Lab 10 Sunlight Intensity and Reflectivity

Name: ______________________ Lab Partner(s): ______________________

Driving Question

Air temperatures near the earth's surface result largely from an interplay of the sun's incoming energy and the absorption, reflection, and radiation of that energy by materials on the earth's surface.

- What is the effect of the absorption, reflection, and radiation of the sun's energy by different materials on the earth's surface air temperatures?
- What are characteristics of materials that best reflect the sun's energy and that best absorb and radiate the sun's energy?

Background

The air temperature near the earth's surface depends primarily on two things: the amount of energy provided by the sun and the amount of energy the earth is radiating. When these two factors are added together, the total energy is greatest shortly after the time of greatest sunlight intensity. On a sunny day with little wind, the greatest intensity of sunlight occurs around mid day. However, typically, the hottest part of the day generally occurs one to several hours later.

The amount of heat the earth's surface can absorb and subsequently radiate depends on the composition of the materials comprising the surface. Dark, rough materials absorb greater amounts of incoming solar radiation and therefore will radiate more energy. Conversely, light-colored, smooth materials reflect greater amounts of solar radiation and as a result have less energy to radiate. The reflectivity of a surface is its albedo. The higher the albedo, the more light is reflected and the less energy is absorbed.

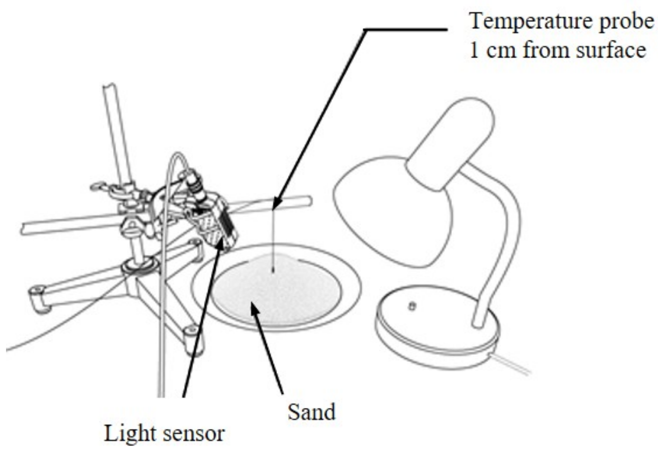
Materials and Equipment

- Light sensor
- Rod and clamp
- Temperature sensor and fast temperature sensor
- White sand, 500 g
- Dark sand, 500 g
- White rock, 500 g
- Dark rock, 500 g
- Scale (1 per class)
- High intensity incandescent lamp (150 W)
- Large disposable plate
- Tripod base and support rod
- Small cardboard box, $(20 \text{ cm})^3$ or larger
- Three-finger clamp
- Tape
- Paper and marking pen
- Scissors

Procedure

Part 1: Measuring reflection and radiation of sand and rock

1. Open *SPARKvue* and build a page with one graph.
2. Connect the light sensor and temperature probe to the data collection system.
3. Display a graph with both Temperature and Solar Iraadiance readings on the y-axis and Time on the x-axis.
4. Put 500 g of white sand in a large plate.
5. Place the lamp on one side of the plate so it will shine down into it at about a 60° angle.
6. Mount the light sensor on the tripod base and rod stand, using the three-finger clamp. Position it on the other side of the plate, directly opposite the light and angled at approximately the same angle as the light source towards the plate.
7. Set up the temperature probe so it hangs about 1 cm above the surface of the sand.



8. Which material do you predict will have the greatest albedo? Which the least?

9. Which material do you predict will absorb the most heat from the light energy?

10. Which material do you predict will radiate the most heat after the light is turned off?

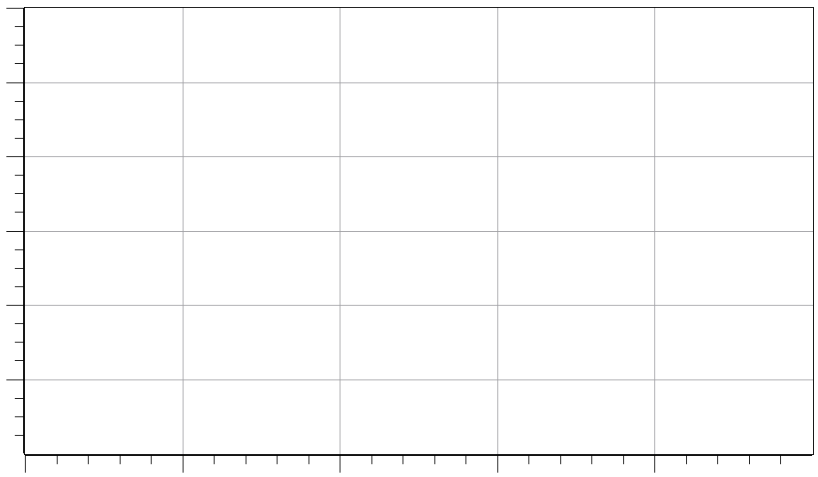
11. Are you measuring direct light or reflected light?

