an engineering unit for energy measurement. It is the amount of heat required to raise the temperature of one pound of water one Fahrenheit degree.

The proper choice of insulating materials is very important to the overall conservation of energy. Not all materials are effective insulators.

Before You Begin

1. Several weeks before this activity is to be done, begin collecting soda cans.

2. Have students bring in various kinds of insulating materials. Check with a store that sells insulation to see if they will provide you with various samples of insulating materials. For better results, use a similar thickness for each insulation type.

3. Two class periods (45 minutes) to do the experiment, one class period to discuss the results.

4. Divide the class into groups of three. One student should be responsible for the timing, and the others should be in charge of reading and recording the temperatures.

5. Have a variety of good and poor insulating materials available.

6. Have a guest speaker come in to talk about home insulation. This could be a builder in the area.

Words To Know

insulation, BTU (British Thermal Unit), R factor

Related Activities

- Find out what type of insulation you have in your house. Does it seem effective?

- Go to the library and find out how insulation is rated as to effectiveness.

- Visit a lumber yard and gather information on insulation, cost, and R factor.

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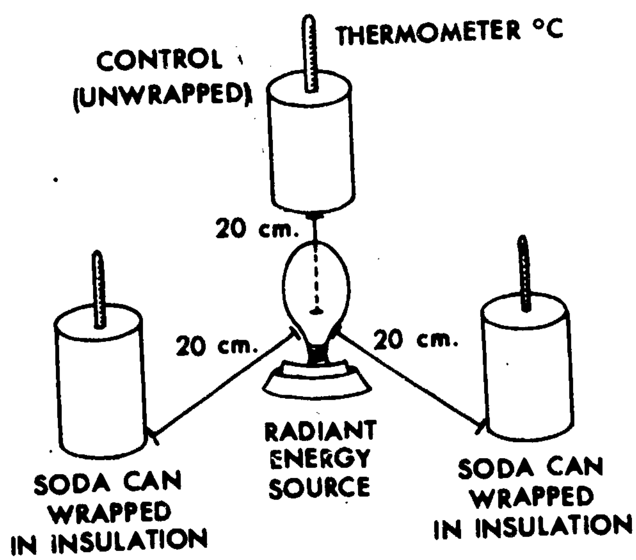
Notes To Myself

STUDENT PAGE

MATERIALS

- Three soda cans of the same size and color.
- Three thermometers (-10°C to 110°C).
- A clock with a second hand
- A source of radiant energy, such as the sun, an infrared lamp, or a heating coil.
- Hot water.
- Various insulating materials, such as fiber glass, wool, styrofoam, newspaper, or aluminum foil.
- Rubber bands.



METHOD PART I

1. Obtain two types of insulating materials and cover one can entirely with one type of material and the second can with another material. (Make sure the top of each can is wrapped.)
2. Identify each can by the type of insulating material used.
3. The unwrapped can should be labeled CONTROL.
4. Place the three cans about 20 centimeters from the heat source.
5. Insert the thermometers through a small hole in the top of each can. Use a rubber band wrapped around the thermometer to keep the thermometer suspended so that it does not touch any part of the can.
6. Record the temperature of each can in Data Table 1.

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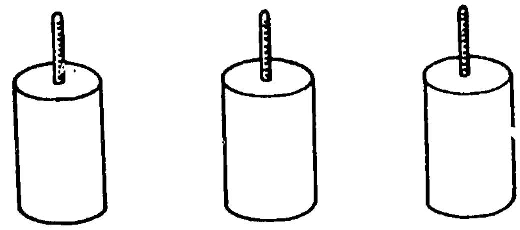
THERMOMETERS (°C)



SODA CANS EACH WITH A
DIFFERENT KIND OF INSULATION

METHOD PART II

1. Fill the three cans used in Part I carefully with hot water to one centimeter from the top.

2. Insert the thermometer into each can of hot water once again being careful not to touch the sides of the can.

3. Record the temperature in Data Table 2.

4. Continue to record the temperature every two minutes for twenty minutes.

5. Graph your results on Graph 2 using different colors for each can.

6. If there is enough time and your teacher permits, repeat this activity using two or more types of insulating materials.

QUESTIONS

1. What general conclusions can you draw from the graphs?

2. From the materials you tested, which material was the best insulator against the absorption of energy?

3. From the materials you tested, which material seemed to allow the least amount of heat loss?

4. Was the same material the best insulator in both cases?

5. Compare your results with the other members of your class. From the collective data, determine the best insulating material against both heat loss and heat gain.

6. What would be some methods to protect your house in the summer from the sun's radiant energy?

7. Find out which types of insulating materials are used in buildings today. Which type seems to be the best insulator?

DATA TABLE 1

INSULATION FROM ABSORPTION OF RADIANT ENERGY

TIME (MIN.)	* TEMP. C	* TEMP. C	CONTROL TEMP. C
0			
2			
4			
6			
8			
10			
12			
14			
16			
18			
20			

*WRITE IN THE INSULATING MATERIAL THAT YOU USED.

DATA TABLE 2

INSULATING AGAINST HEAT LOSS

TIME (MIN.)	* TEMP. C	* TEMP. C	CONTROL TEMP. C
0			
2			
4			
6			
8			
10			
12			
14			
16			
18			
20			

*WRITE IN THE INSULATING MATERIAL THAT YOU USED.

Curriculum Topic

REFLECTION OF SOLAR ENERGY

Energy Topic

ENERGY CONCEPT
ENERGY SOURCES

Grade Level(s) 7 - 12

Site School

Skills

- Read an electric meter or pyranometer
- Record data

Credit

U.S. Department of Energy
Solar Energy Education Project

Objective

At the completion of this activity you should be able to:

1. Demonstrate that solar energy can be reflected.
2. Construct a definition for reflection of solar energy.
3. Compare the amounts of solar energy reflected by different materials of a given set.
4. Name those materials of a given set which are the best and those which are the poorest reflectors of solar energy.
5. Use a solar detecting device.

To The Teacher

This activity is intended to help students gain the knowledge and insight into the basic characteristics of solar energy that will enable them to understand solar design. It should help them understand why such items as solar collectors are designed as they are, and it should also enable them to select materials and designs for their own solar activities. This activity examines reflection of solar energy; two others will examine the properties of absorption and transmission.

A solar cell pyranometer can easily be made by connecting a solar cell to a milliammeter or to a galvarometer. Since the main purpose of this activity is to compare relative amounts of energy reflected and not to measure these amounts, there is no need to calibrate such a "home-made" instrument. (Perhaps it would be better named a solar cell comparometer.) Since the same meter is used to take all of the readings, and since the readings are used only to compare the solar energy reflected by different samples, the numbers alone are enough to tell the story. The higher the reading on the pyranometer, the greater the amount of solar energy reflected and the lower the reading, the smaller the amount.

Before You Begin

1. If your school does not have a pyranometer, one can easily be made.

   a. A solar cell, 1cm x 1cm, delivering 22 miliamps at .45V. This will probably have to be ordered, so allow time for delivery.

   b. A milliammeter, range 0-15 milliamperes, D.C. or a galvanometer. These items are probably available from the supply cabinet.

2. To construct this "solar cell pyranometer", simply connect the leads from the solar cell to the terminals of the milliammeter or the galvanometer. You may want to secure the cell to the side of the meter with masking tape, since the wires attached to the solar cells can easily be separated from the cells.

3. A thermometer whose bulb is covered with copper plate painted with flat black paint can also be used. (See activity constructing a solar pyranometer)

4. One class period to perform the activity and answer questions. One-half class period to discuss the investigation.

5. If enough pyranometers are available then it is suggested that students work in small groups (3 or 4 students) to perform the investigation.

6. Another possibility is to do this activity in conjunction with the two others in this group, "Exploring Basic Properties", and to set up a few stations within the room for each activity. This would help to reduce equipment demand. Given adequate time to perform the activities at one station, each group could then move onto another station.

7. When the activity is completed, the class as a whole can compile lists of materials which reflect or do not reflect solar energy, and place the materials in order from best to poorest reflectors. At this time any discrepancies between individual and class data can be discussed, as can the questions at the end of the activity.

8. Due to weather uncertainties, this investigation is designed to be carried out in artificial light if necessary. A 200 watt incandescent lamp with a reflector will perform just as effectively as sunlight.

Words To Know

reflection (as applies to solar energy), pyranometer, galvanometer, milliampere, milliammeter

Related Activities

- Try some other materials to see whether or not they reflect solar energy and whether they are good or poor reflectors.

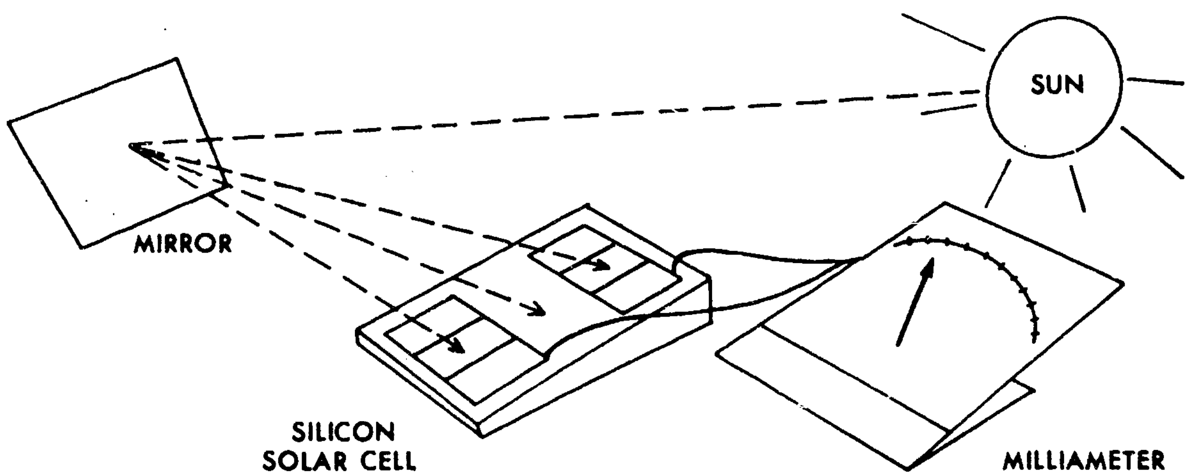
- How would you design a house that uses solar energy for heat in the winter and that keeps out solar energy for coolness in the summer? (Answer in detail.)

Notes To Myself

STUDENT PAGE

MATERIALS

- A pyranometer, or a solar cell connected to a galvanometer or milliammeter.
- Squares, 5 centimeters on a side, of flat glass mirror, flat metal mirror, aluminum foil, flat glass, black construction paper, various colored construction paper, white typing paper, pans of water, dark dry soil, sand, concrete pavement, grass, a large green leaf.
- 200 watt incandescent lamp and reflector, with clamp.
- Ring stand (The last two items are for those students who are unable to do this activity in sunlght.)



METHOD

1. Place the first material to be tested flat on a table top in the sun. Place the pyranometer close to this material, on the opposite side from the sun, and in such a position that the solar cell is receiving the reflection from this material. Position the pyranometer so that it shows almost a full-scale deflection or so that it receives as much reflected light from the test material as possible. (An artificial light may be substituted for the sun if necessary.)

2. Leave the pyranometer in this same position for the rest of the activity.

3. Remove the test sample and replace it in turn with each one of the test materials.

4. Record the reading for each material in the data table.

5. Arrange these materials in order from the best reflectors to the poorest and place on data table.

6. Arrange construction paper colors from the best reflectors to the poorest and compare the results.

DATA TABLE

MATERIAL	READING	MATERIAL	READING
FLAT GLASS MIRROR	______	WHITE TYPING PAPER	______
FLAT METAL MIRROR	______	PAN OF WATER	______
ALUMINUM FOIL	______	DARK DRY SOIL	______
FLAT WINDOW GLASS	______	SAND	______
CONSTRUCTION PAPER		CONCRETE PAVEMENT	______
BLACK	______	GRASS	______
RED	______	LARGE GREEN LEAF	______
GREEN	______		
BLUE	______		
YELLOW	______		

QUESTIONS

1. Of the materials tested, name the three best reflectors.
2. Of the materials tested, name the three poorest reflectors.
3. Of the materials tested, were there any that did not reflect at least some solar energy?
4. What probably happened to the solar energy which was not reflected?
5. How could you use what you've learned about the reflection of solar energy to get maximum heating of your house from solar energy/

Curriculum Topic

TRANSMISSION OF SOLAR ENERGY

Energy Topic

ENERGY SOURCES
ENERGY CONCEPT

Grade Level(s) 7 - 12

Site

School, outside, in classroom with heat lamp

Skills

- Read an electric meter or pyranometer
- Record data

Credit

U.S. Department of Energy
Solar Energy Education Project

Objective

At the completion of this activity you should be able to:

1. Identify and name those materials of a given set which will transmit solar energy and those which will not.

2. Demonstrate that solar energy passes through some materials but not through others.

3. Compare the transmission of solar energy through different materials by using a solar cell and a sensitive electric meter.

4. Construct a hypotheses explaining how some materials are able to transmit solar energy and others are not.

To The Teacher

This activity is intended to help students gain the knowledge and insight into one of the basic characteristics of solar energy that will enable them to understand solar design. It should help them understand why such items as solar collectors are designed as they are, and it should also enable them to select materials and designs for their own solar activities.

A solar cell pyranometer can easily be made by connecting a solar cell to a milliammeter or to a galvanometer. Since the main purpose of this activity is to compare relative amounts of energy transmitted and not to measure these amounts, there is no need to calibrate such a "home-made" instrument. (Perhaps it would be better named a solar cell comparometer.) Since the same meter is used to take all of the readings, and since the readings are used only to compare the solar energy transmitted by different samples, the numbers alone are enough to tell the story. The higher the reading on the pyranometer, the greater the amount of solar energy transmitted and the lower the reading, the smaller the amount that is transmitted.

Use of a galvanometer attached to a solar cell may create too sensitive an instrument when the solar cell is angled directly into the sun. This may cause more than a full scale reading on the galvanometer when using the best transmitting materials. If this occurs, the solar cell should be deflected from the sun just enough to give a full-scale reading with the best transmitters.

Solar cells are highly efficient silicon semi-conductor devices which convert light directly into electricity. When exposed to light, each cell produces approximately the same voltage between its two terminals. When a load is connected between the two terminals, the voltage difference causes a flow of current. This current is caused by the formation of "hole-electron pairs" by the absorbed light photons. Accordingly, the amount of current will depend on the amount of absorbed light, which, in turn, is dependent on the incident light intensity as well as the surface area of the solar cell. (Solar cells may be interconnected in series to provide higher voltage, in parallel to produce more current, or both.)

Before You Begin

1. If your school does not have a pyranometer, one can easily be made.

   a. A solar cell, 1cm x 1cm, delivering 22 ma at .45V. This will probably have to be ordered, so allow time for delivery.

   b. A milliammeter, range 0-15 milliamperes, D.C. or a galvanometer. These items are probably available from the supply cabinet or ask the physics teacher.

2. To construct this "solar cell pyranometer", simply connect the leads from the solar cell to the terminals of the milliammeter on the galvanometer. You may want to secure the cell to the side of the meter with masking tape, since the wires attached to the solar cells can easily be separated from the cells.

3. One class period to perform the activity and answer questions. One-half class period to discuss the investigation.

4. If equipment is limited then this activity is best done as a teacher demonstration.

5. If enough pyranometers are available, then it is suggested that students work in small groups (3 to 4 students) to perform the investigation.

6. When the activity is completed, the class as a whole can compile lists of materials which transmit or are opaque to solar energy, and place the materials in order from best to poorest transmitters. At this time any discrepancies between individual and class data can be discussed, as can the questions at the end of the activity.

7. Due to weather uncertainties, this investigation is designed to be carried out in artificial light if necessary. A 200 watt incandescent lamp with a reflector will perform just as effectively as sunlight.

Words To Know

pyranometer, galvanometer, milliammeter, transparent, translucent, opaque, transmitter (as applies to solar energy)

Related Activities

- Repeat the investigation using materials other than those given or try using combinations of materials in the set given. For example, you might try combinations of the colored plastic sheets - red and blue, red and yellow, blue and yellow, etc. Compare this data with your original data.
- Construct an experiment to determine if reducing the glass area of a car parked in the sun on a warm day has any effect on the temperature inside the closed car.

Notes To Myself

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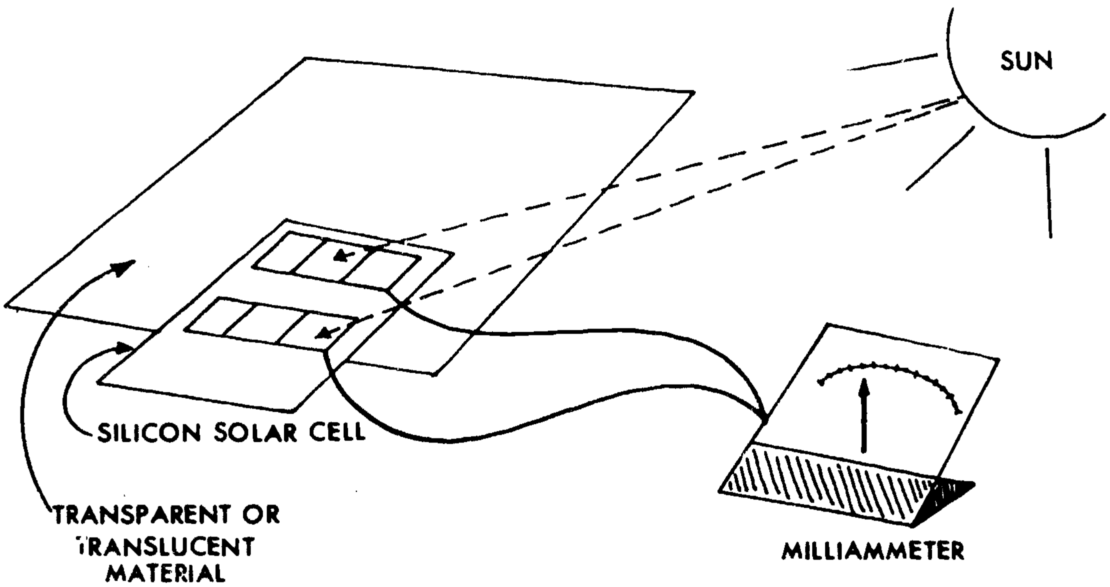
STUDENT PAGE

MATERIALS

- Pyranometer, or a solar cell connected to a galvanometer or milliammeter.
- Squares, 5 centimeters on a side, of window glass, plastic sheets (clear, red, blue, yellow and green), waxed paper, frosted glass, tissue paper, composition paper, cardboard, wood, aluminum foil, copper sheeting, a mirror, a leaf; containers of dark soil and of water, a pair of eye glasses, and a pair of sunglasses.
- 200 watt incandescent lamp and reflector with clamp.
- Ring stand (The last two items are for those pupils who are unable to do this activity in sunlight.)



METHOD

1. Position the solar cell of the pyranometer facing the sun (or the incandescent lamp) so that the meter shows almost a full scale deflection (maximum reading).

2. Record this reading as the initial or beginning reading in the data table.

3. Leave the pyranometer in this same position for each reading of the set of materials being investigated.

4. Hold each piece of material in turn over the solar cell of the pyranometer.

5. Record the reading for each material in the data table.

6. Group the materials into two groups:

a. Those materials which allow at least some solar energy to pass through according to the meter. Arrange these materials in order from the best transmitter to the poorest.

b. Those materials which allow no solar energy to pass through according to the meter.

7. Identify those variables (factors which may influence an experiment) which you think might have affected the reading of the meter. Make plans to control these variables and repeat the investigation. Compare the results.

DATA TABLE

INITIAL READING ______________________________

MATERIAL	READING	MATERIAL	READING
WINDOW GLASS	____________	CARDBOARD	____________
PLASTIC SHEETS:		WOOD	____________
CLEAR	____________	ALUMINUM FOIL	____________
RED	____________	COPPER SHEETING	____________
BLUE	____________	MIRROR	____________
YELLOW	____________	LEAF	____________
GREEN	____________	CONTAINER OF:	
WAXED PAPER	____________	DARK SOIL	____________
FROSTED GLASS	____________	WATER	____________
TISSUE PAPER	____________	EYE GLASSES	____________
COMPOSITION PAPER	____________	SUNGLASSES	____________

QUESTIONS

1. Why was the pyranometer left in the same position for all the readings in the investigation?

2. According to your results, which materials are good transmitters of solar energy? Which are poor transmitters?

3. Name those materials tested which do not transmit solar energy.

4. Construct a definition for the word "transmit" as it applies to solar energy.

5. Define the words "transparent", "translucent", and "opague".

6. Name several materials which are transparent, several which are translucent, and several which are opaque to solar energy.

7. In building a house, where are materials used which transmit solar energy? Explain.

8. In building a house, where are materials used which are opaque to solar energy? Explain.

Curriculum Topic

SUNLIGHT AND SURFACE HEATING EFFECTS

Energy Topic

ENERGY CONCEPT
ENERGY SOURCE

Grade Level(s) 7 - 12

Site School - outdoors

Skills

- Measure distance with a meter stick
- Read a thermometer
- Record data on a table
- Graph data

Credit

U.S. Department of Energy
Solar Energy Education Project

Objective

At the completion of this activity, you should be able to:

1. Set up the heat transfer apparatus on appropriate ground surfaces so as to reduce the effects of wind, direct sunlight or reflecting surfaces.

2. To explain the effect of various surfaces on the surrounding air temperature.

3. To explain the effects of cloud cover on temperature distribution.

4. To explain the reasons behind local air circulations.

To The Teacher

The purpose of this activity is to demonstrate the air warming effects of different surfaces. With knowledge of the effects you can then explore with students the effects of insolation on the earth, such as wind, thermals, cloud formation, mirages, and temperature inversions.

The meter stick in the experiment acts to shield the thermometers from direct heating but is small enough in extent to have minimal influence on the air temperature in its vicinity. Therefore one may satisfactorily assume that the heating measured is purely from conductive and convective influences of the surface. Low air circulation in terms of wind or breezes is essential if the gradient is to be observable.

To understand what happens in this experiment, one must know that when sunlight strikes a material, some of it is changed to heat. Some of the heat is absorbed by the material and some is reflected as infrared radiation. One of the results of this is the warming of the air above the surface. The amount of warming depends on several factors which include: (1) how much radiant energy is absorbed and how much is reflected, (Dark substances are better absorbers than light ones, and water is a better reflector.) (2) what the specific heat of the absorbing substance is, and (3) what the wavelength of the radiant energy is, since some wavelengths are absorbed better than others by certain substances.

In this activity it should be discovered that the amount of heat re-transmitted is sufficient from paved surfaces to produce a 5 celsius degree temperature rise at 10cm over the surface. Reduced heating is also visible for approximately a half meter up. The other substances will offer smaller temperature changes.

Before You Begin

1. The sticks may be produced directly by boring meter sticks but results can be achieved by obtaining wood sticks of the same size as a meter stick and drilling 6 holes 10cm apart.

2. Have each group of students collect data over a different kind of surface and then discuss the results. Be sure that the students are familiar with factors that are extraneous to the procedure but will influence the data. For instance, cloud cover changes, shadow zones, reflection from nearby buildings onto the ground surfaces, etc.

3. One period (45 minutes) for collection of data over one surface. Further time may be used to collect data over other surfaces and also to discuss the results.

4. Establish as many groups as the available thermometers allow. You will need 5 thermometers per group.

5. Have the apparatus prepared before class except for insertion of the thermometers.

6. Have each group of students collect data over a different kind of surface and then discuss the results. Be sure that the students are familiar with factors that are extraneous to the procedure but will influence the data. For instance, cloud cover changes, shadow zones, reflection from nearby buildings onto the ground surfaces, etc.

Words To Know

conduction, convection, long wave radiation, short wave radiation, radiant energy.

Resources

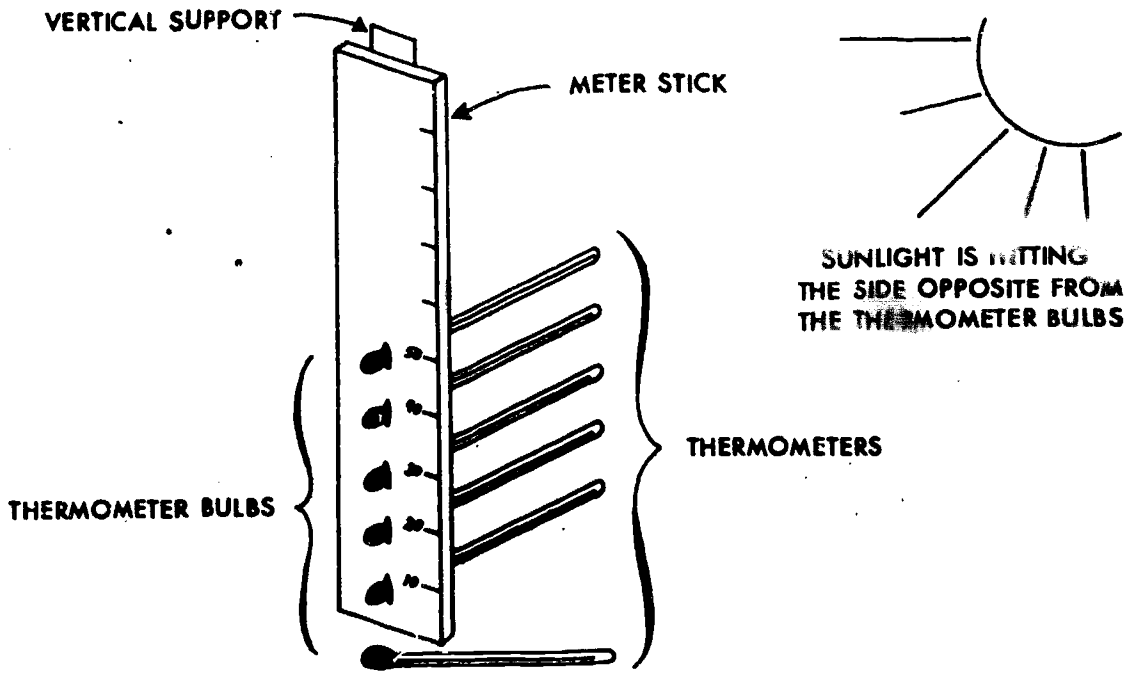
THE FLYING CIRCUS OF PHYSICS, Jearl Walker (New York: Wiley) 1977.

Notes To Myself

STUDENT PAGE

MATERIALS

- Meter stick or similarly marked length of wood with holes at 10cm intervals.
- 5 or 6 thermometers.
- Masking tape.
- Vertical support device such as a music stand or photographic camera tripod.
- Timing device.



METHOD

1. Fasten the meter stick to the vertical support with rubber bands, tape or clamps.

2. Insert the thermometers into the meter stick, securing them with tape.

3. Place the apparatus on the surface to be tested so that the thermometer bulbs are shaded from direct sunlight by the shadow of the meter stick. (See Figure 1)

4. Record the air temperature in the shade with a separate thermometer. (Hold your hand above the thermometer to provide shade, if necessary.) Then place this thermometer on the ground below the thermometers in the apparatus.

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5. After the apparatus has been set up for 15 minutes record the temperatures of each thermometer, including the one on the ground, in the data table in trial 1. See table below.

6. At the end of another 15 minutes record the temperature of each thermometer in the data table under trial 2.

7. If time permits, repeat procedures 3, 4, 5 and 6 over different types of ground surfaces such as grass, pavement, and bare ground.

8. Plot a graph of temperatures vs. height for the first trial with a blue line. On the same graph plot the temperatures for trial 2 in another color.

9. Plot a similar graph for each ground surface tested.

Type of Surface ____________________

Height above ground (cm)	Temperature °C	
	Trial 1	Trial 2
0		
10		
20		
30		
40		
50		

QUESTIONS

1. According to your graphs where was the air temperature the highest? Why do you think this was so?

2. How do the data collected over all of the surfaces compare with the temperature taken in the shade?

3. What factors influence the amount of heat produced at different heights over the surfaces?

4. Does the effect of time produce significant change in the air heating?

Curriculum Topic

THE GREENHOUSE EFFECT

Energy Topic

ENERGY USES,
ENERGY AND THE ENVIRONMENT

Grade Level(s) 9, 10

Site School

Skills

- Read a thermometer
- Graph data using a simple line graph
- Know what is meant by wavelengths

Credit

U.S. Department of Energy
Solar Energy Education Project

Objective

At the completion of this activity you should be able to:

1. Construct a simple apparatus to show the greenhouse effect.
2. Make some comparisons between your apparatus and the earth.
3. Collect data from thermometer readings and record them in a table.
4. Represent your results in the form of a line graph.

To The Teacher

The earth receives energy of varying wavelengths from the sun. These waves make up part of the electromagnetic spectrum. This spectrum includes visible light which ranges from red light with long wavelengths to violet light with shorter wavelengths. Ultraviolet rays are invisible rays lying beyond violet light in the spectrum and these ultraviolet rays have even shorter wavelengths. These rays can give you a suntan. Having longer wavelengths than the visible red light are the infrared rays. These are the rays which make sunlight feel warm to you.

When sunlight passes through the atmosphere some of it may be absorbed by particles of dust and molecules of gas before it hits the earth. The remaining sunlight may be absorbed by substances on the earth's surface, such as rocks, soil, water, and plants. These objects then radiate this energy as longer wavelength infrared rays back into the atmosphere. These rays can be trapped in the atmosphere as heat. This is the greenhouse effect.

One only has to compare a clear winter night which is very cold to a cloudy winter night which is mild to illustrate the effect of atmosphere on heat retention near the land surface.

On a global average, the greenhouse effect causes temperatures to increase from -19°C at the top of the atmosphere to 15°C at the surface of the earth.

The greenhouse effect is obviously based on the similar fact that when sunlight passes through the glass of a greenhouse the shorter visible wavelengths are absorbed by such things as plants and soil in the interior. This light is then changed to light of longer wavelengths, infrared. This heat energy is then trapped because the longer wavelengths cannot pass back out. The temperature inside the greenhouse rises.

Some practical knowledge of this effect can be extended to everyday life. For example, closed automobiles heat up when the sun shines through the windows, curtains opened in winter let sunlight into houses, floral greenhouses retain heat, and solar collectors heat domestic hot water.

Before You Begin

1. One class period to explain the experiment, discuss the electromagnetic spectrum, and set up the experiment.

2. One to two class periods to complete the activity.

3. Pass out the lab sheets a day in advance so that students will be familiar with their responsibilities in the activity. Discuss the electromagnetic spectrum, and allow students to set up their equipment.

4. Divide the class into groups of 2 or 3. (This is provided you have enough materials). Students can take turns timing, reading, and recording.

Words To Know

electromagnetic

spectrum

ultraviolet

Related Activities

- If you do not have enough time, have some groups of students do the experiment without the lid and some do it with the cover. Then compare the results.
- Students may wish to try other kinds of covering such as white cloth or wax paper.
- Try outside with the sun as the heat source.

Resources

- SOLAR ENERGY, William W. Eaton, (Washington: Department of Energy), 1976.

Notes To Myself

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STUDENT PAGE

MATERIALS

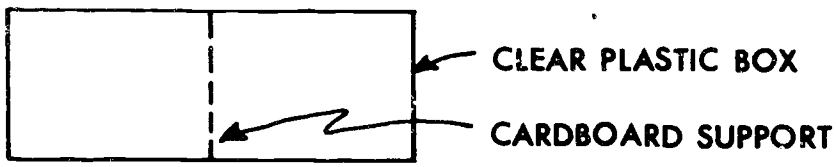
- 1 standard laboratory thermometer (-10°C to 110°C).
- 1 clear plastic box or aquarium with cover.
- Outdoor reflector flood lamp, and mounting stand.
- Soil and water.
- Cardboard support on which to lean the thermometer.

METHOD

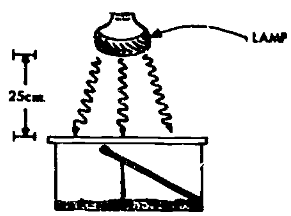
1. Place about 2cm of soil in the bottom of the clear plastic box. Thoroughly moisten the soil with water.

2. Cut out a piece of cardboard so that when inserted in the box, it will divide the box in half. The cardboard should not quite reach the top of the box.

TOP VIEW



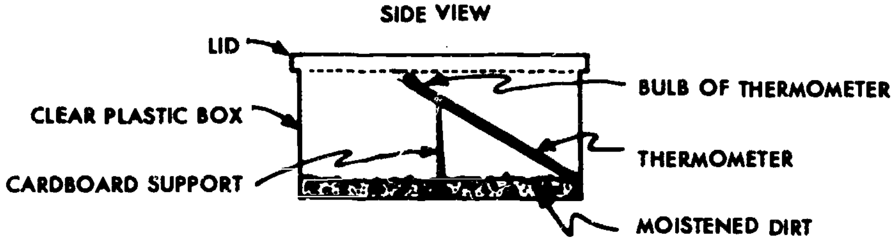
3. Lean the thermometer against the cardboard support with the bulb end up.



4. Put the box and lamp in a part of the room where the effects of direct sunlight, heating and cooling systems, and drafts will be reduced.

5. Put the lamp directly over the thermometer bulb at a distance of about 25cm. Put the lid on the box.

SIDE VIEW



6. Record the thermometer reading for 0 minutes on the data table for the covered box.

7. Turn on the light.

8. Record in your data table the temperature every minute for a total of 15 minutes.

9. At the end of 15 minutes turn off the light, remove the lid and allow the thermometer to return to room temperature.

10. Repeat the procedure with the uncovered box and record all your temperatures in the data table.

11. Plot the data from the covered and uncovered box on the same graph. Use different colors to represent each one. Compare your results.

QUESTIONS

1. In which box did the temperature rise the most?

2. Explain how this activity shows the greenhouse effect.

3. How does this activity relate to the greenhouse effect on the planet earth itself. a) What part of the box represents the earth's surface? b) What part of the box represents the earth's atmosphere?

4. How could air pollutants disturb the greenhouse effect?

5. Describe an experiment that you could do to see how different coverings would affect the temperature change.

6. Could the greenhouse effect ever be harmful?

7. Use a book on solar energy to find out the parts of a solar panel. How is the greenhouse effect related to the panel's construction?

8. In what ways is this activity different from the greenhouse effect on the earth?

Curriculum Topic

VARIATION OF THE SUN'S INTENSITY

Energy Topic

ENERGY THE CONCEPT
ENERGY SOURCES

Grade Level(s) 7 - 9

Site School

Skills

- Collect, record and graph data
- Compute mathematical values using a simple proportion

Credit

U.S. Department of Energy
Solar Energy Education Project

Objective

At the completion of this activity you should be able to:

1. Use the model apparatus to determine light intensity at various positions.

2. Compare the workings of the apparatus to the way the radiation from the sun actually strikes the earth.

3. Determine at what position the intensity is maximum, and at what position it is minimum.

To The Teacher

The earth is warmed by the insolation it receives. Even though the sun emits a constant amount of energy (2 calories/centimeter square/minute or 429 BTU/s square foot/hour), the intensity of the solar radiation falling on any portion of the earth's surface is not constant.

