USDA National Institute of Food and Agriculture
U.S. DEPARTMENT OF AGRICULTURE

# HEAT QUEST

*investigating conduction, convection, and radiation*

6.PS3.2: Use a model to gather evidence to support changes to a system can be caused by transfers of sound or thermal energy (i.e., conduction, convection, or radiation).

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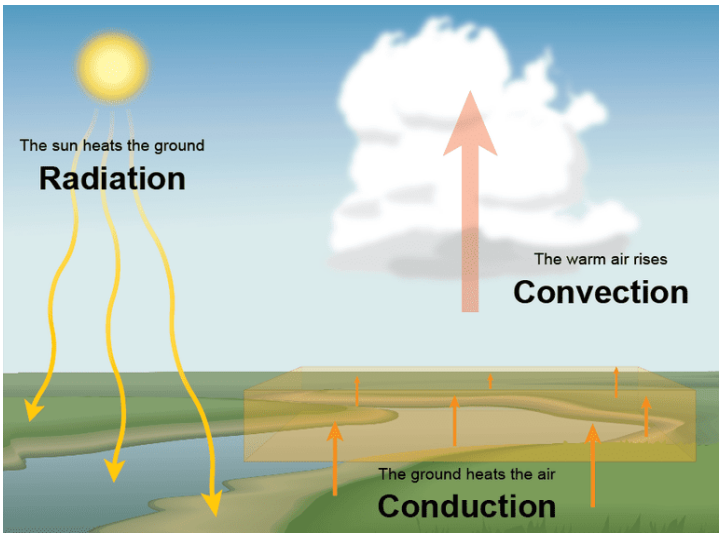
**INTRODUCTION**

Have you ever been camping, especially in cold weather? The three modes of heat transfer - conduction, convection, and radiation - all help you while on a camping trip! When you place a cooking pot directly over the campfire flames, you're cooking through **conduction** (direct contact with heat source)**.** When you hold a marshmallow on a stick above the fire waiting for it to get toasty, you rely on **convection** (heat moving through nearby air or liquids)**.** When you open your tent in the morning and feel the warm sun on your skin, you're feeling heat through **radiation** (waves of energy that travel through air or space).




*Graphic by NOAA*

If you use conduction, convection, and radiation while spending time outside, you can imagine that animals do too! This is especially important when talking about livestock. Livestock animals are **domesticated** (not wild). Because livestock depend on people for their care, it is very important for the humans who raise them to understand how to keep them healthy, including keeping them cool in hot weather and warm in cold weather.

How do you feel when you get too hot - angry, annoyed, uncomfortable? It's the same for animals! For example, if a dairy cow gets too hot, she doesn't produce as much milk. When a flock of chickens gets too hot, they may start to fight each other. If a pig can't cool off, it might pass out due to heat stress.

What about a time when you've been so cold you can't think straight? Animals can also get too cold. For example, if a rooster stays in cold weather too long, his comb (the red, waxy points on the top of his head) can get frostbite and fall off. If a pregnant cow gets too cold, she may not be able to safely keep her baby due to the stress. If a goat doesn't have a warm environment, he may lose his appetite and not eat.

Can you see how important it is to keep animals we raise from getting too hot or too cold? Let's investigate how the three principles of **conduction, convection,** and **radiation** can help us make the best environment possible for our animals!


# EXPERIMENT 1: CONDUCTION

## MATERIALS

| *per group of 4 students* | *per student* |
|---|---|
| • timer<br>• infrared thermometer<br>• measuring cup<br>• 3 small boxes<br>• 3 ice packs (frozen)<br>• 4 cups of straw<br>• 4 cups of wood shavings<br>• 4 cups of shredded paper<br>• paper towel<br>• farm animal | • pen or pencil |

## PROCEDURE

***Imagine:*** Your group raises farm animals. At night, the animals stay in a barn with a concrete floor. During the winter, you notice your animals shiver, huddle together, and seem uncomfortable lying on the cold floor. As winter continues, they eat less and begin to look unhealthy.

**Question:** How can you keep the animals warm using the principle of **conduction**?

**Important:** The box represents the barn, and the ice pack represents the cold winter ground. For all trials after the Empty Box control, keep the box on the ice pack for the full 2-minute trial. Position the infrared thermometer **1 inch above the center of the material in the box when taking each reading**. Use a new box and ice pack for each part of the experiment to maintain consistent starting conditions.

