Heat Conduction

Throughout the guide, teaching tips are in red.

Activity Description & Estimated Class Time

This three-day activity consists of two parts. In the first part, *Hot Nail*, students take the temperature of a nail head over a two minute period while the pointed end of the nail is in hot water, then predict the temperature at the four minute mark. Next, they repeat the experience with a nail that does not touch the hot water inside the cup. The class discusses evidence for the source of the heat in the nail head and how it reached the nail head. In the second part, *Bridge Between Hot and Cold*, student teams have a cup of hot water and a cup of cold water. They measure the temperature in both cups then connect the two cups with a piece of metal and continue measuring temperatures for eight minutes. The teacher has a pair of cups hot and cold water, but these are not connected by metal. Students compare and contrast the temperature changes in a system with a heat conductor connecting hot and cold against a system with no connection between hot and cold.

Objectives

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

- Materials can conduct heat energy from one place to another.
- Materials in contact with each other can transfer heat from one object to the other.
- Materials that are not in contact with each other do not transfer heat by conduction.

Students demonstrate this knowledge and understanding by...

- arranging materials to conduct heat energy from one place to another, measuring the result, and giving reasons for temperature changes.
- Predicting temperatures along an object that is conducting heat from one place to another.

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).

Brief Science Background

Heat flows from materials at higher temperatures to materials at lower temperatures in some combination of three different ways, by convection, radiation, and conduction. This activity provides students with an experience of heat conduction and opportunities to measure temperature changes it causes. When heat moves by conduction, an area of a material that is hot warms the adjacent area, and that newly-warmed area in turn warms the area next to it. In that way, conduction "passes along" heat energy from place to place within the material. Solids, liquids, and gases all conduct heat. This process also passes heat between separate materials that touch. For example, conduction passes heat from hot tea to a spoon immersed in it. It is enough for grade 5 students to know that conduction is the transfer of heat energy within a material or between materials in direct contact. This lays groundwork for middle school and high school, when students learn about the particle theory of matter. At that time, they can better grasp conduction as mediated by molecules vibrating and colliding. It is not necessary to teach about conduction in these terms in grade 5.

Part 1 — Hot Nail

Materials

Materials for the whole class

- 1 copy per team of 3 of BLM 4, Heat Record Sheet
- 10 paper trays
- 1 hot pot
- 1 large thermos
- 20 4-oz foam cups
- 20 plastic lids for 4-oz foam cups
- 10 1-oz cup lids
- 10 8-oz foam cups (save these for a later activity)
- 20 nails
- 10 digital thermometers
- 2 dish pans

Materials for teams of 3 students

- 1 copy of BLM 4, Heat Record Sheet
- 1 nail to be handed out in Part B
- 1 8-oz foam cup to give out in Part B
- 1 additional cup half full of hot water to give out in Part B

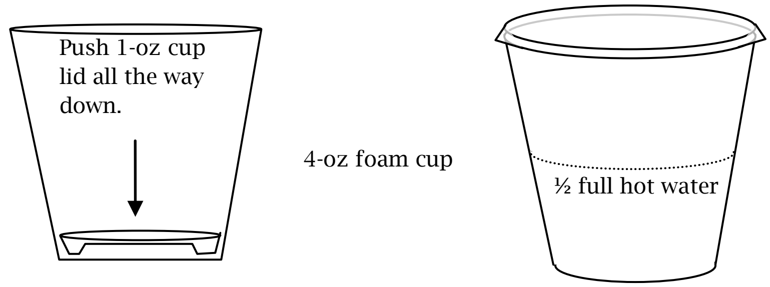
A paper tray containing the following:

- 1 4-oz foam cup with a 1-oz cup lid pressed to the bottom, ½ full of hot water
- 1 lid for a 4-oz foam cup (on the cup half full of hot water)
- one nail
- a digital thermometer

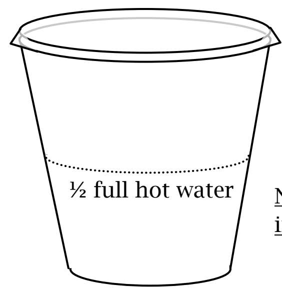
Preparation

1. Heat water 30 minutes before class. Pour 2 hot pots into the thermos (8-10 minutes per pot to heat). Adjust temperature in the thermos to about 130˚F (hotter can burn).
2. One per team, push a 1-oz cup lid to the bottom of a 4-oz foam cup (easier with open side of 1-oz lid up). The lid prevents the nail from puncturing the cup. Just before the activity, pour the cup half full of hot water and seal it with a 4-oz cup lid.

Preparation cont.



3. During Part B of this activity, each team needs another 4-oz cup half full of freshly-poured hot water, sealed with a lid. Do not prepare these additional cups at the beginning of the activity, but be ready to pour and cap them just before Part B of the procedure. Also, for Part B of this activity, have a larger foam cup and another nail available.



4. One per team, place on a paper tray 1 capped 4-oz cup half full of hot water, the nail, thermometer, and empty 8-oz foam cup. Place these where teams can get them.