There are two reasons why the radiation falling on a horizontal surface varies with the elevation of the sun. First, when the sun is low on the horizon, its radiation passes through a thicker layer of the atmosphere than when the sun is overhead. Secondly, when the sun is low in the sky, its radiant energy is spread over a larger area of the earth's surface than when it is high, so that the radiation per unit area is less.

The average insolation per unit area falling on the earth's surface each year is greatest at the equator and smallest at the poles. This is due to the angle at which the sun strikes the earth. As a result of this distribution of insolation, the average annual temperature of the earth's surface and the air near the ground decreases from the equator to the poles.

This activity should serve as the lead activity to investigations relating to solar energy. A basic understanding of the factors that affect the intensity of the sun at a given point on the earth's surface makes it possible for us to collect and make efficient use of the sun's energy.

Before You Begin

1. Several weeks before the activity is planned, purchase materials needed and seek help from the industrial arts teacher in putting the apparatus together.

2. Build several models.

3. Two to four class periods for collecting, graphing, and interpreting data.

4. Have several models built in advance. See the diagram for model specifications.

5. Divide the class into several groups. Have each group experiment with different bar elevations to simulate intensity at different latitudes.

6. The various career opportunities in the field of solar energy could be explored by:

   1. Researching literature pertaining to solar energy.
   2. Guest speakers brought into the classroom.
   3. Obtaining hand-out material from the Department of Energy or your State Energy Office.

Words To Know

insolation, solar constant, B.T.U.

Related Activities

- The apparatus serves as an excellent model of the earth-sun system. If atmospheric conditions are not conducive to collection of data this model will serve the same purpose.
- The circular board can be moved to simulate the sun during the different seasons.

Resources

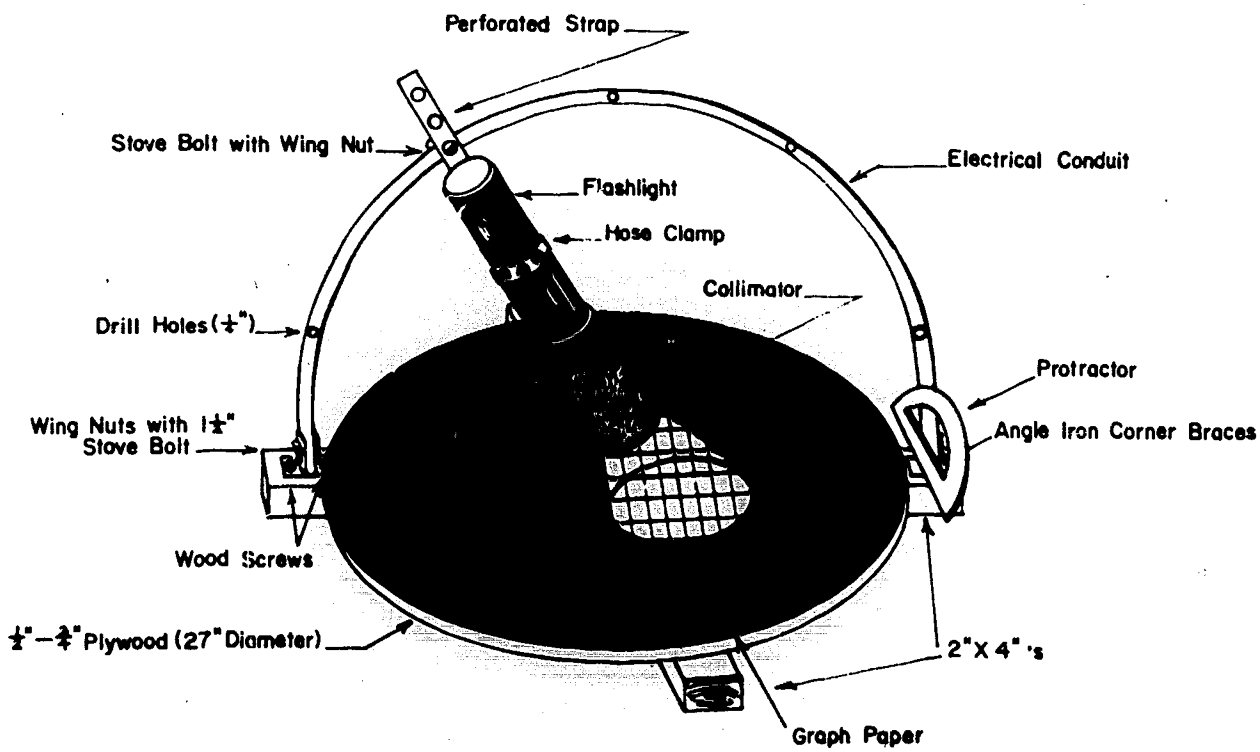
- WORKBENCH, ENERGY ANSWERS, Tom Dean, Modern Handcraft, Kansas City, Missouri, September-October 1977, pp. 30, 60-61.
- INTERMEDIATE MINIMUM PROPERTY STANDARDS FOR SOLAR HEATING AND DOMESTIC HOT WATER SYSTEM, Volume 5, United States Department of Housing and Urban Development, Washington, D.C. 1977, pp. C-6, C-9.

Notes To Myself

STUDENT PAGE

MATERIALS

- A circular piece of 1/2 to 3/4 inch plywood cut to 27" diameter.
- A light source (flashlight, etc.)
- A protractor
- A five-foot length of 1/2 inch diameter thin-wall electrical conduit. Must be shaped into a semi-circle.
- Two 3-foot pieces of two-by-four.
- Four wood screws
- Three 1/4-inch round head screws with wing nuts.
- One plastic column tube clamp.
- One six-inch piece of perforated band strap. (Can be purchased at a plumbing supply house).
- Graph paper
- Piece of cardboard for collimator



METHOD

1. Obtain the apparatus from your teacher.

2. Using the graph paper supplied to you by your teacher, tape the graph paper to fit the configuration of the circle as shown in the diagram.

3. Set the elevation of the glide bar at 90° and set the light source at position 1 marked on the bar. Be sure to tighten the wing nuts and attach the collimator to the light source.

4. With the bar at 90° and the light at position 1, turn the light on. Count and record the number of squares (to the nearest whole square) the light covers at position 1. Record in the data sheet.

5. Keeping the bar at 90° and the light at position 1, turn the light on. Count and record the number of squares the light covers at the other positions marked on the bar. Be sure to orient the light so that it strikes the center of the circle.

6. Change the elevation of the bar to 42° and repeat the procedures #4 and #5.

7. Change the elevation of the bar to 23° and repeat procedures #4 and #5.

8. Using the following relationship compute the intensity of the light for each light setting marked on the bar.

$$\text{INTENSITY} = \frac{\text{NUMBER OF SQUARES COVERED AT THE 3 POSITION}}{\text{NUMBER OF SQUARES COVERED AT THE OTHER POSITIONS}}$$

9. Graph the following relationships:

   a. Light position vs. number of squares covered.
   b. Light position vs. intensity.

QUESTIONS

1. At what light setting was the intensity the greatest? Why?

2. At what light setting were the greatest number of squares covered? Why?

3. At what bar elevation were the greatest total number of squares covered by the light? Why?

4. Using your graph, describe the relationship between the position of the light and intensity.

5. Using your graph, describe the relationship between the elevation of the bar and the light's intensity.

6. What comparisons can you make between this activity and the real world?

DATA TABLE

PROTRACTOR READING ________°

BAR SETTING	# OF SQUARES	INTENSITY
1		
2		
3		
4		
5		

PROTRACTOR READING ________°

BAR SETTING	# OF SQUARES	INTENSITY
1		
2		
3		
4		
5		

PROTRACTOR READING ________°

BAR SETTING	# OF SQUARES	INTENSITY
1		
2		
3		
4		
5		

Curriculum Topic

THE SUN'S POSITION IN THE SKY

Energy Topic

ENERGY THE CONCEPT
ENERGY SOURCES

Grade Level(s) 7 - 12

Site School

Skills

- Measure angles with protractor
- Read and use a magnetic compass
- Graph data

Credit

U.S. Department of Energy
Solar Energy Education Project

Objective

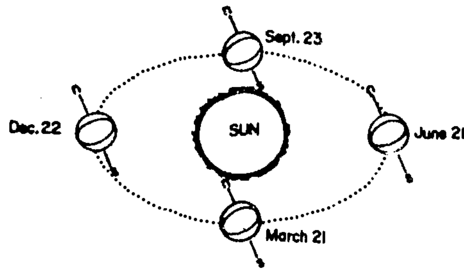
At the completion of this activity, you should be able to:

1. Measure the angle that the sun's rays make with the ground at any time of day.

2. Use published solar position tables to find the sun's altitude and azimuth at any given time and location.

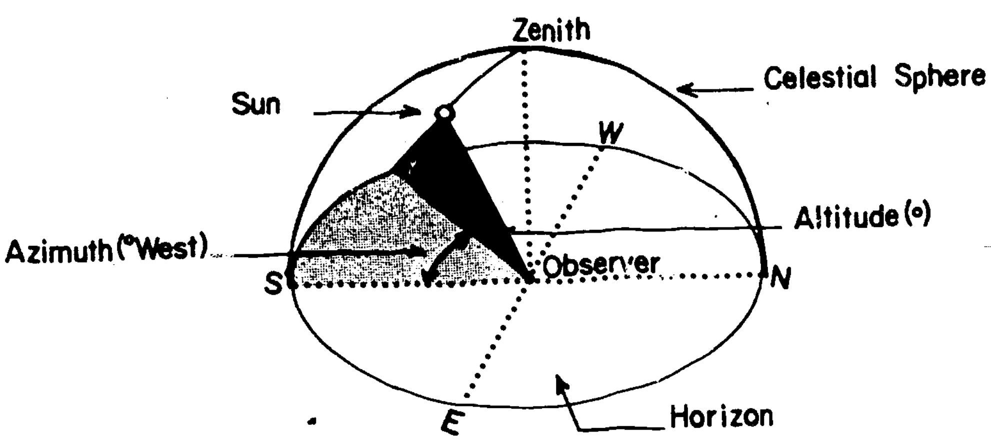
To The Teacher

Perhaps the most fundamental information needed by the solar energy experimenter is solar position and intensity data. The apparent position of the sun changes throughout the day as a result of the earth's rotation about its axis. The sun appears to rise each day in a generally eastern direction and sets in a generally western direction. As the earth revolves about the sun during the course of the year, the exact path that the sun appears to take changes. This is a result of the fact that the earth's rotational axis is titled $23\frac{1}{2}^{\circ}$ with respect to a line drawn perpendicular to the plane of the earth's orbit about the sun. Only twice a year then, around March 21 (the vernal equinox) and September 23 (the autumnal equinox), does the sun appear to rise directly at the east point and set directly at the west point. The sun reaches the lowest point (at noon) in the southern sky December 22 (winter solstice) and the highest point June 21 (summer solstice).



Several systems of coordinates are used to describe the position of celestial bodies. One, which is quite similar to the equatorial system of longitude and latitude on earth, makes use of the "celestial sphere" with star position measured in terms of "right ascension" and declination. Generally, however, the more straightforward horizon system, similar to that used by navigators or surveyors, is used by those working in the solar energy field. The position of the sun is described in terms of its altitude (angle) and its azimuth (angle).

The altitude of the sun is determined by measuring the angle between the observer's line of sight to the sun and the horizon (the horizontal plane of the observer). The azimuth measurement used by solar energy workers is slightly different than that used by surveyors. The azimuth is the angle measured between the N-S line and the projection of the line of sight onto the horizontal plane. The angle is measured between the S horizon point and the projection on the horizontal plane of the line of sight to the sun. The azimuth will therefore be a measurement in degrees E (in the morning) or of degrees W (in the afternoon). (In the surveyor's system, all measurements of azimuth are made by measuring the angle clockwise from the N horizon point and can have the values from 0° to 360°).



In this discussion, the directions referred to are the geographical rather than the magnetic compass directions. Since the north magnetic pole does not correspond with the true or geographical pole, corrections to compass readings must be made to correct for the magnetic declination at any given locality. The magnetic declination is the angle between the direction the compass needle points and true north; values for magnetic declination can be found on local topographical maps or in tables in most physics reference books.

At 12 o'clock noon, sun time, the sun would be located somewhere along the imaginary line that passes through the N-S points and your zenith. However, 12 o'clock sun time does not correspond to 12 o'clock standard time. For this reason, the sun's shadow does not fall exactly along a line running north and south at 12:00 noon (clock time). Correction can be made for local time as follows:

> There are 24 time zones extending around the earth, these extend over 360°. Each time zone covers approximately 15° of longitude (360° - 24). This means that 1° of longitude corresponds to a time difference of 4 minutes. 15° = 1 hr. = 60 minutes therefore, $1^{\circ} = \frac{60}{15}$ minutes = 4 minutes.

Longitude is measured westward from the prime meridian at Greenwich, England. Therefore, longitudes of 0°, 15°, 30°, 45°, 60°, 75° etc. correspond to the center of each time zone. The center of the eastern time zone is the meridian with a longitude of 75°. Add or subtract 4 minutes to the time for every degree of longitude that you are east or west of the center of your time zone.

Example: Your clock reads 10 o'clock eastern standard time. Your longitude is 80°. This is 5° west of the 75th meridian where it is actually 10 o'clock. Subtract 5 degrees x 4 minutes/degree = 20 minutes. It is 4:40 sun time at your locality. The sun will not be on your meridian until 10:20 a.m. (clock time). For very precise measurements an additional correction can be applied to correct for the fact that the sun is sometimes ahead of clock time by a few minutes and other times behind clock time. This correction, known as the "equation of time", can amount to as much as 16 minutes at certain times of year. Graphs or correction tables can be found in most college astronomy textbooks under "Equation of Time". This variation is caused by the eccentricity of the earth's orbit and the obliquity of the ecliptic, the annual path of the sun in the sky.

In this activity, the board must be oriented in some direction. In general, the students appear to be able to handle magnetic north-to-true north corrections more readily than those involving solar time-clock time. Perhaps the simpliest procedure is to have students merely align the boards in a magnetic north-south direction. After all, lot descriptions and building orientations are likely to be done in terms of magnetic compass bearings; but be prepared to tackle the inevitable question, "Why doesn't the shadow lie north-south at 12 o'clock noon?" Most solar position tables are given in terms of solar time and angular measurements from true south; student data will not agree with published data unless these references are used.

Before You Begin

1. All materials necessary are likely to be readily available.

2. Peg board stands are common in many classrooms with holes to accept 3/8" dowels. (size not critical) Have extra dowels on hand.

3. Solar insolation data are available from your nearest United States Weather Bureau Office.

4. Two days.

   a. Day One: Introduction, set up, initial data.
   b. Day Two: Plotting data, comparing results, interpretation.

5. Work in teams of two students.

6. For continuing data collection, get volunteers from each class to take data on a semi-monthly basis. One person may wish to act as a coordinator of the project. A permanent set-up might be made outside of the classroom for collection of this additional data.

Words To Know

altitude, celestial sphere, azimuth, azimuth ascension, declination, solstice, ecliptic, prime meridian.

Related Activities

- "A passive solar house", "A Solar Installation Site Plan", "Tracking the Sun by Computer", "Roof Overhang and Solar Window".

Resources

PRINCIPLES OF ASTRONOMY, Stanley Wyatt, (Allyn and Bacon, Boston), 1964, pp. 545.

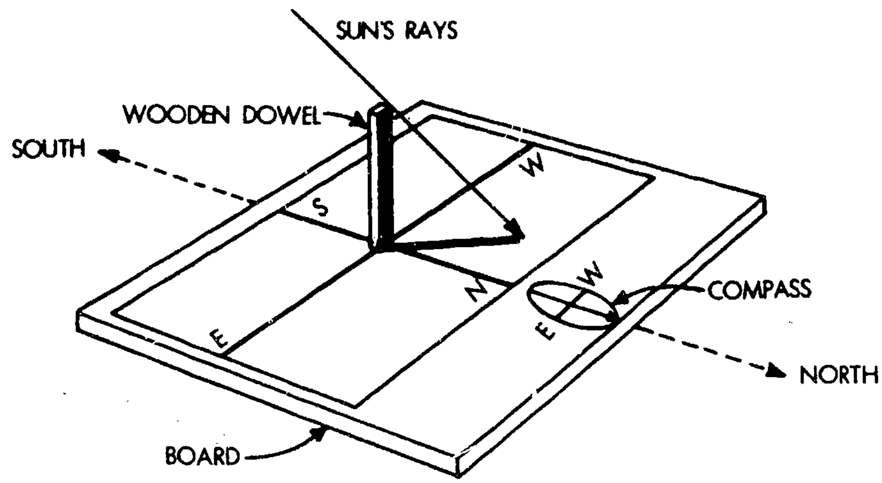
SOLAR ENERGY EXPERIMENTS, Thomas Norton, (Rodale Press, Emmans, Penn.), 1977, pp. 129.

Notes To Myself

STUDENT PAGE

MATERIALS

- A small peg board.
- 3/8 inch wood dowels.
- A magnetic compass.
- A bubble level.
- A clock or watch.
- Paper, pencil, straight edge, and a protractor.



METHOD

1. Locate the mid-point of one long edge of the pegboard and place the dowel into the hole 6 rows in from the mid-point.

2. Place a piece of paper on the board by pushing it down over the dowel.

3. Remove the paper from the board. Draw two lines on the paper, each passing through the center of the hole. One line should be parallel to the long side of the paper; the other should be parallel to the short side of the paper. In other words, these two lines are perpendicular (at right angles or 90^{o}) to each other. Mark the ends N-S, E-W (as shown in the sketch) to show the compass directions to use in lining the board.

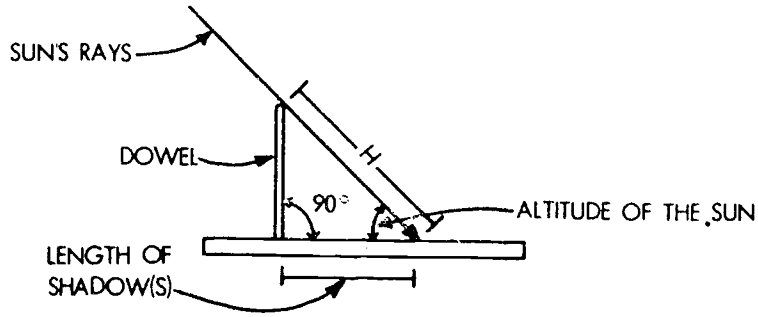
4. Set the board in a horizontal position where it will receive the direct rays of the sun most of the day. Align the board with the compass as shown in figure 1. Use the bubble level to check that the board is level. Level it if needed. (Note: Your instructor may suggest aligning the board in a different way).

5. Measure and record the height of the dowel above the top surface of the board.

6. Each 15 minutes draw a line on the paper showing the position of the shadow. Be careful to mark the end of the shadow accurately. Since the positions of the shadows are needed throughout the day, students in all classes will have to make use of each other's data. Record the time and date for each shadow drawn.

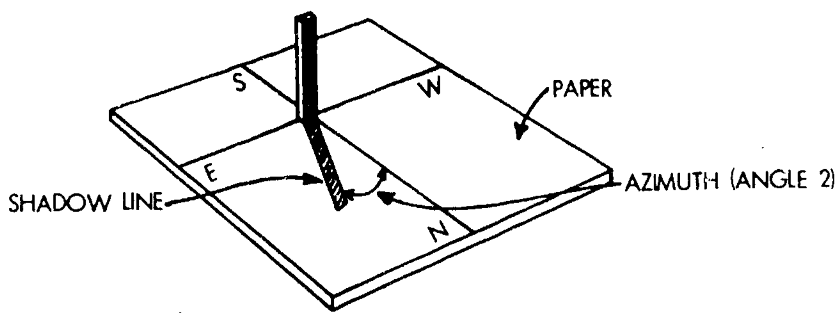
7. For each position of the shadow you will want to measure two angles:

a. The first is the angle between the shadow(s) on the paper and the slanting side (H) of the triangle as shown in the following sketch. This angle is called the altitude of the sun.



On a separate sheet of paper draw a right angle triangle such that the vertical side is equal to the dowel height and the horizontal side is equal to the shadow length. Draw line (H) and measure angle 1. Record: date, time, and altitude of the sun in degrees on the diagram.

b. The second angle tells us how much east or west of the N-S line the sun is. This angle is called the azimuth.



Measure angle 2, and record it directly on the apparatus. If the actual position of the sun is west of the N-S line (in other words, the shadow falls to the east of the N-S line) then the azimuth angle is recorded as so many degrees west. If the sun is east of the N-S line then the azimuth is recorded as a certain number of degrees east. Example: In the sketch above the azimuth might be approximately 30°W.

8. Prepare a data table for the sun's position. Include the following information:

Date:		
Time	Sun's Altitude in degrees	Sun's Azimuth in degrees

9. Since the solar energy designer needs this kind of information for the whole year, tables have been carefully prepared by scientists. Compare your data with that in published tables available from the weather bureau. Why are the tables arranged by latitude? What is the approximate latitude where you live?

QUESTIONS

1. At what time of day is the sun's shadow shortest? What does this mean?

2. Are the sun's shadows longer in summer or winter? Why?

3. It usually seems colder early in the morning than at noon; it is colder in winter than in summer. How are these facts related to what you have just learned?

4. If you wanted to collect the most energy from the sun, how would you position a solar collector? Would its position be the same in winter as summer?

5. Since most solar collectors are fixed (can't be moved) what position would you suggest they be set at? Should they face N, S, E or W? What angle with the ground do you think would be best? (Hint: When are you likely to need the most heat?)

6. How could you use the position of the sun in designing the windows in your home so you get the most benefit of the sun's energy?

7. What effect does the design of roof eaves or overhang have on the energy received by the windows in your home?

8. In landscaping your home, how might trees be used to advantage to help keep your house cooler in summer but warmer in winter? What kind of trees would you use in what position?

9. Using data on solar position, make a simple outline drawing of a house with windows showing how the sun's rays would enter at different times of the year. Show how changes in windows, roof overhang, etc. would affect the amount of direct sunlight energy received.

10. You might want to experiment with cardboard models of a house to show the effect of window size, position, and location as well as roof overhang on the amount of energy received within the interior (inside) of the house.

Curriculum Topic

TRACKING THE SUN BY COMPUTER

Energy Topic

ENERGY SOURCES
ENERGY: THE CONCEPT

Grade Level(s) 9 - 12

Site Classroom

Skills

- Use a computer terminal

Credit

U.S. Department of Energy
Solar Enegy Education Project

Objective

At the completion of this activity, the student should be able to:

1. find the altitude and azimuth of the sun for any date, location and time.

2. find the right ascension and declination of the sun for any date, location and time.

3. by use of the computer visually display a diagram of the sun's position for any date, location and time.

To The Teacher

This computer program was devised by high school students to find answers to their questions about the sun's apparent movements. A knowledge of mathematics, computer science and astronomy was necessary to devise this program. This knowledge then had to be integrated into a scientific tool. This tool could then be used in solving solar energy problems.

The students who devised this program know that the effectiveness of a solar powered device depends on its alignment to the sun. If a collector is properly aligned its effectiveness could be greatly increased. Therefore they wanted to find the sun's exact position. They knew that this position can easily be found by looking in the nautical ephemeris, but in devising a computer program many valuable lessons were learned.

This program is written in BASIC. Make sure that the computer you are using has this language available.

Before You Begin

1. The program must be entered into the schools own data storage system and therefore a program list has been supplied. The program is written in Hewlett-Packard Basic 2000 Level F.

2. Before beginning, students should be adequately instructed in the method of getting this program on the computer and told to follow carefully all instructions, given by the program.

3. If the program is to be used as an informational gathering tool it could be completed in five minutes.

4. If the program is to be used as a stimulus to the development of further programs the time allotment could be several weeks.

5. A flow chart from which this program was developed is available from the Solar Energy Education Project, c/o Bureau of Science Education, State Education Department, Albany, New York, 12234.

Words To Know

Latitude, longitude, azimuth, altitude, declination, right ascension, zenith.

Related Activities

- The program may be modified to include additional astronomical motions.

- Additional informational programs about the sun could be developed, such as, a) a program to compute the duration of sunlight on a given day at a given latitude, b) a program to compute the effectiveness of a collector in a fixed position, as the sun moves along its daily path, and during the sun's change in position throughout the year.

```
RUN
SUN
THIS PROGRAM WILL ALLOW YOUR TO CALCULATE THE RIGHT
ASCENSION, DECLINATION, ALTITUDE, AND AZIMUTH OF THE SUN
ON A GIVEN DATE
THE AZIMUTH OF THE SUN RUNS FROM 0 DEGREES AT THE SOUTH
TO 90 DEGREES AT THE EAST TO 180 DEGREES AT THE NORTH
TO 270 DEGREES AT THE WEST

WHAT IS YOUR LATITUDE IN DEGREES(+ FOR NORTH, - FOR SOUTH)?40

WHAT IS YOUR LONGITUDE IN DEGREES(+ FOR WEST, - FOR EAST)?72

TO FIND THE DESIRED INFORMATION      *      INPUT
IN THIS TIME ZONE                    *      THIS
**********************************************
GREENWICH MEAN TIME                  *      GREENWICH
EASTERN STANDARD TIME                *      EST
CENTRAL STANDARD TIME                *      CST
MOUNTAIN STANDARD TIME               *      MST
PACIFIC STANDARD TIME                *      PST

WHAT IS YOUR TIME ZONE?EST

INPUT THE DATA IN THE FOLLOWING FORM
INPUT THE MONTH(1-12), A COMMA, THE DAY(1-31),
A COMMA, AND THE YEAR(ALL 4 DIGITS)?6,22,1492

INPUT THE TIME OF DAY IN THE FOLLOWING FORM
INPUT THETIME ON THE INTERNATIONAL CLOCK (0-24)
THE TIME MUST BE INPUT AS HOUR,COMMA,MINUTE

THE DECLINATION OF THE SUN IS 23    DEGREES
THE RIGHT ASCENTION OF THE SUN IS 6.3     HOURS
THE ALTITUDE IS 15    DEGREES
THE AZIMUTH IS 108   DEGREES
                                  ZENITH
                              *     *     *
                         *                     *

                    *                               *


              *                                           *



          *                                                   *



        *                                                       *




      *                           0                                *
           (S)                   *I*
                                * I *
                                 * *
      *                         *   *                              *
**************************************************************************
      I          I                 I                   I
      I          I                 I                   I
      NE         E                 S                   W         NW
```

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PROGRAM ADDENDUM

The following changes for some of the attached program instructions are made to assist you in putting this exercise on your systems.

The changes may have to be initiated because of the lack of standardization among BASIC compilers. Any changes suggested conform to the so-called Dartmouth Basic which is as close to being a standard as exists. Instructions for which no comments have been made are common to all BASIC compilers.

To assist you in putting this program on your system a standardized program map has been prepared to include many of the changes.

TABLE OF SUGGESTED CHANGES

1. Statement #(s) — Item

1090 — DIM statement

Comment: String variables are handled by two different methods depending on the compiler.

a) As in this program, by defining the number of characters in the string variable.

Example: DIM A$(9)---

A$ is a string variable 9 alphanumeric characters long.

b) By setting up an array (table) of a specified number of elements or locations.

Example: DIM A$(9)---will create a string variable array A$ of 9 locations of a set length depending on the compiler.

If your system does not handle strings by method (a) above exclude this statement from your program.

2. Statement #(s) — Item

1260 — PRINT

Comment: If your system uses method (a) as described immediately above, it is suggested that the following three changes be made in the program listing. (If your system uses method (b) ignore these changes.)

```
1090   DIM A$(3),F$(1),T$(3)
1260   PRINT "Greenwich Mean Time     *GRE"
2380   DATA "GRE",0
```

3. Statement #(s) — Item

1420 — PRINT
1430 — INPUT

Comment: If you wish to input the time as hours and minutes then make the following:

```
1420   PRINT "The time must be input as hour, comma, minute"
1430   INPUT T1,M
1431   LET T1=T1+M/60
```

4. Statement #(s) — Item

1440 — PRINT LIN(2)

1980 PRINT LINE(3)

Comment: An option for vertical spacing not available in most BASIC compilers. Use a separate PRINT satement for each line of vertical spacing desired.

```
Example:  1440  PRINT
          1441  PRINT
                  "
                  "
                  "
```

5. Statement #(s) Item

1450,1520,2090 RESTORE 2380

Comment: An option not common to most compilers. Normally the computer places all of the numbers listed in all of the DATA statements into a combined list. The values contained in the DATA statements are placed in this combined list in order from left to right sequentially by the ascending DATA statement numbers.

Make the following changes to the program if this option is not available. (These changes incorporate numeric arrays to obtain the proper values for use in the program.)

```
1085  DIM M(12),Z(5)
1086  READ M(1),M(2),M(3),M(4),M(5),M(6),M(7),M(8)
1087  READ M(9),M(10),M(11),M(12),Z(1),Z(2),Z(3),Z(4),Z(5)
1260  PRINT "Greenwich Mean Time     * 1"
1270  PRINT "Eastern Standard Time    * 2"
1280  PRINT "Central Standard Time    * 3"
1290  PRINT "Mountain Standard Time    * 4"
1300  PRINT "Pacific Standard Time    * 5"
1330  INPUT T
1450  Omit
1460  LET B9 = M(D1)
1470  Omit
1520  Omit
1530  LET T9 = Z(T)
1540  Omit
2350  DATA -80,-49,-21,11,41,72,102,133,164,194,225,255
2360  Omit
2380  DATA 0,5,6,7,8
2390  Omit
```

Comment: If the "Picture Printout" portion of the program is to be used, omit statement #2090

6. Statement #(s) Item

1470,1480,1540 etc. #(not equal to)

Comment: As the average keyboard does not contain a #, most BASIC compilers do not understand this symbol. Use a to replace the #.

7. Statement #(s) Item

1570,1580 etc. as in 2

Comment: Not a common exponentiation symbol. Use either a or **.

Try the first.

8. <u>Statement #(s)</u> <u>Item</u>

1570,1580 etc. .5

Comment: In these staements the square root of various quantities are being determined.

Comment: This method is common to most BASICS. If it does not prove satisfactory try the SQR (square root) function.

9. <u>Statement #(s)</u> <u>Item</u>

1610 LET R = (ATN(TAN(A3----------(COS(A3))-1) *-6

Comment: Most compilers will not allow two arithmetic operators to exit next to each other as is double underlined above. Put parentheses around the -6.

Example: *(-6)

10. <u>Statement #(s)</u> <u>Item</u>

1940 IF A1 0----

Comment: If the "Picture Printout" portion of the program is to be excluded change this statement to IF A1 0 THEN 1960. (Don't forget and END statement.)

If it is desired to build a loop into this program so that the results of different input may be determined, it can be done at statement 1960 by asking this question with a PRINT statement, and using an INPUT and IF test.

11. <u>Statement #(s)</u> <u>Item</u>

2170 IF---AND

Comment: This option is not available in many compilers. Use the following:

```
2170  IF(F1+1)   (X-1) THEN 2180
2171  IF(F1+1)   (X-1) THEN 2180
2172  IF Y = U THEN 2140
```

12. <u>Statement #(s)</u> <u>Item</u>

2290,2310 STOP

Comment: If a loop is desired in this program including the "Picture Printout" portion, it can be done at these points by asking this question with a PRINT statement and using an INPUT and IF test. If it is done at this point also include a RESTORE and branch to statement 1086. (see #4)

STUDENT PAGE

MATERIALS

- A computer terminal
- Sun position computer program included in this activity.

METHOD

1. Be sure to follow all instructions exactly as stated by the computer program. Your teacher will give you a set of instructions.

