Understanding Thermal Energy (Heat)

We use heat, called thermal energy, every day. We can't see heat, but we can feel it. Our bodies make heat and our stoves and lights do, too. We heat our houses, our food, and our water.

Sometimes there is too much heat and we move it. Refrigerators take heat away from the food inside. Air conditioners take heat from inside the house and move it outside. Swimming pools take heat from our bodies.

Heat Is the Motion of Molecules

What is heat? Scientists say it is the kinetic energy in a substance. Kinetic energy is the energy of motion. Heat is the motion of the molecules in a substance, not the motion of the substance itself.

Everything is made of atoms. Atoms bond together to form molecules. Molcules are the building blocks of substances. Water is a substance. Have you ever heard water called H-2-0 (H_2O)? That means a molecule of water has two hydrogen (H) atoms and one oxygen (O) atom.

Even though we can't see them, the molecules in substances are never still. They are always moving. That motion is the kinetic energy called heat.

Heat Seeks Balance

Everything in nature seeks balance. Heat seeks balance, too. Heat flows from hotter places to colder places and from hotter substances to colder substances. What happens if you pour hot water into a cold tub? The molecules of hot water have more energy. They are fast moving. They crash into the colder molecules and give them some of their energy.

The molecules of hot water slow down. The molecules of cold water move more quickly. The cold water gets warmer. The hot water gets cooler. Soon all the water is the same temperature. All the water molecules are moving at the same speed. The heat in the water is in balance.

Heat Energy Moves

Heat energy is always on the move. It moves to seek balance. Heat can move in many ways. When a hot object touches a cold object, some of the heat energy flows to the cold object. This is called conduction. **Conduction** is the way heat energy moves in solids.

When we cook food in a pan on an electric stove, we use conduction. The heating element on the stove is hot. The pan is cold. Some of the heat from the heating element flows to the pan. The heat from the pan flows to the food inside. The heat moves by conduction.

Heat Moves by Conduction in Solids

How does the heat move? Let's think about it. All solids are made of molecules. The molecules in solids vibrate. The more energy they have, the faster they vibrate. In a hot object, the molecules vibrate fast. The molecules in a cold object vibrate more slowly.

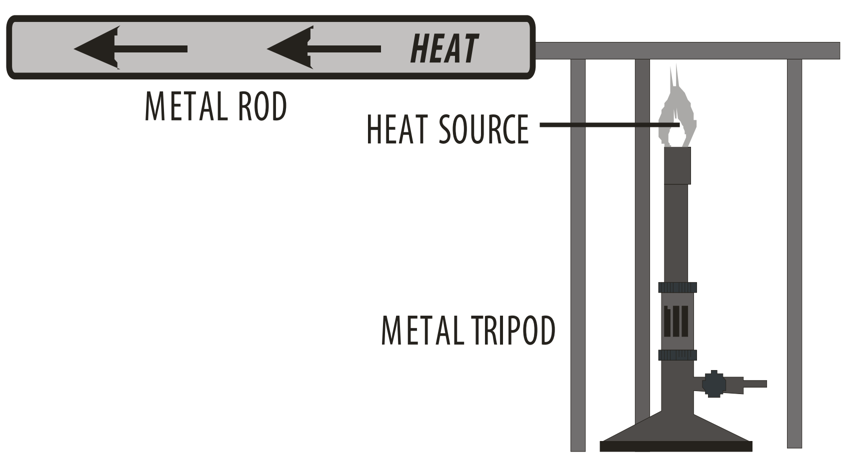
Let's touch a hot object to a cold object. The fast-moving molecules in the hot object push against the slow-moving molecules in the cold object. The fast molecules give up some energy to the slower moving molecules. The vibration of the fast molecules slows down.

The molecules in the cold object gain some energy from the hot object. They vibrate faster. The cold object gets warmer. The hot object gets cooler. The energy in the molecules is seeking balance. When the energy is in balance, all the molecules vibrate at the same speed.

Look at the picture at the bottom of this page. The flame adds heat to the tripod. The tripod gets very hot because it is metal. The metal rod touches the tripod. The molecules in the tripod vibrate against the molecules in the end of the rod. The molecules in that end of the rod vibrate faster.

Now one end of the rod has more energy than the other end. What happens? The hotter molecules transfer some of their energy to the cooler molecules. The molecules in the rod conduct the heat from the hotter end to the cooler end. The heat moves from the tripod to the end of the rod touching it, then through the rod.