Procedure Part A

1. Have teams get BLM 4, Heat Record Sheet, and the paper tray of materials. Ask everyone to turn thermometers on. Project BLM 1 to show everyone how to turn on the thermometer and set it to ˚F. Wait to read temperature until after the numbers begin to change very slowly. Project BLM 2 to show how to measure water temperature by sticking the thermometer through the lid. On BLM 2, point out measuring temperature with the edge of the angled thermometer point flat on the nail.

2. Ask teams to measure the temperatures of the nail and the water. The nail is sitting on the tray and has not yet touched the water. Ask them to use BLM 4, the Heat Record Sheet, to record these temperatures.

3. Explain that we will take temperatures of the nail head at set times, so everyone will start together when the teacher says “start.”

4. When everyone is ready, start time, ask teams to gently push their nail point down through the hole in the 4-oz cup lid to the bottom of the cup, and call “start.” Explain that you will call time after 30 seconds. At that time, everyone will record the temperature of their nail head in the blank on the Heat Record Sheet (BLM 4) marked “30 seconds.” Continue to call time at 30 second intervals, asking teams to write the temperature in the appropriate blank. At 120 seconds, keep the timer running and ask teams to predict the nail head temperature and the temperature of the water at the 4 minute mark. Ask them to write these predictions on BLM 4. **While they do this, one per team, pour another**

Procedure Part A Cont.

small foam cup half full of hot water (next part of the activity).

5. At 4 minutes, ask students to record the nail head temperature and water temperature on BLM 4. Measure the nail temperature first, then remove the nail and push the thermometer tip through the cup lid hole to measure the water temperature. Compare these temperatures with predictions.

6. Discuss results with the class. Ask for ideas about how heat gets to the nail head. **Students might incorrectly guess that "heat rises." If they do, ask them how we could test this. The activity can be repeated with a cup upside down. If you do this, the results will be the same or warmer.** Ask teams to discard the water in their cups in a dishpan, and set the (now hot) nail aside.

Procedure Part B

1. Give each team an 8-oz foam cup, a new nail, and a 4-oz foam cup half full of hot water. Ask teams to cap their empty 4-oz foam cups with no water in them and stick the new nail into the lid of that empty cup. Project BLM 3 to show how to put the small cup with nail inside the larger cup. Ask teams to do this and separate the cups again. Explain that using this setup, hot water in the larger cup does not touch the nail in the small cup.

2. Ask teams to measure the temperature of the nail head. Also ask them to measure the temperature of the water in their 4-oz foam cup by sticking the thermometer probe through the lid into the hot water. Ask them to record these temperatures on BLM 4.

3. Draw out ideas from the class about how the temperature of the nail might change when the cup that it is in goes into the larger cup of hot water.

4. Ask teams to do the following all together. Pour the 4-oz foam cup of hot water into the large foam cup. Push the small cup with nail all the way down into the hot water. As soon as they do this call "start."

5. Call time at 30, 60, 90, and 120 seconds, and ask teams to record the temperature of their nail head on BLM 4 at these times. After teams record temperatures at 120 seconds, ask them to predict the nail and water temperatures at 4 minutes (240 seconds) on BLM 4.

6. Discuss differences between setups and results **(nail touching the hot water, and nail not touching it)**. At the 4 minute mark, ask students to record the nail and water temperatures at 4 minutes. **When this activity is over, save the 8-oz foam cups. They will be used in a later activity**.

Wrap-Up

1. Project BLM 5:
   - Where do you think heat at the head of the nail came from? What is your evidence for this?
   - How do you think the heat got to the tip of the nail?
2. Explain that, in Part A, the heat at the head of the nail came from the water by a process called "heat conduction." The heat moved because a place that is hot warms the place next to it. That place that just got warm, in turn,

Part 1 cont.

warms up the place next to it. Conduction "passes along" heat energy from place to place within a material. All materials conduct heat to some extent, but some materials conduct it better than others. This same process works between separate materials that touch. For example, the hot water passed its heat energy to the nail. Conduction is the transfer of heat energy within a material or between materials in direct contact. In Part B, heat was not transferred directly between the water and the nail because the nail did not touch the water.

Part 2 — Bridge Between Hot and Cold

Materials

Materials for the whole class

- 8 paper trays
- 2 ice cube trays
- 1 roll of heavy duty aluminum foil
- 1 hot pot
- 1 large thermos
- 16 4-oz foam cups
- 8 copies of BLM 6, *Bridge Between Hot and Cold*
- 16 digital thermometers
- 16 8oz foam cups to make into cup stands
- utility knife
- 1 half-gallon container (e.g. pitcher, milk bottle, etc.)*

*supplied by the teacher

Materials for groups of 4 students

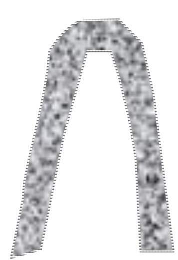
- 1 foot x 2 foot square of heavy duty aluminum foil

On a paper tray:

- 2 4-oz foam cups
- 2 foam cup stands
- 1 copy of BLM 6
- 2 digital thermometers

