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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 earth science experiments. Each unit presents an introduction; objectives; skills and knowledge needed; materials; method; questions; recommendations for further study; and a teacher information sheet. The teacher information sheet includes suggested grade level; additional subject areas involved; background information; hints on gathering materials; suggested time allotment; suggested approach; typical results; precautions; modifications; evaluations; and references. (RE)

DOE/CS-0063

Activities

Earth Science

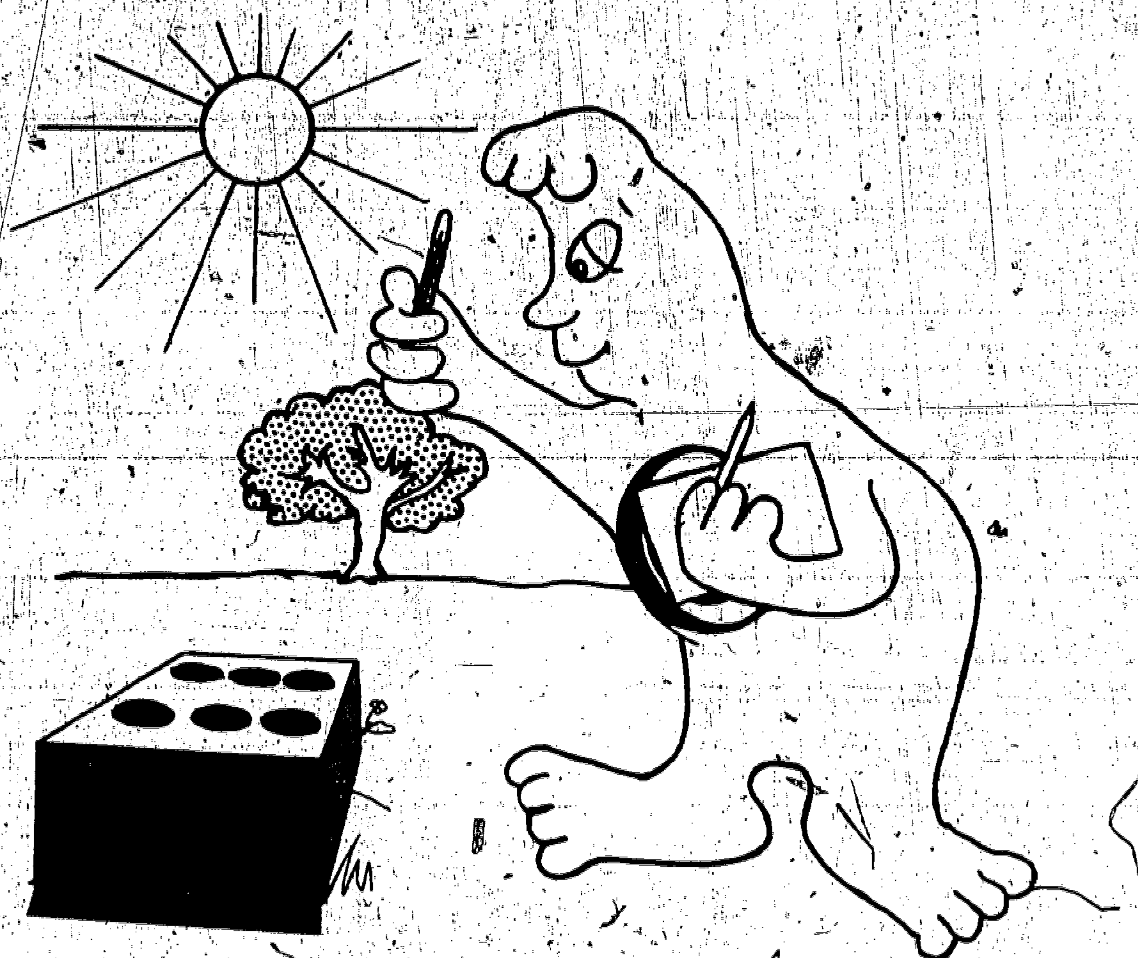
January 1979

U.S. Department of Energy
Assistant Secretary for Conservation
and Solar Applications
Market Development and Training Program
Washington, D.C. 20545

SOLAR ENERGY PROJECT

D R A F T - ACTIVITY 15

A CUP OF SUNLIGHT



INTRODUCTION

As we all know, the sun warms our air and provides the light by which we see. The heat it gives off has direct effects on any surface it strikes. But are the effects the same on all surfaces? Do the effects vary with the depth you go into the object on which the sun is shining? This experiment will ask you to construct an apparatus* to investigate the answers to these questions. From this data you can provide answers to many questions that architects, heating contractors, landscapers and environmentalists must ask before buildings are put up.

OBJECTIVES

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

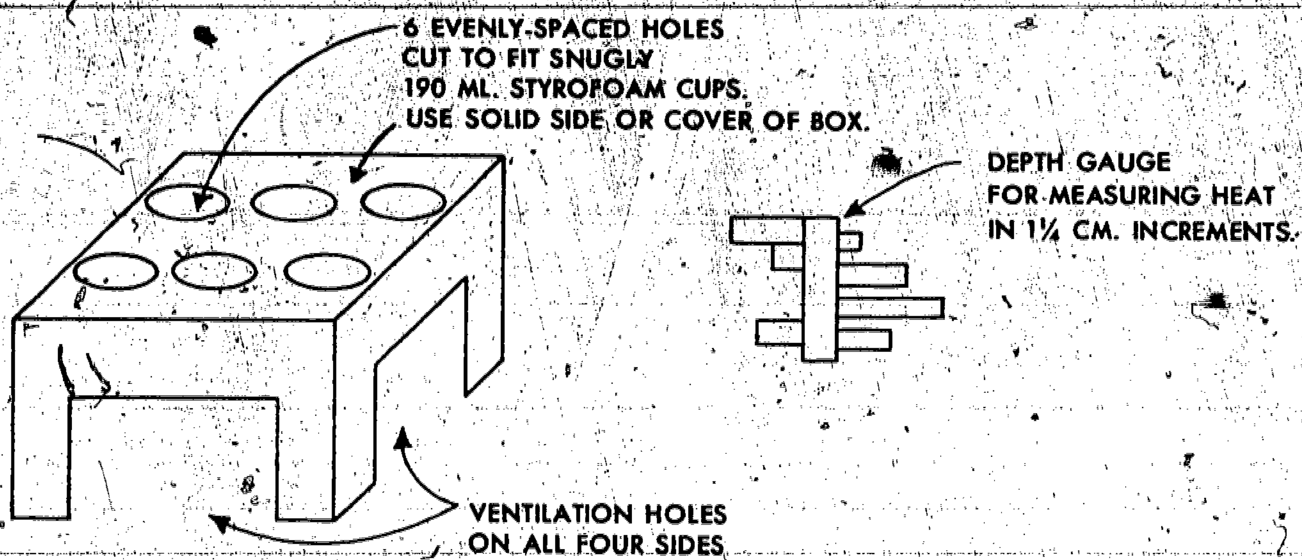
- o construct the heat transfer analysis box.
- o determine by measurement of temperature change, heating as a function of depth of material.
- o determine by measurement of temperature change the heating of different substances.
- o determine the heating of air as a function of duration of sunlight.

SKILLS AND KNOWLEDGE YOU NEED

- How to measure Celsius temperature on a thermometer; metric length on a ruler; time on a clock, watch or stopwatch; mass on a balance; and volume in a graduated cylinder.
- How to plot and interpret graphs of data.

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 20cm 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.



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 disturb 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).

LOOKING BACK

You have investigated the relative absorption of the sun's energy by various substances. It should be possible to conclude from your data which substances absorb best as compared to the other substances you used.

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?

GOING FURTHER

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

- 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?

- 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 procedures 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 SUBSTANCES THAT HAVE ANY POSSIBILITY OF BEING DANGEROUS WHEN HEATED.

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

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

Why is perspiration less evident on windy days?

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

Teacher Information Sheet

A CUP OF SUNLIGHT

Suggested Grade Level and Discipline

9-12 Science
Earth Science
Physics

Background Information

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.

Hints on Gathering Materials

- Check the mimeo room several weeks before the lab data and take up a collection of boxes. Corrugated boxes work the best.
- Styrofoam cups in sleeves of 25 or 50 are low in cost and may be obtained easily.
- 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 hy highway departments is readily graded by sifting it through a screen window.

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

- 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.

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

Suggested Time Allotment

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

- One to three days to gather data.

Suggested Approach

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

- 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.

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

- Emphasis on the GOING FURTHER section will give valuable information to increase the relevance of the procedure and data.

Typical Results

- Differences in temperature of different materials at the surface as well as different depths to 5cm will be on the order of 5°C over a 30 minute observation session in good sun.

- Conduction effects will be quite good for the denser substances but those with high porosity percentages will not work too well nor will convection in fluids give significant depth variation.

Precautions

- *Metal meat thermometer type thermometers may be substituted for mercury bulb ones but in any case care in their use and penetration of samples must be emphasized.*

Modifications

- Further work beyond procedure is advocated and may be personalized as desired.

Evaluation

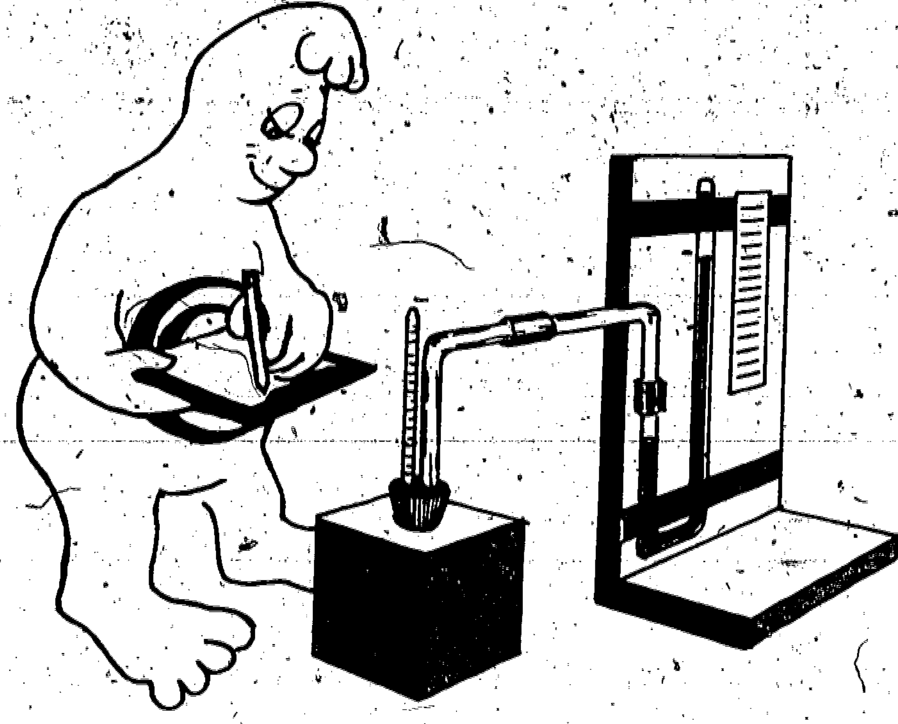
- This is an exercise in inference and as such should be treated as an opportunity to elicit student opinions based on data they gather. Defense of a thesis is a significant skill and establishment of an appropriate one is just as relevant a skill. Encourage the students to speculate by extrapolation from the data.

- Collection of data and graphs plus a brief written explanation of conclusions before and after post-lab discussions will be of value. Quality of procedure and reasoning from it can be determined by this as well as in class discussion performance.

References

- *Circus of Physics with Answers*, Jearl Walker, Wiley, 1977.

A SOLAR THERMOMETER



INTRODUCTION

Have you ever noticed that car tires often seem flatter in cooler weather than in warmer weather? Why might this be so? Heat or lack of heat affects air in many ways. One of these will be investigated in this activity.

Temperature can be measured by using air that is heated or cooled. A solar thermometer can be used to measure air temperature.

This activity deals with several fundamental scientific principles. You should have a clearer understanding of them after completing the activity on the solar thermometer.

OBJECTIVES

At the completion of this activity you will have:

- o constructed a solar thermometer.
- o calibrated your solar thermometer.
- o observed the effects of the sun on the solar thermometer.

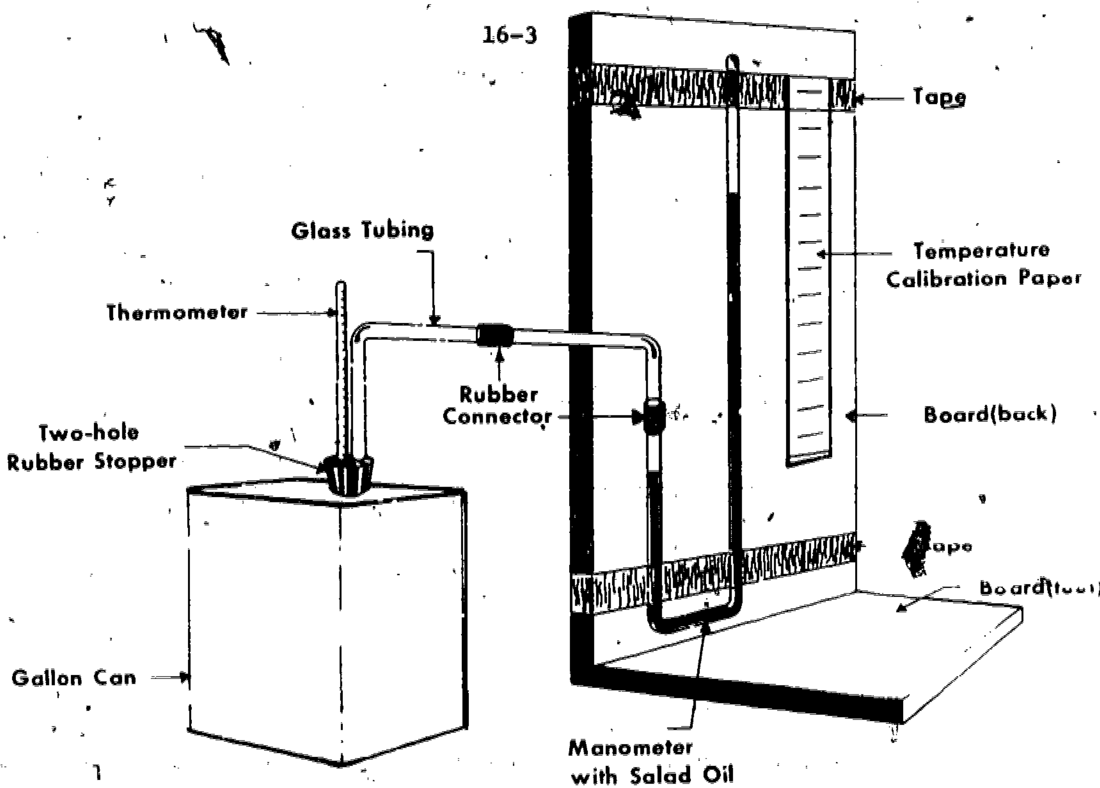
SKILLS AND KNOWLEDGE YOU NEED

- You must be able to read a thermometer.
- You must be able to bend glass tubing.
- You must know what calibrate means.

MATERIALS

- Tin can (ditto fluid).
- 2 hole stopper.
- 3 pieces-4mm glass tubing (2 pieces 45cm, 1 piece 91cm).
- 2 rubber hose connectors
- 1 laboratory thermometer
- 1 board 2½cm x 15cm x 61cm
- 1 board 2½cm x 15cm x 30cm
- Small quantity vegetable oil
- Strip of graph paper for the [illegible]
- 4 #8 nails
- Hammer
- Masking t[illegible]
- 1 piece of [illegible]
- 1 funnel

16-3



METHOD

1. Nail the long (back) board to the short (foot) board. (See diagram.)

2. Bend the glass tubing into 2 - L shapes and 1 - U shape (See diagram.)

3. Connect the glass tubing with the hose connectors.

4. Moisten and insert the thermometer into the stopper, and moisten and insert one end of glass tubing into the stopper. Wrap the thermometer and glass tubing in a cloth when inserting into the stopper to prevent cutting yourself if they break.

