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ABSTRACT

This guide contains lesson plans and outlines of science activities which present concepts of solar energy in the context of chemistry and physics experiments. Each unit presents an introduction to the unit; objectives; required skills and knowledge; materials; method; questions; recommendations for further work; and a teacher information sheet. The teacher information sheet contains information on the target grade levels; background information; hints on gathering materials; suggested time allotment; suggested approach; typical results; precautions; modifications; evaluation; and references. (RE)

DOE/CS-0064

Activities

Chemistry & Physics

January 1979

U.S. Department of Energy
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Market Development and Training Program
Washington, D.C. 20545

SOLAR ENERGY PROJECT

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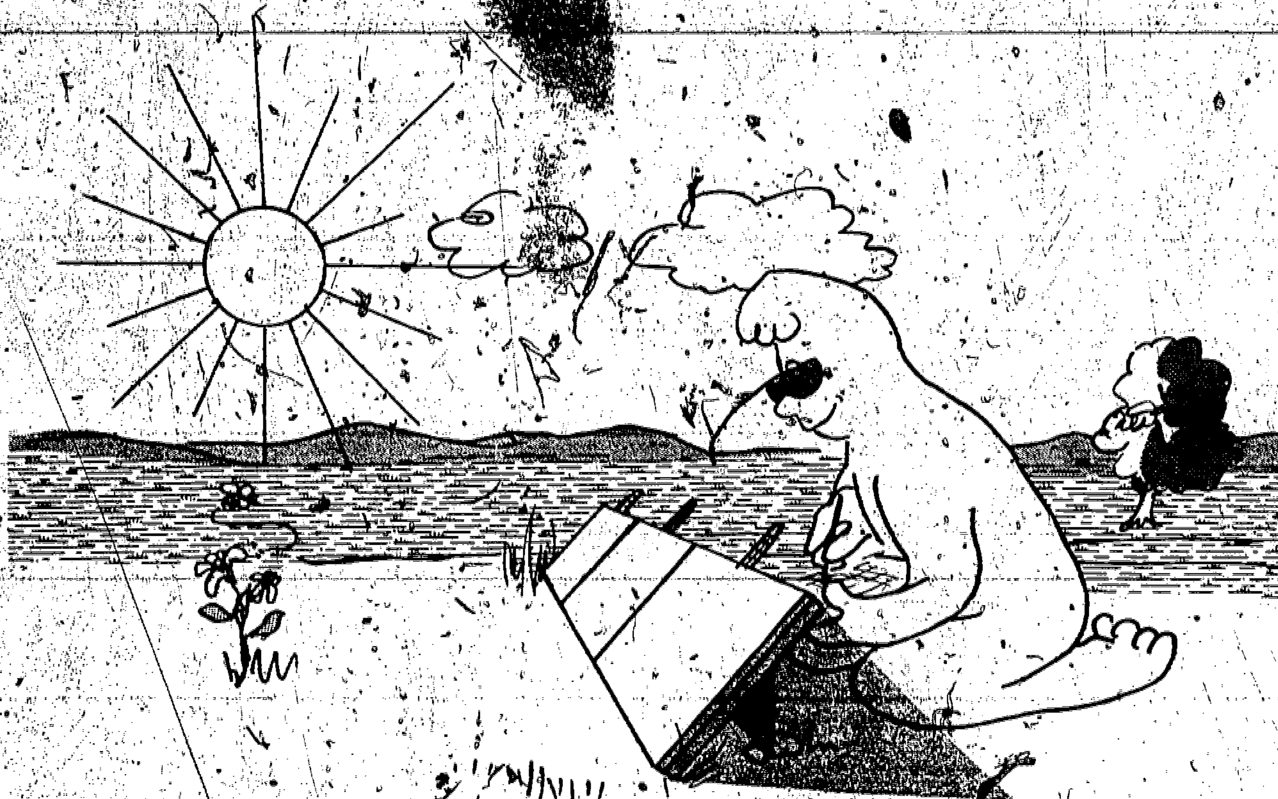
T - ACTIVITY 30

A COMPARISON OF ABSORBER PLATE COATINGS



INTRODUCTION

The absorber plate is an important part of the solar collector. The type of absorber plate coating will change the ability of the collector to absorb solar energy. This activity will allow you to investigate different absorber plate coatings. You will prepare absorber plates with different coatings (such as different color paints) and compare the temperature increase of the plates with time of exposure to a heat source.

OBJECTIVES

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

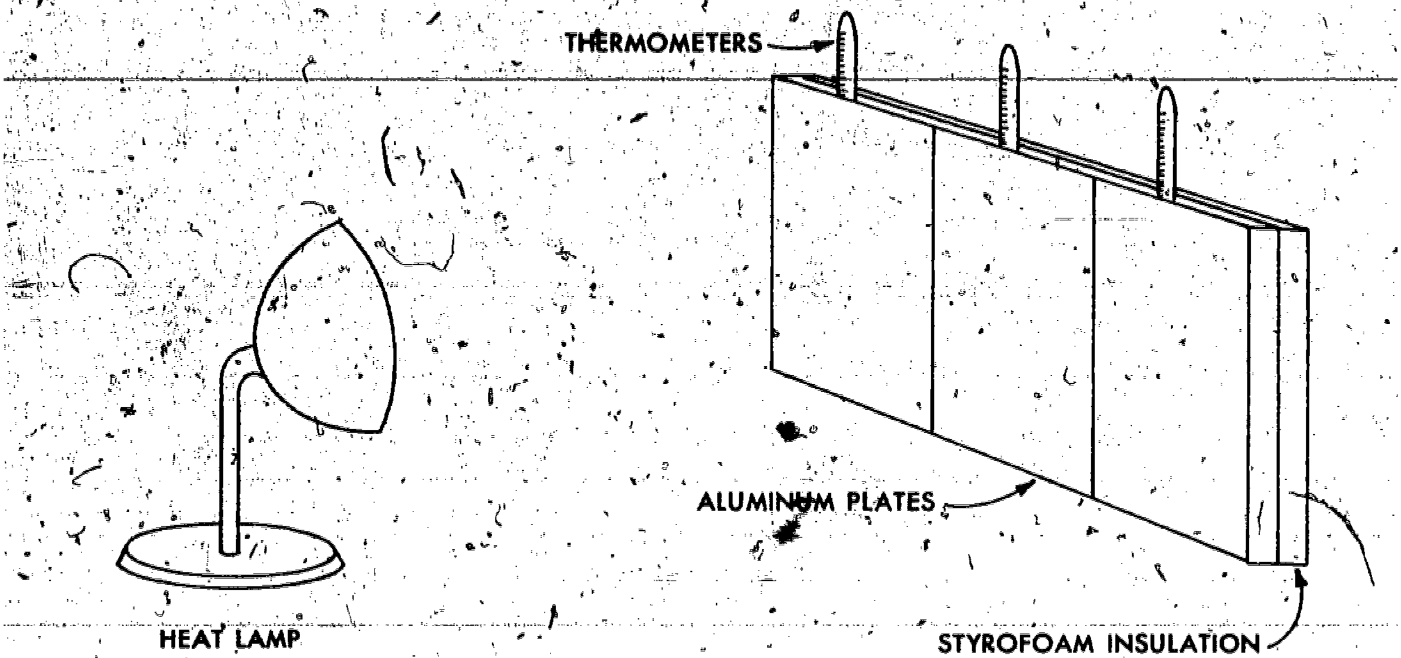
- o plot and interpret a graph of temperature vs. time.
- o determine the best color of material for absorber plate coatings.

SKILLS AND KNOWLEDGE YOU NEED

- Be able to read a Celsius thermometer.
- How to graph data.

MATERIALS

- Three 10cm x 3cm pieces of aluminum.
- Three thermometers.
- Three 10cm x 30cm pieces of styrofoam insulation.
- Tape.
- Heat lamp, if sun is not shining.
- Several coatings, such as black, green or silver paint.



METHOD

1. Prepare two of the metal plates with different colors of coatings and allow them to dry. The third plate (uncoated) will act as your control.

2. In constructing your collectors, be sure the thermometers are inserted between the insulation and the absorber plate. Use the tape to secure the insulation to the metal plate.

3. Set up the equipment according to the diagram with the plates pointing toward the sun. Make sure that all plates are angled the same way.

4. Take temperature readings of each plate at 1 minute intervals for 20 minutes. Use the data table provided.

5. Plot graphs of temperatures vs. time for each metal plate on the same sheet of graph paper using different symbols or colors to represent each metal plate.

DATA TABLE

TIME (MINUTES)	TEMPERATURE (^{o}C)		
	PLATE 1 COATING: ______	PLATE 2 COATING: ______	PLATE 3 COATING: ______
0			
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			

LOOKING BACK

One of the key components of the solar collector is the absorber plate. The material used to coat the absorber plate should be a substance which absorbs most efficiently the solar radiation striking the solar collector. The solar radiation is converted by the absorber plate into heat energy. This heat energy can then be used for heating domestic hot water or for space heating in a building.

You can judge for yourself which type of absorber plate coating absorbs most efficiently by studying the graphs you have made.