QUESTIONS

1. How could this information about the sun be used in the placement of solar collectors?

2. What are the astronomical changes that take place to cause the variations in the sun's path?

3. What effect does the sun's changing position have on the effectiveness of a solar collector?

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LIST
SUN


```
1000  REM **** PROGRAMED BY MICHAEL D. ANGLE ****
1010  REM **** WRITTEN IN HEWLETT-PACKARD BASIC 2000 LEVEL F ****
1020  PRINT "THIS PROGRAM WILL ALLOW YOU TO CALCULATE THE RIGHT"
1030  PRINT "ASCENSION, DECLINATION, ALTITUDE, AND AZIMUTH OF THE SUN"
1040  PRINT "ON A GIVEN DATE"
1050  PRINT "THE AZIMUTH OF THE SUN RUNS FROM 0 DEGREES AT THE SOUTH"
1060  PRINT "TO 90 DEGREES AT THE EAST TO 180 DEGREES AT THE NORTH"
1070  PRINT "TO 270 DEGREES AT THE WEST"
1080  PRINT
1090  DIM A$[9],F$[1],T$[9]
1100  LET A=.91706
1110  LET Z=.017202
1120  LET Z1=57.2958
1130  LET Z2=.017453
1140  LET P1=3.14159
1150  PRINT "WHAT IS YOUR LATITUDE IN DEGREES(+ FOR NORTH, -FOR SOUTH)";
1160  INPUT L1
1170  LET L1=L1*Z2
1180  PRINT
1190  PRINT "WHAT IS YOUR LONGITUDE IN DEGREES(+ FOR WEST, - FOR EAST)";
1200  INPUT L2
1210  LET L2=L2/15
1220  PRINT
1230  PRINT "TO FIND THE DESIRED INFORMATITON     *      INPUT"
1240  PRINT "IN THIS TIME ZONE                    *      THIS"
1250  PRINT "**************************************************"
1260  PRINT "GREENWICH MEAN TIME                  *      GREENWICH"
1270  PRINT "EASTERN STANDARD TIME                *      EST"
1280  PRINT "CENTRAL STANDARD TIME                *      CST"
1290  PRINT "MOUNTAIN STANDARD TIME               *      MST"
1300  PRINT "PACIFIC STANDARD TIME                *      PST"
1310  PRINT
1320  PRINT "WHAT IS YOUR TIME ZONE";
1330  INPUT T$
1340  PRINT
1350  PRINT "INPUT THE DATE IN THE FOLLOWING FORM"
1360  PRINT "INPUT THE MONTH(1-12), A COMMA, THE DAY(1-31),"
1370  PRINT "A COMMA, AND THE YEAR(ALL 4 DIGITS)";
1380  INPUT D1,D2,Y8
1390  PRINT
1400  PRINT "INPUT THE TIME OF DAY IN THE FOLLOWING FORM"
1410  PRINT "INPUT THE TIME ON THE INTERNATIONAL CLOCK(0-24)"
1420  PRINT "THE TIME MUST BE INPUT IN DECIMAL FORM";
1430  INPUT T1
1440  PRINT LIN(2)
1450  RESTORE 2350
1460  READ A9,B9
1470  IF A9#D1 THEN 1460
1480  IF (Y8/4)#(INT(Y8/4)) THEN 1510
1490  IF D1 <= 2 THEN 1510
1500  LET B9=(B9+1)
1510  LET A3=Z*(B9+D2)
1520  RESTORE 2380
```

```
1530  READ A$,T9
1540  IF A$#T$ THEN 1530
1550  IF A3#0 THEN 1570
1560  LET A3=(A3+.00001)
1570  LET S1=(TAN(.410152)*(A^2/(A^2/ABS(TAN(A3))^2+1))^.5)
1580  LET D=ATN(S1/ABS(1-S1^2)^.5)*SGN(SIN(A3))
1590  LET D9=D*Z1
1600  LET D9=INT(D9+(.5*SGN(D9)))
1610  LET R=(ATN(TAN(A3)*COS(.410152)))/.261799+(SGN(COS(A3))-1)*-6
1620  LET R=(INT(R*10+(.5*SGN(R))))/10
1630  IF R >= 0 THEN 1650
1640  LET R=R+24
1650  PRINT "THE DECLINATION OF THE SUN IS"D9"DEGREES"
1660  PRINT "THE RIGHT ASCENTION OF THE SUN IS "R"HOURS"
1670  LET H=(((T1-12)+(T1-12)/360)*.261799-(L2-T9))
1680  LET S1=(SIN(D)*SIN(L1)+COS(D)*COS(L1)*COS(H))
1690  IF S1#1 THEN 1720
1700  LET A1=1.5708
1710  GOTO 1730
1720  LET A1=ATN(S1/ABS(1-(ABS(S1))^2)^.5)
1730  LET S1=((SIN(D)-SIN(A1)*SIN(L1))/(-1*COS(A1)*COS(L1)))
1740  IF S1#0 THEN 1770
1750  LET A2=90
1760  GOTO 1790
1770  LET A2=ATN(ABS(1-ABS(S1)^2)^.5/S1)
1780  LET A2=A2*Z1
1790  LET W=(T1-(L2-T9)/.261799)
1800  IF W >= 12 THEN 1840
1820  LET A2=180+A2
1830  GOTO 1880
1840  IF A2 >= 0 THEN 1870
1850  LET A2=180-A2
1860  GOTO 1880
1870  LET A2=360-A2
1880  LET A1=(A1*Z1)
1890  A1=(INT(A1+(.5*SGN(A1))))
1900  PRINT "THE ALTITUDE IS"A1"DEGREES"
1910  IF A1 <> 90 THEN 1930
1920  LET A2=0
1930  PRINT "THE AZIMUTH IS"(INT(A2+(.5*SGN(A2))))"DEGREES"
1940  IF A1>0 THEN 1970
1950  PRINT "THE SUN IS BELOW THE HORIZON"
1960  STOP
1970  REM **** PICTURE PRINTOUT ****
1980  PRINT LIN(3)
1990  IF L1 <= 0 THEN 2050
2000  IF A2>135 THEN 2030
2010  LET X=INT((135-A2)/3.91304+.5)
2020  GOTO 2060
2030  LET X=35+INT((360-A2)/3.91304+.5)
2040  GOTO 2060
2050  LET X=INT((315-A2)/3.91304+.5)
2060  LET Y=INT(A1/4.28571+.5)
2070  IF A1#90 THEN 2090
2080  LET Y=35
2090  RESTORE 2410
2100  PRINT TAB(33)"ZENITH"
2110  FOR U=21 TO 1 STEP -1
```

