TRANSFER OF **THERMAL ENERGY**

STUDENT HANDOUT

UTAH SEED STANDARD PHYS.2.2
NEXT GENERATION SCIENCE STANDARD HS-PS3-4
GRADE AND TOPIC: HIGH SCHOOL PHYSICS

THE UNIVERSITY OF UTAH
College of Education

UTAHFORGE

Stone Soup?

Group Members _____ _____

_____ _____

Your teacher has decided that the best way to avoid the problem of trying to heat water in a styrofoam cup is to heat a rock instead and add the heated rock to their ramen noodles. Do you think this is a good idea? Do you think it will even work? Let's find out!

You will need a hot plate, 2 beakers of water, 1 metal cylinder, something to safely remove the cylinder from the boiling water, and a thermometer (optional). Remember: Always handle hot items with care. Do not touch the hot surface of the hot plate.

Do this:

- Heat the metal cylinder in a hot water bath until the water comes to a boil.
- Use the tongs to transfer the cylinder from the hot water bath into the other beaker of water.
- Using your hands or thermometer, observe what happens to the cool beaker after you transfer the hot cylinder to the cool beaker.

Discuss this:

- What do you notice about the cool water after you add the hot cylinder?
- What do you think is happening to cause the water to get warm?
- What do you think is happening in and around the water as it is heating?

Draw this:

- Draw a picture of the beaker with water and the cylinder.
- Draw the things that are happening inside and around the water that makes the water heat up.

Based on your observations, do you think your teacher should use this method to cook their ramen?

Station 1: Conduction

Group Members _____ _____

_____ _____

Background Information:

- At this station, you will be observing conduction.
- Conduction is when heat is transferred through direct contact. In other words, heat moves from one object to another object because they are touching.

Do this:

- Place your hand on the outside of each of the three beakers.
- Notice how each beaker feels.

Discuss this:

- Which way do you think the heat is flowing? How can you tell?
- How does this demonstrate conduction?
- What could you do to increase conduction?
- What could you do to decrease conduction?

Write this:

1. How does this demonstrate conduction?

2. When touching the hot beaker, which way does the heat flow? (From the beaker to your hand, from your hand to the beaker, or there is no net heat flow.) How do you know?

3. When touching the cold beaker, which way does the heat flow? (From the beaker to your hand, from your hand to the beaker, or there is no net heat flow.)

   How do you know?

4. When touching the lukewarm beaker, which way does the heat flow? (From the beaker to your hand, from your hand to the beaker, or there is no net heat flow.) How do you know?

5. What is another example of conduction?

6. What if you wanted to make the heat flow from one object to the other faster? For example, if you wanted to cool your computer or cool cookies you are baking. What could you do to increase the heat transfer rate (make the heat move from one object to another faster)?

7. What if you wanted to prevent the heat from flowing from one object to another? For example, if you wanted to stay warm while snowboarding or you wanted to keep your hot chocolate from getting cold. What could you do to reduce the transfer of heat (prevent the heat from moving between the two objects)?

Cool fact: This demonstrates how your body measures temperature. Our neurons don't actually measure temperature the way a thermometer does. Our bodies measure heat flow. This is why if you touch something like the metal chair leg of the desk you are sitting at it feels cold, but if you touch the wooden tabletop it doesn't. The metal feels cold but the wooden table does not. They are both at room temperature, which is colder than your body temperature, so the heat is flowing from you to the desk. But metal conducts heat and wood does not, so you feel that heat flowing when you touch the metal, and you don't feel it flowing when you touch the wood.

Station 2: Convection

Group Members _____ _____

_____ _____

Background Information:

- At this station, you will be observing convection.
- Convection is heat transfer through the movement of fluids.
- Convection can be forced, like when the furnace blows hot air through the ducts in your house.
- Convection also occurs naturally, usually by being heated from the bottom. This causes the hot fluid to rise, displacing the colder fluid above it, which then falls to the bottom. At the bottom, the colder fluid is heated, causing it to rise. ...and the cycle repeats.

