Heating Materials by Radiation

Throughout the guide, teaching tips are in red.

Activity Description & Estimated Class Time

In this 1-day activity, students compare temperature changes in direct sunlight with temperature changes in shade. In general, students record a difference of about 10 degrees as a result of radiant heat from the sun. Next, students receive a porous material that blocks some sunlight and lets some sunlight through. Their challenge is to use measurements of temperature change to determine how much of the direct sunlight this material blocks.

Objectives

Students will demonstrate knowledge and understanding of the following ideas and content:

- Heat energy can move from one place to another through space.
- The amount of radiation affects the amount of heat transferred.

Students demonstrate this knowledge and understanding by...

- comparing temperatures at the same time and location in the sun and in the shade,

Correlations to NC Science Standards

5.P.3.1 Explain the effects of the transfer of heat (either by direct contact or at a distance) that occurs between objects at different temperatures (conduction, convection or radiation).

Correlations to Common Core Mathematics Standards

The second part of the Grade 5 section of the Common Core Mathematics Standards explains: (2) Students develop understanding of why division procedures work based on the meaning of base-ten numerals and properties of operations. They finalize fluency with multi-digit addition, subtraction, multiplication, and division. They apply their understandings of models for decimals, decimal notation, and properties of operations to add and subtract decimals to hundredths. They develop fluency in these computations, and make reasonable estimates of their results. Students use the relationship between decimals and fractions, as well as the relationship between finite decimals and whole numbers (i.e., a finite decimal multiplied by an appropriate power of 10 is a whole number), to understand and explain why the procedures for multiplying and dividing finite decimals make sense. They compute products and quotients of decimals to hundredths efficiently and accurately.

Brief Science Background

Heat can move away from hot objects through space, by radiation. Heat comes to earth from the sun in this way. Radiant heat travels in a straight line, just as light does, and is said to “radiate.” Where heat radiation strikes, it raises the temperature of the material that absorbs it. A solid opaque object can block radiant heat in the same way that it blocks light. This is why it is cooler in the shade. Radiant heat warms the areas in sunlight and temperatures are cooler in the shade because radiant heat is blocked. We feel radiant heat at a distance, without touching its source and without warm air moving it. For example, we feel warmth on our skin when standing at a distance from a stove or a fire. We feel this without a breeze blowing warm air toward us and without making

Part 1 — Restless Heat –50 minutes

contact with the stove or fire. This heat travels by means of radiation. It is also possible to partially block radiant heat. For example, gardeners can buy 50% shade cloth, or 70% shade cloth to put over plants that need less sun .

Materials

Materials for the whole class

- 16 digital thermometers
- BLM 1 to project (to explain how to use the thermometer)
- copies of BLM 2, Heat Shadow Record sheet, one per pair
- coffee filters
- black construction paper

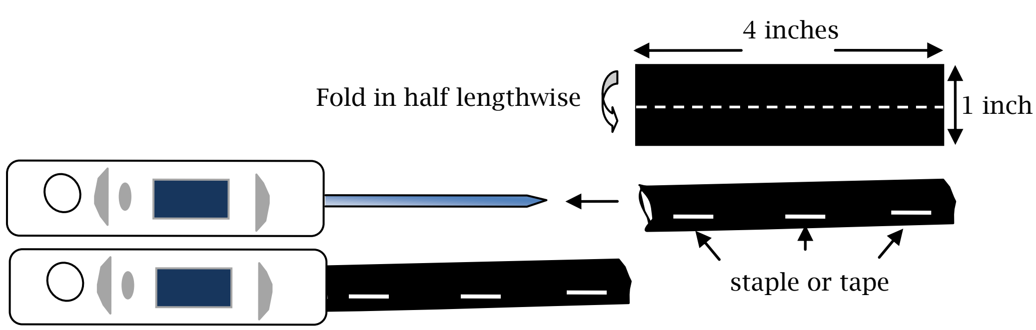
Materials for pairs of students

- BLM 2, Heat Shadow Record Sheet
- 1 coffee filter
- a digital thermometer
- a black paper sleeve
- a notebook or folder to use as shade *

* supplied by students or teacher

Preparation

1. This activity is done outdoors. Choose a clear cool day to do this if possible. Clouds skew readings if they cross the sun while students are measuring temperature. Cooler days produce slightly better results, but the activity also works on a hot day.
2. The activity can work outdoors over any surface, but it works best over grass away from buildings and cars. Hot air from sun-heated pavement, concrete, walls, or vehicles raises shade temperatures.
3. Copy a BLM 2 for every 2 teams and cut copies in half (2 sheets per copy).
4. Students need black paper sleeves to cover the thermometer probes. The sleeves reduce variations in temperature caused by breezes, and they increase the temperature range between sun and shade. Either the teacher or students can cut 1” x 4” pieces of black paper, one per team. Fold the paper in half lengthwise, and staple or tape it. There is no need to close the end.



