**Heat transfer**

is the exchange of [thermal energy](https://en.wikipedia.org/wiki/Thermal_energy) between physical systems. The rate of [heat](https://en.wikipedia.org/wiki/Heat) transfer is dependent on the temperatures of the systems and the properties of the intervening medium through which the heat is transferred. The three fundamental modes of heat transfer are [*conduction*](https://en.wikipedia.org/wiki/Thermal_conduction), [*convection*](https://en.wikipedia.org/wiki/Convection) and [*radiation*](https://en.wikipedia.org/wiki/Radiation). Heat transfer, the flow of energy in the form of heat, is a process by which a system's [internal energy](https://en.wikipedia.org/wiki/Internal_energy) is changed, hence is of vital use in applications of the [First Law of Thermodynamics](https://en.wikipedia.org/wiki/First_Law_of_Thermodynamics). Conduction is also known as diffusion, not to be confused with [diffusion](https://en.wikipedia.org/wiki/Diffusion) related to the mixing of constituents of a fluid.

The direction of heat transfer is from a region of high temperature to another region of lower temperature, and is governed by the [Second Law of Thermodynamics](https://en.wikipedia.org/wiki/Second_Law_of_Thermodynamics). Heat transfer changes the [internal energy](https://en.wikipedia.org/wiki/Internal_energy) of the systems from which and to which the energy is transferred. Heat transfer will occur in a direction that increases the [entropy](https://en.wikipedia.org/wiki/Entropy) of the collection of systems.

Heat transfer ceases when [thermal equilibrium](https://en.wikipedia.org/wiki/Thermal_equilibrium) is reached, at which point all involved bodies and the surroundings reach the same temperature.

The fundamental modes of heat transfer are:

1. Conductivity
2. Convection ( free & forced )
3. Radiation

**Thermal conduction**

is the transfer of heat ([internal energy](https://en.wikipedia.org/wiki/Internal_energy)) by microscopic collisions of particles and movement of electrons within a body. The microscopically colliding objects, that include molecules, atoms, and electrons, transfer disorganized microscopic kinetic and potential energy, jointly known as internal energy. Conduction takes place in all phases of [matter](https://en.wikipedia.org/wiki/Matter), such as solids, liquids, gases and plasmas. The rate at which energy is conducted as heat between two bodies is a function of the temperature difference ([temperature gradient](https://en.wikipedia.org/wiki/Temperature_gradient)) between the two bodies and the properties of the conductive medium through which the heat is transferred. Thermal conduction was originally called diffusion.

Heat spontaneously flows from a hotter to a colder body. For example, heat is conducted from the hotplate of an electric stove to the bottom of a saucepan in contact with it. In the absence of an external driving energy source to the contrary, within a body or between bodies, [temperature](https://en.wikipedia.org/wiki/Temperature) differences decay over time, and [thermal equilibrium](https://en.wikipedia.org/wiki/Thermal_equilibrium) is approached, temperature becoming more uniform.

In conduction, the heat flow is within and through the body itself. In contrast, in heat transfer by [thermal radiation](https://en.wikipedia.org/wiki/Thermal_radiation), the transfer is often between bodies, which may be separated spatially. Also possible is transfer of heat by a combination of conduction and thermal radiation. In convection, internal energy is carried between bodies by a moving material carrier. In solids, conduction is mediated by the combination of vibrations and collisions of molecules, of propagation and collisions of [phonons](https://en.wikipedia.org/wiki/Phonons), and of diffusion and collisions of [free electrons](https://en.wikipedia.org/wiki/Free_electron_model). In gases and liquids, conduction is due to the collisions and [diffusion](https://en.wikipedia.org/wiki/Molecular_diffusion) of molecules during their random motion. [Photons](https://en.wikipedia.org/wiki/Photons) in this context do not collide with one another, and so heat transport by [electromagnetic radiation](https://en.wikipedia.org/wiki/Electromagnetic_radiation) is conceptually distinct from heat conduction by microscopic diffusion and collisions of material particles and phonons. But the distinction is often not easily observed, unless the material is semi-transparent.

