topic VI

What Happens To Solar Energy That Reaches The Earth?

Time Emphasis: 5 days

		A-1a	A-1b	A-1c	A-1d	B-1a	LTI -#14
INVESTIGATION		A-1a	A-1b	A-1c	A-1d	B-1a	LTI -#14
Estimated Time (Periods)		2	0½	1½	2	1½	LTI
TOPIC OUTLINE							
A. Insolation at the earth's surface							
A-1 Insolation factors	*What Are Some Factors Which Affect Insolation?*						
A-1.1 Angle	A-1.11	■	■				
	A-1.12	■					
	A-1.13	■					
A-1.2 Duration	A-1.21			■			■
	A-1.22			■			
	A-1.23			■			
	A-1.24			■			■
A-1.3 Absorption	A-1.31					■	
	A-1.32				■		
A-1.4 Reflection	A-1.41					■	
	A-1.42						
	A-1.43						
A-1.5 Scattering	A-1.51						
	A-1.52						
A-1.6 Energy conversion	A-1.61						
B. Terrestrial radiation							
B-1 Radiation factors	*What Are Some Factors Which Affect Terrestrial Radiation?*						
B-1.1 Material radiation	B-1.11					■	
B-1.2 Gases	B-1.21					■	
B-1.3 Balance	B-1.31						
	B-1.32						
	B-1.33						
PROCESS OF INQUIRY OBJECTIVES							
Mathematical Skill	PIO-1						
Measurement Skill	PIO-2	■		■	■	■	■
Creating Models	PIO-3	■	■	■	■	■	
Analysis of Error	PIO-4	■		■	■	■	
Data Analysis	PIO-5	■	■	■	■	■	■
TITLES		Angle of Insolation	Solar Altitude Observations	Duration of Insolation	Land and Water Temperatures	Terrestrial Radiation	Soil Temperature

Multimedia: Check Multimedia Section of Supplement for reference to this topic.

VI-A-1a: ANGLE OF INSOLATION

QUESTION:

What are some factors which affect insolation?

MATERIALS:

Light source (200W), thermometer (low range), test tube, one-hole stopper, protractor.

SUGGESTED APPROACH:

1. Review the appearance of the sun's path and the seasonal changes of this path. Ask if the position of the sun has any effect on its ability to heat the earth. Discuss this briefly and suggest the following investigation as one method of measuring such an effect.

2. Have students fill a test tube with water, put a thermometer through a one-hole stopper, and stopper the test tube. Be sure the thermometer bulb is not touching the walls of the tube. Place a 200-watt light bulb about 20 cm. away from the test tube and at an angle of incidence of 90°. Turn the light on for 10 minutes; record the temperature at 1-minute intervals.

3. Repeat step 2 for angles of incidence of 60°, 30°, and 0°. Be sure to change the water each time. It is easier to change the angle of the test tube than to change the angle of the light. If enough thermometers are available, all angles can be done at the same time, using a different test tube for as many different angles as are desired.

4. Plot the temperature vs. time for each angle of insolation on the same graph.

5. Lead students in a discussion of the effects of the angle of incidence on heating. The model should be related to the earth-sun situation. Copies can be made of the accompanying diagram to illustrate the seasonal effects.

PRECAUTIONS:

1. Results near an angle of 0° may show more heating than would be expected because of limitations of the model. The students may wish to extrapolate values for 0° rather than measure them.

2. Do not get any water on the hot light bulb. If the light bulb used is a heat lamp, avoid looking directly at it.

TYPICAL RESULTS:

As the angle of incidence is decreased, the temperature change should decrease.

MODIFICATIONS:

1. The investigation can be done using thermometers with pieces of black paper taped to them, and changing the angle of incidence by tipping the thermometers.

2. Give students a statement of purpose; e.g., what effect does the angle of incidence have on heating power? From this statement have the students design and carry out their own procedures for answering the question.

