National Aeronautics and Space Administration

Thermal Energy Transfer

Educator Notes

Learning Objectives

- Students will identify the three types of thermal energy transfer
- Students will experiment with the three types of thermal energy transfer
- Students will classify natural phenomena into one of the three types of thermal energy transfer

Safety

- All students need to use tongs when handling ice cubes
- Ensure the heated water for these experiments is not hot enough to burn or scald

Introduce the Investigation

Ask

- Prepare for this demonstration ahead of time by adding blue food coloring to water and freezing it in ice trays to make blue ice cubes (seven to eight ice cubes will be needed per student group)
- Place students in groups of three or four and supply them with copies of the student worksheet
    - Avoid handing out additional supplies until it is time to conduct each experiment
- Lead the students in a discussion about thermal energy by asking the following questions:
    - What is heat?
        - Possible answers from students:
            - How hot something is…
            - The energy of hot things…
            - What makes things hot…
        - Answer for students:
            - Heat is energy which is transferred from warmer objects to cooler objects
            - We call this energy thermal energy
    - How is heat, or thermal energy, transferred from one object to another?
        - Possible answers from students:
            - Touching something that is hot…
            - Standing close to something hot…
            - Mixing hot things into cold things…
            - Shining bright lights on things…
        - Answer for students:
            - Thermal energy can be transferred three ways:

Grades 6 to 8

Suggested Pacing

60-90 minutes

Materials

This list of materials supports one group of students.

- ☐ Blue and red food coloring
- ☐ Seven to eight blue ice cubes made from water and food coloring
- ☐ Warm water
- ☐ Cool (refrigerated) water
- ☐ Four insulated cups
- ☐ A clear container at least four to six inches deep, such as a small tote or baking dish
- ☐ Three paper bowls
- ☐ Two squares of aluminum foil (about 12”)
- ☐ Two craft sticks
- ☐ Electrical tape
- ☐ Several paper towels
- ☐ Copy of the student worksheet
- ☐ Pencils

National STEM Standards

- NGSS MS-PS3-3
- NGSS MS-PS3-4

        - Conduction – the transfer of thermal energy by coming in direct contact with another object (e.g., holding a cup of hot chocolate, walking bare foot across a cold floor)
        - Convection – the motion of gasses and liquids due to different densities (e.g., when warm air rises in your home)
        - Radiation – the absorption and emitting of visible or invisible light waves, called radiation, to from one object to another (e.g., sunlight on your skin, heating food in a microwave)
    - Can thermal energy be transferred from colder objects to warmer objects?
        - Possible answers from students:
            - Yes, touching cold things makes you feel cold…
            - Yes, in winter, the air makes things cold…
        - Answer for students:
            - No, thermal energy only travels from warmer things to colder things. When you touch something cold, for example ice, thermal energy is moving from your body into the ice. The feeling of cold is the feeling of thermal energy leaving your body. Warmer objects give off thermal energy, while colder objects receive thermal energy
- Introduce the students to the Thermal Energy Transfer STEMonstration video, and tell them a special guest has more information for them about thermal energy and heat transfer

Watch Thermal Energy Transfer STEMonstration Video

Have the students watch the STEMonstration video found at https://www.nasa.gov/stem-content/stemonstrations-thermal-energy/ and answer the following questions from the video on their worksheet.

1. What are the three types of thermal energy transfer?
2. What is the term used to describe living things being in thermal balance with their environments?
3. What type of thermal energy transfer does not occur aboard the International Space Station due to the microgravity environment?

