Heat Transfer

The heat is on! In this lesson, we are going to learn what heat is and how it moves from place to place. You know how they say, "If you can't stand the heat, get out of the kitchen."? Well after this lesson you'll know exactly what it is that you can't stand!

Heat

Believe it or not, the concept of heat is really a bit tricky. What we call heat in common language, is really not what heat is as far as physics goes. Heat, in a way, doesn't exist. Nothing has heat. Things can have a temperature. They can have a thermal energy but they can't have heat. Heat is really the transfer of thermal energy. Or, in other words, the movement of thermal energy from one object to another. If you put an ice cube in a glass of lemonade, the ice cube melts. The thermal energy from your lemonade moves to the ice cube. Increasing the temperature of the ice cube and decreasing the temperature of your lemonade. The movement of thermal energy is called heat. The ice cube receives heat from your lemonade. Your lemonade gives heat to the ice cube. Heat can only move from an object of higher temperature to an object of lower temperature. Do you remember what temperature is? Temperature measures how fast molecules are moving, right? Well, when heat transfers (moves) from one object to another, the movement of the molecules in the higher temperature object slow down and the movement of the molecules in the lower temperature object speed up. In our example of the ice and the lemonade, it would work like this. The lemonade has a higher temperature than the ice. (The molecules are moving faster than the ice molecules.) The faster moving molecules of the lemonade would transfer heat to the ice causing the ice molecules to move faster (increase temperature) and eventually change from solid to liquid. (See the Change of State Bite). In turn, since the faster moving molecules of the lemonade moves energy (transfers heat) to the ice, they slow down. This causes the temperature of your drink to decrease and that is what makes your lemonade nice and cold. Heat can be transfered in three different ways: conduction, convection and radiation.

Conduction

Let's start with conduction. Heat is transfered through conduction the same way pool balls are scattered around a table in the opening break. On a pool table, one ball crashes into another ball which crashes into another ball speeding the balls up and moving them around the table. Heat transfered from one object to another through conduction does the same thing. The molecules near the heat source (candle, stove, etc.) begin moving faster (their temperature increases). As they move faster they crash into other molecules around them which causes them to move faster. As those molecules move faster they crash into more molecules...etc, etc. Thus the molecules in the object are all moving faster. Heat has been transfered by conduction and the temperature of the object is higher. This experiment may make this clearer.

Experiment 1

Wiggle Bump, Wiggle Bump

You Need:

Mixing Bowl

Marbles or popcorn or beans. Any small hard object.

Spoon

1. Fill the bottom of the bowl with the marbles (or whatever your using). Just put enough in so that the objects cover the bottom of the bowl.

2. Put the spoon in the middle of the marbles and wiggle it.

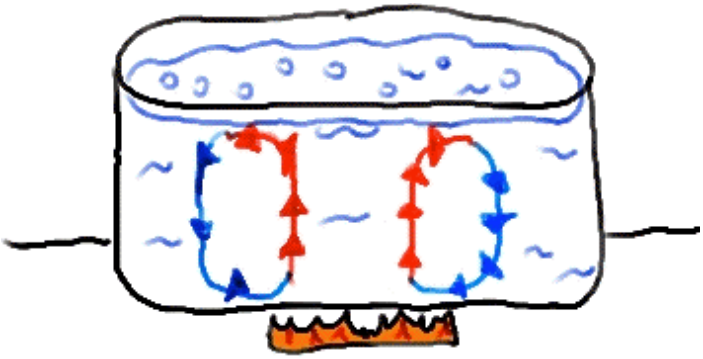
Did you notice how the marbles near the spoon wiggled? Then those marbles bumped into another set of marbles and wiggled them. And then those marbles bumped into another set of marbles and wiggled them. And then...well you get the

picture. Even though the "heat source" (the spoon) was only wiggling in the middle of the bowl the "heat" spread out from "molecule" (the marbles) to "molecule" throughout the bowl. That's conduction. The next time someone is cooking on the stove notice how the metal handle of the pot gets hot. (Be careful.) The reason it gets hot is due to conduction. The molecules wiggle and bump, wiggle and bump all the way from the bottom of the pot, where the flames are hitting it, to the end of the pot handle.

Some materials are better heat conductors then others. Metals conduct heat much better then plastic or glass for example. The molecules in metal can move a bit easier than they can in glass or plastic so they are able to wiggle a little easier and conduct heat through the wiggle and bump method. Metal pot handles are quite dangerous to touch after they have been on the stove for a while. Plastic pot handles, on the other hand, stay cool. Oven mitts are poor heat conductors. This is why you use them to grab metal pot handles. The oven mitts will not conduct the heat from the metal handle to your hand, keeping you safe.

Convection

Convection is a little more difficult to understand. Heat is transfered by convection by moving currents of a gas or a liquid. Hot air rises and cold air sinks. It turns out, that hot liquid rises and cold liquid sinks as well. Room heaters generally work by convection. The heater heats up the air next to it which makes the air rise. As the air rises it pulls more air in to take its place which then heats up that air and makes it rise as well. As the air get close to the ceiling it may cool. The cooler air sinks to the ground and gets pulled back near the heat source. There it heats up again and rises back up. This movement of heating and cooling air is convection and it can eventually heat an entire room or a pot of soup. This experiment should allow you to see convection currents.



Experiment 2

The Ups and Downs of Heat

Caution: This experiment uses a hot stove and a hot pot of water! This experiment could burn or scald you if you're not careful. Make sure an adult helps with this.