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```
2120  IF Y#U THEN 2140
2130  PRINT TAB(X-1)"(S);
2140  READ F1,F$
2150  IF F$="5" THEN 2200
2160  PRINT TAB(F1);
2170  IF (F1+1) >= (X-1) AND (F1+1) <= (X+1) AND Y=U THEN 2140
2180  PRINT F$;
2190  GOTO 2140
2200  PRINT
2210  NEXT U
2220  FOR U1=1 TO 71
2230  PRINT "*";
2240  NEXT U1
2250  PRINT " I"TAB(11)"I"TAB(35)"I"TAB(59)"I"TAB(69)"I"
2260  PRINT " I"TAB(11)"I"TAB(35)"I"TAB(59)"I"TAB(69)"I"
2270  IF L1<0 THEN 2300
2280  PRINT " NE"TAB(11)"E"TAB(35)"S"TAB(59)"W"TAB(68)"NW"
2290  STOP
2300  PRINT " SW"TAB(11)"W"TAB(35)"N"TAB(59)"E"TAB(68)"SE"
2310  STOP
2320  PRINT " ";
2330  GOTO 2140
2340  REM **** DAYS FROM MAR. 21 DATA ****
2350  DATA 1,-80,2,-49,3,-21,4,11,5,41,6,72,7,102,8,133
2360  DATA 9,164,10,194,11,225,12,255
2370  REM **** TIME ZONE MERIDIAN DATA ****
2380  DATA "GREENWICH",0
2390  DATA "EST",5,"CST",6,"MST",7,"PST",8
2400  REM **** PICTURE PRINTOUT DATA ****
2410  DATA 28,"*",35,"*",42,"*",0,"5"
2420  DATA 22,"*",48,"*",0,"5",0,"5"
2430  DATA 16,"*",54,"*",0,"5",0,"5",0,"5"
2440  DATA 9,"*",61,"*",0,"5",0,"5",0,"5"
2450  DATA 5,"*",65,"*",0,"5",0,"5",0,"5"
2460  DATA 3,"*",67,"*",0,"5",0,"5",0,"5",0,"5"
2470  DATA 1,"*",35,"0",69,"*",0,"5"
2480  DATA 34,"*",35,"I",36,"*",0,"5"
2490  DATA 33,"*",35,"I",37,"*",0,"5"
2500  DATA 34,"*",36,"*",0,"5"
2510  DATA 0,"*",33,"*",37,"*",70,"*",0,"5"
2520  END
```

Curriculum Topic

HOW MANY LIGHT BULBS TO MAKE A SUN?

Energy Topic

ENERGY CONCEPT
ENERGY SOURCES

Grade Level(s) 7 - 12

Site

School, classroom with south exposure

Skills

- Read a thermometer
- Solve a simple proportion using inverse square law
- Use scientific notation

Credit

U.S. Department of Energy
Solar Energy Education Project

Objective

At the completion of this activity you should be able to:

1. Construct a simple device to collect the sun's heat energy.
2. Use a mathematical equation to calculate in watts the sun's energy received by this device.
3. Compare the energy output of the sun with a 100-watt bulb.

To The Teacher

The wattage of the sun can be determined experimentally by the use of the inverse square law. Students record the maximum temperature produced by the sun in a simple collector and then duplicate this temperature in the lab using a 100-watt light bulb. By measuring the distance in meters between the bulb and the collector and equating it to the distance between the sun and the earth, they can determine the sun's wattage.

$$\frac{\text{Watts (Sun)}}{d^2\text{(Sun)}} = \frac{\text{Watts (bulb)}}{d^2\text{(bulb)}}$$

The scientifically accepted value for the sun's wattage is 3.70×10^{23} watts. This would require 37×10^{22} 100-watt light bulbs to equal the sun's energy. It is to be expected that the percent of error may be quite large.

The experiment should demonstrate that the sun is an enormous source of energy - so much so that the students will have difficulty in comprehending so large a number as that represented by the sun's wattage. In addition, the students may appreciate that the solution to a seemingly difficult or impossible question can often be found by relatively simple science equipment.

Before You Begin

1. The collector jar can be a glass calorimeter (with the resistance wire removed) or any similar jar, such as a peanut butter jar, with a hole drilled in the center of the cap.

2. Thin metal sheeting can be obtained from either the industrial arts or the art department. Any thickness can be used as long as it can be shaped around the bulb of the thermometer with ease.

3. Class time needed:
   - Pre-lab, 1/2 class period (20 minutes)
   - Lab, 2 class periods (45 to 60 minutes)
   - Post-lab, 1 class period (20 to 45 minutes)

4. This activity should be done when indoor and outdoor temperatures are the same and a day of minimal cloudiness and haze.

5. Students should work in pairs to reduce demand on equipment.

6. In pre-lab discussion, establish the watt as a unit of energy and have students guess at the value of the sun's wattage. The concept of scientific notation of numbers may need explanation.

7. The angle of the sun's rays should be normal (perpendicular) to the absorber's surface.

8. It may be difficult to line the absorber up with the center of the bulb's filament. Shims can be used to adjust the height of the collector. The angle of the bulb's rays also should be normal to the absorber's surface.

9. When the advancing of the collector towards the bulb produces a temperature of 45°C, students should advance the collector only 0.5 cm. at a time. When the desired temperature is reached, it should be maintained for at least two minutes.

Words To Know

watt, suspension, calorimeter.

STUDENT PAGE

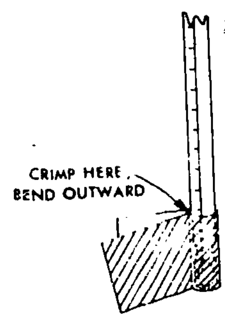
MATERIALS

- Graphite in alcohol (suspension).
- A 2 cm x 6 cm piece of thin metal sheeting.
- A meter stick and a pair of meter stick optic bench stands.
- A glass jar with a hole cut in the lid.
- A one-hole stopper (to fit the hole in the jar lid).
- A Celsius thermometer.

METHOD

1. Fold the center of the metal sheeting around the thermometer bulb so that the ends line up evenly.

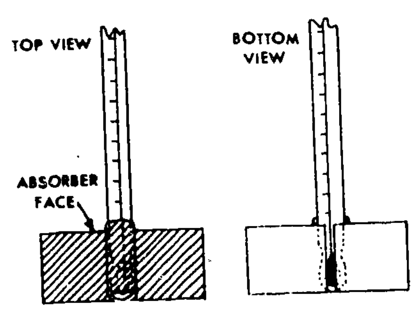
Then crimp the sheeting in so that it completely surrounds the buld. Use the straight edge of a thin plastic ruler to bend the ends of the sheeting outward 90° to form the absorber blades.



2. Paint the face of the absorber with the graphite suspension.

3. Insert the top of the thermometer upward into the stopper and then insert the stopper into the jar lid.

4. Place the lid on the jar and adjust the thermometer tube so that the absorber is in the middle of the jar. Your solar collector is now complete.



5. Position the collector so that the absorber faces directly into the sun. Record the maximum temperature.

6. Allow the collector to cool to room temperature.

7. Position the collector at the 50 cm. mark of the optical bench. Slowly advance the collector, 1 cm. at a time, toward the lighted 100 watt bulb. Stop when the same temperature as that obtained in Step 5 is reached and maintained for two minutes.

8. Record the distance between the filament and the absorber plate.

9. Determine the sun's relative wattage by using the following equation:

$$\frac{\text{Watts (Sun)}}{d^2\text{(Sun)}} = \frac{\text{Watts (Bulb)}}{d^2\text{(Bulb)}}$$

d = distance in meters

d(Sun) = 1.50×10^{11} m.

10. Determine the number of 100 watt light bulbs that would equal the sun's wattage.

11. Using the results obtained by each team, calculate the class average of the sun's wattage.

12. Determine the percent of error in the class average by using the following equation and the accepted value for the sun's wattage:

Accepted value = 3.70×10^{23} watts

$$\%\ \text{error} = \frac{\text{Experimental (class average) - Accepted value}}{\text{Accepted Value}} \times 100$$

QUESTIONS

1. Why is an incandescent light bulb used instead of a fluorescent bulb?

2. Would your location (latitude) and the time of the year affect the results?

3. After completing this activity what is your definition of a watt?

4. If the sun's output were to increase to 10^{25} watts what environmental changes might occur on the earth?

5. If the earth's distance from the sun were increased to 1.5×10^{12} meters, what would be the environmental effects?

6. If your value for the sun's wattage was incorrect by a factor of 10 from the accepted answer, what would be your percentage of error?

7. If both parts of this experiment were to be completed outside of the earth's atmosphere, what differences do you think would occur in the results? Use 3.0×10^5 m. above the surface of the earth (approximately 200 miles) as a possible location for this experiment.

Curriculum Topic

BUILDING AND USING A SOLARIMETER

Energy Topic

ENERGY CONCEPT
ENERGY USES
ENERGY SOURCES

Grade Level(s) 9 - 12

Site Classroom and outside

Skills

- Use of assorted hand tools
- Read scales on solarimeter
- Graph data
- Measure angles

Credit

U.S. Department of Energy
Solar Energy Education Project

Objective

At the completion of this activity you should be able to:

1. Build a simple solarimeter.
2. Use a simple solarimeter to determine the amount of solar energy falling upon a given surface.
3. Relate the energy received to the angle of the sun.
4. Predict the best angle at which to set a solar collector.

To The Teacher

Knowing the amount of energy received on a given area at the earth's surface is fundamental to solar energy design. This energy arrives after passing through layers of atmosphere where different amounts of reflection, absorption, and transmission occur depending upon the wavelength of the incident radiation and the composition of the atmospheric layer. Part of this energy arriving is in the form of direct rays (ultraviolet - 9%, visible light - 41%, and infrared - 50%) from the sun. The rest is indirect radiation which has been reflected or scattered by small particles, droplets of water, and molecules. The exact amount of each varies with sun position and atmospheric conditions such as cloud cover, humidity, size and kind of dust particles, size of water particles, etc. On clear, sunny days the direct energy received may be as high as 90%; on cloudy days nearly all the energy may be indirect.

When this energy arrives at the surface, two things occur; part is reflected, and part is absorbed. Various instruments may be used to measure this energy. For example, the absorbed energy may produce a temperature rise. Thus a thermometer might be used as an indicator of energy absorption. Another effect of radiant energy falling upon the surface of certain metals is the release of electrons, the photoelectric effect. The solar cell is a device that makes use of this effect. As the incident light intensity increases, a greater flow of electrons occurs through a circuit. The amount of current flowing can be used as an indicator of the energy received. It is very important to remember that the amount of energy measured by any instrument is not necessarily the total amount of energy received. Most instruments do not measure reflected or transmitted energy. They only respond to the energy absorbed by the instrument. The response of a solar cell is complex in that the cell is not equally sensitive to all wavelengths of incident radiation. In fact, it doesn't respond at all to the longer wavelengths. It also has a relatively low efficiency in converting radiant energy to electrical energy. Nevertheless it makes a very convenient, easy-to-use instrument when used in conjunction with a milliammeter. Such an instrument is called a solarimeter or pyranometer.

Careful comparisons of locally obtained data with published data for similar latitude and atmospheric conditions should permit the calibration of a homebuilt solarimeter. Direct calibration with commercial models may be arranged by contacting persons having access to these. Many colleges or universities have commercially built solarimeters available as do various weather stations, environmental agencies, and private corporations involved in solar energy research.

Before You Begin

1. D.C. Milliammeter. Available from any scientific supply house. Relatively cheap meters are available from local hobby electronic stores. Range needed depends on photocell output.

2. Photoelectric cell (Solar cell). Plain silicon type solar cell (without integral plastic lens) recommended. These are available in hobby electronic stores.

3. Resistor. This is needed in case the output of the solar cell is larger than the range of the milliammeter. The smallest size (wattage) carbon resistors will be adequate. In general the resistance value will be low, a few ohms at most. A very small, low value (0 - 5Ω) variable resistor could be used.

4. One period for building solarimeter. Two periods for data collection.

a. First Period: Introduction (pre-lab), gather initial data.

b. Second Period: Discuss results, plot class data, examine and discuss published data.

5. Periodic collection of data rest of year (as project continues).

6. Prior to doing this activity introduce the concept of the sun as the earth's major energy source by means of selected readings, lecture presentations, or audio visual materials.

7. Work in teams of 2 or 3 students to minimize the number of instruments needed.

8. Organize work within teams; switch jobs within teams so everyone has a chance to use instruments.

9. Have different teams collect data under identical conditions. Compare data by having groups record angle and energy received on the board, and arrange data from smallest to largest angle of insolation.

10. Have ongoing data collection on a routine basis by volunteers.

11. Prepare calibration curves for instruments.

12. The solarimeter, as described in this activity is really a pyranometer; an instrument for measuring total radiant energy received both directly and indirectly. By fitting a tube of proper size over the solar cell it can be converted into a pyrheliometer, an instrument that measures only direct solar energy. (See notes on building the solarimeter.)

13. A photographic light meter might be substituted for the homemade solarimeter. If direct sunlight results in off-scale readings, suitable filters (such as partly exposed negative film, crossed sheets of polaroid, etc.) might be needed.

14. A galvanometer can be used in place of a milliammeter. A somewhat larger value (ohms) resistor would be needed in series with its coil.

Words To Know

solarimeter, resistor, milliammeter, ohms, voltage, amperes, pyranometer, pyrheliometer, calibration

Related Activities

- Some published data show that more energy is received on a perpendicular (to sun's rays) surface in March than in July. How could you possibly explain this?

- Make a study of the different energy units used by scientists and engineers to measure solar energy.

- See if you can calibrate the solarimeter by comparing your data with published data for areas comparable to yours.

- Convert the solarimeter into a pyrheliometer and measure the amount of direct solar radiation. Determine the ratio between direct and indirect energy measured at different times.

- You may want to see how the reading is affected by taking measurements closer to the sides of a building, fences, etc. Do you notice any changes? Do the readings increase or decrease? How can you explain any changes?

- You may wish to volunteer to be part of a team to collect solar energy data over a longer period of time. It would be useful to obtain data on the energy received each hour throughout the day for each day of the year. This kind of information is needed by the solar energy engineer. Some data of this kind has been collected. Compare your data with published data available from the weather bureau. Make a graph showing daily variations in energy received. How do you explain the variations which occur?

Resources

- SOLAR ENERGY EXPERIMENTS, Thomas W. Norton. (Emmaus, Penn: Rodale Press) 1977

- INTRODUCTION TO THE ATMOSPHERE, Herbert Riehl. (New York: McGraw-Hill) 1965

Notes To Myself

STUDENT PAGE

MATERIALS

- D.C. milliammeter 3" scale - 150 M.A.
- Solar cell 2 1/8" diameter, 400 M.A., .45V
- Resistor (See item 8 in directions) 3 , 1/2 watt carbon
- 2 pieces of k/2" masonite 2cm x 7cm
- Stranded insulated wire (any small diameter)
- Tape
- Glue
- Screw and nut
- Drill and soldering iron

METHOD - PART I - BUILDING A SOLARIMETER

1. Drill two small holes (just large enough for thin insulated wire) in back edge of the top cover of the plastic case.

2. Tape plastic case to meter frame.

3. Drill 1/4" hole in sighting strip before cementing in place.

4. Solder one lead of resistor to the short piece of wire. Attach the other lead of resistor to wire (negative) from solar cell. Solder for permanent setup (or use screw and nut for easy disassembly of cell).

5. Solar Cell - Solder leads of thin stranded wire to cell. Attach lead from backside of cell to positive (red) terminal of D.C. milliammeter; attach lead from top side of cell to negative (black) terminal of milliammeter.

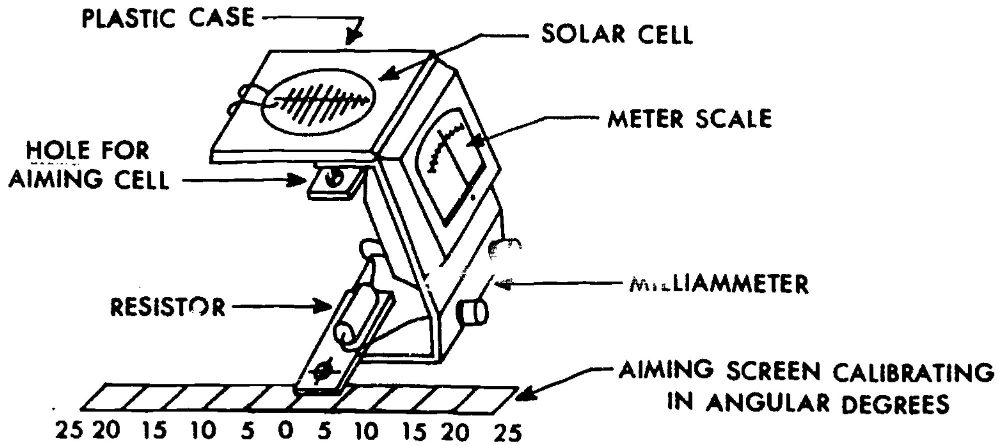
6. By merely disconnecting the leads from the solar cell to the meter, the meter may be used as a milliammeter.

7. Cement small strips of masonite (or wood) to inside top and bottom flange of meter frame. Let 2 cm. of ends of each overhang frame. Glue white paper with inked-on target pattern on bottom piece. These should be aligned so that a beam of light passing through the hole in the top piece strikes the target perpendicular to the plane of the solar cell.

8. The exact size of the resistor will depend on the characteristics of meter and solar cell used. The purpose is to reduce the current output of the cell, under maximum energy conditions, to nearly full scale value of the meter. A rough approximation of the size of the resistor in ohms can be found by using the expression:

$$R = \frac{V_{sc}}{I_{sc} - I_{fs}}$$

where V_{sc} = rated output voltage of cell, I_{sc} = rated current (amperes) of cell, and I_{fs} = full scale value (amperes) of milliammeter.



METHOD - PART II - USING THE SOLARIMETER

1. All your data must be taken outdoors in the open away from buildings, trees, and other obstructions to sunlight. You will take several series of readings and prepare a data table. The table should include the date, time, sky conditions (clear, partly cloudy, hazy, etc.), photocell position, meter reading and special notes as required. A suggested form for recording data is shown below.

Date:		Sky Conditions:	
Time	Energy Rec'd Units:	Photocell Position (measure as angle of incidence)	Special Notes

2. Take the meter outside on a relatively sunny day. UNDER NO CIRCUMSTANCES SHOULD YOU LOOK DIRECTLY AT THE SUN AS IT CAN CAUSE PERMANENT EYE DAMAGE. Place the meter in a horizontal position on the ground. Read the meter and record the values in the data table.

3. Hold your hand about 1.5m above the solarimeter so that a shadow is cast on the photocell. Read and record the data.

4. Hold your hand about 1cm above the photocell so that it blocks off the sunlight. Record the data. How does this reading compare to the previous one?

5. Pick up the solarimeter and tilt it so the solar cell directly faces the sun and record your data.

6. Take readings of at least three other angles of insolation and record the data.

7. Use the data you have collected to fill in the class data record on the chalkboard. How do your data compare with those of other students.

8. Make a graph of solar energy readings vs. angles of insolation.

QUESTIONS

1. When your hand was 1.5m above the solarimeter (step 3) did the meter read zero? What does this indicate?

2. Based on your graph, at what time of day are the sun's rays most nearly perpendicular to level ground? Is this the same time that the temperature usually reaches maximum? If not, explain the difference.

3. Why isn't the energy received by the solar cell, held perpendicular to the sun's rays, the same in early morning as it is at noon?

4. In which position would you place a solar collector so that it would absorb the most energy?

Curriculum Topic

SOLAR ENERGY IN A COFFEE CAN

Energy Topic

ENERGY SOURCES
ENERGY USES

Grade Level(s) 7 - 9

Site

Classroom or outdoors

Skills

- Reading a thermometer
- Graphing data

Credit

Solar Energy Education Project
U.S. Department of Energy

Objective

At the completion of this activity, you should be able to:

1. Construct a solar collector from a can.
2. Determine how the type of cover material (glazing) influences the performance of the collector.
3. Determine how insulation influences the performance of the collector.

To The Teacher

A solar collector has five basic parts. Each will be investigated in this activity.

On major part of a collector is a covering material, called glazing, which transmits as much solar energy as possible. Its purpose is to trap the energy it transmits, inside the collector. The glazing should be able to withstand high temperatures without decomposing or melting, and it must be able to withstand impact from objects that might fall on it.

Another part of any solar collector is the collector plate which absorbs the energy transmitted by the glazing. The collector plate is usually coated with a dark colored material that increases the absorbance of the solar energy. The collector plate and its coating must be able to withstand high temperatures without vaporizing or otherwise breaking down. The collector plate is often made from copper or aluminum but other materials may be suitable.

A third part of a collector, the collector box, houses the various parts of the collector. It can be made from materials such as aluminum, wood, fiberglass or steel. It must be sturdy and able to withstand temperature extremes.

A fourth part of a collector is the insulation that surrounds five sides of the collector box. Conduction losses of trapped solar energy are substantial unless the collector box is well insulated. Fiberglass and various foams are commonly used for this purpose.

The fifth part of the collector is either air or a liquid. It is used to transfer the solar energy to a system for distribution throughout the space to be heated or to a substance to be heated. If water is used as the medium in cold climates, it is often mixed with an antifreeze.

A collector or a series of collectors can be used for space heating or to provide hot water for commercial or domestic uses.

The collector constructed in this activity is an intergral part of typical hot air solar systems.

Before You Begin

1. Several weeks before the activity is planned, have students start bringing in one and three pound coffee cans with or without plastic lids.

2. One or two class periods will be needed.

3. Divide the class into several groups. Have each group use different combinations of glazing and insulating materials.

4. Have each group collect their data under the same environmental conditions. This will help eliminate the number of variables. (Example: change in cloud cover conditions, etc.)

5. Holes could be pre-punched in the cans by someone other than the students. (Use a metal punch to form the holes with an appropriate backing to avoid bending the can.) Or insert thermometers through both layers of plastic and into the center can.

Words To Know

solar energy, collector, collector or absorber plate, insulation.

Related Activities

- This lesson should preceed the "Construction of a Flat Plate Air Flow Solar Collector" activity.

Resources

- KILOWATTS FROM THE SKY, Peter Britton, THE LAMP, Summer, 1976, pp. 16-21.
- SOLAR ENERGY, William W. Eaton, (Department of Energy, Washington, D.C.) 1976.
- SOLAR ENERGY EXPERIMENTS, Thomas Norton, (Emmaus, Pennsylvania: Rodale Press) 1977.

Notes To Myself

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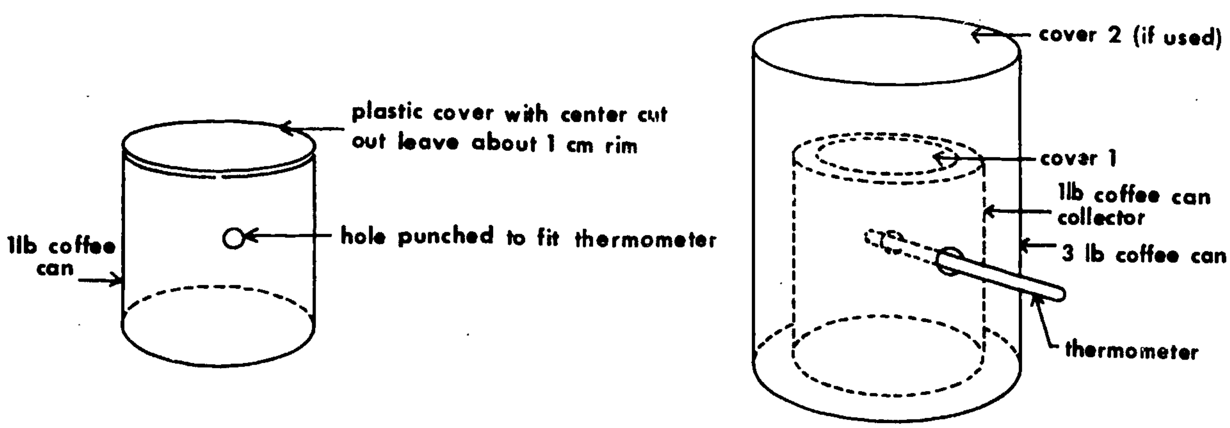
MATERIALS

- A large can about 16cm to 20cm high and 10cm to 13cm wide (a 3 lb. coffee can, for example) with plastic cover.
- A smaller can about 10cm high and 7cm wide (a 1 lb. coffee can, for example) with plastic cover.
- A standard laboratory themometer. ($-10^{o}C$ to $110^{o}C$)
- Several square pieces of transparent and translucent materials such as plastic wrap, polyethylene, waxed paper, etc. (Approximately 15cm square).
- Several types of insulation material such as shredded paper (cellulose), cotton, styrofoam, fiberglass, cork, sawdust.
- A watch or clock with a second hand.
- A can of flat black spray paint.

SOLAR ENERGY IN A COFFEE CAN



METHOD

1. Spray the inside of the smaller can with black paint.
2. Punch a hole in the side of the small can to fit the thermometer.
3. Punch a hole in the outer can so that the thermometer can pass through it. Allow for the insulation being placed in the outer can. Small can will rest on this, not on the bottom of the outer can.
4. Cut the center out of the small can's plastic lid, leaving a 1cm. rim. (See diagram above) or use masking tape to secure the plastic to the can.
5. Choose one of the cover materials to stretch across the top of the smaller can. Hold the material secure by replacing the cut out plastic lid.

6. Put the small can inside the larger can.

7. Insert the thermometer through the hole in the large can and then fit it snugly into the smaller inside can.

8. Place your solar collector in the sun and record the temperature each minute for 15 minutes.

9. Plot the data, temperature vs. time, on a graph. Compare your results to the results of those students who used other cover materials.

10. Repeat procedures using different insulation materials.

11. Compare, on the same set of graph axes, the various types of insulation used.

QUESTIONS

1. According to your graphs, which type of cover material on the small can appeared to be most effective?

2. Why is it necessary to use insulation in a solar collector? Which type of insulation seemed to work best?

3. Of those materials you used, which combination of glazing and insulation material would you recommend for a solar collector?

4. What effect does the slant of a collector have on the temperature attained? Try different angles of orientation (slant toward the sun).

5. How do wind or cloud cover affect the collector's performance?

6. How would adding an additional cover to the outside can affect performance?

7. Would changing the color of the inside of the small can affect the energy collected?

8. Could solar collectors help to heat your home or school building?

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Curriculum Topic

SOLAR ENERGY COLLECTORS -
HOW TO BUILD A SIMPLE SOLAR
WATER HEATER

Energy Topic

ENERGY SOURCES
ENERGY CONCEPT
ENERGY USES

Grade Level(s) 7 - 9

Site Classroom and outside

Skills

- Read a thermometer
- Measure metric length, volume, and mass
- Graph data

Credit

U.S. Department of Energy
Solar Energy Education Project

Objective

At the completion of this activity you should be able to:

1. Understand the basic parts of a solar energy collector.
2. Construct a solar energy collector.
3. Be aware of practical uses for solar energy.

To The Teacher

A solar collector has five basic parts.

One major part of a collector is a covering material, called glazing, which transmits as much solar energy as possible. Its purpose is to trap the energy it transmits, inside the collector. The glazing should be able to withstand high temperatures without decomposing or melting and it must be able to withstand impact from objects that might fall on it.

Another part of any solar collector is the collector plate which absorbs the energy transmitted by the glazing. The collector plate is usually coated with a dark colored material that increases the absorbancy of the solar energy. The collector plate and its coating must be able to withstand high temperatures without vaporizing or otherwise breaking down. The collector plate is often made from copper or aluminum but other materials may be suitable. The collectc plate (metal can) will absorb part of the energy collected but the effect on the change in temperature should be small so it is not absolutely necessary for students to calculate this.

A third part of a collector, the collector box, houses the various parts of the collector. It can be made from materials such as aluminum, wood, fiberglass or steel. It must be sturdy and able to withstand temperature extremes. In this activity the glazing is also the housing.

The fourth part of a collector is the insulation that surrounds five sides of the collector box. Conduction losses of trapped solar energy are substantial unless the collector box is well insulated. Fiberglass and various foams are commonly used for this purpose. A secondary glazing can be used as insulation. The cardboard in the lid provides insulation for heat lost through the metal top.

The fifth part of the collector is either air or a liquid. It is used to transfer the solar energy to a system for distribution throughout the space to be heated or to a substance to be heated. If water is used as the medium in cold climates, it is often mixed with an antifreeze.

A collector or a series of collectors can be used for space heating or to provide hot water for commercial or domestic uses.

Before You Begin

The collector constructed in this activity is a water collector which will simulate the workings of a typical liquid collector.

1. Several weeks before the activity is planned, have students start bringing in jars and cans. The jar openings must be wide enough to accommodate the cans. Students generally perfer to use their own equipment. Insist the jars be clean with all labels and glue removed.

