

Conduction, Convection, and Radiation: Popcorn Lesson (Three Methods of Heating)

(<http://aspire.cosmic-ray.org/labs/atmosphere/popcorn.html>)

All forms of matter, whether a solid, liquid, or gas, are composed of atoms or molecules in constant motion. Because of this constant motion, all atoms have thermal (heat) energy. Whenever a substance is heated, the atoms move faster and faster. When a substance is cooled, the atoms move slower and slower. The “average motion” of the atoms that we sense is what we call temperature.

Temperature and heat ARE NOT technically the same thing. Temperature is the average motion of atoms and molecules. Heat is the energy that flows due to temperature differences. Heat is always transferred from warmer to cooler substances. (When there is no temperature difference, it is called thermal equilibrium, and no heat is transferred.)

There are three ways to heat the atmosphere (or anything else, for that matter). These ways include conduction, convection, and radiation. How can you remember these? Let’s use an analogy to help you figure this out.

There are three ways to cook popcorn:

1. Put oil in the bottom of a pan. Cover the bottom of the pan with popcorn kernels. Place the pan on the stove and turn on the burner to medium heat. Cover the pan with a lid. Periodically shake the pan so the kernels move around in the oil.
2. Obtain a popcorn popper. Place the popcorn kernels in the popper. Plug in/turn on the popper. Hot air will transfer heat to the kernels, making them expand and pop.
3. Microwave a bag of microwave popcorn.

Each of these methods of cooking popcorn is really an example of the three ways heat can be transferred.

Conduction: This method of heat transfer is most familiar to people. If you have ever burned yourself on a hot pan because you touched it, you have experienced this first-hand. Conduction is heat transfer through matter. Metals conduct heat well. Air is not as good a conductor of heat. This is a direct contact type of heat transfer. The only air heated by the Earth is the air at the Earth’s surface. As a means of heat transfer, conduction is the least significant with regard to heating the Earth’s atmosphere. Which popcorn example does it relate to? (#1) The heat is transferred by direct contact from the pan, to the oil, to the kernels of popcorn.

Convection: Convection is heat transfer by the movement of mass from one place to another. It can take place only in liquids and gases. Heat gained by conduction or radiation from the sun is moved about the planet by convection. The radiation from the sun heats the air of the atmosphere, but the heating of the Earth is not even. This is because the amount of sunlight an area receives depends upon the time of day and the time of year. In general, regions near the equator have hotter air. This hot air rises, allowing cooler air to move in underneath the warm air. In our popcorn example this relates to #2. The hot air transfers the heat to the cooler kernels, and when enough hot air heats the kernels, they pop.

Radiation is the only way heat is transferred that can move through the relative emptiness of space. All other forms of heat transfer require motion of molecules like air or water to move heat. The majority of our energy arrives in the form of radiation from our Sun. Objects that are good absorbers of radiation are good radiators as well. The atmosphere, which does not absorb certain wavelengths of solar radiation, will absorb certain wavelengths of radiation. The particles that reach Earth from the Sun are within a wavelength that the Earth’s atmosphere will absorb. When the Sun heats the Earth, the Earth gets warmer in that location and re-radiates heat into the atmosphere, making it doubly warm. This relates to popcorn example #3. The kernels are heated by the radiation in the microwave, and the

kernels heat up, giving off more heat to the kernels surrounding it and making it “doubly warm.”

Radiation is the primary way that air is heated. Convection currents move that heated air around the earth, and the difference between warm and cold air provide the energy needed to create weather.

How Does Heat Travel?

(http://coolcosmos.ipac.caltech.edu/cosmic_classroom/light_lessons/thermal/transfer.html)

Heat can be transferred from one place to another by three methods: conduction in solids, convection of fluids (liquids or gases), and radiation through anything that will allow radiation to pass. The method used to transfer heat is usually the one that is the most efficient. If there is a temperature difference in a system, heat will always move from higher to lower temperatures.

CONDUCTION:

Conduction occurs when two objects at different temperatures are in contact with each other. Heat flows from the warmer to the cooler object until they are both at the same temperature. Conduction is the movement of heat through a substance by the collision of molecules. At the place where the two objects touch, the faster-moving molecules of the warmer object collide with the slower-moving molecules of the cooler object. As they collide, the faster molecules give up some of their energy to the slower molecules. The slower molecules gain more thermal energy and collide with other molecules in the cooler object. This process continues until heat energy from the warmer object spreads throughout the cooler object. Some substances conduct heat more easily than others. Solids are better conductor than liquids, and liquids are better conductor than gases. Metals are very good conductors of heat, while air is very poor conductor of heat. You experience heat transfer by conduction whenever you touch something that is hotter or colder than your skin (e.g., when you wash your hands in warm or cold water).

CONVECTION:

In liquids and gases, convection is usually the most efficient way to transfer heat. Convection occurs when warmer areas of a liquid or gas rise to cooler areas in the liquid or gas. As this happens, cooler liquid or gas takes the place of the warmer areas which have risen higher. This cycle results in a continuous circulation pattern, and heat is transferred to cooler areas. You see convection when you boil water in a pan. The bubbles of water that rise are the hotter parts of the water rising to the cooler area of water at the top of the pan. You have probably heard the expression “Hot air rises and cool air falls to take its place”— this is a description of convection in our atmosphere. Heat energy is transferred by the circulation of the air.

RADIATION:

Both conduction and convection require matter to transfer heat. Radiation is a method of heat transfer that does not rely upon any contact between the heat source and the heated object. For example, we feel heat from the sun even though we are not touching it. Heat can be transmitted through empty space by thermal radiation. Thermal radiation (often called infrared radiation) is a type electromagnetic radiation (or light). Radiation is a form of energy transport consisting of electromagnetic waves traveling at the speed of light. No mass is exchanged and no medium is required.

Objects emit radiation when high energy electrons in a higher atomic level fall down to lower energy levels. The energy lost is emitted as light or electromagnetic radiation. Energy that is absorbed by an atom causes its electrons to “jump” up to higher energy levels. All objects absorb and emit radiation. When the absorption of energy balances the emission of energy, the temperature of an object stays constant. If the absorption of energy is greater than the emission of energy, the temperature of an object rises. If the absorption of energy is less than the emission of energy, the temperature of an object falls.