Measuring the effectiveness of sunshades

Materials

- 2 11.5 oz. Coffee cans
- Bucket to hold ice-water mixture
- Water and enough ice to fill the bucket and keep water cold
- Thermometer
- Stopwatch
- Stir stick
- Strainer (optional)
- Tape
- Standard ruler (30.5 cm, 12 inches)
- Calculator
- Scale
- Protractor

You will now test your sunshade design.

1. Get in your groups and gather materials needed. If your shade requires assembly, do that now.

2. Fill a bucket almost to the top with ice. Add cold water until it covers the ice. Put the thermometer in the water and wait until the temperature reads 0°C. You may need to stir the ice water a couple of times to ensure that the water is the same temperature throughout the bucket. (Be sure that you use a stir stick and not the thermometer to stir.)

3. For this experiment, you will have two coffee cans: one will be the control, with no lid, and the other will use your sunshade. Label one can "Control" and the other "Shade."

4. Weigh the coffee cans on the scale. Fill the control can about one-third of the way with ice, and weigh again. Record these values on Page 3. Repeat for the shade can. (It is not necessary to have exactly the same amount of ice in each can.)

5. Fill each coffee can with water from the ice bucket about two-thirds full, making sure the water covers the ice. Be careful to not get extra ice into the can.

6. Attach your shade to the top of the can labeled "Shade."

7. Bring the cans to the experiment site (quickly, to ensure that the ice melts as a result of the sunlight, and not the time it sits at room temperature). Prop the cans so that the tops are facing the sunlight. Refer to Figure S1 of Student Worksheet 1 for the set-up design. Start the stopwatch.

WARNING

Do *not* look directly at the Sun!

Looking for even a few seconds can cause permanent damage to the eyes! Note that sunglasses do *not* provide an adequate safeguard against looking directly at the Sun.

So remember to ***never*** **look directly at the Sun!**

8. Check your control every 10 minutes. While you are waiting for the ice to melt, you can measure the angle of the Sun in the sky and the angle of your cans, steps 9 and 10 below.

9. Measure the angle of the position of the Sun in the sky. To do this, stand a 30.5-cm (12-inch) ruler up straight with the short edge flat on the ground. With a meter stick, measure the length of its shadow in centimeters. Refer to Figure S2 as you make your calculations.

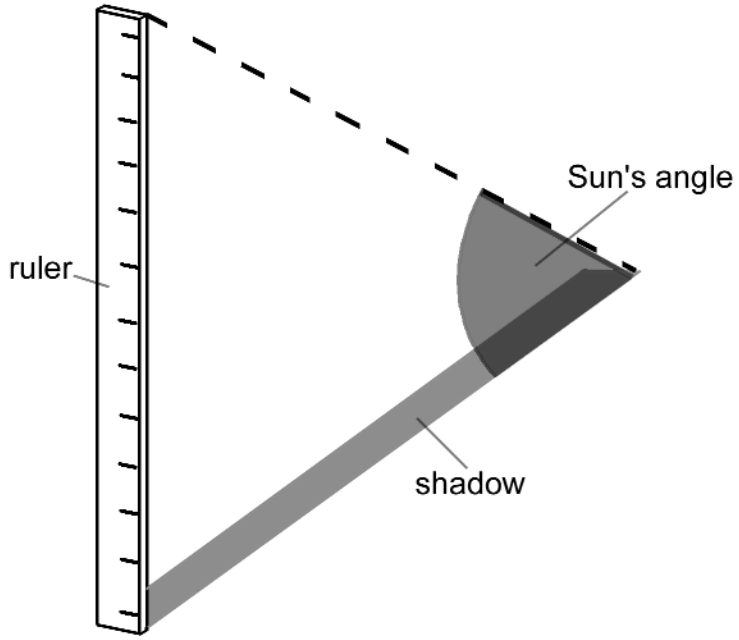

Figure S2: Calculating the Sun's angle.

Measured shadow length:
_____ cm

tangent ϕ = 30.5 cm / x

Where ϕ is the Sun's angle in the sky, and x is the length of the shadow that you measured (in centimeters).