QUESTIONS

1. According to your graph, which absorber plate coating did you find to be most efficient?
2. Why was it important to have all three plates angled the same way?
3. Explain why the graphs leveled off near the end of the experiment.

GOING FURTHER

- Do you think a curved absorber plate would have been more or less efficient than a flat absorber plate?
- What effect do you think the angle of incidence has on the amount of solar radiation absorbed by the solar collector?
- Repeat the experiment without using the insulation behind the absorber plate. What effect did this have on the temperature?
- Do you think if you doubled the size of the collector, that you would double the temperature? Explain your answer.
- On clear nights the temperature at the surface of the earth sometimes becomes very low even if the daytime temperature was very high. The earth's surface radiates its heat back into the atmosphere. If clouds were present, this extreme heat loss would not occur. You may wish to perform the experiment again and record the temperature of the plates for 20 minutes while the plate is in the sun and for 20 min. while the plate is in shade. In this way you can check the heat loss of each of your plates. Can you think of a way to stop this heat loss? (Hint: In the earth's atmosphere clouds act as a "glazing material".)

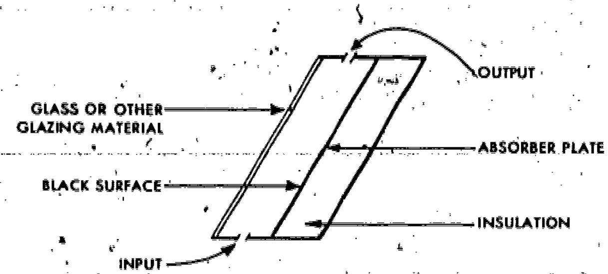
A COMPARISON OF ABSORBER PLATE COATINGS

Suggested Grade Level and Discipline

7-12 Science

Background Information

One of the most important parts of the solar collector is the absorber plate. The absorber plate is the part of the solar collector which collects solar energy and transforms it into heat energy. The efficiency of the collection varies with the type of metal used and the type of coating used on the plate. The figure below shows a typical hot air solar collector in cross section.



The insulation prevents heat loss out the back of the collector and the glazing material creates a "greenhouse effect" which keeps the heat in the collector.

The absorber plates are usually made of good conducting metals, such as copper or aluminum. The surface of the plate facing the glazing material is coated with a flat dark paint. New absorber plate coatings are constantly being tested in search of a more efficient coating. Many of these are selective coatings which absorb the wavelengths of energy that convert to heat but reflect unwanted wavelengths.

Another important factor in collector efficiency is the intensity of light striking the surface. The collectors efficiency is at a maximum when the sun's rays are perpendicular to the collector's plate.

In this activity the students will have the opportunity to test the absorption properties of different coatings.

Hints on Gathering Materials

About a week before the activity is scheduled, you should be sure to have on hand an array of different colored paints. You may have your students bring in a paint color or particular brand of paint that they wish to test.

Latex paint is preferable because it dries quickly and is easy to clean up. You should also cut out some sheets of aluminum or another metal about 10cm x 80cm. A source of heat will also be necessary. If the activity is performed outside, the sun will be your heat source. If the weather does not allow you to do the activity outside, then a heat lamp will be needed. Thermometers and some tape will be needed for the basic experiment. You should score the styrofoam sheets so that the thermometer will be recessed and the styrofoam will fit snugly on the absorber plate.

Suggested Time Allotment

- The total time for this unit should be a maximum of four class periods. The first periods should be used for the introduction of solar collector design and uses. The next class period should be used to allow the students to prepare their absorber plates. The third period should be used for the equipment set up and collection of data. The final period should be used for a discussion of the data and the conclusions of the students.

Suggested Approach

- A good way to begin this unit is to relate the different types of world climates to different types of absorbing surfaces on the earth. For example, you may point out the extremes in annual temperature between the mid-west United States where large bodies of water are scarce and the more moderate climates of the coastal areas. The oceans have a moderating effect on climate because they do not absorb solar radiation as quickly as solid surfaces. After the discussion about the relationship between the earth's surface and climate you may wish to ask the question, "DO you think there is a similar relationship between the type of absorber plate in a solar collector and the collector temperature?" This should lead into a discussion of collector efficiencies.

- The students should be divided into groups. Each group should test two absorber plate coatings as well as the control. This number may be increased at the teacher's discretion.

- During the final day you may play the part of salesman and offer to "sell" the students some solar collectors. You should provide specifications for four or five collectors. The students should all be able to make intelligent "buying" decisions based on what they have learned from their laboratory activities. You may wish to vary the "selling price" in order to have the students determine the value of each collector in terms of initial cost vs. eventual savings.

Typical Results

- The results will vary with each group since each group will probably have a different combination of absorber plate coatings. The data table shows some data collected during this activity. The plate material was aluminum flashing.

DATA TABLE

TIME (MINUTES)	TEMPERATURE (°C)		
	PLATE 1 COATING: *black*	PLATE 2 COATING: *white*	PLATE 3 COATING: *control*
0			
1	35	[illegible]	31
2	46	34	33
3	51	38	36
4	54	41	37
5	56	43	40
6	57	45	42
7	57	48	44
8	58	50	47
9	59	51	47
10	60	52	47
11	60	52	47
12	61	53	47
13	63	53	47
14	64	53	48
15	65	53	48
16	65	53	48
17	66	54	49
18	65	54	48
19	66	54	49
20	66	54	49

Precautions

- *If the absorber plates are painted with "spray" paint be sure that the room is well ventilated.*
- *If a heat lamp is used, caution the students about touching the bulb of the lamp. It get extremely hot.*
- *Metal edges should be taped.*

Modifications

- You may wish to encourage your students to do a little experimenting. It is possible that by increasing the surface area of the absorber plate you will increase its ability to absorb radiation. An easy way of increasing the surface area is by sprinkling iron filings, metal turnings, etc., on the absorber plate before painting. Spray paint the absorber plate, covering the material, and allow it to dry. The material will be secure at least for the duration of the activity. Compare this absorber plate with another plate without additional material. Be sure you use the same paint on both absorber plates.

- Another variation you can use, with more advanced students, is to replace the thermometers with thermocouples. Using the thermocouple will give very accurate results and may be especially useful for physics students.

- You may also have the students vary the angle of incidence of the incoming energy on the absorber plate. The students could then see how the angle of incidence effects the efficiency of the collector.

Evaluation

- Evaluation of the students can be made by using the questions at the end of the activity and by student response to the follow-up discussion.

- Evaluation of student graphs could also be made.

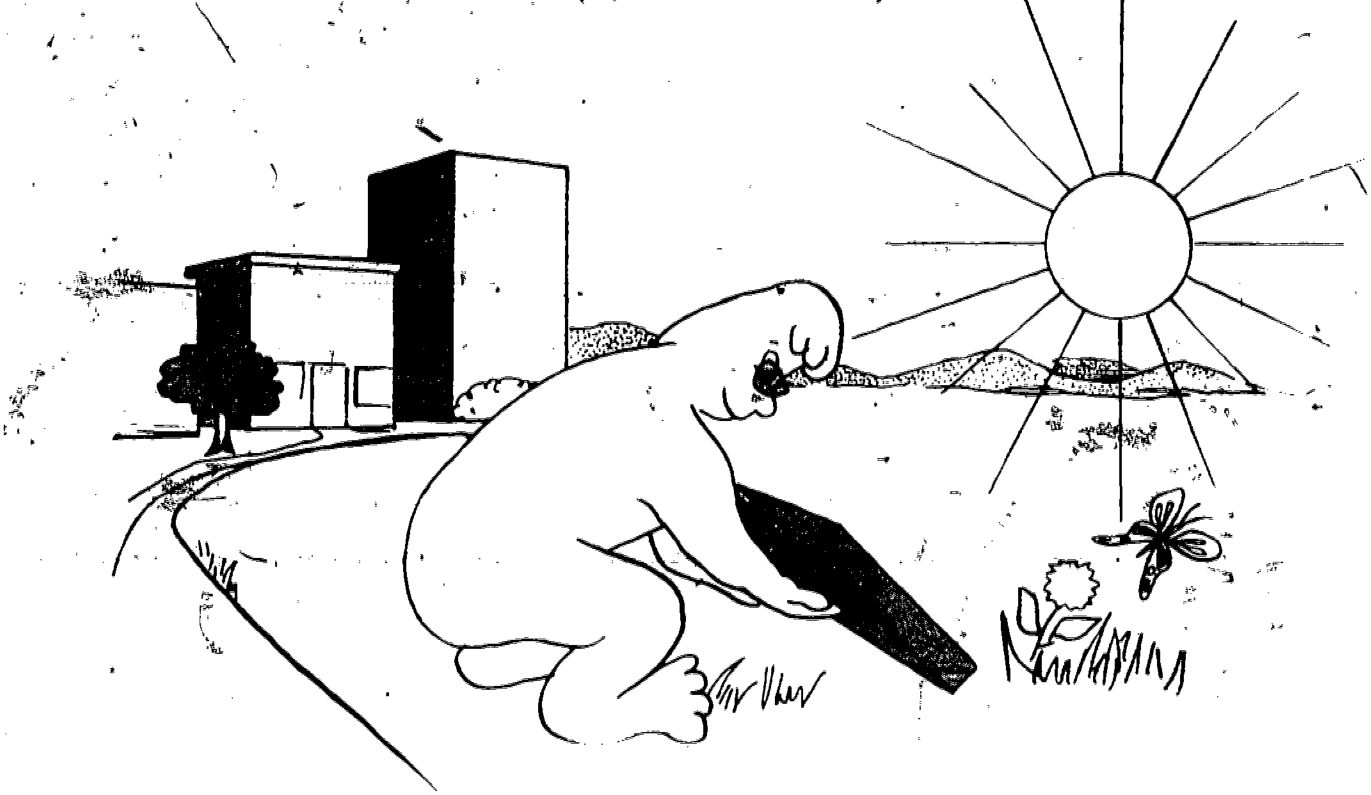
References

- *Producing Your Own Power*, Carol Hupping Stoner, Ed., (Emmaus, Penn.: Rodale Press), 1974.