Preparation

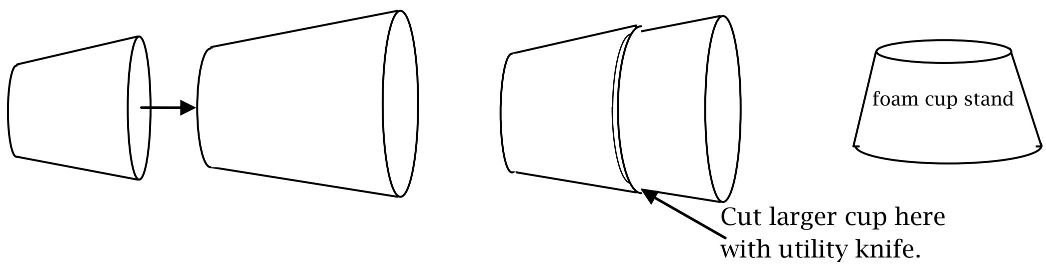
1. Before doing the activity, make a sample heat bridge from a 2' x 1' rectangle of foil folded down to 6" x 6." Fold and roll the 6" x 6" piece tightly into a 6" rod. Bend it to a U shape with legs about 2 ½ inches long. Leave half an inch across the top of the upside-down "U." Show this when students make their heat bridges. It looks like this:



Preparation Cont.

2. Before the activity, make trays of ice, fill a pitcher or jug with it, and top off with water. Remove the ice just before the activity, (ice in cups ruins results).

3. Before the activity, make 16 cup stands. Place a 4-oz foam cup over the bottom of an 8-oz foam cup. Cut around the large cup with a knife where the mouth of the small cup touches it.



4. On the day of the activity, 30 minutes before class, heat water to ≈ 130-140˚F in the hot pot and pour it in the thermos. Water cooler than 130˚F produces small results and water hotter than 140˚F can scald. (5 seconds of exposure at 140˚F can cause a mild burn.) Make 2 pots of hot water and put them in the thermos. A pot takes 8 minutes to heat.

5. On the day of the activity, have two cups (no bridge in these) and two thermometers ready to use for the control cups.

6. On the day of the activity, place the students' heat bridges (made the previous class period), cups, and thermometers on the paper trays. Have one copy of BLM 6 per team.

Procedure

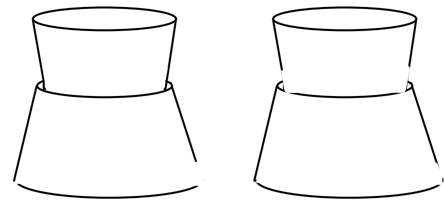
1. The class period before the activity, have students make their "heat bridges." Have your sample and a square of foil ready to demonstrate. Set up teams of 4 and give out 1" x 2" foil sheets. Show the class your U-shaped piece of foil and show them how to fold the square of foil, roll it, flatten it, and shape it. Allow 5 minutes for them to make the foil bridges. Collect these for use in the next class period.

2. On the day of the activity, allow teams to get the paper trays of materials and a copy of BLM 6, *Bridge Between Hot and Cold*. Point out the setup shown on BLM 6.

3. Procedure for Reading and Recording Temperature: Review how to read thermometers by waiting until the reading changes slowly (can take up to 15 seconds). Explain that they will leave the thermometers in the cups, and to get accurate readings, they will swirl the thermometer tip to mix areas of hot and cold in the cups before each reading.

Procedure Cont.

4. Ask teams to put the cups in the foam cup stands to prepare for you to fill them. The cup stands prevent the cups from tipping over when thermometers are placed in them. The 4-oz foam ups in the stands look like this:



5. Circulate to fill the teams' hot and cold cups. To fill cups quickly, ask a helper to pour the cold water. After all cups are full, point out where to enter readings on BLM 6, then ask teams to record the hot and cold cup start temperatures. Ask teams to get their foil bridges and thermometers ready.

6. START When teams have recorded starting temperatures and have foil bridges ready, ask them to connect the two cups with the foil bridge, put the thermometers in, call start, and start the timer. (Teacher Only) Pour the hot and cold control cups (nothing connecting them), swirl with the thermometers, and record their starting temperatures. Leave thermometers in these cups. There is no need to call students' attention to control cups until after teams record final temperatures.

7. At 2 minutes, 4 minutes, 6 minutes, and 8 minutes, call time and ask students to swirl the thermometer tips and record temperatures on BLM 6 when the readings stop rapidly changing.

8. At the 8 minute reading, the teacher records the final temperatures of the water in the control cups, but does not call students' attention to it yet. After the 8 minute reading, ask teams to record the temperature change for both cups over the 8 minute time span (the difference between the start temperature and the 8 minute temperature).

9. Ask teams to report out their start and end temperatures, and write these for all to see. Explain that you have set up two cups with no piece of foil connecting them, and you poured the same hot and cold water in these when everyone began 8 minutes ago. Read out the start temperatures for both cups. Point out the place under "CONTROL CUPS" where they can record these. Ask for predictions of what students think the final temperatures in these cups were, and why. Read out the final temperatures you recorded and ask students to enter them in the appropriate blanks on BLM 6. Also ask them to calculate the temperature changes for both control cups.

10. Ask teams to answer the two questions at the bottom of BLM 6 *as a team*. The whole team must try to agree on answers.

