Heat Transfer

Partial support for this project was provided by the National Science Foundation's Course, Curriculum, and Laboratory Improvement (CCLI) program under Award No. 0737462. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Partial support for this project was provided by the American Society for Heating, Refrigeration, and Air-Conditioning Engineering (ASHRAE) through a Senior Projects grant. Any opinions, findings and conclusions or recommendations expressed here are those of the author(s) and do not necessarily reflect the views of ASHRAE.
ACTIVITY OVERVIEW

**Heat Transfer Kit Overview**

Your sled dog has abandoned you in the middle of a race, and you’re left with nothing but a few supplies in your backpack to keep you warm! In this kit, students will learn how to use heat transfer principles to save their intrepid adventurer. Engineers, designers, architects, technicians, and many others frequently encounter heat transfer in their daily work. Just as engineers test and collect data about certain materials in order to make good design decisions, the students will do the same to help keep their character warm.

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<td>Experience the wind changing the perceived temperature but not the actual temperature.</td>
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**Learning Objectives**

By the end of this lesson, students should be able to…

- Describe what heat transfer is and what the three basic forms of heat transfer are
- Describe heat versus temperature based on experimental observations
- Work in teams to satisfy a design scenario
- Explain how wind chill affects temperature

**NYS Learning Standards**

Standard 1: Students will use mathematical analysis, scientific inquiry, and engineering design, as appropriate, to pose questions, seek answers, and develop solutions. Students will:

- Interpret organized observations and measurements, recognizing simple patterns, sequences, and relationships
- Discuss how best to test the solution; perform the test under teacher supervision; record and portray results through numerical and graphic means; discuss orally why things worked or did not work; and summarize results in writing, suggesting ways to make the solution better

Standard 4: Energy exists in many forms, and when these forms change energy is conserved. Students will:

- Describe the sources and identify the transformations of energy observed in everyday life
- Describe situations that support the principle of conservation of energy
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[?] Signifies Group Discussion

[?] Signifies Activity

The TEAK Project

Rochester Institute of Technology
Definitions

Heat (Thermal) Energy
Heat energy is a form of energy that is present in the molecules and atoms of an object. When an object is hot, its molecules have a lot of energy and therefore move fast. When an object is cold, the molecules begin to slow down thus decreasing the overall amount of energy. The faster the molecules are moving, the more space they take up.

Heat vs. Temperature
Heat is the energy present in an object. Heat energy depends on many factors, such as how fast particles are moving as well as how many particles are present. Temperature is a measure of the average kinetic energy of the molecules in an object. Temperature is not dependent on number or size. While heat and temperature are different, they are directly related. When an object heats up, its molecules become more excited thus increasing the overall speed at which they travel. A temperature reading of this object will detect the increased kinetic energy of the molecules thus generating a higher temperature reading.

Heat Transfer
Heat transfer is the movement of thermal energy from one object to another. According to the Second Law of Thermodynamics, heat will always transfer from a hotter object to a cooler one. Once heat has begun to transfer from one object to another, it can never be stopped (only slowed down). Heat transfer can also occur when an object is at a different temperature than its surroundings. In this case, the object will gain or lose energy until it is the same temperature as its surroundings. This is known as thermal equilibrium.

Conduction
Conduction is heat transfer through direct contact. When adjacent atoms vibrate or exchange electrons, heat energy is transferred between them. Since conduction requires the physical touching of atoms, it is most common in solids. Substances that easily transfer heat energy are called thermal conductors. Substances that resist heat transfer are called thermal insulators.

Convection
Convection is heat transfer between a solid object and the liquid or gas that is passing by it. The faster the liquid or air is moving, the greater the convective heat transfer will be. There are two types of convection: natural and forced. Natural convection is distinguished by the lack of an external source. The motion of the fluid is caused by temperature variations in the fluid. For example, when air passes over a fire, it heats up and the particles spread out (making it less dense). This causes the air to rise. As the air gets farther from the fire it begins to cool down and the particles contract. This causes it to become denser and sink downward. Forced convection occurs when there is an external source, such as a fan or a pump. The fluid will travel in the path it is directed, as opposed to the rise and fall path of natural convection. An example is a furnace, where air is heated up and forced to follow ducts to certain areas of a house/building.