Do this:

- Place the beaker of water on the hotplate.
- Turn on the hotplate (do not touch the hotplate).
- Sprinkle some glitter into the water.
- As the hotplate heats the water, it will form a convection current, you should be able to observe the glitter rising and falling with the water.

Discuss this:

- Which way do you think the heat is flowing? How can you tell?
- How does this demonstrate convection?
- What could you do to increase convection?
- What could you do to decrease convection?

Write this:

1. How does this demonstrate convection?

2. Which direction is heat being transferred or moved by the water in this beaker?

   How do you know?

3. What is another example of convection?

4. What if you wanted to make the heat flow from one object to the other faster? For example, if you wanted to cool your computer or cool cookies you are baking. What could you do to increase the heat transfer rate (make the heat move from one object to another faster)?

5. What if you wanted to prevent the heat from flowing from one object to another? For example, if you wanted to stay warm while snowboarding or you wanted to keep your hot chocolate from getting cold. What could you do to reduce the transfer of heat (prevent the heat from moving between the two objects)?

Cool fact: You get goosebumps when you are cold in order to make your hair “stand on end.” This reduces the air flowing over your body and helps prevent heat from being lost through convection. A wet suit is also designed to reduce convection near your body, this time between the water and your body. By preventing the water from flowing over your body, you are able to stay warm in cold water, even though you are wet.

Station 3: Radiation

Group Members _____ _____

_____ _____

Background Information:

- At this station, you will be observing heat transfer through radiation.
- Heat is transferred by radiation in the form of Infrared light.
- This is why IR cameras and night vision goggles work. All things will lose energy by radiating that energy away from the hot object. If that energy is in the form of infrared radiation, it is one way that heat can be transferred.

Do this:

- Turn on the heat lamp (do not touch the heat lamp).
- Hold your hand in front of the heat lamp.
- Notice what you feel.

Discuss this:

- Which way do you think the heat is flowing? How can you tell?
- How does this demonstrate radiation?
- What could you do to increase radiation?
- What could you do to decrease radiation?

Write this:

1. How does this demonstrate radiation?

2. Which direction is heat being transferred or moved by the heat lamp? How do you know?

3. What is another example of radiation?

4. What if you wanted to make the heat flow from one object to the other faster? For example, if you wanted to cool your computer or cool cookies you are baking. What could you do to increase the heat transfer rate (make the heat move from one object to another faster)?

5. What if you wanted to prevent the heat from flowing from one object to another? For example, if you wanted to stay warm while snowboarding or you wanted to keep your hot chocolate from getting cold. What could you do to reduce the transfer of heat (prevent the heat from moving between the two objects)?

Cool fact: Our bodies have neurons that can detect heat being transferred through infrared radiation. This is how you know that something is warm or that something is hot without actually touching it. This is why you can warm your hands by holding them near a fire. Snakes have special organs on the side of their faces that allow them to “see” infrared radiation, and that enable snakes to hunt small mammals in their dark burrows.

Plan and Conduct an Investigation of the Transfer of Thermal Energy, part 1

In this section of the lesson, you need to plan and conduct an experiment to investigate the transfer of thermal energy. You will be taking two objects at different temperatures, putting them in contact, so that heat can transfer between them, and then collecting data on how the temperature changes. You will be graphing this data, and drawing some conclusions about what is happening.

These handouts are intended to help you plan the investigation. Before you begin, please discuss the answers to the following questions with your group.

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The phenomenon you are investigating is the transfer of thermal energy. This topic is too broad for designing an experiment; you need to be much more specific. What is the purpose of your investigation? What question are you trying to answer?

What do you think the answer will be? This is your hypothesis.

What evidence will you need to answer this question? What data do you need to collect?

In thermal investigations, energy transfer with the environment will skew your results. How will you isolate your components in order to create a nearly closed system? What materials do you need to do this? Remember, a closed system is one where nothing moves into or out of the system. We want to make sure that energy does not come into our system or move out of our system.

What are the boundaries of the system? (The boundaries are the edges, so the place where we denote that this is inside the system and everything else is outside of the system.)