Therefore,

ϕ = arctan [30.5 / x]

ϕ = _____ degrees

10. Measure the angle that your cans are inclined (α) using your protractor.

α = _____ degrees

11. When about one-third of the ice in the control can appears to have melted (or 30 minutes has passed, whichever comes first), remove both cans from the Sun and stop the stopwatch. Remove the sunshade from the can, and pour the water out of the can so that only the ice remains. You can use a strainer placed on top of the can when you remove the water, to make sure the ice remains inside. Weigh the can with ice. Remove ice from the can and weigh the empty can again. Record your results in the chart. Repeat with the control can.

Record your results here.

Time of the day when you performed your experiment: _____

Angle of the Sun in the sky (from horizontal): _____

Angle of can (from horizontal): _____

Cost of shade: $ _____

In the beginning:

Control can:

Diameter of coffee can top: _____ cm

Weight of empty coffee can: _____ g

Weight of can with ice (without water): _____ g

→ Difference (Weight of ice): _____ g

Can with shade:

Weight of empty coffee can: _____ g

Weight of can with ice (without water): _____ g

→ Difference (Weight of ice): _____ g

In the end:

Time used for the experiment: _____ seconds

Control can:

Weight of can with ice (without water): _____ g

Weight of empty coffee can: _____ g

→ Difference (Weight of ice): _____ g

Can with shade:

Weight of can with ice (without water): _____ g

Weight of empty coffee can: _____ g

→ Difference (Weight of ice): _____ g

Calculating the energy used in melting the ice:

The total energy required to melt ice is given by the equation:

$Q = m \times L$

where Q = heat energy (kJ)

m = mass (kg)

L = latent heat (kJ/kg)

Latent heat ("heat of fusion") of water ice: 334 kJ/kg

Surface area of coffee can lid: _____ m^2

Use your measurements and the equation above to fill in the table below:

	Shade can	**Control can**
Mass of ice melted (kg)		
Amount of energy used (kJ)		
Energy/time used (J/s)		
Energy/s/unit area ($J/s/m^2$)		

Use the Energy / time to calculate what percent of the energy your shade kept away from the ice-water mixture:

_____

What is your cost-efficiency (the percentage of energy kept away from the shaded mixture versus the cost of the shade)? (Your units should be %/$)

_____

Interpreting the results

1. How was your coffee can angled with respect to the arriving sunlight? (This is the difference between your measured α and ϕ values.) How do you think it affected your experiment?

2. Why did you have to weigh the can before the experiment as well as after? Were your results different? Why or why not?

3. Why do you think the control can is useful? (Name at least two reasons.)

4. Why is the cost of the shade so important? Think of real-life examples where you might want to minimize the cost of a sunshade.

5. What sources of error might you have?

6. The solar constant (the amount of solar energy received by Earth) on top of the atmosphere is about 1370 $J/s/m^2$. The atmosphere reflects away or absorbs 30-50% of the radiation (depending on the cloud cover), so that the typical amount of solar radiation arriving on the surface of Earth is 700-1000 $J/s/m^2$.
a) How does the amount of energy used in melting the ice in the control (unshaded) can in your experiment compare with the solar radiation?

b) How could you explain the similarities or differences in your value based on the experiment design?

8. Scientists often have to revise their experiments after an initial try when they discover possible sources of errors and must eliminate them. How would you conduct your experiment differently if you had to do it again? Why?

9. Would you construct your shade differently if you had to do the experiment again? Why or why not?

If you would like to improve on the experiment design, describe your modifications and draw a scaled design of the new experiment setup on Page 7 of this worksheet.

Team Members: _____

_____

_____

_____

Modified Experiment Design

Describe how you plan to modify the basic experiment setup described in Figure S1 in Student Worksheet 1:

_____

_____

_____

_____

Explain why you think this experiment setup will work better:

_____

_____

_____

_____

_____

Design drawing for your modified experiment setup

The scale of your drawing: _____