Radiation
Radiation is heat transfer in the form of electromagnetic waves that carry energy from one object to another. There is no physical medium needed for radiation to occur; it will even work in a vacuum. The most common example of radiation is energy from the sun.

Thermal Conductor
A thermal conductor is a material that allows heat to be transferred through it.
**Thermal Insulator**
A thermal insulator is a material that reduces the rate of heat transfer by limiting the amount of conduction and/or convection that occurs.

**Wind Chill**
Wind chill is the apparent temperature felt by a person due to the combination of air temperature and wind speed. While the temperature difference can be perceived, it cannot be measured. Although wind chill is usually associated with winter, it can be felt in warmer weather as well. In the winter, cool breezes make the outside temperature feel colder than it is. When it’s warm out, a fan blowing on a person moves air across their skin and helps it evaporate moisture. The evaporation causes a perceived cooling effect, making the air feel cooler than it actually is.
Heat Transfer

DURATION
65-70 Minutes

CONCEPTS
Heat (Thermal) Energy
Temperature vs. Heat
Conduction
Convection
Radiation
Wind Chill
HEAT TRANSFER INTRODUCTION

Background Information

Heat transfer is the movement of thermal energy from one object to another. According to the Second Law of Thermodynamics, heat will always transfer from a hotter object to a cooler one. Once heat has begun to transfer from one object to another, it can never be stopped (only slowed down). Heat transfer can also occur when an object is at a different temperature than its surroundings. In this case, the object will gain or lose energy until it is the same temperature as its surroundings. This is known as **thermal equilibrium**.

**Simplified Definitions: 5 Minutes**

- **Heat Energy**
  - Heat energy is a form of energy that is present in the molecules and atoms of an object.
  - The motion of atoms and molecules results in heat energy.
- **Conduction**
  - Conduction is heat transfer through direct contact. When adjacent atoms vibrate or exchange electrons, heat energy is transferred between them.
  - **EX:** Heating a pot on a stove
- **Insulator**
  - A material that reduces the rate of heat transfer by limiting the amount of conduction and/or convection that occurs.
  - Prevents heat moving from one place/object to another.
- **Conductor**
  - A material that allows heat to be transferred through it.

**Heat Energy Group Discussion: 5 Minutes**

(Pose the following questions to the group and let the discussion flow naturally…try to give positive feedback to each child that contributes to the conversation.)

**Q:** Do you know what the Universe is made up of?
  - Matter and Energy
    - Matter is made up of atoms and molecules (groupings of atoms).
    - Energy causes the atoms and molecules to always be in motion - either bumping into each other or vibrating back and forth.

**Q:** Does matter still have heat energy, even in the coldest environment you can imagine?
  - Heat energy is present in all matter.
  - Even in the coldest voids of space, matter still has a very small but still measurable amount of heat energy.

**Q:** What are some ways you can think of to heat up a substance?
  - By increasing the speed of its molecules
  - By adding energy to it
    - For example, when we are cold, we can jump up and down to get warmer.
    - The more energy that goes into a system, the more active its molecules and atoms are.
Q: So then what would happen if we were to take energy away?
• When you take energy away, it cools down.

Q: Do you think the amount of heat a substance has is determined by how fast its molecules are moving?
• Yes - the faster molecules move, the more heat or thermal energy they create.
• How fast the molecules are moving also depends on how much energy is put into them.

Q: Do you think temperature is the same thing as heat?
• No, heat and temperature are different.
• Temperature is a measure of how fast the atoms or molecules of a substance are moving.
• It’s a way to measure how hot or cold and object is.

