Climate and Meteorology Experiments

HSB-CM-E

Vernier

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Experiments

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* Weather Vane also required

Modeling Solar Insolation

The sun emits energy in the form of solar radiation, which is made up of ultraviolet light, visible light, and infrared radiation. Solar radiation has a profound effect on life on Earth. For example, solar radiation is transformed into usable energy for living things by photosynthesis. However, solar radiation is not evenly distributed across the Earth.

Insolation is the amount of solar radiation that strikes a specific location on Earth, and it varies from place to place. The tilt of the Earth's axis and the curvature of the Earth cause the angle of insolation, the angle at which solar radiation hits the Earth, to vary across the planet. This affects heating in two different ways:

1. The angle of insolation affects the amount of atmosphere that the solar radiation travels through before reaching the surface. As a result, near the equator, sunlight travels through less atmosphere compared to polar regions.
2. The angle of insolation also influences the amount of area that is heated by solar radiation. Solar radiation is distributed over a smaller surface area in the tropical regions because it hits it at an angle that is closer to perpendicular, while in the polar regions it is distributed over a much larger surface area because solar radiation hits the polar regions at an oblique angle.

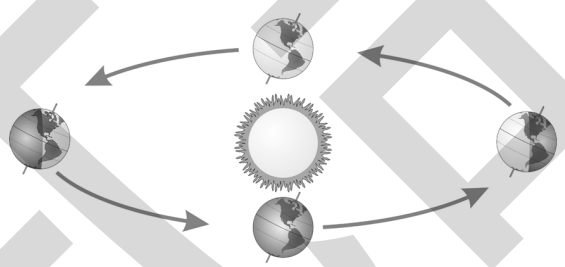


Figure 1

As the Earth orbits around the sun, it travels in an oblong path rather than a perfect circle, so the planet is closer to the sun at some times during the year compared to others as seen in Figure 1. It is a common misconception that this change in distance is the cause of the seasons. However, because Earth is so far from the sun, this difference has a relatively small effect on the temperature you experience when you're sitting outside. In reality, because the Earth is tilted, the North Pole points toward the sun during some parts of the year and the South Pole points toward the sun during the rest of the year. Thus, it is the angle of insolation and the orbit of the Earth around the sun that cause the seasons.

While conceptually this information probably makes sense to you, in this experiment, you will collect data that you will use as evidence to describe what causes the seasons.

OBJECTIVES

- Use a light sensor to model the amount of light that reaches different latitudes.
- Determine the relationship between the amount of light and latitude.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis app
Go Direct Light and Color Sensor
printed illustration of the Earth
tape
ruler
protractor
string
lamp with 100 W equivalent bulb

PROCEDURE

1. Set up the Sun and Earth simulation.
   a. Tape the Earth illustration to a wall or sturdy backing such as a book.
   b. Place the lamp to the left of the illustration so that the North Pole is tilted away from the lamp (see Figure 2).
   c. Identify the point at which the Tropic of Capricorn is closest to the light bulb (the western-most point on the line). Measure the vertical distance from that point to the table.
   d. Adjust the lamp so that the center of the light bulb is at the same height that you measured in the previous step.
   e. Position the lamp so that the center of the bulb in the lamp is 20 cm away from the point on the Tropic of Capricorn that you used to determine the height of the light bulb. **Note**: This placement represents the December solstice.
   f. Do not turn on the lamp until directed.

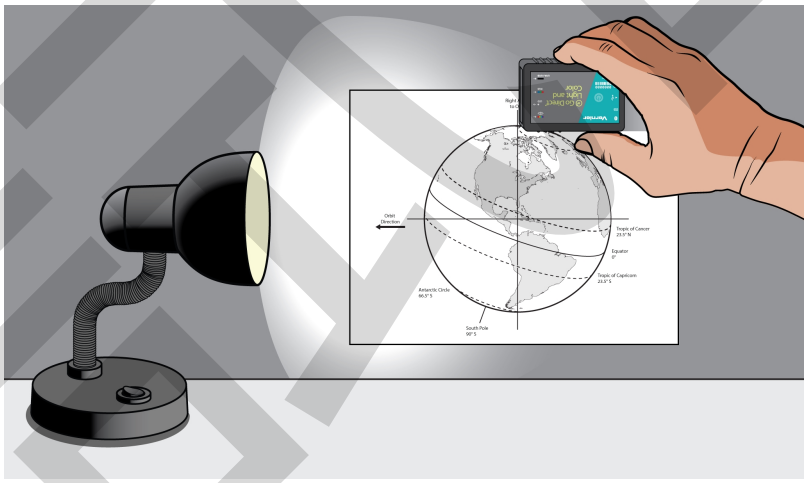


Figure 2

2. Launch Graphical Analysis. Connect the Go Direct Light and Color Sensor to your Chromebook, computer, or mobile device.

