ES 106 Laboratory # 5
EARTH-SUN RELATIONS AND ATMOSPHERIC HEATING

Introduction

Weather is the state of the atmosphere at a particular place for a short period of time. The condition of the atmosphere at any place and time is described by measuring the four basic elements of weather: temperature, humidity, air pressure, and wind. Of all the controls that are responsible for causing global variations in the weather elements, the amount of solar radiation received at any location is certainly one of the most important. Investigating the journey of solar radiation and how it is influenced and modified by air, land, and water will provide a better understanding of one of the most basic weather elements, atmospheric temperature.

Temperature is an important element of weather and climate because it greatly influences air pressure, wind, and the amount of moisture in the air. The single greatest cause of temperature variations over the surface of Earth is differences in the amount of solar radiation received. Secondary factors, such as ocean currents, altitude and differential heating of land and water, can also affect local temperatures. The unequal heating that takes place over the surface of Earth is what sets the atmosphere in motion, and the movement of air is what brings changes in our weather.

For life on this planet, the relations between Earth and Sun are perhaps the most important of all of the astronomical phenomena. The amount of solar energy (radiation) striking Earth is not constant throughout the year at any particular place but varies with the seasons. However, the total amount of radiation that the planet intercepts from Sun equals the total radiation that it loses back into space. It is this balance between incoming and outgoing radiation that keeps Earth from becoming continuously hotter or colder.

Goals and Objectives

- Examine what happens to solar radiation as it enters and interacts with the Earth system.
- Explore the effect that sun angle has on the intensity and duration of solar radiation that any particular location receives throughout the year.
- Diagram the relationship between Earth and Sun on the dates of the solstices and equinoxes.
- Compare how the heating of a surface is related to its albedo and contrast the differences in the heating and cooling of land and water.

Useful Websites

- http://www.physicalgeography.net/fundamentals/6i.html
- http://hyperphysics.phy-astr.gsu.edu/hbase/phyopt/albedo.html
- http://zebu.uoregon.edu/disted/ph162/l4.html
- http://home.iprimus.com.au/nielsens/solrad.html
- http://solardat.uoregon.edu/SolarRadiationBasics.html

Name_________________________

Lab Day/Time___________________

Pre-lab Questions – Complete these questions before coming to lab.

1. Define the following terms:
   A. Equinox

   B. Solstice

   C. Infrared radiation

   D. Albedo

2. The amount of solar energy per unit area hitting the outside of Earth's atmosphere is greater than the amount that actually reaches Earth's surface. Give at least three factors that contribute to the decrease in the amount of energy reaching Earth's surface and explain each.

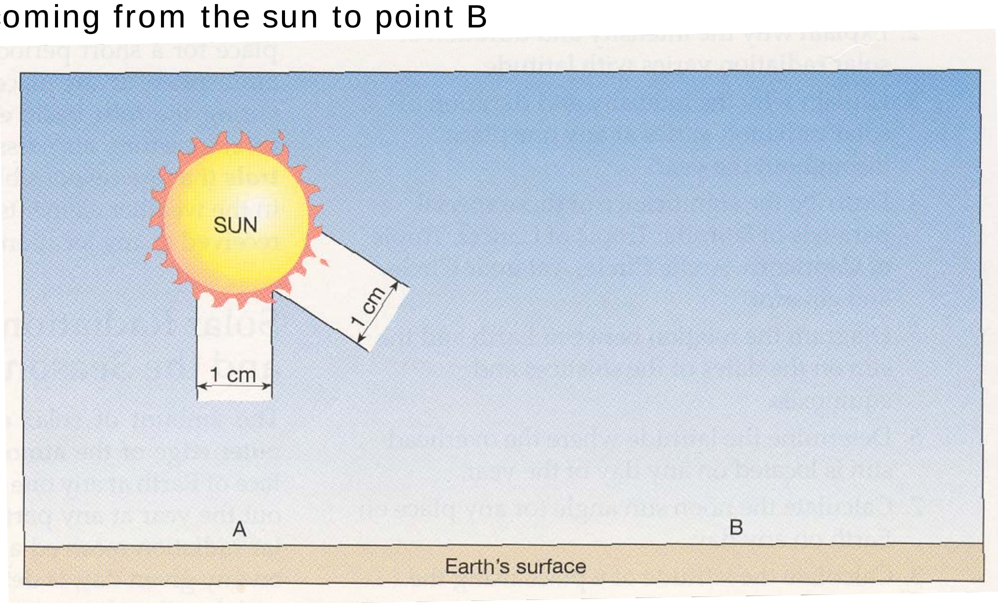
3. With a ruler, draw a line across the bottom of the page. Divide it into centimeters. Divide one of those centimeters into millimeters. Don't guess! Use the ruler to measure. Label them.