Q: Heat travels from a hot object to a cold object. So if you pick up an ice cube, which way is heat flowing? How about if you pick up a cup of hot chocolate?
• From your hand to the ice cube.
• From the hot chocolate to your hand

Heat vs. Temperature Activity – 15 Minutes

Idea obtained from the ASHREA Cool Science Kit, Module #2 – Part 3.

Learning Objectives

By the end of this exercise, students should be able to…
• Feel/understand that heat and temperature are different
• Observe how mass and temperature affect heat

Materials

Included in each kit are:
1. (1) Thermometer
2. (1) Spoon
3. Paper Towels
4. (4) Large Metal Balls
5. (4) Small Metal Balls
6. (4) Rubber Balls

Safety Precautions

Do NOT use boiling water!
Stress that if something is too hot or too cold, to put it down immediately.
Procedure

1. Separate the students into groups of four.
2. Hand out the activity sheet and materials to each group.
3. Fill each group’s container with hot OR cold water. (NOTE: hot/warm water works best)
4. **Emphasize that if something feels too hot or too cold to put it down immediately!**
5. Have the students place all the balls into the container. Let them sit for 2 minutes to ensure that they are the same temperature. Keep track of time on a stopwatch or clock.
   **Make sure to walk among the groups and make sure everyone is doing the activity correctly**
6. Have the students measure the temperature of the water with the thermometer.
7. One student should remove the small metal balls from the water with the spoon and place them on a paper towel.
8. Everyone should pick up a small metal ball between his or her thumb and index finger.
   **PUT DOWN IF IT IS TOO HOT/COLD***
9. Ask the students to observe the heat/coldness they feel.
10. One student should remove the large metal balls with the spoon and place them on a paper towel.
11. Everyone should pick up a large metal ball between his or her thumb and index finger. (Holding it in a fist works too.)
   **PUT DOWN IF IT IS TOO HOT/COLD***
12. Ask the students to observe the heat/coldness they feel.
13. One student should remove the rubber balls with the spoon and place them on a paper towel.
14. Everyone should pick up a rubber ball between his or her thumb and index finger.
   **PUT DOWN IF IT IS TOO HOT/COLD***
15. Ask the students to observe the heat/coldness they feel.
16. Have the students fill out the questions on the activity handout while the instructor empties the containers of water.
17. Thoroughly dry all metal and rubber balls!
18. Put all materials back into the plastic containers.

Expected Results

The students should observe that the small metal ball feels hot for a few seconds, but quickly cools. The large metal ball feels hotter much longer, even though they are the same temperature. Remember, heat is a function of temperature, mass, and material. Since the two metal balls have the same temperature and material, mass is the only variable that affects the heat. More molecules to excite signify more internal energy, and more internal energy means the ball will take longer to cool down. The students should observe that the rubber ball feels hot for a few seconds, but cools quickly. The only variable that changes between the rubber and metal balls is the material. The metal ball feels hotter for longer because the metal allows more heat to be transferred to the fingers than the rubber does.
CONVECTION INTRODUCTION

Simplified Definition: 2 Minutes

Convection

- Convection is heat transfer between a solid object and the liquid or gas that is passing by it. The faster the liquid or air is moving, the greater the convective heat transfer will be.
  EX: Furnace, fire

Convection Group Discussion: 5 Minutes

(Pose the following questions to the group and let the discussion flow naturally...try to give positive feedback to each child that contributes to the conversation.)

Q: Thermal expansion and contraction is when materials grow or shrink when they are heated or cooled. When something is heated do you think it expands (grows) or contracts (shrinks)?
  - It expands when heated.
  - It contracts when cooled.

Q: Think about when you are up and running around in gym class, you use a lot of space in the gym and you get really warm. But when you come back to the classroom and slow down you take up less space and you start to really cool down. The same is true for atoms and molecules, when they are moving fast they take up more space and when they are moving slowly they take up less space.