5. Place the U shaped tubing against the back board and tape firmly into place by putting the tape completely around the board. (See diagram.)

6. Slide the vegetable oil down the open end of the U shaped tube. Use a funnel to do this.

7. Insert the rubber stopper into the tin can.

8. Tape or tack a paper strip to the back board along [illegible] tube. (See diagram.)

9. Cut a small vertical slot in the end of the cardboard shield to the point that the glass tube rests on the slot with both can and foot board resting on table surface.

10. Place the whole thermometer unit in the sun.

    a. With sunlight shining only on the tin can but with the thermometer unit shielded, wait until the vegetable oil level stabilizes, put a mark on the paper strip at the top of the oil level and record the temperature indicated by the thermometer in the tin can.

    b. Now, move the cardboard shield so that the tin can is now in the shade with the thermometer unit. Repeat part (a.) and again record the temperature indicated by the thermometer in the tin can.

11. Repeat this procedure varying the amount of sunlight striking the can, recording at least five temperature readings on the paper strip.

12. Use the thermometer you have made to measure the air temperature in several places such as your classroom, inside a closet, inside a refrigerator etc. Compare the temperatures you measured with your air thermometer with the temperatures measured with a laboratory thermometer.

LOOKING BACK

In the course of this activity you have constructed a simple thermometer that is activated by the expansion and contraction of air in the tin can. In this case the sun's light has provided the energy necessary for the expansion and contraction process. You have calibrated your thermometer and collected data.

QUESTIONS

1. What happens to the air in the can when it is placed in the sunlight?

2. Why was it necessary to slide the vegetable oil into the tube before you inserted the rubber stopper into the can?

3. How do you think the recorded temperatures were related to the amount of solar energy received by the tin can?

4. Thermometers have always been used as indicators of heat energy. From your experience in this activity, what other form of energy could be measured by this thermometer?

GOING FURTHER

- Use different colors and textures of paints on the can.
- Extend the activity for one week, introducing variables such as cloud cover, barometric pressure and time of day
- Do indoors, using different energy sources (for example, ultraviolet light, infrared, and white light.)
- Plot data collected on graphs.

Teacher Information Sheet

THE SOLAR THERMOMETER

Suggested Grade Level and Discipline

7-9 Science
Earth Science

Background Information

The solar thermometer is basically a manometer connected to an air expansion tank (gallon can). As the air in the expansion tank is heated by the sun, the air will expand and move through the connecting tube to force the salad oil in the manometer to change level. By calibrating the level of the salad oil with a conventional mercury or alcohol thermometer the apparatus can be used to measure air temperatures. Conversely, the cooling of the air in the can should produce a reverse reaction.

The outside color of the can (expansion tank) may have an effect on the time it takes to achieve a given temperature and the maximum temperature that can be attained. It is possible to have salad oil forced out the open end of the tube.

The solar thermometer is not particularly practical as a measuring device. It is cumbersome and not very accurate. It does, however, provide a way to examine some basic scientific principles. Expansion and contraction, air pressure, and the effect of dark surface on heat absorption are three areas that can be explored using this device.

Hints on Gathering Materials

- Add Sudan Stain [illegible]
- Use empty [illegible]
- Use strong tape to [illegible] the manometer to [illegible] tape all the way around board

Suggested Time Allotment

One class pe[illegible]

One class period [illegible]

One class period to complete the instructions. More time may be [illegible] extended.

One class period for analysis and [illegible]

Suggested Approach

- Discuss heat and its effects on matter.
- Review how a thermometer works.
- Discuss the diagram and method of construction.
- Construct the solar thermometer.
- Discuss the procedure for calibration. Define the term calibration using examples. Discuss with students how they are going to use the thermometer.
- Provide students with actual hands-on use of the solar thermometer and collection of data. The best results occur if done outside.
- Analysis and interpretation of data collected should follow the activity.

Typical Results

- Temperature readings will be higher when the can is in direct sunlight rather than in the shade.
- The greater the amount of insolation, the higher the expected temperature.

Precautions

- *Depending on student [illegible] the glass.*
- *Be careful when inserting the [illegible] towel to hold the tubing and lubricate it [illegible] glycerin or water*

Modifications

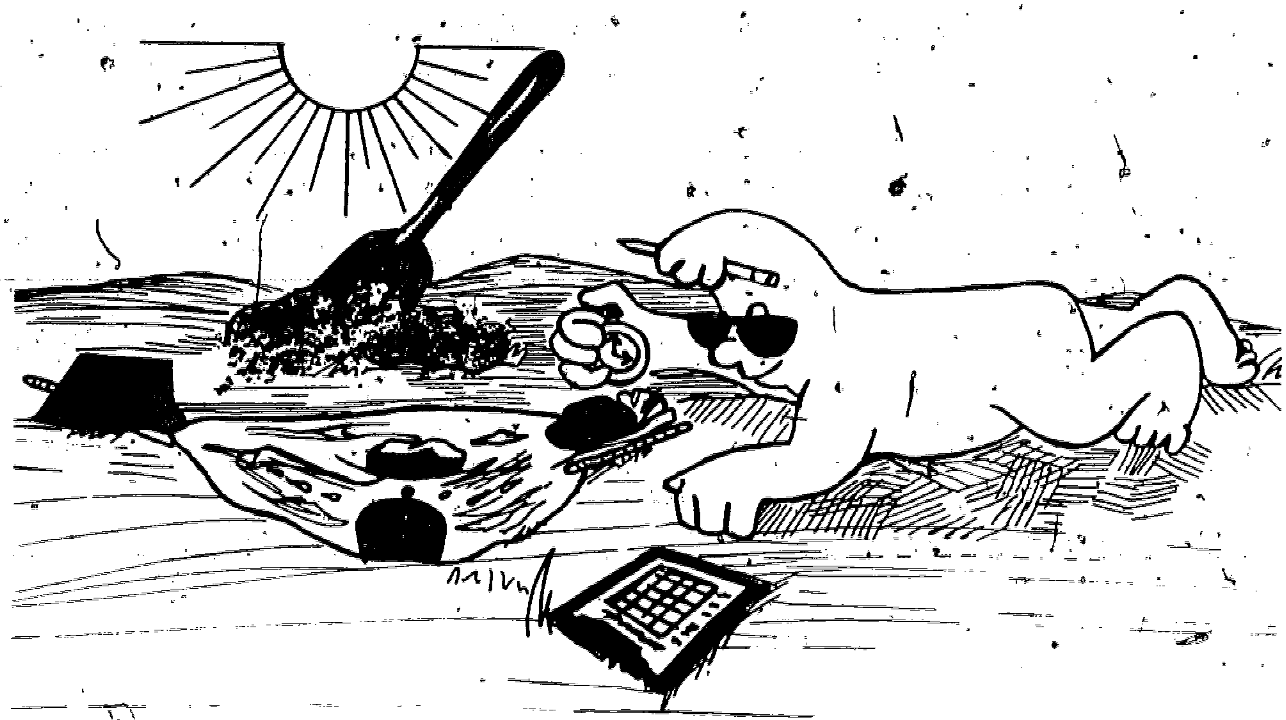
- Clear plastic tubing, [illegible] for the glass tubing in the U tube

Evaluation

- Check students' apparatus [illegible]
- Check students' answers to the [illegible]

D R A F T - ACTIVITY 17

BUILDING A SOLAR STILL



INTRODUCTION

"Water, water is everywhere and if you want your fill
just dig a hole in the ground and make yourself a still.

In many parts of the world water is an abundant and valuable natural resource. Its presence in streams, lakes, rivers, oceans, polar ice caps, the atmosphere, and the ground, means that water is everywhere on earth.

Despite all of the water around us we still hear warnings and complaints about water shortages. Such shortages can become severe enough to cause crop failures during droughts and death to inexperienced travelers in an arid region. If you were ever faced with the crisis of thirst, in a desert region, you might use simple steps to survive.

In this activity you will construct a still which uses solar energy for its operation.

OBJECTIVES

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

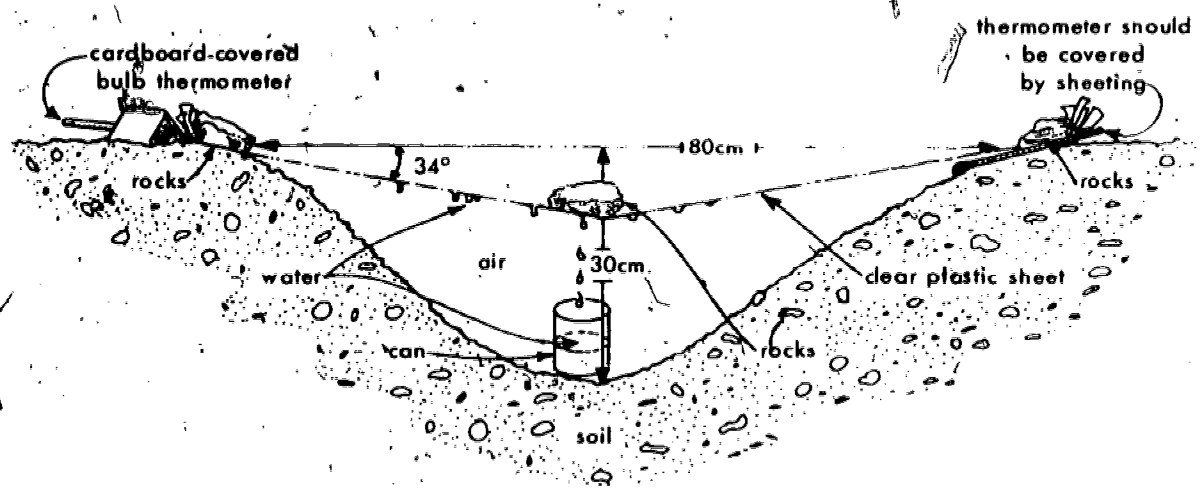
- o build and use a simple solar still.
- o suggest possible practical applications for a solar still.
- o understand the principle of distillation.
- o test for the presence of water.

SKILLS AND KNOWLEDGE YOU NEED

- How to follow directions.
- How to read a thermometer.
- How to graph data.
- How to interpret data.

MATERIALS

- Strong, flexible transparent plastic [illegible] e.g., plastic, storm window covering.
- Several fist size rocks.
- Calibrated collecting can or other [illegible]
- Shovel.
- Two thermometers ($10^{\circ}C$ to $110^{\circ}C$ scale)
- Timing device (wristwatch or stopwatch)
- Piece of cardboard to cover ½ of the th[illegible]
- Graph paper.
- Graduated cylinder.
- Cobalt chloride test paper, or other means of testing water.
- Protractor



METHOD

1. Dig a hole about 80cm in diameter and [illegible] 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 [illegible] over the collecting vessel, and allow the plastic to stretch to at least a 34° angle from the horizontal.

4. Seal the edge of the plastic with soil and small rocks.

5. Insert one thermometer under the plastic sheet with the [illegible] extending into the air chamber, and positioned so that the s[illegible] 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 [illegible] 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.

LOOKING BACK

You have seen that it is possible to get water from dry soil using a very simple technique. The evaporation and condensation of water using the sun is a very useful process for producing distilled water.

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 [illegible] Explain.

5. How did solar energy cause the still to operate?

6. How did the temperature difference influence the [illegible] water collected?

GOING FURTHER

- Repeat the activity measuring the amount [illegible] as a function of time.

- Repeat the same activity with a change in the size of the [illegible] (Hint: a much deeper, narrower hole, or a wider, shallower [illegible]

- Discuss some practical uses for solar stills.
- Check for the purity of the water obtained.
- Check for bacteria.

Teacher Information Sheet

BUILDING A SOLAR STILL

Suggested Grade Level and Discipline

7-9 Science
Earth Science
Outdoor Education
Descriptive Chemistry

Background Information

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 [illegible]. 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.

Hints on Gathering Materials

A calibrated container should [illegible] eliminates the need to pour the water from the collecting [illegible] a graduated cylinder.

Plastic storm window sheeting work [illegible]

Suggested Time Allotment

One class pe[illegible]

One class period fo[illegible] and [illegible]

One class period for graphing and dis[illegible]

Suggested Approach

Try on any warm [illegible]

Divide the class into groups of four or five [illegible]

- 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.

- In order to compare results, each still must be similar to the other stills in construction and orientation.

- 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.

Typical Results

- Sunny days close to the summer solstice will produce most dramatic results.

Precautions

- *Fill in the hole as soon as the experiment is completed.*

- *Make sure the slope of the plastic cover towards center is greater than 34°. If it is not, water will not drip into the collecting vessel.*

Modifications

- 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.

- Another variation might be the addition of food coloring and/or salt to the pan of water. Your students could then observe the collection of fresh water from contaminated water.

Evaluation

- Have students prepare an experiment report including data, graphs and responses to questions.

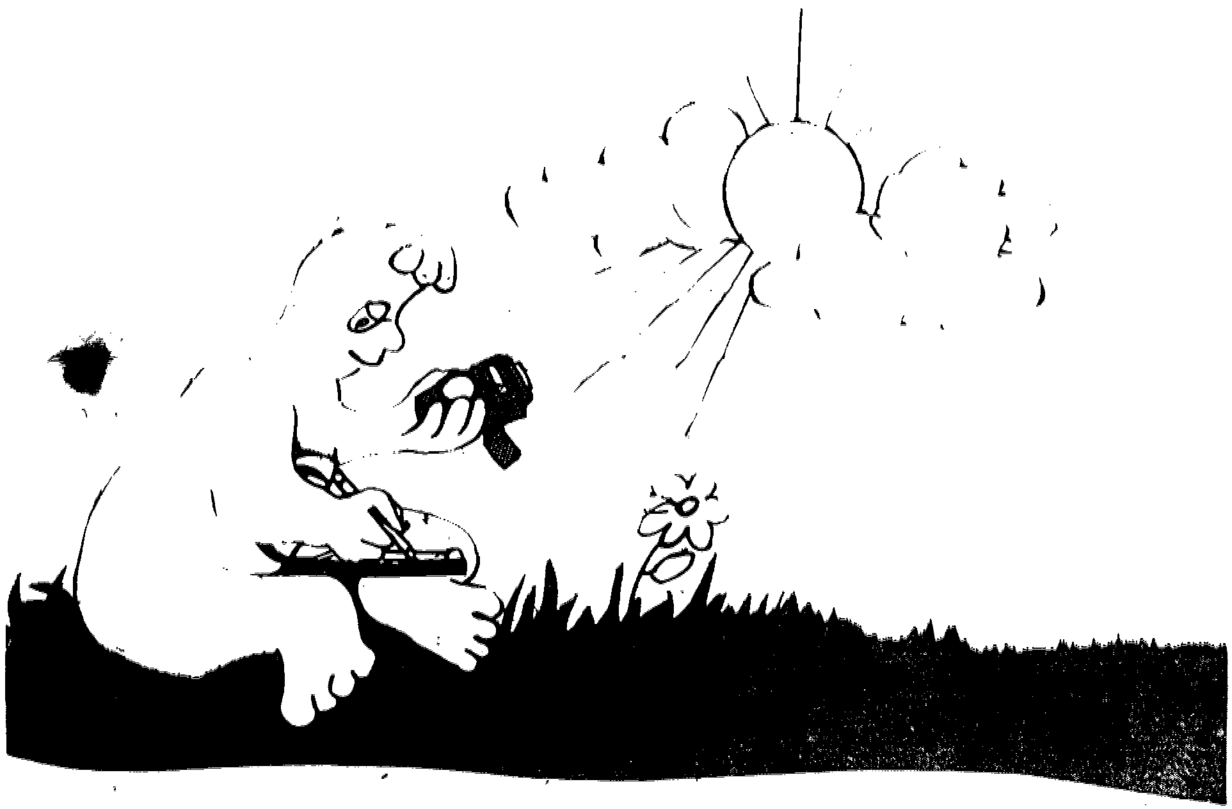
- Use a performance evaluation based on understanding the [illegible] operation of a solar still.