Procedure

1. Before going outdoors, ask teams to put the sleeve over the thermometer probe and keep them there. Ask teams to turn on thermometers and set them to ˚F. BLM 1 helps to explain how to operate thermometers. Be sure every team has BLM 2 for recording and that everyone has a notebook to shade the thermometer (a sheet of paper is not enough).

2. Before teams move into the sun, say that they need to keep thermometers in direct sun the whole time. Try to move move into the sun at the same time. When they are in the sun, immediately start timing. After 2 minutes, call time. Ask everyone to record the temperature on BLM 2.

3. After teams record the temperature in the sun, ask them to shade their thermometers with a notebook on your mark. Call start and after 2 minutes call time. Ask teams to record the shade temperature on BLM 2.

4. Bring the class inside and ask teams to calculate the difference between shade and sun temperatures. Put everyone's results up for all to see. The difference will be between 6-12 degrees depending on the day.

5. Ask these questions. **Accept all answers. Avoid teaching about radiant heat at this time.**

   - Where does the heat come from that warms the thermometer in the sun?
   - Speculate how heat gets from where it originates to the thermometer.
   - Without sun shining on the shaded thermometer, where does the heat come from to warm it?

6. Ask teams to get coffee filters, look at light through them, and describe what they notice. Ask how much light they think the paper blocks. Hold a brief discussion about possible relationships between amount of light blocked and amount of cooling shade provided. **Accept all ideas.** Ask teams to record on BLM 2 a prediction of temperature in the shade of a coffee filter after 2 minutes. Ask teams to agree on and be able to explain their reasons.

7. Take the class back out and use the same procedure as before to measure the temperature in the shade of the coffee filter after 2 minutes. When teams shade with the coffee filter, ask them to keep the thermometer in the shade under the filter and not touch the filter with the black paper on the probe.

9. Bring the class back in and post temperatures in the sun, the shade of the coffee filter, and complete shade. Ask everyone to calculate the % of heat from the sun that they think the coffee filter blocked. **Let the teams struggle with how to do this. This activity is less about getting the right answer than about how to think through this type of problem. Do not give them a formula. In the end, many will arrive at something like this:**

$$\frac{\text{(full sun temp)} - \text{(coffee filter shade temp)}}{\text{(full sun temp)} - \text{(full shade temp)}} \times 100 = \text{\% of heat from the sun blocked by the filter}$$

Wrap Up

1. Ask all teams for their calculation of % of heat from the sun that they think the filter blocked.

2. Ask the class:

   - What evidence do we have that the coffee filter blocks all the heat from the sun?
   - What evidence do we have that the coffee filter blocks no heat from the sun?
   - What evidence do we have that the coffee filter blocks some heat from the sun?
   - How did your team figure the % of solar heating that the coffee filter blocked. **The problem is to represent the fraction of solar heating that the coffee filter blocked. The temperature difference between full sun and complete shade represents how much direct sun heats more than shade. This "whole" (some part of which was blocked) is the denominator of the fraction. The temperature difference between full sun and *partial* shade under the coffee filter represents the amount of heating that the coffee filter blocks. It is the "part," or numerator. To represent this fraction as %, divide the numerator by the denominator and multiply by 100.**

3. Explain radiant heat in terms of what we have seen. The sun gives off heat to things that do not touch it. There is not even a breeze to carry the heat from the sun to the earth (no air in space). Radiant heat travels the same way as light, in a straight line. Where the beam of heat radiation strikes, it raises the temperature of whatever absorbs it. A solid object can block some or all radiant heat in the same way that it would block light. Temperatures are cooler in the shade of a tree because leaves absorb and block the sun's radiant heat. We feel warmth near a stove or a fire because the heat reaches us by radiating through space.