Thermal Energy Transfer Investigation

Investigation 1: Conduction

- Each group of students needs four blue ice cubes on a folded paper towel and three insulated cups – one filled with warm water, one filled with cool water, and one filled with room temperature water.
    - Have each group add red food coloring to the cup of warm water and blue food coloring to the cup of cool water. The cup of room temperature water will remain clear
    - Have each group use tongs to add a single blue ice cube to each of the three cups of water and leave the fourth ice cube on the folded paper towel
    - Have the students observe the ice cubes as they melt while keeping the following questions in mind:
        - Where is the thermal energy coming from to melt the ice cubes? *Answer: From the water*
        - How is the thermal energy being transferred? *Answer: Conduction*
        - Which direction is the heat moving? Into the ice cube or out of the ice cube? *Answer: Into the ice cube*
        - Which of the four ice cubes is melting the fastest? *Answer: The one placed in warm water*
        - Is the ice cube in cool water melting faster than the ice cube on the paper towel? *Answer: Yes*
        - Is the cool water colder than the air in the room? How can the cool water melt the ice more quickly than the warmer air? *Answer: The conduction through water is more efficient than through the air because the water is denser and can transfer its heat into the ice more quickly*
- Have the students record their observations on their student worksheets and clean their stations in preparation for the next experiment.
- Ideally, the ice cube in the warm water should melt the fastest, followed by the room temperature water, then the cool water, then finally the ice cube on the paper towel. The ice cube in the cool water should melt more slowly than the one on the paper towel even if air is warmer than the cool water, because the water is denser and can conduct heat into the ice cube at a faster rate. If the results are not what was expected, possible causes can be discussed during the SHARE portion of the activity.

Investigation 2: Convection

- Each group of students needs one blue ice cube on a folded paper towel, one insulated cup filled with warm water, and one clear container filled with room temperature water.
  - Have the students add red food coloring to the cup of warm water
  - Have the students, as gently as possible, add the cup of red, warm water to one side of clear container of water
    - This should be done very carefully, so that the red, warm water sits on top of the clear water and does not mix right away
  - Have the students use tongs to gently add the blue ice cube to the opposite side of the clear container, so it also sits on top of the water
  - Have the students observe the clear container from the side, being careful not to shake, stir, or otherwise disturb the water while keeping the following questions in mind:
    - Where does the warm red, water stay when first added to the clear water? *Answer: On Top.* Why? *Answer: The warmer water is less dense than the room temperature water, so it floats at the top*
    - Where does the cold ice cube stay when first added to the clear water? *Answer: On* Top. Why? *Answer: Ice in its solid form is less dense than water, so it floats at the top*
    - As the ice cube melts, due to conduction with the room temperature water, where does the cooler blue melted water go? Why? *Answer: It begins to sink. Cold water is more dense than warmer water, so it begins to sink*
    - As the cooler blue water sinks, what starts to happen to warmer red water? *Answer: It begins to move across the top of the water, towards the ice cube*
    - What causes this movement of both masses of warm and cool water? *Answer: Convection. As the cool water sinks, the warmer water moves across the surface to take its place. The movement of masses of water that have different temperatures are called convection currents.*
- Have the students record their observations on their student worksheets and clean their stations in preparation for the next experiment.
- Ideally, the red warm water should sit on top of the room temperature water on one end of the container. As the blue ice melts at the other end of the container, cool, blue water should begin to sink below the ice cube. As more blue water sinks, it will displace water in the container causing the red water to move towards the ice cube, showing a pattern of circulation in the water. If the results are not what was expected, possible causes can be discussed during the SHARE portion of the activity.

Investigation 3: Radiation

- Each group of students will need three paper bowls, two 12" squares of aluminum foil, electrical tape, two craft sticks, and two blue ice cubes (not needed until after solar oven is completed).
  - First, have the students construct their solar ovens:
    - Line the interior of two paper bowls with aluminum foil with the shiny side facing outwards. Fold the excess foil over the rim of the bowls to secure it in place
    - Place one bowl upside down on top the other and secure one edge with a couple of strips of electrical tape to make a hinge
    - Use electrical tape and craft sticks to prop open the lid of the solar oven. The size of the opening will depend on the height of the Sun in the sky. The opening should be large enough so, when facing the Sun, light can shine into the bottom bowl and reflect off the interior of the top bowl