3. Tape small thermometers to various latitudes on a large globe. Hold a 200 watt lamp at least a meter away and directed somewhere between 23 1/2°N and 23 1/2°S. Take temperature readings every minute and graph the data. Be careful that the temperature does not go beyond the range of the thermometers. This could be done with the sun during globe rectification if a large globe is used.

REFERENCES:

Investigating the Earth, pp. 250-252; Teacher's Guide, pp. 303-305.
Our Planet in Space, pp. 138-139, 144-145.

VI-A-1a: ANGLE OF INSOLATION

QUESTION:

What are some factors which affect insolation?

INTRODUCTION:

Sometimes the sun is high in the sky; at other times it is quite low. Where it is depends on the season and on the time of day as you have previously observed. How does this changing angle (the angle of incidence) affect the temperature? In this investigation you will use a model to find an answer to the question.

OBJECTIVES:

When you finish this investigation, you should be able to:

1. describe the relationship between insolation and the angle of incidence.

2. describe how each of the factors, time of day, latitude, and season, influence the heating effect of insolation at a particular location.

METHOD:

1. Fill a test tube with water, put a thermometer through a one-hole stopper, and stopper the test tube. Place a 200 watt light bulb about 20 cm. away and place the test tube at an angle of 90° to the light. Turn on the light for 10 minutes and record temperature readings at 1-minute intervals.

2. Repeat step 1 for angles of 60° and 30° and 0°.

3. Graph the data for all angles on the same set of axis.

4. Use the earth model provided by your teacher to study the effects of latitude variation and seasonal change on the intensity of insolation per unit area.

QUESTIONS:

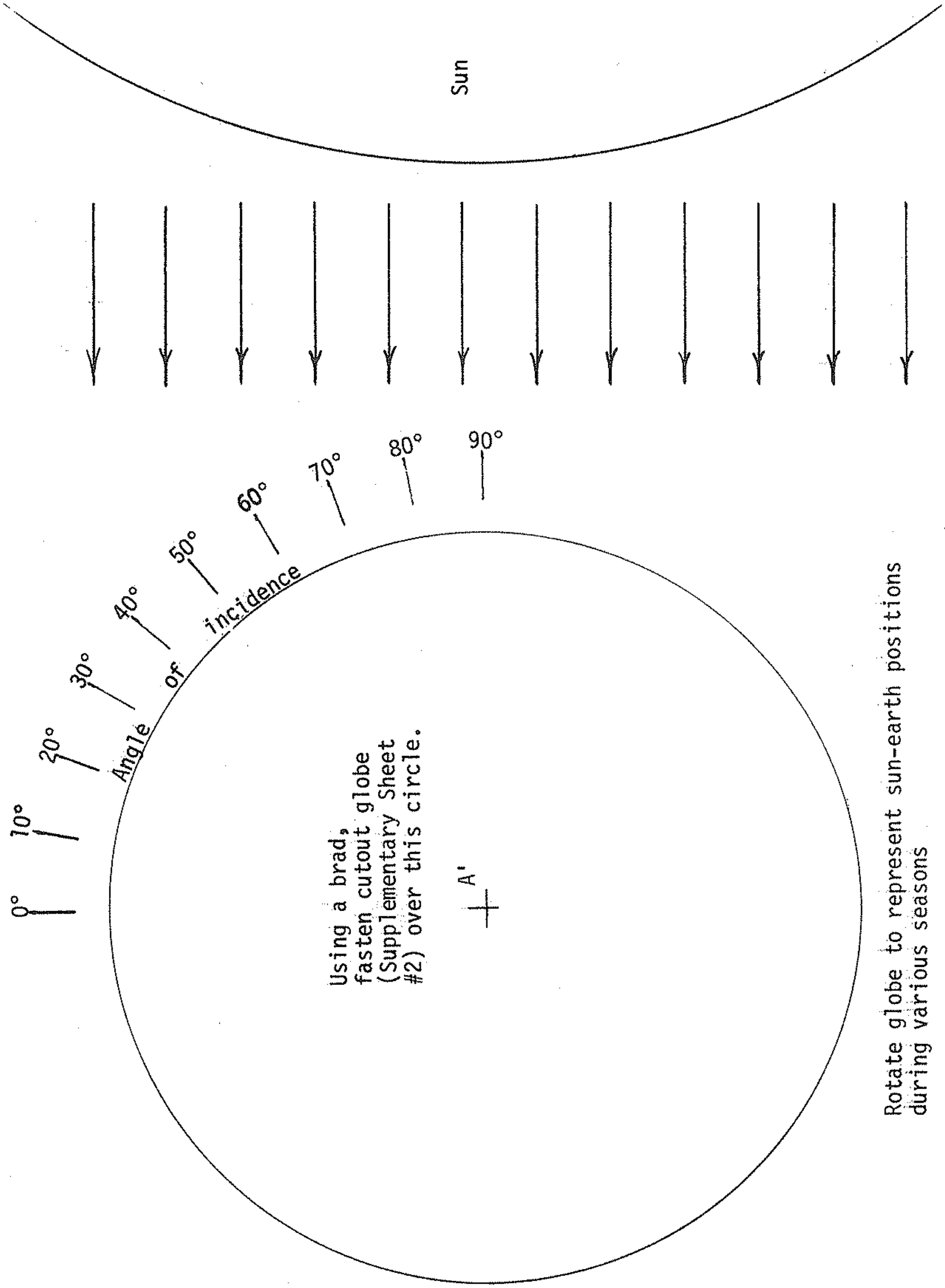
1. What effect does increasing the angle of incidence have on the temperature change in the test tube?