Guided Practice

Guided Practices are similar to typical tests, but require students to reveal their thinking about content. They serve as a practice before a test and should not be graded. They are intended to expose misconceptions before an assessment and to provide opportunities for discussion, re-teaching, and for students to justify answers. They are best given as individual assignments without the manipulatives used in the activity. In that context, pose the following "test items" to the class. Ask them to write responses in notebooks.

1. A girl is sitting outside on a sunny day. She sits in the sun for awhile, and then moves to shade under a tree. Choose the statement below that describes what she would say about the temperature and gives the best reason for what she feels.

   A. The girl says she feels cooler in the sun. Under the tree, the leaves block the breeze. Direct sunlight makes no difference in temperature because the sun is very far away, and it cannot touch the girl.

   B. The girl says she feel warmer in the sun. In the sunlight, radiant heat comes from the sun to warm her skin. In the shade of the tree, the direct rays of the sun can't reach her, so she feels cooler.

C. The girl says the temperature feels the same in both places. If there were thermometers in both the sun and the shade, both would read the same. The only thing that warms the girl is the air around her, which is the same in both places.

2. Heat from a fireplace has warmed up a glass of water sitting on a nearby table. Another glass of water sitting on the table the same distance from the fire has a book between it and the fireplace. Which choice below is the best comparison between the temperatures of the two glasses and the way that the heat traveled to them?

A. The glass with the book between it and the fireplace is cooler because radiant heat from the fireplace cannot reach it. The other glass receives more radiant heat and is warmer for that reason.

B. Both glasses are the same temperature. They are both the same distance from the fireplace, so the temperature is the same for both of them. The book between the glass and the fire makes no difference.

C. The glass behind the book is warmer. The book blocks the breeze and lets that glass warm up more by convection from the air and conduction from the table. The other glass is more exposed to the air, which cools it off.

3. A gardener has covered her vegetables with 50% shade cloth so that they get some sun but not too much. On a day when the temperature in full sun is 100 ˚F and 90 ˚F in the shade, which is the best estimate of the temperature where the vegetables are?

