Key Concepts:

Heat is a form of energy. Things are hot if their molecules are moving quickly and cold if their molecules are moving slowly. Temperature is a measure of how quickly a substance's molecules are moving. Because molecules are always in motion, even cold objects and substances contain heat – they just have less heat than warm objects or substances. When two substances of different temperatures are in contact with one another, heat is transferred from the warmer substance to the colder substance. The molecules of the warmer substance "bump into" the molecules of the colder substance. This causes the warmer substance's molecules to slow down and the colder substance's molecules to speed up. Sometimes the transfer of heat energy creates problems for humans. When heat is transferred from our bodies to the air around us, we feel cold. When heat is transferred from inside our homes to the colder winter air outdoors, it takes more energy to heat our homes. Certain materials slow the transfer of heat – they are called insulators. We use insulated clothing to keep our bodies warm, and we use insulation to make our homes more energy efficient.

Wisconsin's Model Academic Standards for Science:

Physical Science: Transfer of Energy

D.8.8 Describe and investigate the properties of light, heat, gravity, radio waves, magnetic fields, electrical fields, and sound waves as they interact with material objects in common situations

D.8.9 Explain the behaviors of various forms of energy by using the models of energy transmission, both in the laboratory and in real-life situations in the outside world

Objectives: Students will be able to…	**Evaluation Question for Each Objective**
Describe heat energy in terms of molecular motion	What is heat? What does it mean for a substance to be hot or cold?
Explain that when a substance cools, its heat energy does not disappear – it is transferred to another substance.	Katie made a cup of hot chocolate and left it on her kitchen counter. 30 minutes later when she went to take a drink, it was no longer hot. What happened to the heat energy?
Define an insulator as a substance that slows the transfer of heat energy.	What is an insulator?
Provide examples of how humans use insulators in their everyday lives.	Give two or three examples of insulators humans in their everyday lives. Explain how each insulator is useful. Kent was in the basement of his home, and he accidentally bumped into his family's water heater. He expected the tank to burn his skin, but he was surprised to discover that it was not much warmer than room temperature. Why was this?

Vocabulary:

Heat – Energy in the form of molecules' movement
Temperature – The measure of how quickly a substance's molecules are moving
Transfer – The movement of energy from one substance or object to another
Insulator – A substance that slows the transfer of heat
Conduction – The transfer of heat energy between two materials that are touching each other

Required Materials:

For the class:

- A supply of hot water – enough to provide each group with 100 mL (If there is not a sink in the classroom, fill an insulated thermos with hot water just before the start of class.)
- Several graduated cylinders, flasks, or beakers that can be used to measure 100 mL of water
- Several funnels with ends narrow enough to fit into the mouth of a soda can
- A variety of materials that could be used as insulators: cotton balls, scraps of fabric, pieces of foam rubber, foam packing material, paper towel, etc.
- Scissors
- Whiteboard, chalkboard, or easel to record students' ideas
- Molecular motion Java applet (http://chemconnections.org/Java/molecules/) and digital projector.

For each group:

- One 12 oz. aluminum soda can
- One thermometer (preferably a 12" alcohol thermometer or digital thermometer with a probe at least 5" long so temperatures can be read without removing the thermometer from the can)
- One 1000 ml beaker or another container of similar size
- One stopwatch (preferably) or access to a clock for time-keeping

For each student:

- Notebook or lined paper to serve as a journal for recording experiment data, vocabulary terms, and examples of insulators.
- One sheet of ¼" grid paper
- Final Evaluation Sheet

Safety: If hot tap water is dangerously hot, students should pour carefully to avoid scalding. Remind students to handle glassware carefully and get adult assistance if breakage occurs. Caution students not to touch the sharp edge around the soda can's mouth.

