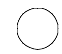
PhyzGuide: Convection

Do you know why you wear a jacket when it's cold outside? Or why you cover yourself with blankets when you sleep? Or why there is wind?

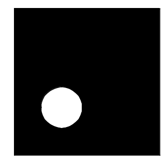
HEATING A FLUID

Consider a hot object in a vacuum. Since there's nothing around it, it cannot transfer thermal energy to anything else by *conduction*. It can undergo *radiation*, but that's a story for another day. For today's story, we will surround the hot object with a fluid. (Remember, a fluid is anything that can flow—gases as well as liquids.)



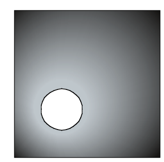
A hot object in a vacuum.

By conduction, the hot object heats the surrounding fluid. If our hot object and surrounding fluid were in a weightless environment, further conduction would eventually heat the rest of the fluid. But we are not in a weightless environment.



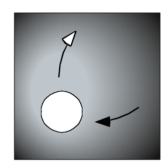
A hot object surrounded by a cooler fluid.

As the fluid's temperature increases, it expands. But the fluid closest to the heat source warms up first. So that fluid expands while the fluid farther out remains unchanged. The expanded fluid is less dense than the fluid around it, so it experiences an upward buoyant force.



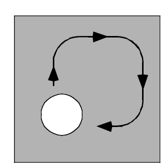
Fluid near the hot object warms and expands.

As the warmed fluid flows upward, cooler fluid moves in to take its place. This brings the cooler fluid into contact with the hot object. So more fluid is heated and more fluid rises. This process can continue until all the fluid is heated. The process by which heat is transferred by currents (gross motion) of particles in an unevenly heated fluid is called **convection.** Unlike conduction (in which heat is transferred by successive collisions between neighboring particles) and radiation (in which heat is transferred by means of electromagnetic waves), convection involves the motion of mass: specifically, the overall motion of particles in the fluid. Convection is also distinct in that it is driven by gravitational force: you could not use a candle to warm the cabin of an orbiting space shuttle.



Expanded fluid rises; cooler fluid takes its place.

AS THE FLUID HEATS UP, WHAT COOLS DOWN?



Circulation warms the whole volume of the fluid.

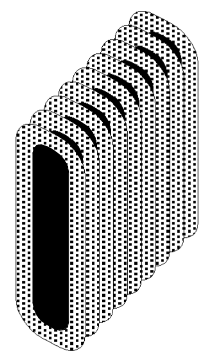
Let's not forget our original hot object. What effect did the convection have on it? As the fluid warmed up, the hot object cooled down. Convection can be seen as a means by which a hot object is cooled by a fluid.

Now suppose that your warm body is placed out in the cold air. You'll warm the air and the air will cool you by conduction. Then convection will cause the newly warmed air to rise and new cool air to surround you. You would then lose energy to heat that air, causing it to rise and to be replaced by a fresh supply of cool air.

If you were wearing a jacket, you'd have insulation that would allow the outside of the jacket to be close to the outdoor temperature and the inside of the jacket to be close to your body temperature. This would reduce conduction and that would reduce subsequent convection.

MISNOMER: THE RADIATOR

Devices known as radiators are used to warm rooms and cool car engines. Car engines generate a great deal of internal energy—engines get very hot. Typically, a fluid is passed near the hottest parts and then pumped to the radiator. The radiator is a metal reservoir near the front of the engine compartment. Cool air blows past the radiator and picks up heat by conduction as it passes by. It is by this conduction, not radiation, that the fluid in the reservoir is cooled. This type of "radiator" might better be called a conductor.



A room-heating radiator is a large set of metal pipes through which steam or hot water is passed. The pipes become hot and serve as a heat source that drives convection currents in the room. Radiators are often painted with shiny metallic paint which, by reducing radiation, ensures the radiator will maintain a high temperature and thereby continue to drive convection. This type of "radiator" might better be called a "convector."

WHAT ABOUT THE WEATHER?

As radiant energy from the sun strikes the Earth, different parts of the Earth heat up at different rates. Land masses heat up faster than water. So the Earth heats up unevenly. Air in the atmosphere is then warmed unevenly at the surface, and convection patterns arise. Areas of high pressure, low pressure, winds, and the water cycle are all driven—to some extent—by convection.