What affects heat and the movement of heat

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Imagine that you are in the kitchen and you are about to bake some cookies. You prepare your cookie dough, tray and oven. You put your tray filled with cookie dough in the oven and in no time the tray starts heating up. After a while, you wouldn't dare touch the tray with your bare hands. It would cause severe damage to your skin. The movement of energy allows the tray to gain energy in the form of heat. The energy that is being taken in by the cookie dough and the tray is all a part of the heat flow that is created when you put the tray into the oven. Heat flow is the thermal energy that is created from the oven going into the tray and exciting the particles that make up the tray. This movement of energy is affected by a few things; one of them is surface area. Surface area is involved in the movement of heat and it affects how fast the transfer is. Knowing how it affects the movement is important to understand ways that heat transfer can be changed and to predict which objects would gain or lose energy faster in a given situation.

Before learning about what affects heat and the movement of heat, we should start with learning about what heat itself is. Heat can be described in multiple ways: the most recognizable is the state of being at a high temperature. In this case, however, heat would be described as external energy moving throughout particles and being transferred between them. Simply speaking, heat is the transferring of energy and " all matter contains heat energy," (Ryan, 2009). This transfer of energy always goes from a higher temperature area to a lower temperature area. The more excited particles with more energy move the particles that are close by. They gain energy and the whole substance is heated. If the cookie tray that comes out of the oven is left on the counter for a long time, it will eventually cool down. The tray is losing its energy when it is left in the room temperature air. As the cookie tray is left on the counter, the air gains energy. The energy from the tray is moving from the tray into the air around it and therefore it makes the surrounding air warmer. You would notice this if you held your hand above the tray: the air will feel warm. The fact that heat moves from hot to cold makes perfect sense, because if you think about it; an object that is hotter than its surroundings would never become even hotter without doing anything to it. The same goes for an object that is colder than its surroundings. So as the energy travels from the tray to the air around it, the two substances eventually reach a point where they are both equal in temperature. This is called the thermal equilibrium. As long as two objects or substances are not equal in temperature, there will always be a flow of heat from the higher temperature to the lower temperature substance. This flow of heat will continue until the substances or objects are equal in temperature. Another example would be if you took the tray straight out of the oven and poured a bag of ice onto it. The tray would cool. The energy in the tray is lost and it is going right into the ice. While the tray cools, the ice heats up. Over time the two will be the same temperature and both objects would be in thermal equilibrium.

Touching two solid materials together that are a different temperature is not the only way to transfer heat. This is only one of the three methods and it is called conduction. Conduction transfers the energy through direct contact of objects. Matter is made up of moving particles and the particles are in constant motion. Whether they are vibrating, translating, or rotating, they are always moving. “ These motions give the particles kinetic energy,” (Henderson, 2011). When the two objects collide, they transfer that kinetic energy to the other object, but nothing between the two physical items are moving. The material is not flowing; just the energy. As two objects collide, the particles in the higher temperature item loses its kinetic energy and the lower temperature item gains kinetic energy. The collision and the transfer of the energy is what would be the conduction. Think about a basketball rolling in one direction. Now think about another basketball that is identical rolling twice as fast in the opposite direction toward the first. After they collide they would roll away from each other because of the hit. The first ball would roll away faster than the second ball now because the second ball had more energy than the first one prior to the collision. Just like with heat flow, the energy was transferred from high to low energy. The higher energy ball lost energy after the collision and the first ball gained energy. Another method of transferring energy is convection. Convection uses the flow of liquids and gasses to move the energy. The movements of the fluids carries the thermal energy along with it to transfer the heat to different regions. Heat expands fluids and makes it less dense. Being less dense then results in a motion between the heated less dense and the non-heated more dense fluids. This motion in fluids creates a circulation within the fluid and carries the energy throughout the entire substance. Think about a bowl containing 10 red balls and 10 blue balls. The red balls would be on the bottom and represent the heated substance and the blue balls would be at the top and represent the original substance. When you stir the balls in the bowl, they are mixed up and are random. The red balls are now relatively evenly mixed with the blue balls. The energy is carried out throughout the blue balls and the entire substance is now heated. This is also why we say that heat rises. The hot air will circulate to the top of a house and the “ lower floors of the building [are] cooler,” (Jarvis, 2015). Radiation is the transfer of heat through electromagnetic waves. Radiation is the heat that comes off of a source and spreads the energy to its surroundings. Everything radiates in the form of electromagnetic waves. The higher amount of thermal energy an object has, the more energy it radiates. When object radiates, it sends off waves that increase the energy of surrounding objects and thus increases their heat as well.