2. What is the pattern of temperature change as the angle changes from 0° to 90°? Why?

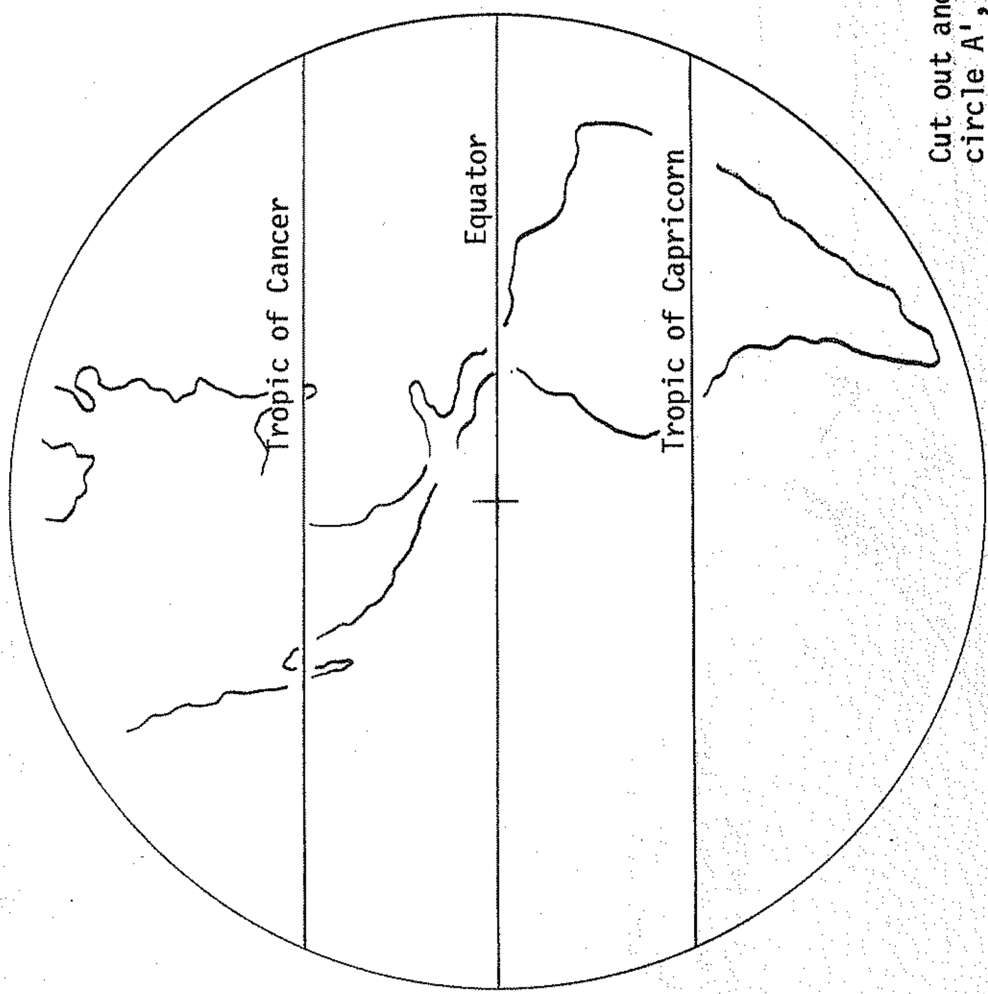
(A-1.11) 3. What effect does increasing the angle of incidence have on the intensity of insolation?