References

- *Solar Energy*, The Australia Sc[illegible] E[illegible]

DRAFT ACTIVITY 18

CLOUD COVERING AND ITS EFFECT ON AVAILABLE INCIDENT SOLAR RADIATION



INTRODUCTION

This [illegible] effect that cloud covering has [illegible] level. You will observe cloud cover, make solarimeter reading[illegible] the data, plot a graph and determine the results of the information obtained.

OBJECTIVES

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

- o operate a solarimeter.
- o construct a graph from the data.
- o draw inferences from the data.
- o demonstrate an understanding of the effect of cloud covering on the available incident solar radiation.

SKILLS AND KNOWLEDGE YOU NEED

- Be able to accurately read a meter.
- Observe and estimate cloud cover.
- Keep accurate and neat notes.
- Be able to calculate percentages.

MATERIALS

- Solarimeter.
- Graph paper and pencil.

METHOD

1. In order to have valid results you must take accurate data and notes. Prepare a data sheet to include the following: observer's name, the location, date, general cloud covering, the time each meter reading is taken, the meter readings, and the cloud cover between the sun and the meter at the moment the reading is made.

2. Data from one class period will be sufficient if the clouds are spaced so that both direct and overcast (indirect) sunlight are observed. Additional readings can be made over a longer period for even better results. The solarimeter should be located away from shadows and bright objects. It may be best to have the meter at or close to eye level. The solar cell must be horizontal. The observer should not interfere with the light.

3. Using the meter readings on the vertical scale and the time on the horizontal scale plot the data on graph paper. Determine the relationship between the cloud cover and the meter reading.

LOOKING BACK

Using the data collected, you should be able to find a relationship between the incident radiation measured and the cloud cover.

QUESTIONS

1. What is the maximum reading recorded?
2. What was the cloud cover at the time of the maximum reading?
3. What was the lowest reading recorded?
4. What was the cloud cover at the time of the lowest reading?
5. If heavy clouds came in front of the sun, why didn't (wouldn't) the reading go to zero?
6. Calculate the percentage of time the sun was clear of clouds.
7. Calculate one half (50%) of the maximum reading.
8. Calculate the percentage of time the readings were below the 50% level.
9. In general, what is the relationship between cloud cover and the amount of solar radiation striking your meter?
10. Do you feel that there is enough available sunlight in your area for solar use? (Do you have enough data to make a good estimate?)
11. Was this type of day typical for your location?

GOING FURTHER

- Data may be collected over a longer period of time - like a full day, week or more.
- Keep a record of just the amount of cloud covering for a long period of time to help determine the availability of sunlight.

- Information may be available for your area on the amount of cloud covering for the year. Write your state capital or the ~~United States Weather Bureau for such information.~~

- Readings can be taken earlier in the morning and through the afternoon to see if the position of the sun has an effect on the radiation.

- Data may also be obtained for different times of the year to see if the values change with the seasons.

Teacher Information Sheet

CLOUD COVERING AND ITS EFFECT ON AVAILABLE INCIDENT SOLAR RADIATION

Suggested Grade Level and Discipline

7-9 Science
Earth Science

Background Information

The use of solar energy as a dependable energy source assumes that the sun's direct energy is available for a large percentage of the daylight hours over a period of years. Many factors affect the amount of direct sunlight that reaches the earth's surface, one of which is the extent and duration of cloud cover.

This activity will investigate the effect cloud cover has on incident solar energy. A solar cell will be used to perform the solar energy measurements. Cloud types and the extent of cloud cover are defined in several weather bureau publications. The longer the time period for data collection the more accurate will be the inferences that can be made about the effect of clouds on incident solar radiation.

A set of sample data is included, should the weather conditions not allow the student to obtain good data.

Hints on Gathering Materials

- A plan for a simple solarimeter is given in the hardware section of this document. A photographic light meter could also be used.

Suggested Time Allotment

- One class period to collect data.
- One class period to graph data and discuss the results.

Suggested Approach

- Divide the class into groups of two or three students.
- Have each student prepare a data sheet prior to starting this activity.
- The activity should be done outdoors away from obstructions.

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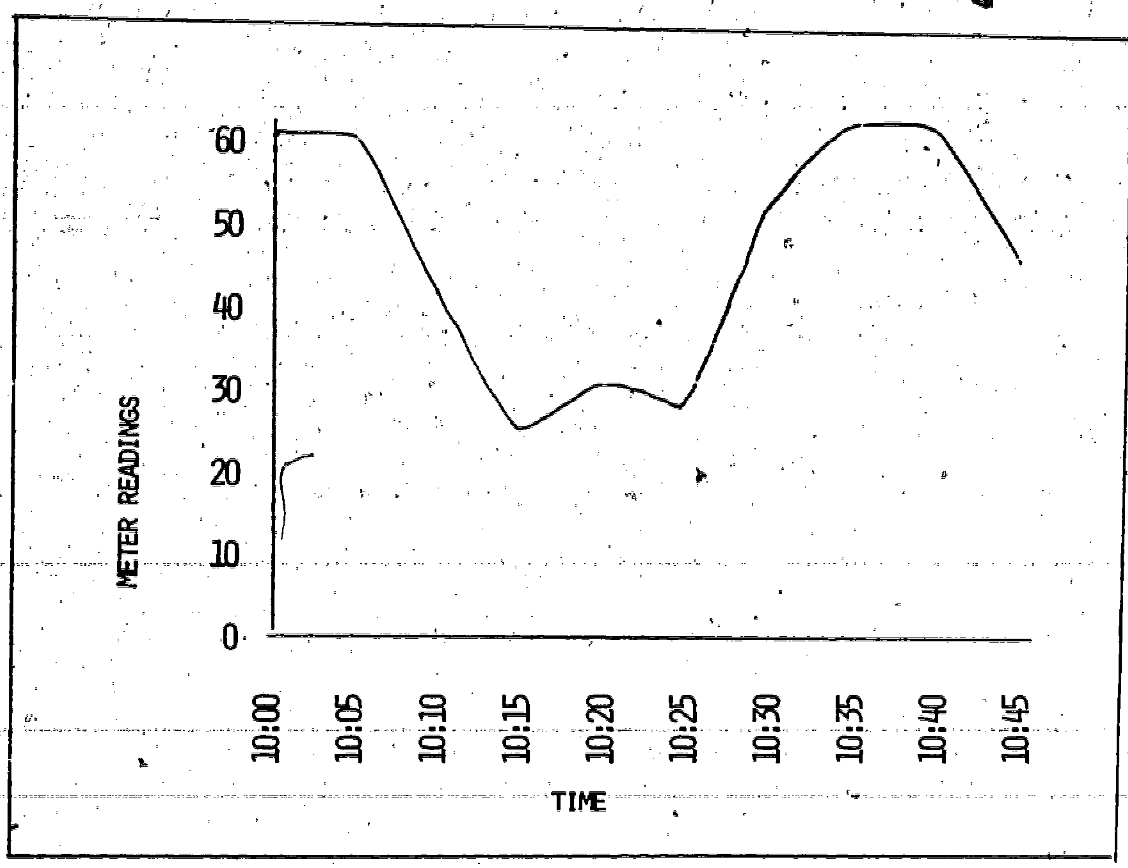
- If the day is completely overcast, very few data points will be sufficient. The activity should be continued for another class period, however, when the sun is shining directly and the clouds are intermittent.

- Each student should collect the data and prepare the graphs and then use the graphs to help answer the questions.

- If solarimeters or light meters are not available in quantity, one or two groups can collect the data for the class to use.

Typical Results

Time	Meter Reading	Remarks
10:00 a.m.	60	Clear
10:05	60	Clear
10:10	41	Cl[illegible]edge over sun
10:15	25	H[illegible] cloud over sun
10:20	30	H[illegible] cloud over sun
10:25	28	H[illegible] cloud over sun
10:30	52	[illegible]loud over sun
10:35	62	Cl[illegible]
10:40	62	Clea[illegible]
10:45	45	Thin [illegible]ud over sun



Precautions

- *Warn students not to look directly at the sun.*

Modifications

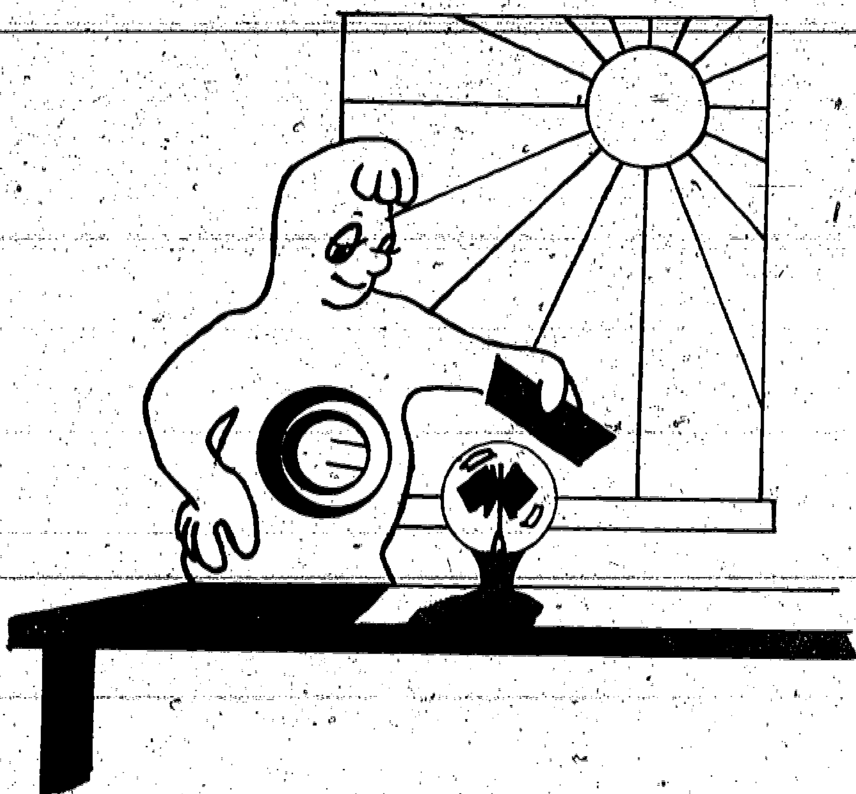
- Light meters may be substituted for solarimeters. Be sure they have a scale that will read direct sunlight.

Evaluation

- During this lesson many questions can be asked by the teacher. In addition, enough time is available to observe and question the students during the experiment and graph work. Accuracy and neatness of the data along with the plotting of the graph and the calculations may also be used to evaluate the students.

DRAFT - ACTIVITY 19

DETECTING SOLAR ENERGY



INTRODUCTION

Solar energy is energy radiated from the sun. This energy travels through space in all directions. The earth receives only a small portion of this energy, mostly in the form of light.

How can we detect the presence of solar energy? We know that our skin and clothes feel warm when we stand in the sunlight. We also know that our houses tend to be warmer on sunny days. But the key to detecting solar energy is remembering that energy is defined as the ability to do work. One instrument that allows us to "see" the work done by solar energy is called a radiometer. By using a radiometer similar to the one pictured above, we can detect the presence or absence of solar energy, and we can determine when we have different amounts of it.

OBJECTIVES

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

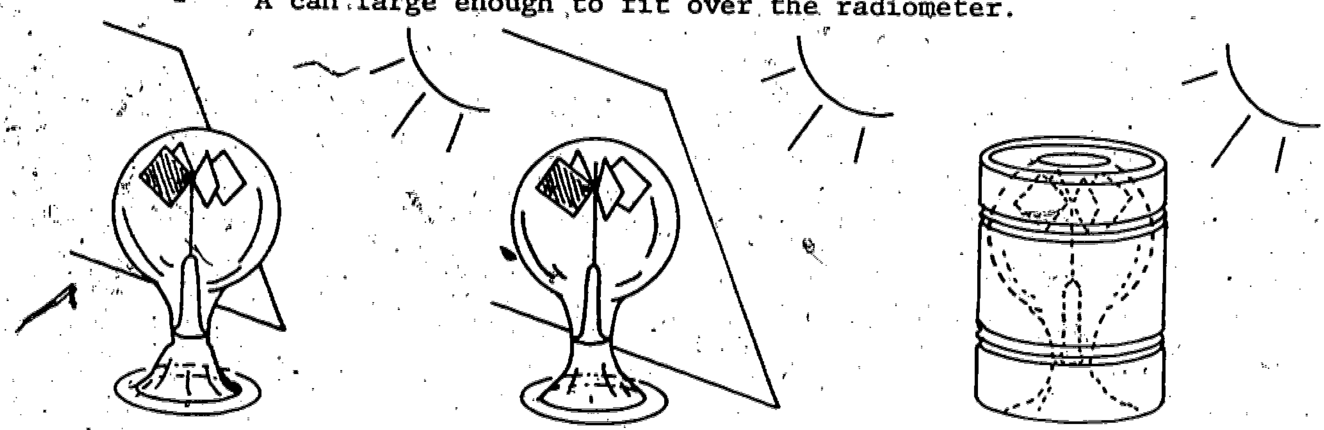
- o describe the appearance of a paddle type radiometer.
- o explain the purpose of the radiometer.
- o distinguish between the presence and the absence of sunlight by means of the radiometer.
- o distinguish between high and low levels of sunlight by use of the radiometer.
- o demonstrate that radiation from the sun can do work.
- o devise a definition of solar energy.

SKILLS AND KNOWLEDGE YOU NEED

How to follow directions.

MATERIALS

- Paddle type radiometer.
- Square pieces of cardboard (or black construction paper) 30 cm on a side.
- A can large enough to fit over the radiometer.



METHOD

1. Examine the radiometer carefully to see how it is constructed; especially the paddles.
2. Place the radiometer on a table in sunlight. Observe what happens, and record your observations.

3. Use the cardboard pieces to partly shade the radiometer from the sunlight. Observe what happens and record your observations.

4. Use the cardboard pieces to completely shade the radiometer from the sunlight. Observe what happens, and record your observations.

5. Place the coffee can over the radiometer in the sunlight. Leave the can over it for a few minutes, then remove it quickly. Observe the paddles the instant you remove the can. Record your observations.

LOOKING BACK

The radiometer is just one simple instrument which can detect the presence of solar energy. By the rate at which its paddles turn, it can give you some idea of the amount of solar energy present. The radiometer can show that sunlight is energy.

QUESTIONS

1. Describe the appearance of the radiometer.

2. What are the differences in the two sides of each paddle in the radiometer?

3. What happened a) when the radiometer was placed in the sunlight? b) when it was partly shaded? c) when it was completely shaded? d) when it was just removed from under the can?

4. In which direction does the paddle wheel spin, dark sides facing forward or light sides facing forward?

5. Under what light condition did the radiometer paddles spin the fastest? the slowest? not at all?

6. How does the radiometer detect solar energy?

7. How does the radiometer show that sunlight is energy that can do work? (Hint: What is work?)

8. Based on what you have learned in this activity, write a definition for solar energy.

GOING FURTHER

- We have demonstrated that the radiometer can do work. But we have no idea how this work is done. By recalling the differences in the two sides of each paddle, can you explain what causes the paddle to turn in the sunlight?

- How do you think the radiometer would work if the inside was a perfect vacuum?

Teacher Information Sheet

DETECTING SOLAR ENERGY

Suggested Grade Level and Discipline

7-9 Science
General Science
Earth Science

Background Information

The radiometer is a simple instrument which illustrates clearly that sunlight is a form of energy. It can also be used to compare roughly various intensities of light by the rate of rotation of its paddles.