DAY 1

ENGAGEMENT

What the Teacher Will Do/Say	Expected Student Responses	What the Students Will Do
Pour some hot water in a cup. Say, "This is the hottest water I could get from the faucet here at school. How hot do you think it is?" Record several students' predictions on the board.	Students will likely give estimated temperatures in degrees Fahrenheit.	Students will share their estimates and/or consider their classmates' estimates.
Say, "you gave your estimates in degrees Fahrenheit, but scientists usually do not use this scale. In this lesson, we are going to use the Celsius scale instead. Water freezes at 0° Celsius, and it boils at 100° Celsius. The temperature of		

this room is about 20° Celsius." Circle the lowest and highest estimates made by students. Rewrite these temperatures in degrees Celsius – use the formula Tc = (5/9)*(Tf-32).		
Say, "Let's see how hot this water really is." Place a thermometer in the cup of water and have a student read the temperature in degrees Celsius. Write the actual temperature on the board. Ask, "What will happen if we let the cup sit and read the temperature again in 20 minutes?"	Students will predict that the water will get cooler.	
Ask, "How did this water get hot in the first place?"	Students will likely say that there is a water heater somewhere in the school that warmed up the water before it came out of the faucet. Some students may have point of use water heaters in their homes, so they may predict that there is a small water heater under the sink.	Students will answer the question and/or consider their classmates' answers.
Say, "There are some newer water heaters that heat the water very quickly as it flows through the pipes, but most buildings still use water heaters that use a large tank. The water is heated inside this tank, and it is stored there until someone uses it. Can you think of a problem with using this kind of a water heater?"	Students will likely give a variety of answers. Some may say that the tank could leak. Others may identify that it could be hard to heat up such a large volume of water. If no one mentions the problem of the water cooling before it is used, say, "This cup is like a smaller version of the tank. Could our discussion from a couple of minutes ago help you to think of another problem with this sort of water heater?"	Students will share their ideas and/or consider their classmates' ideas.
Show the students a soda can. Say, "Today we are going to use soda cans to represent water heater tanks. We will begin by putting 100 mL of hot water in each can, and then we will measure its temperature every 2 minutes for 20 minutes all together. Before we start, I want you to create a prediction, or hypothesis. How many degrees	Students will have a variety of hypotheses. Hot tap water will have a temperature around 45° Celsius. If students think critically, they should realize that the temperature will not fall below room temperature, so reasonable estimates will be less than or equal to about 25 degrees. Some students may make estimates greater than this. For now, simply	Students will share their hypotheses and/or consider their classmates' hypotheses.

cooler do you think the water will be after 20 minutes? Don't tell anyone your hypothesis just yet." While students think about this, give one copy of the lab sheet to each student. After each student has a sheet, have the students write their predictions in the provided space on the lab sheet. Call on students to establish the least and greatest estimates for the temperature change.	document the predictions without commenting on their reasonableness. Some students may realize that classmates' predictions are outside of the reasonable range, but save this discussion until later in the lesson.	

TRANSITION

Now that you have your hypotheses, let's conduct an experiment to test them.

EXPLORATION

What the Teacher Will Do/Say	Expected Student Responses	What the Students Will Do
Put the students into groups of 2 or 3. Have each group obtain one soda can, one 1000 mL beaker (or similarly sized container) one thermometer, and one stopwatch. Explain that the can should sit inside of the beaker. (**Note:** During this part of the lesson, the beaker will help to prevent the can from tipping over. More importantly, the beaker will serve as an outer casing for an insulated tank later on. While this first experiment does not require the outer casing, it is good to use it anyway so that the different result in the second experiment is attributed to the insulating materials and not the beaker.)		Students will gather the supplies and prepare their work spaces.
Instruct students to fill their cans with 100 mL of water and insert the thermometer into the can. After taking their initial temperature readings, students should read the temperature every 2 minutes, recording the temperatures in their journals. As they begin working, give each	Students will begin the experiment.	Students will measure out 100 mL of hot water, use a funnel to pour it into the soda can, and immediately place the thermometer in the can. After the initial temperature has been read, students will start the stopwatch. Every two minutes for 20 minutes,