(A-1.12) 4. How does a change in latitude affect insolation?

(A-1.13) 5. How does the angle of incidence of insolation at any location change between sunrise and sunset?


Sun
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
Angle of incidence
Using a brad, fasten cutout globe (Supplementary Sheet #2) over this circle.
A'
Rotate globe to represent sun-earth positions during various seasons

Cut out and fasten over
circle A', using a brad
through the centers, so that
the top circle can be rotated.



Challenging (0.5)

VI-A-1b: SOLAR ALTITUDE OBSERVATIONS

QUESTION:

What are some factors which affect insolation?

SUGGESTED APPROACH:

1. Initiate a discussion about the altitude of the sun at noon. Raise questions such as: How high is the sun at noon? Is the noontime altitude of the sun always the same? What is the pattern of change in noontime altitude?

2. Have the students plot the data from the table (see supplementary sheet). This can best be done as a homework assignment.

3. Discuss student answers to the preliminary questions and those on the student sheet.

PRECAUTIONS:

Students may need some assistance in setting up the graph axis.

TYPICAL RESULTS:

The resulting graph is a sinusoidal curve which should clearly show the pattern of change of solar noontime altitude during the year.

MODIFICATIONS:

1. If time permits, have the students measure the altitude of the noontime sun.

REFERENCES:

Investigating the Earth, pp. 92-94, Teacher's Guide; pp. 131-133.

Do Not Print

VI-A-1b: SOLAR ALTITUDE OBSERVATIONS

QUESTION:

What are some factors which affect insolation?

INTRODUCTION:

How high up in the sky is the sun at noontime? Is the sun's noontime altitude always the same? Observations of the sun have been made at noontime for the period of a year. You will have an opportunity to analyze this data and draw some inferences about it.

OBJECTIVES:

When you finish this investigation, you should be able to:

1. describe the relationship between altitude change and the time of year at this latitude.
2. indicate the time of year when the altitude of the sun is greatest and the time when it is least at any latitude, given a graph or table of data.
3. describe the effect of a change in solar altitude on the intensity of insolation.

METHOD:

1. Graph the altitude of the noontime sun for the days given in the data table.
2. Analyze the graph and answer the questions below.

QUESTIONS:

1. What time of year is the altitude greatest? least?
2. What is the difference between the highest and lowest altitudes?
3. What is the cause of this change?

(A-1.11) 4. On what date would the intensity of insolation be greatest?

5. What was the approximate latitude at which these readings were taken?
6. How would the date be affected if the latitude at which the readings were taken was increased?