A. 50 ˚F because 50˚F is 50% of 100˚F (the full sun temperature), and below the shade temperature

B. 95 ˚F because 5˚F is 50% of the difference between the sun and shade temperatures

C. 45 ˚F because 50˚F is 50% of 90˚F (the shade temperature), and below the

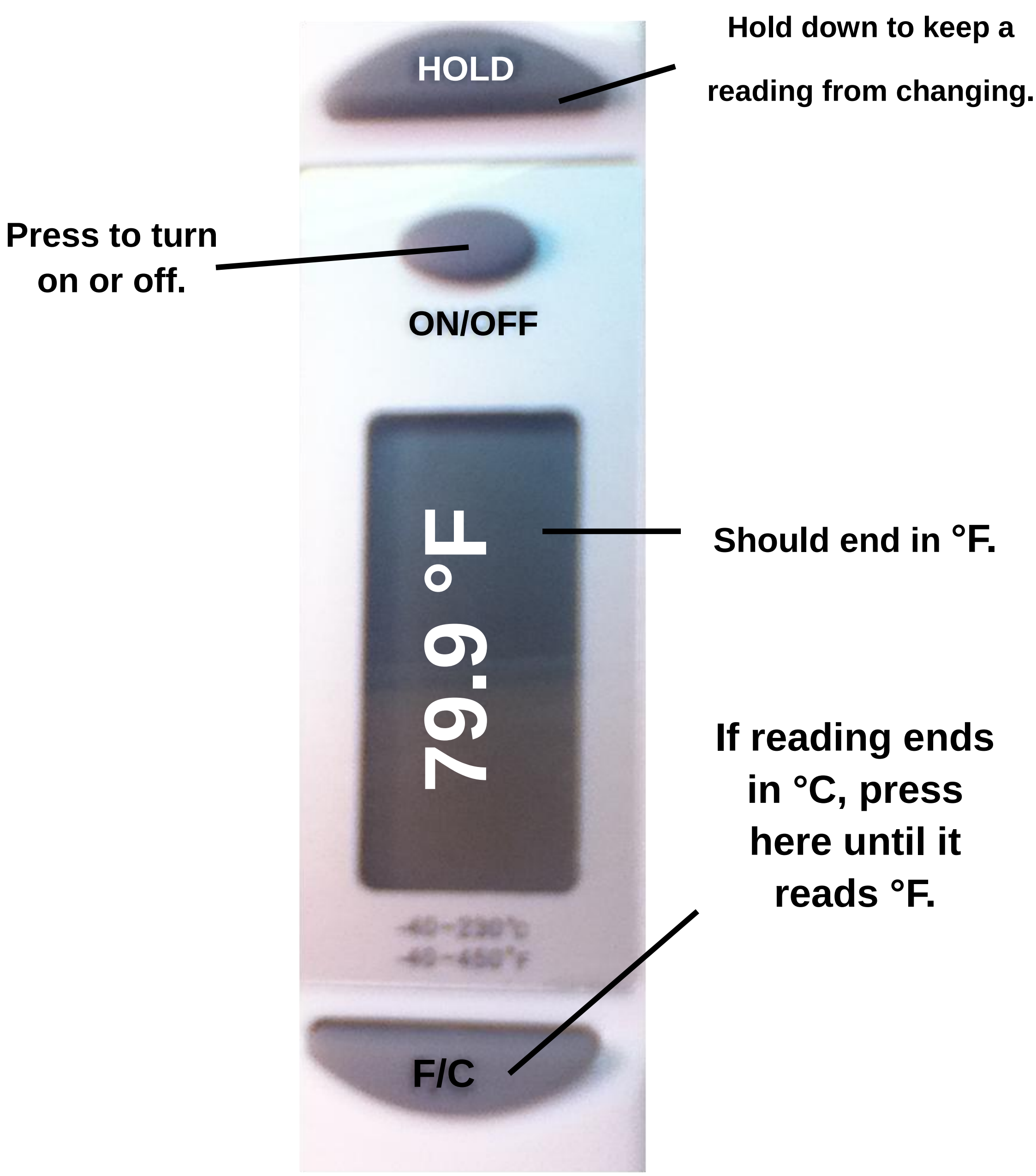
Answer Key

1. A. is incorrect because direct sunlight does make a difference in temperature even though the sun does not touch the girl. The girl is being warmed by radiant heat, which does not require contact. **B. is correct.** C is incorrect because the girl, and thermometers, would be warmer in the radiant heat from the sun.

2. A. is correct for the reason given. B. is incorrect because the book blocks radiant heat from the fire and leaves the glass behind it cooler. C. is incorrect because convection and conduction would warm or cool both glasses equally. The radiant heat from the fire would heat up the glass that is exposed to the fire.

3. A. is incorrect because the 50% shade cloth would block 50% of the temperature change between full sun and full shade, not 50% of the 100 ˚F in full sun. **B is correct for the reason given**. C. is incorrect because is incorrect because 50% shade cloth would block half of the temperature change between full sun and full shade, not 50% of the 90 ˚F in full shade.

BLM 1


HOLD
Hold down to keep a reading from changing.
Press to turn on or off.
ON/OFF
79.9 °F
Should end in °F.
If reading ends in °C, press here until it reads °F.
F/C

BLM 2 Sun and Shade Record Sheet

Names____Date________

What's the Difference Between Sun and Shade?

Temperature after 2 minutes in shade:_________________________°F

Temperature after 2 minutes in sun:__________________________°F

Temperature difference between sun and shade_________________°F

Partial Shade

Prediction of % of heating that the coffee filter blocks____________%

Temperature after 2 minutes shaded by coffee filter_____________°F

Actual % of heating that the coffee filter blocks__________________ %

Names____Date________

What's the Difference Between Sun and Shade?

Temperature after 2 minutes in shade:_________________________°F

Temperature after 2 minutes in sun:__________________________°F

Temperature difference between sun and shade_________________°F

Partial Shade

Prediction of % of heating that the coffee filter blocks____________%

Temperature after 2 minutes shaded by coffee filter_____________°F

Actual % of heating that the coffee filter blocks__________________ %

Common Student Preconceptions About This Topic

Appendix

Most children's ideas of energy are associated with living things, or linked with a force, a movement, or some kind of fuel. Children often view energy as a fluid that is an ingredient in things. Very few children view heat as a form of energy that can radiate through empty space like light. Because of this, although researchers have studied children's ideas of heat transfer through conduction, there are few studies of children's conception of radiant heat. In general, children's ideas of radiant heat do not develop much differently from their ideas of the nature of light. For Grade 5 students, it is enought to know that light and heat can interact with materials to warm them up, that this can happen without an object touching the source of heat, and that the amount of heating depends upon the amount of light reaching the object.