CON EDISON WEB-BASED MIDDLE SCHOOL ACTIVITY

Well Insulated Houses:
Helping to Stay Warm in Winter and Cool in Summer

Overview

In this activity, you and your students will build two house models from discarded cardboard boxes. One model will be well insulated and energy efficient; the other will be poorly insulated. By placing a thermometer and an incandescent lamp inside each house (as a source of heat) and then taping the houses shut, your class can observe and measure rates of temperature change.

The poorly insulated house consists of only one box. The well-insulated house consists of two cardboard boxes that nest closely yet comfortably inside one another. The windows of the houses are plastic wrap taped to the sides of the boxes.

You can increase the insulation value of the double cardboard boxes by packing the space between the “walls” with Styrofoam®, bubble wrap, or other air-trapping material. To add an additional variable, you could line the “floor” with clay tiles, sand, or other heat-holding materials.

Objectives

By doing this activity students will:

• Understand that heat moves from warm to cool.
• Apply that understanding to two basic principle of physics: that heat is molecular motion and that molecules in motion tend to slow down, and when they do, the temperature cools.
• Understand how technology and housing design can conserve energy by preventing the flow of warm air to cooler air.

Time Requirements

One class period for the activity
One optional class period for follow-up discussion

Building the models the first time will take about one hour for each set.

Materials

• Three cardboard boxes that are roughly 10" to 16" in each dimension. Two of the boxes should be about the same size. The third one should be slightly larger than the other two so one of the smaller ones fits comfortably inside it.
• Two thermometers to put inside the boxes.
• Two lamb bases (or electric bulb holders) and two 60-watt bulbs (for heat sources)
• Plastic wrap (to use as windows and door coverings)
• Packing tape or masking tape (for securing the plastic wrap)
• Heavy-duty scissors or a utility knife (to cut the doors and windows)
• A watch with a second hand to time the temperature changes in the boxes

Optional Materials for Extenders
• Styrofoam® or bubble-wrap to better insulate the walls and windows of the well-insulated house.
• Tile or sand to line the floors as a heat reservoir for the well-insulated house.

Procedure for Building the Models (illustration on page 3)

NOTE: The nesting boxes represent a well-insulated house. The single box represents a poorly insulated house.

Make windows and doors in the houses.
1. Mark and cut openings for the windows and door on your boxes. For the two nesting boxes, cut out the openings on the larger box first, and then mark them on the smaller box. In that way, the windows and doors will line up nicely.

Insulate the windows and doors.
2. On the model of the well-insulated house (the nesting boxes, with two layers of walls), cover the openings with plastic wrap, and tape it down securely. The model should have at least two layers of plastic wrap – one on each of the two boxes. You could use bubble-wrap to insulate the windows and doors better (or you could put on up to four layers of plastic wrap).
3. On the model of the poorly insulated house (the un-insulated box), use only one layer of plastic wrap, and don’t worry if it is not taped down tightly. (After all, many houses have leaky windows.)

Put a “heater” in the house.
4. Put a lamp and incandescent light bulb inside each box, and carefully tape shut the area where the electric wire goes into the box. Make sure the switch is turned on and the lamp is unplugged from the wall. Take care not to let the light bulb touch the cardboard. It could become a fire hazard.
5. Secure thermometers inside each model so you can read them through the windows.
6. Paint and decorate the house models if you like. (You will be able to re-use them year after year.)

Procedure for Your In-class Activity
1. Record the ambient room temperature.
2. Light the lamps in both boxes by plugging them into the wall.
3. Record the temperature inside each box. Continue recording the temperature inside both boxes every thirty seconds for five to ten minutes or until the temperature stops rising.
4. Unplug both lamps from the wall, and continue measuring and recording the temperature inside each box until the temperature stops falling.
5. Have your students graph the data.
6. Analyze the graph and discuss your findings. You may want to use the graphing template on page 3.
Use this graph for recording and analyzing your data.
1. Model windy conditions by blowing a fan on the houses, or change the “ambient” temperature by working outside on a cold day. Compare the results.

