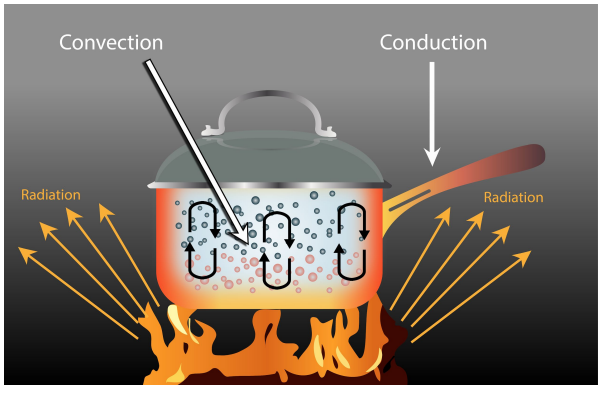
Thermal Energy Transfer

Reflect

Water flows in rivers; air flows across the planet. What about heat? Water and air are fluids, which means they are substances. It is easy to imagine how they flow. Heat is not a substance; it is a form of energy. However, heat does move from place to place. How do you think heat moves, or flows? In this STEMscopedia, you will learn how heat flows in three different ways: **conduction**, **radiation**, and **convection.**



conduction – transfer of thermal energy that occurs in solids, liquids, and gases when two substances of different temperatures touch
radiation – the transfer of energy by the movement of electromagnetic waves or subatomic particles
convection – heat transfer caused by the rising of hotter, less dense fluids and the falling of cooler, denser fluids

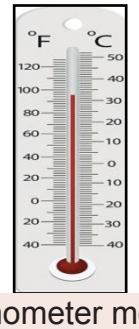
Heat is different from thermal energy.
There is an important difference between heat and thermal energy. *Heat* is thermal energy that is being transferred from one place to another. So what is thermal energy? All matter is made of tiny particles that cannot be seen with the naked eye. These particles are always in motion, and motion is a form of energy. An object's *thermal energy* equals the total energy of all its moving particles. *Heat transfer* happens when some of this energy moves from one object to another.

Energy is never created and never destroyed; it simply changes form. This is the *law of conservation of energy*. Most forms of energy are eventually transformed into thermal energy, which then flows away into nature. This is what we mean when we say that a system loses energy as heat. In most cases, we cannot capture and reuse this energy. For example, a fire gives off heat as it burns. Eventually, the fire burns itself out. Its energy has not been destroyed, even though we can no longer use it. It has simply been transformed into heat.

Look Out!

A thermometer measures temperature. However, temperature does not measure heat or thermal energy. Temperature measures the *average* energy of motion of an object's particles. Thermal energy is a measure of the *total* energy of motion of an object's particles.

Suppose a glass of water and a lake have the same temperature. The average water particle in the lake and the average water particle in the glass have the same energy of motion. However, the lake has much greater thermal energy, because it contains many more particles.



A thermometer measures the average energy of particle motion in an object.

Reflect

Thermal energy is transferred by three main processes.

How does thermal energy move as heat from one object to another? Think of the different ways you experience heat. You feel heat as the sun shines on you and when you sit by a fire (radiation). You can use an oven to heat cold food (convection). The stove can burn you if you touch it (conduction). Each of these processes involves the transfer of heat. How are they similar? How are they different?

Thermal energy can transfer by conduction.

Try to imagine the tiny, constantly vibrating particles that make up an object. Imagine placing a metal frying pan that has an average temperature on a hot burner on a stovetop. The burner transfers heat to the pan, and the pan gets hot. The bottom of the pan gets hot before the pan's handle. Why does this happen? The hot burner is at a much higher temperature than the pan. In other words, the particles that make up the burner are moving at a greater average speed and, therefore, have greater thermal energy.

When the burner is turned on, the handle of the pan will get hot last.

The burner's particles collide with the particles in the bottom of the pan. Some of the energy in the burner's particles transfers to the pan's particles, which then move faster. These particles collide with nearby particles in the pan, which collide with other particles. Each collision passes energy from particles moving quickly to particles moving slowly. In this way, the energy spreads throughout the pan and finally reaches the handle.

This process is called conduction. Conduction is the transfer of heat that happens when particles collide with each other. It can happen in solids, liquids, and gases.

Heat is radiated from fires, furnaces, and other hot things.

Thermal energy can also transfer by radiation.

You don't actually have to touch a fire to know it is hot. If you hold out your hand a few inches from the flames, you can feel the heat. How is it possible to feel heat without touching a hot object? The answer is that hot objects emit radiation.

Heat radiation is energy that travels as infrared electromagnetic waves. You do not need to touch an electromagnetic wave to feel it. Sunlight is another form of radiation. Light from a light bulb and heat from our bodies are also examples of radiation. Microwaves use radiation to heat food.