ALTITUDE OF THE SUN AT HIGH NOON

Date	Altitude		Date	Altitude	
Jan. 1	24°	55'	July 10	70°	21'
Jan. 10	25	54	July 20	68	50
Jan. 20	27	41	July 30	66	44
Jan. 30	30	06	Aug. 10	63	50
Feb. 10	33	21	Aug. 20	60	45
Feb. 20	36	45	Aug. 30	57	20
March 1	40	27	Sept. 10	53	17
March 10	43	32	Sept. 20	49	27
March 20	48	32	Sept. 30	45	34
March 30	51	25	Oct. 10	41	42
April 10	55	36	Oct. 20	37	59
April 20	59	12	Oct. 30	34	31
April 30	62	29	Nov. 10	31	07
May 10	65	23	Nov. 20	28	31
May 20	67	47	Nov. 30	26	30
May 30	69	38	Dec. 10	25	10
June 10	70	57	Dec. 20	24	35
June 20	71	26	Dec. 30	24	46
June 30	71	14			

Difficult (1.5)

VI-A-1c: DURATION OF INSOLATION

QUESTION:

What are some factors which affect insolation?

MATERIALS:

Light source, thermometer, container of soil.

SUGGESTED APPROACH:

1. Place the thermometer 1 cm. below the surface of the soil, and place the light source 20 cm. above it (closer if a low wattage bulb is used).

2. The light source should be turned on and off in a pattern which simulates the variation in the length of day and night during the year. Provide students with data regarding the length of day and night at the various times of the year (see note below). Have them suggest a sequence of times that could be used for the model. A possible sequence of times would be:

Date	Light on (sec.)	Light off (sec.)
March 23	120	120
April 23	130	110
May 23	145	95
June 23	150	90
July 23	145	95
August 22	130	110
September 22	120	120
October 22	105	135
November 22	95	145
December 22	85	155
January 22	95	145
February 21	105	135
March 23	120	120

<u>Note</u>: The above numerical values were obtained by multiplying by 10 the approximate number of hours of daylight and darkness at 42°N latitude on the given dates.

3. Temperature readings should be taken just before the heating period <u>or</u> just after the heating period, but not both.

4. Pupils should graph the temperature readings vs. time. Each graph will be a model of the earth's absorption and radiation pattern.

5. A general statement by each group of what happened to the temperature of the soil they used will show at what time of the year the soil is being warmed and when the soil is cooling.

PRECAUTIONS:

1. Better results are obtained if the setup is brought to a state of radiative balance before the sequence is begun. This can be accomplished by alternately turning the light on for 2 minutes and off for 2 minutes until the change in temperature stabilizes.

2. Remove the lamp during periods when it is off.

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TYPICAL RESULTS:

1. Students should have little difficulty detecting periods of absorption and radiation.

2. Students should be able to detect a heating lag. The maximum temperature will probably be reached later for the model than it occurs on the earth. This can be related to the fact that for the earth the angle of insolation also changes.

MODIFICATIONS:

1. The sequence may be halved so as to run from vernal equinox to autumnal equinox or from autumnal equinox to vernal equinox. The former should indicate the time of maximum temperature; the latter the time of minimum temperature.

2. The ratio of daylight and darkness hours to light on and off times may be changed depending on the total amount of available time.

3. As an additional variable, the angle of insolation can also be varied to produce a model more closely related to the earth.

4. An additional graph of input energy (measured in terms of the amount of time the light is on) may be plotted on the same axis as temperature, but using an appropriate scale. This will enable the student to make a direct comparison of cause and effect, and temperature lag.

REFERENCES:

Investigating the Earth, pp. 158-161.

VI-A-1c: DURATION OF INSOLATION

QUESTION:

What are some factors which affect insolation?

INTRODUCTION:

What is the effect on the earth's temperature of a changing ratio of daylight and darkness? In this investigation, you set up a model using the daylight-darkness ratio for the Northern Mid-latitudes. From this model, some relationships may be inferred concerning the seasonal variation of insolation.