In the engineering sciences, heat transfer includes the processes of [thermal radiation](https://en.wikipedia.org/wiki/Thermal_radiation), [convection](https://en.wikipedia.org/wiki/Convection), and sometimes mass transfer. Usually, more than one of these processes occurs in a given situation. The conventional symbol for the material property, [thermal conductivity](https://en.wikipedia.org/wiki/Thermal_conductivity), is K

The inter-molecular transfer of energy could be primarily by elastic impact, as in fluids, or by free electron diffusion, as in metals, or [phonon vibration](https://en.wikipedia.org/wiki/Phonon), as in insulators. In [insulators](https://en.wikipedia.org/wiki/Thermal_insulation), the heat flux is carried almost entirely by [phonon](https://en.wikipedia.org/wiki/Phonon) vibrations.

Metals (e.g., copper, platinum, gold, etc.) are usually good [conductors](https://en.wikipedia.org/wiki/Heat_conduction) of thermal energy. This is due to the way that metals bond chemically: [metallic bonds](https://en.wikipedia.org/wiki/Metallic_bond) (as opposed to [covalent](https://en.wikipedia.org/wiki/Covalent_bonds) or [ionic bonds](https://en.wikipedia.org/wiki/Ionic_bonds)) have free-moving electrons that transfer thermal energy rapidly through the metal. The *electron fluid* of a [conductive](https://en.wikipedia.org/wiki/Electrical_conductor) metallic solid conducts most of the heat flux through the solid. Phonon flux is still present, but carries less of the energy. Electrons also conduct [electric current](https://en.wikipedia.org/wiki/Electric_current) through conductive solids, and the [thermal](https://en.wikipedia.org/wiki/Thermal_conductivity) and [electrical conductivities](https://en.wikipedia.org/wiki/Electrical_conductivity) of most metals have about the same ratio. A good electrical conductor, such as [copper](https://en.wikipedia.org/wiki/Copper), also conducts heat well. [Thermoelectricity](https://en.wikipedia.org/wiki/Thermoelectricity) is caused by

interaction of heat flux and electric current. Heat conduction within a solid is directly analogous to [diffusion](https://en.wikipedia.org/wiki/Diffusion) of particles within a fluid, in the situation where there are no fluid currents.

To quantify the ease with which a particular medium conducts, engineers employ the [thermal conductivity](https://en.wikipedia.org/wiki/Thermal_conductivity), also known as the conductivity constant or conduction coefficient, *k*. In [thermal conductivity](https://en.wikipedia.org/wiki/Thermal_conductivity), *k* is defined as "the quantity of heat, *Q*, transmitted in time (*t*) through a thickness (*L*), in a direction normal to a surface of area (*A*), due to a temperature difference (Δ*T*) [...]". Thermal conductivity is a material [*property*](https://en.wikipedia.org/wiki/Physical_property) that is primarily dependent on the medium's [phase](https://en.wikipedia.org/wiki/List_of_phases_of_matter), temperature, density, and molecular bonding. [Thermal effusivity](https://en.wikipedia.org/wiki/Thermal_effusivity) is a quantity derived from conductivity, which is a measure of its ability to exchange thermal energy with its surroundings.

**Steady-state conduction**

Steady state conduction is the form of conduction that happens when the temperature difference(s) driving the conduction are constant, so that (after an equilibration time), the spatial distribution of temperatures (temperature field) in the conducting object does not change any further. Thus, all partial derivatives of temperature *with respect to space* may either be zero or have nonzero values, but all derivatives of temperature at any point *with respect to time* are uniformly zero. In steady state conduction, the amount of heat entering any region of an object is equal to amount of heat coming out (if this were not so, the temperature would be rising or falling, as thermal energy was tapped or trapped in a region).