2. Break the insulation on one part of the well-insulated house, perhaps by leaving one window loose or by leaving a hole in the roof. How does one area with poor insulation affect the performance of the whole house?

3. Track the rate at which the houses cool down. Do they cool faster or slower when the inside is at its warmest? (The temperature probably dropped faster when the temperature difference between the inside and outside air was at its greatest.) Ask your students to develop a hypothesis to explain this phenomenon. (See discussion in the Background Science section.)

4. Add more insulation to the walls and windows of the well-insulated house using Styrofoam or bubble wrap. Repeat the experiment and compare the results. Ask students to develop a hypothesis about how insulation prevents heat from escaping. (See discussion below.)

5. Add “thermal mass,” such as tile, sand, or other materials that retain heat, to the well insulated house by lining the floor. This variation simulates the heat reservoirs used in houses heated by solar energy, which often use bricks or stones in a greenhouse area. This thermal mass absorbs energy during the day and releases it slowly throughout the night. Have students research the scientific principles that explain the different between heat energy and temperature, and encourage them to apply these principles to housing design.

6. Research the insulating values of various common insulating materials. How much insulation should go into walls? Floors? Ceilings? What factors influence the insulating ability of windows? How much less might well insulated houses cost to heat and cool than poorly insulated houses?

**Background Science**

Energy moves from warm to cold. That is one of the fundamental rules of physics, called the First Law of Thermodynamics. It states that objects in motion move from motion to rest. Heat is actually a measure of molecular motion, so warm objects become cooler as their molecules slow down. (Absolute Zero, or –273˚C, is defined as the absence of molecular motion.)

You can help your students remember the direction of the flow of energy by asking them to consider a ball or a car. If you throw a ball as hard as you can, does it speed up or slow down? If you or accelerate a car to 60 miles per hours, does it continue to speed up after you take your foot off the accelerator? Of course not. The moving objects slow down as soon as no more force is being applied.

Since temperature is really a measure of molecular motion, the same principle holds. As molecular motion increases, temperature rises. As molecular motion decreases, the temperature falls. Molecules want to slow down and stop, just like the car or ball, so warmer molecules always want to cool down. Getting warmer requires work (energy)!

In the wintertime, the air is heated by an energy source: the heater or furnace that burns fuel. Those fast moving molecules want to rest. Thus, the warm air inside a heated building wants to get outside where it can rest and get colder. As the temperature difference between the inside air and the outside air increases, keeping warmth inside becomes more and more difficult. The warm, inside air will escape through tiny holes in the building shell and migrate outside. Keeping the house warm on a cold day uses a lot of heat energy, but as this activity shows, good insulation reduces heat loss and saves energy.
Likewise, in the summertime, the hot outside air tries to get inside an air-conditioned building. When that happens, the inside temperature warms up and the air conditioner has to work harder. Keeping the air cool on a hot day requires a lot of extra energy if the building is not well insulated.

**How Does Insulation Work?**

Insulation slows or blocks the flow of energy. In a building, it keeps the heat and cool where you want them, keeping the heated air inside on a winter day, and keeping the hot air outside in summer. In that way, insulation is a critical factor in saving both energy and money.

![Diagram showing heat flow through an uninsulated and insulated wall](image)

Uninsulated wall
(does not block the flow of energy.)

Insulated wall

Your students may be familiar with another form of insulation: the rubber or plastic covering over electric wires. That insulation keeps the electric energy inside the wire and prevents shocks and fires by shielding you from the current.

Insulation is any material that does not conduct energy. (It is the opposite of a conductor.) In the case of electricity, common insulators include plastic, rubber, glass, or ceramic. In the case of temperature, insulation is made of substances that trap air. If you break a piece of Styrofoam, for example, you will see that it really consists of tiny plastic bubbles, and each bubble is filled with air. Those pockets of air create the insulating value. Most household insulation for walls, ceilings, and floors is either fiberglass insulation or solid foam, which is sturdier than Styrofoam, but regardless of how it is made, it is mostly just trapped air. Insulated windows consist of two or three panes of glass that trap air between them, slowing the flow of heat energy.