Look Out!

The campfire warms people by transferring heat through radiation.

Like light, heat waves can travel through air—they can even move through empty space! Think about standing around a campfire.

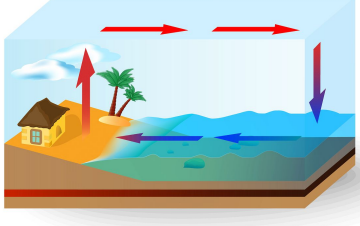
Most of the heat you feel reaches you by radiation. If a large group of people are gathered around a campfire, only the people in the front row will feel the heat. If someone is standing in front of you, he or she will block the heat from reaching you.

Reflect

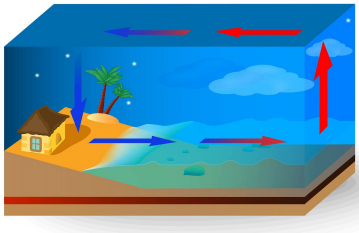
Thermal energy can transfer by convection.
Many kitchen stoves have hoods several feet above the burners. The purpose of the hood is to carry smoke and other fumes away from the stovetop. But why is the hood above the stove? Why isn't it on the side? Similarly, why are chimneys above fireplaces? You never see a chimney next to or beneath a fireplace. This is because hot air rises. This brings us to the third type of heat transfer: convection.

During conduction, heat energy moves between particles that touch each other. During convection, however, the particles themselves move. This happens only in liquids and gases, because the particles in solids are stuck in place and cannot move. Particles that move more quickly are "hotter." As hot particles move into a new area, they increase the area's thermal energy. This makes the area hotter as well.

Look Out!



Sea breeze



Land breeze

Convection currents can transfer heat in our atmosphere through a cycle of warm air moving toward cooler air.

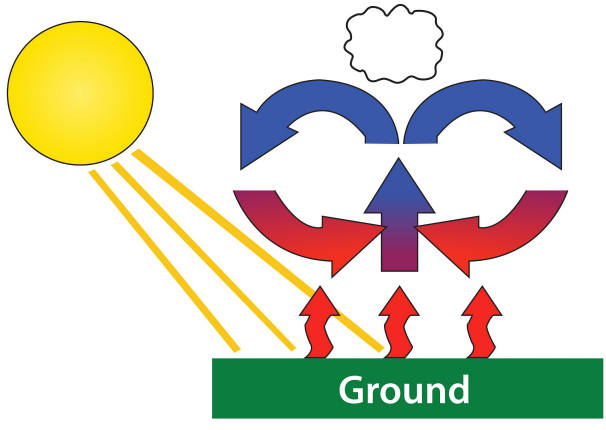
Sea breeze: In the day, the warm air above the land rises to form clouds and moves to cooler areas at sea (arrows at the top of the cycle). Cool air from the sea moves inland, forming a sea breeze (arrows at the bottom).

Land breeze: As warm air from the ocean moves at the top of the cycle toward the cooler land air, the land air is pushed out to the ocean (arrows at the bottom).

What Do You Think?

Why do you think warm air particles rise? As particles increase their speed, they also move farther apart. As the particles in a group move apart, the whole group becomes lighter than the surrounding "colder" particles. As a result, the "hotter" particles rise. As the particles rise, they gradually lose energy, cool, and sink. This creates a cycle of rising and sinking particles. This circular motion is called a *convection cycle*.

Hot-air balloons rise because of convection. A flame heats air particles inside the balloon. The heated air rises, because it is lighter than the surrounding air outside the balloon. As the heated air rises, the balloon rises as well.



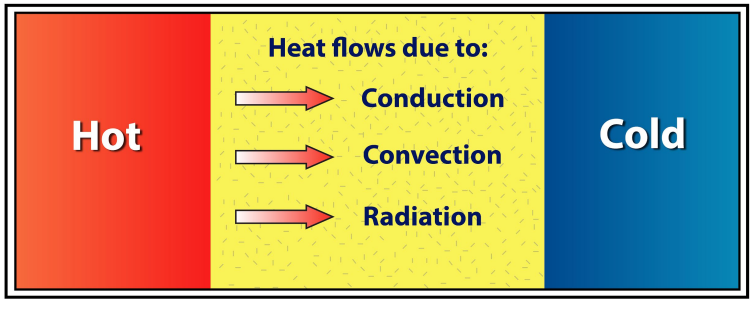
As sunlight heats the ground, air above the ground warms and rises. As the air rises, it cools and then sinks back to the ground, where it heats and rises again. This results in a convection cycle and causes wind. Convection cycles also occur in seawater, which causes ocean currents.

Reflect

Heat flows in a predictable pattern.

Remember this important rule about heat flow: when objects of different temperatures are in contact, heat *always* moves from the warmer object to the cooler object until their temperatures are equal.