You need:

A pot

A stove

Pepper

Ice cubes

Food Coloring (optional)

1. **Fill the pot about half way with water.**
2. **Put about a teaspoon of pepper into the water.**
3. **Put the pot on the stove and turn on the stove (be careful please).**
4. **Watch as the water increases in temperature. You should see the pepper moving. The pepper is moving due to the convection currents. If you look carefully you many notice pepper rising and falling.**
5. **Put an ice cube into the water and see what happens. You should see the pepper at the top of the water move towards the ice cube and then sink to the bottom of the pot as it is carried by the convection currents.**
6. **Just for fun, put another ice cube into the water, but this time drop a bit of food coloring on the ice cube. You should see the food coloring sink quickly to the bottom and spread out as it is carried by the convection currents.**

Did you see the convection currents? Hot water rising in some areas of the pot and cold water sinking in other areas of the pot carried the pepper and food coloring throughout the pot. This rising and sinking transfered heat through all the water causing the water in the pot to increase in temperature. Heat was transfered from the flame of the stove to the water by convection. More accurately, heat was transfered from the flame of the stove to the metal of the pot by conduction and then from the metal of the pot throughout the water through convection. Every time I'm served a hot bowl of soup or a cup of coffee with cream I love to sit and watch the convection currents. You may look a little silly staring at your soup but give it a try sometime!

Radiation

Heat is transfered by radiation through electromagnetic waves. Remember, when we talked about waves and energy in the Energy Bites? (If not, you may want to go back and take a quick look at that section.) Well, heat can be transfered by electromagnetic waves. Energy is vibrating particles that can move by waves over distances right? Well, if those vibrating particles hit something and cause those particles to vibrate (causing them to move faster/increasing their temperature) then heat is being transfered by waves. The type of electromagnetic waves that transfer heat are infra-red waves. The Sun transfers heat to the Earth through radiation.

Experiment 3:

You Light up My Temperature

Be careful. You will be bringing your hand close to something that can burn you. An adult needs to help you with this. You could get burned.

You need:

An incandescent light bulb

A hand

1. Turn on a light bulb.

2. Let it glow for at least one minute.

3. Slowly bring your hand closer to the light bulb until you can feel heat on your hand.

4. Do not touch the light bulb!

What you felt was radiation! Now don't panic. It's not a bad kind of radiation like you get from x-rays. It's infra-red radiation. Heat was transfered from the light bulb to your hand. The energy from the light bulb resonated the molecules in your hand. (Remember resonance? Look back in the sound section if you need a refresher.) Since the molecules in your hand are now moving faster, they have increased in temperature. Heat has been transfered! In fact, an incandescent light bulb gives off more energy in heat then it does in light. They are not very energy efficient.

Experiment 4

Soaking in the Sun

You need:

2 ice cubes, about the same size.

A white piece of paper

A black piece of paper

A sunny day

1. Put the two pieces of paper on a sunny part of the sidewalk.

2. Put the ice cubes in the middle of the pieces of paper.

3. Wait.

What you should eventually see, is that the ice cube on the black sheet of paper melts faster then the ice cube on the white sheet. Dark colors absorb more infra-

red radiation then light colors. Heat is transfered by radiation easier to something dark colored then it is to something light colored and so the black paper increased in temperature more then the white paper.

In a Nutshell

- Heat is the movement of thermal energy from one object to another.

-Heat can only flow from an object of a higher temperature to an object of a lower temperature.

- Heat can be transferred from one object to another through conduction, convection and radiation.

- Conduction is the wiggle and bump method of heat transfer. Faster moving molecules bump into slower moving molecules speeding them up. Those molecules then bump into other molecules speeding them up and so on increasing the temperature of the object.

- Convection is heat being transfered by currents of moving gas or liquid caused by hot air/liquid rising and cold air/liquid falling.

-Radiation is the transfer of heat by electromagnetic radiation, specifically infrared radiation.

Did You Get It

1. What is heat?

2. Does heat flow from higher to lower temperature, from lower to higher temperature or does it matter?

3. When I first turn on the shower the shower curtain keeps blowing into my legs. Is this an example of conduction, convection or radiation?

4. When I bite into a pizza, the heat is transfered painfully to the roof of my mouth. Is this an example of convection, conduction or radiation?

5. Someone sits a little too close to me on a bus and I can feel the heat coming off of them. Is this an example of convection, conduction or radiation?

6. My daughter holds my hand as we walk across the street. I can feel heat coming from her hand to mine. Is this an example of convection, conduction or radiation?

7. It's a hot sunny day outside. Am I better off wearing a dark shirt or a light shirt if I want to stay cool?

Answers

1. Heat is the movement of thermal energy from one object to another.

2. Heat can only flow from a higher temperature object to a lower temperature object.

3. Convection. The heat from the hot water in the shower heats up the air in the shower. The heated air rises. As the heated air rises, it creates a convection current. Which draws air into the shower and blows the shower curtain into my legs. Many of the winds on the Earth are caused by hot air rising and cold air sinking.

4. This is conduction. The fast moving molecules of the pizza bombard my poor mouth molecules. This, in turn, creates sound energy as I scream "OUCH!".

5. This is radiation. Humans can transfer heat by radiation. The fellow sitting next to me was giving off infra-red radiation.

6. **This time it's primarily conduction. The molecules in her little hand are vibrating quickly and causing my molecules to vibrate quicker as well. There is probably some radiation going on as well, but since our hands are touching her molecules can directly effect my molecules.**

7. **A light colored shirt reflects more infra-red radiation so I'll stay cooler.**