The atmosphere inside the radiometer is a partial vacuum, so the air molecules left inside the radiometer are able to move about much more freely than those outside. Each paddle has a light-colored side and a dark colored side. The light colored side does not absorb as much solar energy and it is clearly the cooler side, and the dark side is the warmer side. When the air molecules strike the dark side, they take on a great deal of energy and bounce away at a high speed. The result is that the paddle wheel begins to move as the faster molecules "kick away" from the dark sides of the paddle wheel.

The greater the light intensity, the more energy there is to be absorbed by the dark colored sides to "heat" them up. Thus, the air molecules bounce away faster as the light intensity increases, making the radiometer paddles turn faster.

The dark sides of the paddles are actually absorbing infrared radiation, causing the surface molecules to store heat by their increased kinetic energy. This increased kinetic energy is transferred to the air molecules when they strike the dark sides of the paddles and causes the "kicking away" effect.

Hints on Gathering Materials

- Have cardboard squares pre-cut.
- Students can bring in coffee cans.

Suggested Time Allotments

- 1 to 2 class periods, depending on whether questions are answered in or out of class, and depending upon the amount of class discussion.

Suggested Approach

- To be done as a lab activity with a pair of students working with a radiometer.

- If radiometers are in short supply, this could be done as a teacher demonstration, with students answering questions.
- This activity serves as a good elementary introduction to solar energy, as it effectively demonstrates sunlight as a form of energy.

Typical Results

- The radiometer will rotate fastest with the highest intensity of sunlight, slowest with the least. When the coffee can is just removed, the radiometer should not be rotating at all.

Precautions

- *The radiometer is a delicate instrument which should not be dropped, tipped, shaken or otherwise misused. Since the radiometer is a vacuum-packed instrument, it is recommended that students wear safety glasses when using it. If the radiometer were to be accidentally broken, this would eliminate the danger to the eyes of flying glass.*

Modifications

- If it is impractical to do this activity in sunlight, a 200-watt incandescent lamp with reflectors can be substituted, although the effectiveness of the activity with young students may be reduced when they do not actually use solar energy as their source of light.

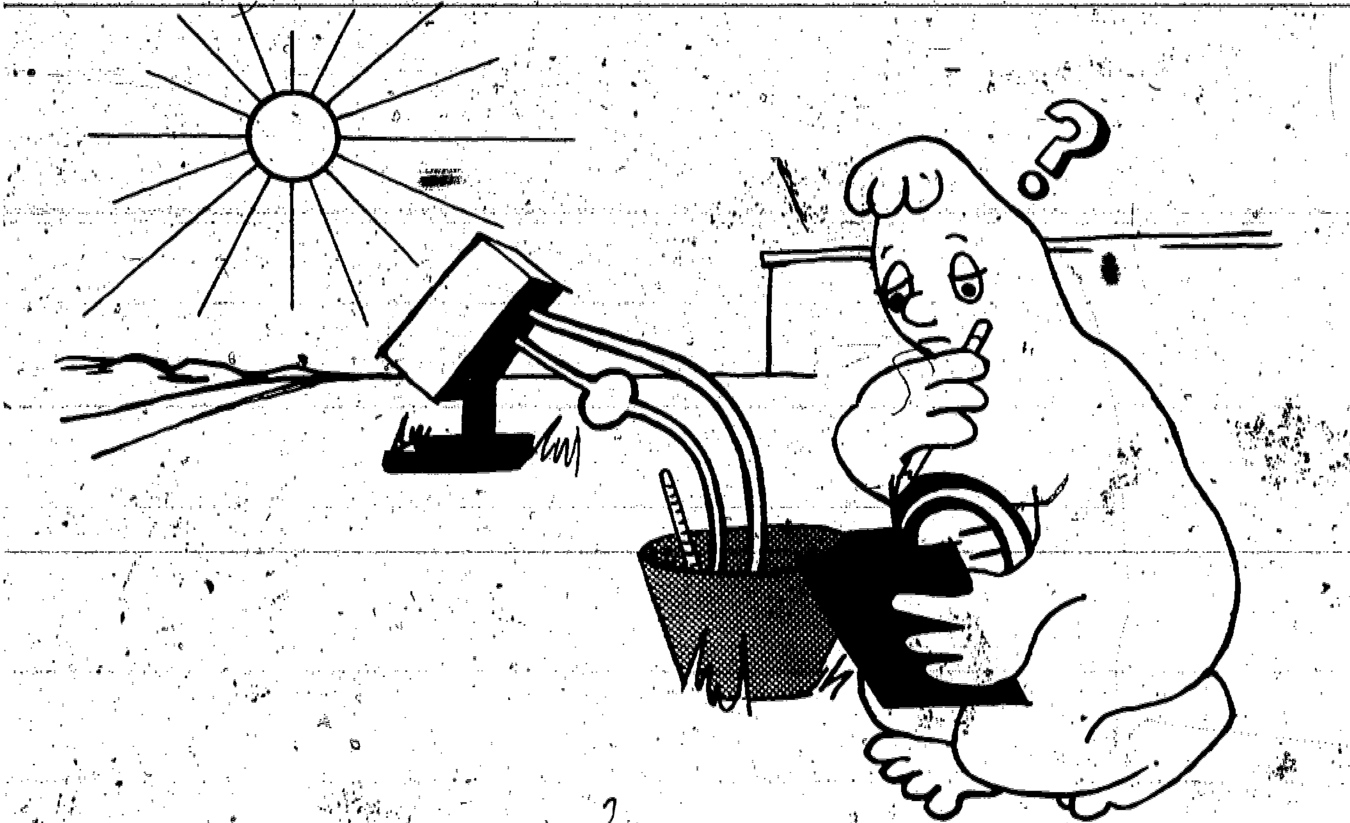
Evaluation

- Collect student answers to questions. Have they been answered in a satisfactory manner?
- Has the student tried GOING FURTHER? Is his explanation reasonable?
- Observe the student's ability to follow written directions and the manner in which he handles the radiometer. Is he following safety precautions?

References

- *The Radiometer - What Makes it Work?*, (Windsor Electronics, Inc., PO Box 662, Wheaton, Illinois, 60187.)

SOLAR ENERGY - HOW WELL DOES IT WORK?



INTRODUCTION

As our supply of fossil fuels decreases solar energy has become more and more popular as an alternatate energy source. The use of solar energy involves collecting the sun's energy and converting it into useful heat. This conversion of energy is being done constantly by the materials on earth as well as our atmosphere. You can feel this effect while getting into a closed car on a sunny day. But while we have so much of the sun's energy reaching the earth, we must ask ourselves if solar energy can be concentrated enough to become a practical alternative, or even a portion of the alternative to fossil fuels.

This activity will help to answer this question by comparing the temperature changes and heat added to air and water under different conditions.

OBJECTIVES

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

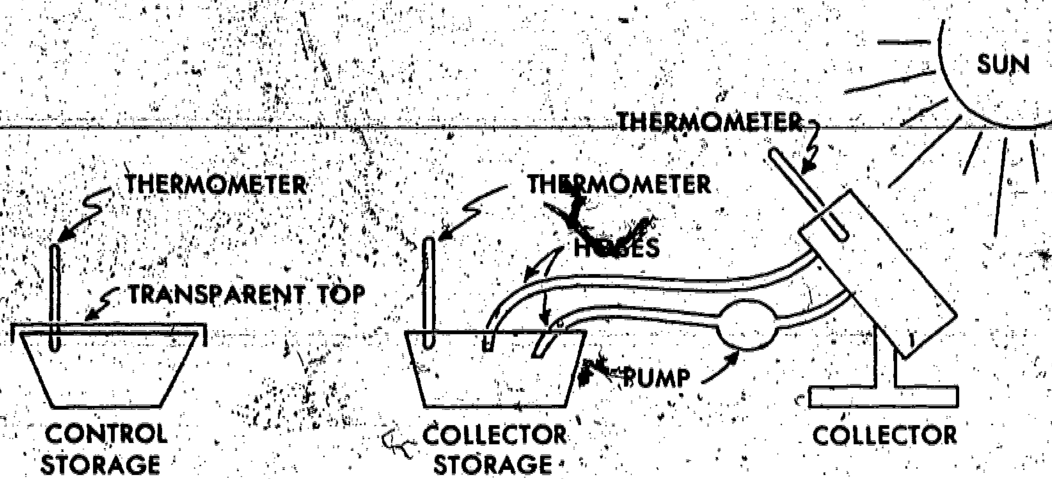
- o plot and interpret a temperature vs. time graph.
- o calculate the amount of heat gained in calories.
- o judge if solar energy can be used as an alternative to fossil fuels.

SKILLS AND KNOWLEDGE YOU NEED

- How to read a timing device.
- How to read a thermometer.
- How to record data.
- How to graph data.

MATERIALS

- Solar collector.
- 4 standard laboratory thermometers.
- Data tables (see sample).
- Graph paper.
- Timing device.
- 1000 ml. beaker.



CONTROL STORAGE - used to monitor the amount of heat energy collected by a container of water in the sun. The container has a transparent top.

COLLECTOR STORAGE - used to store the heat energy collected by the solar collector.

COLLECTOR - used to collect the sun's energy and to transfer this energy into useful heat.

METHOD

1. Place the collector so it faces the sun at all times. Place the beaker of water in the sun with the thermometer in it.
2. On the data table provided record the time under "actual time".
3. Check the thermometers and record the temperature of the first three variables, "outside air temperature", "collector air temperature", and "outside water temperature".
4. Run the drill pump for 15 seconds to transfer the water from the collector to the pump. Take the thermometer reading in the collector storage and record the fourth variable under "collector water temperature".
5. Leave the last two columns blank for computing "calories". This will be done by the entire class.
6. Repeat this procedure every 5 minutes.

7. Plot on the same graph, the temperature of the four fluids at 15 minute intervals.

8. Using the formula: Heat in calories = temperature change x mass of water find the calories of heat added to the collector water and to the outside control water at 15 minute intervals.

9. Using another sheet of graph paper, plot on the same graph, the heat added to the two masses of water.

LOOKING BACK

We know our supply of fossil fuels is limited and an energy source must be found. The use of solar energy is one of several alternatives available today. Solar energy will be used only if it is demonstrated to be practical. The data you have collected will allow you to decide for yourself whether solar energy can be used as an alternative to fossil fuels.

QUESTIONS

1. Which of the four variables had the greatest change in temperature?

2. Which variable had the least change in temperature?

3. Which liquid gained the most heat?

4. At what time did we receive the maximum amount of energy?

5. Does the celsius temperature of the collector water represent a temperature which we could use in the home for heating or bathing?

GOING FURTHER

- Would the slant of the collector be different during other times of the year?

- What suggestions do you have for improving the efficiency of the collector (design changes)?

- Could we have collected more energy by using a different liq... How would we calculate the heat added using a liquid other than water? (Hint: Look up specific heat in the library)

- What are some things that could cause the collector air and collector water storage temperature to be different?

Teacher Information Sheet

SOLAR ENERGY - HOW WELL DOES IT WORK?

Suggested Grade Level and Discipline

8-9 Science
Earth Science

Background Information

The solar collector is a simple device which allows solar radiation to penetrate the glazing material (transparent surface) and strike the absorber (auto heater core). This energy heats the absorber and the heat from the absorber is transferred to the fluid (water). The fluid is then transferred to the area of desired heating. In addition to allowing the solar radiation to penetrate, the glazing traps most of the long wave infrared radiation, keeping it inside the collector to be transferred by the fluid. The glazing is usually thermopane for better insulation against conducted heat lost.

The common collectors are either flat plate collectors using water or flat plate collectors using air as the collecting and transferring fluids. The collector diagrammed in this unit is more of a concentrating flat plate collector using water as the fluid. The object of a concentrating collector is to collect the solar radiation on a large surface and focus it onto a smaller surface.

Though solar energy is much talked about, there is still some skepticism about it serving as a viable alternative to our present-day energy sources.

This activity is designed to give the student a look at solar energy, its good points and its shortcomings. It should also make the student more aware of literature concerning solar energy and aid him in interpreting the literature in a critical way.

Hints on Gathering Materials

- The materials needed include: auto heater core (absorber), styrofoam insulation, plywood, aluminum flashing, glazing material (plastic, glass, or plexiglass), 2 auto heaters or washer hoses, 3 small styrofoam picnic containers, variable speed drill, variable speed drill pump, 4 standard laboratory thermometers.
- The materials should be collected over a long period of time by both student and teacher.
- The absorber (heater core) can be purchased from an auto wrecking yard at a relatively low price
- All other materials can be purchased from a hardware store or from around the school or home.
- A styrofoam container used to transp [illegible] collector construction.

Suggested Time Allotment

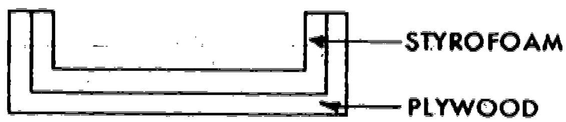
- One day to collect data.

- Three to four days for doing heat problems, graphing, and discussion of results.

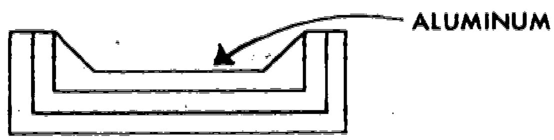
Suggested Approach

- The construction of the collector pictured in this unit was done in the following manner:

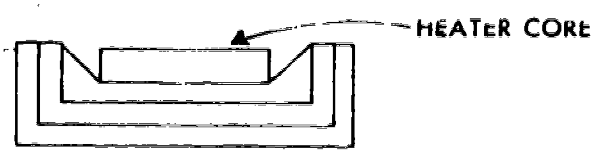
  a. Plywood was placed around a styrofoam container for stronger construction. The styrofoam was used as insulation.



  b. Aluminum was folded in a manner to serve as a reflector for concentration of the sun's energy.



  c. The heater core was placed on top of the aluminum to serve as the absorber.



  d. The entire inside was painted flat black except the [illegible] surface. (Cover with newspaper during painting)

  e. Double pane glazing was placed on top.

- Set up a schedule of your more advanced or more [illegible] in class to monitor the collection during the day.

- Measure equal amounts of water and add to the control storage and the collector storage before class.

15 minutes before the end of your first period [illegible] and the collector with all components outside to begin the operation

- Explain the operation to the entire class and allow the monitors to begin work.

- Your school day can proceed as usual with the last 10 or 15 minutes being set aside to take the class outside to view the collection and to gain information about its operation.

- The data collected by the monitoring students should be copied and distributed to all students for graphing and discussion.

- A possible follow-up to this activity could be a field trip to some agency using solar energy for heating, or bringing in resource persons to discuss solar energy as an alternative energy source.