**Empty Box (Control-No Ice Pack)**

1. Place the empty box on the table **without** the ice pack underneath it.
2. Place the farm animal in the center of the box.
3. Take the temperature 1 inch above the center of the box. This is your control measurement.
4. Record the starting temperature in **Table 1** on page 4 under **Empty Box (No Ice Pack)**.

**Empty Box on Ice Pack (No Bedding)**

1. Carefully place the box, with the farm animal still inside, on top of the frozen ice pack.
2. Close the lid and allow the box to sit for **2 minutes**.
3. After 2 minutes, open the lid and measure approximately 1 inch above the center of the bottom of the box. Record the temperature in **Table 1** under **No Bedding**. Then remove the box from the ice pack and take the farm animal out of the box.

**Shredded Paper**

1. Place **4 cups** of shredded paper in the box, spreading it evenly across the bottom. Make sure the bottom does not show through the paper. Place the farm animal in the center and close the lid. Place the box on top of the ice pack.
2. Set a timer for **2 minutes**.

| **Predict** |
| --- |
| Will the shredded paper ***raise*** or ***lower*** the temperature of the barn floor? Why? |
| |

3. After 2 minutes, take the temperature by pointing the infrared thermometer 1 inch above the shredded paper in the middle of the box. Record that number in **Table 1** under **Shredded Paper** on page 4.
4. Remove the shredded paper and farm animal from the box. Repackage the shredded paper as instructed by your teacher.

**Wood Shavings**

1. Place **4 cups** of wood shavings in the box, spreading it evenly across the bottom. Make sure the bottom does not show through the shavings. Place the farm animal in the center and close the lid. Place the box on top of the ice pack.
2. Set a timer for **2 minutes**.

| **Discuss** |
| --- |
| What do you use at home to keep warm at night?<br>How does it relate to the shredded paper and wood shavings in this experiment? |
| |

3. After 2 minutes, take the temperature again by pointing the infrared thermometer 1 inch above the wood shavings in the middle of the box. Record that number in **Table 1** under **Wood Shavings** on page 4.
4. Remove the wood shavings and farm animal from the box. Repackage the shavings as instructed by your teacher.

**Straw**

1. Place **4 cups** of straw in the box, spreading it evenly across the bottom. Make sure the bottom does not show through the straw. Place the farm animal in the center and close the lid. Place the box on top of the ice pack.
2. Set a timer for **2 minutes**.

| **Predict** |
| --- |
| Will straw work ***better*** or ***worse*** than shredded paper and wood shavings to keep your animal warm? Why? |
| |

3. After 2 minutes, take the temperature again by pointing the infrared thermometer 1 inch above the straw in the middle of the box. Record that number in **Table 1** under **Straw** on page 4.
4. Remove the straw and farm animal from the box. Repackage the straw as instructed by your teacher.
5. Return the rest of your items to your teacher as instructed.
6. If the ice pack has left condensation on the table, wipe it off with the paper towels.

| **Table 1 - Conduction Experiment** | |
| --- | --- |
| *bedding type* | *temperature in **°F*** |
| Empty Box (Control-No Ice Pack) | |
| Empty Box on Ice Pack (No Bedding) | |
| Shredded Paper | |
| Wood Shavings | |
| Straw | |

| Conduction Experiment Analysis + Conclusion |
| --- |
| A. Which type of bedding kept the barn floor the warmest? |
| |
| B. Which type of bedding was the coldest? |
| |
| C. Which type would you choose for your barn? |
| |
| D. Why did you choose that type? Use evidence from your temperature data to support your answer. |
| |
| E. How do you see conduction at work in this experiment? Explain using evidence from your investigation. |
| |

# EXPERIMENT 2: CONVECTION

## MATERIALS

| *per group of 4 students* | *per student* | *from your teacher:* |
|---|---|---|
| • timer<br>• infrared thermometer<br>• ruler<br>• small plastic tub<br>• 2 plastic cups<br>• permanent marker<br>• paper towels<br>• ice packs (frozen) | • pen or pencil | • hot and room temperature water |

## PROCEDURE

***Imagine:*** Your team manages a cattle farm. Your cows spend hot summer days in a large pasture with a pond where they can drink and cool off. On especially hot days, some cows begin panting and appear overheated.

***Question:*** How can a pond help cool animals using the principle of **convection**?

The cold-water bath represents the pond, and the cups of water represent the cows' body temperatures.

**Important:** Keep the cup at the same depth in the pond throughout each trial. Do not allow pond water to enter the cup.