## k {\displaystyle k} .Fourier's law

The law of heat conduction, also known as [Fourier](https://en.wikipedia.org/wiki/Joseph_Fourier)'s law, states that the time rate of [heat transfer](https://en.wikipedia.org/wiki/Heat_transfer) through a material is [proportional](https://en.wikipedia.org/wiki/Proportionality_%28mathematics%29) to the negative [gradient](https://en.wikipedia.org/wiki/Gradient) in the temperature and to the area, at right angles to that gradient, through which the heat flows. We can state this law in two equivalent forms: the integral form, in which we look at the amount of energy flowing into or out of a body as a whole, and the differential form, in which we look at the flow rates or [fluxes](https://en.wikipedia.org/wiki/Heat_flux) of energy locally.

[Newton's law of cooling](https://en.wikipedia.org/wiki/Newton%27s_law_of_cooling) is a discrete analog of Fourier's law, while [Ohm's law](https://en.wikipedia.org/wiki/Ohm%27s_law) is the electrical analogue of Fourier's law.

The thermal conductivity, k {\displaystyle k} , is often treated as a constant, though this is not always true. While the thermal conductivity of a material generally varies with temperature, the variation can be small over a significant range of temperatures for some common materials. In [anisotropic](https://en.wikipedia.org/wiki/Anisotropy) materials, the thermal conductivity typically varies with orientation; in this case k {\displaystyle k} is represented by a second-order [tensor](https://en.wikipedia.org/wiki/Tensor). In non-uniform materials, k {\displaystyle k} varies with spatial location.

For many simple applications, Fourier's law is used in its one-dimensional form. In the *x*-direction,

q x = − k d T d x {\displaystyle q\_{x}=-k{\frac {dT}{dx}}}

**Convecti**on

is the transfer of heat from one place to another by the [movement of fluids](https://en.wikipedia.org/wiki/Advection). Convection is usually the dominant form of heat transfer in liquids and gases. Although often discussed as a distinct method of heat transfer, convective heat transfer involves the combined processes of unknown [conduction](https://en.wikipedia.org/wiki/Conduction_%28heat%29) (heat diffusion) and [advection](https://en.wikipedia.org/wiki/Advection) (heat transfer by bulk [fluid flow](https://en.wikipedia.org/wiki/Fluid_flow)).

Convection can be "forced" by movement of a fluid by means other than buoyancy forces (for example, a water pump in an automobile engine). Thermal expansion of fluids may also force convection. In other cases, natural buoyancy forces alone are entirely responsible for fluid motion when the fluid is heated, and this process is called "natural convection". An example is the draft in a chimney or around any fire. In natural convection, an increase in temperature produces a reduction in density, which in turn causes fluid motion due to pressures and forces when fluids of different densities are affected by [gravity](https://en.wikipedia.org/wiki/Gravity) (or any [g-force](https://en.wikipedia.org/wiki/G-force)). For example, when water is heated on a [stove](https://en.wikipedia.org/wiki/Stove), hot water from the bottom of the pan rises, displacing the colder denser liquid, which falls. After heating has stopped, mixing and conduction from this natural convection eventually result in a nearly homogeneous density, and even temperature. Without the presence of gravity (or conditions that cause a g-force of any type), natural convection does not occur, and only forced-convection modes operate.

The convection heat transfer mode comprises one mechanism. In addition to energy transfer due to specific molecular motion ([diffusion](https://en.wikipedia.org/wiki/Diffusion)), energy is transferred by bulk, or [macroscopic](https://en.wikipedia.org/wiki/Macroscopic), motion of the fluid. This motion is associated with the fact that, at any instant, large numbers of molecules are moving collectively or as aggregates. Such motion, in the presence of a temperature gradient, contributes to heat transfer. Because the molecules in aggregate retain their random motion, the total heat transfer is then due to the superposition of energy transport by random motion of the [molecules](https://en.wikipedia.org/wiki/Molecules) and by the bulk motion of the fluid. It is customary to use the term convection when referring to this cumulative transport and the term advection when referring to the transport due to bulk fluid motion.