3. Set up the data-collection mode.
   a. Click or tap Mode to open Data Collection Settings.
   b. Change Mode to Event Based.
   c. Enter **Latitude** for the Event Name and **degrees** for the Units.
   d. Click or tap Done.

4. Determine the angle of insolation for each latitude you will measure. **Note**: During this step, you will measure angles between the bulb and points on the illustration. Each time you connect the string to the illustration, always choose the point on the line that is closest to the bulb (i.e., the western-most point on the line for December solstice and the eastern-most point on the line for June solstice).
   a. Tape a piece of string from the Tropic of Capricorn to the center of the end of the bulb. This string should be taut and parallel to the table. Use only as much of the string as needed.
   b. Tape another piece of string to the center of the end of the bulb.
   c. Place the other end of the string on the Arctic Circle on the illustration. Make sure the string is taut.
   d. Using a protractor, measure the angle between the strings. Record the angle in your data table.
   e. Now, move the second string to the Tropic of Cancer; do not remove the tape from the light bulb.
   f. Measure the angle between the strings, and record the angle in your data table.
   g. Repeat Steps e–f for the Tropic of Capricorn, the Equator, and the Antarctic Circle.
   h. Remove the tape and string from the bulb and illustration.

5. Collect data.
   a. Start data collection, and turn on the lamp.
   b. Hold the Go Direct Light and Color Sensor at the Arctic Circle so that the light sensor is facing toward the direction of the light (see Figure 2).
   c. Once the reading is stable, click or tap Keep. Enter **66.5** for the Latitude, and click or tap Keep Point to store the data.
   d. Next, hold the Go Direct Light and Color at the Tropic of Cancer so that the light sensor is facing toward the direction of the light.
   e. Once the reading is stable, click or tap Keep. Enter **23.5** for the Latitude, and click or tap Keep Point.
   f. Repeat Steps d–e at the Equator, Tropic of Capricorn, and Antarctic Circle, entering 0, –23.5, and –66.5 for the respective latitudes.
   g. Stop data collection, and turn off the lamp. **Caution**: Do not touch the bulb. It will be very hot.

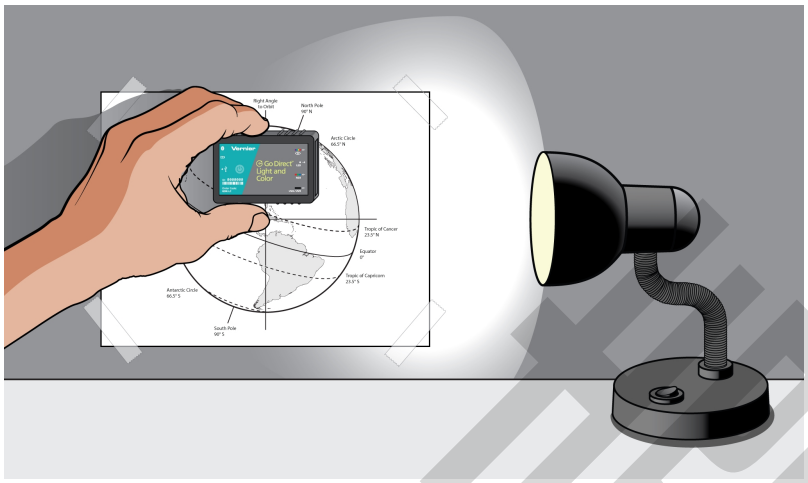


Figure 3

6. Reposition the setup for June solstice data collection.
   a. Place the lamp to the right of the illustration so that the North Pole is tilted toward the lamp as shown in Figure 3.
   b. Measure the vertical distance from the Tropic of Cancer to the table. Position the bulb so that its center is the same height from the table.
   c. Position the lamp so that the center of the bulb in the lamp is 20 cm away from the Tropic of Cancer on the Earth illustration (see Figure 3). **Note**: This placement represents the June solstice.
   d. Do not turn on the lamp until directed.