11. Leave the setups undisturbed (they will be used in the wrap-up).

Wrap-Up

1. Ask students to try to explain the movement of heat energy through the whole system. Students who explain it most clearly will explain something like the following: Hot water touching the foil passed heat energy to the foil. The foil passed heat energy from place to place within itself (just like the nail in the previous activity). The hot foil touched the cold water and conducted heat energy to it. Heat energy can transfer between different materials that are touching.

Procedure Cont.

2. Ask students for evidence that heat energy passed between the cups through the foil.

   - Hot water touching the foil passed heat energy to the foil. Our only evidence for this was that the foil did not feel hot when we put it in the water. Evidence from measurement could have been obtained by measuring the temperature of the foil before it went into the hot water, but we did not do this.
   - The foil conducted heat along itself just like the nail. If someone felt the foil after taking it out of the setup, one side was hot and the other side cold. That would be consistent with heat conduction. On the top of the bridge, the foil might show gradual difference in temperature as you move along it, but we did not measure temperatures there.
   - The foil conducted heat to the cold water. We have evidence to support this. The cold water heated up more with foil connecting it to hot water than in the control cups where there was no foil connection. The difference between all the teams' setups and the control is consistent with the foil conducting heat from the hot to cold water.

3. Project BLM 7. Ask students to predict in their notebooks the temperatures at points A, B, and C, then measure the temperatures at those places. Discuss results in terms of heat conduction. Save the cup stands for the next activity.

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. I notice that when I use a hot pad to hold a pan cooking pancakes over a stove, the hot pad gets warm after awhile. I wonder how the warmth in the hot pad gets to my hand. Select the best explanation below.

   A. The heat energy comes from the stove under the pan. The pan conducts the heat energy to the pan handle. When I hold the handle with the hot pad, the hot pad conducts some of the heat energy to my hand so that I can feel some warmth.

   B. The heat energy comes from the stove. The heat moves from the stove through the air and into my arm. The heat is conducted down my arm and into the hot pad from my hand. After awhile, heat builds up in the hot pad and I can feel it.

   C. The heat is only from my hand. Heat energy from the stove cannot move through the metal pan into the hot pad. Heat energy can only be conducted inside of a material, not between materials.

2. Jan put her glass of iced tea down on a metal table that had gotten hot in the sun. Her friend, Wilyetta, held her iced tea in a foam drink holder. A few minutes later, Jan's ice was melted, but Wilyetta still had plenty of ice. Select the best explanation below.

   A. Because heat rises, the heat energy from the table rose up into Jan's drink. If the drink had been touching the underside of the table, even if the table was hot, the drink would have stayed cold. Some of the heat

Procedure Cont.

from her drink would have gone up into the table, making the drink a little cooler.

B. The cold from the drink went out into the table, and the drink lost so much coldness that the ice melted. The hot table attracted the coldness. It also attracted the coldness from Wilyetta's drink. Wilyetta's drink also lost some cold even though it did not touch the table, but not enough for the ice to melt.

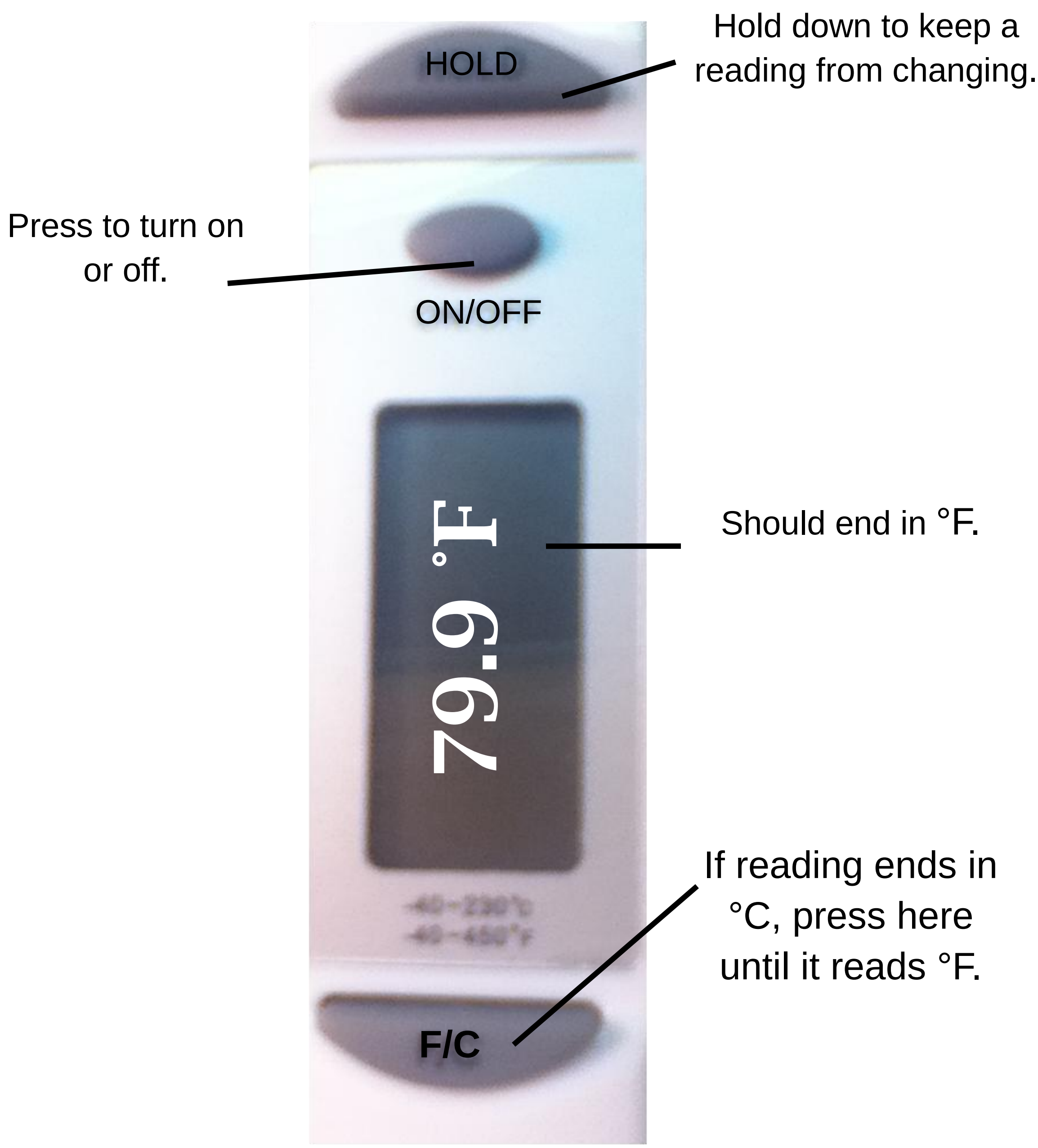
C. Heat energy in the metal table warmed up the outside of the glass where the hot table touched it. After awhile, the heat energy warmed the glass all the way through. The warm glass passed the heat energy to the drink inside it. The drink passed the heat energy to the ice. The heat energy melted the ice.