OBJECTIVES:

When you finish this investigation, you should be able to:

1. given a graph showing the variations in temperature produced by variations in the duration of insolation:

   a) identify patterns of annual maximum and minimum temperatures,

   b) identify periods of absorption and radiation,

   c) relate maximum and minimum temperatures to maximum and minimum duration of insolation.

2. describe the ways in which the model is analogous to the earth and the ways in which it is not.

METHOD:

1. Set up a container of soil. Place the thermometer bulb 1 cm. below the surface of the soil and the light source 20 cm. above it (closer if a low wattage bulb is used).

2. Turn the light source on and off in a pattern which simulates the variation in length of daylight during the year at your latitude.

3. Record temperature readings just before the light is turned on or just before it is turned off, but not both.

4. Graph your results (time vs. temperature).

QUESTIONS:

(A-1.21) 1. What effect does an increase in the duration of insolation have upon the soil temperature?

(A-1.23) 2. At what time of the year is the duration of insolation at a maximum?

(A-1.24) 3. How does the time of maximum surface temperature compare with the time of maximum duration of insolation for the model? for the earth? Account for any differences.

(A-1.22) 4. How is the duration of insolation related to the various seasons?

(A-1.22) 5. How would the duration of insolation during the year be affected by an increase in latitude?

Challenging (2)

VI-A-1d LAND AND WATER TEMPERATURES

QUESTION:

What are some factors which affect insolation?

MATERIALS:

Three plastic hemispheres, six thermometers (low range C.°), dark-colored soil, light-colored soil (sand), water, heat lamp.

SUGGESTED APPROACH:

1. Initiate a discussion about the abilities of land and water to change temperature when heated. The comparison of land and water temperatures as observed at a beach can be used to relate to a probable common experience among students.

2. Have the students assemble apparatus as directed on handout sheet. Then make and record appropriate time and temperature measurements. Prepare graphs for both soils and the water.

3. Encourage students to interpret their own graphs and try to construct a mental model to explain what energy transformations are taking place and why. Have them relate the results to previous investigations in topic V and to their own experiences outside of school.

PRECAUTIONS:

1. Check to make sure thermometers are not buried too deeply in the soil. Soils are poor conductors of heat; and if the thermometers are buried too deeply, no change in temperature will result. The soil should just cover the bulb on the thermometer.

2. Be sure to use dry soils.

3. All three thermometer bulbs should be placed equidistant from the heat source.

4. Thermometers should all start at the same temperature.

5. Students will probably attempt to oversimplify the interpretations of their results. This investigation deals with various factors, such as: specific heats of the various materials; reflective abilities of the surfaces of each, including color; the ability to distribute heat energy by conduction or convection; and the depths to which energy can penetrate directly.

TYPICAL RESULTS:

If the apparatus is set up as directed, the temperature change should be greatest for the dark soil and least for the water.

MODIFICATIONS:

1. This could be done with only one type of soil and water. The additional soil serves to illustrate that all solid earth materials do not absorb energy at equal rates. Later in the course, this investigation can be related to land and sea breezes. Air convection currents are also set up as a result of unequal heating of solid earth...

materials; however, the result is not as dramatic.

2. Students could be shown aerial photographs and be asked to interpret the tone (black and white shading) of various earth materials such as sand, clay soil, water, and forest vegetation.

REFERENCES:

Investigating the Earth, pp. 172-173; Teacher's Guide, pp. 209-211.

VI-A-1d: LAND AND WATER TEMPERATURES

QUESTION:

What are some factors which affect insolation?

INTRODUCTION:

Have you ever noticed that on a hot summer's day the sand on the beach becomes uncomfortably hot while the water seems cool when you enter? However, if you have ever gone swimming early in the morning, you will remember that the reverse was true, the sand was cool and the water felt warm. How could this apparent change take place?