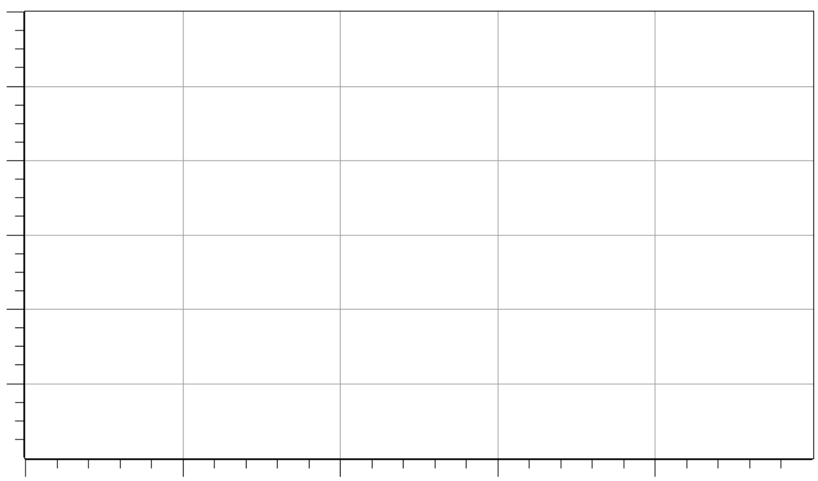
12. Turn on the light.
13. After 30 seconds, start data recording.
14. After 60 seconds, turn the light off. Do not stop recording data.
15. Record data for an additional 180 seconds (for a total of 240 seconds).
16. Put the sand back into the container.
17. Name your data run.
18. Repeat this procedure for the remaining materials: dark sand, white rock, and dark rock. Note: Exercise care to keep the positions of the light, plate, temperature sensor, and light sensor constant throughout the testing of the four materials.
19. View the statistics for each graph, select the appropriate data points on each data run, and record the mean values that are called for in Table 1.

Table 1: Reflection and radiation of sand and rock

Material	Mean Reflected Light Intensity (W/m^2)	Change in Temperature (On→Off) (°C)
White Sand		
Dark Sand		
White Rock		
Dark Rock		

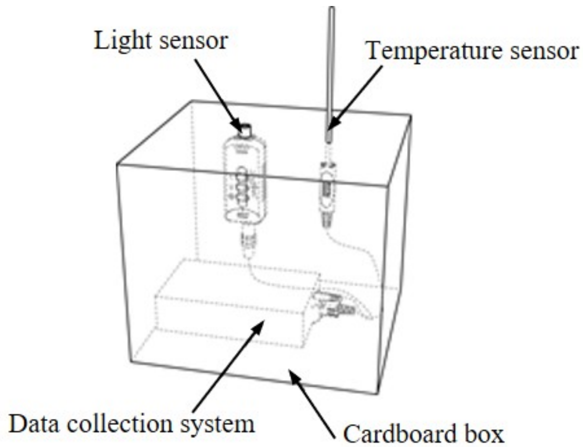
20. Sketch parameter (light intensity, temperature) versus time graphs of your data for the four experimental conditions. Label your four runs, the overall graphs, the x-axes, and the y-axes. Include units and scales on the axes.





Part 2: Measuring sunlight intensity and the earth's reflectivity

1. Make an outdoor equipment station: Cut one holes in the bottom of a small cardboard box such that a stainless steel temperature sensor will be held snuggly in it.



2. Set up remote logging
   (a) Open SPARKvue, or select Main Menu and select Start New Experiment.
   (b) Click Remote Logging
   (c) Turn on the sensor. In the list of available devices, click the sensor which matches your sensor's device ID.
   (d) Configure remote logging for each sensor:
      i. Select a sensor to configure from the Sensor menu.
      ii. Toggle Sensor Enabled to ON.
      iii. Set the Sample Rate using the left and right arrows to 1 sample per minute. Make sure your data collection system is fully charged. Toggle Common Sample Rate to Off to set different sample rates for each sensor.
      iv. Optional: Toggle Sensor Button Deferred Logging to On to make the sensor wait to begin data logging until you press the sensor's power button. Data logging begins immediately after you click OK, or after you press the power button on the sensor if you selected Sensor Button Deferred Logging. The Bluetooth Status LED blinks yellow and green until data logging begins. When the sensor starts logging data, the Bluetooth Status LED blinks yellow.
3. Make a portable experiment station
   (a) Turn the box upside down
   (b) Thread the light and temperature sensors through the holes until they fit securely, and point straight up in the air. Use tape if necessary to help secure them.
4. Make a sign that says:

   DO NOT DISTURB! EXPERIMENT IN PROGRESS.