student a sheet of ¼ inch grid paper for use in graphing the temperature change over time. Circulate through the room to ensure that students are following the lab procedure correctly. Ask students to describe their observations. How does the rate of change compare to their predictions? How warm do they predict the water will be at the end of 20 minutes?		the students will read the thermometer and record the temperature in a table in their journals. Between readings, the students should create a coordinate graph with minutes on the horizontal axis and temperature on the vertical axis. For each reading recorded in the table, the students should plot the corresponding point on the graph and connect each point to the next to show change over time.
When students finish the experiment, direct them to clean up their work areas, return their materials to the materials station, and return to their seats. Designate an area of the board, and have one student from each group write the group's temperature change there.		Students will clean up and return to their seats.
Ask, "How did your temperature changes compare to your hypotheses?"	Answers will vary, depending on the students' hypotheses. Typically, the temperature will drop by 10 to 12 degrees.	Students will compare the experimental results to the hypotheses.
Say, "If your soda can was really a hot water heater's tank, this would be a real problem. The water heater would have to use a lot of energy to keep heating the water, because of all this cooling. Can you think of any ways to solve this problem?"	Students will suggest ways to keep the water from cooling so quickly. Some students may suggest wrapping the can inside of something to" keep the heat in."	Students will consider solutions to the cooling problem.
Tell the students, "Tomorrow you are going to repeat this experiment, but with an important difference. Your goal will be to have the warmest water possible at the end of the 20 minutes. To accomplish this, you may fill the space between the can and the beaker with materials that will slow down the energy loss. You may bring items from home to	Students will brainstorm potentially useful materials. Students are likely to identify fabric and other soft materials like cotton balls.	Students will discuss ideas in their groups and plan to bring useful materials to tomorrow's class.

use, but you are not allowed to use anything that adds heat energy to the water (hand warmers, etc). In the time that you have remaining today, talk with your group about materials that might be useful, and form a plan to determine who will bring which materials from their homes.”		

DAY 2

EXPLORATION		
What the Teacher Will Do/Say	**Expected Student Responses**	**What the Students Will Do**
Say, “Today we are going to find out which group can keep its hot water the hottest for 20 minutes. You have brought some materials from home, and there are also some things at the materials station that might be useful. You will have 10 minutes to prepare your water heater tank by placing materials around the can. Remember that the can and all of the surrounding materials must still fit into your beaker. You can get into your groups and start working.” Allow the students ten minutes to prepare their tanks. Warn them where there are 5 minutes, 2 minutes, and 1 minute remaining.	Many students may think that they should pack the space between the can and the beaker with as much material as possible. Some groups may recognize the benefit of covering the top and bottom of the can, but other groups might only cover the sides.	Students will gather materials and begin assembling their tanks.
Instruct students to follow same protocol that was used in the prior day’s experiment. Again, they should record the temperatures in their journal. Today, they should graph their temperature data on the same coordinate graph they used yesterday, using a different color to differentiate today’s data from yesterday’s. Circulate while students are working, and ask	Students will begin the experiment.	Students will measure out 100 mL of hot water, use a funnel to pour it into the soda can, and immediately place the thermometer in the can. After the initial temperature has been read, students will start the stopwatch. Every two minutes for 20 minutes, the students will read the thermometer and record the

them to compare today's results with yesterday's. Ask them to explain why they think the extra material makes a difference.		temperature in a table in their journals. Between readings, the students should create a coordinate graph with minutes on the horizontal axis and temperature on the vertical axis. For each reading recorded in the table, the students should plot the corresponding point on the graph and connect each point to the next to show change over time.
When students finish the experiment, direct them to return their thermometers and stopwatches to the materials station. Designate an area of the board, and have one student from each group write the group's temperature change there.		Students will clean up and return to their seats.
Ask, "How did today's temperature changes compare to yesterday's?"	Students will identify that the temperatures dropped fewer degrees today.	Students will look at the data and draw conclusions.
Ask groups to share their tank designs with the class. If there is not time to share all of the designs, choose the two or three groups with the least heat loss.	Groups will identify the materials they used and how they placed the materials. They will discuss the reasoning behind their design decisions.	Students will present their tanks and/or consider their classmates' tanks.
Have students take apart their tanks and return their materials to the materials station prior to the end of class.		Students will clean up their work areas.

DAY 3

EXPLANATION

What the Teacher Will Do/Say	Expected Student Responses	What the Students Will Do
Say, "Yesterday most groups saw that their water lost less heat than it did on the first day. Why do you think it helped to place material around the cans?" Give students a minute to think about their response, and then have them	Students will probably only be able to explain this in vague terms (e.g. "The material kept the heat inside the can") because they have not spent a lot of time discussing the concept of heat as molecular motion.	Students will share their ideas and/or consider their classmates' ideas.