There are factors that affect the rate at which heat is transferred. Temperature plays an important role in the rate of transfer. Specifically, the difference in temperature between two substances plays the role. Because heat will always try to move and transfer to form a thermal equilibrium, the rate at which energy is transferred will depend on the difference in the temperatures. The higher the difference, the higher the rate. A very hot substance will lose its energy to a very cold substance faster than a mildly warm substance will lose its energy to a cool substance. The rate at which the energy is transferred however, is always changing. If the difference in temperature is a factor of the rate, and as time goes on that difference becomes smaller, the rate will slow down overtime. If we use the ice on the hot tray example again, the ice would gain energy at a very fast rate because of the big difference in the temperature between the tray and the ice. Similarly, the tray would lose energy at a fast rate. Overtime, the ice will melt and be much warmer, but not quite be the same temperature as the tray. The tray will cool down as well, but not quite be the same temperature as the ice. Because of the now smaller difference in temperature, it is known that the cool now-melted ice will gain energy at a slower rate and the warm tray will lose its energy at a slower rate.

Another factor contributing to the heat transferring rate is the materials that the substances are made of. If hot water were placed in a coffee mug, it would take a little while to make the mug very hot; but take the same hot water into a plastic or Styrofoam cup instead, and the cup would feel hot in no time. This is because the material that the two cups are made of are different. The coffee mug makes the rate at which it gains energy slower than the plastic cup. Different materials gain and lose energy at different rates. This difference and the effect that a material has in the transfer rate of heat is called the thermal conductivity of the material; conductivity being the transferring of heat through direct contact of two objects. The higher the thermal conductivity is for an object, the higher the rate at which heat is transferred by it is. Scientists experiment with different materials to see which has a higher or lower thermal conductivity value. “ Low thermal conductivity values are referred to as thermal insulators,” (Henderson, 2011).

The distance that the heat must be conducted also plays a part in the rate of transfer. The thicker the wall of an object is, the slower the rate of transfer. Think about the walls of a cup. “ As the ceramic particles at the boundary between the [heat] and the mug warm up, they attain a kinetic energy that is much higher than their neighbors,” (Henderson, 2011). This means that the particles heat up their neighbors while taking time and eventually the heat will transfer through an object. Taking a plastic cup and pouring hot water into it would make the cup heat up at a fast rate because of its material, but that rate can be slowed down if the thickness of the plastic cup is increased. Because the hot water has to travel a longer distance to lose its energy, the cup is heated at a slower rate. The distance between the two slows down the transfer rate. The farther the energy has to go, the slower the rate. People wear multiple layers of clothing and coats when going out into cold weather. This is because the radiation of heat coming off our bodies is transferred into the cold air slower because of the multiple layers. Thickness is a good way of insulating heat and keeping things warm. The heat coming off of our bodies is trapped under the coats and multiple layers and continues to keep our bodies warm since it is not lost to the coldness of the air around us.

As we know, " if we bring two objects that are initially at different temperatures into physical contact, they eventually achieve thermal equilibrium," (Hall, 2014). Thickness affects this movement because it takes longer to move further. Since thickness or distance affects the conductive heat transfer, it would only make sense that the area of the objects being transferred are involved as well. If a marble was placed over a small fire, and another marble twice the size was placed the same, the small marble would gain the thermal energy of the fire faster than the big marble. All chefs know that trying to cook two things that are different in size in the same oven for the same time will never work. The two foods would just never cook the same. One food would be cooked and the other raw, or one will be cooked and the other burnt. This is because of the area in the objects. A larger area will slow down the rate of transferring the heat. The wider a surface area an object has the slower the rate of transfer. Why does this happen? It all has to do with what is actually involved in the transfer of thermal energy. The " faster moving particles excite the nearby particles," (Ryan, 2009) and the energy is carried out through the whole object. Every particle of an object's surface is always involved in the transfer of thermal energy. Therefore, the more area an object has, the more particles are involved and the longer it will take to conduct the energy.

The reason why heat flow exists is because there is a difference in temperature and the energy is being transferred to maintain an equality of energy. Unless the thermal equality is reached, there will be a heat flow between the substances. The movement of heat and the transferring of thermal energy is affected by (depending on which method) the material, the temperature difference, the distance, and the surface area of the two objects. The factors that cause these differences in rates are important to understand the behavior of thermal energy and how it works. The flow can be insulated with distance, material and area. The area affects the rate because every particle of the object is involved in the transferring of energy. The larger area an object has, the slower the rate of transfer.

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