## Convective heat transfer

The basic relationship for heat transfer by convection is:

Q ˙ = h A ( T a − T b ) {\displaystyle {\dot {Q}}=hA(T\_{a}-T\_{b})} 

Where  Q ˙ {\displaystyle {\dot {Q}}} is the heat transferred per unit time, *A* is the area of the object, *h* is the [heat transfer coefficient](https://en.wikipedia.org/wiki/Heat_transfer_coefficient), *Ta* is the object's surface temperature and *Tb* is the fluid temperature.

The convective heat transfer coefficient is dependent upon the physical properties of the fluid and the physical situation. Values of *h* have been measured and tabulated for commonly encountered fluids and flow of situations.

**Thermal radiation** is [electromagnetic radiation](https://en.wikipedia.org/wiki/Electromagnetic_radiation) generated by the [thermal motion](https://en.wikipedia.org/wiki/Thermal_motion) of [charged particles](https://en.wikipedia.org/wiki/Charged_particles) in [matter](https://en.wikipedia.org/wiki/Matter). All matter with a [temperature](https://en.wikipedia.org/wiki/Temperature) greater than [absolute zero](https://en.wikipedia.org/wiki/Absolute_zero) emits thermal radiation. When the temperature of a body is greater than absolute zero, inter-atomic collisions cause the [kinetic energy](https://en.wikipedia.org/wiki/Kinetic_energy) of the atoms or molecules to change. This results in charge-acceleration and/or dipole oscillation which produces electromagnetic radiation, and the wide spectrum of radiation reflects the wide spectrum of energies and accelerations that occur even at a single temperature.

Examples of thermal radiation include the [visible light](https://en.wikipedia.org/wiki/Visible_light) and [infrared light](https://en.wikipedia.org/wiki/Infrared_light) emitted by an [incandescent light bulb](https://en.wikipedia.org/wiki/Incandescent_light_bulb), the infrared radiation emitted by animals is detectable with an [infrared camera](https://en.wikipedia.org/wiki/Infrared_camera), and the [cosmic microwave background radiation](https://en.wikipedia.org/wiki/Cosmic_microwave_background_radiation). Thermal radiation is different from [thermal convection](https://en.wikipedia.org/wiki/Thermal_convection) and [thermal conduction](https://en.wikipedia.org/wiki/Thermal_conduction)—a person near a raging bonfire feels [radiant heating](https://en.wikipedia.org/wiki/Radiant_heating) from the fire, even if the surrounding air is very cold.

[Sunlight](https://en.wikipedia.org/wiki/Sunlight) is part of thermal radiation generated by the hot [plasma](https://en.wikipedia.org/wiki/Plasma_%28physics%29) of the [Sun](https://en.wikipedia.org/wiki/Sun). The [Earth](https://en.wikipedia.org/wiki/Earth) also emits thermal radiation, but at a much lower [intensity](https://en.wikipedia.org/wiki/Intensity_%28physics%29) and different [spectral distribution](https://en.wikipedia.org/wiki/Electromagnetic_spectrum) (infrared rather than [visible](https://en.wikipedia.org/wiki/Visible_light)) because it is cooler. The Earth's absorption of solar radiation, followed by its outgoing thermal radiation are the two most important processes that determine the temperature and climate of the Earth.

If a radiation-emitting object meets the physical characteristics of a [black body](https://en.wikipedia.org/wiki/Black_body) in [thermodynamic equilibrium](https://en.wikipedia.org/wiki/Thermodynamic_equilibrium), the radiation is called blackbody radiation.[[1]](https://en.wikipedia.org/wiki/Thermal_radiation#cite_note-1) [Planck's law](https://en.wikipedia.org/wiki/Planck%27s_law) describes the spectrum of blackbody radiation, which depends only on the object's temperature. [Wien's displacement law](https://en.wikipedia.org/wiki/Wien%27s_displacement_law) determines the most likely frequency of the emitted radiation, and the [Stefan–Boltzmann law](https://en.wikipedia.org/wiki/Stefan%E2%80%93Boltzmann_law) gives the radiant intensity.[[2]](https://en.wikipedia.org/wiki/Thermal_radiation#cite_note-2)

Thermal radiation is one of the fundamental mechanisms of [heat transfer](https://en.wikipedia.org/wiki/Heat_transfer).