- *Solar Energy Experiments*, Thomas Norton, (Emmaus, Penn.: Rodale Press), 1977.

DRAFT - ACTIVITY 31

CONSTRUCTION OF A FLAT PLATE AIR FLOW SOLAR COLLECTOR



INTRODUCTION

The sight of a solar collector [illegible] of [illegible] the [illegible] and is becoming common. Such collectors, however, have been used around the world for many years to heat things from buildings to swimming pools.

Most of the collectors have parts that are very similar even though they may be arranged differently. In this activity, you will construct and experiment with a solar collector that uses air to transfer the sun's energy to usable heat

OBJECTIVES

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

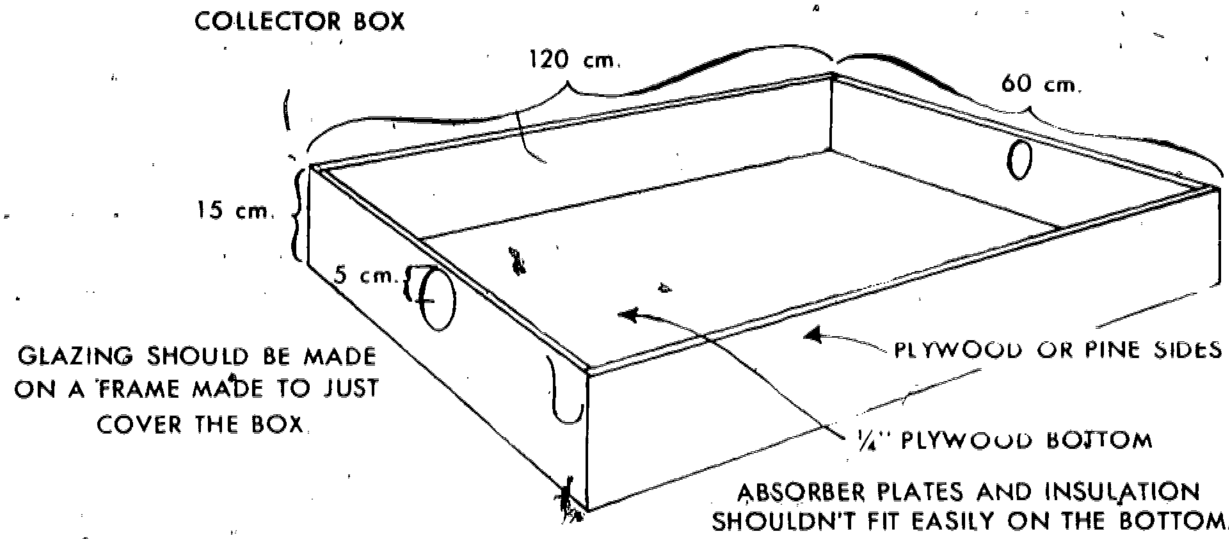
- o construct a flat plate air flow solar collector
- o determine the importance in your collector of the glazing (cover material), the insulation, the absorber plate color, and the absorber plate material.

SKILLS AND KNOWLEDGE YOU NEED

- Know the parts of an air flow solar collector.
- Know for what purpose each part of an air flow solar collector is used.
- How to read a thermometer and a stop watch or other timing device. (school clock, wrist watch, etc.)
- How to graph data.

MATERIALS

- 2 thermometers
- Solar collector [illegible]
- Various insulation pieces ([illegible])
- Various colored absorber plates (60cm x 120cm)
- Various glazing covers (60cm x 120cm)
- Stop watch (or other time-keeping device)



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 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 the 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 insulating materials, absorber plates, and glazing.

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.

LOOKING BACK

In this activity you have constructed a flat plate air flow solar collector. You should have an understanding of the types of materials you used and the reasons for using them. With a finished collector you were able to collect data which gives an indication of collector efficiency. From your data you were able to plot the information collected and compare the temperature changes that occurred. You were also able to compare the insulation, absorber color, and glazing in different combiantions.

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 [illegible] and [illegible] are the best for your collector?

5. An indication of collector [illegible] the [illegible] difference between input air temperature and output air temperature. Based on the differences you measured what [illegible] did the type of insulation have on the collector efficie[illegible]

6. How might your family use such a collector to [illegible]

GOING FURTHER

- Try other [illegible] and glazings.

- Try double or triple [illegible]

- Change the angle of the [illegible] and record the differences in input and output temperatures. Use a protractor to measure the angle. *[illegible] at the sun. If you do not know how to [illegible] the angle, ask your teacher for help.*

- Determine the effect various weather [illegible] performance of your solar collector.

Teacher Information Sheet

CONSTRUCTION OF A FLAT PLATE - AIR FLOW SOLAR COLLECTOR

<u>Suggested Grade Level and Discipline</u>

General Science 7-9
Earth Science
Physics

<u>Background Information</u>

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.

<u>Hints on Gathering Materials</u>

Absorber plates can [illegible] made [illegible] anything [illegible]

Sheets of styrofoam insulation, other insulation, and plywood [illegible] are available at most building supply companies.

Glazing can be made of glass, Saran Wrap or plastic [illegible] frame.

<u>Suggested Time Allotment</u>

1 to 2 periods

<u>Suggested Approach</u>

The pr[illegible] d[illegible] glazing materia[illegible] on students previous experience.

Discuss materials that are used [illegible] Review why these materials were selected for this [illegible] activity.

- 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.

- In order to infuse the concept of career education into the classroom activity it is suggested that the teacher contact industrial, utility and business representatives in the energy field. For example, a solar heating system dealer may be invited into the classroom to discuss the job of supplying materials necessary for considering the installing solar systems. Sample materials may be provided during the presentation as well as "hand-out" information. Beyond this activity, students may be asked to visit local firms and interview individuals associated with the energy industry. For example, the students could speak with a utility company representative, a gas station operator, a solar collector manufacturer, a county planner, and a local newspaper representative, as well as plumbing and electrical contractors.

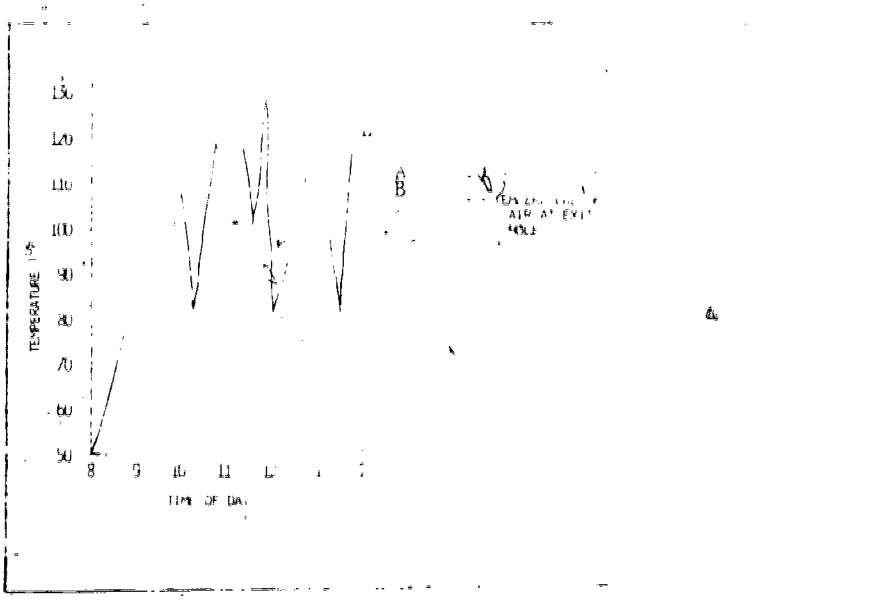
- The teacher may wish to combine data from various students and project this information on an overhead projector.

- Various combinations of collector parts allow for a wide range of possible experiments.

Typical Results

- Air temperature leaving the collector should be measurably higher than input temperature.

- The graph below is an example from actual student data.



