Title
Lab#7: Albedo/Angle of Incidence

Questions
What is albedo? Does the albedo change from surface to surface? How does albedo affect the warming of the atmosphere? Can a change in the Earth's average albedo affect "Global Warming"? Why is it colder in the winter in the Northern Hemisphere even though the Earth is closer to the Sun? Can the angle at which light strikes a surface determine the amount of energy that that surface will absorb? What objects/materials are affected by albedo? Can albedo be used intentionally to cool or heat an object?

Overview
The angle at which light strikes a surface is a bigger factor to the heating of that surface than is the distance from the light source to the surface. The Earth/Sun relationship is a perfect example of this (winter in the Northern Hemisphere even though the Earth is closer to the Sun). An experiment to show the amount of heating of a surface relative to the angle at which light rays strike a surface is easy to perform.

On US ITASE 99 an ice storage container, mounted on a Berko sled, was hauled from sampling site to sampling site in which ice cores and snow samples were stored. The container, approximately 4 meters wide x 6 meters long x 3 meter high, was painted white to create a passive cooling storage container. This storage unit was able to maintain interior temperatures of below zero and was adequate for the locations traversed in 1999. Future US ITASE expeditions are hoping to have an actively cooled unit. Because of the high albedo of white surfaces the ice storage unit was able to keep the ice cores from melting/sublimating. If this passive ice storage unit was painted a different color than white it would have been ineffective and the ice cores would have melted/blimated.

Grade Level
5^{th} – 9^{th}

Objectives
In this activity students will:
1. Measure the ratio of angle of incidence to heating.
2. Experiment with changes in albedo and heating.
3. Understand how a change in the average albedo of the Earth's surface can affect a change in "Global Warming".

National Standards
Transfer of Energy
Earth in the Solar System

NH Standards

4b. Students will demonstrate an increasing ability to understand that the Earth is a complex planet with five interacting systems, which consists of the solid earth (lithosphere), air (atmosphere), water (hydrosphere), ice (cryosphere), and life (biosphere).
5c. Students will demonstrate an increasing ability to understand the relationships among different types and forms of energy.
5g. Students will demonstrate an increasing understanding that heat is the product of many natural processes.
6a. Students will demonstrate an increasing ability to recognize parts of any object or system, and understand how the parts interrelate in the operation of that object or system.

Teacher Preparation

Materials (assume 2 students per group)

For each group:
2 - 6" long pieces of 2" X 4" lumber
2 standard size pieces of black construction paper
1 standard size piece of white construction paper
2 glass standard thermometers (alcohol thermometers are safer and accurate enough for this exercise)
1 protractor
tape or stapler

Time Frame

2 (45 minute) class periods

TEACHING SEQUENCE

Engagement and Explanation

To test angle of incidence vs. heating

1. Have each group set-up their 2 blocks of wood by stapling or taping the pieces of black construction paper to the wood. On one block, on the opposite side of the black construction paper, staple or tape the white construction paper. Leave a little space between the paper and the wood, enough to insert the thermometers. Support each block of wood on a table so that each is at a different angle. (The greater the difference in the angles of the two blocks of wood, the greater the difference in heating). See figure 1-.
2. Record the initial temperature of the blocks/paper. The temperatures should be the same at room temperature. Any difference may be from the two thermometers. If this is the case then students need to understand that the two thermometers are still useable but that they are recording the change in temperature from the initial temperature displayed on each thermometer. The graph of the data should reflect the amount of temperature change and the rate of change.

3. Turn on the light source and position the two blocks at the same distance from the light source but at two different angles.
4. Record the temperature of each thermometer every 3 minutes. Record on spreadsheet (Figure 2).
5. At the end of 15 minutes turn off the light source and graph the data (Figure 3).
6. Answer evaluation questions.