What will your initial conditions be? (What will your set-up look like right as you start the experiment, this includes both the objects and the temperatures of these objects.)

What will your final conditions be? (What will your end result look like, this includes both the objects and the temperatures of these objects.)

What data will you collect? How will you collect this data? What materials do you need to collect the data?

How often will you take these measurements?

What is your experimental setup? Which items will you be testing? Which one will be at the higher temperature? Which one will be at the lower temperature? How will you obtain this temperature difference? What materials do you need to do this?

How many trials will you complete?

What data will you graph?

How will you analyze your data?

What are your lab safety procedures for this experiment?

After everyone conducts their experiments, we will be sharing our data as a class in order to look for patterns so that we can have a better understanding. Please make sure you collect the data needed to complete the following table.

Higher Temperature Material, Object 1	
Lower Temperature Material, Object 2	
Initial Temperature of Object 1	
Initial Temperature of Object 2	
Final Temperature of Object 1	
Final Temperature of Object 2	
Change in Temperature of Object 1	
Change in Temperature of Object 2	
(If assigned) Change in Energy of Object 1	
(if assigned) Change in Energy of Object 2	

If you have been assigned to calculate the change in energy, you will need to measure the masses of each object and look up the specific heat for each object.

After you have discussed these questions with your group and written the agreed-upon answers, complete the experimental design part of the Transfer of Thermal Energy handout.

Transfer of Thermal Energy

Group Members _____ _____

_____ _____

Question:

Write the question you are answering.

Hypothesis:

Write what you think the answer to your question will be.

Materials:

Write what materials you need. Remember, you need the objects you are testing, you need materials to make measurements, you need materials to isolate your system, you need materials to create a temperature difference.

Safety:

You need to be cautious when working in the lab. Write the safety precautions you will take.

Methods:

Write all the steps that you will be doing in this investigation. If you need to do something, make sure that you write it here. Use additional pages as needed.

Set up:

In this part, write all the steps you need to take before you begin collecting data. This section includes things like the placement of your materials (ex. Fill 500 mL beaker with 300 mL water, place on a hot plate, add 100-gram copper cylinder to the beaker, suspend the thermometer in the water using a thermometer clip on a ring stand, etc.) and your plans for isolating the system (ex. Obtain calorimeter to transfer hot and cold items into).

Procedure:

Now that you are all set up, you are ready to begin the experiment and collect data. In this section, write everything you will do to perform the experiment (ex. Turn on the hotplate and heat the copper cylinder in the hot water bath until the water has reached 90 degrees C, etc.) and collect the data (ex. Measure the temperature of the thermometer every 30 seconds).

Teacher approval _____

Get teacher approval before beginning the next step. Once you have teacher approval, you are ready to begin your experiment. Follow the steps you outlined above.

Data:

As you collect your data, record it here: You might want to make a data table. Make sure you record data for each trial.

Graph:

Draw a graph of your data here.

Analysis:

Answer these questions

What were the initial conditions?

What were the final conditions?

What happened to the temperature of the hot object after it was placed in contact with the cold object?

What happened to the temperature of the cold object after it was placed in contact with the hot object?

Calculate the change in temperature for each object for each trial. Are these the same values? Why or why not?

When did the heat flow (thermal energy transfer) stop? How do you know?

Measuring the temperature is not the same as measuring the thermal energy. What do you think happened to the thermal energy? What else would you need to know to figure out what happened with the energy?

Quantitative Variation: If you were instructed to calculate the heat transferred, calculate the heat lost from the hot object, and the heat gained by the cold object.

Quantitative Variation: Are these the same value? Why or why not?

Quantitative Variation: If you found different values for heat lost and heat gained, what do you think you could have done differently so that the heat lost was equal to the heat gained?

Conclusions:

In this section write what you learned, describe the results of your graph and analysis, and describe what you would do differently next time.