Answer Key

1. A is correct. B is not entirely wrong because some heat does move from the stove into the air, and some of that could move into someone's arm. If you hold a piece of cloth for a long time, it's possible to feel body heat build up in it. However, all of that would be very small in comparison with heat being conducted from the pan handle. C is not correct because heat energy can move from the stove through the metal pan, and it can be conducted between different materials.

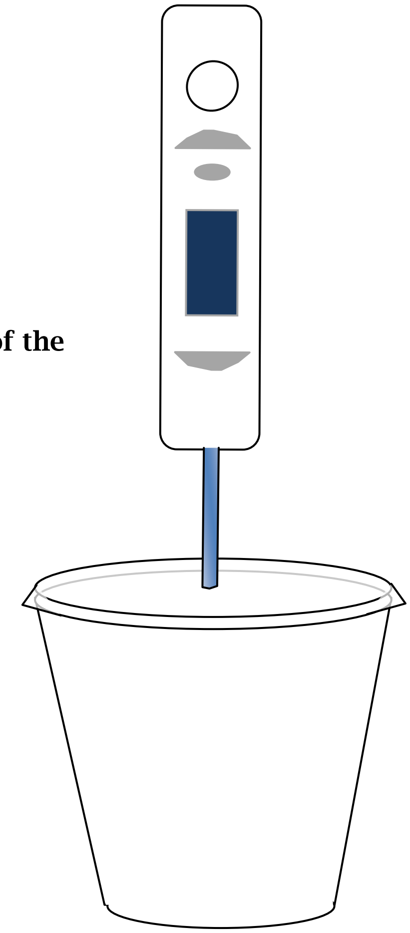
2. A is incorrect. Heat rising is a result of convection in gases or liquids. It does not happen in solids, such as a glass. The heat from the glass would not rise up into the table. B is incorrect because "coldness" is not a substance that moves around or is attracted. For Wilyetta's drink to warm by conduction, her glass must contact something warm. C is correct.