If you accidentally touch a hot burner, the heat moves from the burner to your hand, because your hand is cooler. What happens if you touch a piece of ice? Heat moves from your hand, which is warmer, to the ice, which is cooler. In other words, your body loses heat—that is why ice feels cold.



What Do You Think?

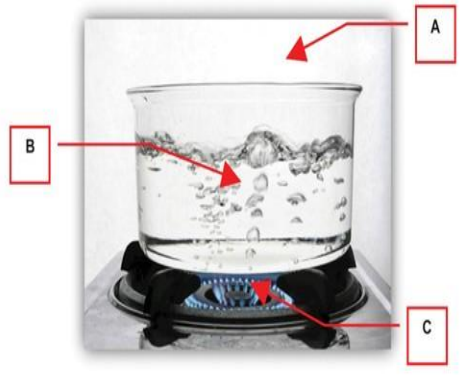
A metal hammer has been lying in the sunlight on a hot day. When you pick up the hammer, it feels very warm in your hand. Can you explain the different ways that heat is moving in this situation?

A pot is placed on a gas flame, and the water inside the pot begins to boil. Heat moves in three different ways, as shown in the image below. Which part of the image shows conduction? Which part shows convection? Which part shows radiation? Write your answers below.

Heat is carried away from the pot in all directions. This shows _____.

Warm water rises within the pot. This shows _____.

Heat moves from the flame to the bottom of the pan. This shows _____.



Reflect

Getting Technical: How a Refrigerator Works

A refrigerator relies on the properties of gases to stay cool. The inside of a refrigerator contains a compressor and an expansion valve. Metal coils connect these two parts. Inside these coils is a substance called tetrafluoroethane (HFC).

Depending on the amount of pressure put on it, HFC can be either a liquid or a gas. As the HFC flows through the compressor, it is squeezed into a gas. This causes the HFC to heat up. The heat is released into the air outside the refrigerator.

The HFC then flows through the expansion valve. There the pressure is decreased and the HFC expands back into a liquid. When this happens, it gets very cold. The cold liquid flows through the refrigerator, cooling it. This process requires a lot of energy. Most refrigerators are powered by electric motors.

This is the compressor of a kitchen refrigeration unit. It is located in the back of the refrigerator.

What Do You Think?

If you recall, heat always flows from hot to cold. You want a good insulator to keep your lunch cold and prevent heat transfer. Various materials have different abilities to resist heat transfer.

Insulated soft bag

Lightweight plastic box

Paper bag

Mini ice chest

What do you think would be the best insulating lunch container among the ones above? Explain your thinking.

What do you think would be the worst insulating lunch container among the ones above? Explain your thinking.

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Reflect

Preventing Heat Transfer in Light Bulbs

What energy transfer takes place in a light bulb? Electrical energy is changed into light energy, which is desirable, and some changes into heat energy, which is undesirable. We consider the energy that changes to heat energy in a light bulb to be wasted energy. The bulb on the right is an incandescent bulb.

As electricity passes through a filament inside the bulb, it gets very hot and glows, giving off both heat and light. (Have you ever touched an incandescent bulb that has been on for a few hours?) Since the purpose of the bulb is to create light, we consider the heat an unnecessary by-product that wastes electrical energy.

CFLs, or compact fluorescent light bulbs, such as the one shown on the left, can glow as brightly as incandescent bulbs but use as little as one-fifth of the electrical energy. After they have been on for a few hours, they are still cool to the touch. That is because they are designed differently from incandescent bulbs. They have no filaments to heat up and waste energy. They are considered a great improvement in minimizing heat transfer over incandescent bulbs for these reasons.

Try Now

Which way does heat travel?

Think about what happens when you touch something such as a hamburger. The thermal energy from the hamburger is shared with your hand. Your hand feels warmer than before it touched the hamburger. The hamburger loses some of its thermal energy, so it becomes cooler. The energy from the hamburger is transferred to your hand.

Thermal energy is always shared between objects that touch each other, such as your hand and a hamburger. Thermal energy always travels from the item with the most thermal energy to the item with the least. Find out how the heat moves with the following activity.

Purpose: To determine whether heat travels from warm to cold or from cold to warm

Materials: 2 thermometers, hot water, cold water, 1 large beaker, 1 small beaker

Procedure

Fill the large beaker half full with hot water.
Fill the small beaker half full with cold water.
Place a thermometer in each beaker.
Record the two temperatures.
Carefully set the small beaker *with the thermometer still in the beaker* inside the large beaker.
Check both water temperatures after 10 minutes.
Record final temperatures.

Data

	Starting Temperature	Final Temperature
Large Beaker with Hot Water		
Small Beaker and Cold Water		

Conclusion

Which way does heat travel? Explain your answer.