**Part A: Room Temperature Water**

1. Fill the plastic tub with water. Place the frozen ice packs in the tub for approximately **10 minutes** to cool the water. Once the water is cold, remove the ice packs and place them underneath the tub. Leave the ice packs under the tub for both trials to help maintain a consistent pond temperature throughout the investigation. *(The plastic tub represents the pond on your farm.)*
2. Use the ruler to make sure the water is at **3 inches deep**. Add or remove water as needed.
3. Label one plastic cup **Cow 1** and the other **Cow 2** using the permanent marker.
4. Fill the **Cow 1** cup with room temperature water.
5. Hold the infrared thermometer approximately **1 inch above the center of the water's surface** in the Cow 1 cup. Measure and record the starting temperature in **Table 2** under **Cow 1 – Room Temperature Water**.

| **Predict** |
|---|
| What do you think will happen to the temperature of Cow 1 after it sits in the pond? Explain. |
| |

6. Place the cup into the pond and immediately start the 5-minute timer. You may need to hold the cup. (This represents a cow getting in the pond to cool off.)
7. Every 30 seconds, measure the temperature and record the value in **Table 2**.
8. When 5 minutes have passed, remove the cup from the pond.

**Part B: Hot Water**

Before beginning Part B, check that the pond water is still close to its starting temperature. If needed, allow the water to cool before beginning the Cow 2 trial.

1. Fill the Cow 2 cup with hot water from your teacher.
2. Hold the infrared thermometer approximately **1 inch above the center of the water's surface** in the Cow 2 cup. Measure and record the starting temperature in **Table 2** under **Cow 2 – Hot Water.**

| **Predict** |
|---|
| Will Cow 2 cool faster, slower, or at the same rate as Cow 1? Explain. |
| |

3. Place the **Cow 2** cup into the pond and immediately start the 5-minute timer. You may need to hold the cup.
4. Every 30 seconds, measure the temperature and record the value in **Table 2**.
5. Clean up water and cups as instructed by your teacher.
6. Dry any water on the table with the paper towel.

| **Table 2 - Convection Experiment** | | |
|---|---|---|
| **Time (in seconds)** | **Cow 1 Room Temperature Water** | **Cow 2 Hot Water** |
| | *temperature in **°F*** | *temperature in **°F*** |
| Starting temperature | | |
| 30 | | |
| 60 | | |
| 90 | | |
| 120 | | |
| 150 | | |
| 180 | | |
| 210 | | |
| 240 | | |
| 270 | | |
| 300 | | |

| Convection Experiment Analysis + Conclusion |
| --- |
| A. Which cow started the experiment with a higher temperature? |
| |
| B. How did the temperature of each cow change during the 5-minute investigation? |
| |
| C. Which cow cooled down the fastest? Use evidence from your data table to support your answer. |
| |
| D. Why did heat move from the water inside the cup to the colder water in the pond? |
| |
| E. How does the movement of water in the pond help remove heat from the cow? Explain how this models **convection**. |
| |
| F. Based on your results, why is providing ponds, sprinklers, or moving water important for livestock during hot weather? |
| |
| G. How could a farmer use convection to help keep livestock cool during hot weather? |
| |

# EXPERIMENT 3: RADIATION

## MATERIALS

| *per group of 4 students* | *per student* |
|---|---|
| • timer<br>• infrared thermometer<br>• heat lamp with bulb<br>• ruler<br>• 2 grass patches<br>• sheet of foam<br>• sheet of cork<br>• farm animal | • pen or pencil |

## PROCEDURE

***Imagine:*** Your team runs a cattle farm. You have a large pasture for the cows to roam around on, eating grass and enjoying the sunshine. In the summer, you notice some cows don't look happy. They may be panting like a dog or acting sick. Your pasture does not have a pond or trees for shade.

Question: How can you cool the cows using the principle of radiation?

**Important:** You will test one pasture condition at a time. Before beginning a new trial, use a new grass patch at room temperature or allow the grass patch to cool back close to its starting temperature. Also allow the farm animal to cool to room temperature before beginning the next trial. Keep the heat lamp **12 inches above the grass patch** for every trial.

**Before turning on the heat lamp for each trial, measure and record a new starting temperature.** Hold the infrared thermometer approximately **1 inch above the same area of the farm animal**. The starting temperatures for the No Shade, Foam Shade, and Cork Shade trials should be as similar as possible.

When using foam or cork for shade, **do not lift, remove, or reposition the shade during the 5-minute trial.** Hold the shade 4 inches above the grass so the infrared thermometer can be aimed underneath it from the side. Keep the foam and cork the same distance above the farm animal during their respective trials.