7. Once the bulb is cool enough repeat Step 4, attaching the first string to the Tropic of Cancer.

8. Repeat Steps 5 to collect light data for each latitude measured.

DATA

Table 1: December Solstice			
	Latitude (°)	Angle of insolation (°)	Illumination (lux)
Arctic Circle			
Tropic of Cancer			
Equator			
Tropic of Capricorn			
Antarctic Circle			

Table 2: June Solstice			
	Latitude (°)	Angle of insolation (°)	Illumination (lux)
Arctic Circle			
Tropic of Cancer			
Equator			
Tropic of Capricorn			
Antarctic Circle			

ANALYSIS QUESTIONS

1. Click or tap the vertical axis label and adjust the columns to display the data for the December and June solstices. Using the graph, explain any patterns you notice between the December and June solstice data.

2. Disconnect or turn off the light sensor. Then, start a new file in Graphical Analysis and select Manual Entry. Enter your data for angle of insolation and illumination, and then adjust the graph axes to create a graph representing the relationship between angle of insolation and illumination. Using the graph, explain the relationship between the angle of insolation and illumination.

3. During which time of year is the sunlight more direct in the Northern Hemisphere? Explain.

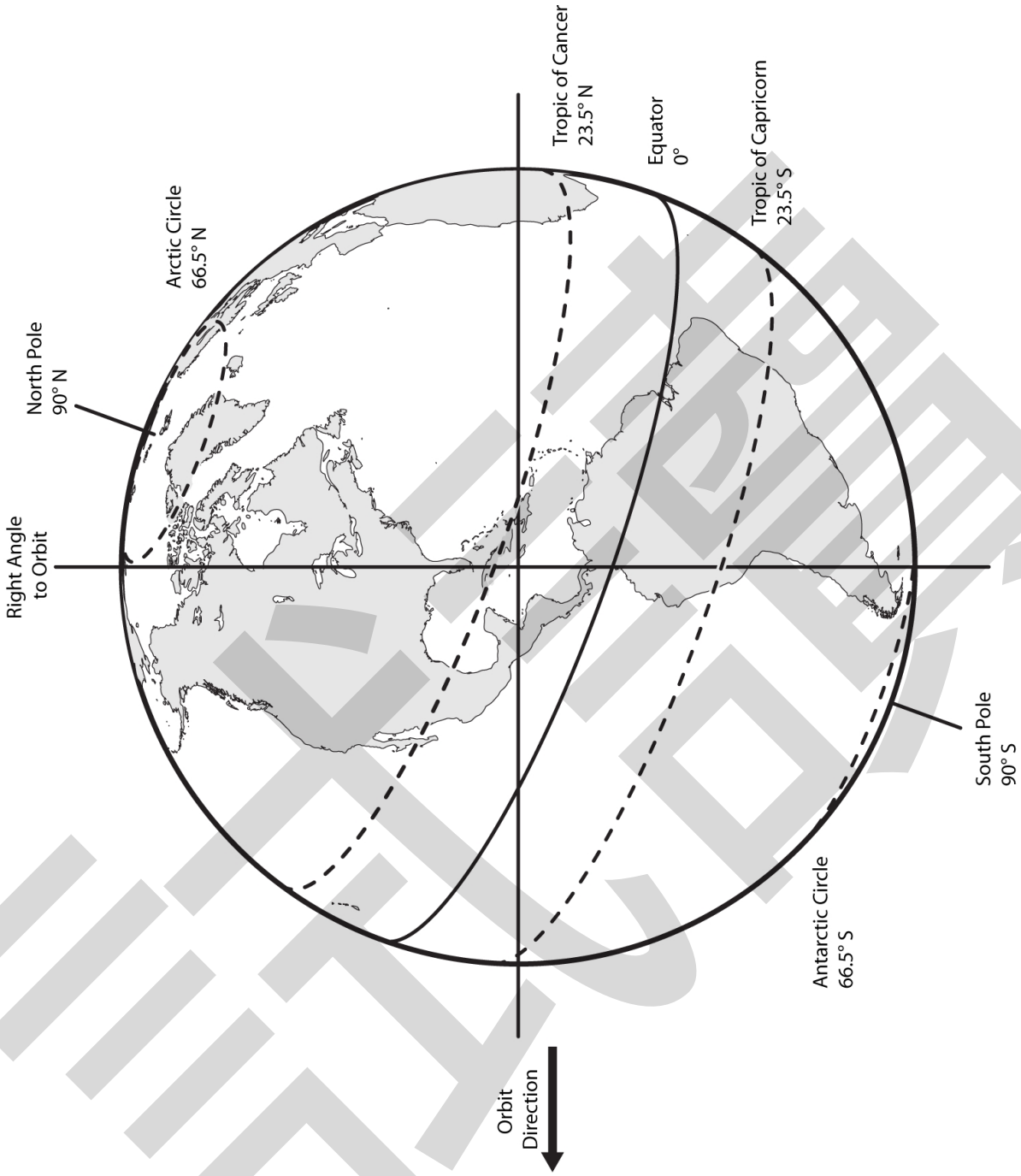
4. Describe what you would expect the illumination data to look like during the spring and autumn equinox. Draw a graph to support your description.