Part A – Solar Radiation and the Seasons

The amount of solar energy (radiation) striking the outer edge of the atmosphere is not uniform over the face of Earth at any one time, nor is it constant throughout the year at any particular place. The intensity and duration of sunlight determine the amount of solar radiation received at any particular place on Earth on any given day. *Intensity* is the amount of solar energy per unit area per unit time that hits a given surface and is determined by the angle at which the rays of sunlight strike the surface. *Duration* refers to the length of daylight. The typical unit of solar radiation is watts per square meter. The average intensity of solar radiation falling on a surface perpendicular to the solar beam in the upper reaches of the atmosphere is about 350 watts per square meter. As the radiation passes through the atmosphere, it undergoes absorption, reflection, and scattering. Therefore, at any one location, less radiation reaches Earth's surface than was originally intercepted at the upper atmosphere.

Activity 1: Sun Angle Solar Radiation and Latitude
The amount of radiation striking a square meter at the outer edge of the atmosphere, and eventually Earth's surface, varies with latitude because of different **sun angles** at different latitudes. **On Figure 1, extend the 1 cm wide beam of sunlight from the Sun vertically to point A on the surface**. **Extend the second 1 cm wide beam, beginning at the sun, to the surface at point B.** Notice that the sun is directly overhead (vertical) at point A and the beam of sunlight strikes the surface at a 90° angle above the horizon. Using a protractor, measure the angle between the surface and the beam of sunlight coming from the sun to point B

Figure 1 Vertical and oblique sun beams.



Refer to Figure 1 to fill in this table

	POINT A	**POINT B**
Angle of beam to surface	90°	
Width of beam in mm		

1. Of the two beams, which is more spread out at the surface and covers a larger area. ___________
2. Which surface would receive more watts per square meter? ___________

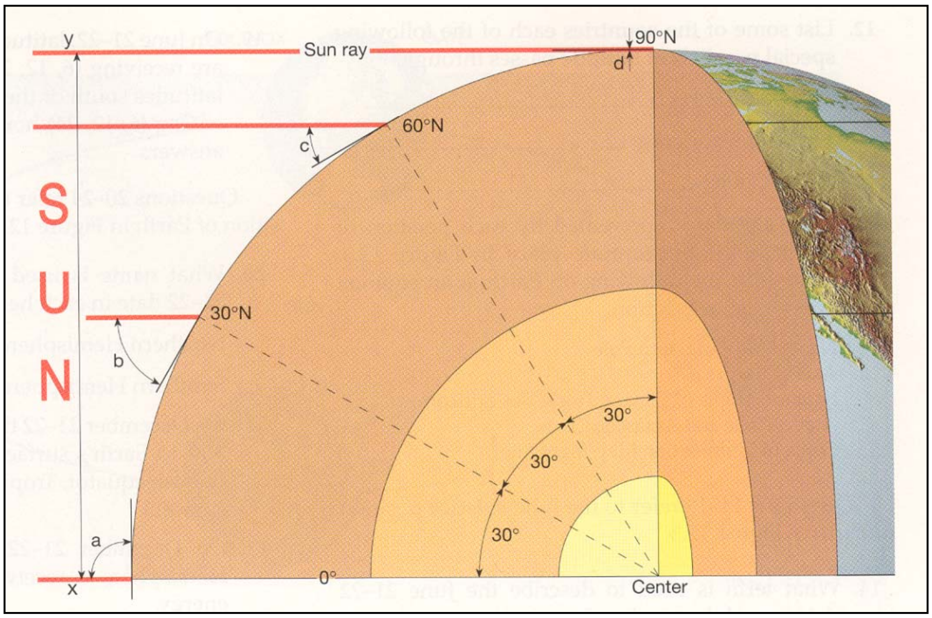


Figure 2
Distribution of solar radiation per 30° segment of latitude on Earth's surface.

Use Figure 2 to answer questions concerning the total amount of solar radiation intercepted by each 30º segment of latitude on Earth.

3. With a metric ruler, measure the total width of incoming rays from point *x* to point *y* in Figure 2.
   The total width is :→ _______ cm = ________ mm.
4. Assume the total width of the incoming rays (from point *x* to point *y*) equals 100% of the solar radiation that is intercepted by Earth.
   Each millimeter would equal:→ __________%.
5. What percentage of the total incoming radiation is concentrated in each of the following zones? (Hint: Multiply the total distance in mm by %/mm, from above.)