2. Any flat black paint will do as long as it is not water soluble when dry. Latex paint is preferred for clean up and for short drying time.

3. 3/4 to 1 inch paint brushes may be borrowed from the art teacher. They are less messy than larger brushes, spray paint may be easier to use.

4. Corrugated cardboard may be pre-cut to fit into the jar lids to save time.

5. One period to construct the collectors. Two or three periods for collection and interpretation of data.

6. Take data every three minutes.

7. Have no more than two students to each collector.

8. The collection should be done outside or through a direct sun-exposed window. Use a relatively sunny day to collect data. The results should be good on a partly cloudy or hazy day, but not dramatic enough during totally overcast weather. Variations in weather will create challenging variables in results to interpret.

9. In the graph, temperature should be on the vertical axis and time will be on the horizontal axis.

10. To infuse the concept of career education into the classroom, there are numerous sources of energy materials available. The Department of Energy and energy related industries and utilities will supply media resources upon request. Businesses, including solar heating system dealers, may be willing to come to your classroom or invite your group to their business to discuss their aspects of energy.

11. Each student should be encouraged to explore his own home and determine where energy is wasted and how such wastes could be eliminated.

12. It may be advantageous to determine the mass of the metal can and include the heat energy absorbed by the can in the calculations.

Words To Know

clinometer, glazing, collector box, collector plate, transfer medium, insulation, calorie, insolation

Related Activities

- Do an experiment to see what air temperatures can be reached if no water was placed in the can. Does just warming the air have any practical use?

- Determine what effect the slant of a collector has on the temperature attained. Try different angles of insolation.

- What effect do different outside air temperatures have on temperatures obtained? Is your collector just as effective in winter as in summer?

- Find out what effects wind and cloud cover have on your collector's performance.

- Experiment with changing the color of the beverage can. Does this affect the performance of the collector?

- Experiment with other liquids inside the beverage can. Does this affect your collector's performance?

- Experiment using a steel can for the collector plate. Does this change your results.

- Place the mayonnaise jar inside a larger glass jar. What effect does this have on your collector's performance?

Resources

WORLD'S MOST ADVANCED SOLAR HOME, Solar Energy Handbook, 1978 (New York: Times Mirror Magazines.) 1978

ALTERNATE FORMS OF ENERGY, Jeffrey Feinmon. (New York: Kenington Publishing Co.) 1977

THE SOLAR HOME BOOK, Bruce Anderson. (Harrisville, New Hampshire: Chesshire Books) 1976

Notes To Myself

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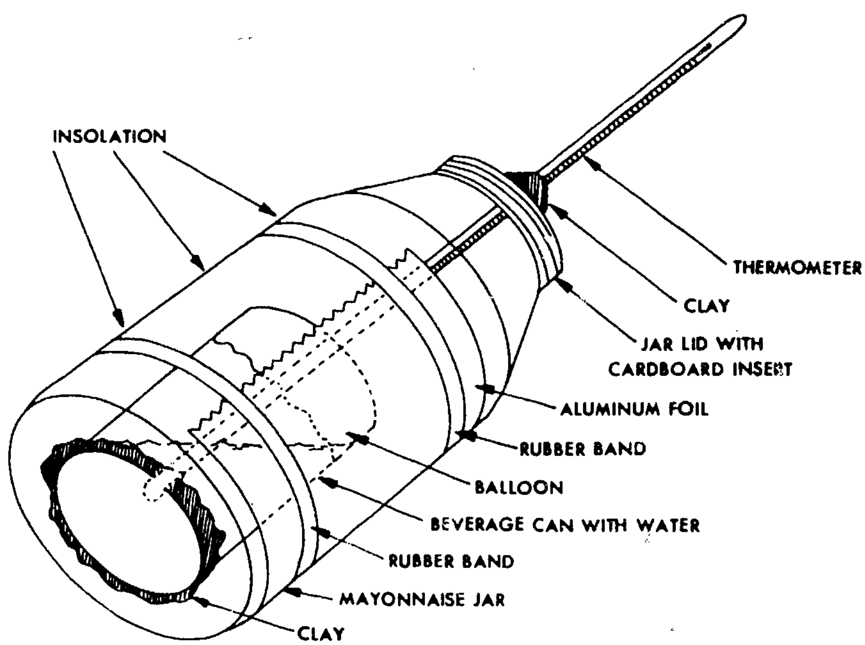
STUDENT PAGE

MATERIALS

- Quart size mayonnaise or canning jar; wide mouth with lid
- 12 oz. aluminum beverage can
- Thermometer; 12", 75mm immersible $0^{\circ}C$ - $100^{\circ}C$
- 50ml or 100ml graduated cylinder
- Flat black paint
- Sandpaper
- Paint brush
- Modeling clay
- Balloon or rubber membrane
- Corrugated cardboard
- Aluminum foil
- Rubber bands
- Scissors
- Water
- Clinometer (optional)



METHOD

1. Sand the outside of the beverage can so the paint will stick to it. Paint the outside of the can with flat black paint.

2. Cut a circle of cardboard to fit inside the jar lid.

3. Punch or drill a hole in the center of the lid and cardboard so the thermometer will fit through.

4. Put 200ml of tap water into the beverage can.

5. Cut off the end of a balloon and fit it over the open end of the beverage can. Puncture the balloon to allow the thermometer to pass into the water in the can.

6. Position the beverage can in the center of the jar, anchoring it in position with a small ball of clay by pressing down on the can. Be careful not to spill the water.

7. Screw the lid on the jar.

8. Carefully fit the thermometer into the jar and can positioning it so you can read the water temperature. Do not force the thermometer in or turn the lid once the thermometer is in place. The thermometer breaks easily.

9. Pack a small amount of clay around the thermometer to plug the hole on the lid and make it air tight.

10. Wrap a piece of aluminum foil, shiny side in, around half of the jar. Secure the foil with rubber bands.

11. Enter all initial data on your data sheet. The sun's altitude can be determined with a clinometer or by asking your teacher. REMEMBER NEVER TO LOOK DIRECTLY AT THE SUN BECAUSE IT CAN CAUSE PERMANENT EYE DAMAGE.

12. Place your solar collector on an angle directly facing the sun with the foil side away from the sun. Begin making readings at 3 minute intervals for a total of 30 minutes. Record this information on your data sheet. In the "Notes" column, list any changes, such as cloud cover or a movement of the collector, which might occur during the experiment.

13. Graph water temperature vs. time.

QUESTIONS

1. Interpret your graph. When did the temperature increase the most? Account for any dips or increases in the graph. If your graph leveled off, explain why.

2. List five different parts of the collector and explain their functions.

3. How many calories of heat energy were collected in the water? The number of calories = mass of water (in grams) x temperature change (in $^{\circ}C$) x specific heat of water which is 1 cal./$g^{\circ}C$.

SOLAR COLLECTOR DATA SHEET

NAME ______________________________

DATE ______________________________

APPROXIMATE ALTITUDE OF SUN ________° (Do not look directly at the sun.)

WEATHER CONDITIONS ______________________________

AMOUNT OF H_2O IN COLLECTOR ________ML

STARTING TEMPERATURE OF H_2O ________°C

OTHER INFORMATION ______________________________

____

TIME	TOTAL TIME ELAPSED	WATER TEMP.	TOTAL WATER TEMP. CHANGE	NOTES

Curriculum Topic

CONSTRUCTION OF A FLAT PLATE AIR FLOW SOLAR COLLECTOR

Energy Topic

ENERGY SOURCES
ENERGY USES
ENERGY CONCEPT

Grade Level(s) 7 - 12

Site

School - indoors with heat lamp or outside

Skills

- Record, graph and evaluate data
- Read a thermometer
- Evaluate the efficiency of a solar collector

Credit

U.S. Department of Energy
Solar Energy Education Project

Objective

At the completion of this activity you will be able to:

1. Construct a flat plate air flow solar collector.

2. Determine the importance in your collector of the glazing (cover material), the insulation, the absorber plate color, and the absorber plate material.

3. Evaluate the efficiency of a flat plate solar collector.

4. Infer from collected data the feasibility of heating a building with solar power.

To The Teacher

The solar collector is a device for transforming light energy to heat energy and thus raising the temperature of any medium. Visible light rays enter the collector through glazing material. Upon striking the absorber plate surface some of these rays are lengthened into infrared (heat) rays and others are absorbed and re-radiated as longer wavelength infrared rays. A black surface increases the efficiency of the process, while the insulation and glazing keep these heat rays inside the collector. The input hole allows outside air in. This air is heated while inside the collector and because hot air is less dense, it will rise and escape by convection through the upper hole for output. When properly functioning, the flat plate air flow solar collector will have an output air temperature substantially higher than the input temperature.

Any solar collector regardless of size or complexity always contains the following five elements: a collector box, glazing, an absorber plate, insulation, and heat transfer medium such as air, water, etc.

Before You Begin

1. Absorber plates can be made of anything from cardboard to copper metal.

2. Sheets of styrofoam insulation, other insulation, and plywood for boxes, are available at most building supply companies.

3. Glazing can be made of glass, saran wrap or plastic stretched over a wood frame.

4. If materials suggested are not available, many alternatives exist. Cardboard boxes, styrofoam packing containers, drawers from lab cabinets etc. could be utilized as collector boxes. Newspapers, cardboard, or various packing materials could be used as insulation. Any transparent or translucent material may be used for glazing.

5. Allow one or two class periods to complete building collectors.

6. The procedure may be used to both reinforce and develop the concepts of glazing material, collector box, insulation and absorber plate needed to make any solar collector.

7. Discuss materials that are used in the construction of a solar collector. Review why these materials were selected for this particular activity.

8. Students should be aware that after constructing the collector they will take the collector out of doors in order to collect temperature data about the sun's effect upon the air within the collector. If the weather is overcast or raining, aim one heat lamp at each collector being tested.

9. Teacher and students should be aware that clouds will affect air temperature in and out of the collector. (Note: A dramatic correlation between collector temperature and momentary cloud cover can be shown graphically.)

Students should be warned to never look directly at the sun.

Words To Know

convection, glazing, insulation, absorber plate.

Related Activities

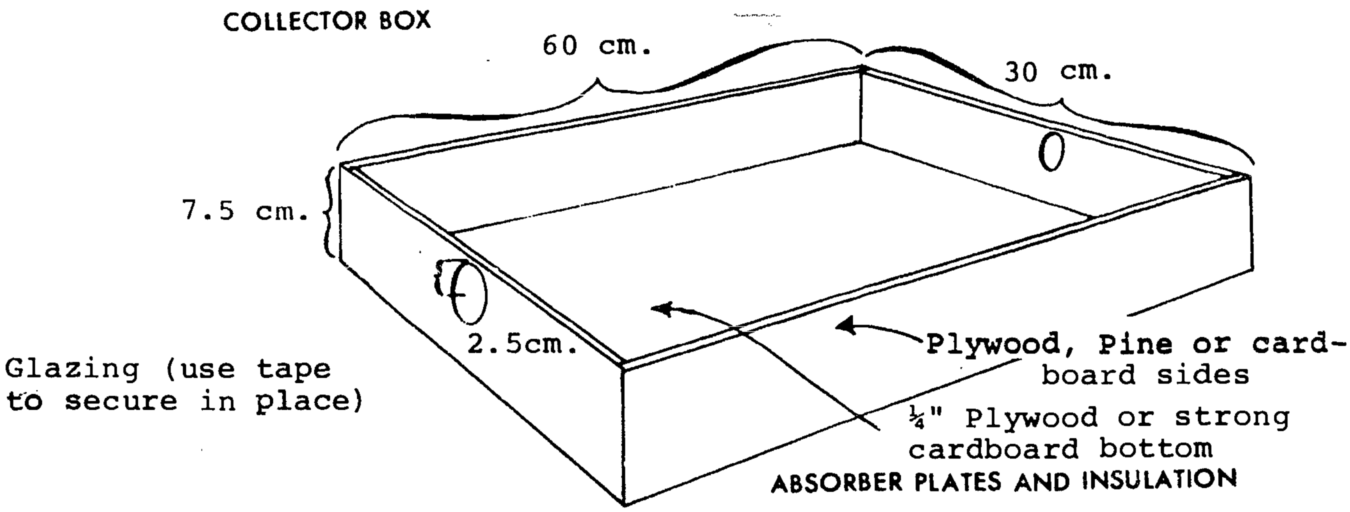
- Try other combinations of insulation materials, absorber plates, and glazings.
- Try double or triple glazing to see if it makes a difference.
- Change the angle of the sun's rays when it hits the collector and record the differences in input and output temperatures. Use a protractor to measure the angle. Do not look directly at the sun. If you do not know how to measure the angle, ask your teacher for help.
- Determine the effect various weather conditions have on the performance of your solar collector.

Resources

SOLAR ENERGY EXPERIMENTS, Thomas W. Norton, (Emmaus, Penn.: Rodale Press), 1977.

Notes To Myself

STUDENT PAGE



METHOD

1. Obtain a solar collector box from your teacher.

2. In the bottom of the box place some insulation and one colored absorber plate.

3. Over the top of the box place a glazing cover.

4. Carefully tape the thermometers on the sides of the box so that the bulbs of the thermometers extend over the input and output holes.

5. Take your solar collector outside and aim it directly at the sun. Make sure that one of the holes is near the top (this is the output hole) and that one hole is near the bottom (this is the input hole).

6. On a data sheet record the input and output temperatures in the collector every three minutes for 30 minutes.

7. On one graph plot the time vs. the input temperature and time vs. output temperature. Make sure to record the type of insulation, absorber plate color and glazing material you used.

8. Repeat the experiment using different combinations of insulation materials, absorber plates, and glazings.

9. Collect data for each combination of glazing, absorber plate and insulation that you decide to try.

10. Prepare a graph, as you did in step 7, for each combination of glazing, absorber plate, and insulation.

DATA SHEET

Flat Plate Air Flow Solar Collector

MATERIALS

- A collector box
- Glazing material: ______________________________
- Insulation: ______________________________
- Color of absorber plate: ______________________________
- Two thermometers
- A watch (or other time keeping device)

Input Temperature

Starting Temp. ________ Final Temp. ________

Minutes	Temp.	Minutes	Temp.
3	______	18	______
6	______	21	______
9	______	24	______
12	______	27	______
15	______	30	______

Output Temperature

Starting Temp. ________ Final Temp. ________

Minutes	Temp.	Minutes	Temp.
3	______	18	______
6	______	21	______
9	______	24	______
12	______	27	______
15	______	30	______

QUESTIONS

1. Based on your graphs, how do the input and output temperatures compare over the time the data was collected? Explain.

2. Which color absorber plate was the best for heating the air in the collector?

3. What effect did the glazing material have?

4. What combinations of insulation, absorber color and glazing are best for your collector?

5. An indication of collector efficiency is the temperature difference between input air temperature and output air temperature. Based on the differences you measured what effect did the type of insulation have on the collector efficiency?

6. How might your family use such a collector to save energy?

Curriculum Topic

SOLAR HOT WATER FROM A FLAT PLATE COLLECTOR

Energy Topic

ENERGY USES
ENERGY SOURCES

Grade Level(s) 7 - 12

Site

School - outside or in classroom with heat lamp

Skills

- Read a thermometer
- Graph data

Credit

U.S. Department of Energy
Solar Energy Education Project

Objective

At the completion of this activity you should be able to:

1. Construct a working model of a solar water heater.
2. Understand the principles of solar energy collection.
3. Determine how the efficiency of a solar collector can be increased.
4. Design a solar water heating system that can be used in your home.

To The Teacher

Practical application of solar energy no longer is a matter for the future; it now is in the realm of any do-it-yourselfer. Installing a system that heats water with the energy from the sun is no more difficult than installing a conventional-type water heater that uses gas or electricity. Hundreds of homes in the United States use solar energy for heating water all through the year.

This activity will give the student basic information about the operation of a simple solar water heater. A solar water heater consists of nothing more than a heat-absorbing unit, a storage tank, and simple plumbing. Cold water is circulated through the absorber where it is heated by the sun's rays to about 140°F, and then it is stored in the tank ready for use. By using the energy of the sun to heat our water we can help eliminate our dependance on the rapidly disappearing fossil fuels.

An efficient home solar water heater can provide 1.5 gallons of hot water per square foot of absorber surface on an average sunny day. A family of four will require an absorber with 54 square feet of surface connected to an 80 gallon storage tank to satisfy every-day needs.

Before You Begin

1. If it is impractical to use the sun as a source of solar energy, or if the sun is not shining when you plan to do this activity, then a 200 watt incandescent lamp clamped to a ringstand will work quite well.

2. See instructions for construction of a flat plate air flow solar collector.

3. Condensers, tubing beakers and ringstands are generally standard laboratory equipment.

4. Two class periods to perform the activity and answer the question. One class period to discuss the activity and to go further.

5. If materials are not readily available, do the activity in 2-3 large groups or as a whole class demonstration. Normally groups of 3 or 4 work well.

Words To Know

absorber, heat exchanger, thermosiphon, convection.

Related Activities

- After the collector has been in the sun for about 30 minutes add 15-20 drops of dark food coloring to the system through the funnel. Observe the currents that move the color through the system. Define the term convection.

- Experiment further by devising ways to make the system produce a higher temperature in less time. Suggestion: Analyze such factors as the color of the absorber surface, insulation, the use of a pump, the use of mirrors and magnifying lenses, changing the angle of the collector to the imcoming sun rays, different covers for the collector, colors and lengths of tubing, etc. Compare your results to the data collected in the original activity.

- Try hooking up the condenser as a closed system, let the water in the system "thermosiphon" with the condenser as a heat exchanger. There should be no air in the lines for this to work properly. (See diagram)

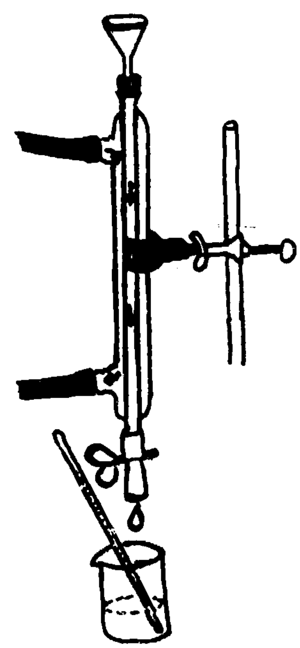
Resources

- ENERGY, Life Science Library. (New York: Time Incorporated) 1963

- THE WORLD OF MATTER-ENERGY, Paul F. Brandwein, Alfred D. Beck, Violet Strahler, Leland G. Hollingworth and Matthew J. Brennan. (New York: Harcourt, Brace & World, Inc.) 1964

- THE POPULAR MECHANICS ILLUSTRATED HOME HANDYMAN ENCYCLOPEDIA AND GUIDE, (New York: Readers Institute of America, Inc.) 1962

Notes To Myself



THERMOSIPHON

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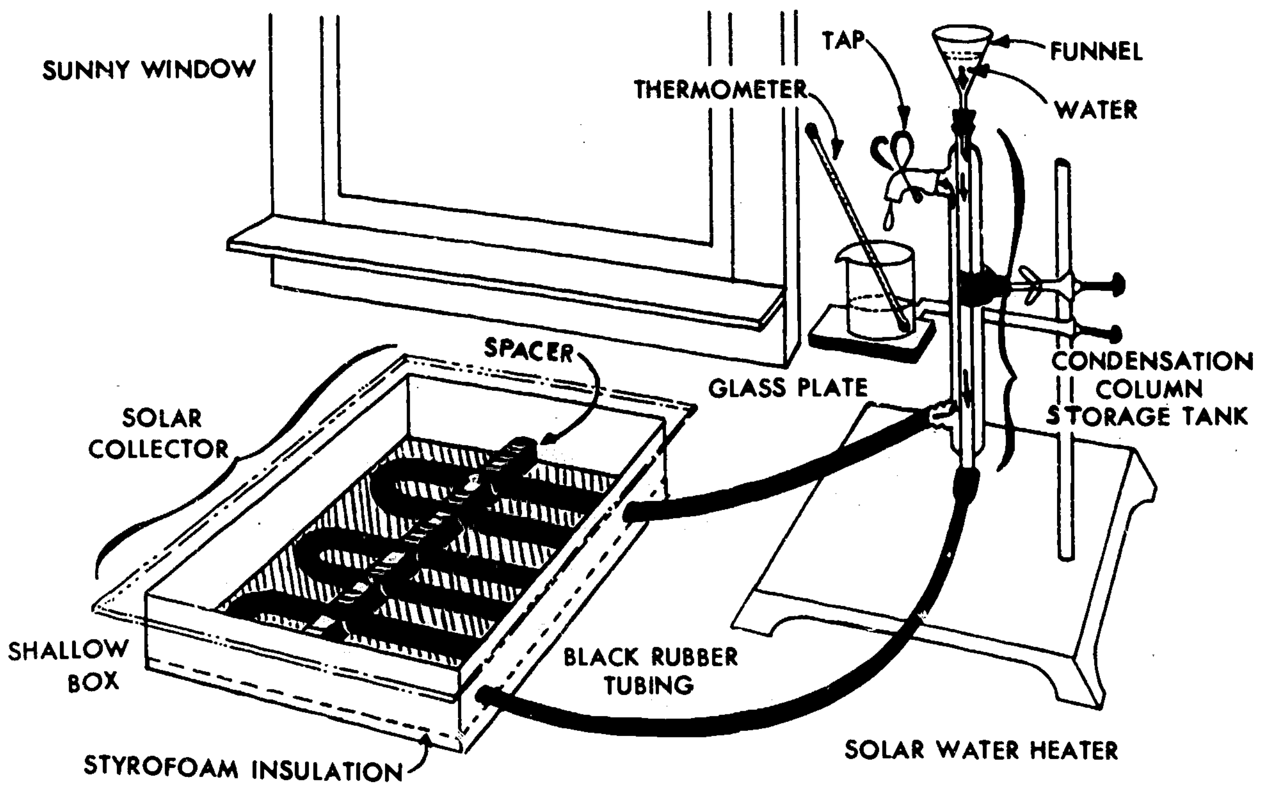
STUDENT PAGE

MATERIALS

- 1 shallow box (cardboard or constructed from wood)
- 1 sheet of glass or plexiglass (large enough to cover the box)
- 20 feet of black rubber tubing
- 1 ring stand
- 1 large clamp
- 1 condensation column (Leibig condenser)
- 1 pinch-cock
- 1 Celsius thermometer
- 1 50ml beaker
- 1 one-hole stopper or cork.
- 1 funnel
- 1 can of black spray paint

* Same box may be used as in Solar Air Flow Collector experiment. Modily by closing air flow holes and drilling new holes to accommodate tubing.



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METHOD

1. Assemble the apparatus for your solar water heater according to the diagram provided.

2. Fill the entire unit with water. (Be sure that the tubing and condensation column are completely filled.)

3. Drain off 50ml of water from the tap and record the temperature on your data chart.

4. Pour the water back into the funnel.

5. Place the solar collector in the sun and record the temperature of a sample of water each minute for 20 minutes or until a maximum temperature is reached. (Be sure to pour each sample back into the system.)

6. Graph your data on paper provided by your teacher.

7. Drain the entire system. Paint the absorber surface black and allow to dry, then repeat steps 2-5 of this activity.

8. Compare, on the same graph, the data received from the painted and unpainted collector boxes.

DATA CHART

UNPAINTED BOX: INITIAL WATER TEMPERATURE ________

MINUTE #	TEMP. READING	MINUTE #	TEMP. READING
1	________	11	________
2	________	12	________
3	________	13	________
4	________	14	________
5	________	15	________
6	________	16	________
7	________	17	________
8	________	18	________
9	________	19	________
10	________	20	________

PAINTED BOX: INITIAL WATER TEMPERATURE ________

MINUTE #	TEMP. READING	MINUTE #	TEMP. READING
1	________	11	________
2	________	12	________
3	________	13	________
4	________	14	________
5	________	15	________
6	________	16	________
7	________	17	________
8	________	18	________
9	________	19	________
10	________	20	________

Curriculum Topic

MEASURING HEAT OF A SOLAR COLLECTOR USING A THERMOCOUPLE

Energy Topic

ENERGY SOURCE
ENERGY CONCEPT

Grade Level(s) 7 - 10

Site Classroom or outside

Skills

- Read a millivolt meter
- Graph data

Credit

U.S. Department of Energy
Solar Energy Education Project

Objective

At the completion of this activity, you should be able to:

1. Construct a thermocouple that can be used to measure heat difference.

2. Use this thermocouple to measure solar energy in a very simple flat plate collector.

To The Teacher

When two wires that are twisted around each other are heated, an electric field is set up which creates a current in the wire which is proportional to the heat applied. When another twist of wire is placed in a reference container (usually at 32°F or 0°C) the difference in electrical potential can be measured on a voltmeter, using millivolts as the unit. The number of millivolts will therefore turn out to be an accurate measure of the heat on the twist of wire. Most reference books of physics and chemistry contain tables which relate the millivoltage of the thermocouple to the temperature using a set reference such as the ice-water equilibrium mixture. The chart which has been reproduced is such a reference for the thermocouple made with copper and constantan wires. Other wire combinations are possible but require the use of a different chart of conversion. The styrofoam sheet with aluminum foil acts as the collector and the increase in heat will correspondingly cause an increase in the millivoltage.

TEMPERATURE - VOLTAGE READINGS FOR A
COPPER - CONSTANTAN THERMOCOUPLE

°F	°C	MILLIVOLTS	°F	°C	MILLIVOLTS
0	-17	-.67	110	43	+1.75
10	-12	-.47	120	49	+1.99
20	- 6	-.26	130	55	+2.23
30	- 1	-.04	140	60	+2.47
40	5	+.17	150	66	+2.71
50	10	+.39	160	72	+2.96
60	15	+.61	170	77	+3.21
70	21	+.83	180	82	+3.46
80	27	+1.06	190	88	+3.71
90	32	+1.29	200	93	+3.97
100	38	+1.52	210	99	+4.22

Before You Begin

1. The constantan wire can be acquired from chemical supply firms while the millivoltmeter is a usual item in the physics laboratory. The rest of the material can be found in local hardward or building supply companies.

2. One class period to do the activity.

3. One class period to discuss the results.

4. Divide the class into groups of 2 or 3 students. Have each group make one device.

Words To Know

thermocouple, voltmeter, millivolt.

Related Activities

- You may want to hook up your thermocouple to another collector with which you may have worked and check the results against a thermometer to see if the results are correct.

- Test surfaces other than aluminum foil such as copper sheeting, galvanized steel, or sheet metal.

- Use colors other than black and compare your results.

- Perhaps if the sun is shining, allow students to test their thermoucouples by facing the sun. Then devide the class and allow some to have their apparatus face the sun, some face away from the sun, and others use a heat lamp.

- Your school may have some commercially available thermocouples which you may wish to use in place of your own, or to compare with the one you made.

Resources

CRC HANDBOOK OF CHEMISTRY AND PHYSICS, R. C. Weast, PH.D., The Chemical Rubber Co., Cleveland, Ohio (Thermocouple Calibration Tables)

Notes To Myself

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DATA TABLE

TIME (MIN.)	VOLTAGE (MILLIVOLTS)	TEMPERATURE °C
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

MATERIALS

- 1 meter of copper wire per group
- 1 meter of constantan (an alloy of copper and nickle)
- 1 millivoltmeter
- 1 insulated container filled with water and ice
- 1 piece of styrofoam (60 cm. x 60 cm. x 5 cm.)
- 1 13 ox. flat black spray enamel
- 1 piece of aluminum foil (painted black) - 60 cm. x 60 cm.
- 1 heat lamp (optional)
- 1 watch or clock
- White glue
- Pliers
- Wire cutters

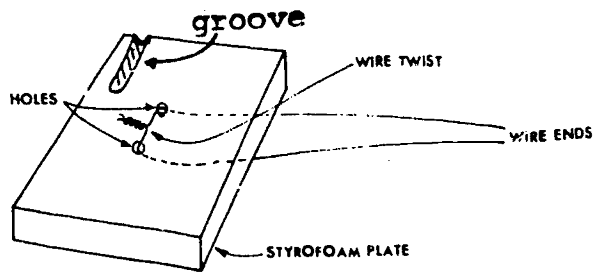
STUDENT PAGE

METHOD

1. Carefully take the piece of copper wire and cut it into two pieces, one slightly longer.

2. Take the end of the longer copper wire and twist it together with the constantan wire so that about ten tight turns are made (you may need pliers).

3. With a nail, make two holes in the styrofoam sheet about 2 cm. from each other and near the center. Feed the ends of the twisted wire through the holes as far as they can go without untwisting the two wires. (See Figure 1) Also cut small groove to fit thermometer.



4. Take the end of the constantan wire which is not twisted and twist it together with the smaller piece of copper wire in the same fashion that you used in step 2.

5. Place this twist in the insulated container filled with ice and water. It helps to make a styrofoam cover to improve the insulation of the container.

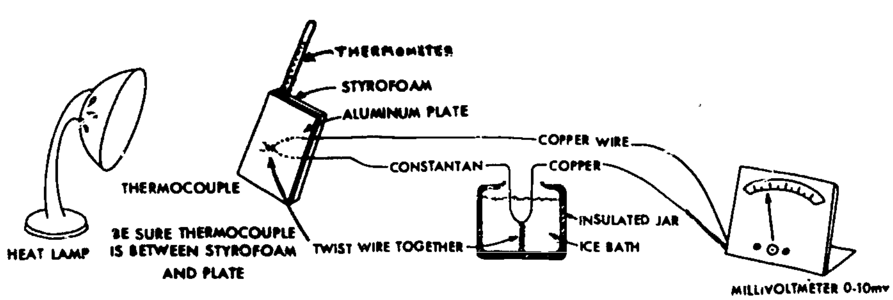
6. Paint aluminum with black spray paint on one side.

7. Carefully glue (in only 2 or 3 spots) the aluminum foil to the outside of the styrofoam sheet, painted side up, to serve as an absorber plate. Be careful not to rip the aluminum foil on the rough edges of the wire.

8. Place the voltmeter between the two copper wires that are not attached. If the voltmeter does not read a value, switch the terminals so that the voltage reading is positive. (See Figure 2)

9. CAREFULLY take your equipment outside. (If no sun is available, use the heat lamp inside).

10. See Figure 2 for an illustration of this activity.



CONSTANTAN-COPPER THERMOCOUPLE

11. On a data sheet record the voltage reading every minute for fifteen minutes.

12. Carefully take your equipment apart so that all the pieces may be used again.

13. Using the conversion scale, determine the approximate temperatures which your collector had during each interval that you measured. Place this beside your voltage reading on your data sheet.

14. Plot the data, temperature vs. time on a graph.

15. Insert thermometer in groove behind plate and record the actual temperature vs. the calculated temperature.

QUESTIONS

1. As the voltage of the thermocouple increas[illegible] what happened to the temperature of the collector plate?

2. What happened to the voltage with rel[illegible]o time?

3. What effect does the slant to[illegible] or closeness of the sun lamp have on the graph of [illegible] temperature?

Curriculum Topic

MEASURE CALORIES FROM
PARABOLOID SOLAR COLLECTOR

Energy Topic

ENERGY THE CONCEPT
ENERGY SOURCES
ENERGY USES

Grade Level(s) 10 - 12

Site School classroom and outside

Skills

- Work with geometry and trigonometry

Credit

Science Activities in Energy
Solar II
American Museum of Science and Energy - Oak Ridge Associated Universities

Objective

At the conclusion of this activity the student will be able to:

1. Understand the concept of a paraboloid collector.
2. Determine the units of energy collected in calories.
3. Determine the pros and cons of using parabolic collectors.

To The Teacher

Collection of solar energy is taking many new directions. Flat plate collectors are relatively inefficient for the collection of solar energy. Many engineers believe if an inexpensive tracking and concentrating collector were developed solar use would grow by leaps and bounds. Paraboloid collectors have been used for centuries dating back to 200 B.C. when Archimedes burned Roman ships using shields of the army as reflecting mirrors. Today, this concept is being applied again on a large scale with the concept of the solar power tower. Parabolics can concentrate large amounts of energy at one point, resulting in much nore efficient use of that energy. In this activity, students will build a paraboloid collector and test its energy output by heating water.

Before You Begin

1. Purchase materials not available in lab from art or hobby store. Aluminum foil, cans and coat hangers may be accumulated by the students in advance of the activity.

2. This activity is best done with teams of three or four depending on class size. Different teams may decide on different size collectors for a comparison of data.

3. One class period should be used for an introduction to parabolic collectors and the mathematics involved in creating a true parabola. (A paraboloid simulates a true parabola on a more or less flat surface.) One or two class periods will involve the construction of the collector. (It may help to review the instructions as a class so that the trigonometry involved is understood.) One class period can be devoted to collecting solar energy outside and computing the number of calories collected for a given time (15 minutes).

Words To Know

Sine and cosine, parabola, paraboloid, calorie, focal length

Related Activities

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

Notes To Myself

STUDENT PAGE

MATERIALS

- Poster board of desired dimensions (the larger it is the more solar heat will be collected).
- Protractor
- 25cm wire (any type wil 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.

METHOD

CONSTRUCT A PARABOLOID SOLAR COLLECTOR

1. Decide on a focal length. In our example we chose 25cm. Decide on a size of posterboard. In our example we chose 50cm. (Refer to figure 1)
2. Draw horizontal line Hl across bottom of posterboard.
3. Draw line PQ from midpoint of Hl (P) to height of focal distance. (Q)
4. Decide on the size of the focus point. 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 AC the lenght of diameter of focus spot. Extend in other direction making AQ=QC. Do the same thing at point P with line BD so that BP=PD.
6. Draw AB.
7. Draw BC.
8. Using B as the center, adjust protractor so that the 90^{o} mark bisects the angle between AB and BC. (Refer to figure 2)
9. Mark point E at 180^{o} 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 Ac) from B.
12. Draw B'C through F. Mark B' where it intersects line Hl.
13. Draw from B'.
14. Using B' as a center for the protractor, bisect the angle between

and B'C. Make a point E' at 180° mark. Draw line B'E'.