Energy Distribution

Group Members _____ _____

_____ _____

In this section of the lesson, you are asked to determine what happens to the energy of each object as when objects at different temperatures are placed in contact. You have already determined that energy will be transferred from hotter objects to cooler objects until the temperatures are the same. How much energy is that? Will the energy of each object be the same after the energy transfer?

To answer these questions, you will repeat a similar experiment to the one you conducted in class using the PhET applet:
https://phet.colorado.edu/sims/html/energy-forms-and-changes/latest/energy-forms-and-changes_en.html
Turn on the energy symbols, and count the energy before and after the energy is transferred from the hotter object to the colder object.

Investigation 1

What materials did you use in your in-class investigation?

Select two objects in the PhET applet that are most like the ones you used in the in-class investigation.

Which object was at the higher temperature? This is Object 1. Was this at room temperature or hotter than room temperature?

Which object was at the cooler temperature? This is Object 2. Was this at room temperature or colder than room temperature?

Using the PhET applet, start by turning on the energy symbols. The objects all start at room temperature. Draw the thermometer at room temperature.

If Object 1 was hotter than room temperature, place it on the hot plate and heat it until it is as hot as desired. If Object 1 was at room temperature, do not heat Object 1. Click on the Pause button to prevent energy loss. Draw the thermometer at this temperature.

How many energy units does Object 1 have at the desired temperature?

If Object 2 was colder than room temperature, place it on the ice and cool it until it is as cold as desired. If Object 2 was at room temperature, do not cool Object 2. Click on the Pause button to prevent energy loss. Draw the thermometer at this temperature.

How many energy units does Object 2 have at the desired temperature?

Do Object 1 and Object 2 have the same number of energy units?

Did you expect them to have the same number of energy units? Why or why not?

Place Object 1 and Object 2 in contact. Wait until the thermometers read the same value and the energy units stop moving. Draw the thermometers.

How many energy units does Object 1 have now?

How many energy units does Object 2 have now?

How are the number of energy units for Object 1 and Object 2 related?

Did you expect this? Why or why not?

What is the change in energy for Object 1?

What is the change in energy for Object 2?

How is the change in energy for Object 1 and Object 2 related?

Did you expect this? Why or why not?

Investigation 2

Repeat this investigation with other objects at other temperatures. Let Object 1 be the hotter object and Object 2 be the cooler object

Select 2 materials to use to measure thermal energy transfer. Which material will you choose to be the hotter object (Object 1)? Which one will you choose to be the cooler object (Object 2)?

Heat Object 1 to the desired temperature. Click on the Pause button to prevent energy loss. Draw the thermometer at this temperature.

How many energy units does Object 1 have at the desired temperature?

Cool Object 2 to the desired temperature. Click on the Pause button to prevent energy loss. Draw the thermometer at this temperature.

How many energy units does Object 2 have at the desired temperature?

Do Object 1 and Object 2 have the same number of energy units?

Did you expect them to have the same number of energy units? Why or why not?

Place Object 1 and Object 2 in contact. Wait until the thermometers read the same value and the energy units stop moving. Draw the thermometers.

How many energy units does Object 1 have now?

How many energy units does Object 2 have now?

How are the number of energy units for Object 1 and Object 2 related?

Did you expect this? Why or why not?

What is the change in energy for Object 1?

What is the change in energy for Object 2?

How is the change in energy for Object 1 and Object 2 related?

Did you expect this? Why or why not?

Investigation 3

Select another 2 materials to use to measure thermal energy transfer. Which material will you choose to be the hotter object (Object 1)? Which one will you choose to be the cooler object (Object 2)?

Heat Object 1 to the desired temperature. Click on the Pause button to prevent energy loss. Draw the thermometer at this temperature.

How many energy units does Object 1 have at the desired temperature?

Cool Object 2 to the desired temperature. Click on the Pause button to prevent energy loss. Draw the thermometer at this temperature.

How many energy units does Object 2 have at the desired temperature?

Do Object 1 and Object 2 have the same number of energy units?

Did you expect them to have the same number of energy units? Why or why not?

Place Object 1 and Object 2 in contact. Wait until the thermometers read the same value and the energy units stop moving. Draw the thermometers.