Latitude range	mm	%
0º - 30º		
30º -60º		
60º - 90º		

6. Use a protractor to measure the angle between the surface and sunray at each of the following locations in Figure 2. (Round off to the nearest 5 degrees.) Angle B is already done as an example.

Angle a:	
Angle b:	**60º**
Angle c:	
Angle d:	

7. What is the general relationship between the amount of radiation received in each 30º segment and the angle of the sun's rays?

8. Briefly explain in your own words what fact about Earth creates the unequal distribution of solar energy, even though each zone represents an equal 30º segment of latitude.

Figure 3
Earth-Sun relations

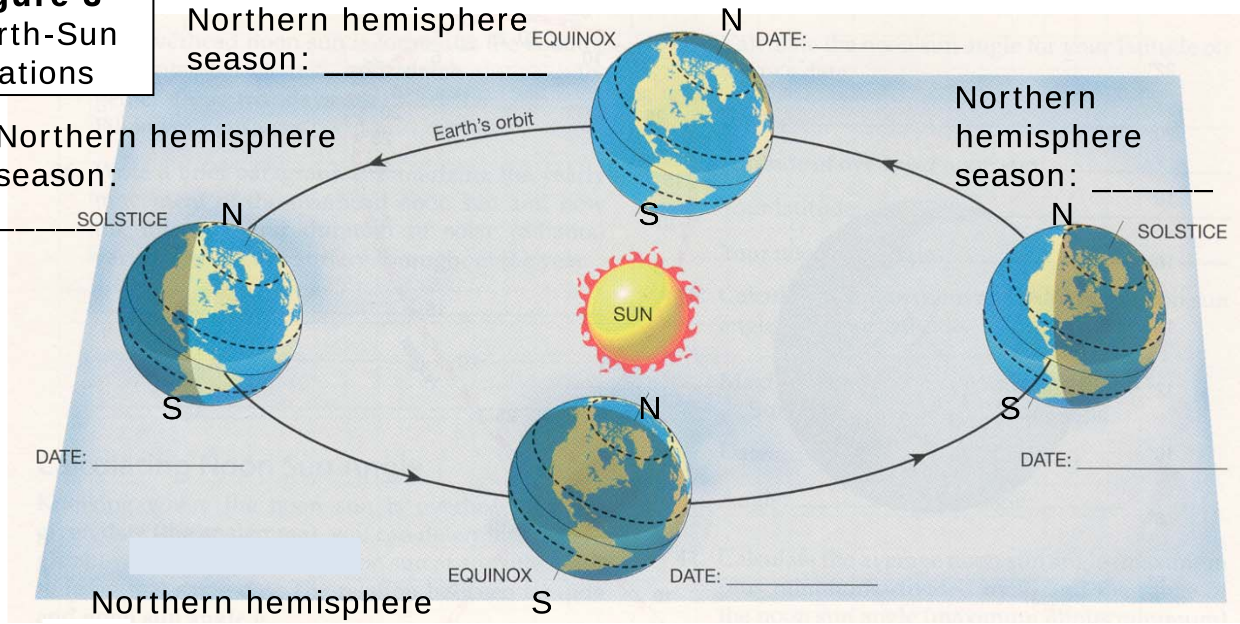
Fill in the proper names and dates on Figure 3

Northern hemisphere season: ____________

Northern hemisphere season: _____

Northern hemisphere season: ______

Northern hemisphere season: ____________



Activity 2: Yearly Variation in Solar Energy

The amount of solar radiation received at a particular place would remain constant throughout the year if it were not for these facts:

- Earth rotates on its axis and revolves around (orbits) Sun.
- Earth's axis is inclined 23 ½^o from perpendicular to its plane of orbit.
- Throughout the year, Earth's axis points to the same place in the sky. This causes the noon Sun to appear directly overhead at the equator twice a year, as it migrates from directly over the Tropic of Cancer (23 ½^o N latitude), to directly over the Tropic of Capricorn (23 ½^o S latitude), and back, from one June solstice to the next.

As a consequence, there are variations in the intensity of solar radiation and changes in the length of daylight and darkness at every place on Earth. The seasons are the result of this changing intensity and duration of solar energy, and subsequent heating of the atmosphere.

Table 1, below, lists the hours of daylight on the solstices and equinoxes at each 10^o of latitude on Earth's surface. Use this table and Figure 3 to answer the questions on the following page.