Precautions

- *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 mometary cloud cover can be shown graphically.)*
- *Students should be warned to never look directly at the sun.*

Modifications

- In general science courses, the results could be used to develop ideas for the importance of glazing, insulation, and collector materials.
- 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 such as transparent sandwich wrap or plastic used to cover windows.

Evaluation

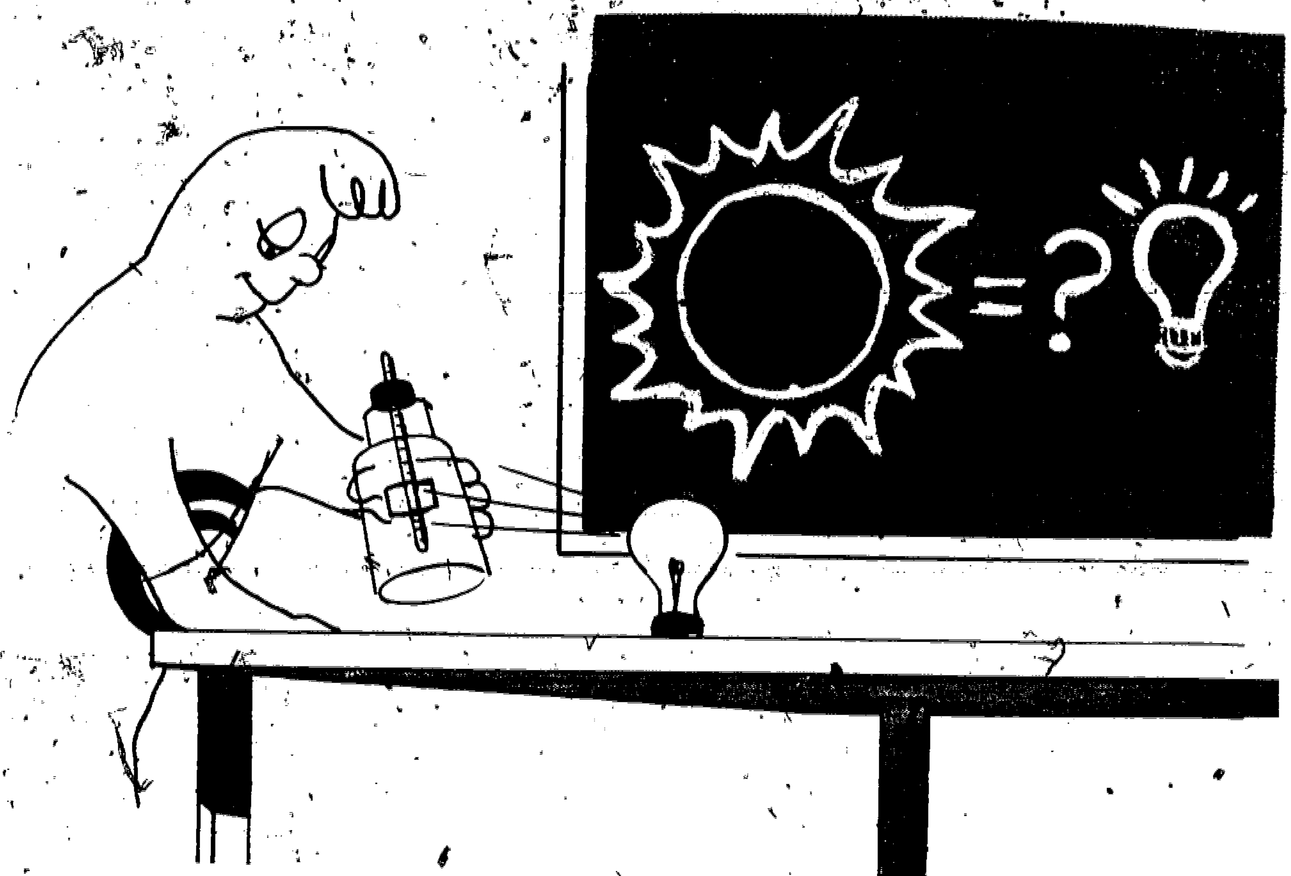
- How well were the graphs prepared?
- Were the graphs used in answering the questions?
- Were the students able to discuss, with a degree [illegible] the construction and operation of their collector?

References

[illegible] 1977.

RAFT - ACTIVITY 32

HOW MANY LIGHT BULBS = THE SUN'S ENERGY



INTRODUCTION

Have you ever wondered how much energy is given off by the sun? In this activity, you will be able to compare the sun's energy to the energy of a 100-watt light bulb. How many light bulbs do you think would have to be turned on to equal the energy produced by the sun?

OBJECTIVES

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

- o construct a simple device to collect the sun's heat energy.
- o use a mathematical equation to calculate in watts the sun's energy received by this device
- o compare the energy output of the sun with a 100 watt bulb.

SKILLS AND KNOWLEDGE YOU NEED

- How to read a Celsius thermometer
- How to perform mathematical calculations

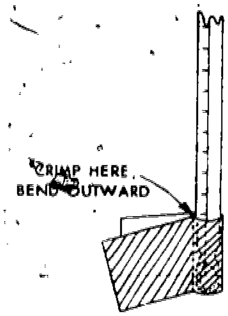
MATERIALS

- Graphite in alcohol (suspension)
- A 2 cm x 6 cm piece of thin metal [illegible]
- A meter stick and a pair of meter stick [illegible]
- A glass jar with a hole cut in the lid
- A one-hole stopper to fit the hole in the [illegible]
- A Celsius thermometer

METHOD

1 [illegible]
bulb so that th[illegible]

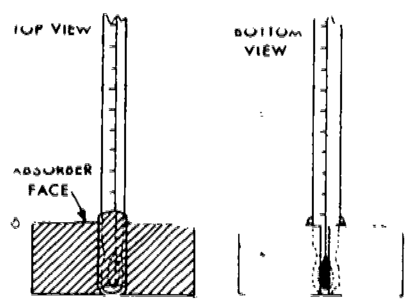
Then crimp the sheeting in so that it completely surrounds the bulb. Use the straight edge of a thin plastic ruler to bend the ends of the sheeting outward 90^o to form the absorber blades.



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 [illegible] 3.70 x 10[illegible] watts

$$\% \text{ error} = \frac{\text{Experimental (class average)} - \text{Accepted Value}}{\text{Accepted Value}} \text{ [illegible]}$$

LOOKING BACK

With the use of this relatively simple apparatus you have collected data and made a mathematical determination of the sun's wattage which turned out to be a very large value. From this you determined the number of 100-watt light bulbs which would equal the sun's wattage. Would it be possible to turn on this many light bul[illegible] at once?

QUESTIONS

1. Why is [illegible] light bulb [illegible] fluorescent bulb?

2. Would your location [illegible] affect the results?

3. After completing this [illegible] a watt?

GOING FURTHER

- If the [illegible] what environmental [illegible]

If the earth's distance from the sun [illegible] 1.5 x 10^{12} meters, what would be the environmental [illegible]

If your value for the sun's watt[illegible] from the accepted answer, what would be your percent of error?

If both parts of th[illegible] outside of the earth's atmosphere [illegible] think would occur in the results? Use [illegible] 0 x 10^{5} m a[illegible] the surface of the earth (approximately 200 miles) [illegible] possible location for this experiment.

Teacher Information Sheet

HOW MANY LIGHT BULBS = THE SUN'S ENERGY

Suggested Grade Level and Discipline

Physics
General Science

Background Information

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^{25} 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 [illegible] en[illegible], 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 by found by relatively simple science equipment.

Hints on Gathering Materials

The collector jar ca[illegible] [illegible] [illegible] [illegible] removed) or any simil[illegible] ja[illegible], such as a peanut butter jar, with [illegible] drilled in the center of the cap.

Thin metal sheeting can be obtained from either the [illegible] the art department. Any thickness can be used as long as [illegible] shaped around the bulb of the thermometer with ease.

Suggested Time Allotment

- Pre-lab, 1/2 class period [illegible]
- Lab, 2 class periods (45 to 60 minutes
- Post-lab, 1 class period (20 to 45 min.

Suggested Approach

- This activity should be done when indoor and outdoor temperatures are the same.
- Students should work in pairs to reduce demand on equipment.
- 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.
- If your school has a computer available, it is possible to give students a tangible idea of the number "1 million" (10^6) by obtaining a readout of 1 million dots. (For example, 200 pages of 5,000 dots each.)
- The angle of the sun's rays should be normal to the absorber's surface.
- The experiment should be done on a day of minimal cloudiness and haze.
- 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.

  Measurements should be made from the center of the filament to the absorber.
- When the advancing of the collector towards th[illegible] temperature of 45°, students should advance the collector only [illegible] at a time. When the desired temperature is reached, it should be maintained for at least two minutes.

[illegible] Results

An electric [illegible] [illegible] [illegible]
This same temperature [illegible] obtained [illegible]
from the filament of a clear bulb.