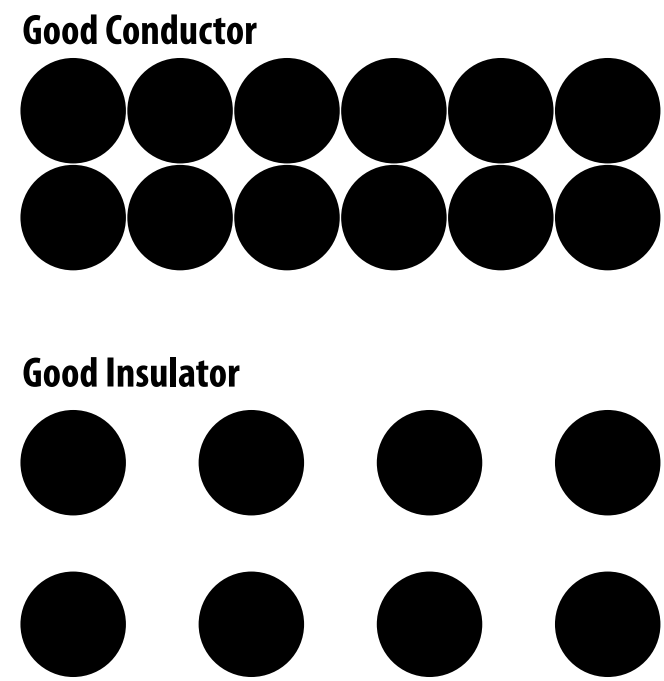
Conduction in Solids



The energy flows from molecule to molecule as they vibrate against each other. Heat is moving by conduction.

Conductors and Insulators

In some materials, heat flows easily from molecule to molecule. These materials are called **conductors**. They conduct—or move—heat energy well.



Look back at the picture with the metal rod and the tripod. You would not hold the metal rod with your bare hand. You would get burned! The metal would conduct the heat to your hand. Metals are good conductors of heat.

If you touched a wooden pencil to the tripod, would it conduct heat as well as the metal rod? No—wood is not a good conductor of heat. Materials that don't conduct heat well are called **insulators**.

The molecules in good conductors are close together. There is very little space between them. When they vibrate, they push against the molecules near them. The energy flows between them easily.

The molecules in insulators are not so close together. It is harder for energy to flow from one molecule to another in insulators.

Conductors and Insulators

Look at the objects to the right. The pot, the spoon, and the fork are made of metal. The pot and the fork have plastic handles. The dish is made of glass. The oven mitt is made of cotton fabric.

Which materials are the insulators? The insulators are the materials that don't move heat. They protect us from heat. Our experience tells us that wood, plastic, and cotton are all good insulators. Metals are good conductors. The metal part of the pan moves heat to the food inside to cook the food. The plastic handle protects our hands. The cotton glove protects our hands, too.

What about glass? It is not as good of a conductor or insulator as the other materials. It is used to conduct heat in pots and pans, and can also be used to insulate. It used to be used on power and telephone lines as an insulator.

We use **insulation** in our homes to help stop the movement of thermal energy in our homes. When we spend money to heat or cool the air inside, we want to keep it in. Insulation helps slow down the movement of thermal energy, so it seeks balance more slowly, and keeps us more comfortable longer. Heat moves in more than one way than conduction. How else can thermal energy move?

Movement of Heat in Fluids

Fluids are liquids and gases. Heat also moves in fluids. Heat doesn't move by conduction. In fluids, the molecules are too far apart to conduct energy as they vibrate. The molecules in fluids are free to move and spin. As they move, they bounce against each other. The molecules with more energy give up some energy. The molecules with less energy gain some.

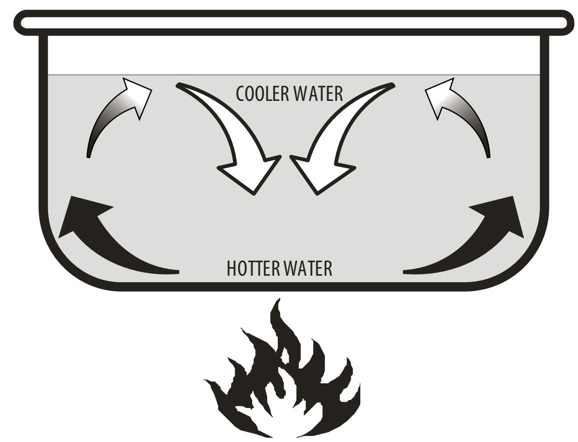
Heat energy in liquids and gases moves in currents by **convection**.

If we heat water on a stove, the water molecules begin to move and flow faster. The molecules near the flame have more energy. They push against each other and move farther apart.