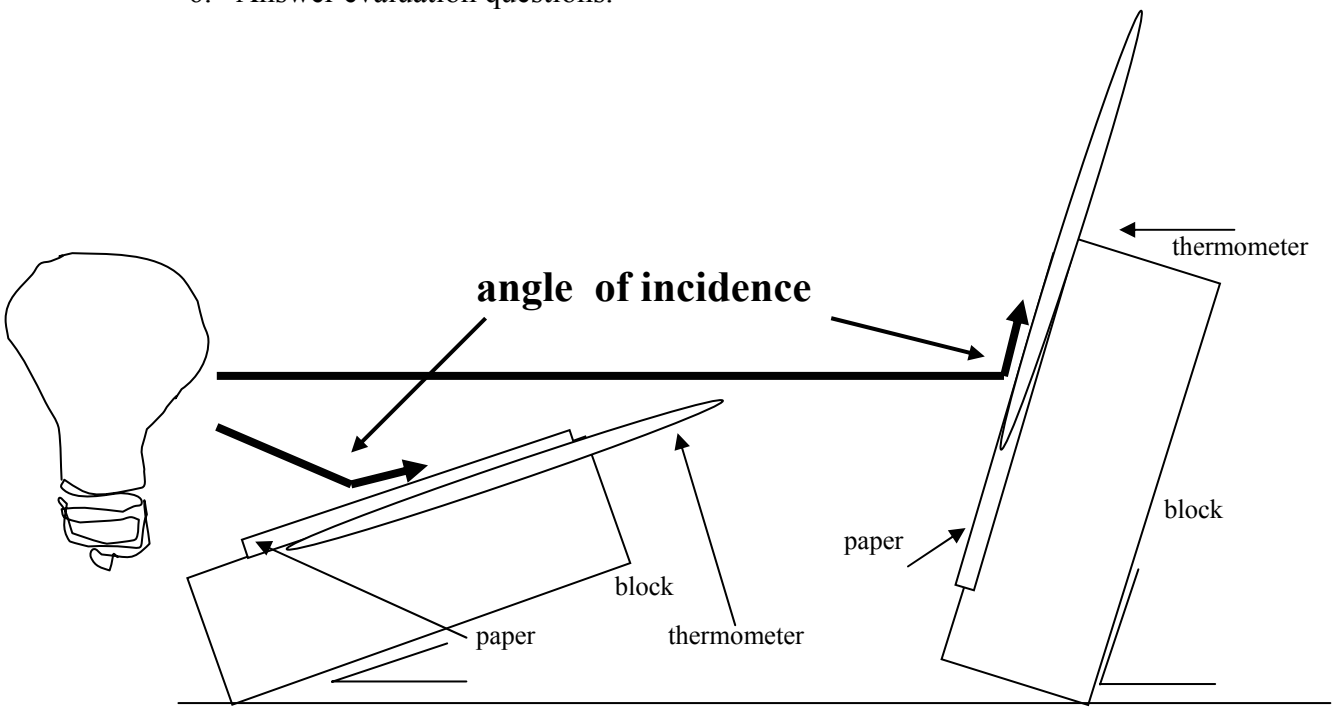

Figure 1: Experiment set-up.

To test Albedo:
Perform the same experiment as above but this time with the two blocks of wood at the same angle (best results occur around 90 degrees) with one black and one white side facing the light source. Insert the thermometers, record temperature on a spreadsheet every 3 minutes, stop experiment after 15 minutes, graph results.

Time

	0	3	6	9	12	15
White						
Black						

Temperature in degrees Celsius

Figure 2: Spreadsheet record of temperature change.

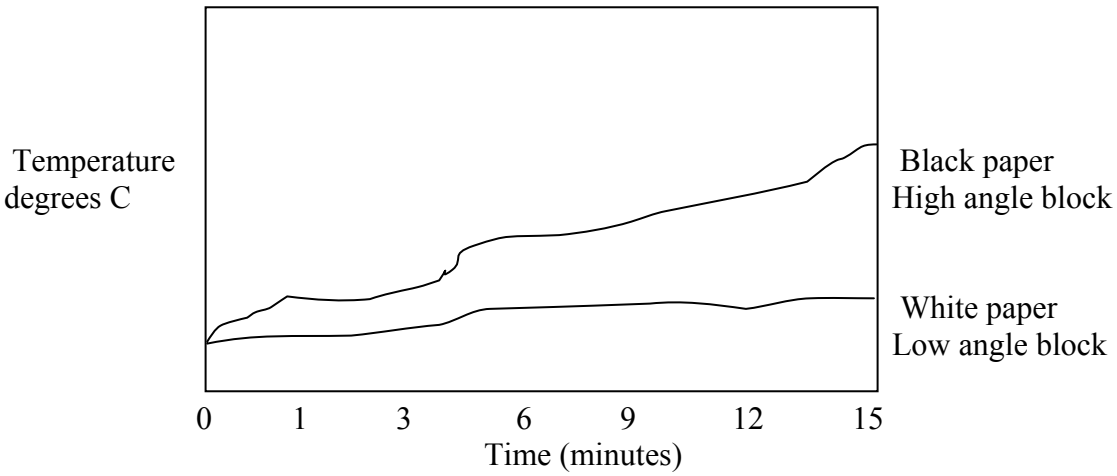

Figure 3: Graph of temperature change (albedo).
Similar graph for angle of incidence.

Elaboration

Try each of the above two experiments and substitute: different types of material, i.e. different textured paper, and different colored paper in place of the black and white construction paper; different distances from the light source; and different angles of incidence. Students should compare their results with other groups in the class and even go back and test other experiment variations.

Exchange

Have the students go outside and measure the angle of the sun using the shadow from a stick, "astrolab", sectant, or other device. Calculate the angle of the Sun at other seasons of the year and compare that to the average temperature of each season.
List a number of natural materials that occur on the surface of the Earth and place them in order of their relative albedo (grass, sand, water, ice, etc).

Evaluation-questions

1. Which block of wood heated up the fastest?
2. Which block of wood had the highest (greatest change) temperature after 15 minutes?
3. How does this data explain the difference in temperature on the Earth during the summer and winter?

4. How much do you think the albedo of ice differs from that of dirt? How does it compare to the white and black paper?
5. What does an albedo of 100% mean? 0%?
6. What natural and anthropogenic (man-made) changes are taking place on the surface of the Earth that would change albedo? How can a change in albedo affect Global Warming?
7. How does the energy absorbed by the Earth warm the atmosphere?
8. Where do the solar rays go that are reflected by the surface of the Earth?
9. Does albedo have a positive feedback effect? (If ice reflects enough light back into space to cool temperatures in the troposphere, does it create more glacial ice which reflects more light which creates more glacial ice and so on).
10. Standing over which type of surface would you get the worst sunburn?
11. Which is more important to heating, distance from the energy source or the angle of incidence?
12. At what angle of incidence is heating most effective?
13. If you lived in New Hampshire and you placed solar panels on your home, at what angle do you tilt the solar panels for maximum effectiveness in winter? Summer?
14. If Arctic and Antarctic ice melts away, how will it affect the Earth's average albedo?

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Resources

http://zebu.uoregon.edu/~js/glossary/albedo.html
http://www-cger.nies.go.jp/grid-e/gridtxt/grid7.html
http://bigmac.cee.mtu.edu/public_html/classes/ce459/projects/t16/earthbal.htm
http://www.secretsoftheice.org

Background

Glossary

Albedo: The amount of light that is reflected by a surface measured in percent.
Angle of incidence: The angle between the incident ray of light and the normal to the surface (surface of wooden block).
Berko Sled: Steel sled (4" x 6') used in Antarctica to transport equipment.
Sublimate: When a solid goes directly to the gas phase.