discuss their ideas with a partner for another minute. Call on students to share their thinking about this. Prompt students to justify their answers ("Why?" "What evidence do you have?").		
Say, "I noticed that when you were explaining your ideas, many of you said that the material you added 'kept the *heat* inside the can' or 'stopped the *heat* from getting out'. Can anyone explain exactly what *heat* is?"	Students will likely struggle to explain heat in concrete terms. Most will probably talk about heat as a description of warmth. Some may use the word "energy". Few are likely to identify molecular movement.	Students will share their ideas and/or consider their classmates' ideas.
Say, "Let's consider how scientists define heat. Some of you identified that heat is energy, and this is true. Here's something that can help us better understand this type of energy." Show the molecular motion applet from chemconnections.org. Set the mass of the molecules to 100 amu. Say, "Each dot here represents a molecule of some substance. What do you notice about how these molecules are behaving?"	Students will identify that the molecules are moving.	Students will observe the model.
Say, "At the moment, these molecules are at a very low temperature – they do not have much heat energy. How do you think the molecules' behavior would change if they were warmer?" Call on several students to share their thinking.	Students will probably predict that the molecules will move faster.	Students will answer the question and/or consider their classmates' responses.
Say, "Let's find out." Adjust the temperature of the red molecules to 800° Kelvin. Say, "We can see that when the molecules are warmer, they move faster. In fact, this is what it means when we say something is warm. We really mean that it's molecules are moving faster than they would be if it was cold. The heat does not *cause* the molecules to move faster, and the faster movement does not *create* heat. The heat *is* the movement, and the		Students will write down the following definitions: *Heat* – Energy in the form of molecules' movement *Temperature* – The measure of how quickly a substance's molecules are moving

movement *is* the heat. When we measure the temperature of a substance, we are actually measuring how fast its molecules are moving." Have the students write the definitions of heat and temperature in their journals.		
Say, "Let's make the blue molecules warmer, too." Increase their temperature to 273° Kelvin. Say, "We can see that the red molecules are moving much faster than the blue molecules. They have more heat energy, so they are warmer than the blue molecules."		
Say, "Notice that these temperatures are not given in degrees Fahrenheit or Celsius. These temperatures are shown on the Kelvin scale. 273° might sound hot, but it is actually the same as 0° Celsius or 32° Fahrenheit – the freezing point of water."		
Change the red molecules' temperature to 318° Kelvin and the blue molecules' temperature to 293° Kelvin. Say, "The red molecules are shown here at the temperature of your hot water when you first put it into the can. The blue molecules are at room temperature. Why do you think it is difficult to see the difference in their speeds?	Students will notice that compared to the possible range of temperatures, these temperatures are very close together.	Students will discuss the question.
Change the temperature of the blue molecules to 273° Kelvin. Say, "Here are molecules at the freezing point of water, and they are still in motion, so we can tell that they still have heat energy, even at that cold temperature." Change the temperature of the blue molecules 1° Kelvin. Say, now these molecules are extremely cold. 1° Kelvin is equal to about -272° Celsius and about -458° Fahrenheit. The molecules are		

moving very slowly, but they have not stopped moving. In fact, molecules only stop moving at 0° Kelvin, but it is impossible to get anything this cold.		
Say, "So, now you know that heat is the movement of molecules. At the end of your experiment, the water molecules were moving slower than they were at the beginning. Somehow, the molecules lost heat. Heat, however, does not simply disappear. Why, then, did your water get cooler? What do you think happened to the heat energy?" Give the students some time to think about this alone and discuss with their neighbors.	Students may be able to determine that the heat "left" the water and went somewhere else, but they will likely have difficulty arriving at the conclusion that the heat was transferred to the can and the surrounding air.	Students will consider the question alone, with a partner, and with the whole class.
Say, "Let's look back at this model. Notice that the red molecules are moving very quickly, but they are not leaving this rectangular area. Why are they staying here?"	Students will say that there are walls keeping the molecules inside the box.	Students will respond to the question and/or consider their classmates' responses.
Say, "Suppose these red dots are your water molecules, and the outline of this box is the can that holds the water. Remember that the can is made of molecules, too. What do you suppose happens to the can's molecules when the water molecules run into them?"	Students will say that the molecules start moving faster.	Students will respond to the question and/or consider their classmates' responses.
Say, "When a fast-moving molecule runs into a slow-moving molecule, some energy moves from the fast molecule to the slow one. This causes the slow molecule to speed up. What effect do you think the collision has on the fast molecule?"	Students will say that the fast molecule slows down.	Students will respond to the question and/or consider their classmates' responses.
Say, "So, if the water molecules are running into the can's molecules, what effects do these collisions have on the water and the can?"	Students will say that the water cools and the can heats up.	Students will respond to the question and/or consider their classmates' responses.
Say, "This movement of energy from warm, fast molecules to		Have students write the following definitions in their