Q: When atoms and molecules are moving fast and they expand, do you think they rise up or sink lower? Why?
  - They will rise upwards.
  - This is because when they separate, they become less dense. For example, if three students are sitting next to one another, they will weight a certain amount. If those same three students get excited and run away from each other, they will weigh the same amount but their weight will be spread out over a greater area.

Q: If hot air rises because it expands, what does cold air do?
  - It sinks towards the ground.

Convection Currents Activity – 5 Minutes
Learning Objectives

By the end of this exercise, students should be able to…

- See/understand the way hot and cold fluids move
- Understand the concept of convection

Materials

1. Large container with lid
2. Small container with lid
3. Food coloring

Procedure

1. Fill the large container with cold water.
2. Fill the small container with hot water and food coloring.
   **Try to do the first two steps before starting the lesson**
3. Have all the students gather around so that they can see.
4. Place the small container into the larger container and remove the lid.
5. Explain what is happening to the students. Relate the movement of water to the movement of air. Use the expected results paragraph for a guide of what to mention.
6. Replace the lid on the larger container, and empty after the lesson is over.

Expected Results

The warm water will rise out of the small container, since it is less dense than the cold water surrounding it. As the warm water gets cooler it will start to sink towards the bottom of the container. This is because heat is always transferred from hot to cold objects. Eventually, the hot water will become the same temperature as the cold water. This is called thermal equilibrium. The movement of the water demonstrated the concept of natural convection. Some examples of natural convection are: weather, smoke from a fire rising into the air, a loft being warmer than ground level.
RADIATION INTRODUCTION

Simplified Definition: 1 Minute

Radiation

- Radiation is heat transfer in the form of electromagnetic waves that carry energy from one object to another. There is no physical medium needed for radiation to occur; it will even work in a vacuum. EX: The sun!!! Even though the sun is about 93 million miles away from the earth, we still feel some of its heat. It travels to earth through the vacuum (no air) of space by way of rays!

Radiation Group Discussion: 5 Minutes

(Pose the following questions to the group and let the discussion flow naturally…try to give positive feedback to each child that contributes to the conversation.)

Q: The sun is common to all places on Earth. Is the radiation from the sun stronger in some areas versus others?
   - Yes, radiation from the sun is stronger in areas where the rays hit the Earth more directly (the equator area gets more direct radiation than the poles do).

Q: Even though the radiation may be less direct in certain areas, do you think those areas can still be heated by the sun?
   - Yes, those areas will still be heated a little. It will not be as hot as other areas though.

Q: Rochester doesn’t have very direct radiation rays, but heating through radiation still works well here. Can you think of any structures that are heated up by the sun in this area?
   - Greenhouses
   - Car interiors
   - Sun rooms
Learning Objectives

By the end of this exercise, students should be able to…

- Understand the concept of radiation
- See/understand how radiation transfers heat by using thermal crystals

Materials

Each group gets:

1. (1) K’nex structure
2. (1) Bag of materials
3. (2) Thermal crystals

Other materials:

1. (3) Clip lamps
2. (1) Surge Protector
3. (3) Laminated Test Layouts

Setup Procedure

(For instructor’s purpose only...DO NOT have students help with this)

1. Room Arrangement
   
   This activity requires 3 working stations. They all need to be around a central location so that the power cords will reach.

Design A: The activity was designed and tested with the clip lamp attached to the back of a chair and the materials set up on a table. This setup allows the students to see what is happening and to easily manipulate the activity.

Design B: If the desks and chairs cannot be moved, using only chairs is a suitable alternative.
2. Clip Light Arrangement
   Make sure that the clip lamps are set up facing away from each other so that they don’t interfere with other groups’ thermal crystals.