BLM 1 the Digital Thermometer

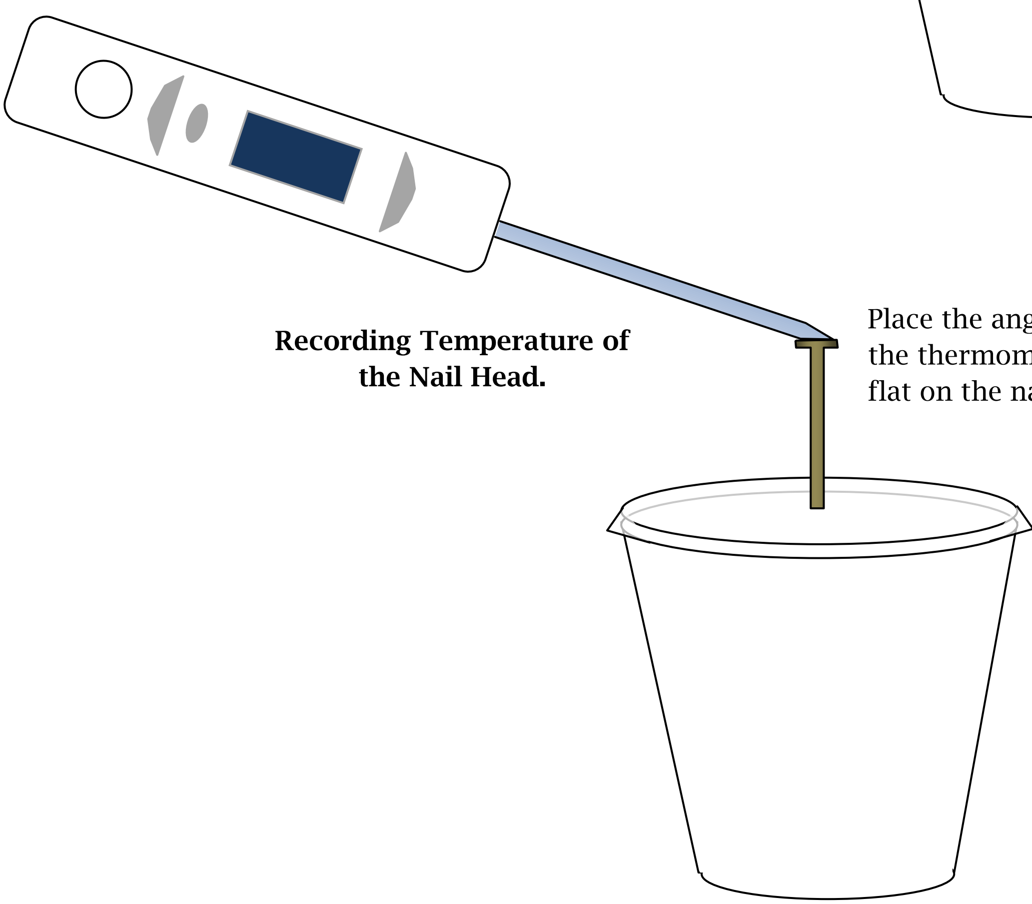


BLM 2

Recording Temperature of the Hot Water.