  - Have the students bring their solar ovens, third paper bowl, and tongs outside
    - Each group should set up their solar ovens facing the Sun and adjust the lid height as necessary
    - Provide each group with two blue ice cubes and have the students place one in the center of their solar ovens and the other into the center of the plain paper bowl
  - Have the students observe the two ice cubes as they melt, keeping the following questions in mind:
    - Where is the thermal energy coming from that is melting the ice cubes? *Answer: The Sun*
    - How is it being transferred? *Answer: Radiation*

  - Which direction is the energy moving? Into the ice cube or out of the ice cube? *Answer: Into the ice cube*
  - Which ice cube is melting faster? *Answer: The one in the solar oven*
  - If both ice cubes are sitting in the sunlight, why is one melting faster than the other? *Answer: The foil in the solar oven helped reflect more solar radiation (sunlight) into the ice cube*
- Ideally, the ice cube in the solar oven should melt more quickly than the ice cube in the plain paper bowl. Even though the air temperature outside is the same for both ice cubes, the one in the solar oven receives and absorbs more direct radiation from the sun. If the results are not what was expected, possible causes can be discussed during the SHARE portion of the activity

Classifying Thermal Heat Transfer

Have the students place a checkmark next to following examples of thermal energy transfer to classify each as an example of either conduction, convection, or radiation.

	Conduction	Convection	Radiation
Standing beside a campfire to get warm.			
Steam rising off a pot of boiling water.			
Feeling cold after jumping into a pool.			
Cold oceanic water sinking near the arctic.			
Dark clothing getting warm in sunlight.			
Burning your mouth after eating hot pizza.			

Have the students come up with their own examples for each of the three types of thermal energy transfer.

- Conduction_____
- Convection_____
- Radiation_____

Share

Lead the students in a discussion. Have each group present their findings from their investigations and their ideas for examples for each of the three types of thermal energy transfer.

Extensions

Consider using the solar ovens to make a warm treat, like melted marshmallows or chocolate.

Thermal Energy Transfer Student Worksheet

Thermal Energy Discussion

Think about the following questions and share your ideas as your teacher leads a discussion.

- What is heat?
- How is heat, or thermal energy, transferred from one object to another?
- Can thermal energy be transferred from colder objects to warmer objects?

STEMonstration Video

Watch the STEMonstration video entitled "Thermal Energy Transfer" as directed by your teacher and answer the following questions from the video:

1. What are the three types of thermal energy transfer?
2. What is the term used to describe living things being in thermal balance with their environments?
3. What type of thermal energy transfer does not occur aboard the International Space Station due to the microgravity environment?

Thermal Energy Transfer Investigation

Investigation 1: Conduction

- Your group will need four blue ice cubes on a folded paper towel and three insulated cups – one filled with warm water, one filled with cool water, and one filled with room temperature water
  - Add red food coloring to the cup of warm water and blue food coloring to the cup of cool water. The cup of room temperature water will remain clear
  - Use tongs to add a single blue ice cube to each of the three cups of water and leave the fourth ice cube on the folded paper towel
  - Observe the ice cubes as they melt while keeping the following questions in mind:
    - Where is the thermal energy coming from to melt the ice cubes?
    - How is the thermal energy being transferred?
    - Which direction is the heat moving? Into the ice cube or out of the ice cube?
    - Which of the four ice cubes is melting the fastest?
    - Is the ice cube in cool water melting faster than the ice cube on the paper towel? Is the cool water colder than the air in the room? How can the cool water melt the ice more quickly than the warmer air?
- Record your observations below and clean your station in preparation for the next experiment
    - Where is the thermal energy coming from tho melt the ice cubes?

_____

    - How is the thermal energy being transferred?

_____

    - Which direction is the heat moving? Into the ice cube or out of the ice cube?

- Which of the four ice cubes is melting the fastest?