**Heat Reservoirs**

Thermal mass, such as stone, tile, or water, contributes to energy storage in a well-insulated building by getting warm when sunlight strikes it, then releasing that heat slowly long after the sun has set. Of all the substances on earth, water has one of the greatest capacities to store heat energy. The earth’s average temperature swings between day and night are relatively small because of the heat-holding ability of the oceans. (Desert nights get very cold because of the absence of moisture in the air.)
Insulating Your Home

You use insulation when you pull the covers tight on a cold night. The blankets prevent your body heat from escaping into the cold room, so you feel snug and warm.

Insulation slows the flow of energy, whether it is in the form of sound, electricity, or heat. Home insulation slows the flow of heat out of a living space in cold weather. The same insulation also helps keep air conditioned rooms cooler in summer.

Insulation in the walls, ceilings, and floors of buildings works just like your blanket, only more precisely. Engineers have developed a measuring system called “R-values” to rate the insulating qualities of different materials. “R” stands for “resistance,” or the ability of the material to resist the flow of heat.

R-values depend on two factors: the insulating qualities and the thickness of the material. Most commonly used for home insulation come in roll, loose fiber, or rigid foam boards. Here are some typical R-values.

<table>
<thead>
<tr>
<th></th>
<th>3.5 in. thick</th>
<th>6 in. thick</th>
<th>9 in. thick</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fiberglass rolls</strong></td>
<td>R-11</td>
<td>R-19</td>
<td>R-30</td>
</tr>
<tr>
<td><strong>Loose fiber</strong></td>
<td>R-8</td>
<td>R-13</td>
<td>R-20</td>
</tr>
<tr>
<td><strong>Solid foam board</strong></td>
<td>R-24</td>
<td>R-42</td>
<td>R-63</td>
</tr>
</tbody>
</table>

Insulated windows work because of the air trapped between two or three panes of glass, but even good windows only have an R-value of 2.5 to 3.0.

There are a few other places where you might find or use insulation in your home. For example, you can stop drafts coming through the walls and windows by sealing cracks with “caulk” or “weatherstripping.” In addition, your refrigerator stays cold and your oven stays hot because of the insulation in the door and walls.

Suggestions for Observations Students Can Make At Home

Have your students observe and record the heating and cooling features of their homes.

- Do they have single-pane or double-pane windows?
- Do they know if their home is insulated?
- If they have access to an attic area, is the floor of the attic insulated?
- Are there any broken windows or obvious air leaks that could be fixed?
- If any of your students’ families can control their heating and air conditioning with a thermostat, at what temperature do they keep the thermostat set when they are home, when they are away, and when they are sleeping?
- Can they open windows on comfortable days, and if so, do they?
- Do they keep doors and windows closed in rooms with air-conditioning?

As a class, discuss the energy impacts of these conditions and these practices. Ask what they would change about their current home or their current practices if they could change only one energy-related thing.
Discussion and Research Topics

1. How does heat escape from the model houses?
2. How does heat/air conditioning escape from your house or apartment? School? Car?
3. How does the double layer of boxes slow down the escape of heated air? How do the insulated windows help slow down the loss of heat?
4. What kinds of energy do we use to heat our homes in the winter and cool them in the summer?
5. What are some reasons why we want to reduce energy use?
6. How is insulation used in a home?
7. Since heat remains in the well-insulated house better than in the poorly insulated house, so do airborne contaminants, such as smoke. Have your students research indoor air quality and learn about ventilation techniques.
8. Have your students use the Internet or visit a home building supply store to learn about types of insulation, insulating techniques, types of insulating windows, and roofing materials.

Review

1. What is heat?
   Molecular motion.
2. What do molecules in motion want to do?
   Slow down/cool off.
3. In which direction does heat flow?
   From warm to cool.
4. What is one effective way to slow the movement of heat energy?
   Create a pocket of trapped air.
5. How does insulation work?
   It adds trapped air pockets that slow the flow of energy.
6. How does insulation help reduce energy use?
   It prevents heat or cool from moving from where it is wanted to where it is not needed, thus limiting the amount of energy required to keep the indoor temperature at the desired level.