   Design A: Attach clip lamp to the back of the chair

3. Structure Arrangement
   a. Place one test layout at each workstation. Make sure that the layout is in proper position, and then tape it down. The structures/solar panels will go in the labeled boxes on the test layout.
4. Shade Orientation
   a. The orientation of the lampshade is critical.
   b. Place a K’NEX structure in the labeled box on the test layout. The face of the lamp needs to be parallel to the red rods on the K’NEX structure. While it doesn’t have to be perfect, use the structure to get the shade as parallel as possible.

   a) Another way to get the shade in proper position is to make sure that there is just enough room between the silver clamp arm and the lampshade to fit your fingers.
   b) Make sure that the shades are tightened so they don’t slide.

Safety Precautions

The lamps get very hot! Instruct the students NOT to touch the lamps for any reason. They should ask for assistance if they need to adjust their lamp. The lamps are very bright! **Instruct students NOT to look directly into the light.**

Procedure

1. Have the students help move desks/chairs to create three workstations.
2. Have the students return to their groups. Pass out a structure, test materials bag, and activity handout to each group.
3. Read through the design scenario with the students. Make sure that everyone understands the activity.
4. Have the students take the materials out of the bag. As a group, they should decide on three materials that they think best meet the design criteria. They should write their materials in the table on the activity handout.
a. While the groups are doing this, the instructor should set up the three clip lamps (making sure that each lamp is set up to allow enough working space for two groups). The instructor should attach each lamp to the surge protector, and plug it in (making sure to switch it off). The instructor should also set up a test layout at each test station. See Setup Procedure for more details.

5. Assign each group to a clip lamp. Have the students bring their structure, materials, and thermal crystals to their lamp.

6. The instructor should remind the students that the lamps get hot, and they are not to touch them for any reason.

Read the instructions to the students step by step. Have a different student perform each step. Have students raise their hands after they complete a step so the instructor knows to move on.

7. Record the color of the room temperature thermal crystal. When the lamp is turned on, all students will need to watch the thermal crystals and see the order in which they change colors.

8. Place the thermal crystal in the structure box on the test layout.
   (This is done with no insulation so the students can see how the crystals change color.)

9. INSTRUCTOR: Flip the switch on the surge protector to turn on the lamps, then count to 15. When 15 seconds are up, flip the switch back off.

10. Record the color of the heated crystal.

11. Put the K’NEX structure in the appropriate box on the test layout.

12. Put a thermal crystal into the structure.
   (Make sure that the students hold the crystals on the sides, so as to transfer as little heat as possible to them.)

13. Put a material onto the structure. It should be resting on the green pegs and leaning back against the incline.
   a. INSTRUCTOR: Quickly walk around to make sure that all materials are leaning against the structure so that the thermal crystal will be covered.

14. INSTRUCTOR: When everyone is ready, flip the switch to turn the lights on and remind the students not to look into the light. Start the timer when the lights are switched on.

15. INSTRUCTOR: When one minute is up, turn the lights off.

16. Remove the material from the K’NEX structure and look at the color of the thermal crystal.
   (This needs to be done quickly, so that the crystal doesn’t start to change colors.)

17. Record the color of the thermal crystal.

18. INSTRUCTOR: Repeat steps 12-17 so the students can test their other two materials.
   b. It may be necessary to repeat the experiment a 4th time, in case groups mess up on one of their tests.

End Keeping-Heat-In Design Activity
Concluding Discussion: 5 Minutes

Q: What material do you think is best to keep the heat in Emmy’s shelter?
   • Sandwich Bag
   • Tarp

Q: Why do you think these materials worked best?
   • They are clear and plastic, so they allow radiation in but don’t let heat escape.
   • They are not reflective (like the wrapper) so they allow radiation through them.

Q: Did you expect these materials to work best? Why or why not?
   • Can be whatever answer the think is correct.

Q: Do you think the idea of trapping radiation/heat is used in engineering today?
   • YES! Passive Design
   • Engineers and architects use large windows that face the sun to heat up buildings in the winter. The buildings include special overhangs to allow the sun to come in during the winter and to keep it out during the summer.