15. Read b_2 and record. On B'E', measure 10cm(= to 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 our rings and space between angle marks as shown.

23. Join rings 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.

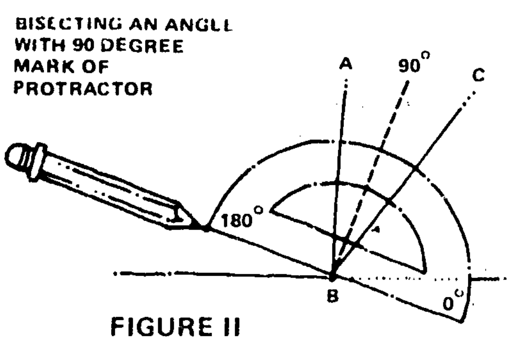
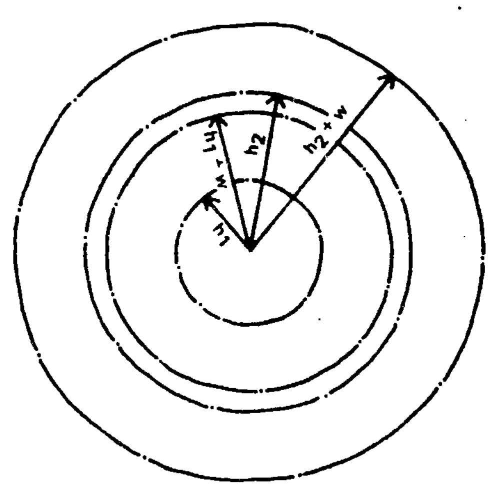


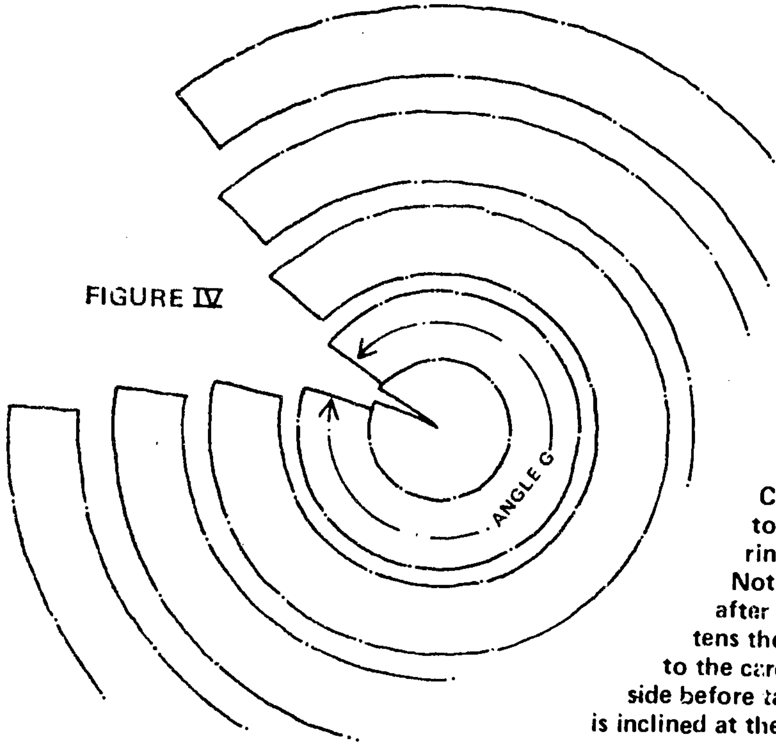
FIGURE II

FIGURE III



W = Width of Focal Spot

FIGURE IV

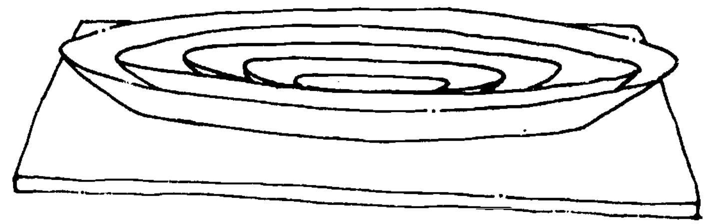


Cut on solid lines, then splice the ends of the ring together. Mark your drawing before cutting out rings.

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



24. Paint outside of tomato paste can with flat black spray paint.

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

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

a. Weight of H_2O (subtract weight of can)
b. Temperature (before)

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

____

c. Temperature after

Calculate the number of heat calories generated:

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

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	352	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

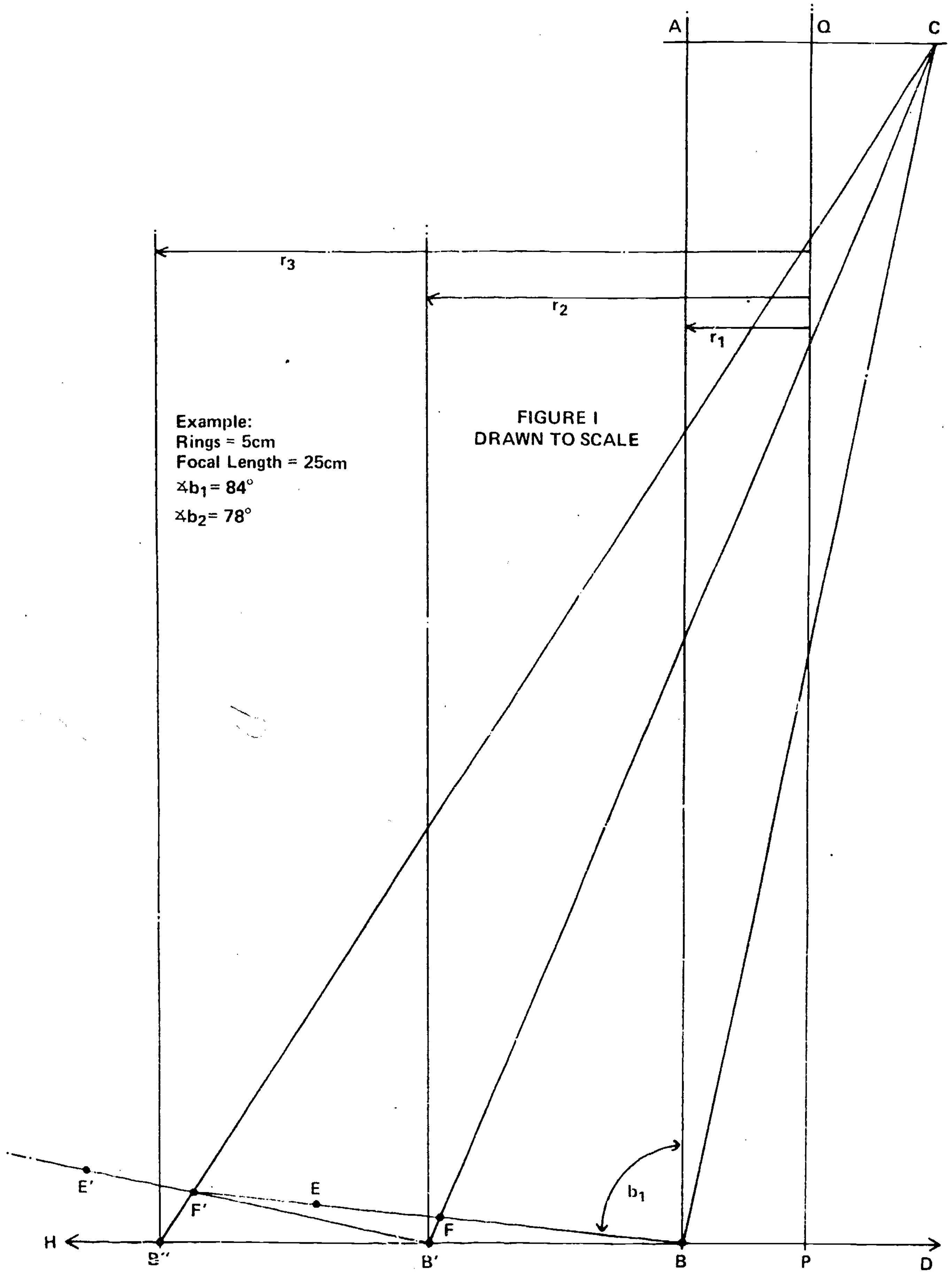
Focus length 25cm
Focus spot 10cm

	∡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

QUESTIONS

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

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



A
Q
C
r_3
r_2
r_1
Example:
Rings = 5cm
Focal Length = 25cm
∡b_1 = 84°
∡b_2 = 78°
FIGURE I
DRAWN TO SCALE
E'
E
F'
F
b_1
H
B''
B'
B
P
D
I

Curriculum Topic

ENERGY STORAGE

Energy Topic

ENERGY SOURCES
ENERGY USES
ENERGY CONCEPT

Grade Level(s) 8 - 9

Site School - indoors

Skills

- Read a thermometer and stop watch or other timing device
- Construct and interpret a graph

Credit

U.S. Department of Energy
Solar Energy Education Project

Objective

At the completion of this activity, you should be able to:

1. Describe how rocks can be used to store heat energy.

2. Determine which substance, rocks or air, absorbs heat the fastest and releases heat the fastest.

To The Teacher

The purpose of this activity is to demonstrate that heat can be stored for use at a later time. In this case, rocks are used, as they are the most common storage medium for a hot air solar system.

Storage can be done in several ways. If you are using a solar collector that circulates water, you can use a large tank of water to store the heat, generally 1 or 2 gallons per square foot of house. Insulation of the storage tank is very important to keep heat loss to a minimum.

If you are circulating air, there are several possibilities. One way is to store heat using the melting process. Such heat, called latent heat or heat of fusion, changes the state of a solid, such as paraffin, into a liquid with no change in temperature. When such substances turn back into solids they release their stored heat. Another way, used in this procedure, is to store hot air in solids without melting them, similar to that seen in water storage. The amount of heat energy that can be stored will be related to the amount of material, and the properties of the material itself.

Before You Begin

1. Gravel is available from hardware stores, lumber yards, and pet shops. Firring strips are readily available from lumber yards or school work shops (any wood strips of about 3/4" thickness and about 1" to 2" wide may be used). Thermometer holes are easily punched in the gallon tin before the bottom is removed. A large nail will easily puncture the walls of the tin can. Just give the nail a hard sharp tap with a hammer. Cardboard should be the corrugated type-two sheets which when taped together will provide added strength. The cardboard cover (or wood) should be large enough to completely cover the open can.

2. Allow 1 to 2 class periods for this activity.

3. Depending on the abilities of the class, this activity could be introduced with a review or study of specific heat and latent heat. If students have had these concepts in earlier grades, their attention should be called to those experiences. The class could be divided into as many groups as there are boxes.

4. The can filled with gravel is heavy. Be sure that the support is sturdy enough to hold it.

5. Exercise caution when using the hot plate.

Words To Know

insulation, latent heat, heat of fusion, heat energy.

Related Activities

- Heat can be stored by melting a solid, such as paraffin (wax). Construct a box with thin sheets of paraffin in trays. You must select the paraffin with an appropriate melting point. See if you can store and extract heat from this type of storage.
- Is there any difference between storage in large rocks compared to small ones?
- How does insulating the storage container affect its heat storage properties?
- What other materials can be used to capture and hold heat energy?

Resources

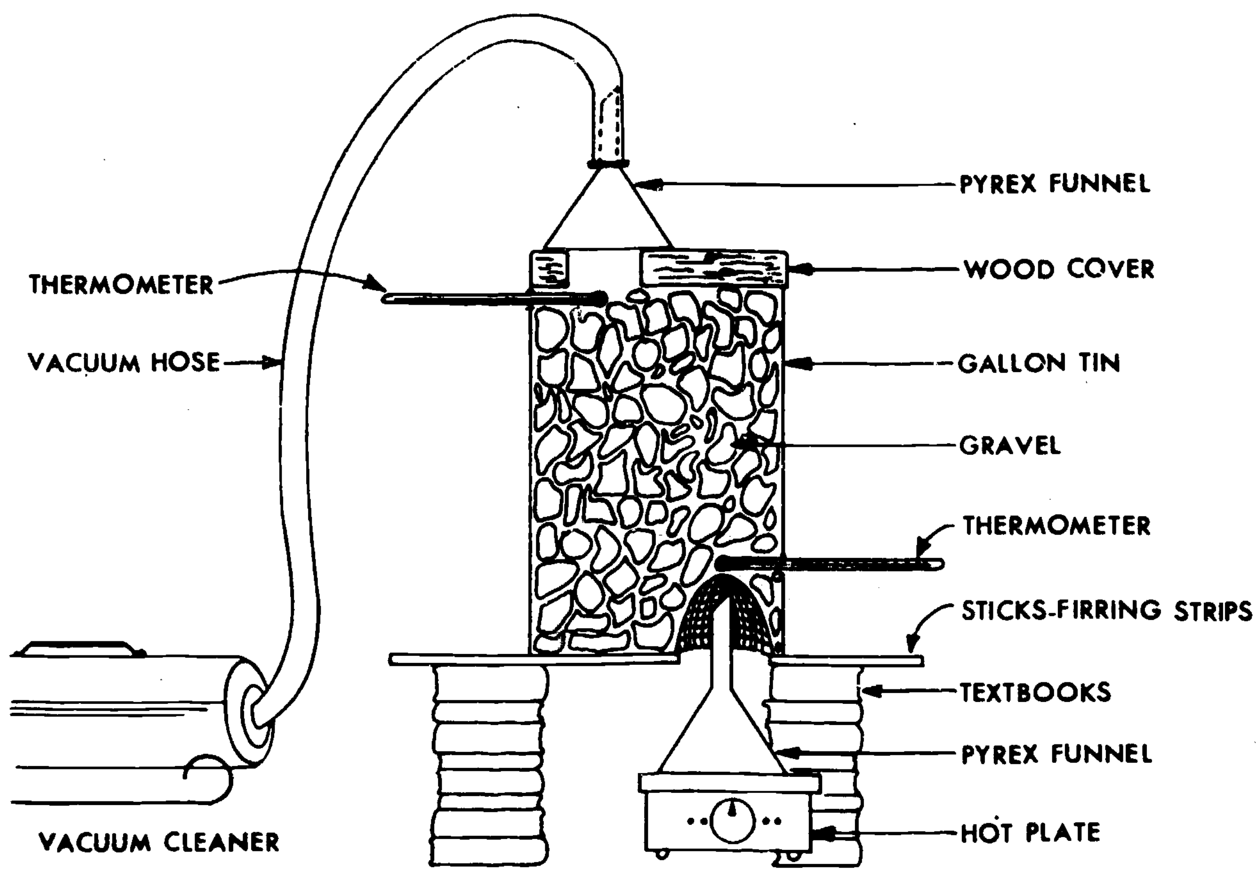
SOLAR ENERGY EXPERIMENTS, Thomas W. Norton, (Emmaus, Penn.: Rodale Press), 1977.

Notes To Myself

STUDENT PAGE

MATERIALS

- Gallon tin (ditto fluid can) with bottom removed and two holes for insertion of thermometer.
- Cardboard or wood, with a hole cut about 2" from one corner. Size of the hole may vary from about 2" to 4".
- Gravel enough to fill the gallon tin.
- Wire screen - 1/8" to ¼" gauge.
- Thermometers $0^{o}C$ to $100^{o}C$.
- Vacuum pump (vacuum cleaner) (used to circulate air in apparatus)
- Hot plate.
- Funnels.
- Support (text books may be used as the major support with 2 strong pieces of wood to hold the gallon tin can.).



METHOD

1. First, set up the apparatus as shown without the gravel.

2. Turn on the hot plate and allow it to heat for about one minute.

3. Turn the vacuum cleaner on low.

4. Record on your data sheet, both thermometer temperatures each minute for 5 minutes.

5. After 5 minutes remove the hot plate. With the vacuum device still operating, continue recording temperatures for another 5 minutes.

6. Next, fill the gallon tin with gravel (be sure the screen is in place.).

7. Repeat steps 2 - 6.

8. Graph the data - temperature vs. time for each material, air and gravel. Prepare a graph for the heating phase and a second graph for the cooling phase.

QUESTIONS

1. Referring to your graphs, which material, air or gravel heated most rapidly? Explain your answer.

2. Referring to your graphs, which material, air or gravel, cooled most rapidly? Explain your answer.

3. If you were designing a sclar heating system, which material, air or gravel, would you choose to store the heat energy you gathered? Explain your choice.

DATA SHEET

AIR

Time	Lower Thermometer	Upper Thermometer
heating		
1		
2		
3		
4		
5		
cooling		
6		
7		
8		
9		
10		

GRAVEL

Time	Lower Thermometer	Upper Thermometer
heating		
1		
2		
3		
4		
5		
cooling		
6		
7		
8		
9		
10		

Curriculum Topic

THE HEAT OF HYDRATION
APPLICATIONS TO SOLAR STORAGE

Energy Topic

ENERGY CONCEPT
ENERGY SOURCES
ENERGY AND ECONOMICS

Grade Level(s) 11 - 12

Site

Skills

- Read a thermometer
- Use a pan balance
- Use a calculator
- Balance a chemical equation
- Make calculations for heat of hydration

Credit

U.S. Department of Energy
Solar Energy Education Project

Objective

At the completion of this activity you should be able to:

1. Determine the heat of hydration of $Na_2SO_4 \cdot 10H_2O$ and $NaC_2H_3O_2 \cdot 3H_2O$.
2. Describe the relationship between stored solar energy and heat of hydration.
3. Determine the economic feasibility of using heat of hydration as a storage medium for solar energy.

To The Teacher

Water and rock are two means of storing solar energy. The advantages to these systems are their relative abundance, non-toxicity, and availability. However, to store heat for an average home, you would need a 1000 cu.ft. tank of water (6000 gallons) or a rock pile of 2250 cu.ft. (20' x 18' x 6').

Latent heat storage systems require a much smaller storage volume. For example, a closet-size space of 115 cu.ft. of Glauber's salt provides the same heat storage capacity as a 1000 cu.ft. tank of water. This system also has limitations. With time, salts settle out and this limits the efficiency of re-hydration. Salts also corrode metals used in heat system plumbing.

This experiment yields results that can be used to select a salt for solar heat storage. The equations involved and their application to solar energy storage are explainable in the following way.

Heating $Na_2SO_4 \cdot 10H_2O$ (the hydrated salt) will yield the following equation:

$$Na_2SO_4 \cdot 10H_2O \longrightarrow Na_2SO_4 + 10H_2O$$

Heating $NaC_2H_3O_2 \cdot 3H_2O$ (the hydrated salt) will yield the following equation:

$$NaC_2H_3O_2 \cdot 3H_2O \longrightarrow NaC_2H_3O_2 + 3H_2O$$

The amount of energy released when sodium sulfate or sodium acetate reforms its hydrated salts upon the addition of water is equivalent to the stored solar energy. To determine the amount of stored energy (solar energy), we will determine the heat of solution of the hydrated salt and then the heat of solution of the anhydrous salt. The difference in the heats of solution is the hydration energy (stored solar energy). In both cases our dilution of the hydrated and anhydrous salt will be 2 moles per 400 moles of water.

Before You Begin

1. One period for hydrated salts.
2. One period for anhydrous salts.
3. One period to discuss results.
4. A prior discussion of calorimetry is suggested. Students should have done problems applying the principles involved.
5. If there is enough time have students repeat the experiment more than once to check results.
6. Give the data to students regarding the volume of water and rocks needed to store heat.

Precautions

- IT IS PREFERABLE TO USE STYROFOAM CUPS WITH A PIECE OF STYROFOAM TO COVER THE CUP WITH THE THERMOMETER INSERTED INTO THE TOP.

  a. HAVE STUDENTS GENTLY AGITATE THE CONTENTS OF THE CUP.
  b. THE MORE ACCURATE THE THERMOMETER THE BETTER THE RESULTS.
  c. THE HYDRATED SALTS MUST BE FRESH OR FROM A SEALED BOTTLE.

d. DO NOT REMOVE THE ANHYDROUS SALTS FROM UNDER THE SUN LAMP UNTIL READY TO USE.
e. USE A FLAT PAN FOR HYDRATED SALTS SO THAT ALL CRYSTALS ARE EXPOSED TO THE HEAT.

Words To Know

latent heat, heat of hydration, molecular bonding, anhydrous, mole, calorie, molecular weight

Related Activities

- Investigate the literature to determine what some of the problems would be in using heats of fusion in storing solar energy.
- Are there other substances besides sodium sulfate and sodium acetate that are being considered for solar energy storage?
- Further investigation may be done in the area of heat of fusion and its applications to solar storage.

Resources

- SOLAR ENERGY CONCEPTS IN THE TEACHING OF CHEMISTRY, Joseph S. Cantrell, Journal of Chemical Education, Jan. 1978 (Vol. 55 No. 1), p. 41.

Notes To Myself

STUDENT PAGE

MATERIALS

- A balance
- A calorimeter or 4 styrofoam cups
- A stirring rod
- 50 ml graduated cylinder
- A watch or laboratory clock
- Heating lamp or a source of sunlight
- $Na_2SO_4 \cdot 10H_20$ (Glauber's Salt).
- $NaC_2H_30_2 \cdot 3H_20$
- Distilled water

METHOD

Data tables are provided on the next two pages for all data and calculations. Also note that formulas for the calculations are located after the data tables.

HEAT OF HYDRATION OF NA_2SO_4

Part A

1. Weigh 5.1 g of $Na_2SO_4 \cdot 10H_20$ and put it into a styrofoam cup (your calorimeter.)
2. Measure 50 ml of distilled water using a graduated cylinder (Assume 1 g of water occupies 1 ml.).
3. Measure the temperature of the water.
4. Pour the water into the calorimeter. Stir the misture with a glass stirring rod and record the temperature every 30 seconds for 3 minutes or until it reaches its maximum value.

Part B

1. Measure 2.0 g of anhydrous Na_2SO_4 (prepared by placing the hydrated salt in sunlight or under a heating lamp.)
2. Measure 50ml of water and record the temperature.
3. Pour the water into the calorimeter. Stir the mixture and record the temperature every 30 seconds for 3 minutes or until it reaches its maximum value.

DATA TABLE

THE HEATS OF SOLUTION OF THE HYDRATED AND ANHYDROUS SODIUM SULFATE SALT

PART A

1. WEIGHT OF 50 ML OF H_2O (1 ML WEIGHS 1 G) ____________
2. WEIGHT OF HYDRATED $NA_2SO_4 \cdot 10H_2O$ ____________
3. TOTAL WEIGHT OF SOLUTION ____________
4. ORIGINAL TEMPERATURE OF WATER (T_1) ____________
5. FINAL TEMPERATURE OF SOLUTION (T_2) ____________
6. TEMPERATURE CHANGE ($\Delta T = T_2 - T_1$) ____________
7. HEAT GAINED BY SOLUTION (K CAL) ____________
8. HEAT GAINED BY 1 MOLE OF $NA_2SO_4 \cdot 10H_2O$ ____________

PART B

1. WEIGHT OF 50 ML OF H_2O ____________
2. WEIGHT OF ANHYDROUS SALT ____________
3. TOTAL WEIGHT OF SOLUTION ____________
4. ORIGINAL TEMPERATURE OF WATER (T_1) ____________
5. FINAL TEMPERATURE OF SOLUTION (T_2) ____________
6. TEMPERATURE CHANGE ($\Delta T = T_2 - T_1$) ____________
7. HEAT EVOLVED BY SOLUTION (K CAL) ____________
8. HEAT EVOLVED BY 1 MOLE OF NA_2SO_4 ____________
9. MOLAR HEAT OF FUSION OF SODIUM SULFATE ____________

DATA TABLE

THE HEATS OF SOLUTION OF THE HYDRATED AND ANHYDROUS SODIUM ACETATE SALT

PART A

1.	WEIGHT OF 50 ML OF H_2O (1 ML WEIGHS 1 G)	________
2.	WEIGHT OF HYDRATED $NaC_2H_3O_2 \cdot 3H_2O$	________
3	TOTAL WEIGHT OF SOLUTION	________
4.	ORIGINAL TEMPERATURE OF WATER (T_1)	________
5.	FINAL TEMPERATURE OF SOLUTION (T_2)	________
6.	TEMPERATURE CHANGE $(\Delta T = T_2 - T_1)$	________
7.	HEAT GAINED BY SOLUTION (K CAL)	________
8.	HEAT GAINED BY 1 MOLE $NaC_2H_3O_2 \cdot 3H_2O$	________

PART B

1.	WEIGHT OF 50 ML OF H_2O	________
2.	WEIGHT OF ANHYDROUS SALT	________
3.	TOTAL WEIGHT OF SOLUTION	________
4.	ORIGINAL TEMPERATURE OF WATER (T_1)	________
5.	FINAL TEMPERATURE OF SOLUTION (T_2)	________
6.	TEMPERATURE CHANGE $(\Delta T = T_2 - T_1)$	________
7.	HEAT EVOLVED BY SOLUTION (K CAL)	________
8.	HEAT EVOLVED BY 1 MOLE OF $NaC_2H_3O_2$	________
9.	MOLAR HEAT OF FUSION OF SODIUM ACETATE	________

HEAT OF HYDRATION OF $NAC_2H_3O_2$

Part A

1. Repeat the procedure from Part A above using 2.56 g of $NaC_2H_3O_2 \cdot 3H_2O$ instead of $Na_2SO_4 \cdot 10H_2O$.

Part B

1. For the heat of solution of the anhydrous sodium acetate salt use 1.13 g of salt and 50 ml of water as in Part B on previous page.

CALCULATIONS

1) Heat of Solution (K Cal) = Weight of Solution (g) x $t^{o}C$ x specific heat $(\frac{Cal}{g^{o}C})$ x $\frac{1 \text{ K Cal}}{1000 \text{ Cal}}$. Assume the specific heat of the solution is 1 $\frac{Cal}{g^{o}C}$.

2) Molar Heat of Solution $(\frac{K\ Cal}{Mole})$ =

$$\frac{\text{Molecular Wt. of solute (g) x Heat of Solution (K Cal)}}{\text{Weight of solute (g)}}$$

3) Molar Heat of Fusion = Hydrated Salt Molar Heat of Solution - Anhydrous Salt Molar Heat of Solution. The Molar Heat of Fusion will equal the solar energy that can be stored. The Molar Heat of Solution of a hydrated salt is a negative quantity because this is an endothermic reaction.

QUESTIONS

1. Ignoring the cost of the salt, which of the two anhydrous salts used will be the most effective for storing energy. Explain your answer.

2. How could such salts be used to store collected solar energy?

3. The cost of hydrated sodium acetate is approximately \$7.00/lb and that of hydrated sodium sulfate is \$5.90/lb. Which one of the two would be the most economical to use for the storage of solar energy? Explain the reason(s) for your choice.

Curriculum Topic

BUILDING A SOLAR STILL

Energy Topic

ENERGY SOURCES
ENERGY USES
ENERGY ECONOMICS
ENERGY CONSERVATION

Grade Level(s) 7 - 12

Site School, outside

Skills

- How to read a thermometer
- How to graph data
- How to interpret data

Credit

U.S. Department of Energy
Solar Energy Education Project

Objective

At the completion of this activity, you should be able to:

1. Build and use a simple solar still.
2. Suggest possible practical applications for a solar still.
3. Understand the principle of distillation.
4. Test for the presence of water.

To The Teacher

Stills are used to purify liquids for various purposes. Through a process of evaporating and condensing liquids, non-volatile impurities can be separated from the liquids to make them usable for desired activities.

Soil always contains some moisture although it is often difficult to use. By digging a hole in the ground and covering the hole with a transparent material, the temperature in the hole will go up dramatically and the moisture from the soil will vaporize. As the water touches the cooler undersurface of the plastic, it will condense and run down the plastic to drip into the container. This is a good survival technique to know as well as a demonstration of basic scientific principles.

Before You Begin

1. A calibrated container should be used as a collection vessel because it eliminates the need to pour the water from the collecting vessel into a graduated cylinder.

2. Plastic storm window sheeting works well for the plastic covering.

3. Allow two or three class periods.

4. Try on any warm day but sunny days will yield best results.

5. Discuss some practical uses for solar stills.

6. Each student should help with an aspect of construction of the still. Divide the labors so that the construction takes a minimal amount of time.

7. In order to compare results, each still must be similar to the other stills in construction and orientation.

8. Compile the data from all the stills and discuss the trends that seem evident. A discussion of the control of variables should be part of this lesson.

Words To Know

distillation, evaporation, condensation, purify

Related Activities

- If desired, this activity can be done with a large cardboard box in place of the hole. In this setup the soil must be moistened. Or fill a large bowl or sink half full of water, place an empty container in the center instead of digging a hole in the ground.

- Another variation might be the addition of food coloring, dirt and/or salt to a pan of water. Your students could then observe the collection of fresh water from contaminated water. See the activity "Solar Desalinizer".

- Another test may be performed to determine cleanliness of water. Evaporate two separate samples in watch glasses (one clean, one muddy). The clean sample should leave no residue.

- Repeat the activity measuring the amount of water collected as a function of time.

- Repeat the same activity with a change in the size of the hole. (Hint: a much deeper, narrower hole, or a wider, shallower hole.)

Resources

- SOLAR ENERGY, The Australia Science Education Project, 1974
- SCIENCE ACTIVITIES IN ENERGY, Northeast Solar Energy Center, Cambridge, Ma., 1979.

Notes To Myself

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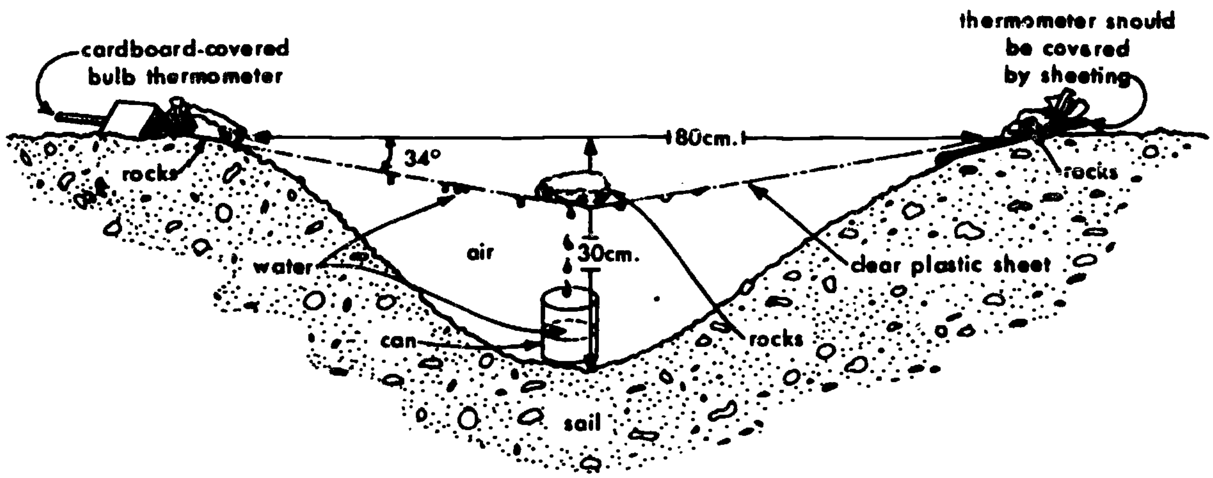
STUDENT PAGE

MATERIALS

- Strong, flexible transparent plastic sheet at least 1m square; e.g., plastic storm window covering.
- Several fist size rocks.
- Calibrated collecting can, or other such vessel.
- Shovel.
- Two thermometers ($-10^{\circ}C$ to $110^{\circ}C$ scale).
- Timing device (wristwatch or stopwatch).
- Piece of cardboard to cover ½ of the thermometer.
- Graph paper.
- Graduated cylinder.
- Cobalt chloride test paper, or other means of testing for water.
- Protractor.



METHOD

1. Dig a hole about 80cm in diameter and 30cm deep and place the soil to one side. Center the collecting vessel in the bottom of the hole.

2. Place the piece of plastic over the hole and firmly anchor one edge with small rocks.

3. Place one small rock in the center of the plastic sheet directly over the collecting vessel, and allow the plastic to stretch to at least a 34° angle from the horizontal.

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4. Seal the edge of the plastic with soil and small rocks.

5. Insert one thermometer under the plastic sheet with the bulb extending into the air chamber, and positioned so that the scale can be read.

6. Place the other thermometer near the solar still with the bulb covered by cardboard (as shown in the diagram), and positioned so that the scale can be read.

7. Simultaneously record the temperatures of both the inside and the outside thermometers at two-minute intervals. Construct a data table to record your results.

8. At the end of 20 minutes, carefully remove the plastic shield and retrieve the calibrated collecting vessel. Pour into the graduated cylinder to check the original reading and record the amount of liquid collected in ml.

9. Check the liquid collected to determine its identity; cobalt chloride paper may be used.

10. Construct two graphs with time on the x-axis and the temperature readings on the y-axis, using the same scale.

    a. Have graph I represent the outside thermometer reading vs. two minute intervals.

    b. Have graph II represent the inside thermometer reading vs. two minute intervals.

11. The hole should be filled in when the activity is complete.

QUESTIONS

1. Where did the water come from?

2. Why did it collect on the undersides of the plastic?

3. Why did it drip into the collecting vessel?

4. Compare graphs I and II. Are they similar or different? Explain.

5. How did solar energy cause the still to operate?

6. How did the temperature difference influence the volume of water collected?

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Curriculum Topic

A SOLAR DESALINIZER

Energy Topic

ENERGY USE
ENERGY AND ECONOMICS

Grade Level(s) 7 - 12

Site Classroom and home

Skills

- Follow directions carefully
- Measure metric length and volume
- Collect and interpret data from an experiment

Credit

U.S. Department of Energy
Solar Energy Education Project

Objective

At the completion of this activity, you should be able to:

1. Construct a small "still" that uses solar energy to make fresh water from saltwater.

2. Explain the process by which solar energy is used to remove impurities from water.

To The Teacher

The solar desalinization of sea water is currently used in some coastal regions of the world located below 40^{o}N latitude, where solar insolation is direct enough for desalinization to be economically feasible. A solar desalinizer utilizes two basic principles to produce freshwater for drinking. First, the solar insolation causes the sea water to evaporate causing the salt and other minerals to remain as residue in the evaporation vat. Secondly, the water vapor, which is now devoid of salt and other minerals, rises, cools, and condenses on a surface above the evaporation vat and is collected as freshwater. This process of separating mixtures by means of evaporation and condensation is called distillation.

All of the materials in this laboratory activity are readily accessible from the local grocery and hardware store at a minimal cost. The only item which cannot be purchased separately is the jar lid commonly used on jars containing instant coffee and other products. Consequently, have the students start bringing these into class two to three weeks prior to the activity to assure an adequate supply.

Before You Begin

1. Before the experiment, the teacher should build a solar still model for the students to examine. This will eliminate the need for lengthy instructions.

2. Approximately one class period is required to construct the desalinizer.

3. One school day (5 to 6 hours) is required for the apparatus to desalinize the salt water.

4. One to two class periods are required for the collection, interpretation, and discussion of data.

5. Use 250 watt heat lamp at a distance of 1 meter above the apparatus if there is no effective sunlight.

6. You may wish to make a stock salt solution to insure more uniform results.

Words To Know

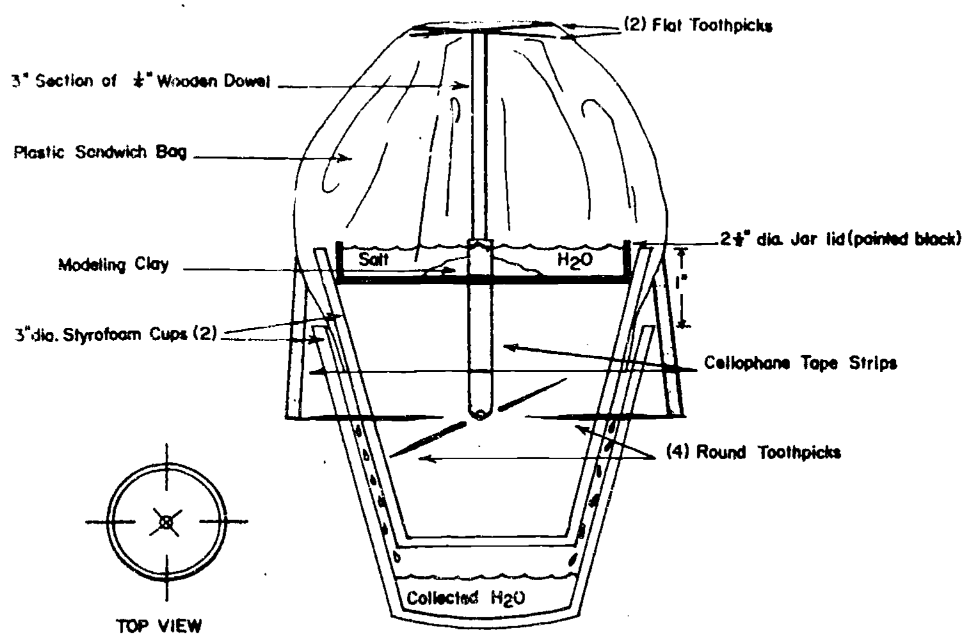
desalinizer, insolation

Resources

Solar Energy Project - Junior High Science Activities

Notes To Myself

STUDENT PAGE



MATERIALS

- 2 styrofoam cups.
- 3 flat toothpicks.
- 4 round toothpicks.
- 1 plastic sandwich bag.
- 1 7.5cm long section of ¼" wooden dowel.
- 1 piece of modeling clay.
- 1 jar lid.
- A small amount of salt.
- 1 ruler (metric).
- 1 sheet of newspaper.
- Black enamel paint.
- White glue.
- Cellophane tape.
- 250ml graduated cylinder.

METHOD

1. Refer to the diagram as your desalinizer.

2. Glue two flat toothpicks together at right angles to each other forming an + , and then glue them to one end of a 7.6cm section of wooden dowel. Let this dry.

3. Place the jar lid inside up on a sheet of newspaper and paint all of its inside surface black. Let it dry.

4. Measure 2½cm from the top of one styrofoam cup and draw a pencil line completely around the outside of the cup.

5. Lower the marked cup inside the second styrofoam cup until the drawn line is level with the tope of the outside cup. To fasten the two cups, put the four round toothpicks through both cups at 90° intervals.

6. To avoid being hurt by the sharp ends of the round toothpicks, put masking tape around their ends.

7. Mold modeling clay around the plain end of the wooden dowel. Place this clay, dowel, and toothpick assembly in the center of the jar lid. It should stand stright up.

8. Put the jar lid into the top of the inner styrofoam cup in a level position.

9. Refer to the diagram and the teacher's model as you construct your own solar still. Do not place the plastic bag over the still until your teacher tells you to do so.

10. Pour 125ml of hot tap water into a clean container and add a small amount of table salt.

11. Use clean hands to carefully taste the solution by dipping your finger tip into it and placing it on your tongue. How does it taste?

12. Put enough salt water solution into the jar lid to almost fill it. Be careful not to spill any of the solution into the outer cup.

13. Without letting the plastic bag touch the salt water solution, place it over the tow flat toothpicks. Carefully use another flat toothpick to tuck the sides of the bag between the two styrofoam cups.

14. To prevent the sandwich bag from collapsing, run four strips of cellophane tape from the sides of the bag to the four round toothpicks.

15. Place your still in direct sunlight for the school day.

16. After several hours, or when told to do so by your teacher, carefully remove the sandwich bag. What is in the jar lid? Taste it using the method already described and record your results.

17. Carefully remove the four toothpicks and separate the two cups. What is in the outer cup? If there is something there taste it. How does it taste? Use a graduated cylinder to determine the amount of liquid in the outer cup in milliliters and record your results.

QUESTIONS

1. a) What did the solution in the jar lid taste like before distillation? b) What did the solution in the jar taste like after distillation?

2. a) Was anything in the outer cup? b) If there was, what did it taste like? c) How many milliliters of liquid were in the outer cup?

3 How did the taste of the solution in the jar lid compare to the taste of the solution in the outer cup?

4. Energy was required to remove the salt from the saltwater solution. Where did the energy come from?

5. Explain as best you can how the still removed the salt from the saltwater.

6. Why was the jar lid painted black?

7. Are there any regions of the world where this method of water purification would not be feasible? Why not?

8. Can you think of uses other than water purification of an apparatus such as this? Explain your answer.

9. Can you think of a method for disalinizing water which does not use solar energy? What are the advantages and disadvantages of such a method as compared to solar desalinization?

Curriculum Topic

A PASSIVE SOLAR HOUSE

Energy Topic

ENERGY SOURCES, CONSERVATION, ECONOMICS, ENVIRONMENT

Grade Level(s) 7 - 12

Site Classroom

Skills

- Creative thinking
- Evaluating information
- Measuring angles

Credit

U.S. Department of Energy
Solar Energy Education Project

Objective

At the completion of this activity, you should be able to:

1. Understand the basic features required in a simple passive solar heating design.
2. Apply your knowledge of vegetation to landscaping arrangements that conserve energy in buildings.
3. Apply your knowledge of the angle of the sun during different seasons to the problem of building design.

To The Teacher

Passive use of solar energy involves using the sun's energy to heat a structure or substance without the need for any other energy source to accomplish energy transfer. The antithesis of this is the active use of solar energy which usually involves pumps and/or fans powered by electricity to accomplish the energy transfer.

There are various designs for passive solar systems, many of which were created by individuals for their own unique situation. Passive solar energy use involves many simple ideas that a homeowner can incorporate into a new home or an existing home.