OBJECTIVES:

When you finish this investigation, you should be able to:

1. identify a graph for soil and a graph for water, given two unlabeled temperature vs.time graphs for samples of the materials which have been exposed to a heat source.

2. identify areas of lowest temperature, shown two diagrams, each showing a shoreline between a body of water and land, one labeled "day" and the other "night."

METHOD:

1. Fill each of three plastic hemispheres about 1/3 full; one with water, one with dry, light-colored soil (sand), and the other with dry, dark-colored soil.

2. Place two thermometers in each hemisphere. One should be placed just under the surface of the material and the other just above the surface. This is accomplished best in the soil by making a small depression with your finger, placing the bulb of the thermometer in the depression, and then sprinkling loose soil over the thermometer bulb until it is just covered.

3. Place a heat lamp 20-30 cm. above the hemispheres, and turn it on.

4. Record the temperatures on the thermometers each minute for 10 minutes.

5. Turn off the light and continue recording temperatures each minute for 10 minutes.

6. Graph your data.

QUESTIONS:

1. Which received more energy from the lamp, the soils or water?

(A-1.32) 2. How did the temperatures in and above the hemispheres vary?

3. What characteristics of the materials could explain the variations in temperatures of the materials?

4. What effects do the differences in heating and cooling rates of land and water surfaces have upon the atmospheric conditions?

Challenging (1.5)

VI-B-1a: TERRESTRIAL RADIATION

QUESTION:

What are some factors which affect terrestrial radiation?

MATERIALS:

Two containers of soil, two thermometers (low range C.°), one plastic hemisphere, heat source (lamp or sun).

SUGGESTED APPROACH:

1. Initiate a discussion about radiation from the earth. Have students suggest factors which may influence the amount of energy radiated from the earth's surface. This discussion can be focused on the effect of the atmosphere on surface radiation.

2. Have the students set up the apparatus as described on the student sheet and conduct the investigation.

PRECAUTIONS:

1. Care should be taken in relating the model to the earth. The results should be analogous to the effect of the atmosphere but not entirely because of limitations of the model. For example, the hemisphere restricts air circulation which is not true for the earth.

TYPICAL RESULTS:

The soil in the covered container should heat up slower and cool slower.

MODIFICATIONS:

Use additional hemispheres of soil; introduce atmospheres containing dust, water vapor, smoke, or carbon dioxide. Cover them and test for the effect of each material on surface radiation.

REFERENCES:

Investigating the Earth, pp. 159-161.

VI-B-1a: TERRESTRIAL RADIATION

QUESTION:

What are some factors which affect terrestrial radiation?

INTRODUCTION:

What is the effect of the atmosphere on radiation from the earth's surface?

OBJECTIVES:

When you finish this investigation, you should be able to:

1. indicate conditions of rapid heating and rapid cooling, given a time vs. temperature graph of covered and uncovered soil that has been exposed to a light source.

2. suggest some factors that could account for differences in the heating and cooling rate between the covered and uncovered soil.

METHOD:

1. Place the same amount of soil in each of two containers. A thermometer should be buried 1 cm. deep in the soil in each container.

2. Place both containers under a heat lamp or in the sun until the temperatures in both have risen 15°-20° above room temperature.

3. Place a plastic hemisphere over one of the containers.

4. Record the temperature in both containers every 2 minutes for at least 20 minutes.

5. Graph your results (time vs. temperature).

QUESTIONS:

1. Which container of soil received the most energy from the heat source?

2. In which container of soil did the temperature change the most? Why?

(A-1.31)
(A-1.41) 3. In what ways is the effect of the cover on temperature changes similar to the effect of the atmosphere? In what ways is it not?

(B-1.11) 4. How do the wavelengths of the radiation absorbed and radiated back by the soil compare? How do they compare for the earth?

(B-1.21) 5. What materials in the atmosphere produce the same effect for the earth that the cover produced on the soil?