Q: If you were going to build a structure to try to keep heat out, which materials would work best? Why?
   • Insulated foil because the air filled pockets disrupt the heat transfer and the reflective surface keeps radiation from getting through.
   • The energy bar wrapper because it reflects the radiation rays away.

Trouble-Shooting Guide

1. Crystals turn color without being touched.
   a. If the classroom is warm, the crystals may show “warmer” colors without being touched.
2. The crystals aren’t turning the color ranges described on the handout answer key
   a. Make sure the structure is in the box on the test layout.
   b. Make sure that the test layout is positioned correctly.
   c. Make sure the lamp is angled down so that it is aiming at the structure.
   d. Make sure the students are checking the thermal crystal color promptly after the light is turned off.
HEAT TRANSFER KIT

Lesson Extender

DURATION
15 Minutes

CONCEPT
Wind Chill
WIND CHILL INTRODUCTION

Background Information

Wind chill is the apparent temperature felt by a person due to the combination of air temperature and wind speed. While the temperature difference can be perceived, it cannot be measured. Although wind chill is usually associated with winter, it can be felt in warmer weather as well. In the winter, cool breezes make the outside temperature feel colder than it is. When it’s warm out, a fan blowing on a person moves air across their skin and helps it evaporate moisture. The evaporation causes a perceived cooling effect, making the air feel cooler than it is.

Simplified Definition: 1 Minute

- Wind Chill
  - The temperature felt by a person due to the combination of air temperature and wind speed. While the temperature difference can be felt, it cannot be measured.

Group Discussion: 5 Minutes

(Pose the following questions to the group and let the discussion flow naturally… try to give positive feedback to each child that contributes to the conversation)

Q: Has anyone heard of or experienced wind chill? When was it?

- Hopefully people have heard of wind chill. If not, mention winter months and how schools usually close if the wind chill is too bad.
- Usually, people associate wind chill with the winter months.

Q: Does anyone think that wind chill can happen in warm weather?

- The students may answer yes or no.
- Either way, explain that a fan blowing on a person when it’s warm out creates a wind chill effect. The fan blows air across a person’s skin and helps moisture evaporate. The evaporation makes the person feel cooler than they are. This temperature difference is only felt; it cannot be measured.
Learning Objectives

By the end of this exercise, students should be able to…

- Understand the concept of wind chill
- Feel a perceived temperature difference

Materials

1. (3) Clip Lamps
2. IR Thermometer
3. (3) Mini-fans

Safety Precautions

The lamps get very hot! Instruct the students NOT to touch the lamps for any reason. They should ask for assistance if they need to adjust their lamp.

Procedure

1. The instructor will need to paint/color a small black square onto their hand. A piece of construction paper could also be taped on. This needs to be done so that the IR Thermometer will get an accurate reading (just using your skin will cause jumpy, inaccurate temp. measurements).
2. Have all of the students gather around one clip light. The instructor should plug in the clip light.
3. The instructor should put his/her hand under the light. Count to 20 and then measure the temperature of the square using the IR thermometer.
4. Have a student turn on a mini-fan and aim it at the instructor’s hand. Count to 20 seconds again, and then retake the temperature of the square. The temperature should be the same (or very close). The instructor should tell the students if their hand feels colder.
5. Have the students return to their assigned clip light from the previous activity.
6. Have students take turns putting their hands under the light with and without the fan to experience the perceived temperature change. Remind the students that the temperature of their skin is not changing, as demonstrated by the IR thermometer.
7. After everyone has had a turn, unplug all the clip lights and put them away.

Concluding Discussion: 1 Minute

Q: Did this activity help you to see that wind chill can be felt in a warm area too?
   • Whatever answer they give will be correct.

Q: Did it surprise you that your hand felt cooler, but it was actually the same temperature?
   • Whatever answer they give will be correct.
HEAT TRANSFER ACTIVITIES HANDOUT

Heat vs. Temperature Questions

Does the smaller or larger metal ball feel hotter/colder for longer?