Latitude (degrees)	**Summer Solstice**	**Winter Solstice**	**Equinoxes**
0	12 h	12 h	12 h
10	12 h 35 min	11 h 25 min	12
20	13 12	10 48	12
30	13 56	10 04	12
40	14 52	9 08	12
50	16 18	7 42	12
60	18 27	5 33	12
70	24 h (for 2 mo)	0 00	12
80	24 h (for 4 mo)	0 00	12
90	24 h (for 6 mo)	0 00	12

Table 1: Hours of daylight.

Use Table 1 and Figure 3 to answer the question on the next page.

1. What term is used to describe June 20-21 in each hemisphere?	Northern Hemisphere:
	Southern Hemisphere:
2. What latitude is receiving the most intense solar energy on June 20-21?	Latitude:
3. What name is used to describe Dec. 21-22 in each hemisphere?	Northern Hemisphere:
	Southern Hemisphere:
4. For the Northern Hemisphere, what terms are used to describe these dates?	March 20-21:
	September 22-23:
5. For the Southern Hemisphere, what terms are used to describe these dates?	March 20-21:
	September 22-23:

6. (Circle responses) On June 20-21, latitudes north of the Arctic Circle are receiving (**0 / 6 / 12 / 24**) hours of daylight, while latitudes south of the Antarctic Circle are experiencing (**0 / 6 / 12 / 24**) hours of darkness.
7. (Circle response) On December 21-22, the (**Northern / Southern**) Hemisphere is receiving the most intense solar energy.

8. What latitude is receiving the most intense solar energy on:	March 21?
	September 22?

9. Describe the length of daylight everywhere on Earth on March 20-21 and September 22-23:

10. Use the Table 1 to find how many hours of daylight there would be at each of the following latitudes on December 21-22.

90 degrees N: ______________ hrs ______________ min

40 degrees N: ______________ hrs ______________ min

0 degrees: ______________ hrs ______________ min

40 degrees S: ______________ hrs ______________ min

90 degrees S: ______________ hrs ______________ min

Part B – The Nature of Earth's Surface and Atmospheric Heating

The various materials that comprise Earth's surface play an important role in determining atmospheric heating. Two significant factors are the albedo of the surface and the different abilities of land and water to absorb and reradiate radiation. *Albedo* is the reflectivity of a substance, usually expressed as the percentage of radiation that is reflected from the surface. Since surfaces that have high albedo are not efficient absorbers of radiation, they cannot return much long-wave radiation to the atmosphere for heating. Most light-colored surfaces have high albedo, causing light-colored surfaces (and the air above them) to be typically cooler than dark surfaces.

Activity 1: Albedo Experiment
To better understand the effect of albedo on atmospheric heating, conduct the experiment below using the provided apparatus and answer the questions. Before getting started, predict which will have the higher albedo – the black can or the silver can.

Procedure:

Step 1: Place the black and metallic containers (with lids and thermometers) about 6 inches away from the light source.

- **Make certain** that both containers are equal distance from the light and are not touching one another.
- Have the light is **shining on the sides** of the cans, not on the white foam lids.
- **Use cans that have cooled** since another group did the activity.
- Be sure thermometers are **not touching the sides** of the cans.

Step 2: Start recording the temperature of both containers with the computer by pressing 'start', or fill out Table 2 "Albedo Experiment Data" by reading the thermometer.

Step 3: Turn on the light and allow the computer to continue to record the temperature of both containers **for 5 minutes**, or read it from the thermometers and record on the data table at about 30-second intervals **for 5 minutes**.

Step 4: Print the graph, or plot the temperatures from the data table on Figure 4, the albedo experiment graph. Be sure to label which line represents the black can and the metallic can.

Do not fill out if you used the computer.

Use the printout instead of the table and graph**.**

Table 2: Albedo Experiment Data	**Starting Temperature**	**30 sec**	**1 min**	**1.5 min**	**2 min**	**2.5 min**	**3 min**	**3.5 min**	**4 min**	**4.5 min**	**5 min**
Black Container											
Silver Container											