5. How does the amount of solar radiation affect the weather and climate?

6. What other factors affect the weather in a region?

EXTENSION

Repeat the experiment using a Surface Temperature Sensor at the different latitudes to measure how the temperature differs at each.


Right Angle
to Orbit
North Pole
90° N
Arctic Circle
66.5° N
Tropic of Cancer
23.5° N
Equator
0°
Tropic of Capricorn
23.5° S
Orbit
Direction
Antarctic Circle
66.5° S
South Pole
90° S

What Causes Land and Sea Breezes?

Land and sea breezes are phenomena that are often found near large lakes and coastlines due to the uneven heating of the different surfaces (land *vs*. water) throughout the day. Winds are often named for the direction they blow from, so land breezes blow from the land to the water while sea breezes blow from the water to the land. A similar phenomenon also exists between mountains and valleys.

In Part I of this experiment, you will expose sand and water to a light source representing the Sun. You will monitor the temperature of the sand and the water and compare their warming behaviors. In Part II, you will monitor the temperature as warm sand and water cool. This simulates the situation when the sun goes down in the evening. You will then apply your results to local weather patterns.

OBJECTIVES

- Use a temperature sensor to measure the temperature of land and water.
- Calculate temperature changes.
- Apply your results to local weather patterns.
- Predict the occurrence of land and sea breezes.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis app
2 Go Direct Surface Temperature Sensors
2 petri dishes or pans
sand
water
ruler
tape
lamp with 100 W equivalent bulb

PROCEDURE

Part I Heating sand and water

1. Launch Graphical Analysis. Connect both Go Direct Surface Temperature Sensors to your Chromebook, computer, or mobile device.

2. Set up the data-collection mode.
   a. Click or tap Mode to open Data Collection Settings.
   b. Change End Collection to 600 seconds.
   c. Click or tap Done.

3. Tape each sensor to the bottom of a petri dish. The thermistor, which is located at the end of the wire, should be at the center of the petri dish (see Figure 1). Make sure the tape does not cover the thermistor.

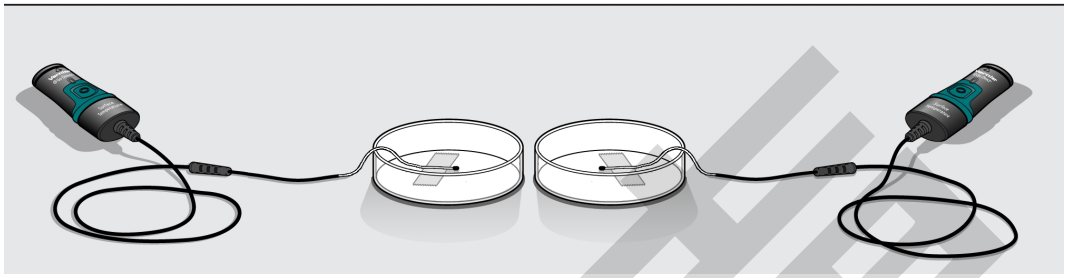


Figure 1

4. Fill one petri dish with sand 1.0 cm deep and the other petri dish with water 1.0 cm deep.

5. Position a light bulb directly over the boundary between the two dishes, with the end of the bulb approximately 10 cm above the surface of the sand and water, as shown in Figure 2. The bulb should be the same distance from both thermistors.

