Building a Well-Insulated House: Keeping the Hot and the Cold Where They Belong

Setting the Scene: Hot and Cold

"Hot" and "cold" are words used to describe temperature. Temperature, though, is not simply a measure of "hot" and "cold." Technically it is a measure of molecular motion. As energy is added to a substance, the molecular motion increases, so the temperature rises. As the molecules slow down, the temperature falls.

You can use this understanding of heat to experiment with ways to keep a house comfortable in an extreme climate without wasting a lot of electricity or heating fuel.

The Basic Science: Moving from Hot to Cold

Energy moves from warm to cold. That is one of the fundamental rules of physics. (It's called the First Law of Thermodynamics.) "Absolute zero," or –273°C, is defined as the absence of any molecular motion. As the molecules move, the temperature of the substance rises.

Here's a way you can think about and remember that rule. Consider a ball or a car. If you throw a ball as hard as you can or accelerate a car to 60 miles per hour, does it continue to speed up after you stop applying the force? Of course not. In fact, the answer is so obvious that you might even think it was a silly question. It was, but it can help you remember that energy flows from warm to cold. Things that are in motion want to stop. Just like the ball or car, the particles in atoms and molecules want to slow down too.

In Your Community

Northeast Florida in mid-summer is a hot, uncomfortable place to be. In the days before air conditioning, people tried to keep their houses cool by drawing the shades, running fans, and opening the windows to breezes. Today, air conditioning is commonplace, but it uses a lot of electrical energy. Electricity is expensive. In addition, making it usually uses precious, non-renewable resources like natural gas and oil. Electricity production also causes environmental damage and air pollution. Thus, it's important not to waste energy on inefficient air conditioning. The trick to efficient air conditioning is to cool just the areas you want to cool. Cooling the outdoors would waste a lot of energy and money.

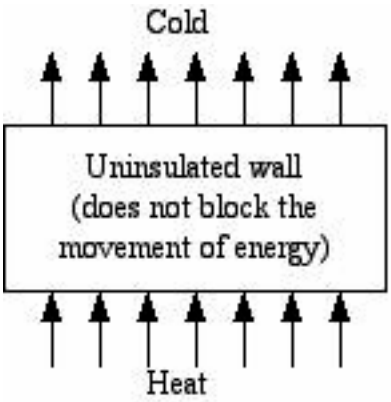
Energy, though, wants to move from warmth to cold … from high motion to less motion. So if you cool the air in your home – or the box of your refrigerator – warmth will want to move in. The more it succeeds, the more you have to use energy to create more cold (or technically, remove more heat).

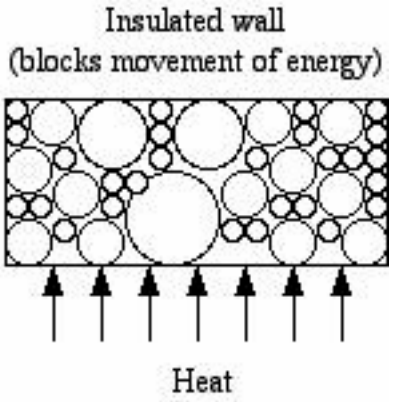
The trick to using less energy for air conditioning or heating is good insulation. Insulation helps slow down the flow of energy. In summertime, it keeps the hot outside so the inside can stay cool. In wintertime, it keeps the heat inside so it doesn't escape to the outside.

What is Insulation?

Insulation on an electric wire helps keep you from getting shocked by keeping the electric current inside the rubber casing. In your house, insulation helps keep the hot and cold just where you want them.

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. For example, Styrofoam™ is a good insulator. If you break a piece of Styrofoam, you will see that it is really little tiny plastic bubbles, and each bubble is filled with air. Those pockets of air are what create the insulating value. Most household insulation is either fiberglass insulation, or solid foam, which is sturdier than Styrofoam.





Building a Model of a Well-Insulated House

You can build models of well-insulated and poorly insulated houses, and compare their abilities to hold heat under a variety of experimental conditions. To build these models, you will need just a few easy-to-obtain materials.

Materials

- Three cardboard boxes that are roughly 10" to 16" in each dimension. Two of the boxes should be identical. The third one should be slightly larger than the other two so one of the smaller ones will fit comfortably inside it. The two "nesting" boxes will become a well-insulated, double-walled house. The single box will become a house with poor insulation or no insulation.
- Two thermometers to put inside the boxes.
- Two lamb bases (or electric bulb holders) and two 60-watt bulbs (to use as heat sources)
- Plastic wrap (to use as windows and door coverings)
- Tape (for securing the plastic wrap)
- A utility knife (to use ***with the help of an adult*** to cut the doors and windows)
- A watch with a second hand to time the temperature changes in the boxes

Procedure for making the model

1. Decide where you want windows and doors on your model houses. (The two houses should have the same number of openings, and the openings should be roughly the same size.)

2. For the two boxes that nest one inside the other, cut out the openings on the larger box first, and then mark those openings on the smaller box before cutting them out. In that way, the windows and doors will line up nicely.
3. 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 on each opening – one on each of the two boxes – but you could use more.
4. On the un-insulated experimental model (the single box), you may decide how much glass and insulation (plastic wrap and tape) to use, depending on the experimental conditions you want to test.
5. Put a lamp base and light bulb inside each box, and carefully tape shut the area where the electric wire goes into the box. ***Take care not to let the light bulb touch the cardboard. It could become a fire hazard.***
6. Secure thermometers inside each of the two models so you can read them through the windows.
7. Paint the house models however you like.

Suggested Projects

1. *The basic experiment*
   Measure and record the room temperature of your surroundings. Turn on the bulb in each house and observe the thermometers until the temperature in both houses does not go up any more. How long did it take for each of the two houses to reach that temperature? Now turn off the bulbs, and measure the time needed for each of the two boxes to return to room temperature. Graph and analyze the difference.

2. Model different weather conditions. You may do this, for example, by blowing a fan on the houses to model windy conditions, or working outside on a chilly night to see the effect of large temperature differences.

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

4. If heat remains in the well-insulated house better than in the poorly insulated house, what could you surmise about what happens to airborne contamination, such as smoke? Research indoor air quality in well-insulated homes and learn about techniques for insuring good ventilation. (You may want to build a model of an "air-to-air heat exchanger.")

5. 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 to see which systems might work best. You may also want to talk to homebuilders about the energy efficiency decisions they make when they build a home. (You may find that some builders want to keep the purchase price of the house low, so they use fewer energy-efficiency

materials. Others may want to sell houses with low long-term operating costs, so they build with energy efficient materials and sell their houses for more money. To succeed, however, they must show their buyers how the house will cost them less to heat and cool over time.)

6. Calculate the life-cycle costs associated with either building a well-insulated house or insulating an old, drafty house. How much would it cost to build a more energy efficient house in the first place? How much money might the homeowners save during a ten-, twenty-, or thirty-year stay in the house? Make a recommendation to homeowners about the energy decisions they should make.

7. Use the Internet to learn more about energy conservation and energy conserving appliances. Two web sites to check out are http://www.jea.com, and http://www.energystar.gov.

Putting It Together

Display your two house models with charts or graphs showing how they retain heat or cold in different climate conditions. Add displays about various insulating techniques and materials. Include a written or oral report about the costs and savings of building and operating a well-insulated house.