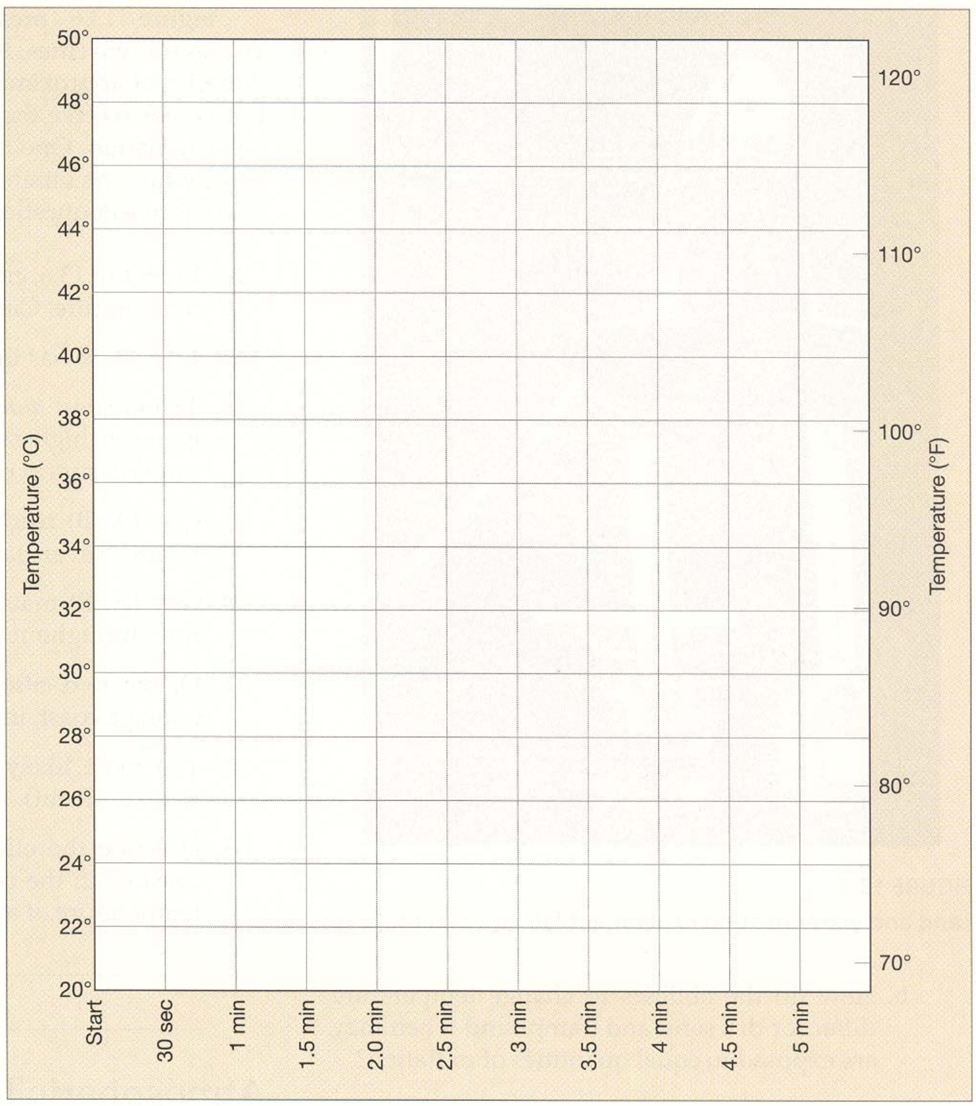


Figure 4: Graph of data from the albedo experiment.

Questions:

1. Which container has the higher albedo? ___________________________

2. Does this result match your prediction?

3. Write a brief summary of the results of the albedo experiment.

4. List two examples of natural Earth surfaces or materials that have high albedo.

5. List two examples of natural Earth surfaces or materials that have low albedo.

6. Given equal amounts of radiation reaching the surface, the air over a snow-covered surface will be (**colder** / **warmer**) than air above a dark-colored, barren field. Explain your choice fully in terms of what you have learned about albedo.

7. Why is it wise to wear light-colored clothes on a sunny, hot day?

8. If you lived in an area with long cold winters, a (**light** / **dark**) –colored roof would be the best choice.

Activity 2: Land and Water Heating Experiment

Land and water influence the air temperatures above them differently because they do not absorb and reradiate energy equally. In this activity, you will investigate the differential heating of land and water. Use the equipment provided, follow the lab procedure given below, and answer the questions.

Procedure:

Step 1: Hang a light from a stand so it is equally about 5 inches above the top of the two beakers – one containing dry sand and the other containing water at room temperature.