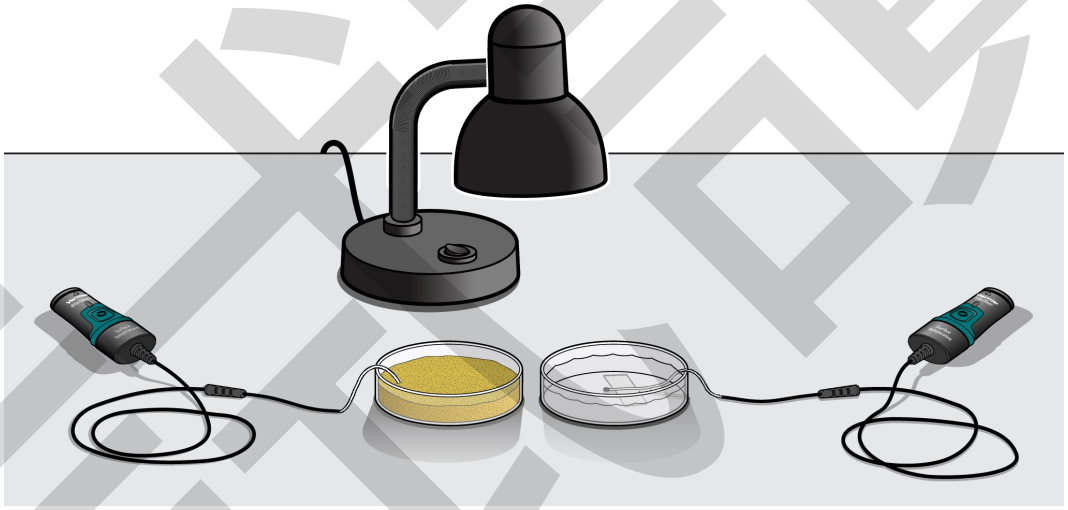


Figure 2

6. Start data collection and turn on the light.

7. When data collection is complete, turn the light off.

8. Record your beginning and final temperatures in the data table.
   a. To examine the data pairs on the displayed graph, click or tap any data point. Click or tap the data point at 0 seconds, and record the temperature values at 0 seconds for both sensors in the data table (to the nearest 0.1°C). **Note**: You can also adjust the Examine line by dragging the line.
   b. Click or tap the data point at 600 seconds. Record the temperature values in the data table (to the nearest 0.1°C).

9. Apply a linear curve fit to determine the rate of temperature change.
   a. Click or tap Graph Tools, , and choose Apply Curve Fit.
   b. Linear is the default curve fit. Click or tap Apply to apply a linear curve fit.
   c. Record the slope, *m*, as the rate of temperature change in the data table.
   d. Dismiss the Curve Fit box.

Part II Cooling sand and water

10. Note the temperature readings displayed on the screen. When the temperatures stop rising, start data collection.

11. When data collection is complete, repeat Steps 8 and 9 to record the beginning and final temperatures and the rate of temperature change for both sensors.

DATA

Table 1				
	Part I		Part II	
	Sand	Water	Sand	Water
Maximum temperature (°C)				
Minimum temperature (°C)				
Temperature change (°C)				
Rate of temperature change (°C/s)				

Table 2		
	Sand	Water
Temperature at 2000 s (°C)		

PROCESSING THE DATA

1. Subtract to find the temperature changes for each probe for both parts, and record the values in Table 1.

2. Use the Interpolate tool to extrapolate out to 2000 s for Part II data.
   a. You will use a graph of the Part II temperature vs. time data for this step. If necessary, click or tap the y-axis and select only Part II data (Data Set 2).
   b. Click or tap Graph Tools, , and choose Edit Graph Options.
   c. Change the Right x-axis range to **2000** and the Bottom y-axis range to **0**, if necessary.
   d. Close Graph Options.
   e. Click or tap Graph Tools, , and choose Apply Curve Fit.
   f. Select Linear as the curve fit. Click or tap Apply.

g. Click or tap Graph Tools, , and turn on Interpolate.

h. Click or tap the graph to dismiss the menu, and then use the Interpolate tool to determine the value for both sensors at 2000 s. Enter the values in Table 2. **Note**: You can also adjust the Interpolation line by dragging the line.