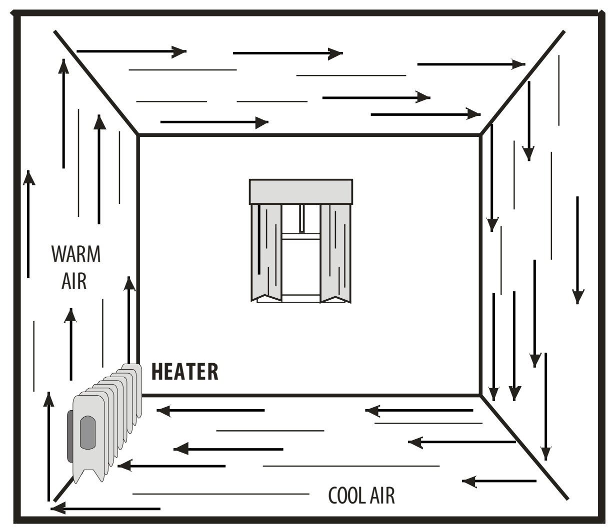
The water at the top of the pan is cooler. Its molecules don't have as much energy. They are closer together than the molecules of hot water. They are denser.

The cooler, denser molecules flow down. The warmer, less dense molecules rise up. They form currents of flowing molecules. During this motion, the hotter molecules transfer energy to the cooler molecules. This transfer of heat through the motion of currents is called convection.

Convection in Liquids



Convection in Gases



Heat also moves by convection in gases. Air is the gas you know best. You may have noticed that the top floor of a building is warmer than the basement. The air near the ceiling is warmer than the air near the floor.

The molecules of gases are like molecules in liquids. The more energy they have, the farther apart they are. In a room, the cooler, denser air flows down. The warmer, lighter air rises. A current of flowing air is formed.

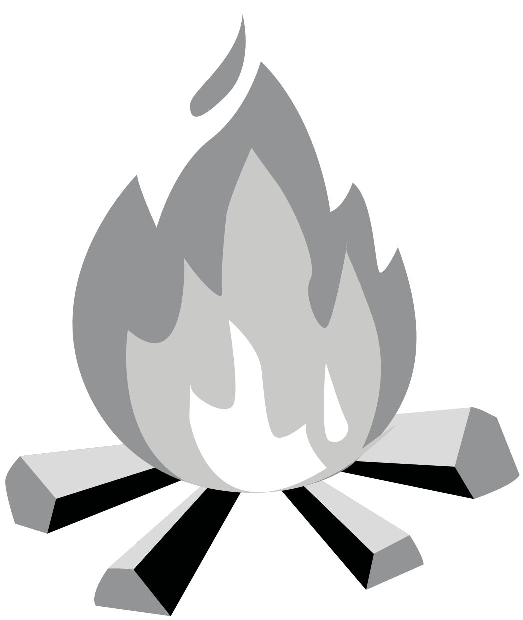
The warmer molecules give up energy as they bounce against cooler molecules. They give up some energy, become cooler, and flow down again. The heat is transferred by convection.

Energy Moves by Radiation

Most of the Earth's energy comes from the sun. Every day, the sun gives off a lot of energy. However, it doesn't start out traveling to us as thermal energy (heat). It comes from the sun in rays or waves called radiant energy. Heat must move from molecule to molecule and there are no molecules in space. Solar energy travels in rays or waves until it hits the Earth. Once the radiant energy hits the Earth, it hits molecules in the air, ocean, on land, and on living things. The molecules turn this energy into heat that we can feel.

The same thing happens with a fireplace or a campfire. When you light a fire the radiant energy from the fire will spread out, or radiate, to the molecules in the air close by. You can feel the heat from the fire when standing a few feet away because the molecules radiate the heat out. The area closest to the fire will stay the warmest until the fire goes out. Once that happens, the thermal energy continues to radiate out and back until the room or the area has reached an even temperature.

Campfire



Heat and Temperature

Heat and **temperature** are different things. Two cups of boiling water would have twice as much heat as one cup of boiling water, but the water would be at the same temperature.

A giant iceberg would have more heat energy than a cup of boiling water, even though its temperature is lower. It would have more heat energy because it is so big.

Heat is the total amount of kinetic energy in a substance. Temperature is a measure of the average kinetic energy of the molecules in a substance. Temperature is also described as a measure of the hotness or coldness of a substance.

Heating and Cooling Systems

Heating and cooling systems are used in buildings to help keep the temperature comfortable. These systems use more energy than any other systems in schools, offices, and homes. Natural gas and electricity are usually used to heat, and electricity is used to cool. Using these systems wisely can reduce environmental concerns, like releasing carbon dioxide. You can save energy and money too, by having proper insulation to seal cracks around doors and windows, taking care of the heater and air conditioner regularly, changing the filters, and practicing energy-saving behaviors.