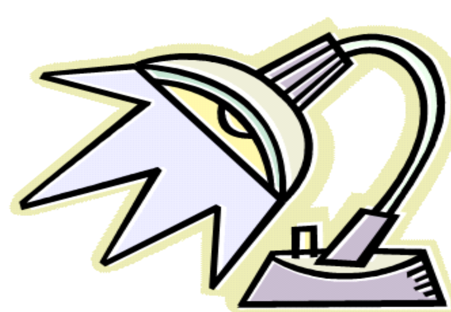
Step 2: Put temperature probes with plastic sleeves on them in the beakers of sand and water. Place them so that **the tips are just below** the surfaces of the sand and water. Use the plastic sleeves to support them in this position. Or use thermometers in similar positions.

Step 3: Start recording the temperatures for both the dry sand and water by pressing 'start' on the computer, or record in Table 3 "Land and Water Heating Data", if you are using the thermometers.

Step 4: Turn on the light and have the computer record the temperatures for **10 minutes**. Press stop at the end of 10 minutes. Or record the data in table at about one-minute intervals for 10 minutes if you are using the thermometers.

Step 5: Print the graph, or plot the temperatures for the water and dry sand from the data table on Figure 5. Be sure each line is labeled

Note: the tips of the temperature probes are only just below the surface of the sand and water.



Do not fill out if you used the computer.

Use the printout instead of the table and graph**.**

Table 3: Land and Water Heating Data. If you used the computer, do not record the data here. Use the printout instead of the table and graph

	0 min	**1 min**	**2 min**	**3 min**	**4 min**	**5 min**	**6 min**	**7 min**	**8 min**	**9 min**	**10 min**
Water											
Dry Sand											

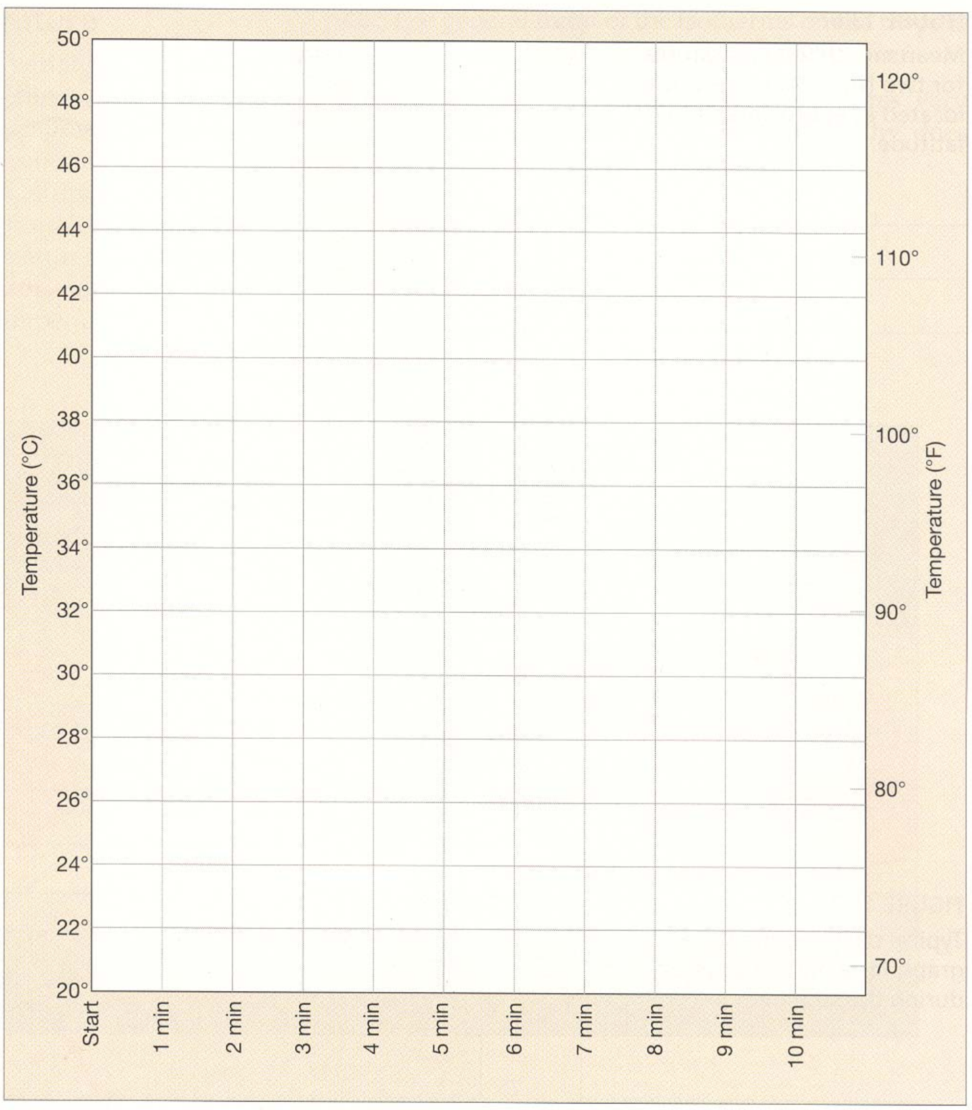


Figure 5: Graph for land and water heating experiment.
Do not use this if you have the computer print-out of your data.