ANALYSIS QUESTIONS

Part I

1. According to your data, which material was warmed faster by the "sun," the water or the sand?

2. As surface materials are warmed by the sun, they in turn warm the air above them. As the sun shines, would you predict that the air is warmer above the sand or the water?

3. Use your data and previous knowledge to respond to the following prompts.
   a. Based on your answer to Question 3, place arrowheads on the two vertical lines in Figure 3 indicating the general direction of air movement over the sand and the water on a sunny day.

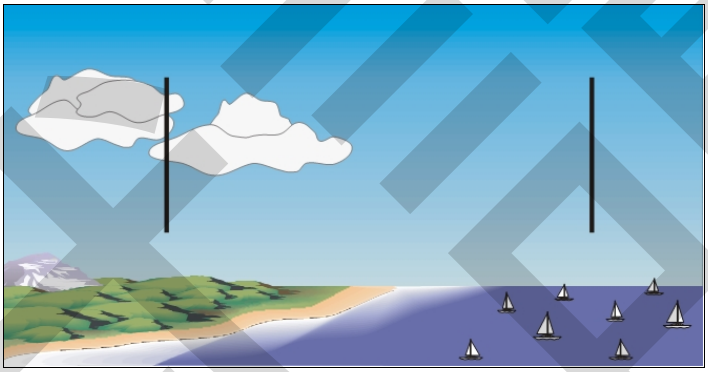


Figure 3 A sunny day at the beach

   b. The two vertical arrows you have drawn form the basis of a circular convection current. Now draw two horizontal arrows that complete the path of this convection current on Figure 3.

4. Imagine yourself standing on the beach in the diagram above. According to the arrows you drew, where would the breeze be coming from? Is this a sea breeze or a land breeze?

Part II

5. According to your data, which material cooled faster, the water or the sand?

6. Why was it helpful to use the Interpolate tool to extrapolate your data? What did it show?

7. As surface materials cool, they in turn cool the air above them. After the sun goes down and the warm surfaces cool, would you predict that the air is warmer above the sand or the water?

8. Use Figure 4 to complete the following tasks.
   a. Based on your answer to Question 7, place arrowheads on the two vertical lines in the diagram indicating the general direction of air movement over the sand and the water after the sun goes down.

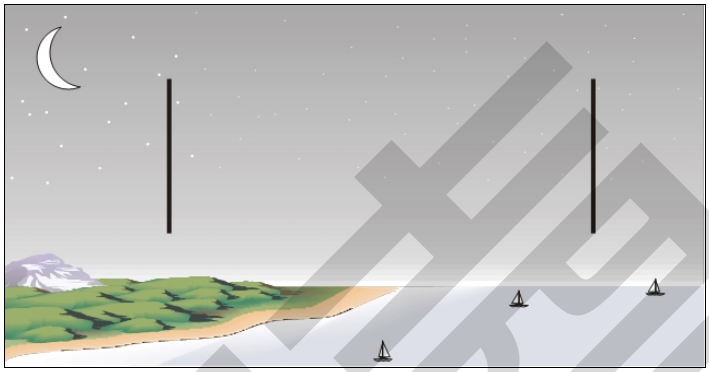


Figure 4 An evening at the beach

   b. The two vertical arrows you have drawn form the basis of a circular convection current. Draw two horizontal arrows that complete the path of this convection current on Figure 4.

9. Imagine yourself standing on the beach in the diagram above. According to the arrows you drew, where would the breeze be coming from? Is this a sea breeze or a land breeze?

10. What time of year would you expect land and sea breezes to be stronger? Why?

EXTENSIONS

1. Compare the heating rates of different-colored sands or soils.

2. Compare the heating and cooling rates of dry and wet sand.