The underlying principles involved in using passive solar energy for heating combine various structural patterns with landscaping to have the maximum use of the sun during the cold weather and minimum use of the sun during warm weather. To accomplish these ends, an overall site plan for a building lot must be devised based on some elementary knowledge of the sun's position at various times during the year. Most of the information about the motions and positions of the sun is available for a given locality from weather bureau publications. However, specific features on or near a building lot must be studied to account for their effect on the sun's availability at various times of a day or year. Hills, large trees, and other structures are some of the factors that can directly affect the availability of sunlight for a given locale. It is best, if a new building is to be built, to collect information about the sun's availability before deciding on the orientation of the building.

For a new building, certain structural design features will make passive solar heating attainable. Windows should be maximized on the south and west sides of the building and minimized on other sides. The windows should be at least double glazed on the south and west sides and tripled glazed on the other sides. An overhang should be built on the south and west windows which cuts out the sun during the summer and early fall and allows the sun to penetrate during late fall, winter and early spring. The windows on the sun side of the house should be covered at night with insulating drapes or by other means to keep the warm house air from contacting the cooler windows. The house should be properly insulated and weatherstripped to avoid infiltration and conduction heat losses as much as possible.

The landscaping of a building can contribute to best use of the sun's energy. Deciduous trees should be located on the south and west side of the building. Their leaves will shade the house in the summer and when their leaves fall will allow the sun to strike the building during fall and winter.

Coniferous trees should be located on the wind side of the building. They provide very good wind breaks for the prevailing winds in an area. Wind usually increases infiltration heat losses from a building. Reducing the wind should cut these losses.

This activity encourages the students to be creative in designing a passive solar home. Many other passive solar designs are available. Students might investigate them by reading the literature and incorporating a more complex system into their designs.

Before You Begin

1. Refer or complete the activity "The Sun's Position in the Sky" to encourage accurate testing procedures.

2. Allow two class periods.

3. Have the students work individually and compare results after completing their designs.

4. Leaving some of the work on display will encourage further discussion and investigation.

5. An alternative would be to assign the activity for homework and follow up with a full period of display and discussion directed by the teacher.

6. Tape toothpicks to backs of trees for added strength.

7. Worksheets A, B and C can be reproduced by various copying machines on heavyweight paper or traced onto a ditto master.

Words To Know

passive solar energy

Related Activities

- Modify the activity for students with greater sophistication by encouraging precise measurement of sun angle, roof pitch, overhang length, etc.
- Encourage the artistic student to design interior room spaces based on the best energy utilization.
- Refer to the activity "The Sun's Position in the Sky".
- Construct a model home from other materials such as wood or plaster of paris incorporating various passive solar design features.

Resources

- ENERGY BOOK #1, John Prenis, editor, (Running Press, Philadelphia, Penn.), 1975, pp. 112.
- PASSIVE SOLAR: A Controlled Experiment in Home Heating, Arthur Fisher, (Popular Science), April, 1978, pp. 76-79.
- SOLAR ENERGY, THE ULTIMATE POWERHOUSE, John L. Wilhelm (National Geographic) March, 1976, pp. 392-393.

STUDENT PAGE

MATERIALS

- Scissors
- Tape
- Straight edge
- Worksheets A, B, and C
- Light Source (filmstrip projector, lamp, etc.).
- Protractor

METHOD

1. Cut and fold the model dwelling and assemble without taping. (Worksheet A)

2. Place the folded model dwelling on the plot plan (Worksheet B) and decide on the setting of the dwelling. Make decisions about the room, windows and door placements. Unfold the dwelling and draw in the windows and doors.

3. Refold and tape the dwelling. Then tape the roof in place. Place the taped model dwelling on the plot plan. Cut out the model trees and shrubs and fold the bases. Use as many tree models as you desire to landscape the plots by taping the models in place. Remember, deciduous trees lose their leaves in fall.

4. Set the light source at the approximate angles for the winter and summer sky. Check the effectiveness for winter heating and summer shading of your landscaped plot. Be sure to replace summer deciduous models with winter models and visa versa.

QUESTIONS

1. How does your dwelling compare to those of other students in placement of windows, size of doors and roof arrangements?

2. What are common procedures in landscaping passive solar homes?

3. In which direction should the largest roof overhand face to take advantage of winter sun while avoiding summer sun?

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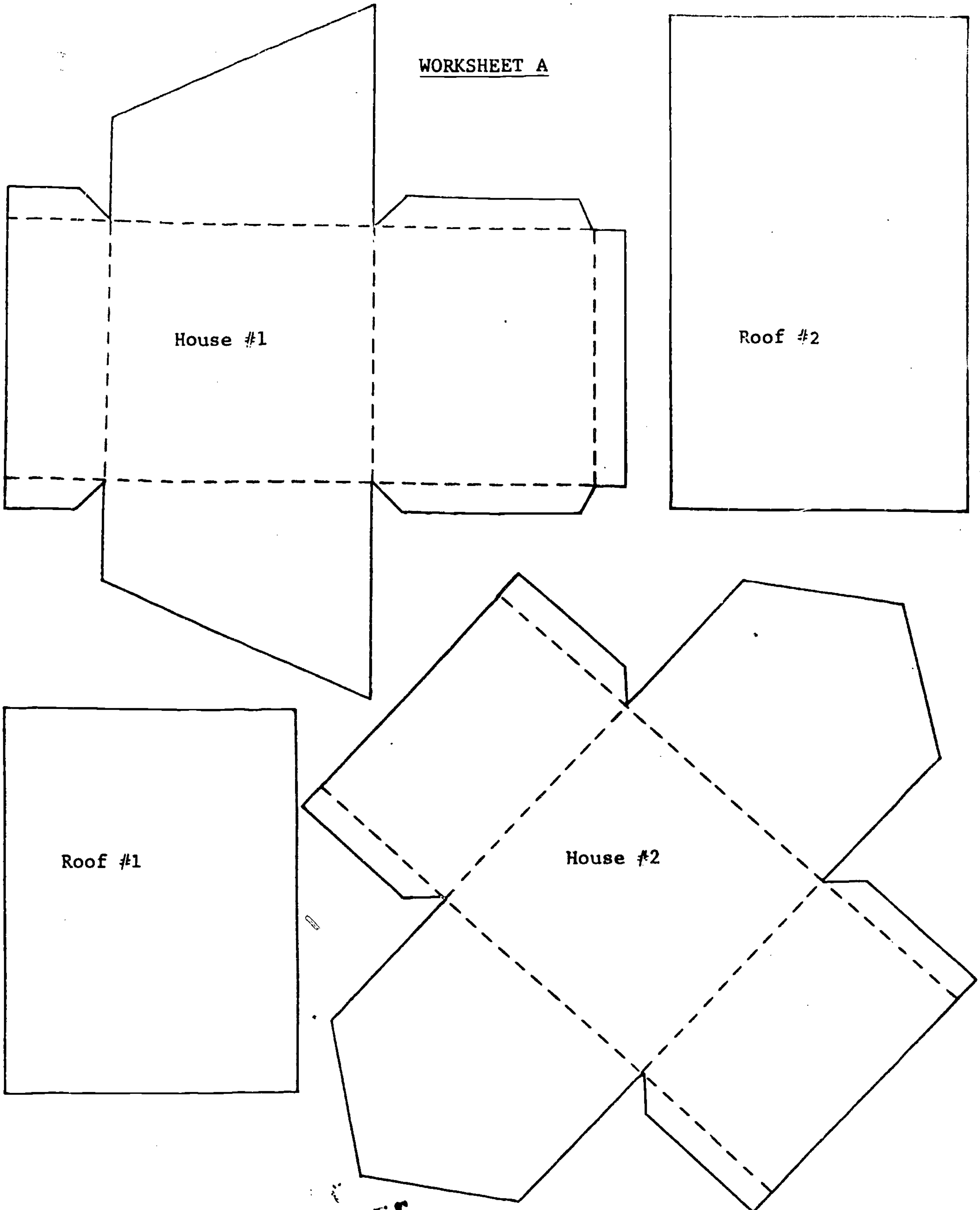
WORKSHEET A



WORKSHEET B

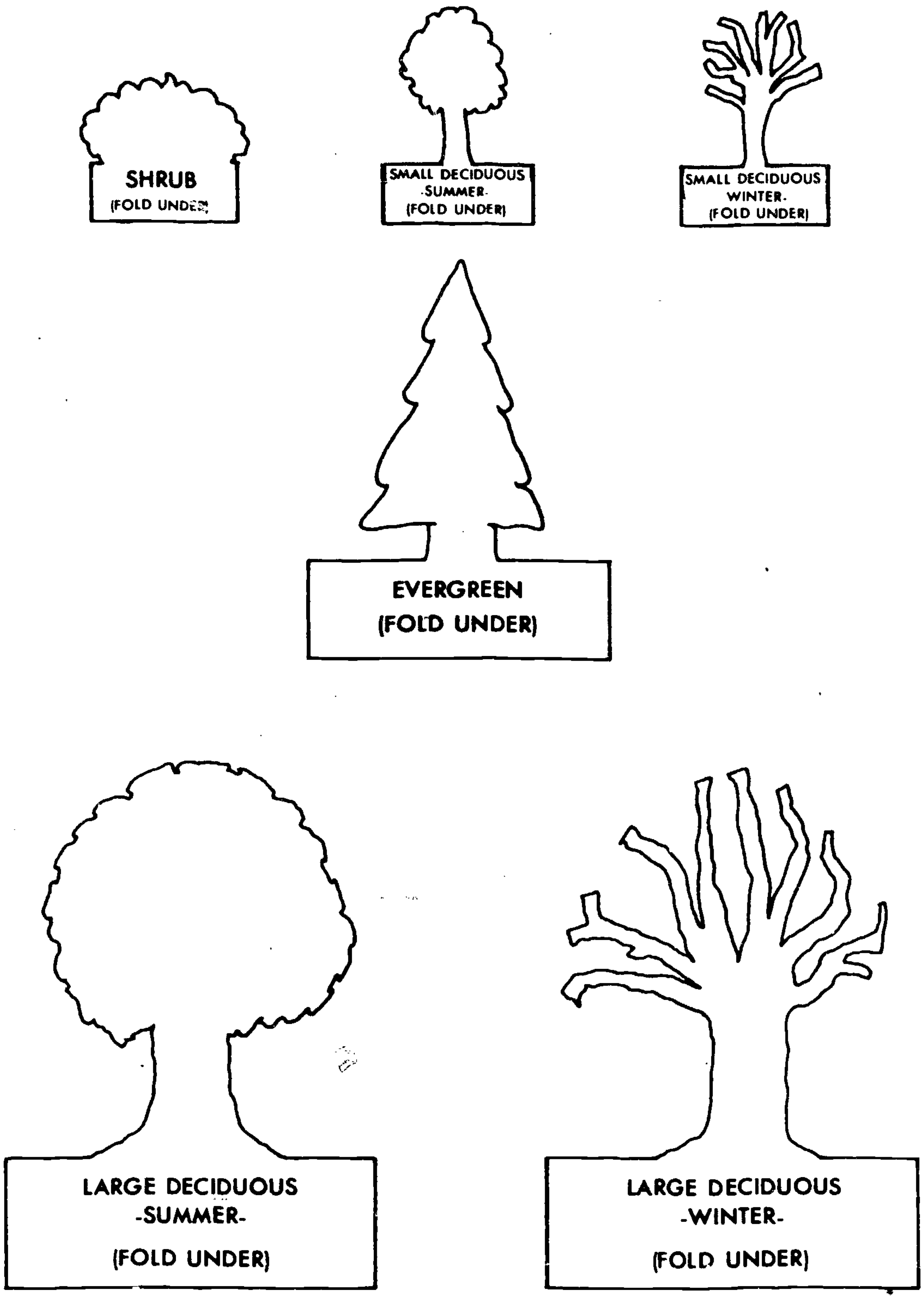
KEY

Fence (Indicate Height)

Driveway

Sidewalk

WORKSHEET C


SHRUB
(FOLD UNDER)
SMALL DECIDUOUS
-SUMMER-
(FOLD UNDER)
SMALL DECIDUOUS
-WINTER-
(FOLD UNDER)
EVERGREEN
(FOLD UNDER)
LARGE DECIDUOUS
-SUMMER-
(FOLD UNDER)
LARGE DECIDUOUS
-WINTER-
(FOLD UNDER)

Curriculum Topic

ROOF OVERHANG AND SOLAR WINDOW

Grade Level(s) 7 - 9

Site Classroom

Skills

- Read a thermometer.
- Read a stop watch or other timing device.
- Graph data.

Energy Topic

ENERGY SOURCES
ENERGY CONCEPT
ENERGY AND ECONOMICS

Credit

U.S. Department of Energy
Solar Energy Education Project

Objective

Upon completion of this activity you should be able to:

1. Determine how a feature of your home, roof overhand, relates to solar heating of your home.

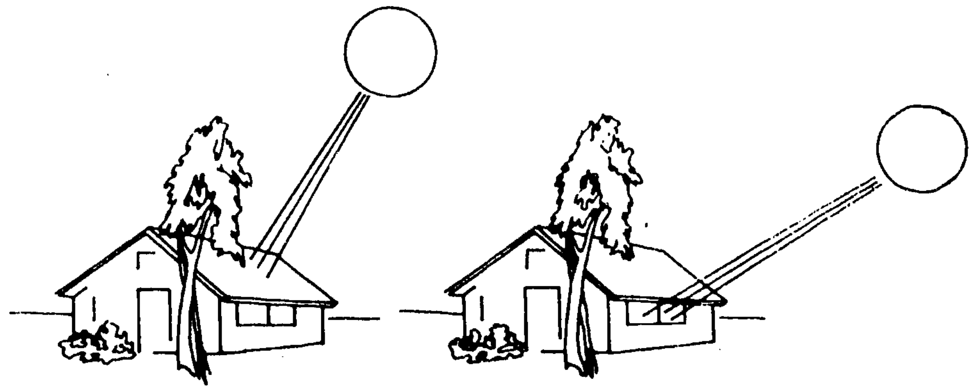
To The Teacher

The purpose of this activity is to demonstrate the value of properly placed roof overhangs in passive cooling and heating of a home.

When light passes into a house and strikes any surface, the visible radiation is absorbed and infrared is re-radiated. This longer wavelength radiation is associated with heat. The glass allows light in but doesn't allow the heat out. This is referred to as the 'greenhouse effect'. A darker surface absorbs better due to greater production of this infrared radiation.

During the summer where the sun is at a higher angle, the overhang should be far enough out so that the window is covered completely. In the winter with a smaller angle, the sun has a greater chance of entering the same window.

The optimum overhang for a house will vary with latitude, position of the window, etc.



SUMMER AT NOON   WINTER AT NOON

Before You Begin

1. The model homes can be constructed using styrofoam panels available as insulation in a lumber yard. They are, generally, approximately 2cm x 120cm. One model house is easily constructed out of a single panel this size ending up 20cm deep by 40cm wide by 30cm high. The styrofoam is easily cut with a razor blade and glued together with a thick white glue. The white glue seals up openings in the seams as well as holds it together. Windows can be made of clear plastic or plexiglass glued to the inside of the model with the same glue. The use of styrofoam provides insulation as well as an easily handled construction material. The roof, also made of styrofoam, is 40cm x 30cm and made to fit on top and also overhang. The size of the window is approximately 10cm x 10cm. The location of the half-shadow can be marked on the house at the time of construction.

2. Two class periods. (One class period for collecting data, one class period for results and discussion.)

3. This lab could be implemented in a heat or solar energy unit. The activity illustrates the absorption of radiation, the purpose of insulation and could be related to a solar collector.

4. This lab could be introduced by having students measure the roof overhang on their homes facing south. They might discuss in post-activity whether their house has an optimum design.

5. Divide the class into several groups and have each group collect data under the same conditions.

Words To Know

overhang, infrared radiation, greenhouse effect

Related Activities

- Determine on the south side of your own home, the percentage of window area covered by shadows or roof overhangs.

- What effect would a home with no insulation have on the experiment?

- Using information about the angle of the sun at various times of the year at different latitudes, found in an earth science book, figure the best size overhang for the windows in your home.

- Determine the effects of a double glazed window, roof cover, and different interior colors on the experiment.

- Construct a removable vent cut out from lower north wall of house (1 x 5cm). Cut two more vent plugs (1 x 2cm) on both sides of the window just under the roof overhang. This experiment will demonstrate convection cooling in the summer (a solar plenum).

- Measure the temperature with vent plugs in for your initial reading. Compare this with the outside temperature. Remove the plugs and take temperature readings at 2 minute intervals.

- The model houses could be made of virtually any insulating material (wood, cardboard, newspaper, etc.). The window could be made of polyethylene or kitchen wrap type of plastic film. GLASS SHOULD NOT BE USED BECAUSE OF ITS WEIGHT AND THE CHANCE OF BREAKAGE.

Notes To Myself

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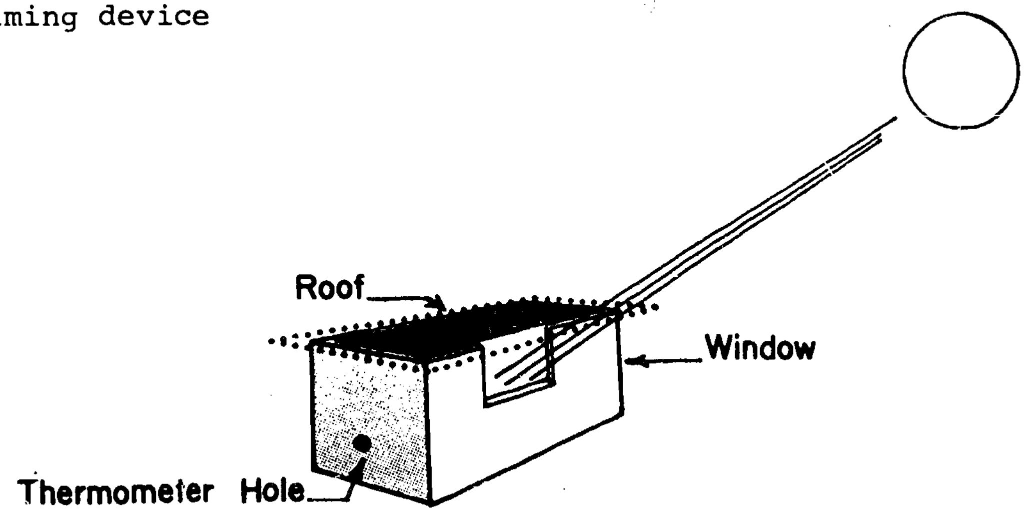
STUDENT PAGE

MATERIALS

- 1 insulated model house (per group).
- 1 laboratory thermometer (per group).
- (1 sun lamp, if done on a cloudy day).
- Timing device



METHOD

1. Get an insulated model home from your teacher. BE CAREFUL SINCE THE MODELS ARE SOMEWHAT FRAGILE AND SHOULD BE HANDLED WITH CARE. It consists of a styrofoam box, painted black inside. It has one window in the side and another piece of styrofoam to form a flat roof. (See diagram).

2. Make a data sheet to record all information to be measured. A suggested form for recording data is shown on the next page.

3. Place a thermometer into the hole at the side of the house and record the temperature on your data sheet.

4. Place the model in direct sunlight and adjust it so that the sun shines directly into the window without the roof overhang casting a shadow on it. If it is cloudy, you can use a heat lamp in place of the sun.

5. Record the temperature inside the model each minute for five minutes on your data sheet.

6. Remove the roof from the house in order to allow the air inside the building to return to the same temperature as the surrounding air. Fanning with the roof will speed this.

7. Plot the data, temperature vs. time, on a graph.

8. Repeat steps 5, 6, and 7 using different amounts of shadow on the window. First, it should be done by adjusting the roof to cast a shadow which covers ½ the window, and then it should be repeated where the window is entirely in shadow. Plot all the information on the same graph.

Time	Temperature ($^{\circ}C$)		
	Direct Sunlight	½ Shadow	Full shadow

QUESTIONS

1. If you were designing a home or remodeling one, what could you do with roof overhang to make the building cooler in the summer?

2. In the summer the sun is higher in the sky than it would be in the winter. Explain how this might help or hinder the heating or cooling of your home with roof overhang.

3. What are some other possible forms of heating and cooling that can be used in your home that would not require purchased energy, such as electricity and oil?

Curriculum Topic

A SOLAR INSTALLATION SITE PLAN

Energy Topic

ENERGY: THE CONCEPT
ENERGY USES
ENERGY SOURCES

Grade Level(s) 11 and 12

Site School or home, outside

Skills

- Use a compass.
- Use simple geometry to determine angles.
- Use a clinometer.

Credit

U.S Department of Housing and Urban Development
U.S. Department of Energy
Installation Guidelines for Solar DHW* Systems
*Domestic Hot Water

Objective

At the completion of this activity, students will be able to:

1. Obtain a true north-south line to determine best solar orientation.

2. Determine the path of the sun across the sky at chosen site for mid-winter heating needs.

3. Decide upon a plan to improve a site for a solar installation.

To The Teacher

The way in which a building is oriented is critical for the potential use of solar energy. In this activity students learn what is the best orientation for a new home or make an analysis of an existing structure such as their own home or school. Factors such as local climate and seasonal changes in the sun's path must be taken into account.

For both active and passive solar use a collector should be oriented true south. Collectors 15° to the east or west of south perform nearly as well. With roofs of existing structures greater than 15° from souch special mountings for solar collectors would have to be considered at an added expense.

Because the earth's magnetic field is not aligned paraellel with the earth's north-south axis, there are some parts of the United States where the needle of a magnetic compass can point as much as 20 degrees east or west of true north. However, there are several ways to determine the true south in your area. You can consult a local surveyor, a plot map in your local tax office, or a recent isogonic chart of the United States published by the U.S. Coast and Geodetic Survey, U.S. Department of Commerce (Figure 1.7) and adjust your magnetic compass reading according to the meridian nearest to you. Don't use old charts, as there are annual variations in the readings. When using a magnetic compass, beware of standing near large metallic objects or power lines because they will affect the compass readings.

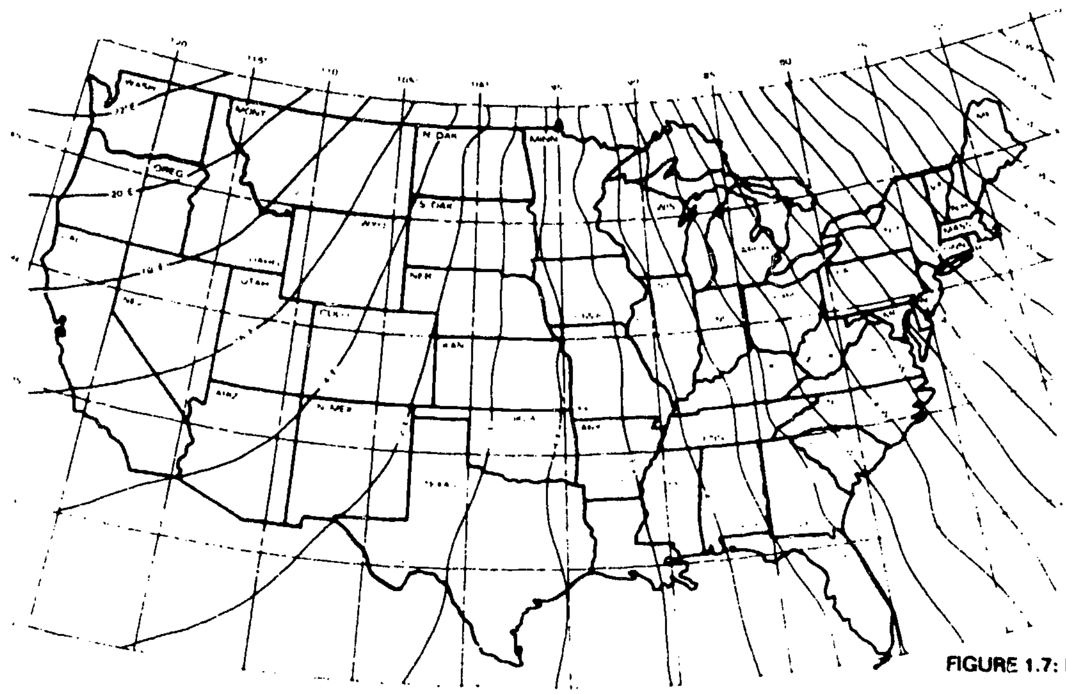


FIGURE 1.7: ISOGONIC CHART OF THE U.S.

Also, you can easily determine true south yourself, right at the installation site. Place a stake in the ground and mark the location of the shadow of the top of the stake. Connect the end point of a morning shadow with the end point of an afternoon shadow by a straight line. A line drawn 90° to that line is a true north-south line. (Figure 1.8)

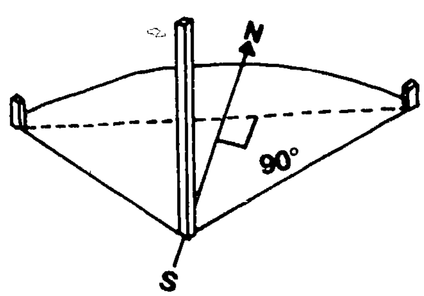


FIGURE 1.8: STAKE AND SHADOW METHOD

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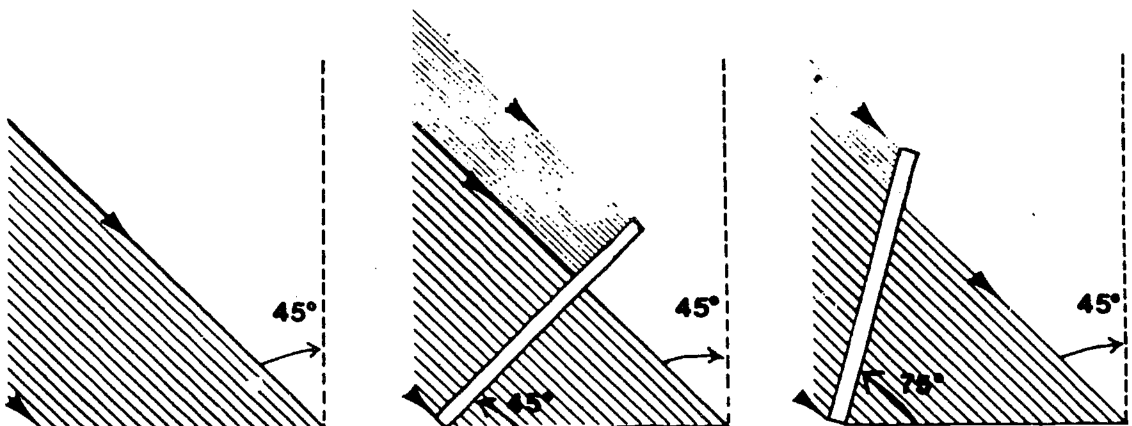
There is an even faster way to determine your local north-south line. The shadow of a stake cast by the sun at solar noon will be on the true north-south line. Solar noon is exactly halfway between sunrise and sunset on any given day. Most local TV weather shows and newspapers give the exact times of sunrise and sunset each day.

Although performance will not be substantially affected, take local weather conditions into consideration when deciding on collector orientation. Although angling the collectors toward the east will start the system earlier in the morning, orientation slightly to the west can increase system performance because ambient temperatures are usually higher in the afternoon. As a result, collectors will lose less heat and operate more efficiently. If early morning fogs are common in your area, angle the collectors slightly toward the west.

COLLECTOR TILT

Collector tilt- the angle the surface of the collector makes with the horizon - is also an important factor in system performance. Ideally, collectors should be nearly as perpendicular to the sun's hottest rays as possible (Figure 1.9). For a solar DHW system, a tilt equal to the local north latitutde is usually considered the



(a) Collector Tilt Angle 0° (b) Collector Tilt Angle 45° (c) Collector Tilt Angle 75°

FIGURE 1.9: RADIATION ON HORIZONTAL, NORMAL AND NEARLY VERTICAL SURFACES

Radiation Intercepted by a Horizontal Collector
Additional Radiation Intercepted by Tilting Collector

optimum angle. Variations 10^{o} either way will not seriously affect the total annual performance of the system, all other things being equal, but a greater tilt will favor winter system operations when the sun is low in the sky (Figure 1.10). Also, in heavy snow areas a tilt of 50^{o} will allow snow to slide off the collectors more readily The following chart will help you determine the angle of the existing roof:

TABLE 1.1 ANGLE/ROOF PITCH CONVERSION TABLE

ROOF ANGLE

SLOPE	PITCH	ANGLE (APPROX.)
2/12	1/12	9°
3/12	1/8	14°
4/12	1/6	18°
5/12	5/24	22°
6/12	1/4	26°
7/12	7/24	30°
8/12	1/3	33°
9/12	3/8	37°
10/12	5/12	39°
11/12	11/24	42°
12/12	1/2	45°
13/12	13/24	48°
14/12	7/12	50°
15/12	5/8	52°
16/12	2/3	54°
17/12	17/24	55°
18/12	3/4	57°
19/12	19/24	59°
20/12	5/6	60°

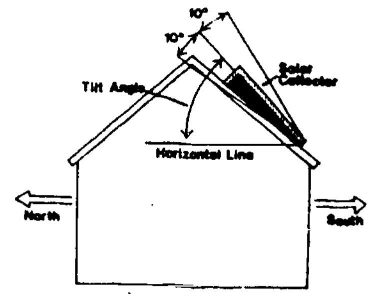


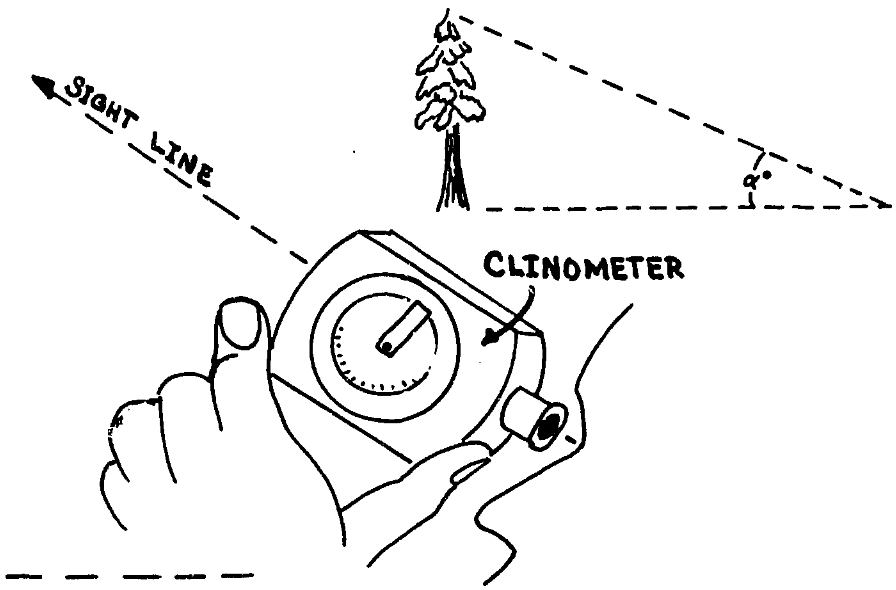
FIGURE 1.10: COLLECTOR TILT

COLLECTOR SHADING

No more than 5% of the collector area should be shaded between 9:00 a.m. and 3:00 p.m. Standard Time when greatest solar potential occurs. One of the major sources of shading is trees, so the home owner should be aware of the effect of future growth. Chimneys, dormers, other buildings, new construction, and even fences may shade the collector array, especially in the winter when sun angles are low and shadows are long. By knowing the altitude, (angle of sun above horizon) and the azimuth (angle between true south and point on horison below sun) of the sun throughout the year, you can accurately determine if the homeowner is going to have shading problems.

THE SOLAR WINDOW

Imagine the sky as a transparent dome with its center at the solar collector array of a house. The path of the sun during the year can be etched (projected) on the dome, as can the outline of surrounding houses and trees (Figure 1.11). The sun's path during the optimum hours between 9:00 a.m. and 3:00 p.m. Standard Time throughout the year scribes a "solar window" on the dome. Almost all of the useful sunlight that reaches the collector array must come through this window, except for the amount resulting from diffuse radiation. If any surrounding houses, trees, hills, etc. block part of this window, that intrusion will cast a shadow on the collector. The elevation of the solar window in the local sky will decrease with increasing latitude.



CLINOMETER

A clinometer is a simple instrument used to measure vertical angles. This device may be used to determine roof angles by sighting up the slope of the roof.

The clinometer will also allow you to sight on the various features of the horizon especially those obstructing the winter sun. The altitude (vertical angle) and azimuth (compass bearing corrected for declination) of the obstructions and horizon features can then be plotted on a mercator grid. From this a plan for sight improvement can be formulated.

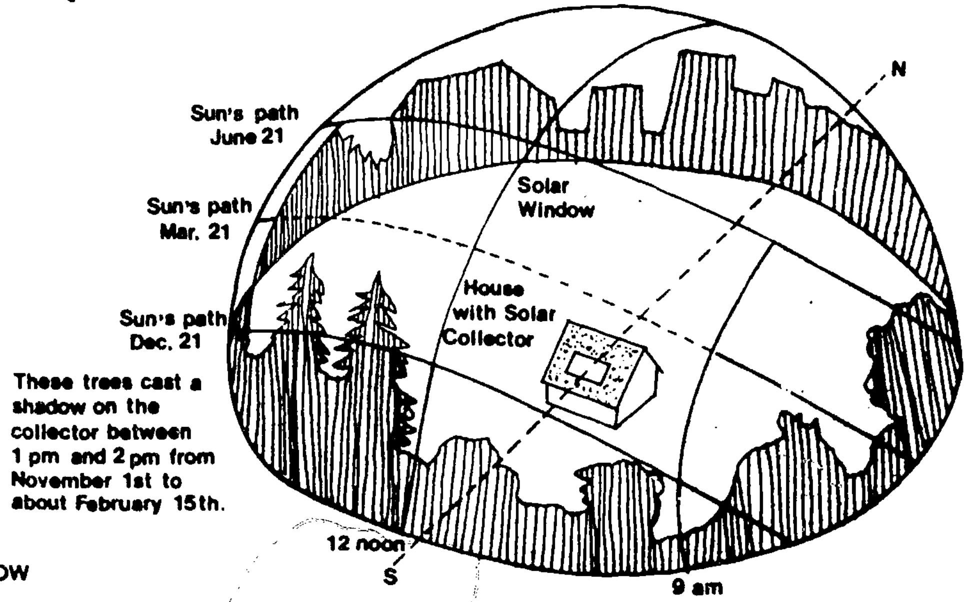


FIGURE 1.11: THE SOLAR WINDOW

MERCATOR PROJECTION

The sky dome with its "solar window" can be mapped using a Mercator projection in which the latitude and longitude lines are straight (Figure 1.12). Such a map is very useful for comparing the site

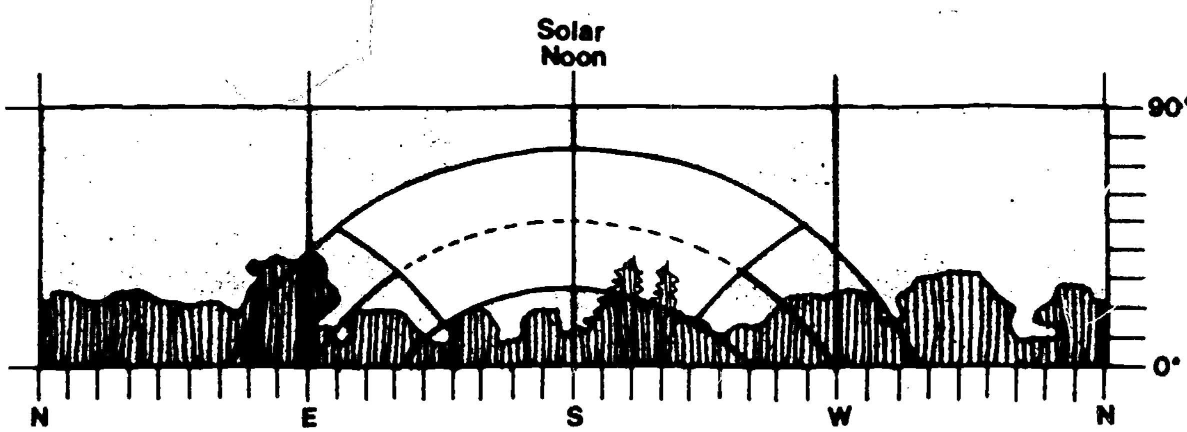


FIGURE 1.12: MERCATOR PROJECTION

surroundings with the "solar window", because both can be easily plotted on the map. Any elements surrounding the site that intrude into the "solar window" will cast shadows on the collector.

THE POPULAR SCIENCE SUN LOCATOR

A simpler method was created for Popular Science Magazine*. Make a copy of the sun locator (Figure 1.13) and glue it to a cardboard backing. Trim along the line of the latitude nearest you. Place locator in a level position in the area where collectors are to be mounted. Align the compass along the correct magnetic declination line or per a recent isogonic chart (Figure 1.7) to obtain a true north-south line(see Collector Orientation). Sight from the

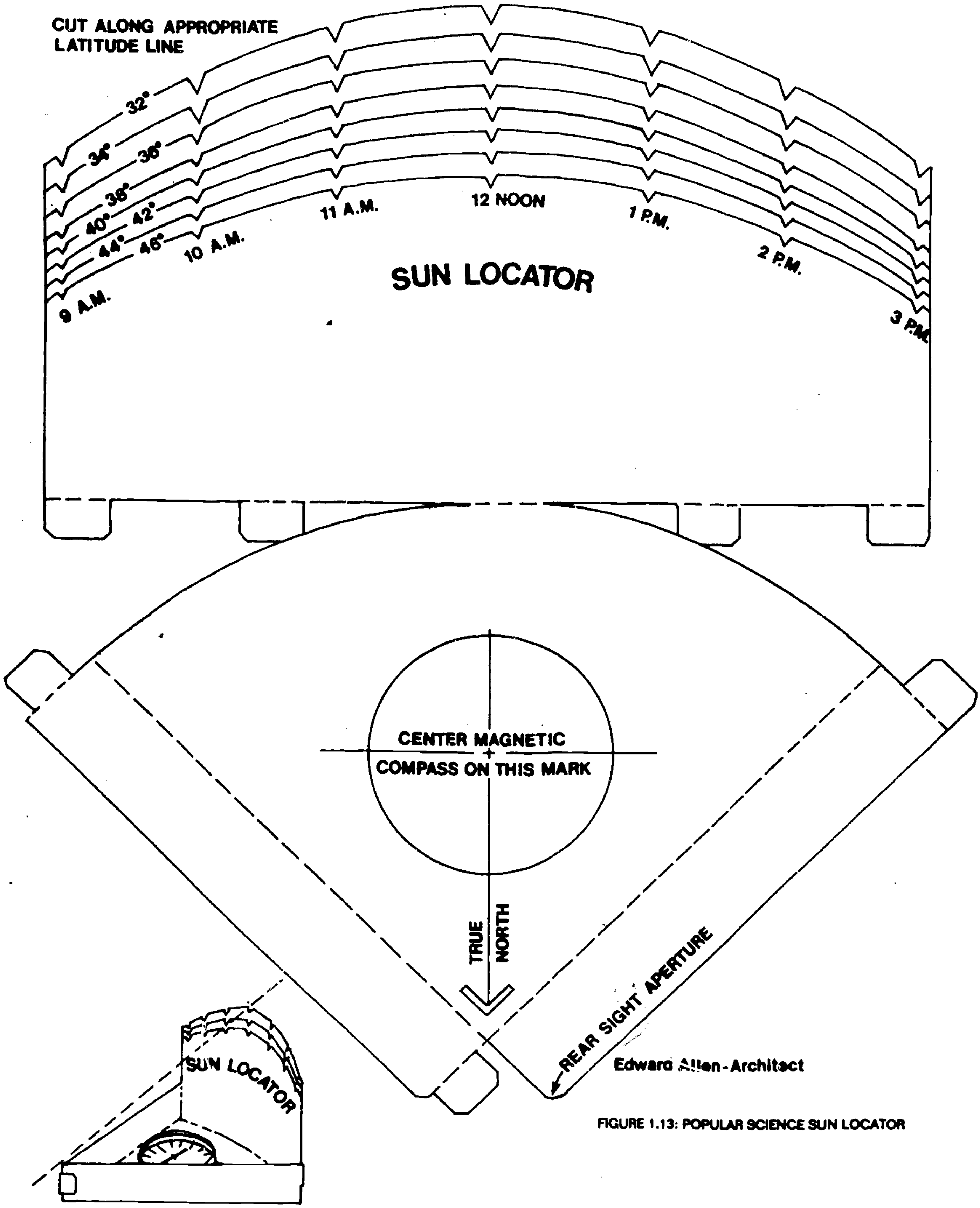


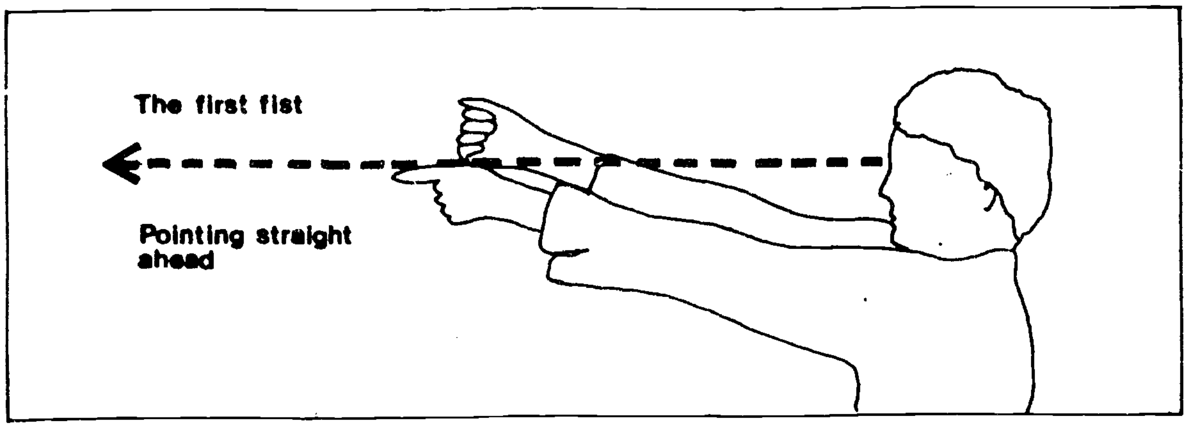
FIGURE 1.13: POPULAR SCIENCE SUN LOCATOR

corner over the top of the latitude line from 9:00 a.m. to 3:00 p.m. This is the path the sun will take in midwinter. If more than 5 percent of the path is blocked, the site may need closer evaluation.

Even tree branches without leaves can block a considerable amount of winter sunlight if the branches are thick. Consider trimming, if necessary.

THE ENERGY TASK FORCE ROUGH APPROXIMATION METHOD

The Energy Task Force of New York suggests a way of roughly determining the solar window. Stand where the collectors are to be placed and face true south. Point so that your finger and your eye are horizontal (Figure 1.14). Place one fist on top of another the exact number of times to be determined by consulting the table (Table 1.2).



GURE 1.14: POINTING LEVEL WITH EYE

*See Solar Energy Handbook 1978. Popular Science, Times Mirror Magazines, Inc., 380 Madison Ave., New York, NY 10017 . . . $1.95.

TABLE 1.2. THE ENERGY TASK FORCE SOLAR WINDOW APPROXIMATION METHOD

LATITUDE	12 O'CLOCK POSITION = 0° BEARING	11 O'CLOCK POSITION = 30° BEARING ANGLE (EAST)	1 O'CLOCK POSITION = 30° BEARING ANGLE (WEST)
28°N	4½ FISTS (47° ALT.)	3 FISTS (30° ALT.)	SAME AS 11 O'CLOCK
32°N	3½ FISTS (34° ALT.)	2½ FISTS (26° ALT.)	SAME AS 11 O'CLOCK
36°N	3 FISTS (30° ALT.)	2¼ FISTS (23° ALT.)	SAME AS 11 O'CLOCK
40°N	2½ FISTS (27° ALT.)	2 FISTS (20° ALT.)	SAME AS 11 O'CLOCK
44°N	2¼ FISTS (23° ALT.)	1½ FISTS (17° ALT.)	SAME AS 11 O'CLOCK
48°N	2 FISTS (20° ALT.)	1½ FISTS (14° ALT.)	SAME AS 11 O'CLOCK

Sight over top of fists at true south and 30° east and west (with adjustments in fist height) to determine shading effects. Any object above your fists will cast a shadow on your collecotrs; and anything below your fists will be of no concern.

Before You Begin

1. Introduce the activity, discuss the use of a compass, true south, and how to determine a site.

2. Construct a sun locator and complete activity.

3. Complete maps and discuss a site plan.

4. Pass out lab sheets a day in advance to familiarize students with the problem. Discuss the concept of solar energy and the use of solar collectors for a heating system.

5. Divide the class into groups of two or three.

6. Have each group select a site around your school.

7. Locate true south and map the surroundings.

8. Sites with trees or buildings and uneven terrain make for a more interesting activity, although the site should be somewhat in the open.

Words To Know

Solar window, azimuth, Standard Time, solar time, mercator projection, magnetic north and south vs, true north and south

Related Activities

- Students may take this activity home to help make a solar plan for their own home site and make recommendations for improvement of their respective home sites.

Resources

INSTALLATION GUIDELINES FOR SOLAR DHW SYSTEMS IN ONE AND TWO-FAMILY DWELLINGS. U.S. Department of Housing and Urban Development, 1979.

CLIMATE ATLAS OF THE UNITED STATES. National Climatic Center, Federal Building, Asheville, North Carlina.

DESIGNING AND BUILDING A SOLAR HOUSE. D. Watson, Garden Way Publlishing, 1977.

NO HEAT, NO RENT: AN URBAN AND ENERGY CONSERVATION MANUAL. Energy Task Force, New York, NY.

Notes To Myself

STUDENT PAGE

MATERIALS

- Compass
- Clinometer
- Mercator Grid
- Sheet of cardboard
- Scissors

METHOD

1. Construct a sun locator. Be sure to cut along the proper latitude line.

2. Choose a site for a solar installation around your school.

3. Locate a true north-south line for this location using stake and shadow method, or compass with declination.

4. Starting at east (90^o) find the vertical angle (above 0^o) of trees, buildings and uneven terrain in relation to your site using a clinometer

5. Repeat Step 4 for each 10^o on the compass to south (180^o) and finally to west (270^o) and plot all points on your mercator grid.

6. Plot on your mercator grid the coordinates at each bearing. (Note whether trees are deciduous or coniferous as they will affect sunlight penetration at different times of the year.)

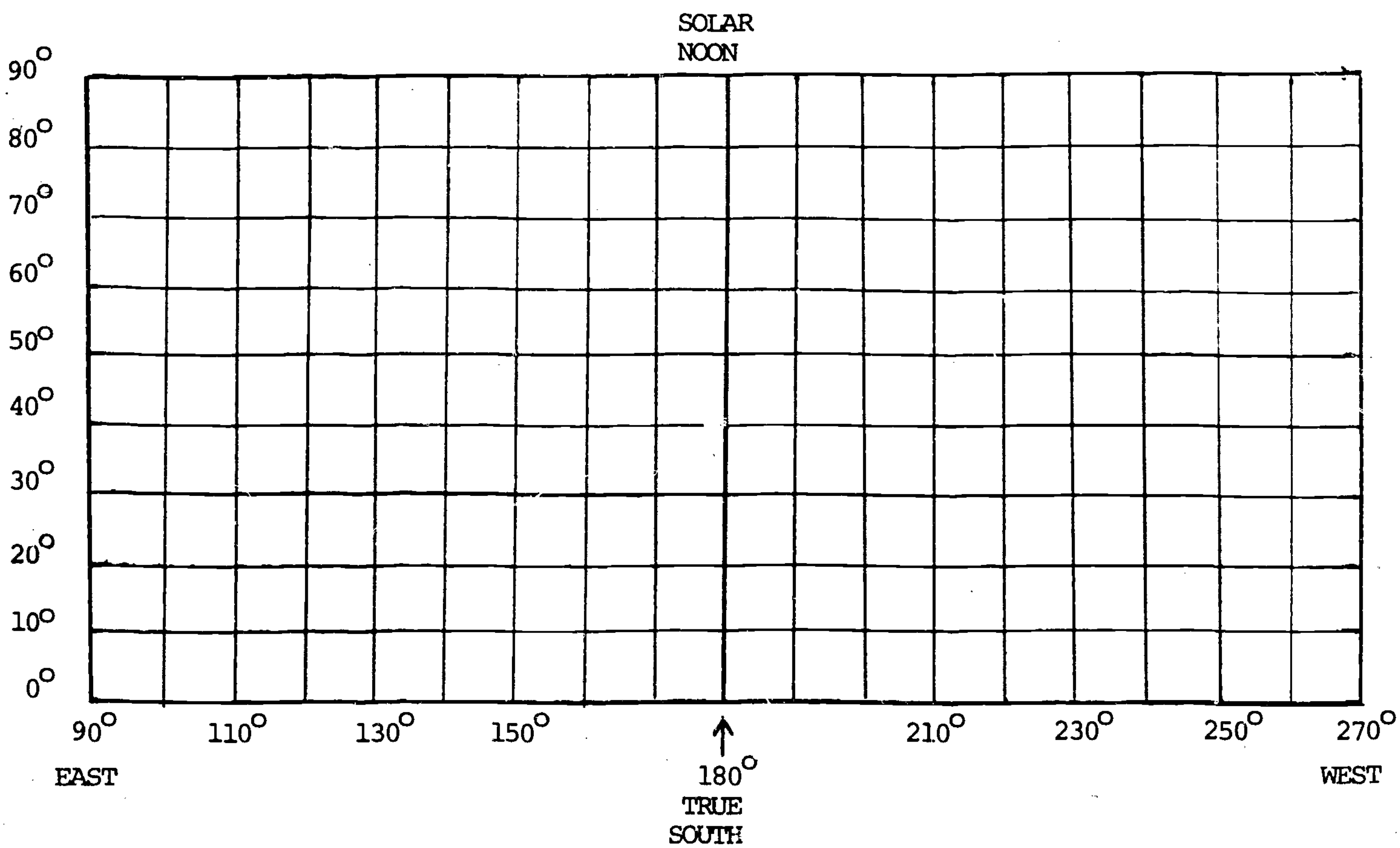
7. Determine if objects (trees, buildings, etc) are permanent or moveable for later site modifications.

8. Using your "sun locator" determine the path of the midwinter sun across the sky for your site.

9. Plot this line on your mercator grid and determine what site features interfere with the sun's midwinter path.

10. Make a plan to modify the site for the best solar installation.

MERCATOR GRID



Curriculum Topic

MEASURING WIND ENERGY WITH A HOMEMADE WIND SPEED INDICATOR

Energy Topic

ENERGY SOURCES
ENERGY CONCEPT

Grade Level(s) 7 - 12

Site School or home

Skills

- Recording, graphing, and interpreting data
- Building a measuring device

Credit

Science Activities in Energy
The American Museum of Science and Energy
Oak Ridge Associated University

Objective

At the completion of this activity you should be able to:

1. Build a wind measuring device.
2. Record and graph data.
3. Speculate on the feasibility of wind power generation at different test sites. (Average 8-10 mph winds are needed to make wind power generation worthwhile)

To The Teacher

Wind Energy

Mankind has been making use of wind power for centuries. One of the first known uses was to propel sailing ships. This was followed, centuries later, by the development of windmills. Windmills enabled the Netherlands to become one of the world's most industrialized nations by the 17th century. In the United States, windmills played an increasingly important role in the nation's development from the early 1800's through the first quarter of the twentieth century. As use of fossil fuels became more widespread, the use of windmills became considerably less important in our economic development. Now, as we gradually use the world's known oil reserves, the use of wind power appears as an alternative source of energy to be harnessed for productive work.

Wind is a form of solar energy. About 2% of the solar radiation that falls on the earth is converted to wind energy in the atmosphere. At any given moment, half of the earth's atmosphere is exposed to the sun, and an equal amount is in shadow. The cyclical heating and cooling transforms the biosphere into a huge heat engine, generating energy, some of which is manifested as wind.

Like solar energy, the major drawback to the use of wind as an important energy source is the problem of storage. Wind can be used to generate electricity, but only if the winds constantly remain over 8-10mph. Thus, effective storage mechanisms, such as batteries, must be used if wind is to be a substitute for current sources such as coal and oil. Like solar energy, wind is free and has potentially less harmful environmental impact than use of fossil fuels. Like solar energy, there are technological problems associated with storage.

The activities in this series cover some of the uses and problems associated with wind power.

Before You Begin

1. Most materials needed can be purchased from local discount stores.

2. If bubble levels are too expensive, use a small test tube with water. Fill almost to the top with water, place stopper in top. When placed on its side a small air bubble should appear. This air bubble can be used as a leveling bubble. If bubble is too large just add more water.

3. One class period will be needed to construct wind measuring device.

Words To Know

calibrate

Related Activities

- Another simple method of measuring wind speed is shown below. Try comparing your data recorded with the wind speed indicator with measurements recorded by using this flag method.

Estimating Wind Velocity a Flag

Appearange of flag	ind speed (mph)
Flag limp	less than 4 mph
Flag flaps	4 to 8 mph
Flag waves	9 to 12 mph
Flag stands out	13 to 18 mph
Flag pulls hard on rope	19 to 24 mph
Flag makes a snapping noise	25 to 31 mph
Remove flag	More than 35 mph

Notes To Myself

STUDENT PAGE

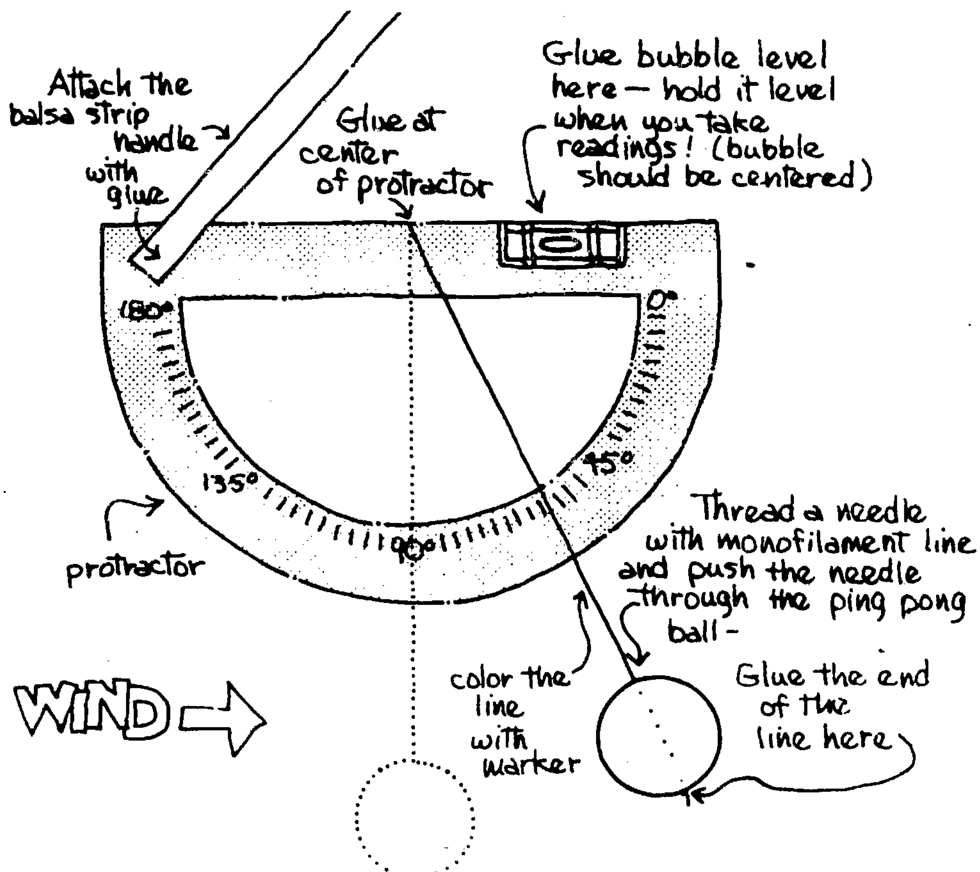
Building a Wind Speed Indicator

MATERIALS

- 1 ping pong ball
- 1 piece fishline (.08" - .02" diameter monofilament nylon line, 30cm long - try a fishing/bait shop or sporting goods store)
- Protractor
- Red magic marker
- 1 strip balsa, about ½cm square x about 18cm long (¼" thick)
- 1 bubble level (the kind with an air bubble inside - try a local hardware store)
- Glue