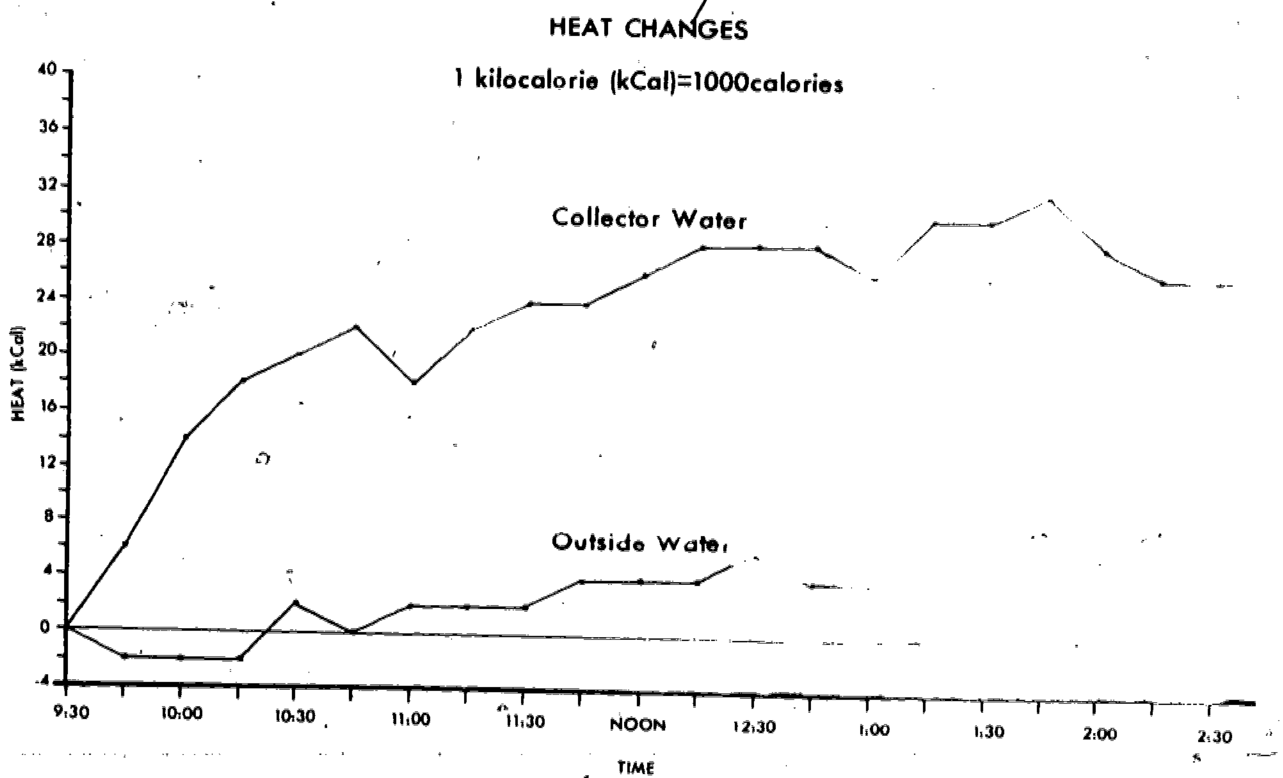
Typical Results

- Students should quickly realize that the temperature of the water and air inside the collector increases more rapidly than the water and air not in the collector.

- The collector air temperature should be higher than the water temperature.

- The outside air temperature may be higher than the outside water temperature.

- The data table and graphs shown below give actual student results for this activity.



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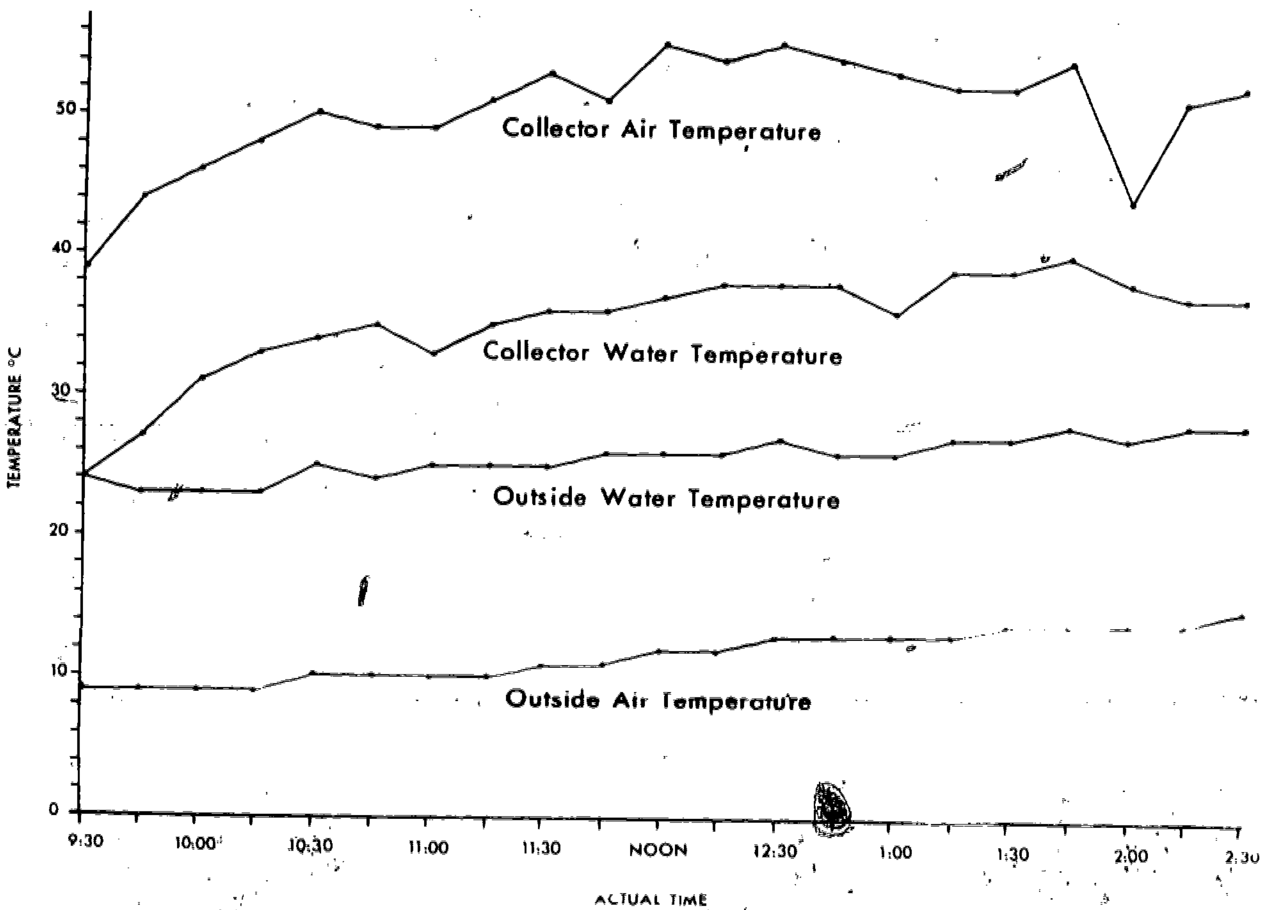
TEMPERATURE CHANGES



Precautions

- *Any time an electrical device is used outside a shock hazard may exist. Be sure proper grounding instructions are followed and avoid setting up the experiment in damp areas.*

- *If glass is used for glazing a safety hazard may exist.*

Modifications

- The collector can be made with traversed copper tubing under a copper or aluminum plate serving as the absorber, or any other variation which applies the same principle.

- Various materials can be used for glazing and insulation. Again, however, they must have the basic characteristics for the function they serve.

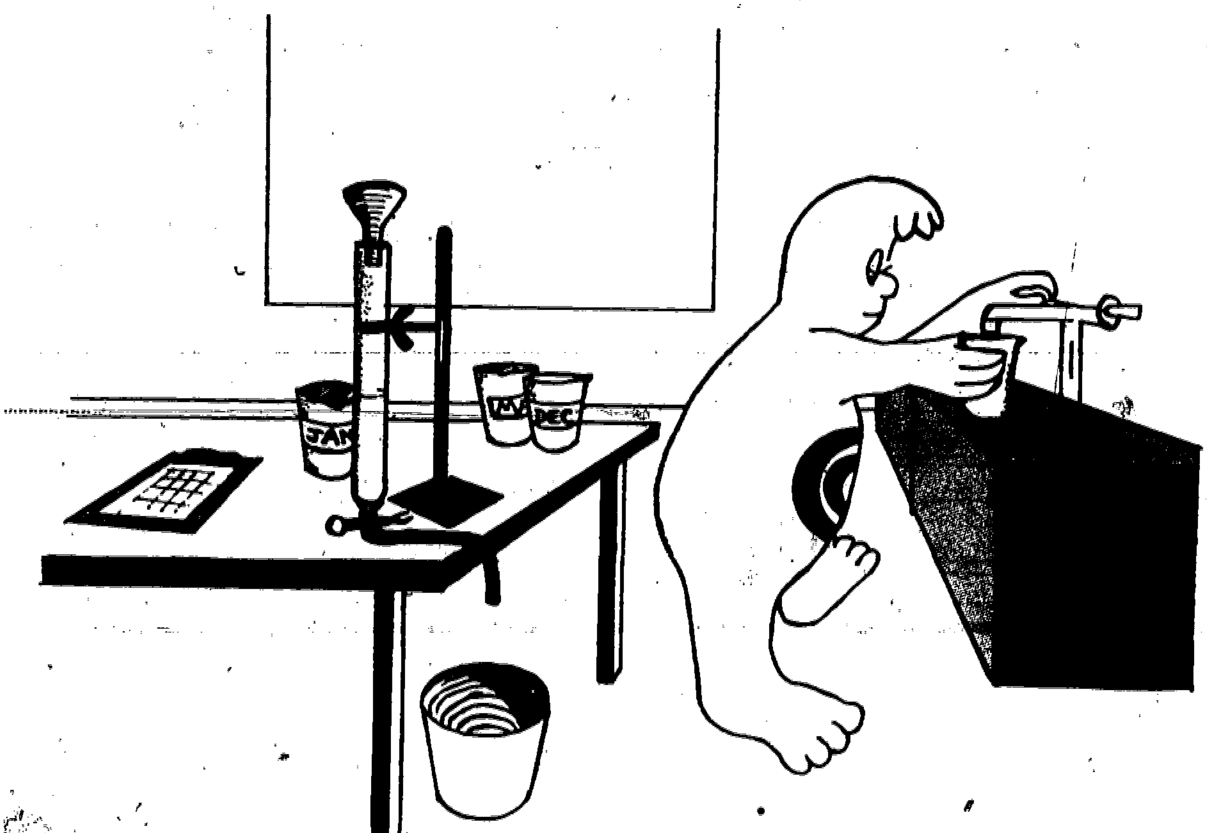
- It may be of interest to conduct the experiment on partly cloudy days as well as sunny days.

DATA TABLE

5 Minute intervals	Actual time	Outside air temp. °C	Collector air temp. °C	Outside H_2O temp. °C 700 ml. H_2O	Collector H_2O temp. °C 700 ml. H_2O	Calories added outside H_2O	Calories added collector H_2O
5	*9:30*	9	39	24	24		
10	9:35	9	41	23	25		
15	9:40	9	43	23	26		
20	*9:45*	9	44	23	27		
25	9:50	9	45	23	29		
30	9:55	9	47	23	30		
35	*10:00*	9	46	23	31		
40	10:05	9	46	23	31		
45	10:10	9	47	23	32		
50	*10:15*	9	48	23	33		
55	10:20	9	49	23	33		
60	10:25	9	50	24	34		
65	*10:30*	10	50	25	34		
70	10:35	10	50	23	35		
75	10:40	10	50	24	34		
80	*10:45*	10	49	24	35		
85	10:50	10	48	25	34		
90	10:55	10	48	25	35		
95	*11:00*	10	49	25	33		
100	11:05	10	49	25	34		
105	11:10		52	25	35		
110	*11:15*	10	51	25	35		
115	11:20	10	52	25	35		
120	11:25	10	52	25	35		
125	*11:30*	11	53	26	36		
130	11:35	11	51	26	36		
135	11:40	11	51	25	31		
140	*11:45*	11	51	26	36		
145	11:50	11	52	25	37		
150	11:55	11	53	26	37		
155	*12:00*	12	55	26	37		
160	12:05	12	56	26	38		
165	12:10	12	55	26	38		

170	12:15	12	54	26	38
175	12:20	12	53	23	38
180	12:25	12	54	27	39
185	12:30	13	55	27	38
190	12:35	13	55	27	38
195	12:40	13	54	26	38
200	12:45	13	54	26	38
205	12:50	13	53	27	36
210	12:55	13	53	27	36
215	1:00	13	53	26	36
220	1:05	13	53	28	36
225	1:10	13	52	27	39
230	1:15	13	52	27	39
235	1:20	13	52	28	40
240	1:25	13	52	27	39
245	1:30	14	50	27	39
250	1:35	14	53	27	39
255	1:40	14	53	28	39
260	1:45	14	54	28	40
265	1:50	14	54	27	40
270	1:55	14	51	27	39
275	2:00	14	44	27	38
280	2:05	14	46	[illegible]	37
285	2:10	14	49	28	37
290	2:15	14	51	[illegible]	37
295	2:20	14	51	[illegible]	37
300	2:25	14	52	28	37
305	2:30	15	52	28	37
310	2:35	15	52	28	38
315	2:40	15	52	28	37
320	2:45	15	51	29	37
325	2:50				
330	3:00				

THE EARTH'S ENERGY BUDGET



INTRODUCTION

The amount of insolation in a particular area has a direct effect on the temperature of the earth in that same area. In this investigation, you will set up a model of the pattern of insolation for the northern mid-latitudes over a period of time. From this model, a relationship may be inferred concerning insolation patterns and temperature

OBJECTIVES

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

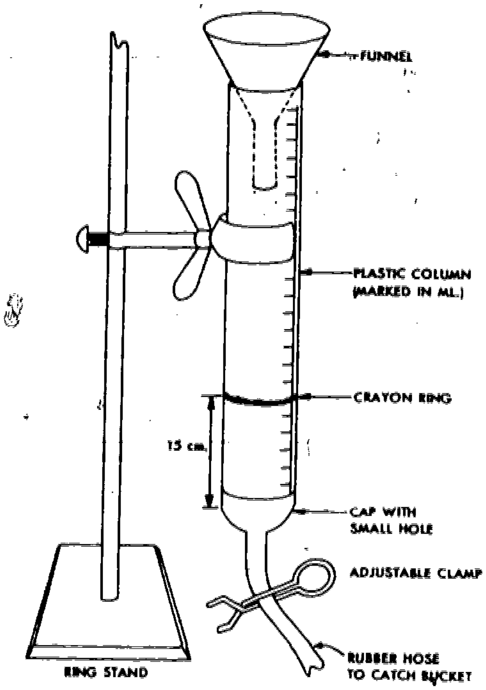
- o describe similarities and differences between the earth and the model.
- o construct a graph showing the maximum insolation per month.
- o construct a graph showing the maximum temperature per month.
- o show the relationship between the two graphs.
- o identify patterns of annual maximum and minimum temperatures.
- o relate maximum and minimum temperatures to maximum and minimum duration of insolation.

SKILLS AND KNOWLEDGE YOU NEED

- Be able to read a metric ruler or meter stick.
- Be able to measure volumes in moles.
- Be able to time.

MATERIALS

- Plastic column kits
- Ring stand and clamp(s)
- Catch basins.
- 12-1000 ml. beakers [illegible]
- Crayon.
- Funnel.
- Time piece with second sweep
- Rubber hose.
- Adjustable clamp
- Graduated cylinde.
- Water.



METHOD

1. Read through entire directions first before you start the activity.

2. Set up the plastic column, ring stand, catch bucket as shown in the diagram above.

3. Measure up 15cm from the bottom of the column and mark a ring around the tube at this level with a crayon.

4. Adjust the clamp on the rubber hose so that the rate of flow is about 600ml/min. or so the level of the water falls from the top of the column to the ring in 50 to 60 seconds.

5. Into each of 12 beakers (labeled 1-12) place an amount of water proportional to the amount of insolation for that month. A possible scheme appears below.

6. Pinch the hose and fill the plastic column to the level of the ring. As you release the hose, add the water from bea[illegible] and begin timing the experiment.

MONTH	BEAKER NO.	(APPROX. HRS.) DURATION OF INSOLATION	AMOUNT OF WATER (ML)
JANUARY 22	1	9 1/2	475
FEBRUARY 23	2	10 1/2	525
MARCH 23	3	12	600
APRIL 23	4	13	650
MAY 23	5	14 1/2	725
JUNE 23	6	15	750
JULY 23	7	14 1/2	725
AUGUST 22	8	13	650
SEPTEMBER 22	9	12	600
OCTOBER 22	10	10 1/2	525
NOVEMBER 22	11	9 1/2	475
DECEMBER 22	12	8 1/2	425

NOTE: THE ABOVE VALUES FOR THE VOLUME OF WATER WERE OBTAINED BY MULTIPLYING BY 50 THE APPROXIMATE NUMBER OF HOURS OF DAYLIGHT AT 42°N LATITUDE FOR THE GIVEN DATES.