Questions about the Land—Water heating activity:

1. How do the abilities to change temperatures differ for dry sand and water when they are exposed to equal amounts of radiation?

2. List and thoroughly describe *two* reasons for the differential heating of land and water.

Activity 3: Temperature Relationships to Land-Water and Cloudy-Clear

Figure 6 (top of next page) presents the annual temperature data for two cities, City A and City B, located in North America at approximately 37º-north latitude. On any given date, both cities receive the same intensity and duration of solar radiation. One city is in the center of the continent, while the other is on the west coast (say San Francisco, CA and Wichita, KS). You may want to refer to Fig. 16.18, p. 498-499, *Earth Science, 14th ed.*, by Tarbuck, et al. to help you understand these questions

Circle the answer for following questions using Figure 6.

1. City (A / B) has the highest average monthly temperature.
2. City (A /B) has the lowest average monthly temperature.
3. The greatest annual temperature range (difference between highest and lowest monthly temperatures) occurs at City (A / B).
4. City (A / B) reaches is maximum average monthly temperature at an earlier date.
5. City (A / B) maintains a more uniform temperature throughout the year.
6. Of the two cities, City A is the most likely to be located (along a coast / in the center of a continent).

7. The most likely location for City B is (coastal / mid-continent).

8. Describe the effect that the location of each city has on the temperature variations of that city throughout the year.

Figure 6
Mean monthly temperatures for two North American cities located at approximately 37°N latitude.