If 10 cm is used as a sample distance [illegible]
sun's wattage would be 2.25×10^{26} watts [illegible]
light bulbs needed to match this wattage would be 2.2 [illegible]
percentage of error in this measurement would be [illegible]

[illegible]

None

Modifications

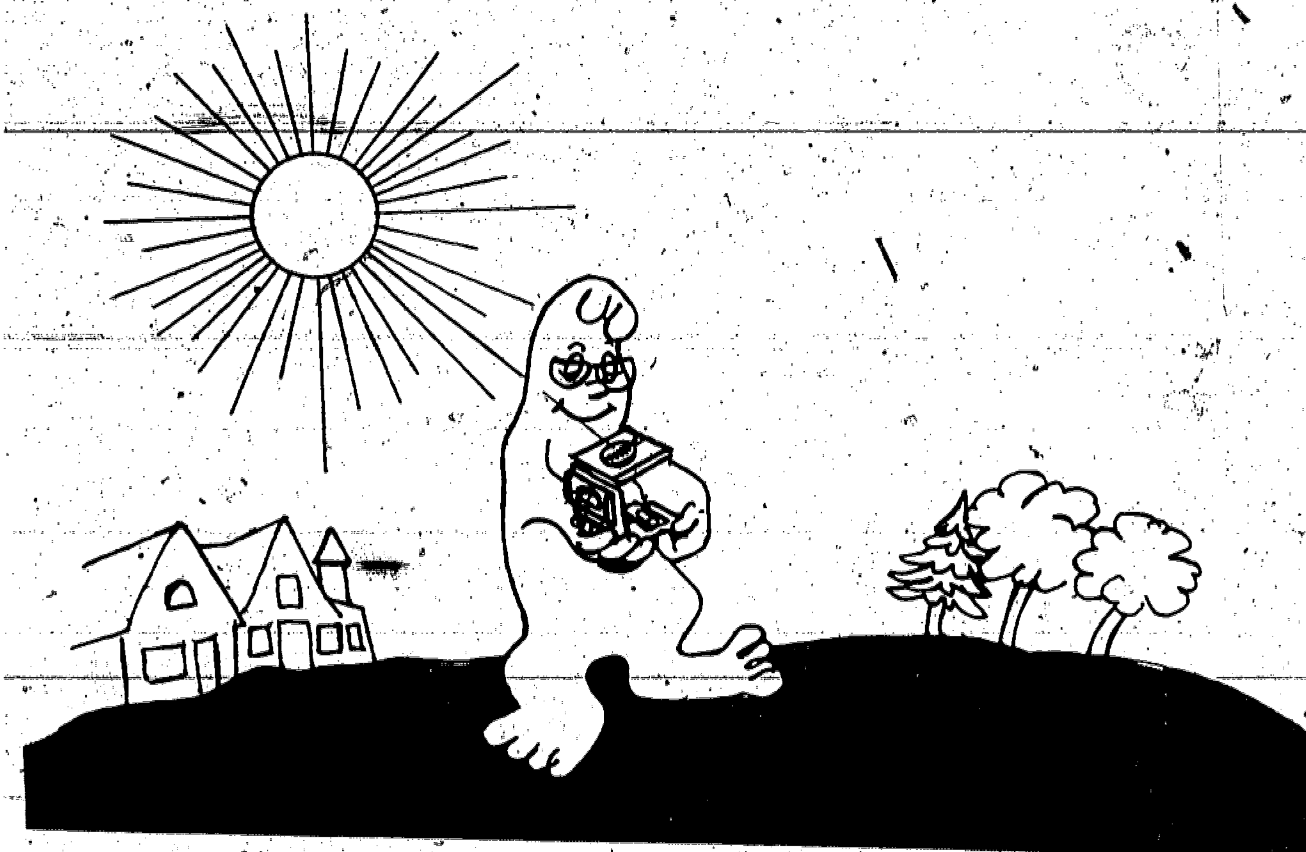
None Suggested

Evaluation

- The collector's construction and its use in the experiment can be evaluated for care in construction and correctness of experimental procedure.
- Student calculations and answers to questions can be evaluated for correctness and for depth of understanding.

D R A F T - ACTIVITY 33

MEASURING ENERGY FROM THE SUN



INTRODUCTION

Man has been using solar energy for thousands of years. Does this surprise you? Can you think of some examples? In fact, nearly all of our energy comes directly from the sun. There would be no coal, oil, gas, or wood if the sun's energy did not reach the earth. There would be no water power or wind power if the sun did not shine. Why not?

You can see that the use of solar energy is not really new. When we talk about using solar energy as an alternative to fossil fuels we are considering the use of a clean and renewable resource to replace polluting resources which are rapidly diminishing. The sun is nature's original and direct source of energy. We might use the sun directly to heat our water. The more we use the sun's energy directly, the more important it becomes that we have accurate and complete data on the amount of energy received from the sun at any time or place on the earth.

In this activity you will find out more about the sun's energy. You will use a simple device that will indicate the amount of energy falling upon a surface.

OBJECTIVES

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

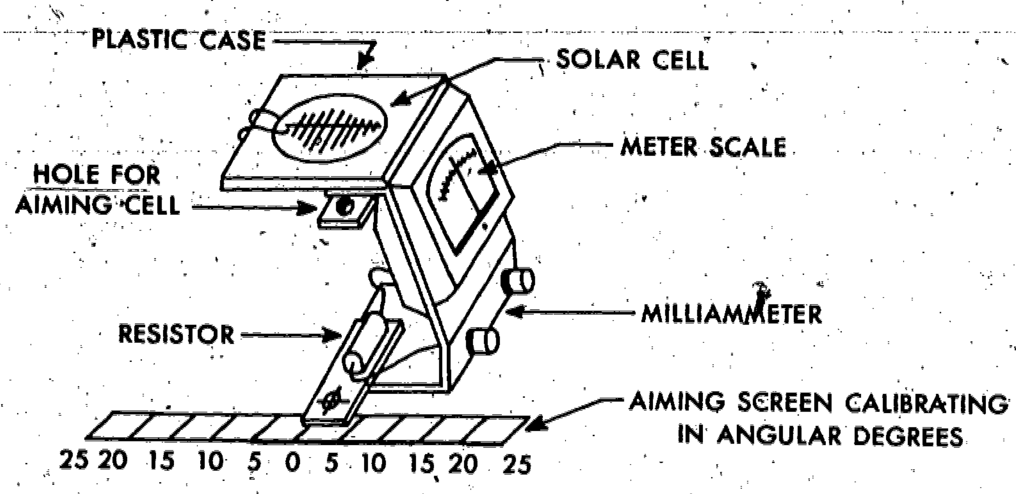
- o use a simple solarimeter to determine the amount of solar energy falling upon a given surface.
- o predict the best position of the solarimeter to receive and absorb maximum solar energy.

SKILLS AND KNOWLEDGE YOU NEED

- How to read scales on the solarimeter.
- How to graph data.
- How to measure angles.

MATERIALS

- Photocell solarimeter. A complete description of the construction of the solarimeter can be found in the hardware section.



METHOD

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 on the next page.

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

LOOKING BACK

The amount of solar energy received at any spot on earth varies with time of day and with the season of the year. It also depends on other factors such as cloud cover, haze, reflected light, etc. Surfaces that directly face the sun (are at right angles to the sun's light rays) receive more energy per unit area than surfaces at other angles. All these variations can be measured by means of a simple instrument called the solarimeter. Data tables similar to yours have been prepared for various localities that show such things as the hourly variation in actual energy received (measured) each day per month; others show how much energy theoretically would be available each day on a cloudless day. This information is needed in order to design efficient solar energy systems.

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?

GOING FURTHER

- 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?

Teacher Information Sheet

MEASURING ENERGY FROM THE SUN

Suggested Grade Level and Discipline

7-9 Science
Earth Science
Physics (Construction, Calibration and Modification of solarimeter)

Background Information

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.

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Hints on Gathering Materials

- 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.

- Photoelectric cell (Solar cell). Plain silicon type solar cell (without integral plastic lens) recommended. These are available in hobby electronic stores.

- 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 ($0 - 5\,\Omega$) variable resistor could be used.

Suggested Time Allotment

- Two periods.

    a. First Period: Introduction (pre-lab), gather initial data.
    b. Second Period: Discuss results, plot class data, examine and discuss published data.

- Periodic collection of data rest of year (as project continues)

Suggested Approach

- 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.

- Work in teams of 2 or 3 students to minimize the number of instruments needed.

- Organize work within teams; switch jobs within teams so everyone has a chance to use instruments.

- 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.

- Have ongoing data collection on a routine basis by volunteers.

- Prepare calibration curves for instruments.

Typical Results

- Meter reading inside building will be very low, almost zero.

- Maximum readings will result when solar cell is held at right angles to sun's rays. (Angle of incidence = 0°).

- The readings will be somewhat lower when the cell is in a horizontal position instead of directly facing sun.

- Smooth curves will be obtained on sunny days; rough curves will be obtained on partly cloudy days with intermittent sunshine.

- If data is taken throughout the year the highest values, with the photocell held perpendicular to the sun's ray, will be found in the winter, not summer, months. There are several reasons for this, one of which is the fact that the earth is actually closer to the sun (at perihelion) in January than in July. There is also likely to be less moisture in the atmosphere at this time.