7. Using the crayon, quickly mark off the maximum level the water reaches in the plastic column and indicate the beaker number.

8. At the end of one minute, add the water from beaker 2, again marking off maximum water level and beaker number.

9. Proceed as above for all beakers, adding a new beaker every minute.

10. Measure (in ml) the volumes of the maximum water levels in plastic column for each beaker and record on data table.

11. On the same graph, graph the maximum water level vs the month and the volume of water in the beaker vs. the month.

LOOKING BACK

In this model the amount of water in each beaker rep... the amount of insolation present for the month. The maximum height of water in the column is representative of the maximum temperature for the month. From this activity you should be able to see a relationship between the amount of insolation and the maximum temperature for a particular area.

DATA TABLE

BEAKER NUMBER	MONTH REPRESENTED	VOLUME OF WATER IN THE BEAKER (ML.)	MAXIMUM LEVEL OF WATER IN COLUMN (ML.)
1	JANUARY	475	
2	FEBRUARY	525	
3	MARCH	600	
4	APRIL	650	
5	MAY	725	
6	JUNE	750	
7	JULY	725	
8	AUGUST	650	
9	SEPTEMBER	600	
10	OCTOBER	525	
11	NOVEMBER	475	
12	DECEMBER	425	

QUESTIONS

1. What effect does an increase in the duration of insolation have upon the temperature?

2. At what time of the year is the duration of insolation at a maximum; at a minimum?

3. How does the time of maximum surface temperature compare with the time of maximum duration of insolation for the model?

4. How is the duration of insolation related to the various seasons?

5. What does the one minute waiting period represent for your model?

6. For your model, what does the water flowing out of the bottom of the tube represent?

7. Describe the ways in which the model is analogous to the earth and the ways in which it is not.

GOING FURTHER

- How would the duration of insolation during the year be affected by an increase in latitude?

- The teacher may wish the students to run the sequence through several years.

EARTH'S ENERGY BUDGET

Suggested Grade Level and Discipline

Earth Science
Physics

Background Information

Insolation is the amount of energy received from the sun at a given place in a given time. This energy is transferred into heat energy which we see as temperature changes as the amount of insolation changes. Where you live and the time of year it is, will determine the temperatures for the northern middle latitudes. Insolation is at its maximum in June and minimum in December. The maximum temperatures however, are reached sometime after the maximum insolation. The minimum temperatures are reached sometime after minimum insolation.

Hints on Gathering Materials

- Materials should be available in most earth science classrooms.

Suggested Time Allotment

- One period to do activity and record data.
- One period to make graphs and discuss results.

Suggested Approach

- Have basic [illegible]
- Divide students into small groups (one to mark, [illegible] etc.).
- Explain to students that the amount of water in each beaker [illegible] used to represent the amount of insolation for that month.
- Explain to students that the maximum height of water in the [illegible] representative of the maximum temperature for that month.

Typical Results

- Students should easily [illegible] a minimum in December.
- Students should easily see that maximum [illegible] time after maximum insolation and that minimum temperature [illegible] sometime after minimum insolation.

Precautions

- *Be sure to check all equipment to make sure it is functioning properly.*
- *Be sure to check the rate of flow.*

Modifications

- It may be difficult to adjust the rate of flow to 600ml/min. Another method is to time the water level from full to the ring (15cm above the bottom.) When the flow is adjusted correctly, the level takes about 50-60 seconds to fall from the top to the ring.
- The teacher may wish to experiment and develop his own time table and rate of flow.
- Minimum levels of the column may also be taken so as to give a temperature range throughout the year.

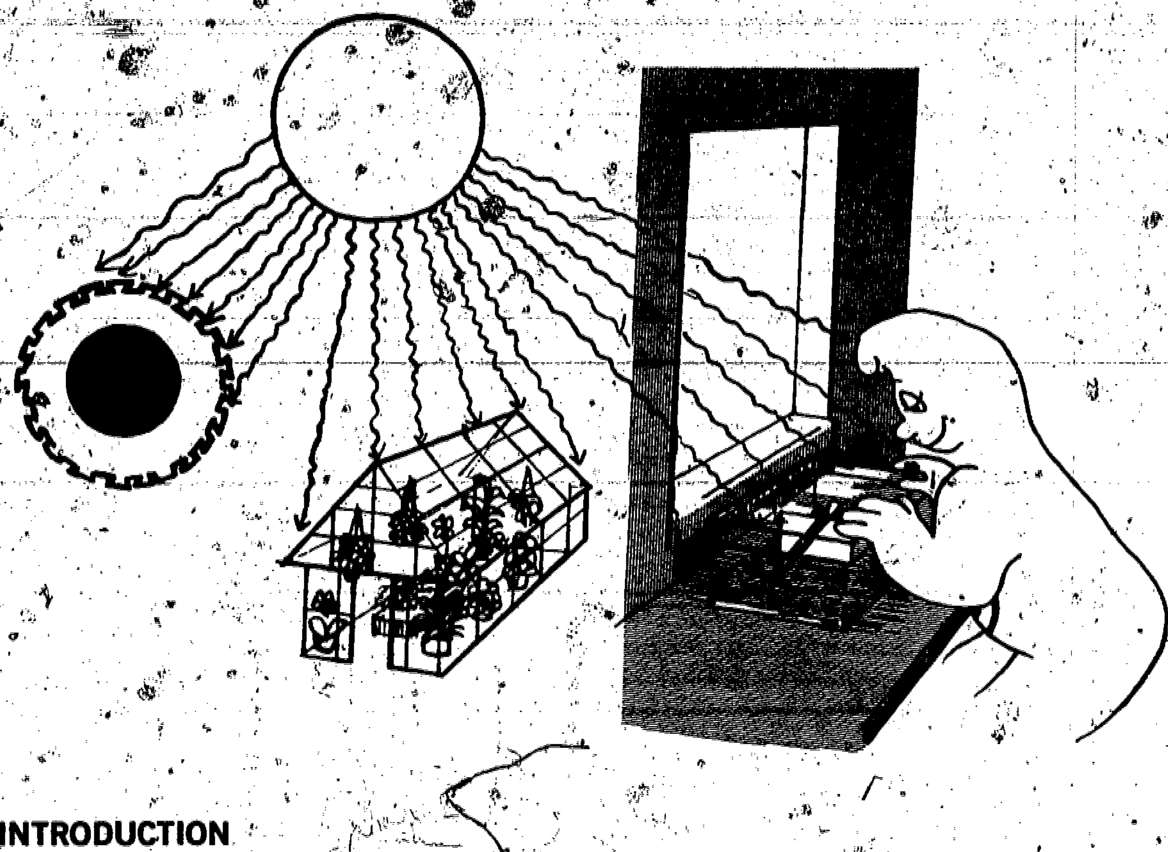
Evaluation

- Check students' data sheets.
- Check students' answers to questions.
- Check students' graphs.

References

- *Investigating the Earth*, (Earth Science Curriculum Project, Houghton Mifflin, Boston), 1968, PP. 158-161.

THE GREENHOUSE EFFECT



INTRODUCTION

Large amounts of sunlight pass through the atmosphere and hit the earth's surface every day. This light is absorbed by the earth's surface and turned into heat waves which have longer wavelengths. These heat waves are called infrared rays. The longer wavelength infrared rays cannot easily pass back through the atmosphere into space because certain substances like carbon dioxide and water in the atmosphere absorb them. When this heat energy is prevented from escaping back into space, the "greenhouse effect" occurs.

In this activity you will be investigating the "greenhouse effect".

OBJECTIVES

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

- o construct a simple apparatus to show the greenhouse effect.
- o make some comparisons between your apparatus and the earth.
- o collect data from thermometer readings and record them in a table.
- o represent your results in the form of a line graph.

SKILLS AND KNOWLEDGE YOU NEED

- How to read a thermometer.
- How to graph data using a simple line graph.
- Know what is meant by wavelengths as used in the INTRODUCTION.

MATERIALS

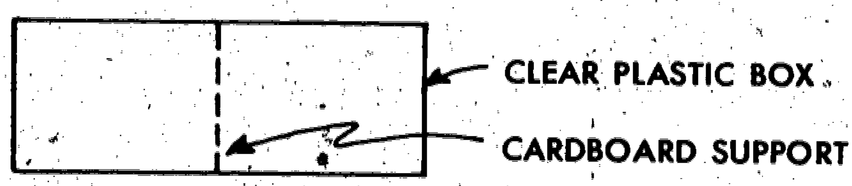
- 1 standard laboratory thermometer (-10°C to 110°C).
- 1 clear plastic shoe box with cover.
- Outdoor reflector flood lamp, and mounting stand.
- Soil and water.
- Cardboard support on which to lean the thermometer.

METHOD

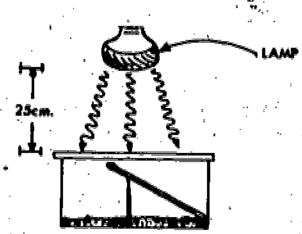
1. Place about 2cm of soil in the bottom of the clear plastic box. Thoroughly moisten the soil with water.

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



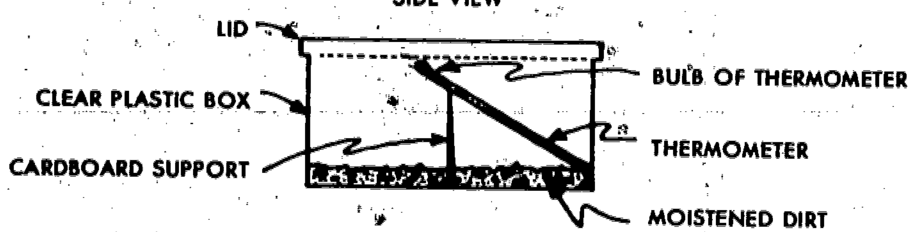
3. Lean the thermometer against the cardboard support with the bulb end up.



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.

LOOKING BACK

It is possible to trap incoming light and change it to heat. The trapping of this heat energy under a covering is referred to as the "greenhouse effect". On earth the greenhouse effect is created between the atmosphere which may act as a blanket to keep the heat in, and the earth's surface. Consider in this activity that the box with no lid on it represents the earth with no atmosphere.

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?

GOING FURTHER

- How could air pollutants disturb the greenhouse effect?
- Describe an experiment that you could do to see how different coverings would affect the temperature change.
- Could the greenhouse effect ever be harmful?
- 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?
- In what ways is this activity different from the greenhouse effect on the earth?

DATA SHEET

TIME (MINUTES)	COVERED TEMPERATURE °C	UNCOVERED TEMPERATURE °C

288-999 O - 79 - 5

THE GREENHOUSE EFFECT

Suggested Grade Level and Discipline

Middle School Science
Earth Science
Grade 9 - General Science

Background Information

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 $-19^{\circ}C$ at the top of the atmosphere to $15^{\circ}C$ 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 wavelenghts, 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.

Hints on Gathering Materials

- The clear plastic shoe boxes with lids work well. A small fish tank with a glass cover would also work well.
- An outdoor reflector lamp put in a socket and then attached to a ring stand should work well. A lamp that throws a lot of heat is necessary for good results.

Suggested Time Allotment

- One class period to explain the experiment, discuss the electromagnetic spectrum, and set up the experiment.
- One to two class periods to complete the activity.
- One class period to discuss the results.
- A class period is about 45 minutes.

Suggested Approach

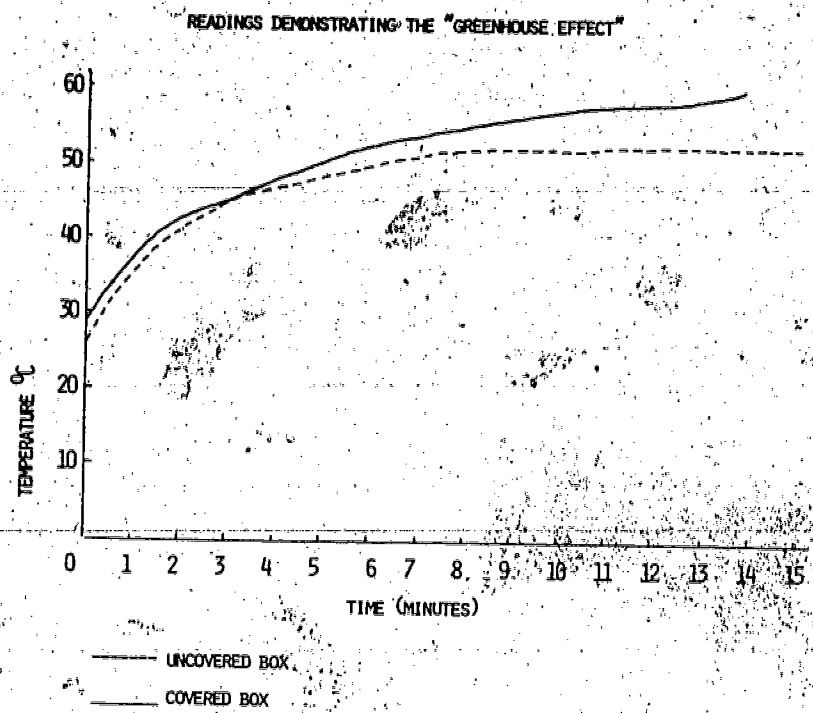
- Pass out the lab sheets a day in advance so that students will be familiar with their responsibilities in the activity. Discuss the electromagnetic spectrum, and allow students to set up their equipment.
- Divide the class into groups of 2 or 3. (This is provided you have enough materials). Students can take turns timing, reading, and recording.

Typical Results

- The thermometer reading in the covered box should have been higher.

DATA SHEET

TIME (MINUTES)	COVERED TEMPERATURE °C	UNCOVERED TEMPERATURE °C
0	28	26
1	38	36
2	42	41
3	46	45
4	48	48
5	52	49
6	54	50
7	55	51
8	56.5	51
9	57	52
10	58	52
11	59	52
12	59.5	52
13	59.5	52
14	61	52
15	62	52



Precautions

- *Remind students not to touch the heat source.*

Modifications

- 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.

Evaluation

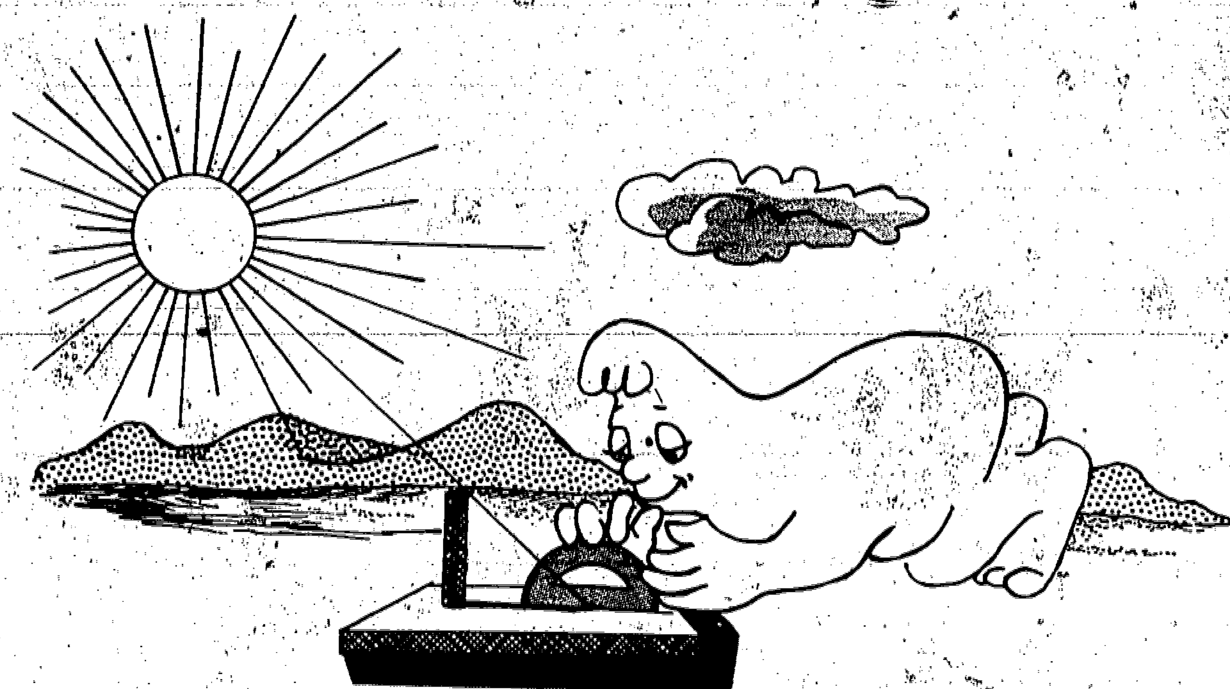
- Check the students data table and graphs to determine how well they can read a thermometer and how well they can represent it on a graph.