- Needle (long enough to go through the ping pong ball)

METHOD

1. Build a device to measure the wind according to diagram below.



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2. Calibrate the wind speed with the table below.

Angle	MPH	Angle	MPH	Angle	MPH
90	0	65	13.4	40	21.4
85	5.8	60	14.9	35	23.4
80	8.2	55	16.4	30	25.8
75	10.1	50	18.0	25	28.7
70	11.8	45	19.6	20	32.5

3. Keep an ongoing record of wind speed at various locations.

<u>Wind Speed Chart</u>

Date	Time	Location	Test Device Used	Wind Speed

<u>QUESTIONS</u>

1. Is there a strong wind between two buildings in your area?

2. What is the difference in wind speed at ground levels and at higher elevations?

3. Are the winds stronger in the valley or in the hills where you live?

Curriculum Topic

BUILDING AND TESTING WINDMILLS

Energy Topic

ENERGY: THE CONCEPT
ENERGY SOURCES

Grade Level(s) 7 - 12

Site

School classroom and outside

Skills

- Use simple tools
- Record and graph data

Credit

Science Activities in Energy
The American Museum of Science & Energy
Oak Ridge Associated Universities, TN

Objective

At the end of this activity students will be able to:

1. List the major features of three different windmill designs (Helix, Savonius, and Conventional rotors)

2. Build a model of a windmill

3. Record and graph data from the operation of different windmill models

4. Infer from the data, windmill efficiency according to design

To The Teacher

With growing energy shortages it has become necessary to explore alternative energy sources both new and old. Wind has been used by man for centuries as an inexhaustible but undependable source of power.

In many parts of the country wind power may be impractical especially for standard rotor type windmills which require average wind speeds of 10 - 15 MPH. This lesson will explore windmill design and the practical application of a windmill for your area.

Before You Begin

1. Have students accumulate materials around the house several weeks in advance of activity in order to have enough for each student.

2. Class time should be set aside for an introduction to windmills, history and design. One class will be taken up in windmill construction and one for measurements and testing.

3. Have students choose one type of windmill. If time permits they may wish to build other types or design one of their own, this activity works best with students working in groups of two.

4. Group judgements may be made as to the design and efficiency of each type of windmill. Decide which is better for low winds (10 MPH or less) and high winds (greater than 10 MPH).

5. The Savonius and Helix rotors are designed to turn with multi-directional winds on a vertical axis but for this activity they are held horizontal. Show students wind direction with wet finger or a tell tale hung in the wind.

Words To Know

Savonius rotor, Helix rotor, conventional windmill

Related Activities

- Full size windmills may be constructed with older students, a bicycle wheel works very well
- Measuring wind energy with a home-made wind speed indicator.
- In this guide, larger Savonius rotors may be constructed from tin cans to oil drums.

Resources

- Wind and Windspinners, Michael Hackleman and David House, Peace Press, Culver City, California, 1974.

- Catch the Wind, Dennis Landt, Four Winds Press, New York, New York, 1976.

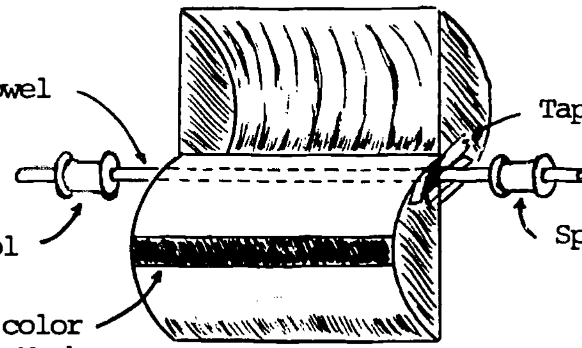
Notes To Myself

STUDENT PAGE

BUILDING A SAVONIUS ROTOR

MATERIALS

- 1 empty 1 lb. salt box
- masking tape, scissors
- 1 dowel 3/16"
- 2 wooden spools



METHOD

1. Cut the salt box in half, lengthwise.

2. Carefully tape each half together as shown in the diagram.

3. Punch a hole in each end of one of the halves, as shown in the diagram.

4. Insert the dowel.

5. Push the wooden spools over each end of the dowel--you will use these to hold the windmill.

6. Paint a stripe of color down one half of the salt box on the convex side as shown. This will enable you to easily see the revolutions of your windmill.

7. Holding the windmill horizontally outside in the wind, count and record the number of revolutions in one minute.

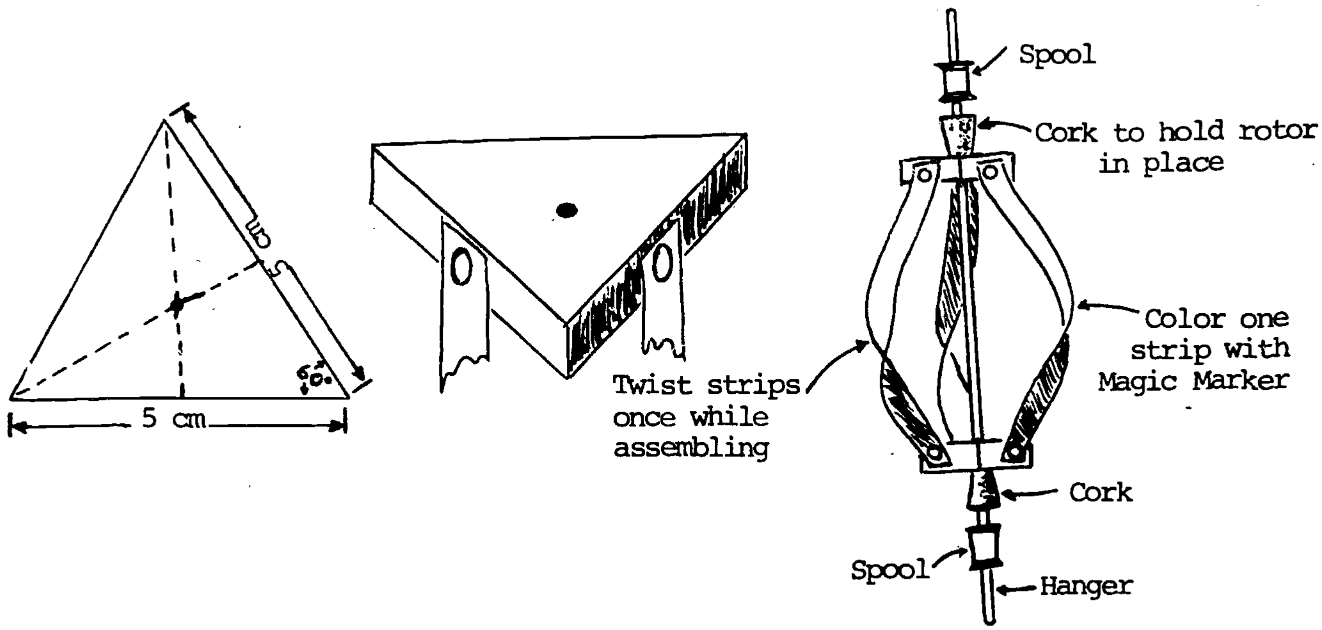
BUILDING A HELIX ROTOR

MATERIALS

- razor knife
- 1 coat hanger
- 1 piece ½" balsa or styrofoam
- 2 corks or one-holed stoppers
- 2 wooden thread spools
- 1 magic marker
- 1 sheet oak tag or construction paper

- 6 thumbtacks

HELIX ROTOR



METHOD

1. Using a razor knife, cut a 5 cm x 5 cm x 5 cm triangular block of balsa or rigid styrofoam.

2. Cut three strips of oak tag, 2 cm wide.

3. Find center of triangular block and make a hole slightly larger than the diameter of the coat hanger.

4. Create helix by giving a half twist to the oak tag strips and pinning them to the sides of the triangle. Before adding all three strips, make one a different color with a magic marker.

5. Assemble entire rotor as in diagram.

6. Hold rotor vertically and test outside. Recording the number of revolutions in one minute.

BUILDING A CONVENTIONAL ROTOR

MATERIALS

- coat hanger
- 8 tongue depressors
- 5 cm x 5 cm piece of ½" balsa

- 2 corks or one-holed stoppers

METHOD

1. Cut a 5 cm x 5 cm piece of balsa wood into a perfect octagon.

2. Cut angular grooves across the side faces of the octagon to accomodate the tongue depressor rotor blades (all angles should be the same).

3. Trim blades square on the end to be inserted into the balsa block and glue these into place. Color one blade for recording revolutions.

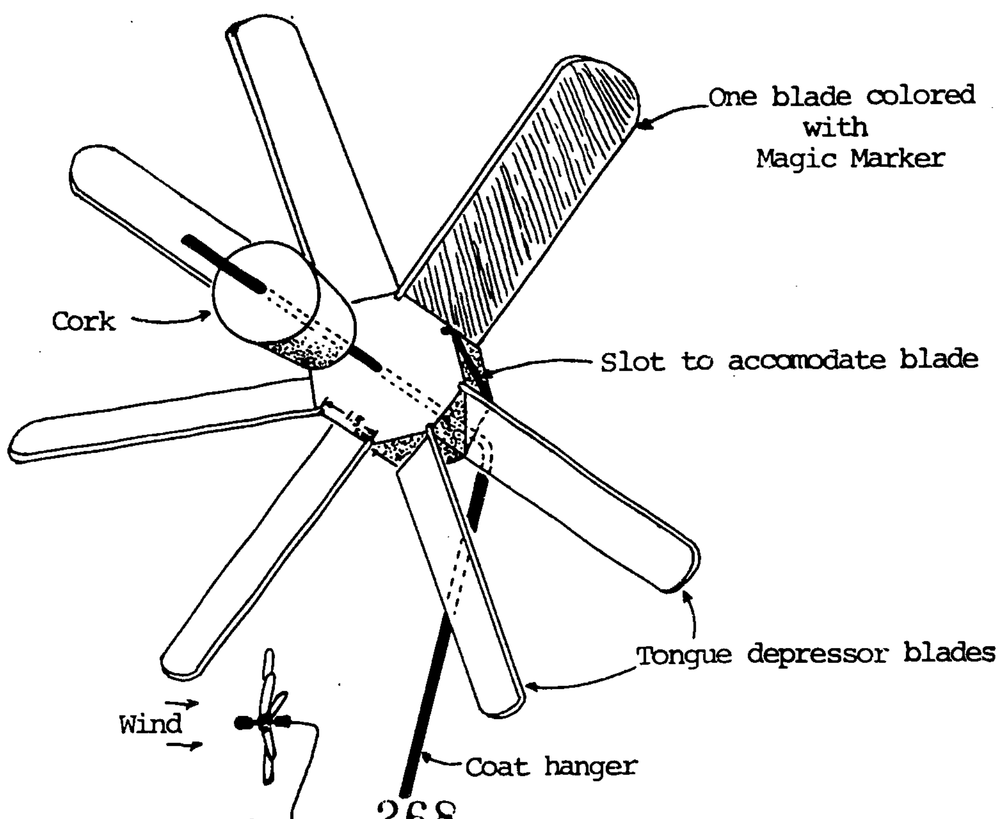
4. Find the center of the octagon and make a hole slightly larger than the diameter of the coat hanger.

5. Bend a right angle in the coat hanger. Slide one cork on as a stop to hold rotor in place, then slide on rotor with another cork in front. (A piece of paper may be used as a washer between corks and rotor to reduce friction.)

6. Hold in wind and count revolutions.

7. Try with a 2 or 4 blade design if time allows.

CONVENTIONAL WINDMILL



Curriculum Topic

ELECTRICITY FROM WIND POWER

Energy Topic

ENERGY SOURCES
ENERGY THE CONCEPT

Grade Level(s) 7 - 12

Site Classroom

Skills

- Understand electrical units; watts, volts, and ohms

Credit

Science Activities in Energy
The American Museum of Science and Energy
Oakridge Associated Universities

Objective

1. Find a propeller angle which works best to drive a windmill.

2. Determine what effects wind speed and propeller size have on the production of electricity.

To The Teacher

Wind power is being considered more and more as an alternative energy source. The main problem is that winds are not dependable. Most wind generators work at an optimum wind speed of 10-15 mph. Keeping this in mind, an average year-round wind speed of 8-10 mph is required. Most parts of our country are below this average with the exception being coastal areas, the midwestern plains and higher mountain ranges. With this unit, the student will explore the concepts of the standard windmill design and find where improvements can be made.

Before You Begin

1. The electrical components of this experiment may be found in your physics lab. If not, you may purchase them from a local hobby

or electronics store.

2. It is helpful to have more than one fan, but this may account for some different results since fan speeds may vary.

3. It would be best to have students work in groups of 2 or 3, each group trying different variables.

4. The activity may take two or three periods to complete depending on on the degree of experimentation with different variables.

5. Using a fan helps to make a constant variable against which each design may be tested. If time permits, further testing may be done outdoors with a natural wind.

Words To Know

Volts, voltmeter, ohms, watts, resistor, power, DC vs AC power

Related Activities

- The electricity generated may be put to use to light a flash-light bulb (1.5v). Two motors may be wired in tandem for another result.

- See in the guide: Measuring wind with a homemade wind-speed indicator; Building and testing windmills.

Resources

CATCH THE WIND. Dennis Landt, Four Winds Press, New York, New York 1976.

WIND AND WIND SPINNERS. Michale Hackleman and David House, Peace Press, Culver City, California 1974.

Notes To Myself

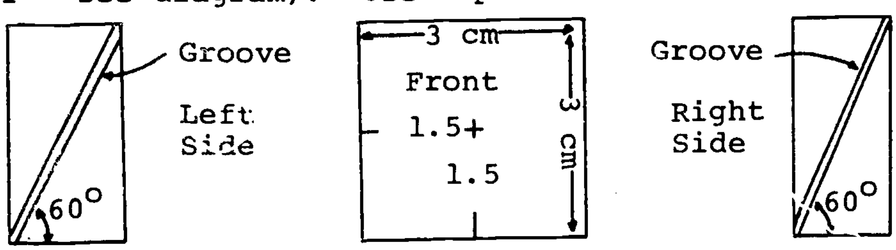
STUDENT PAGE

MATERIALS

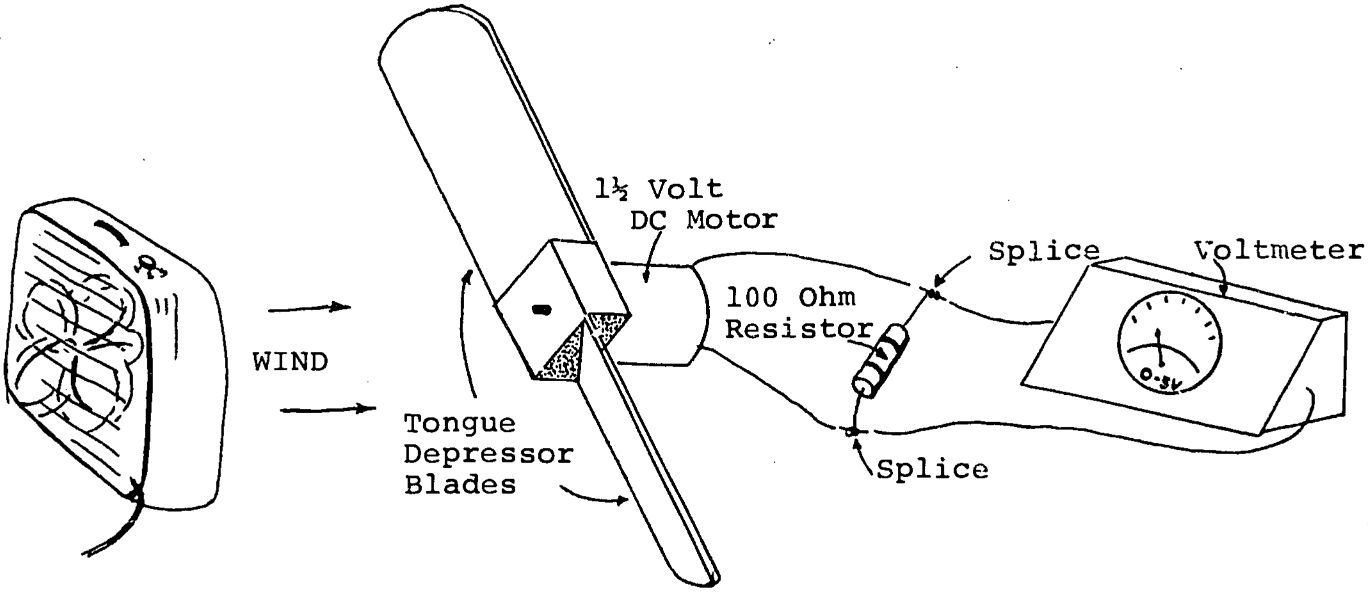
- 1 tongue depressor cut in half (propellers). More tongue depressors may be obtained from the teacher as you progress further in this activity.
- 2 pieces of ½" balsawood 3cm x 3cm.
- 1 small 1½ volt DC motor.
- 1 voltmeter (0 - 5 volts).
- 1 100 ohm (½ watt) resistor.
- 30cm plastic insulated hook-up wire.
- 1 plastic model airplane propeller.
- 1 fine hacksaw blade, razor knife, hammer and small nail or drill for hole in propeller (not larger than motor shaft).
- Fast-drying glue.

METHOD

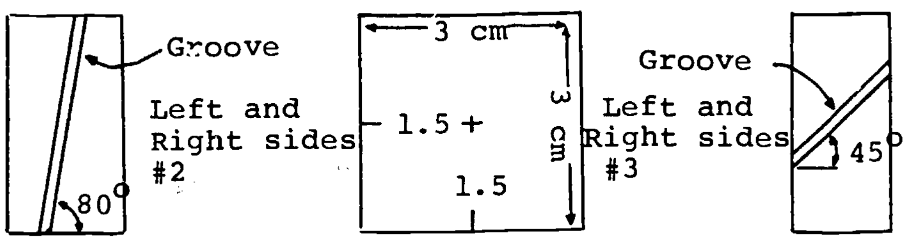
1. Carefully cut a 3 x 3cm block of ½" balsa with a razor knife.
2. Using a fine hacksaw blade, make a diagonal groove on opposite sides of your block (these angles sould be exactly the reverse of eachother - see diagram). Use a protractor to determine angles.



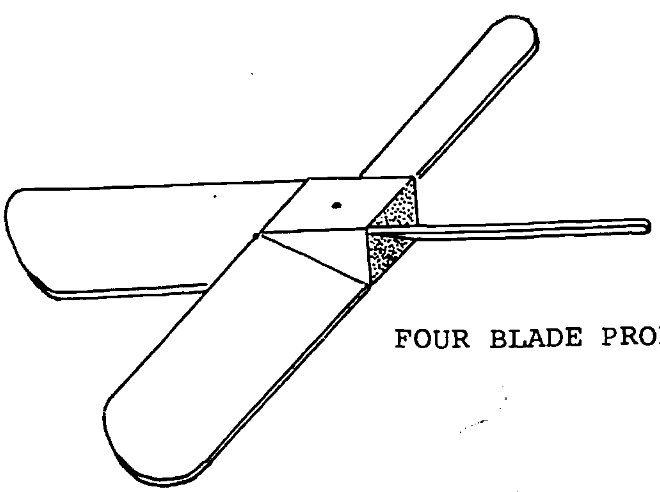
3. Using a ruler, find the center of the front of your block. Make a hole ½cm deep and not larger than the motor shaft. (Use a hammer and nail or a small drill.)
4. Cut a tongue depressor in half and glue the square ends into the slots in your mounting block.
5. Force the block onto the motor shaft using the pre-drilled hole. (The blades should turn the motor shaft.)
6. Hook up leads from motor to voltmeter splicing the 100 OHM resistor between the two wires.
7. Turn on the fan and test your propeller holding it by the motor. (If the voltmeter reads negative, reverse the lead wires.) Try this with different fan speeds and record your results.



8. Build a second propeller using the same procedure but change the angles. (See diagram, use angle for either #2 or #3.)



9. Test this propeller in the same way.
10. Determine the best angle by comparing results.
11. A third design can be built with four blades.



FOUR BLADE PROP

12. A fourth design can be built with a full-size tongue depressor for each blade. (One end will have to be trimmed square for each to fit in the groove.)

13. Test a plastic airplane propeller and compare to your design.

14. Test your design outside. Is the voltage constant?

STUDENT TABLE - METERED NUMBER OF VOLTS

FAN SPEED	2 prop. 60°	2 prop. 80°	2 prop. 45°	2 prop. long blades	4 prop.	plastic airplane prop.
1						
2						
3						
OUTSIDE WIND						

15. Calculate and compare the electric power produced for each design.

$$\text{Power (watts)} = \frac{\text{voltage x voltage}}{\text{100 OHMS}} \quad \text{or} \quad W = \frac{V^2}{R}$$

$$\text{Example volts} = .6 \qquad \frac{.6v \times 6v}{\text{100 OHMS}} = .0036 \text{ watts}$$

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Curriculum Topic

PRODUCING HYDROGEN WITH ELECTROLYSIS

Energy Topic

ENERGY SOURCES

Grade Level(s) 7 - 12

Site School laboratory

Skills

- Use of simple lab set-up

Credit

Science Activities in Energy
The American Museum of Science and Energy
Oakridge Associated Universities

Objective

At the completion of this activity the student will be able to:

1. Understand the process of splitting water molecules into hydrogen and oxygen through electrolysis.
2. Create a new volatile energy source.

To The Teacher

Hydrogen is often referred to as the energy of tomorrow. Hydrogen has already been used for years in space flight and is a very efficient, clean-burning fuel, but it has many drawbacks. Hydrogen is very volatile and unstable, making it a dangerous fuel to store and burn. (The amount created in this experiment should not be a dangerous quantity, but caution should be exercised when igniting the gas.) Scientists have devised a way to charge fragments of porous metals with this volatile gas. In this form the gas is released slowly and can be used to power automobiles and buses. (Many prototypes are now being developed using this concept, but it is expensive.) New, cheaper ways of developing hydrogen have to be developed if we are to depend on it as a fuel of the future.

Before You Begin

1. This experiment is best performed in a laboratory. The students should work in pairs.

2. The activity should take only one period (45 minutes to 1 hour) to complete, but a follow-up on the potential uses and drawbacks of hydrogen as a future fuel would help complete this unit.

3. The students may also need an introduction to molecular structure and ionic charges.

4. The positively charged hydrogen will be attracted to the negative electrode. The oxygen will split off and will be attracted to the positive electrode.

5. Have the students predict which gas will have a greater volume from the molecular formula of water and atomic weights.

Words To Know

Electrolysis, ion, H_2O, H^+

Related Activities

- Determine ways in which hydrogen may be produced cheaply. Many ideas are found in future science articles in newspapers and magazines.

Notes To Myself

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STUDENT PAGE

MATERIALS

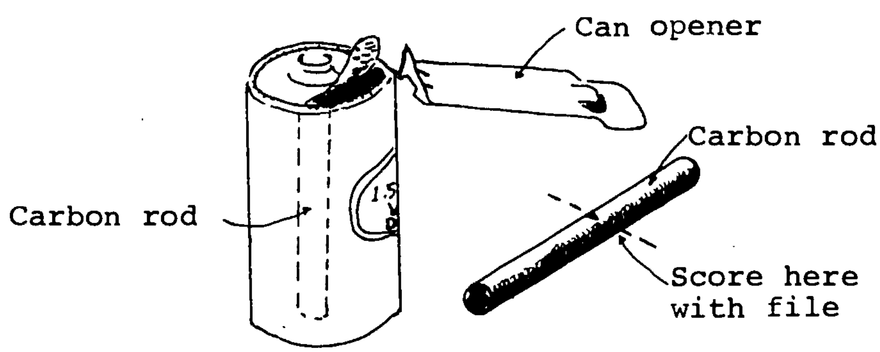
- 2 45cm pieces of #24 enameled copper wire
- 1 6v lantern battery
- Electricians tape
- Angular file
- 1 drinking glass or beaker (100 ml)
- 1 used flashlight battery
- 1 can opener
- 1 tablespoon baking soda
- Dull knife

METHOD

1. Carefully open a used flashlight battery with a can opener.

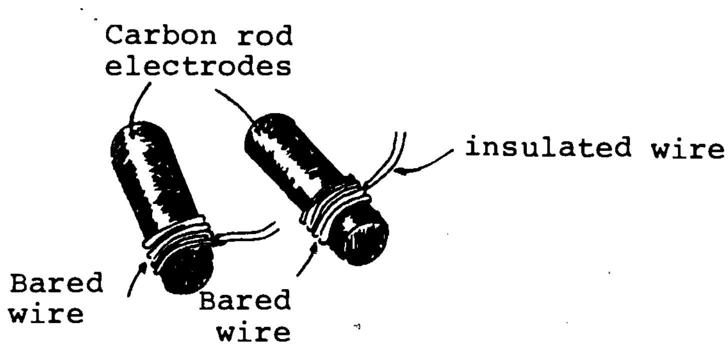
2. Remove the carbon rod in the center and scrape it clean with a dull knife.

3. Score the rod in the center with a file and break it into two pieces. (A pencil lead may be substituted for the carbon rod but will not be as effective.)



4. Bare one end of each piece of wire for 5cm.

5. Wrap one bared wire around one end of each carbon rod.



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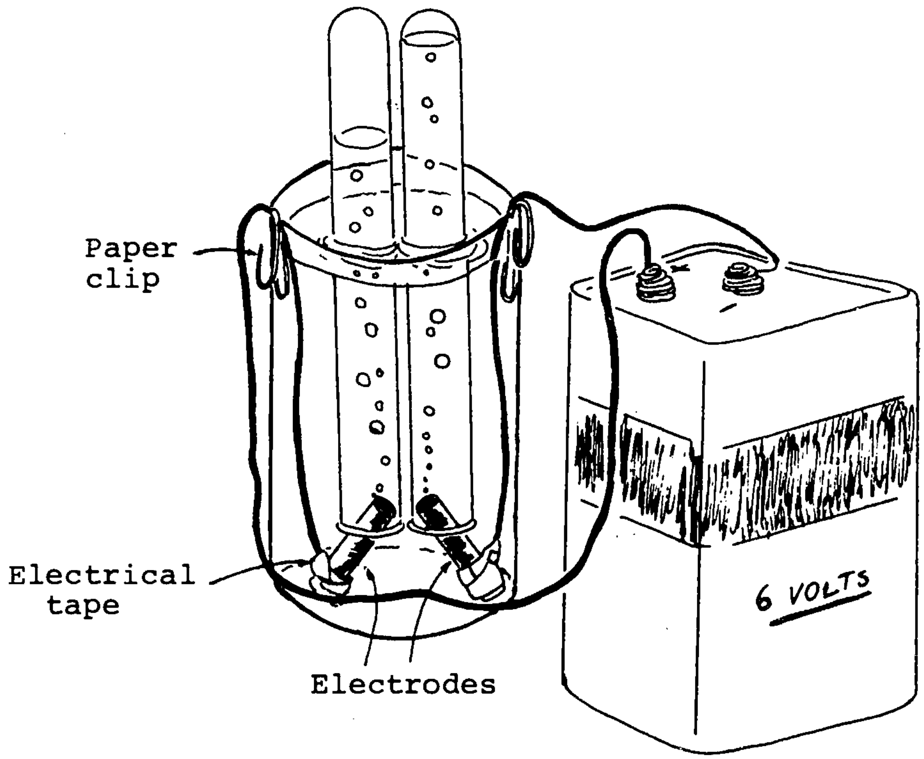
6. Wrap the bared wire on the electrode with electrician's tape. (Be sure and cover all the bared wire.)

7. Fill your beaker or glass with water.

8. Fill both test tubes with water and invert them in the beaker, holding your thumb over the end so no water escapes.

9. Put the electrodes in place, one under each test tube. (Do not connect your wires to the battery until the teacher directs you to.)

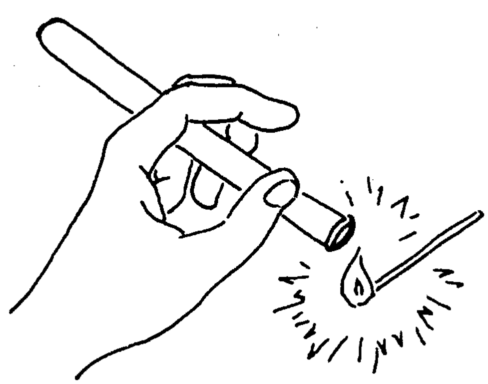


10. Using a stopwatch or clock, connect your wires for 5 minutes.

11. Hydrogen will be collected at the negative electrode, oxygen at the positive.

12. Remove the test tubes one at a time, holding your thumb over the end. (Do not let the gas escape.)

13. Hold the hydrogen tube upside down, (hydrogen is lighter than air) and remove your thumb.



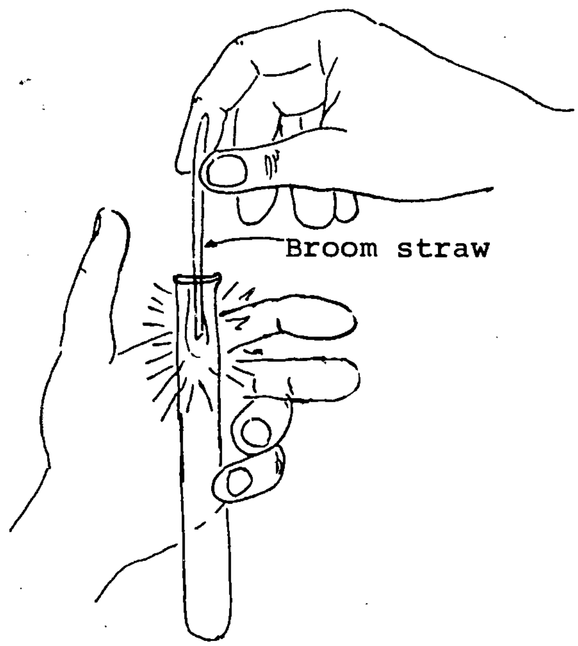
Hydrogen Test

14. Hold a lighted match to the mouth of the test tube. The gas will explode with a soft pop.

15. Remove the oxygen tube holding your thumb over the mouth with the tube upright.

16. Light a broom straw, blow out the flame, and place the glowing end into the test tube. Watch the glowing ember burst into bright flame.

Oxygen Test



Curriculum Topic

GAS FROM COAL

Energy Topic

ENERGY SOURCES

Grade Level(s) 7 - 12

Site Classroom

Skills

- Setting up lab equipment
- Perform a controlled experiment
- Observational skills

Credit

Science Activities in Energy

The American Museum of Science and Energy

Oak Ridge Associated Universities

Objective

At the completion of this activity the student will be able to:

1. Demonstrate a process for producing methane gas from coal.

To The Teacher

Today with increasing energy costs we have to look to many alternatives. Coal is still a plentiful resource in North America and will help us offset our energy deficit for many years to come.

However, a major problem with coal is the damaging effects coal has on the environment. First of all, mining coal today is most often done by strip mining where massive amounts of earth and covering vegetation are removed to expose the layers of coal. Secondly, coal is not a clean burning fuel because it contains many impurities. One of these impurities is sulfur. This element when combined with rain water produces sulfuric acid and is responsible for the pollution of many lakes and streams, often hundreds of miles away from the coal burning source. Acid rain is also responsible for dissolving limestone and marble surfaces of buildings and statues.

Methane gas, on the other hand, produced from coal or other organic materials is a clean burning and efficient fuel. Perhaps this is one way we may use our coal resource and minimize the effects on the environment.

Before You Begin

1. Coal is now being distributed by many small dealers around New England and is being burned in coal furnaces and stoves. The amount of coal used in this experiment probably would be donated for a small class or you may end up buying a 25 lb. bag. One of your students may burn coal at home giving you a connection to a source in your area.

2. One period may be spent on background material (mining, processing and distribution of coal). The experiment will take a very short time to set up and perform (20-30 minutes). Two days later you may set up a short period to test the gas. It may help to leave this over a weekend to allow continuity of the lesson.

Words To Know

Bituminous coal, methane, natural gas, coal gassification, strip mining.

Related Activities

- The coal may be weighed before and after the experiment to determine how much gas was produced.
- Methane may be fermented from many other organic waste products. Alcohol is another organic fuel obtained by using the process of distillation.
- Many sewage treatment plants collect methane from organic waste treatment and use this gas as a heating fuel for the plant. A visit to such a plant may be an enrichment activity.

STUDENT PAGE

MATERIALS

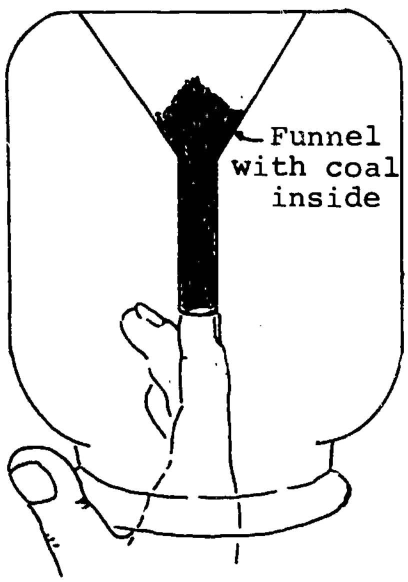
- Soft or bituminous coal
- Funnel
- Quart jar
- Water
- Test tube
- Rubber band
- Hammer

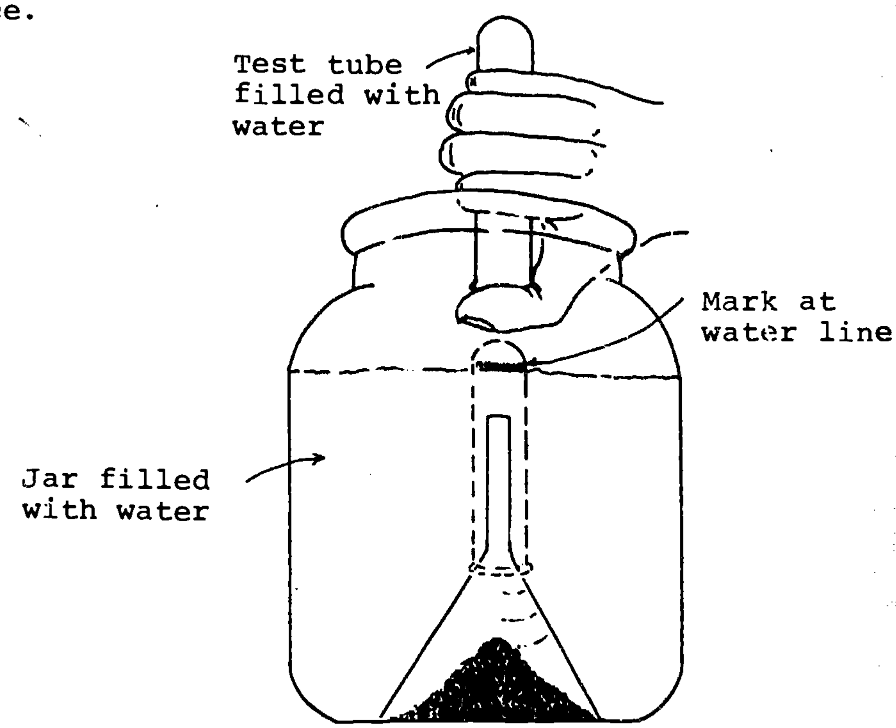
METHOD

1. Hammer several lumps of soft coal into a pile of coarse powder.

2. Place about ½ cup of coal into a funnel while holding your finger over the end.

3. Invert a glass jar over the upright funnel and turn the jar over holding the funnel in place.





4. Fill the jar with water above the tapered end of the funnel (fill slowly so the coal does not come out of the funnel, although a little may float to the top).

5. Fill a test tube with water (Don't let air in), holding your finger over the end . Invert the test tube over the neck of the funnel.

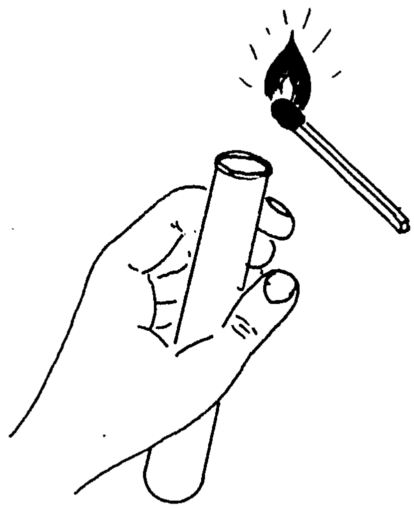
6. Mark the water line on the test tube with a rubber band or a china marker. (See diagram)

7. Leave this apparatus in a spot where it will not be disturbed

for two days.

8. Has the test tube moved? After the gas has been collected, you may remove the test tube from the water holding your finger over the end. (Do not let the gas escape!)

8. Turn the test tube upright and light a match. Let the gas out and see if it burns.



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Curriculum Topic

THERMAL POLLUTION'S EFFECTS ON LIFE

Energy Topic

ENERGY SOURCES
ENERGY AND CONSERVATION
ENERGY: THE CONCEPT

Grade Level(s) 7 - 12

Site Laboratory

Skills

- Data skills; collecting, compiling and interpreting.
- Use alcohol burner.

Credit

Earthwatch
Environmental Education Center
A program of Area Cooperative Educational Services (ACES)

Objective

At the end of this activity the students will be able to:

1. explain that living things use up more dissolved oxygen when the temperature increases from increased metabolic activity and,

2. explain how increasing the temperature of water decreases the amount of dissolved O_2.

To The Teacher

Any transfer or conversion of energy is, in part, inefficient. Useful energy is degraded to useless energy which is dissipated from the energy-using system to the environment as heat. Even the simplest human activities, such as hammering a nail, transfer energy releasing some as heat.

While the total amount of heat generated by human activities is slight compared to the heat of the sun absorbed by the earth, excessive heat discharges at particular sites can often cause local climatic and ecological changes. This is especially true when we dispose of our waste energy by heating water instead of air, as water has a much higher heat capacity per unit volume. For example,

Before You Begin

A one-million-watt (electrical generating) facility, running at 40 percent efficiency, would heat 30 million gallons of water by 8.5 Celsius degrees (15 Fahrenheit degrees) every hour. A one-million-watt nuclear plant, operating at about 32 percent efficiency, would require 50 million gallons of coolant water every hour to extract the same quantity of heat. It is not surprising that such large quantities of heat, added to aquatic systems, cause ecological disruptions. The term thermal pollution has been used to describe these heat effects.

The processes of life involve chemical reactions and the rates of chemical reactions are very sensitive to changes in temperature. As a rough approximation, the rate of a chemical reaction doubles for every rise in temperature of 10 Celsius degrees (18 Fahrenheit degrees). We know that if our own body temperature rises by as much as $5^{\circ}C$ (or $9^{\circ}F$, which would make a body temperature of $98.6 + 9 = 107.6^{\circ}F$) the fever may be fatal.

We, fortunately, are <u>endotherms</u>. This means that, like other mammmals, we have internal mechanisms for temperature control. With the exception of the aquatic mammals and birds, all water-dwelling species are ectotherms. Their body temperatures conform to the temperature in the surrounding environment.

When a fish responds to a temperature increase, all its body processes (its metabolism) speed up, and its need for oxygen and its rate of respiration therefore rise. The increased need for oxygen is especially serious since hot water has a smaller capacity for holding dissolved oxygen than cold water. Above some maximum tolerable temperature, death occurs from failure of the nervous system, the respiratory system, or essential cell processes. The brook trout, for example, swims more rapidly and becomes generally more active as the temperature rises from 40° to $48^{\circ}F$. In the range from 49° to $60^{\circ}F$ activity and swimming speed decrease, with a consequent decline in the trout's ability to catch the minnows on which it feeds. This inactivity is more critical because the trout needs more food to maintain its higher metabolic rate in the warmer water. Outright death occurs at about $77^{\circ}F$.

Temperature changes which adversely affect any organism in the food chain (fish or not) have wide consequences upon an ecosystem.

The most important concept for students to understand in this activity is that at the very time organisms need the most dissolved oxygen it is least available. During the experiment, students should find that oxygen is used up faster by the yeast in the warm test tube. The warm test tube should become colorless in 6-8 minutes, while the tube at room temperature takes 12-15 minutes. This indicates that increasing temperature increases metabolic activity and oxygen demand. In number seven of the discussion questions on the student worksheet, yeast and a fish living in its natural environment are brought into comparison. Since both carry out the same life processes, the assumption in question seven should seem reasonable.

1. Students will need to have some background information:

a. Discuss with them heat (thermal) pollution and its sources.

b. Explain that methylene blue is an indicator which becomes colorless as oxygen is used up. Yeast are single-celled plants which use O_2 and sugar (in the powdered milk) to produce energy with the release of CO_2 and alcohol.

2. When most of the methylene blue in tubes 1 and 2 changed, a ring of methylene blue remains at the surface of the liquids. This is because oxygen from the air dissolves in the upper layer of the mixtures. Don't offer this explanation too soon! Let students think it out.

3. Caution: Clean glassware is essential to the success of this experiment.

4. One class period will be needed to complete this activity.

Words To Know

metabolism, thermal pollution, decolorization, solubility, ecosystem.

Related Activities

- Experiment to show that the solubility of CO_2 also decreases as water temperature increases. This increase affects plant life.

- In these days of energy crisis, it is strange to think of "waste heat". Yet the 30-40% efficiencies given for the production of electric power are about the best we can do. Discuss ways to conserve energy and reduce thermal pollution by using this waste heat. Possibilities are: aquaculture, home heating, greenhouse heating, irrigation providing steam for industrial users.

- Discuss ways to reduce thermal pollution: cooling towers, new "dry" cooling towers, improvements in efficiency such as magneto-hydrodynamics (MHD), cooling ponds, use of solar cells (which add more heat than the sun provides naturally).

Resources

- Cunningham, J., Biology, You and Your Environment, P.C. Heath & Co., 1976, pp. 62-64.

- Environmental Science Probing the Natural World, Intermediate Science Curriculum Study; Silver Burdett Co., 1972, pp. 23-26.

- [illegible]k, A., et al, Environmental Science, W.B. Saunders, 1974, pp. [illegible]8-208.

Notes To Myself

STUDENT PAGE

MATERIALS

- ½ teaspoon dry yeast
- ½ teaspoon powdered milk
- 1 dropper bottle methylene blue
- 2 - 10 ml graduated cylinders
- 3 test tubes
- 1 test tube rack
- thermometer
- stirring rod
- plastic spoon
- 250 ml beaker
- alcohol burner and stand
- 2 small beakers (50 or 100 ml)
- clock
- marking pencil

METHOD

1. Heat a 250 ml beaker half-filled with water until the water temperature reaches 40°C. While the water is heating, go onto the next step, but don't forget to keep your eye on the thermometer!

2. Make some milk by adding ½ teaspoon powdered milk to 20 ml water in a small beaker. Mix it well.

3. Make a yeast mixture by adding ½ teaspoon dry yeast to 10 ml water in another small beaker. Mix it well.

4. Mark 3 test tubes 1, 2, and 3. Place them in the test tube rack. The following table tells you what substances to put into the 3 test tubes. Be sure to use a well rinsed graduated cylinder each time you change substances. Mix well.

Test Tube		Methylene Blue	Yeast Mixture
1	3 ml milk	20 drops	20 ml
2	3 ml milk	20 drops	20 ml
3	5 ml water	20 drops	-----

5. Quickly put test tubes 2 and 3 into the beaker of warm water and record the time in Table 1 on your Record Sheet. Observe the 3 test tubes carefully and watch for the color to disappear (decolorization). If it occurs record the time it took in Table 1.

STUDENT RECORD SHEET

TABLE 1 Results of Experiment

Test Tube	Temp °C	Starting Time	Time for Decolorization	Total time for Decolorization (min)
1				
2				
3				

QUESTIONS

1. What does the decolorization in the test tubes show?

2. For what is milk used in this experiment?

3. Did increasing the temperature of the water have an effect on the rate at which oxygen was used by the yeast? If so, what was the effect?

4. If the rate at which oxygen was used was increased by heating, what must have been happening to the rate of the chemical changes (metabolism) in the yeasts' bodies?

5. You should have observed a ring of methylene blue that stayed at the top of the liquids in test tubes 1 and 2. Why did the methylene blue near the surface not become colorless?

6. What purpose did test tube #3 serve in this experiment?

7. Do you think it is reasonable to assume that a fish would use more dissolved oxygen if the temperature of its environment were increased? Why or why not?

8. You have found that living organisms use more dissolved oxygen when the temperature increases. This could account for the more rapid color change in warm water containing yeast. Look at Table 2 and see if you can determine another possible explanation for the faster color change in the warm test tube.

Table 2 Temperature and Solubility of Oxygen

Temperature $^{\circ}C$	Amount of Oxygen Gas that Will Dissolve in Water (g/100 ml)
0	0.0069
10	0.0054
20	0.0043
30	0.0036
40	0.0031
50	0.0027
60	0.0023
70	0.0019
80	0.0014
90	0.0008
100	0.0000

9. If an aquatic animal was very active and needed a lot of oxygen, would you expect to find this animal living in cold or warm water? Explain your answer.

10. What do you think would happen to the activity of the aquatic animal if its environment were changed by thermal pollution?