Precautions

- *Be sure students are warned against looking directly at the sun and explain why the equipment is very fragile and must be handled with care.*

Modifications

- 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.)

- A photographic light meter might be substituted for the <u>homemade</u> 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.

- A galvanometer can be used in place of a milliammeter. A somewhat larger value (ohms) resistor would be needed in series with its coil.

Evaluation

- Have the students measure the energy falling upon a unit area of a given plane surface.

- Have the student position the solarimeter (with the solar cell covered) to receive maximum solar energy. Uncover cell and check.

- Check students' answers to questions.

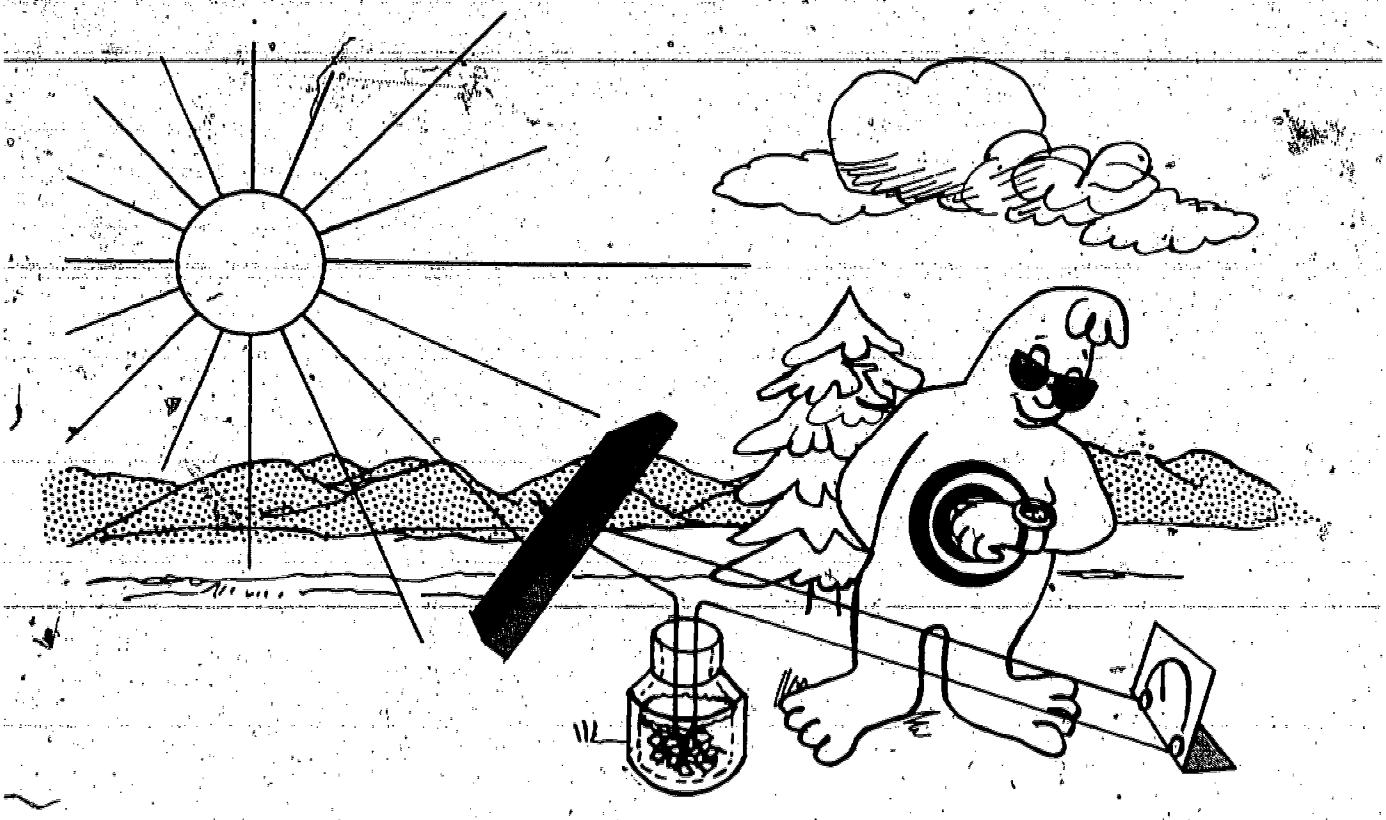
References

- *Solar Energy Experiments*, Thomas Norton. (Emmaus, Pennsylvania: Rodale Press) 1977

- *Introduction to the Atmosphere*, Herbert Riehl. (New York: McGraw-Hill) 1965

D R A F T - ACTIVITY 34

MEASURING THE HEAT OF A SOLAR COLLECTOR USING A THERMOCOUPLE



INTRODUCTION

The efficiency of a solar collector is usually determined by a change in the temperature of a collector absorbing plate or some type of flowing material such as air or water. Typically, the method used for measuring this temperature uses a thermometer. This activity will give you an opportunity to look at an alternate way of measuring temperature with considerably more accuracy using a pair of twisted wires known as a thermocouple.

OBJECTIVES

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

- o construct a thermocouple that can be used to measure heat difference.
- o use this thermocouple to measure solar energy in a very simple flat plate collector.

SKILLS AND KNOWLEDGE YOU NEED

- How to read a millivolt meter
- How to graph data

MATERIALS

- 1 meter of copper wire per group
- 1 meter of constantan (an alloy of copper and nickel)
- 1 millivoltmeter
- 1 insulated container filled with water and ice
- 1 piece of styrofoam (60 cm. x 60 cm. x 5 cm.)
- 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

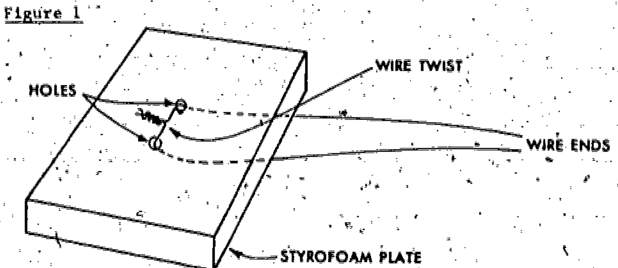
METHOD

1. Carefully take the piece of copper wire and cut it into two identical pieces.

2. ~~Take the end of the 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)

Figure 1



4. Take the end of the constantan wire which is not twisted and twist it together with the other half of the copper wire in the same fashion that you used in step 2.

5. Place this twist in the insulated jar filled with ice and water.

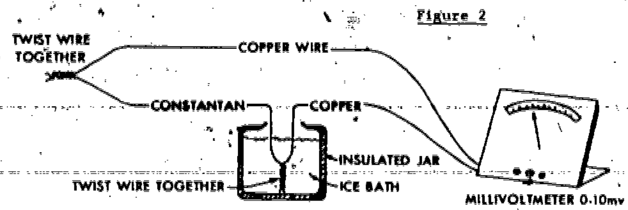
6. CAREFULLY take your equipment outside. (If no sun is available, use the heat lamp inside).

7. Carefully glue (in only 2 or 3 spots) the aluminum foil to the outside of the styrofoam sheet, to serve as an absorber plate. Be careful not to rip the aluminum foil on the rough edges of the wire.

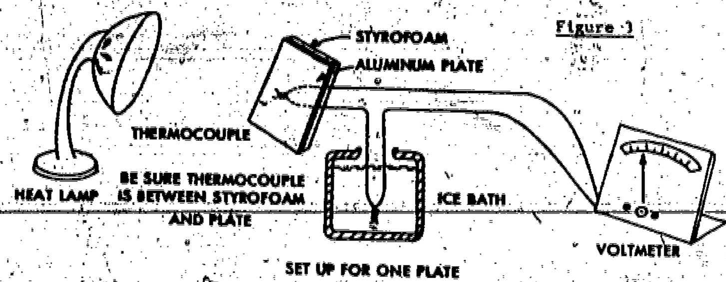
8. Place the voltmeter between the two copper wires that are not attached. If the voltmeter does not read a value, switch the terminals so that the voltage reading is positive. (See Figures 2 and 3)

9. See Figures 2 and 3 for an illustration of this activity.

Figure 2



CONSTANTAN-COPPER THERMOCOUPLE



10. On a data sheet record the voltage reading every minute for fifteen minutes.

11. Carefully take your equipment apart so that all the pieces may be used again.

12. 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.

13. Plot the data, temperature vs. time on a graph.

LOOKING BACK

Solar collectors can be made very simply. The indication of the performance of that collector is usually made by measuring the temperature. There are, however, other properties that can be measured that are related to the temperature. The thermocouple measures such a property, the creation of an electric current in the twists of wire when it is heated or cooled.

QUESTIONS

1. As the voltage of the thermocouple increased what happened to the temperature of the collector plate?

2. What happened to the voltage with relation to time?

GOING FURTHER

- What effect does the slant toward the sun or closeness of the sun lamp have on the graph of time vs. temperature?

- Does your school have another type of thermocouple? You may want to compare one to another.

- 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.