- Check the answers to the questions.

References

- *Solar Energy*, William W. Eaton, (Washington: Department of Energy), 1976. pp. 48.

THE SUN'S POSITION IN THE SKY



INTRODUCTION

The sun's position in the sky changes. Where is the sun found in the early morning? At noon? In the afternoon? Does the position change with the seasons as well as the time of day?

This activity will give you a chance to measure the sun's position and obtain data which is useful in solar energy design. If we are going to use solar energy to heat our homes, then we need to know something about the sun's position throughout the whole year.

You will construct a very simple device that will help you measure the angle that the sun's rays make with the ground. You will compare your data with data other members of the class have collected at different times during the year. You will also compare your data with published solar position data.

OBJECTIVES

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

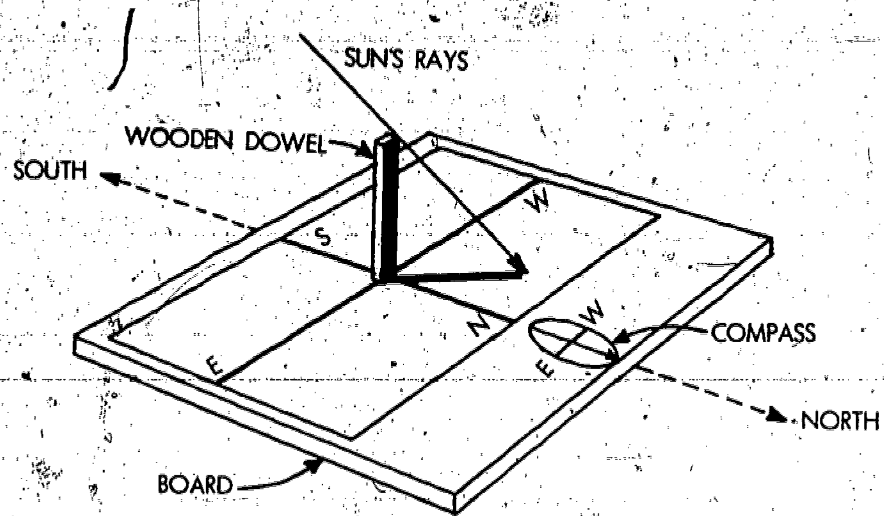
- o measure the angle that the sun's rays make with the ground at any time of day.
- o use published solar position tables to find the sun's altitude and azimuth at any given time and location.

SKILLS AND KNOWLEDGE YOU NEED

- How to measure angles with a protractor.
- How to level a board using a bubble level.
- How to read and use a magnetic compass.
- How to graph data.

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°) 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.

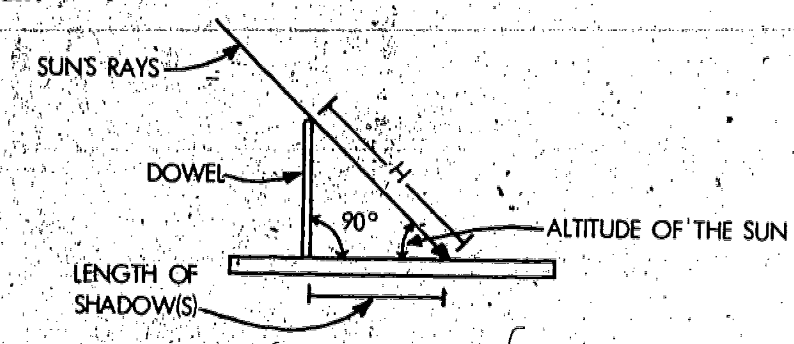
4. Set the board in a horizontal position where it will receive the direct rays of the sun most of the day. Align the board with the compass as shown in Figure 1. Use the bubble level to check that the board is level. Level it if needed. (Note: Your instructor may suggest aligning the board in a different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

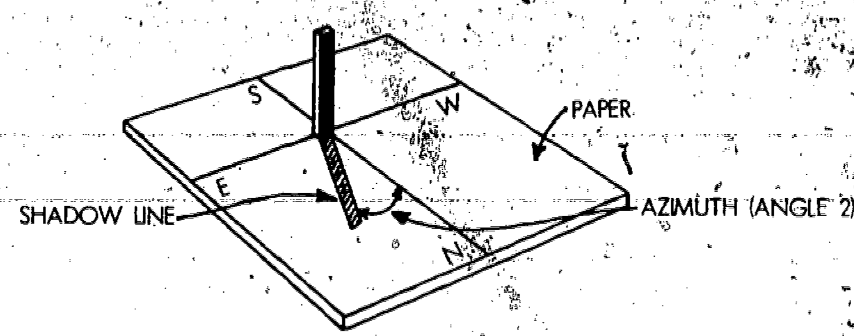
7. For each position of the shadow you will want to measure two angles:

   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 sketch below. 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 on the previous page 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?

LOOKING BACK

The position of the sun in the sky is important in solar energy design. This can be determined with simple equipment. Tables can be prepared so that the position can be predicted for any time or place.

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?

GOING FURTHER

- If you wanted to collect the most energy from the [illegible], how would you position a solar collector? Would its position be the same in winter as summer?
- Since most solar collectors are fixed ([illegible]), 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?
- 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?
- What effect does the design of roof [illegible] have on the energy received by the windows in your home?
- In landscaping your home, how might trees be used [illegible] to help keep your house cooler in summer but warmer in winter. What kind of trees would you use in what position?
- Using data on solar position, make a sample [illegible] 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 sun light energy received.
- You might want to experiment with cardboard models of [illegible] 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.

Teacher Information Sheet

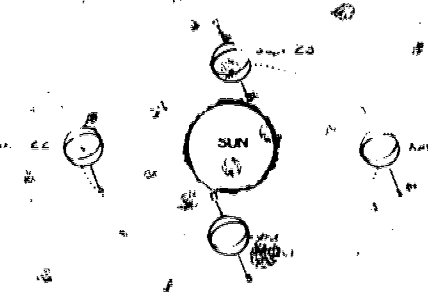
THE SUN'S POSITION IN THE SKY

Suggested Grade Level and Discipline

7-9 Science
Earth Science

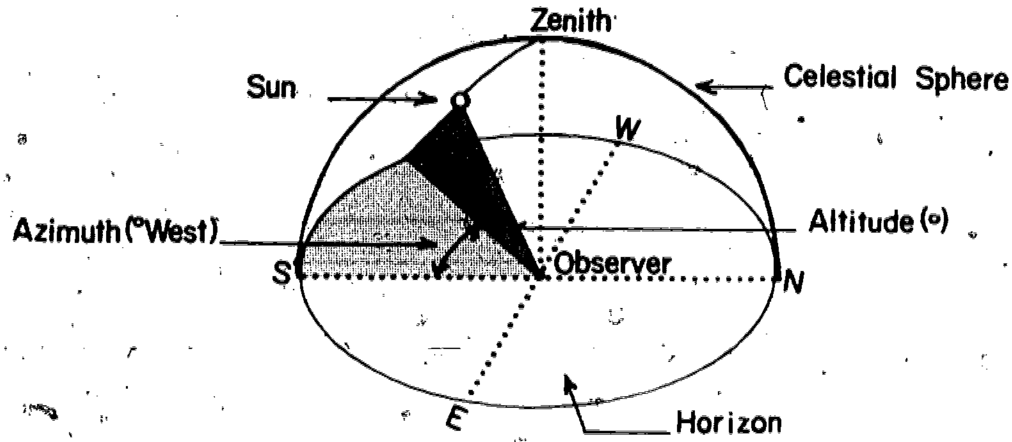
Background Information

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 23½° 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).



S[illegible] [illegible] [illegible] [illegible] are used [illegible] bodies. One, which is quite similar to the equatorial sy[illegible] [illegible] on earth, makes use of the "celestial sphere" with star positions measured [illegible] "right ascension" and declination. Generally, however, the more straight[illegible] 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 [illegible] the angle b[illegible] observer's line of sight to the sun and the horizon (the horizontal plane of the obs[illegible]. The azimuth measurement used by solar energy workers is slightly different than that [illegible] 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 ($360° \div 24$). This means that 1° of longitude corresponds to a time difference of 4 minutes.
>
> $15° = 1$ hr. $= 60$ minutes therefore, $1° = \frac{60}{15}$ 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 9:40 sun time at your locality. The sun will not be on your meridan 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.

Hints on Gathering Materials

- All materials necessary are likely to be readily available.
- Peg board stands are common in many classrooms with holes . 3/8" dowels. (size not critical) Have extra dowels on hand
- Solar insolation data are available from your nearest United [illegible] Weather Bureau Office.

Suggested Time Allotment

Two days.

a. Day [illegible]
b. Day Two: [illegible]

[illegible]

[illegible]

Work [illegible]

[illegible] data on a semi monthly basis [illegible] of the project

A permanent [illegible] this additional data [illegible] orientation of the data [illegible] time and true N S orientation

[illegible]

Ang[illegible] degrees [illegible] the board initially as well [illegible]

The students will be [illegible]

- The symmetry of morning and afternoon readings will become apparent.
- Student data will agree closely enough with published data to make this meaningful to the students.

Precautions

- *AT NO TIME SHOULD THE STUDENTS LOOK DIRECTLY AT THE SUN. This could cause serious injury to their eyes.*

Modifications

- Some students may wish to examine sundial theory and construction as an offshoot of this work.
- If this activity were carried out with students possessing a knowledge of trigonometry, then the solutions of angles using trigonometric functions instead of measurement by protractor would be appropriate.

Evaluation

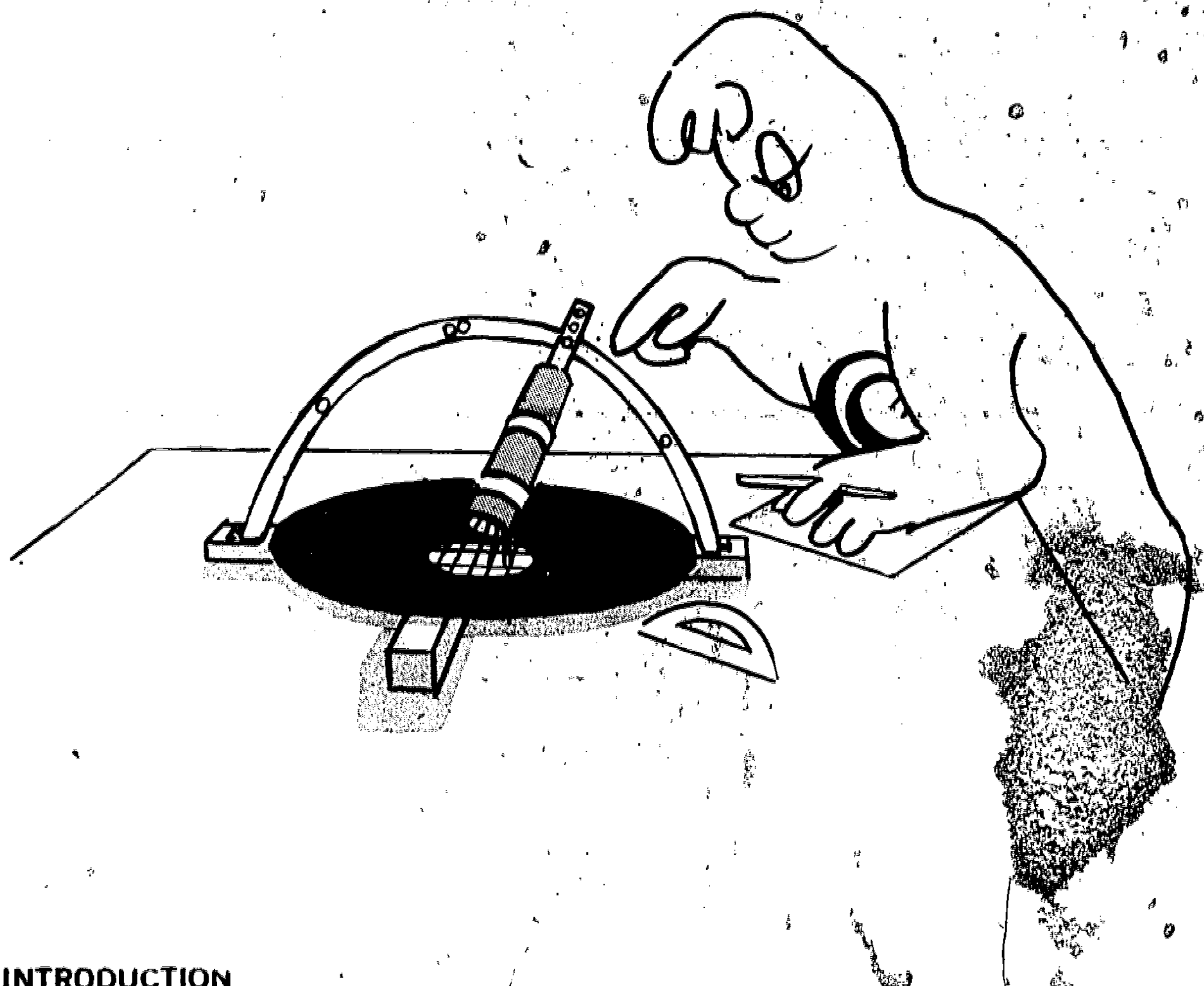
- Can the student set up the apparatus and obtain reasonable [illegible]
- Is this data organized in such a way that it can be used by the [illegible] the classes?
- Can the students interpret and use published [illegible]

References

Principles of Astronomy [illegible]

Solar Energy Experiments. Thomas Norton [illegible] pp. 129.

VARIATION OF THE SUN'S INTENSITY



INTRODUCTION

The chief source of heat on the earth [illegible] the sun. As far as we know the sun emits energy at a nearly constant rate. The quantity [illegible] energy that strikes the earth is known as the solar constant. The intensity of solar radiation falling on any portion of the earth's surface, however, is not constant. In this activity you will be investigating the relationship of the sun's intensity to its position in the sky.

