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The transfer of thermal energy can occur in three ways

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Image 1. Radiation is one way that heat transfer occurs. All objects radiate some amount of heat as electromagnetic waves, even humans. Hotter objects, like light bulbs and campfires, radiate higher-energy light that we can see. Photo by National Geographic

NATIONAL GEOGRAPHIC

Thermal energy comes from the movement of atoms. Since atoms make up the entire known universe – and it is impossible to reach absolute zero (minus 273.15 degrees Celsius or minus 459.67 degrees Fahrenheit), the theoretical temperature at which even atoms are frozen in place – everything has thermal energy. Whether they are zipping around in a gas or barely shivering in a solid, atoms are constantly moving.

Although all objects have thermal energy, they do not all have the same amount. Extremely hot objects such as the sun have vastly more thermal energy than cold objects like ice. However, the sun can transfer some of its thermal energy to ice, which is what causes an ice cube to melt on a warm, sunny day. The movement of thermal energy from a hotter object to a colder object is called heat transfer.

Heat transfer can happen in three different ways: through conduction, convection, and radiation. All three forms of heat transfer happen constantly in daily life, and in fact, heat transfer is essential to life itself.

Conduction

Conduction requires contact between the objects involved. Solids, liquids and gases can all conduct heat. As with any form of heat transfer, there must be a temperature difference for conduction to happen, and thermal energy is always transferred from the hotter object to the colder one. Once the objects reach the same temperature, the heat transfer stops. This is called thermal equilibrium.

On a microscopic level, conduction happens when particles bump into each other. Consider a cold metal spoon in a hot cup of coffee: The molecules in the coffee are moving freely and the metal molecules in the spoon are vibrating. Since the coffee is hotter than the spoon, its molecules are (overall) moving more. As they bump up against the spoon, the coffee molecules transfer some of their energy to the spoon molecules. As these collisions keep happening, the spoon gets warmer and the coffee gets slightly cooler until both are the same temperature.

Once the spoon and the coffee reach this thermal equilibrium, the particles do not quit bumping against each other. They continue transferring energy back and forth, but there is no longer a net flow of thermal energy in one direction. The two objects remain at the same temperature unless acted on by something else that adds or subtracts heat from them. In most cases, that something is the air in the room, which draws heat from the coffee. Eventually, if allowed to sit, the coffee cup, the coffee, and the spoon will all be the same temperature as the ambient air. They are once again at thermal equilibrium, but this time with their surroundings.

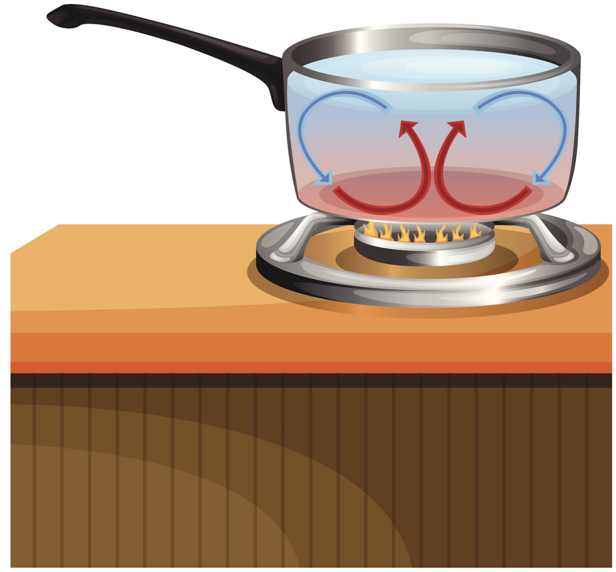
Some materials conduct heat better than others. Materials that conduct heat well, like metals, are called conductors, while materials that do not conduct heat well, like wood and plastic, are called insulators. This is why people often choose wooden or plastic-handled spoons when cooking – they do not get nearly as hot as metal spoons.

Convection

Heat transfer via convection happens only within fluids, like liquids and gases. Fluids are not very good conductors, so they transfer heat mostly by convection. Consider a pot of water heating on a stove: The heat source –the stove burner – is beneath the pot, so water near the bottom of the pot heats up first. Fluids expand when they heat up, so the water near the bottom becomes less dense. The difference in density between water at the bottom and at surface produces circulation currents. Hotter, less-dense water begins to rise and displace colder, denser water, which then sinks to the bottom where it is heated and begins to repeat the cycle. As time goes on, more of these circulation currents develop, transferring heat throughout the liquid. These convection currents can be easily observed when boiling rice in water.

Convection currents also allow heated air to circulate through a room. The phrase "heat rises" should really be "heated air rises," since it is the heated air molecules that are rising and circulating.

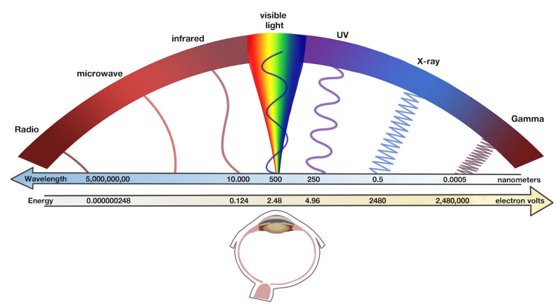
Convection plays a large role in moving plate tectonics. Earth's solid outer layer, the lithosphere, sits on top of a semi-molten layer called the asthenosphere. The asthenosphere is heated from even-hotter regions below, so – just like a pot on a stove – this heat source creates slow, but massive, convection currents within the asthenosphere, which causes some of the movement of Earth's tectonic plates.



Radiation

To understand radiant energy, we need to understand electromagnetic waves. Light can act as both a particle and a wave, and when it acts as a wave, the waves are referred to as electromagnetic. These waves can have different amounts of energy based on how fast they vibrate up and down. Fast-vibrating (high-frequency) waves have more energy than slow-vibrating (low-frequency) waves. All of these waves exist on the electromagnetic spectrum, with low-energy waves on one end and high-energy waves on the other. Humans can only see light waves in a specific part of this range, called the visible spectrum.

Radiation is the transfer of heat via electromagnetic waves. All objects radiate some amount of heat as electromagnetic waves, even humans. Humans radiate energy as infrared light, which is too low-energy for us to see. However, we still feel it as heat – in fact, infrared radiation is commonly referred to as "heat rays." Hotter objects, like light bulbs and campfires, radiate higher-energy light that we can see.



Radiation can even transfer heat through the vacuum of space. The sun radiates heat through millions of miles of empty space down to Earth. Because the sun has so much thermal energy, it radiates many kinds of electromagnetic waves, including infrared light, visible light, ultraviolet light, and X-rays. Ultraviolet light and X-rays are high-energy forms of light that we cannot see.