DATA TABLE

TIME (MIN.)	VOLTAGE (MILLIVOLTS)	TEMPERATURE °C
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

MEASURING THE HEAT OF A SOLAR COLLECTOR USING A THERMOCOUPLE

Suggested Grade Level and Discipline

7-9 Science
Physics

Background Information

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^{o}F or 0^{o}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.

Hints on Gathering Materials

- 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 hardware or building supply companies.

Suggested Time Allotment

- One class period to do the activity.
- One class period to discuss the results.

Suggested Approach

- Divide the class into groups of 2 or 3 students. Have each group make one device.

Typical Results

- The millivoltage should rise to a maximum value and then remain relatively constant the longer the sun shines on the collector.
- The sudden appearance of cloud cover will cause variations in the readings which can be noted.

TEMPERATURE - VOLTAGE READINGS FOR A COPPER - CONSTANTAN THERMOCOUPLE

°F	°C	MILLIVOLTS
0	-17	-.67
10	-12	-.47
20	- 6	-.26
30	- 1	-.04
40	5	+.17
50	10	+.39
60	15	+.61
70	21	+.83
80	27	+1.06
90	32	+1.29
100	38	+1.52
110	43	+1.75
120	49	+1.99
130	55	+2.23
140	60	+2.47
150	66	+2.71
160	71	+2.96
170	77	+3.21
180	82	+3.46
190	88	+3.71
200	93	+3.97
210	99	+4.22

Precautions

- *Be very careful with the use of wire, wire cutters, and nails especially when twisting the wires and placing the holes in the styrofoam backing.*

Modifications

- Perhaps if the sun is shining, allow students to test their thermocouples by facing the sun. Then divide 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.

- You may wish to use the thermocouple on different solar collectors and compare the results to those monitored by thermometers.

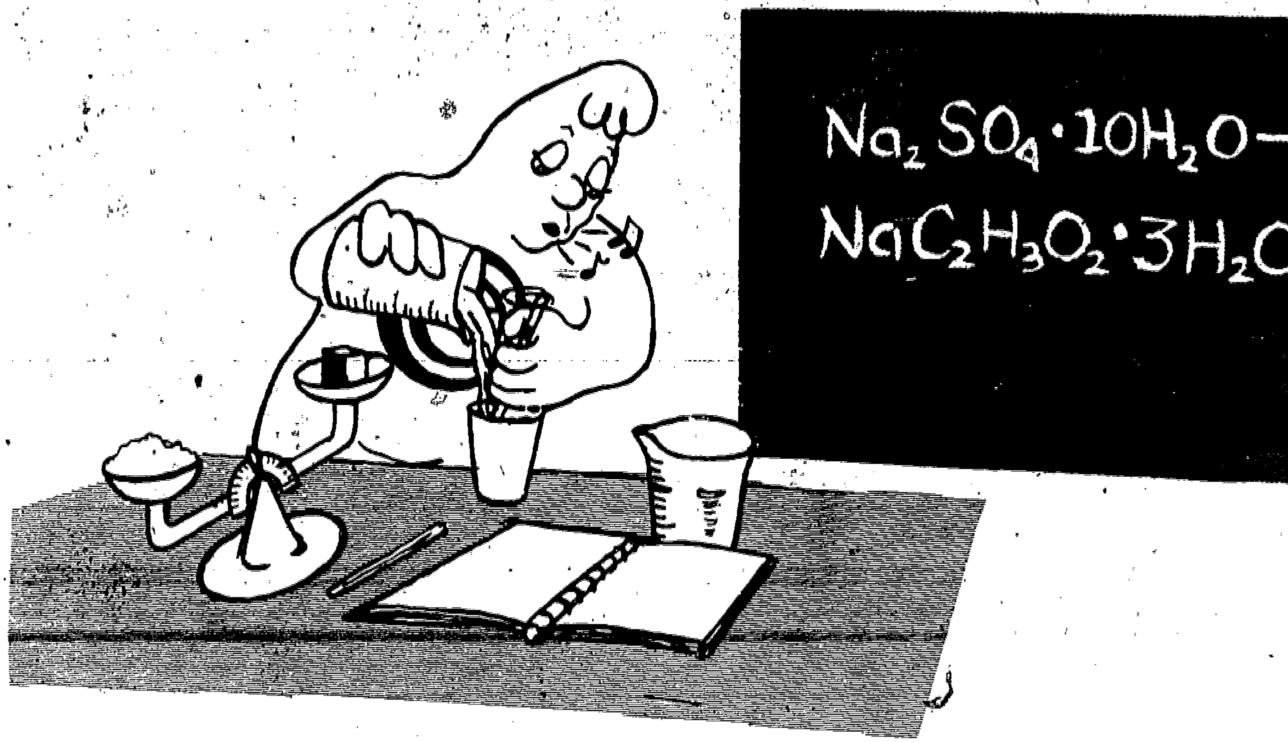
- You may make the collector more efficient by any number of means and test this efficiency by using your thermocouple.
- Try the same experiment using a thermometer and compare graphs.

Evaluation

- Observe the students as they follow instructions and construct their thermocouples.
- Examine the data collected and gather feedback on logical explanations for the working of a thermocouple.
- See whether the graphs which were drawn are suitable for data analysis.
- Check students' answers to the questions.

DRAFT - ACTIVITY 35

SOLAR ENERGY AND THE HEAT OF HYDRATION



INTRODUCTION

Today, water and rocks are the main materials for storing solar energy. Due to the large volume of water and the weight of rocks needed, alternate means of storage are being investigated. Utilization of heat of fusion and/or heat of hydration are proposals being investigated. If a non-toxic stable inexpensive material with a high heat of fusion or hydration can be found it will enable us to store solar energy without being involved with the problem of where to put either a large tank for water or structures that hold a large quantity of heavy rocks. In the laboratory we will investigate the heat of hydration of two substances, Na_2SO_4 and $NaC_2H_3O_2$. Using the data collected, you will be able to speculate about the use of these substances to store solar energy.

OBJECTIVES

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

- o determine the heat of hydration of $Na_2SO_4 \cdot 10H_2O$ and $NaC_2H_3O_2 \cdot 3H_2O$.
- o describe the relationship between stored solar energy and heat of hydration.
- o determine the economic feasibility of using heat of hydration as a storage medium for solar energy.

SKILLS AND KNOWLEDGE YOU NEED

- How to use a balance, read a thermometer and use a calculator.
- How to calculate the heat of hydration.
- Concepts of heat, calorie, molecular weight, balancing an equation, bonding, and the mole concept.

MATERIALS

- A balance.
- A calorimeter of 4 styrofoam cups
- A stirring rod.
- 50 ml graduated cylinder.
- A watch or laboratory clock.
- Heating lamp or a source of sunlight
- $Na_2SO_4 \cdot 10H_2O$ (Glauber's Salt).
- $NaC_2H_3O_2 \cdot 3H_2O$.
- 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 $Na_2SO_4 \cdot 10H_2O$ 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 mixture 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.

HEAT OF HYDRATION OF $NaC_2H_3O_2$

Part A

1. Repeat the procedure from Part [illegible] above [illegible] $NaC_2H_3O_2 \cdot 3H_2O$ instead of $Na_2SO_4 \cdot 10H_2O$.

Part B

1. For the heat of solution of the anhydrous [illegible] salt use 1.15 g of salt and 50 ml of water as in Part B.

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 ________

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 __________

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CALCULATIONS

1) Heat of Solution (K Cal) = Weight of Solution (g) x $\Delta t^{o}C$ x specific heat $\left(\frac{Cal}{g^{o}C}\right)$ x $\frac{1\ K\ Cal}{1000\ Cal}$. Assume the specific heat of the solution is 1 $\frac{Cal}{g^{o}C}$.

2) Molar Heat of Solution $\left(\frac{K\ Cal}{Mole}\right)$ =

$$\frac{\text{Molecular Wt. of solute (g)} \times \text{Heat of Solution (K Cal)}}{\text{Weight of solute (g)}}$$

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.

LOOKING BACK

As the use of solar energy for heating homes becomes more widespread, better storage methods will have to be developed. A possible method might be the use of the heats of hydration of certain salts. While this method has advantages over present methods of solar energy storage, problems do exist that will have to be solved.

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.

GOING FURTHER

- 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?

Teacher Information Section

SOLAR ENERGY AND THE HEAT OF HYDRATION

Suggested Grade Level and Discipline

11 - 12 Science
Chemistry or Advanced Placement Chemistry

Background Information

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.

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.

Suggested Time Allotment

- One period for hydrated salts.
- One period for anhydrous salts.
- One period to discuss results.

Suggested Approach

- A prior discussion of calorimetry is suggested. Students should have done problems applying the principles involved.

- If the class is large have students work in pairs.

- If there is enough time have students repeat the experiment more than once to check results.

- 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.*

Evaluation

- Observe students' ability to work in the laboratory and follow instructions.

- Collect and collate the data. Have the students discuss areas of possible error.