OBJECTIVES

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

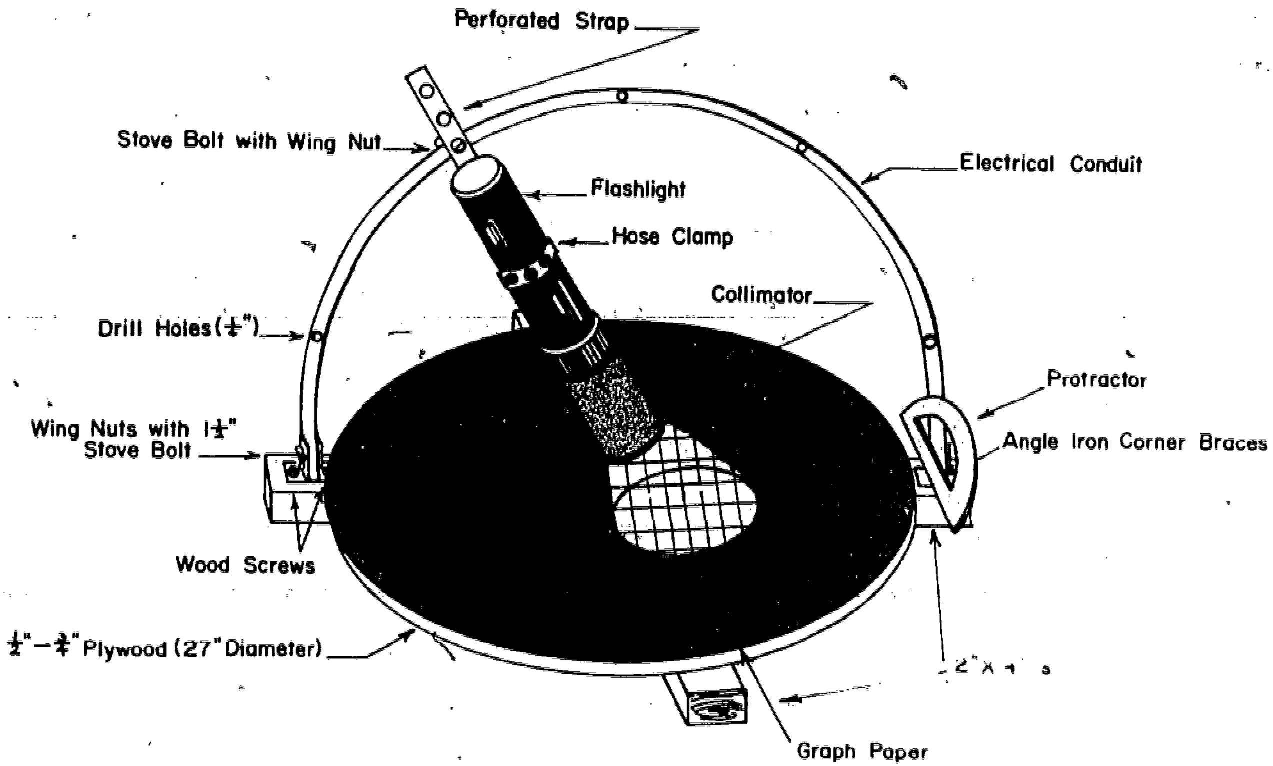
- o use the model apparatus to determine light intensity at various positions
- o compare the workings of the apparatus to the way the radiation from the sun actually strikes the earth.
- o determine at what position the intensity is maximum, and at what position it is minimum.

SKILLS AND KNOWLEDGE YOU NEED

- How to collect, record and graph data.
- How to compute mathematical values using a simple proportion.

MATERIALS

- A circular piece of 1/2 to 3/4 inch ply... ... cut ... 2... diameter.
- A light source (flashlight etc.)
- A protractor
- A five-foot length of 1/2 inch ... ...all electrical conduit Must be shaped int a semi-c... l
- Two 3-foot pieces of two by-... ...
- Four wood screws
- Three 1/4-inch round head ... ... nuts
- One plastic column tube clamp
- One six-inch piece of perfora... ... ...an purchased at a plumbing supply h use)
- Graph paper
- Piece of cardboard for ...



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 above.

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.

LOOKING BACK

The altitude and the seasonal path of the sun are two important factors that determine the amount of insolation striking the earth at a given point. Other factors such as number of cloudy days, duration of insolation, and atmospheric pollution also affect the total amount of insolation received by the earth at a given point.

QUESTIONS

1. At what light setting was the intensity the greatest? Wh[illegible]
2. At what light setting were the greatest number of squares covered? Why?
3. At what bar elevation were the greatest total number of s[illegible] 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 real world?

GOING FURTHER

- Would changing the diameter [illegible] light [illegible] the intensity striking a given point? Try it.
- If the beam of light were closer to the board would that [illegible] any effect on intensity? Try using collimators of different lengths.

DATA TABLE

PROTRACTOR READING ______ o

BAR SETTING	# OF SQUARES	INTENSITY
1		
2		
3		
4		
5		

PROTRACTOR READING ______ o

BAR SETTING	# OF SQUARES	INTENSITY
1		
2		
3		
4		
5		

PROTRACTOR READING

BAR SETTING	# OF SQUARES	INTENSITY
1		
2		
3		
4		
5		

Teacher Information Sheet

VARIATION OF THE SUN'S INTENSITY

Suggested Grade Level and Discipline

7-9 Science
Earth Science
Solar Science

Background Information

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.

Hints on Gathering Materials

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

  Build several models.

Suggested Time Allotment

- Two to four class periods [illegible]

Suggested Approach

- Have several models built in advance. See the diagram for model specifications.
- Divide the class into several groups. Have each group experiment with different bar elevations to simulate intensity at different latitudes.
- 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.

Typical Results

- Once the data has been collected, recorded, and graphed, the following relationships should be in evidence:

    1. As the altitude of the light increases the area covered by the light decreases.
    2. As the area covered increases the intensity decreases.
    3. As latitude increases intensity decreases.

Precautions

[illegible] the light [illegible] light [illegible] the same spot on the board.

Modifications

[illegible] an excellent [illegible] atmospheric conditions are not conducive t[illegible] this [illegible] will serve the same purpose.

The circular board can be moved to [illegible] the [illegible] seasons.

Evaluation

[illegible]llect [illegible]

- Check a student's responses to questions
- Determine the ability of the students to [illegible] real world.

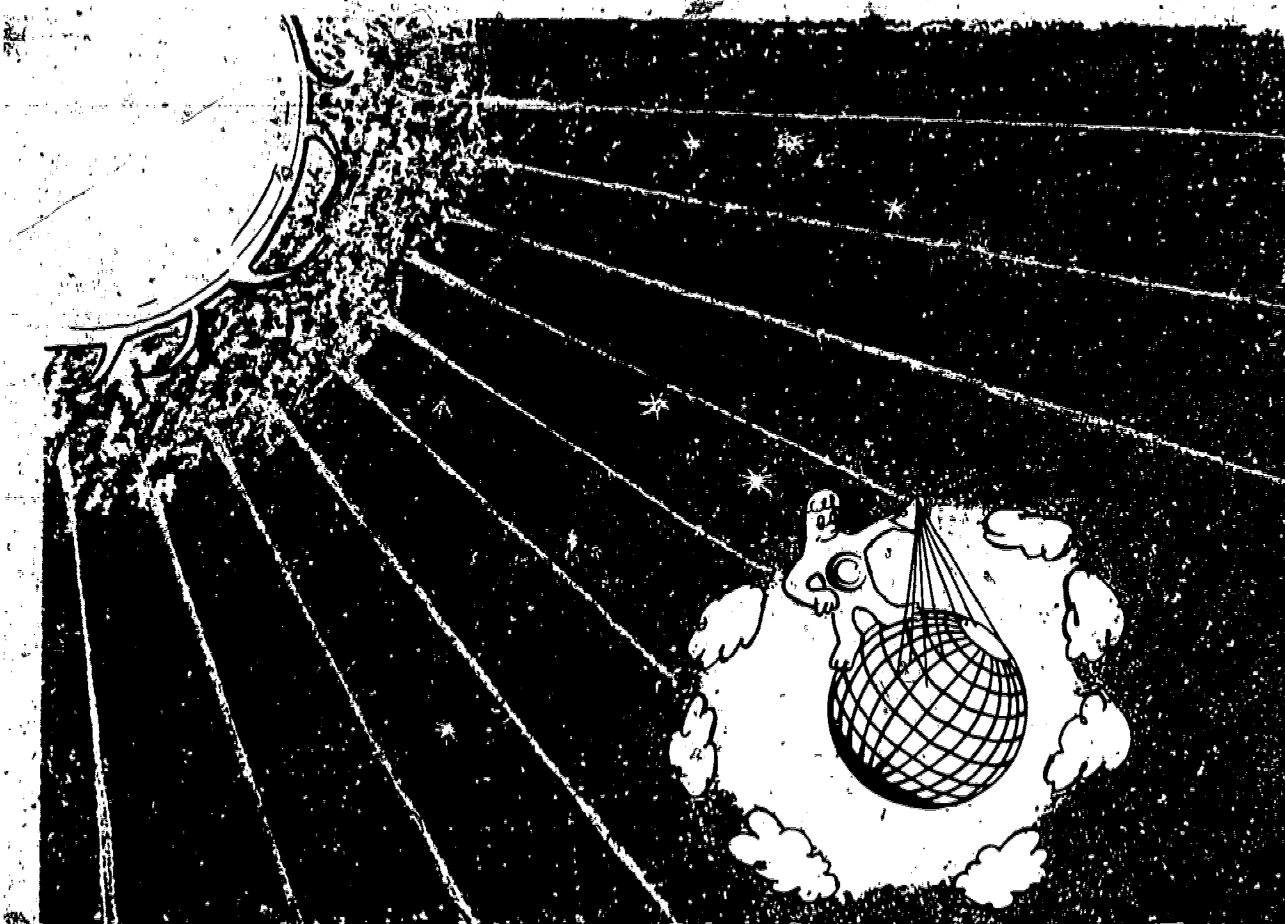
References

- *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.

DRAFT - ACTIVITY 25

WHAT IS SOLAR ENERGY?



INTRODUCTION

The growth of green plants, the heating of the atmosphere and, indeed, life on earth would not be possible without energy from the sun. Today we hear more and more about harnessing solar energy so it can be used directly by man to produce electricity, to run machines and to heat and cool our buildings. It is becoming more and more important to understand solar energy.

In this activity you will learn about some of the characteristics of radiant energy.

OBJECTIVES

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

- o list the types of radiant energy in the electromagnetic spectrum from shortest wavelengths to the longest.
- o explain how radiant energy in the electromagnetic spectrum is used by man or how it affects man.
- o list the types of solar radiant energy that reach the surface of the earth.
- o construct a graph that shows the distribution of incoming solar radiation.

SKILLS AND KNOWLEDGE YOU NEED

- How to use science reference books to locate information on solar energy topics.
- How to use a prism, spectroscope, radiometer and laboratory thermometer.
- How to construct and interpret a line graph.

MATERIALS

- Resource books on solar energy.
- 1 thermometer with the bulb painted black.
- 1 prism.
- 1 spectroscope.
- 1 light socket with a 300 watt standard incandescent bulb and a 300 watt infrared bulb.
- 1 fluorescent light source.
- 1 jar of water (each group must have a jar the same size.)

METHOD

1. Direct sunlight through a prism onto a sheet of paper. Draw a labeled diagram to describe what you observe.

2. Use reference books to read about the visible spectrum. Next to your first diagram make another labeled diagram to show the visible spectrum shown in your reference book.

3. Point your spectroscope to the side of the sun and draw a labeled diagram of what you observe. NEVER LOOK DIRECTLY AT THE SUN EVEN THROUGH A SPECTROSCOPE. Point your spectroscope toward a fluorescent light and draw a labeled diagram of what you observe.

4. a. Place a black bulb thermometer on the lab counter and hold a 300 watt incandescent lamp .5m directly above the black bulb for 5 minutes. Record the temperature.

   b. Allow the thermometer to return to room temperature and then repeat the same procedure using a 300 watt infrared bulb. Record the temperature at the end of 5 minutes.

5. Use reference books to locate a graph showing the intensity and type of solar radiation that reaches the earth and record the information in your notebook. Place a copy of the graph in your notebook.

LOOKING BACK

The story of solar energy begins when the nuclei of 4 hydrogen atoms join to form a helium atom within the core of the sun. The enormous amount of energy released by the nuclear fusion reaction heats elements on the surface of the sun. These elements give off the different forms of radiant energy found in the electromagnetic spectrum.

Some of the harmful solar radiation is absorbed by the earths atmosphere before reaching the earth's surface. Ultraviolet, visible light and infrared radiation eventually reach the earth's surface.

The next chapter in the solar energy story concerns itself with what happens to the solar energy once it reaches the earth.

QUESTIONS

1. What evidence have you seen that suggests sunlight contains different types of radiant energy?

2. Describe ways in which your two diagrams are alike. Should they be about the same?

3. Compare the color pattern of sunlight and the fluorescent light. How are they different? Do all light sources give off the same type of radiant energy?

4. Which thermometer recorded the highest temperature?

5. Refer to your graph - The distribution of the sun's energy reaching the earth is about 5% in the ______________ region, 40% in the __________________ region and 55% in the __________ region.

GOING FURTHER

- Read further to find out how the sun produces its energy.

- Research is being conducted to use here on earth the same energy producing process, fusion, that takes place on the sun. What are the latest developments in fusion research?

WHAT IS SOLAR ENERGY?

Suggested Grade Level and Discipline

7-9 Science
Earth Science
Physical Science

Background Information

Some background information about how radiant energy is produced on the sun is appropriate.

The sun is made up of a very large amount of different gases. Helium makes up 25 percent of the sun's mass; hydrogen gas makes up 74 percent; one percent is made up of small amounts of all the other known chemical elements. The weight of all the matter in the sun creates a great pressure within the sun's core. This pressure is nearly on billion times the air pressure at the earth's surface.

Such high pressure and temperatures cause four hydrogen nuclei to join and form a helium nucleus. This process of small nuclei joining to form a single larger helium nucleus is called fusion. It is this process of hydrogen fusion that starts the formation of solar energy.

The helium that is produced has a little less mass than the four hydrogen nuclei had together. The small amount of the missing hydrogen mass seems to be changed into a large amount of energy.

This change of mass to energy takes place deep inside the sun. The energy produced inside the sun makes its way to the surface. At the surface, gases absorb the energy and become hot and give off radiant energy. Radiant energy travels away from the sun at a speed of 186,000 miles per second. This means that radiant energy travels from the sun to the earth in about 8 minutes.

The sun sends out radiant energy of all kinds. Most of the energy leaving the sun is in the form of visible light and infrared rays. Together they account for more than 90 percent of the energy produced by the sun. Most of the remaining 10 percent is accounted for by ultraviolet rays, x-rays, and gamma rays. Not all of the sun's radiant energy reaches the earth's surface. The earth's atmosphere absorbs harmful x-rays, gamma rays and most of the ultraviolet rays. The solar energy that does reach the surface of the earth is visible light for the most part. A small amount is in the form of infrared and ultraviolet rays.

Hints on Gathering Materials

A wall chart of the electromagnetic spectr[illegible] be ordered free of charge from General Electric Lamp Divisi[illegible]a Park, Cleveland, Ohio.

Suggested Time Allotment

- One period to complete METHOD step 1 and 2.
- One period to complete METHOD step 3 and 4.
- One period to complete METHOD step 5.

Suggested Approach

- Relevancy Lecture - Describe ways in which a knowledge of solar energy is important to students' way of life.

  a. Overexposure - skin cancer, sunburn
  b. Energy source for natural systems - weather, plant life, etc.
  c. Limiting factor for human activity - available energy which can be harnessed by man has implications for energy conservation, change of life style or new ways for harnessing solar energy.

- Students name each type of energy in the electromagnetic spectrum and its use by or effect on man. (cosmic rays, x-rays, ultraviolet rays, visible light, infrared, and radio waves).

- After METHOD step 5, use an overhead transparency with a graph showing the distribution of incoming radiation from the sun.

- Have students plan an experiment to win a hot water contest. Each lab group will be provided with a thermometer, a 300 watt incandescent bulb and a jar of water. The object will be to see which group can raise the water temperature the most using only the bulb as a source of energy. They may do research and bring in other material. Have students keep a written record of their plan. On a sunny day, the sun's energy may be substituted for the electric light bulb.

Typical Results

- With good technique the activities should illustrate the concepts. Monitor results to identify errors.

Precautions

- *Warn students about electrical hazards and heat from lamps.*
- *Do not look directly at the sun with the spectroscope.*

Modifications

- If resource textbooks are not available, lecture or filmstrip presentations could be used.
- Lab activities could be performed as teacher demonstrations.

Evaluation

- Observe and grade students' working techniques, and ability to follow instructions and work with other classmates.
- Collect and grade answers to questions.
- Administer a test based on the performance objectives.

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