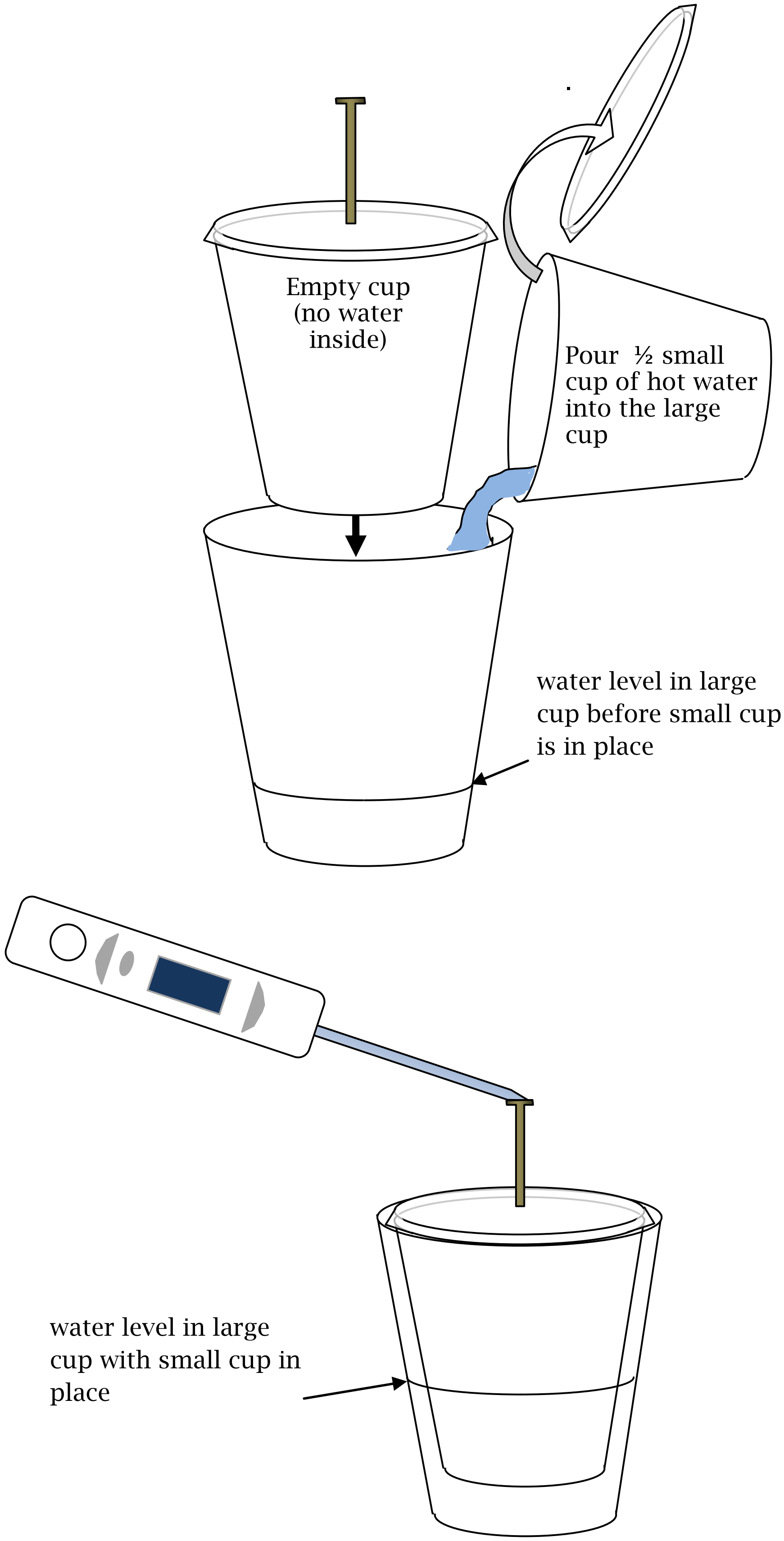


Recording Temperature of the Nail Head.



Place the angled side of the thermometer point flat on the nail head.

BLM 3 Setup for Hot Water that Does Not Touch the Nail



BLM 4 Heat Record Sheet

CUP WITH THE NAIL IN HOT WATER

Temperature of the nail head before it went into the cup ________˚F

Starting temperature of water in the cup________˚F

nail head temperature at 30 seconds______˚F

nail head temperature at 60 seconds______˚F

nail head temperature at 90 seconds______˚F

nail head temperature at 120 seconds__________˚F

nail head temperature at 240 seconds **predicted**______˚F **actual**_________˚F

water temperature at 240 seconds **predicted**_________˚F **actual**_________˚F

CUPS WITH HOT WATER THAT THE NAIL DOES NOT TOUCH

Starting temperature of water in the cup________˚F

Temperature of the nail head before it went into the cup ________˚F

nail head temperature at 30 seconds______˚F

nail head temperature at 60 seconds______˚F

nail head temperature at 90 seconds______˚F

nail head temperature at 120 seconds__________˚F

water temperature after 120 seconds_____˚F

nail head temperature at 240 seconds **predicted**______˚F **actual**_________˚F

water temperature at 240 seconds **predicted**_________˚F **actual**_________˚F

Questions:

Where do you think the heat that warmed up the nail head came from?

____

____

How do you think the heat got to the head of the nail?

____

____

____

____

____

____

BLM 5

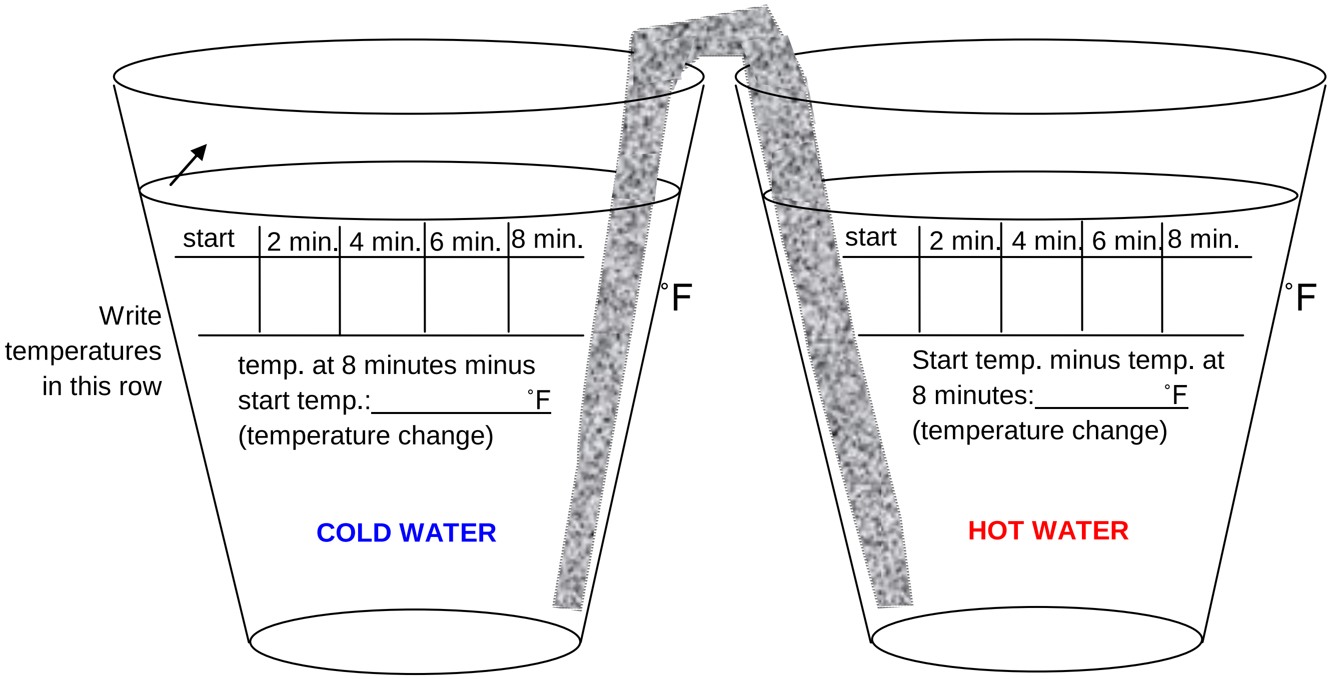
Each Team must agree on answers to these questions

- Where do you think the heat on the tip of the nail came from? What is your evidence for this?