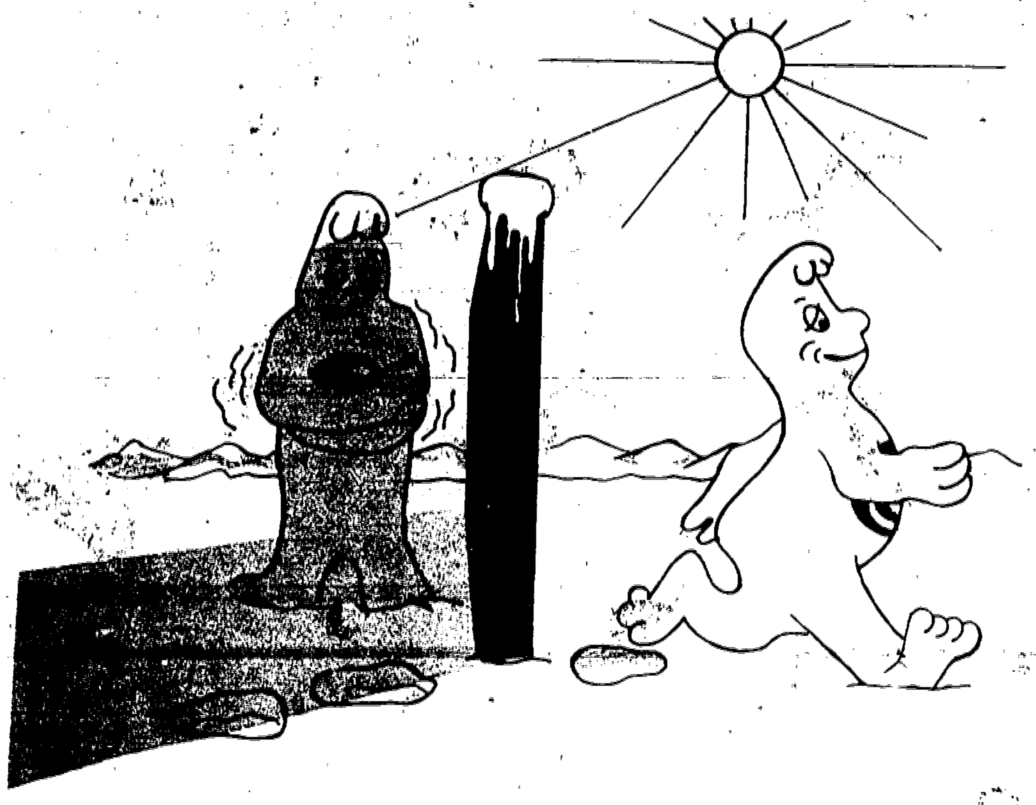
- Collect the students' laboratory reports and grade them.

References

- *Solar Energy Concepts in the Teaching of Chemistry*, Joseph S. Cantrell, Journal of Chemical Education, Jan. 1978 (Vol. 55 No. 1), p. 41.

D R A F T - ACTIVITY 36

SUNLIGHT AND SURFACE HEATING EFFECTS



INTRODUCTION

During the winter, even on sunny, windless days, the outdoor air temperature is often below freezing. If you are in the shade, you are very aware of the cold temperature, but if you move into the sun you feel warmer. Why does the temperature significantly change from sunlight to shade?

One of the reasons for this change is surface heating. When sunlight hits the earth's surface, the surface absorbs the light, changes it to heat, and releases this heat back into the surrounding air It is because of varied surface heating, as well as the earth's rotation, that we have the weather systems we do.

In order to understand the effects of surface heating, in this activity you will be observing the process of heat flow from a variety of ground surfaces by measuring the air temperature above them

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OBJECTIVES

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

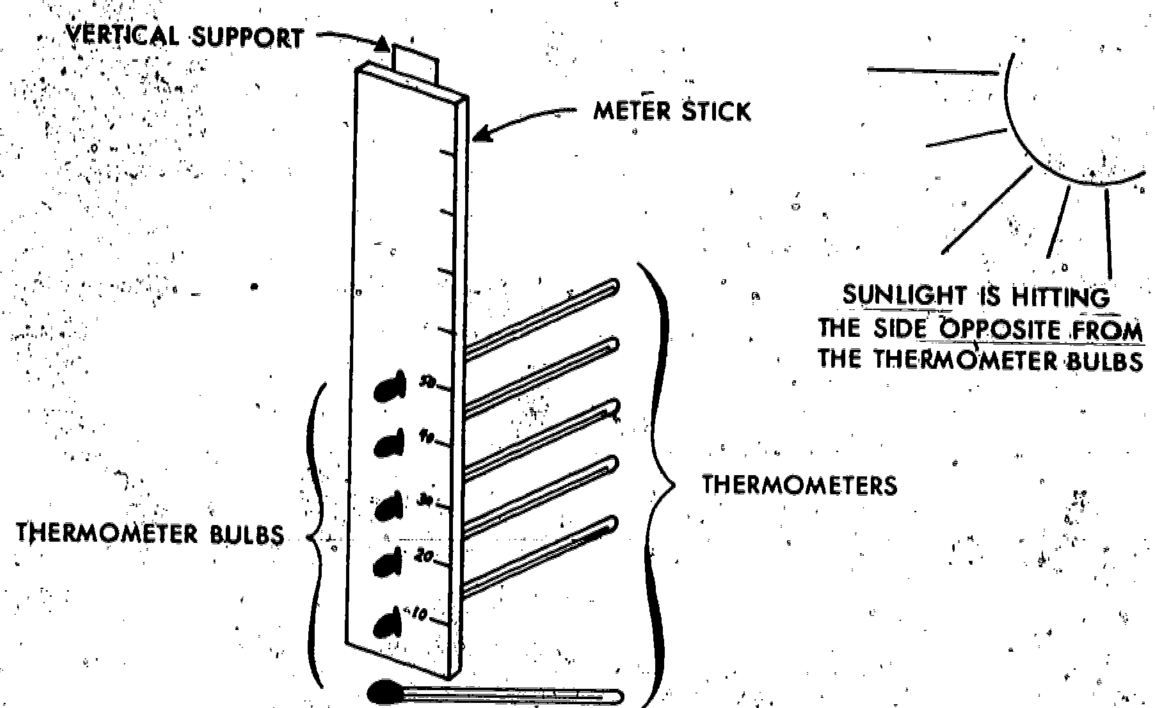
- o set up the heat transfer apparatus on appropriate ground surfaces so as to reduce the effects of wind, direct sunlight or reflecting surfaces.
- o measure air temperatures at regular intervals above the ground surface.
- o determine the effect of various surfaces on the surrounding air temperature.

SKILLS AND KNOWLEDGE YOU NEED

- How to tell time.
- How to measure distance with a meter stick.
- How to read a thermometer.
- How to record data on a table.
- How to graph data.

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.

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 next page for data table.

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		

LOOKING BACK

Air heating is accomplished mainly by circulation from warm surfaces. Warmer air has a tendency to rise. In this activity we wanted to determine how significant the factors of time, height and surface materials were in changing air temperatures.

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?

GOING FURTHER

Using the data you have collected and your knowledge of physical science, answer these questions:

1. Explain why mirages are seen over deserts and black top roads but not over green grass and other cool surfaces.

2. Explain the generation of sea breezes along the coast.

3. In terms of the data gathered by you in this experiment and your general knowledge of meteorology, explain one reason why clouds are rather uncommon in polar latitudes, as compared to temperate ones.

4. Why are baseball stadiums so much hotter in summer than the rest of the outdoors? And especially, why are those surfaced with astro-turf even hotter than grass fields?

5. All other factors being unchanged, will time of exposure change the air temperature at a given location over a surface? Explain.

6. Why are the thermometers placed in shade, not direct sunlight?

To further explore the heating of air by warm surfaces you can use the same procedure to answer these questions.

1. What is the effect of wind?

2. What is the effect of humidity?

3. What data could you collect over a liquid surface such as a puddle, a swimming pool or a pond?

Teacher Information Sheet

SUNLIGHT AND SURFACE HEATING EFFECTS

Suggested Grade Level and Discipline

Grades 7-12
Earth Science and Physics

Background Information

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 macadam 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.

Hints on Gathering Material

- The support tripods may be available in the science rooms; if not, most music departments have tripods that can be readily adapted for use. The less the bulk of the tripod, the better it may be used to produce minimal change in the heating configuration.

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

- The big problem again will be getting enough thermometers.

Suggested Time Allotment

- 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.

Suggested Approach

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

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

- 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.

Typical Results

- The amount of heat re-transmitted is sufficient from macadam surfaces to produce a 5 celsius degree temperature rise at 10cm over the surface. Reduced heating is visible for approximately a half meter up.

- Blacktop, concrete, dirt, grass, and water produce progressively less surface heating and air temperature rise.

Precautions

- *Danger from broken thermometers mandates that the stick be secured carefully to the tripod and the thermometers fitted carefully into it.*

Modifications

- It is possible to simply shift the thermometers from hole to hole but this will prejudice the data if external conditions change during the process of data gathering.

Evaluation

- Check students' data table and graph.
- Check students' answers to the questions.
- Observe students' ability to adequately follow directions in performing the experiment.

References

- *The Flying Circus of Physics*, Jearl Walker. (New York: Wiley) 1977.

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