**Starting Temperature:**

1. Place one grass patch in the middle of the table. (The grass patch represents your pasture.)
2. Place the farm animal in the center of the grass patch.
3. Position the heat lamp **12 inches above the grass patch**. Keep the heat lamp **off**.
4. Hold the infrared thermometer approximately **1 inch above the farm animal**.
5. Measure and record the **Starting Temperature – No Shade** in Table 3.

**No Shade:**

1. Turn on the heat lamp and set a **5-minute timer**. **Never touch the bulb of the lamp directly; it gets very hot and will burn you.** (This represents the sun coming up over your pasture.)
2. Every **30 seconds**, measure the temperature **1 inch above the farm animal**. Record each temperature in Table 3.
3. Leave the grass patch and farm animal under the heat lamp with **no shade** for the entire 5 minutes.

| Predict |
| --- |
| Will the temperature of the animal increase or decrease after 5 minutes under the heat lamp? Explain your answer. |
| |

4. After 5 minutes, record the 300-second temperature in Table 3.
5. Turn off the heat lamp.

**Reset Before the Next Trial**

1. Remove the farm animal and grass patch from beneath the heat lamp.
2. Replace the grass patch with a new grass patch at room temperature **or** allow the current grass patch to cool until it is close to the original starting temperature.
3. Allow the farm animal to cool to approximately room temperature before beginning the next trial.
4. Place the farm animal back in the center of the cooled grass patch. With the heat lamp off, measure and record the starting temperature for the next trial in Table 3.

## Foam Shade

1. Hold the sheet of foam **4 inches** above the farm animal and grass patch without touching the animal, grass, or heat lamp. Position the foam so that it completely shades the farm animal from the heat lamp.
2. Turn the heat lamp back on.
3. Immediately set a **5-minute timer**. Keep the foam shade in place for the entire 5 minutes.
4. Every **30 seconds**, aim the infrared thermometer approximately **1 inch above the farm animal** underneath the foam from the side. Record each temperature in Table 3.

| Predict |
| --- |
| How do you think the foam shade will affect the temperature compared with having no shade? Explain your answer. |
| |

5. After 5 minutes, record the 300-second temperature in Table 3 and remove the foam shade.
6. Turn off the heat lamp.

**Reset Before the Next Trial**

1. Remove the farm animal and grass patch from beneath the heat lamp.
2. Replace the grass patch with a new grass patch at room temperature **or** allow the current grass patch to cool until it is close to the original starting temperature.
3. Allow the farm animal to cool to approximately room temperature before beginning the next trial.
4. Place the farm animal back in the center of the cooled grass patch. With the heat lamp off, measure and record the starting temperature for the next trial in Table 3.

**Cork Shade**

1. Hold the sheet of cork **4 inches** above the farm animal and grass patch without touching the animal, grass, or heat lamp. Position the cork so that it completely shades the farm animal from the heat lamp.
2. Turn the heat lamp back on.
3. Immediately set a **5-minute timer**. Keep the cork shade in place for the entire 5 minutes.
4. Every **30 seconds**, aim the infrared thermometer approximately **1 inch above the farm animal** underneath the cork from the side. Record each temperature in Table 3.

| **Predict** |
| --- |
| Do you think cork will block more or less heat than foam? Explain your answer. |
| |

5. After 5 minutes, record the 300-second temperature in Table 3 and remove the cork shade.
6. Turn off the heat lamp.
7. Return all materials to your teacher as instructed.

**Table 3 - Radiation Experiment**

| **Time (in seconds)** | **No Shade** | **Foam Shade** | **Cork Shade** |
| --- | --- | --- | --- |
| | temperature in **°F** | temperature in **°F** | temperature in **°F** |
| Starting Temperature* | | | |
| 30 | | | |
| 60 | | | |
| 90 | | | |
| 120 | | | |
| 150 | | | |
| 180 | | | |
| 210 | | | |
| 240 | | | |
| 270 | | | |
| 300 | | | |

* Record the starting temperature before each trial.

| Radiation Experiment Analysis + Conclusion |
| --- |
| A. How did the temperature of the cow change during the No Shade trial? Use evidence from your data. |
| |
| B. Which shade material reduced heating the most? Use evidence from your temperature data. |
| |
| C. Why do you think that material worked better? |
| |
| D. What would have happened to the temperature if you had measured up to 10 minutes? |
| |
| E. If you had a farm, which material would you choose to build a sunshade over your pasture? |
| |
| F. How do you see radiation at work in this experiment? |
| |