   CONTACT: [YOUR NAME].

   THIS EXPERIMENT IS BEING CONDUCTED FROM [DATE] [TIME] TO [DATE] [TIME].
5. Carry the portable experiment station, sign, and tape outside. Find a location with the following characteristics:
   - It is a safe place to leave the experiment station;

- It will receive full sun all day with no shading;
- It is not near (within 5 meters) a building or on pavement;
- The box will not get wet from sprinklers.

6. What time of day do you predict the intensity of insolation will be the greatest?

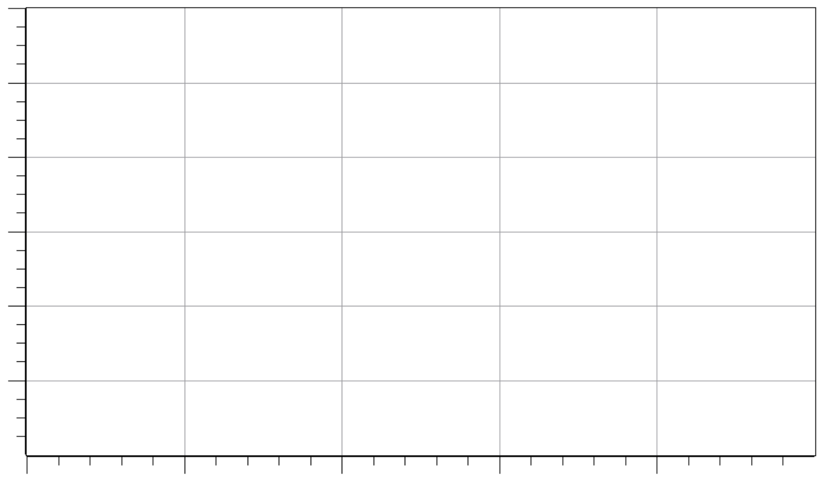
7. What time of day do you predict the air temperature will be the greatest?

8. Start data recording. Record your starting time in Table 2.
9. Carefully enclose the data collection system inside the box using tape to hold the flaps closed.
10. Place the box in the test location. Make sure the sensors are still pointing straight up.
11. Record data until late afternoon or evening. Then, stop data recording, save your experiment, and clean up according to your instructor's directions.
12. Find the coordinate values for the maximum temperature and light intensity on the graph, and complete Table 2.

Table 2: Reflection and radiation of sand and rock

	Start Time	Greatest Value	Seconds from Start When Maximum Occurred	Time of Day
Light Intensity (Wm^{-2})				
Temperature (°C)				

13. Sketch a parameter versus time graph of your data for the two experimental variables. Use a key to differentiate your two variables. Label the overall graph, the x-axis, the y-axis, and include units on your axes.



Analysis Questions

Part 1: Measuring reflection and radiation of sand and rock

1. Compare your predictions with your results.

2. What were the dependent variables in this experiment? The independent variable?

3. Why were you careful to leave the same amount of space between each material and the light sensor, temperature sensor, and light source for each data collection?

4. Which characteristics of the materials make them good reflectors?

5. What is the relationship between the magnitude of the albedo of the material and the final air temperature?

6. What happens to the light that is not reflected? What happens to this energy? How might this occurrence affect daily temperatures on the earth's surface?

Part 2: Measuring sunlight intensity and the earth's reflectivity

1. Does your data support your predictions? Explain.

2. Explain how the warmest temperature of the day could be in the late afternoon when the sun's greatest intensity is earlier in the day.

Synthesis Questions

Use available resources to help you answer the following questions.

1. Discuss what happens to the energy in sunlight when it strikes surfaces that have a high albedo.

2. Discuss what happens to the energy in sunlight when it strikes surfaces that have a low albedo.

3. Explain how the warmest temperature of the year could be after the date when the sun's greatest intensity occurs.

4. What type of material would you use to make a solar heater for a swimming pool? Why?

5. What type of material would you use to make summer curtains for your home windows? Why?

6. You want to build a new home using energy efficient passive solar technology. Since you live in Columbus, Ohio, you want your house to be cool in the summer and warm in the winter. Answer the following questions:

   (a) At latitudes above the Tropic of Cancer and below the Tropic of Capricorn, how does the angle of the sun change with the seasons? How would you use the difference to help you with the design of your new home?

(b) What are two ways to enhance solar absorption in the winter?

(c) What are two ways to reduce solar absorption in the summer?

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. Which of the following best quantifies how reflective a surface is?
   - A. Light intensity
   - B. Albedo
   - C. Absorption
   - D. Angle of incidence
   - E. Temperature
2. Compared with a material with a high albedo, a material with a low albedo:
   - A. Absorbs more solar energy
   - B. Reflects more solar energy
   - C. Reflects less solar energy
   - D. Emits more infrared radiation
   - E. Both A and C
   - F. Both B and D