How many energy units does Object 1 have now?

How many energy units does Object 2 have now?

How are the number of energy units for Object 1 and Object 2 related?

Did you expect this? Why or why not?

What is the change in energy for Object 1?

What is the change in energy for Object 2?
How is the change in energy for Object 1 and Object 2 related?

Did you expect this? Why or why not?

Investigation 4

Select another 2 materials to use to measure thermal energy transfer. Which material will you choose to be the hotter object (Object 1)? Which one will you choose to be the cooler object (Object 2)?

Heat Object 1 to the desired temperature. Click on the Pause button to prevent energy loss. Draw the thermometer at this temperature.

How many energy units does Object 1 have at the desired temperature?

Cool Object 2 to the desired temperature. Click on the Pause button to prevent energy loss. Draw the thermometer at this temperature..

How many energy units does Object 2 have at the desired temperature?

Do Object 1 and Object 2 have the same number of energy units?

Did you expect them to have the same number of energy units? Why or why not?

Place Object 1 and Object 2 in contact. Wait until the thermometers read the same value and the energy units stop moving. Draw the thermometers.

How many energy units does Object 1 have now?
How many energy units does Object 2 have now?

How are the number of energy units for Object 1 and Object 2 related?

Did you expect this? Why or why not?

What is the change in energy for Object 1?

What is the change in energy for Object 2?

How is the change in energy for Object 1 and Object 2 related?

Did you expect this? Why or why not?

Explanation

What patterns or trends did you see between these experiments?

What did you find regarding the final amount of energy in the two objects?

Does the energy flow result in a more uniform or less uniform distribution of energy?

Plan and Conduct an Investigation of the Transfer of Thermal Energy, part 2

In this part of the lesson, you will plan and conduct an experiment to investigate another question you have about thermal energy. You will use the same process as before. Before you begin, please discuss the answers to the following questions with your group.

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What is the purpose of your investigation? What question are you trying to answer?

What do you think the answer will be? This is your hypothesis.

What evidence will you need to answer this question? What data do you need to collect?

In thermal investigations, energy transfer with the environment will skew your results. How will you isolate your components in order to create a nearly closed system? What materials do you need to do this?

What are the boundaries of the system?

What will your initial conditions be?

What data will you collect? How will you collect this data? What materials do you need to collect the data?

How often will you take these measurements?

What is your experimental setup? Which items will you be testing? Which one will be at the higher temperature? Which one will be at the lower temperature? How will you obtain this temperature difference? What materials do you need to do this?

How many trials will you complete?

What data will you graph?

How will you analyze your data?

What are your lab safety procedures for this experiment?

After you have discussed these questions with your group and written the agreed-upon answers, complete the experimental design part of the Further Investigations of Thermal Energy handout.

Further Investigations of Thermal Energy

Group Members _____ _____

_____ _____

Question:

Write the question you are answering.

Hypothesis:

Write what you think the answer to your question will be.

Materials:

Write what materials you need.

Safety:

You need to be cautious when working in the lab. Write the safety precautions you will take.

Methods:

Write all the steps that you will be doing in this investigation. If you need to do something, make sure that you write it here. Use additional pages as needed.

Set up:

In this part, write all the steps you need to take before you begin collecting data.

Procedure:

Now that you are all set up, you are ready to begin the experiment and collect data. In this section, write everything you will do to perform the experiment and collect the data.

Teacher approval _____

Get teacher approval before beginning the next step. Once you have teacher approval, you are ready to begin your experiment. Follow the steps you outlined above.

Data:

As you collect your data, record it here: You might want to make a data table. Make sure you record data for each trial.

Graph or Drawing:

Draw a graph of your data here. Some data might be qualitative, you can represent this visually with a drawing.

Analysis:

Answer questions here that will help you understand and analyze your data. Possible questions include: What were the initial conditions? What were the final conditions? What are the boundaries of your system? What did your data show? What inferences can you make from your data?

Conclusions:

In this section write what you learned, describe the results of your graph and analysis, and describe what you would do differently next time.