AIR CONDITIONING SYSTEM

We Can Measure Temperature with a Thermostat

We use thermometers to measure temperature. In schools, homes, and offices, these devices are called **thermostats**. They help measure the temperature of a room and communicate with the heater or air conditioner to turn it on when needed. Programmable thermostats automatically control the temperature of buildings for time of day and can save energy and money. During heating seasons, for example, they lower the temperature of a building when no one is using it. When people are active in the building, the thermostat automatically raises the temperature.

PROGRAMMABLE THERMOSTAT

Insulation and Weatherization

Air leaking in and out of a building wastes energy. Insulation slows down the movement of thermal energy (heat) and keeps the inside air separated from the outside air. Building owners can reduce heating and cooling costs by buying proper insulation. Some insulation materials work better than others in certain climates. Building owners should pick the right insulation for their weather and building design.

Insulation is like a blanket for buildings, but air can still leak in or out through small cracks. Sometimes, many small leaks can add up to the same amount of energy loss as leaving a door wide open. One of the easiest energy-saving measures is to caulk, seal, and weather-strip cracks and openings to the outside. These tools and actions are called **weatherization**. Homeowners can typically save up to $200 a year in heating and cooling costs by air sealing their homes and adding insulation. Larger buildings, like schools and offices, can save even more by following the same steps.

INSULATION

Image courtesy of Owens Corning

Door and Windows

Some air leaks happen around and through the doors and windows. Doors should seal tightly and have door sweeps at the bottom to prevent air leaks. Insulated storm doors help stop leaking air. School entryways with two sets of doors are built to keep cold air from blasting inside during the winter and outside during the summer. Both sets of doors should always be kept closed.

Most buildings have more windows than doors. The best windows shut tightly and are made of two or more pieces of glass. Caulk or seal any cracks around the windows and make sure they seal tightly. If you have older windows, you can install shutters or sheets of clear plastic to create added air barriers. Insulated blinds also help to prevent air flow and are often good when you want to sleep in! During heating seasons, open them on sunny days and close them at night. During cooling seasons, close them during the day to keep out the sun.

DOOR WITH A WORN OUT DOOR SWEEP

Moisture & Ventilation

Moisture is a term used to describe water as a liquid and a gas. Like heat and air, it is important to have the right amount of moisture in a building. Most moisture inside is water vapor, or in our air molecules. The amount of water vapor in the air is important to our health and comfort.

Humidity tells us how much water vapor is in the air. It is measured with a tool called a **hygrometer**. Air acts like a sponge and absorbs water during evaporation. Warmer air will hold more water vapor. Colder air does not hold as much water vapor.

When cold air from outdoors is heated, it feels very dry and makes the occupants of the building uncomfortable with stuffy noses, chapped lips, and dry skin. Air that is too dry can cause health problems when our sinuses are too dry. When there is too much moisture in a room, especially a room like a classroom where paper and books are found, it can create a problem. As you know, paper is made from wood. Fungi, like mold and mildew, grow in warm, moist, dark places. When moisture can build up on a surface, mold and mildew grow. As the molds get bigger, they release spores, which are carried in the air to other surfaces where they can grow more mold. These spores can be harmful to breathe in.

The right amount of moisture in the air in a room will help it keep the temperature from dropping or rising too much, which can reduce the number of times a heating or air conditioning system has to run. Humidity levels should be kept between 30% and 60%. Using a dehumidifier in the summer and a humidifier in the winter can help keep the appropriate humidity levels.

Bringing in air from outside can create humidity problems in our air. However, we need to bring in fresh air to help our systems run and our schools and homes to stay healthy. Imagine if you never brought fresh air inside your school. What a stinky place it might be! **Ventilation** systems bring in fresh air. Schools need this fresh air to run the heating and cooling systems properly and help keep humidity under control in warm climates.

Water Heating

You don't think too much about the hot water you need at school, but it is definitely needed. At home you probably have a water heater that is fueled by natural gas or electricity. When you turn the hot water on in the kitchen or bathroom, you might have to let the water run a bit before it's warm.

In a school, having water heater would mean you might need to let the water run for a very long time before water could reach faucets far away from the heater. Most schools have more than one large water heater, and the hot water is constantly moving through the school with a pump, so hot water can get to the sinks quickly.

The temperature of the water at school is important. At home, you probably have your hot water heater set at 120-140 °F, and rarely any higher because of the danger of a serious burn injury. This is true for the hot water at school except in the kitchen. Cafeteria workers must wash all dishes and serving equipment in water that is at least 160 °F. But at this temperature, you can burn your skin.

This is why many schools have more than one water heater. They can have one for the cafeteria and the other for the rest of the school. The cafeteria water is kept very hot while the rest of the school is kept at a safer temperature that is much lower.

Water Heater for the Home

Tankless Water Heater for the School