cooler, slower molecules is called a *transfer* of energy." Heat can be transferred in several ways. When it is transferred from one material to another material it is touching, the transfer is called *conduction*.		journals: *Transfer* – The movement of energy from one substance or object to another *Conduction* – The transfer of heat energy between two materials that are touching each other
Say, "But wait a minute – if the can is getting warmer and its molecules are moving faster, why don't those molecules just cause the water inside the can to warm back up again? If the heat isn't going back into the water, where is it going?" Use think-pair-share to discuss this question.	Students may have difficulty identifying that the heat energy is transferred from the can to the air. If so, the teacher may need to ask probing questions (e.g. "The can is touching the water inside of it. What else is it touching?"	Students will think about the question, discuss it with neighbors, and respond to the question and/or consider their classmates' responses.
Ask, "Yesterday you added some materials between the can and the beaker. Why did these materials slow the cooling of the water? How can our knowledge about heat, temperature, and energy transfer help us explain what happened yesterday?" Use think-pair-share to discuss this.	Students may struggle to understand that energy transfer happens more readily among some materials than others. To get them thinking more about this, ask them to consider why a metal spoon feels colder than a wooden spoon, when they are both at room temperature.	Students will think about the question, discuss it with neighbors, and respond to the question and/or consider their classmates' responses.
Say, "Materials that slow heat transfer are called insulators."		Have students write the following definition in their journals: *Insulator* – A substance that slows the transfer of heat

TRANSITION

Now that we have talked about heat transfer and insulators, you are going to spend some time thinking about how insulators are used in the world around you.

ELABORATION

What the Teacher Will Do/Say	**Expected Student Responses**	**What the Students Will Do**
Ask students to list, in their journals several examples of insulators. Encourage the students to think of human-made insulators and naturally occurring insulators	At first, students may have difficulty generating more than a couple of examples, but through probing questions and group discussions, they will gradually	Work individually and collaboratively to generate a list of insulators. Share ideas and consider the ideas of others during whole-group

(whale blubber or animal fur, for example). In addition to naming each insulator, students should also describe how it is used (fur helps warm-blooded animals maintain their body temperatures in cold weather, winter coats perform a similar function for humans). Ask students to consider whether insulators can only be used to keep things warm, or if they have other uses (keeping a beverage cold, keeping an air-conditioned home cool in the summer). After a couple of minutes working alone, put students into small groups to share their ideas. Finally, have students share ideas with the entire class. Make a list of their ideas on the board.	begin to understand that the world is full of manufactured and natural insulators.	discussion.
Say, "We know that insulators slow the transfer of heat energy. Look at the insulators we have listed on the board. What sorts of characteristics seem to make a material a good insulator?" Use think-pair-share to discuss this question.	Students may notice that many insulators consist of fibers (animal fur, household insulation, hats and mittens, etc.). They may also identify that insulators are often composed of layers or "fluffy" materials. This can be a fairly short conversation; a discussion of specific heat is beyond the scope of this lesson.	Students will share their ideas and/or consider their classmates' ideas.

EVALUATION

What the Teacher Will Do/Say	Expected Student Responses	What the Students Will Do
Hand out the Evaluation sheet to students and give them time to answer the questions. This may need to be done on Day 4, depending on how long it takes to complete the EXPLANATION and ELABORATION phases of the lesson.		Students will work individually to answer the questions on the evaluation sheet.

Name ____ Date ____________________

Heat Loss – Evaluation

What is heat? What does it mean for a substance to be hot or cold?

Katie made a cup of hot chocolate and left it on her kitchen counter. 30 minutes later when she went to take a drink, it was no longer hot. What happened to the heat energy?

What is an insulator?

Give two examples of insulators humans in their everyday lives. Explain how each insulator is useful.

Kent was in the basement of his home, and he accidentally bumped into his family's water heater. He expected the tank to burn his skin, but he was surprised to discover that it was not much warmer than room temperature. Why was this?