- Is the ice cube in cool water melting faster than the ice cube on the paper towel? Is the cool water colder than the air in the room? How can the cool water melt the ice more quickly than the warmer air?

Investigation 2: Convection

- Your group will need one blue ice cube on a folded paper towel, one insulated cup filled with warm water, and one clear container filled with room temperature water.
  - Add red food coloring to the cup of warm water
  - As gently as possible, add the cup of red, warm water to one side of the clear container of water. This should be done very carefully, so that the red, warm water sits on top of the clear water and does not mix right away
  - Use tongs to gently add the blue ice cube to the opposite side of the clear container, so that it also sits on top of the water
  - Observe the clear container from the side, being careful not to shake, stir, or otherwise disturb the water while keeping the following questions in mind:
    - Where does the red, warm water stay when first added to the clear water? Why?
    - Where does the cold ice cube stay when first added to the clear water? Why?
    - As the ice cube melts, due to conduction with the room temperature water, where does the cooler blue melted water go? Why?
    - As the cooler blue water sinks, what starts to happen to warmer red water?
    - What causes this movement of both masses of warm and cool water?
- Record your observations below and clean your station in preparation for the next experiment.
  - Where does the red, warm water stay when first added to the clear water? Why?

  - Where does the cold ice cube stay when first added to the clear water? Why?

  - As the ice cube melts, due to conduction with the room temperature water, where does the cooler blue melted water go? Why?

  - As the cooler blue water sinks, what starts to happen to warmer red water?

  - What causes this movement of both masses of warm and cool water?

Investigation 3: Radiation

- Your group will need three paper bowls, two 12” squares of aluminum foil, electrical tape, two craft sticks, and two blue ice cubes (not needed until after solar oven is completed)

- Frist, you will construct your solar ovens
  - Line the interior of two paper bowls with aluminum foil with the shiny side facing upwards. Fold the excess foil over the rim of the bowls to secure it in place
  - Place one bowl upside down on top the other and secure one edge with a couple of strips of electrical tape to make a hinge
  - Use electrical tape and craft sticks to prop open the lid of the solar oven. The size of the opening will depend on the height of the Sun in the sky. The opening should be large enough so, when facing the Sun, light can shine into the bottom bowl and reflect off the interior of the top bowl
- Bring your solar ovens, third paper bowl, and tongs outside
  - Set up your solar oven facing the Sun and adjust the lid height as necessary
  - After getting two blue ice cubes from your teacher, place one in the center of your solar oven and the other into the center of the plain paper bowl
- Observe the two ice cubes as they melt, keeping the following questions in mind:
  - Where is the thermal energy coming from that is melting the ice cubes?
  - How is it being transferred?
  - Which direction is the energy moving? Into the ice cube or out of the ice cube?
  - Which ice cube is melting faster?
  - If both ice cubes are sitting in the sunlight, why is one melting faster than the other?

- Record your observations below
  - Where is the thermal energy coming from to melt the ice cubes?

_____

  - How is thermal energy being transferred?

_____

  - Which direction is the energy moving? Into the ice cube or out of the ice cube?

_____

  - Which ice cube is melting faster?

_____

  - If both ice cubes are sitting in the sunlight, why is one melting faster than the other?

_____

Classifying Thermal Heat Transfer

Place a checkmark next to following examples of thermal energy transfer to classify each as an example of either conduction, convection, or radiation.

	Conduction	Convection	Radiation
Standing beside a campfire to get warm.			

Steam rising off a pot of boiling water.			
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Cold oceanic water sinking near the arctic.			
Dark clothing getting warm in sunlight.			
Burning your mouth after eating hot pizza.			

- Come up with your own examples for each of the three types of thermal energy transfer.
  - Conduction_____
  - Convection_____
  - Radiation_____

Share

Participate in the discussion with your class. Share your findings from your investigations and your ideas for examples for the each of the three types of thermal energy transfer.