- How do you think the heat got to the tip of the nail?

BLM 6 Bridge Between Hot and Cold

YOUR CUPS



CONTROL CUPS

Starting Temperature of the **cold** Control Cup__________________________

Starting Temperature of the **hot** Control Cup___________________________

Temperature of the **cold** Control Cup **after 8 minutes**___________________

Temperature of the **hot** Control Cup **after 8 minutes**____________________

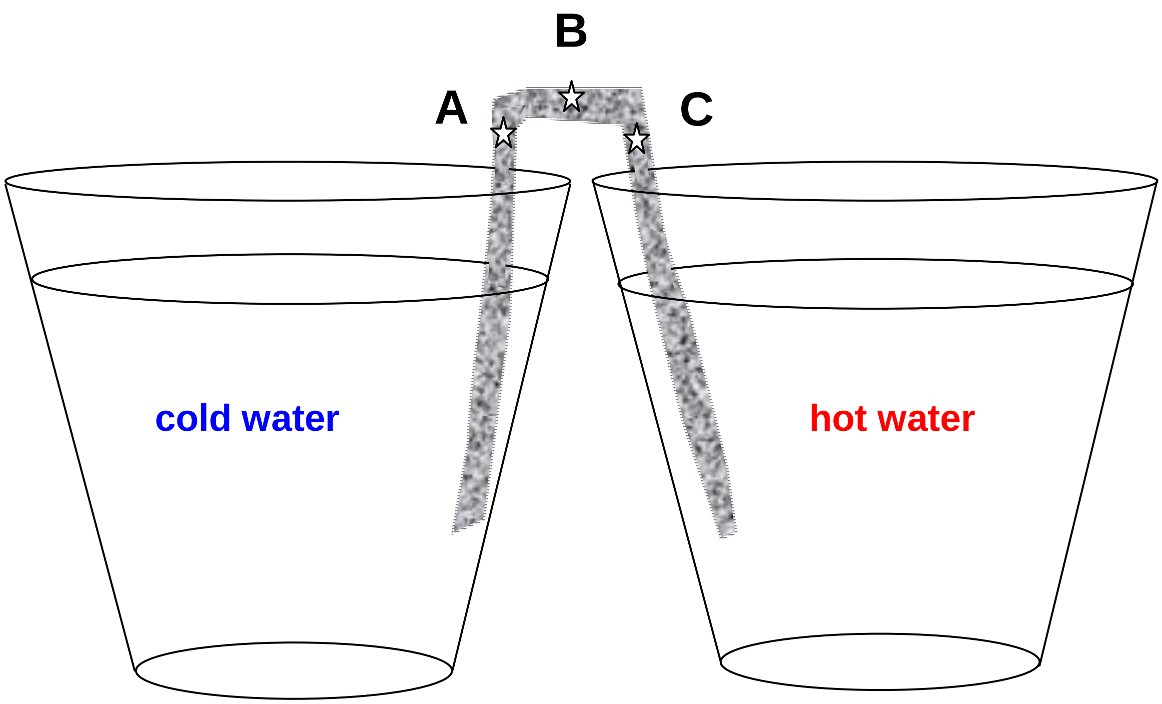
Temperature change of the **cold** Control Cup **after 8 minutes**___________

Temperature change of the **hot** Control Cup **after 8 minutes**____________

Give reasons that you think might explain changes in temperature in the cups connected by the foil:
____
____
____
____

After 8 minutes, temperatures in the cups that were connected by foil changed differently from the cups that were not connected. Calculate the differences and give reasons that you think might explain them:____
____
____
____
____

BLM 7



Predict the temperatures at points A, B, and C in the diagram above. Give reasons for each prediction.

After you predict, measure and record actual temperatures at these places.

Point	Predicted Temperature	Actual Temperature	Reason for Prediction
A	˚F	˚F	
B	˚F	˚F	
C	˚F	˚F	

Appendix

Common Student Preconceptions About This Topic

Many students imagine heat as a substance that can flow into and out of objects, rather than as energy that is transferred. Many also think that cold is a substance that flows in the same way, like a fluid, but is the opposite of heat. This is also a common and natural conception among adults. When someone opens a door on a cold winter day, people very reasonably say, “Don’t let the cold in!” 5th grade students might understand the examples in this activity as a “hotness material” or “coldness material” flowing through things. This is much the way early scientists understood heat, as fire-like elements contained in matter called “phlogiston” or “caloric.” Even after students grasp the particle theory of matter later on in middle grades and high school, there is little in the way of concrete experience to shift the concept of heat as a substance. Explanations of heat transfer as invisible abstractions such as molecules, atoms, electrons, vibration, collisions, and kinetic energy are unlikely to clarify understanding. At grade 5, it is enough for students to understand that energy in the form of heat can transfer through materials in different ways, depending on the material. They can also understand that some materials transfer heat more efficiently than others.