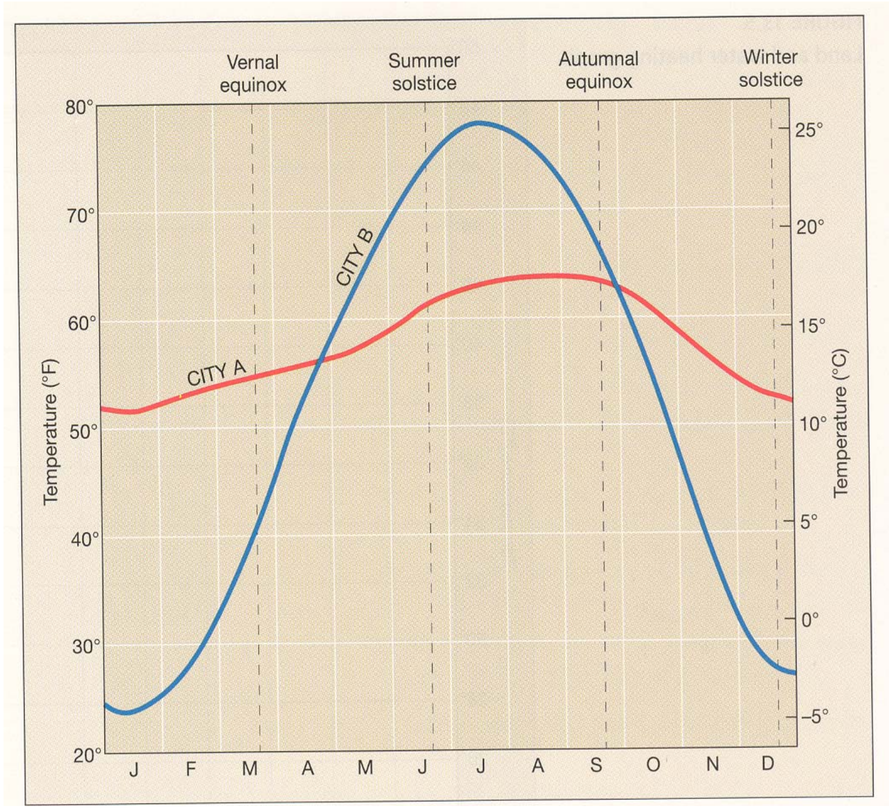
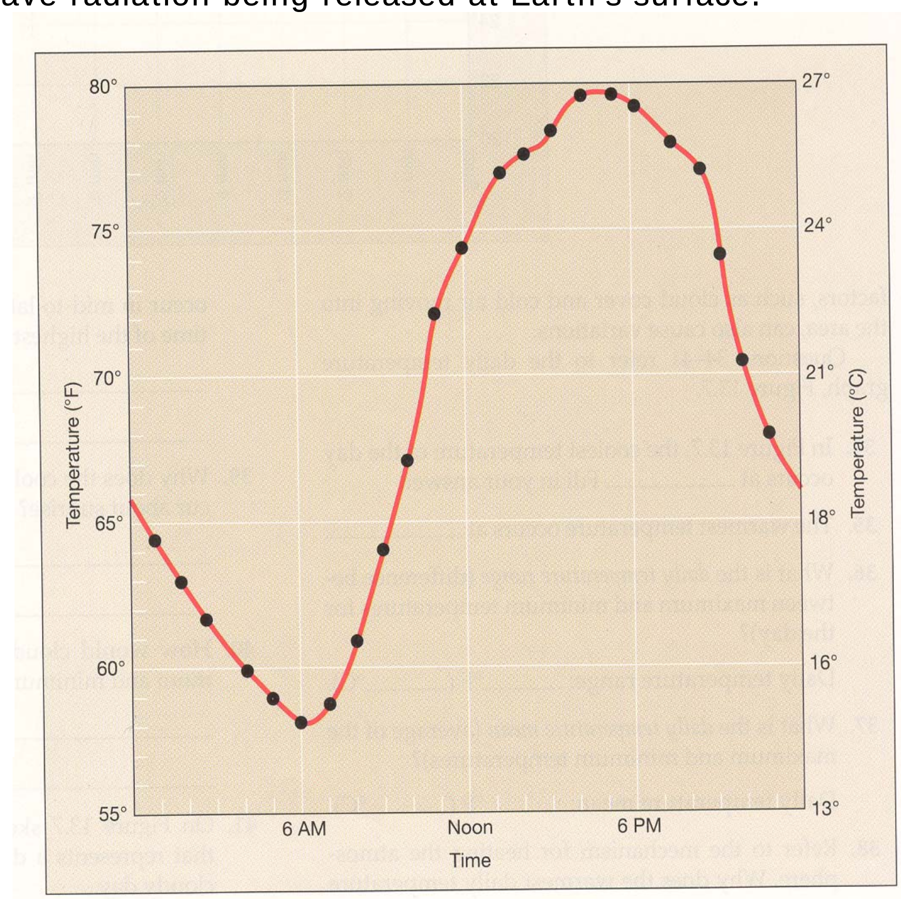


Figure 7 shows how daily temperature varies for a typical mid-latitude city. In general, the daily temperatures that occur at any particular place are the result of long-wave radiation being released at Earth's surface. However, secondary factors, such as cloud cover and cold air moving into the area, can also cause variations.

Figure 7
Typical daily temperature graph for a mid-latitude city during the summer.



Use Figure 7 to answer these questions:

3. The coolest temperature of the day occurs at ____________________,

   and the warmest temperature occurs at ________________________.
   (time of day)

4. What is the daily temperature range (difference between maximum and minimum temperatures for the day), in degrees Celsius?

5. What is the daily mean temperature (average of maximum and minimum temperatures) in degrees Celsius?

6. Considering how the atmosphere is heated, why does the warmest daily temperature not occur at the time of the highest sun angle, but rather in mid to late afternoon?

7. Why does the coolest temperature of the day occur about sunrise?

8. How would cloud cover influence daily maximum and minimum temperatures?

9. **On Figure 7**, sketch and label a line that would represent a daily temperature graph for a cloudy 24 hour period.

Name________________________

Lab Day/Time_________________

POST-LAB ASSESSMENT

Imagine that you are designing a house that gets its heat and electricity from solar energy. The house is located in Oregon.

1. How would you want to angle the solar collector panels to receive the most energy from the Sun? Would the collectors face north, south, east or west? Would the collectors lie horizontally (flat on the ground), vertically (like a billboard), or at an angle? Justify your answers.

2. Would the optimal orientation for the panels change during the day? How and why, or why not?

3. Would the optimum orientation change through out the year? How and why, or why not?

4. Using what you have learned in lab today, explain why deserts often have very cold nighttime temperatures.

5. Using what you have learned in lab today, explain why an expansion of ice sheets would lead to an overall cooling of Earth's atmosphere. Be sure to consider what happens to incoming visible solar radiation when it hits a snowy or icy surface.