Does the metal or rubber ball feel hotter/colder for longer?

Why does the metal ball feel warmer than the rubber ball?

What three things do you think heat depends on?

1.

2.

3.

How do you think heat and temperature are related?

What type of heat transfer was experienced in this activity?
**Heat vs. Temperature Questions (ANSWERS)**

Does the smaller or larger metal ball feel hotter/colder for longer?  
The larger metal ball will feel hotter/colder for longer because of its size. Since the larger ball has more mass, it has more molecules that can be excited. The greater the amount of molecules that are excited, the longer the ball will retain its feeling of heat/cold.

Does the metal or rubber ball feel hotter/colder for longer?  
The metal ball feels hotter for longer because of its material. It feels hotter because metal allows more heat to be transferred to your fingers than the rubber ball does.

Why does the metal ball feel warmer than the rubber ball?  
Rubber is an insulator while metal is a conductor.

What three things do you think heat depends on?  
1. Temperature – the measure of how fast an object’s molecules are moving  
2. Mass – the size of the object  
3. Material – what the object is made of

How do you think heat and temperature are related?  
Heat is the form of energy present in the molecules and atoms of an object; the movement of the molecules and atoms makes heat. Temperature is the measure of how fast the molecules and atoms are moving.

Simply: Heat is the movement itself; temperature is the measure of the movement.

What type of heat transfer was experienced in this activity?  
Conduction!
**KEEPING WARM DESIGN ACTIVITY**

**Location:**
Ruby, Alaska

**Time of Year:**
Winter

**Time of Day:**
9:00 am

**The Story:**
Emmy is a 25 year-old engineer, who has decided to compete in the IDITAROD dogsled race for the first time. She has gone dog sledding many times but never on her own. The IDITAROD is a very stressful race, and Emmy is trying to remember everything that she needs to do. On the 13th night of the race, Emmy and her dogs camp out in the town of Ruby. In the morning, Emmy gets up, packs her gear, and hooks the dogs to the sled. They begin their journey to the next town, only along the way something goes terribly wrong! Emmy’s dogs come unhooked and run on without her! Emmy is stranded! The temperature is only 1°F, and Emmy knows she needs a way to stay warm until someone can come help her. All she has around her is her sled, the supplies she packed, and a few sticks she can gather from the woods.

**Her Supplies:**
- A map
- A sandwich bag
- A t-shirt
- An energy bar wrapper
- A tarp
- Sticks

**The Challenge:**
Use Emmy’s supplies to make a shelter that will keep the cold Arctic snow out, but let the sun warm her up!

**Thermal Crystal Data:**

<table>
<thead>
<tr>
<th>Color</th>
<th>Approximate Temp. (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>76-77</td>
</tr>
<tr>
<td>Red</td>
<td>77-79</td>
</tr>
<tr>
<td>Light Green</td>
<td>79-81</td>
</tr>
<tr>
<td>Dark Green</td>
<td>81-83</td>
</tr>
<tr>
<td>Blue</td>
<td>83-85</td>
</tr>
</tbody>
</table>

**Design Tables:**

<table>
<thead>
<tr>
<th>Unprotected Crystal</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOT in the Light</td>
<td></td>
</tr>
<tr>
<td>In the Light</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Material</th>
<th>Color</th>
</tr>
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<tbody>
<tr>
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The TEAK Project      Rochester Institute of Technology
**Keeping Warm Design Activity (ANSWERS)**

Design Tables:

<table>
<thead>
<tr>
<th>Material</th>
<th>Color</th>
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<tbody>
<tr>
<td>Sandwich Bag</td>
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</tr>
<tr>
<td>Tarp</td>
<td>Dark Blue</td>
</tr>
<tr>
<td>Sticks</td>
<td>Blue to Black Rainbow</td>
</tr>
<tr>
<td>Map</td>
<td>Dark Green/Blue</td>
</tr>
<tr>
<td>T-shirt</td>
<td>Red/Light Green</td>
</tr>
<tr>
<td>Wrapper</td>
<td>Black/Light Red</td>
</tr>
<tr>
<td>Insulated Foil</td>
<td>Black</td>
</tr>
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</table>

**Colors of the students thermal crystals may vary based on testing error.**
EXTRA ACTIVITY WORKSHEET

*Keeping Cool Design Activity*

**Location:** The Colorado Plateau  
**Time of Year:** Summer  
**Time of Day:** 11:00 am

**The Story:**
Emmy is a 25 year-old math teacher, who has decided to go hiking since she has the summer off from work. She decides to go on a 3-day hike, since she has never gotten to explore the Colorado Plateau for that long. The first two days go fine, but when Emmy gets up on the third day she realizes that she lost her GPS. She doesn’t know how to get back, but she starts hiking in the direction she thinks she should go. However, after a few hours of hiking Emmy realizes she is lost and disoriented. She doesn’t have a lot of water or food left, so she wants to make a shelter to keep her cool until the heat of the day passes. She decides to lay her hiking poles up against the side of the plateau, and lay a material over the poles to make a shelter.

**Her Supplies:**
- A map
- A sandwich bag
- A t-shirt
- An energy bar wrapper
- A tarp
- An insulated cooler

**The Challenge:**
Use Emmy’s supplies to make a shelter that will keep her cool in the hot desert sun.

**Crystal Data:**

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<tr>
<th>Color</th>
<th>Approximate Temp. (°F)</th>
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</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>Red</td>
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<tr>
<td>Light Green</td>
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<td>81-83</td>
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<td>Blue</td>
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**Design Tables:**

<table>
<thead>
<tr>
<th>Unprotected Crystal</th>
<th>Color</th>
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<tbody>
<tr>
<td>NOT in the Light</td>
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<tr>
<td>In the Light</td>
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<table>
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<th>Color</th>
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**Keeping Cool Design Activity (ANSWERS)**

Design Tables:

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<tbody>
<tr>
<td>Unprotected Crystal</td>
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</tr>
<tr>
<td>NOT in the Light</td>
<td>Black/Light Red</td>
</tr>
<tr>
<td>In the Light</td>
<td>Dark Blue</td>
</tr>
<tr>
<td>Insulated Cooler</td>
<td>Black/Light Red</td>
</tr>
<tr>
<td>Wrapper</td>
<td>Black/Red</td>
</tr>
<tr>
<td>T-shirt</td>
<td>Red/Light Green</td>
</tr>
<tr>
<td>Map</td>
<td>Dark Green/Blue</td>
</tr>
</tbody>
</table>

**While these are not all the possible material choices, they are the materials that offer the most protection from the sun. Also, colors may vary based on testing error.**
IMAGE SOURCES

   http://www.geography.hunter.cuny.edu/~tbw/wc.notes/2.heating-earth.surface/images/mechanisms.heat.transfer.jpg

   http://www.teachersource.com/product/touch-and-see-square

EXTENDED INFORMATION/RESOURCES


U.S. Department of Energy website
   http://www.doe.gov

Some typical insulation and R-values

How Stuff Works
   http://www.howstuffworks.com

Engineering K-12
   http://www.engineeringk12.org
## REVISIONS

<table>
<thead>
<tr>
<th>Date</th>
<th>Changes Made</th>
<th>Changes Made By</th>
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<tbody>
<tr>
<td>10/21/2009</td>
<td>Added new activities and concepts, reorganized the lesson plan layout, and changed the handout</td>
<td>Heather Godlewski</td>
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<tr>
<td>3/23/2012</td>
<td>Edited for grammar and syntax issues. Reorganized to new format.</td>
<td>Dillon Jourde</td>
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<tr>
<td>3/12/2013</td>
<td>Updated formatting. Added table of contents and work cited page. Fixed grammar and syntax issues.</td>
<td>Todd Jackson</td>
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