

Definition of heat transfer

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DEFINITION OF HEAT TRANSFER | Heat transfer is energy in transit due to temperature difference . Whenever there exists a temperature difference in a medium or between media, heat transfer must occur. The basic requirement for heat transfer is the presence of temperature difference . There can be no net heat transfer between two mediums that are at the same temperature. The temperature difference is the driving force for heat transfer, just as the voltage difference is the driving force for electric current flow and pressure difference is the driving force for fluid flow. The rate of heat transfer in a certain direction depends on the magnitude of the temperature gradient (the temperature difference per unit length or the rate of change of temperature) in that direction. The larger the temperature gradient, the higher the rate of heat transfer | **PHYSICAL ORIGINS AND RATE EQUATIONS:** It is important to understand the physical mechanisms which underlie the heat transfer modes and that we are able to use the rate equations that quantify the amount of energy being transferred per unit time. **Conduction:** Conduction can be imagined as a atomic or molecular activity which involves the transfer of energy from the more energetic to the less energetic particles of a substance due to interactions between the particles. | **Explanation:** The physical mechanism of conduction is explained as follows: Consider a gas in which there exists a temperature gradient and assume that there is no bulk motion. The gas may occupy the space between two surfaces that are maintained at different temperatures, as shown in Figure 1. 2. The temperature at any point is associated with the energy of gas molecules in proximity to the point. This energy is related to the random translational motion, as well as to the internal rotational and

vibrational motions, of the molecules. | Higher temperatures are associated with higher molecular energies, and when neighboring molecules collide, as they are constantly doing, a transfer of energy from the more energetic to the less energetic molecules must occur. In the presence of the temperature gradient, energy transfer by conduction must then occur in the direction of decreasing temperature. This transfer is evident in the Figure 1. 2. The hypothetical plane at x_0 is constantly being crossed by molecules from above and below due to their random motion. However, molecules from above are associated with a larger temperature than those from below, in which case there must be a net transfer of energy in the positive x - direction. Hence, the net transfer of energy by random molecular motion may be thought of as diffusion of energy. It is possible to quantify heat transfer processes in terms of appropriate rate equations. These equations may be used to compute the amount of energy being transferred per unit time. The rate equation for heat conduction is known as Fourier's Law. The rate equation for the one dimensional plane wall shown in Figure below, having a temperature distribution $T(x)$ is given by | (1. 1) | The heat flux (W/m^2) is the heat transfer rate in the x -direction per unit area perpendicular to the direction of transfer, and it is proportional to the the temperature gradient, dT/dx , in this direction. The proportionality constant k is a transport property known as the thermal conductivity ($W/m. K$) and is a characteristic of the wall material. The minus sign is a consequence of the fact that the heat is transferred in the direction of decreasing temperature. Under the steady state conditions shown in Figure 1. 3, where the temperature distribution is linear, the temperature gradient may be expressed as | (1. 2) | and the heat

flux then | (1. 3) | or | (1. 4) | This equation provides a heat flux , that is, the rate of heat transfer per unit area. The heat rate by conduction $q_x(W)$, through a plane wall of area A is then the product of the flux and the area $q_x = \dot{Q} / A$. Convection takes place when energy is transferred from a surface to a fluid flowing over it as a result of a difference between the temperatures of the surface and the fluid. Convection heat transfer mode is comprised of two mechanisms * Energy transfer due to random molecular motion (diffusion) * Energy transferred by the bulk or macroscopic motion of the fluid (advection) This fluid motion is associated with the aggregate or collective movement of the large number of molecules. Such motion, in the presence of temperature gradient, contributes to the heat transfer. Because the molecules in the aggregate retain their random motion, the total heat transfer is then due to a superposition of energy transport by the random motion of the molecules and by the bulk motion of the fluid. Convection heat transfer may be classified according to the nature of the flow. * Forced convection takes place when the flow is caused by an external agent such as fan, pump or atmospheric winds. For example, consider the use of a fan to provide forced convection air cooling of hot electrical components on a stack of printed circuit boards. * Natural convection takes place when the flow is induced by density differences caused by the temperature variations in the fluid. For example, consider heat transfer that occurs from hot components on a vertical array of circuit boards in still air. * The rate equation for convection is known as Newton's law of cooling. This is given by | (1. 5) | * q'' is the convective heat flux (W/m^2). Convective heat flux is proportional to the difference between the surface and temperatures, T_s and T_f , respectively.

The proportionality constant is termed the convection heat transfer coefficient. It depends on the surface geometry, the nature of the fluid motion, and the fluid involved. Any study of convection ultimately reduces to a study of the means by which h may be determined. Although consideration of these means is postponed to Chapter 6, convection heat transfer will frequently appear as a boundary condition in the solution of conduction problems. In the solution of such problems we presume h to be known, using typical values given in Table.

* RADIATION: * Thermal radiation is energy emitted by matter that is at a finite temperature. Radiation occurs not only from solid surfaces but also from liquids and gases. Regardless of the form of the matter, the emission may be attributed to changes in the electron configurations of the constituent atoms or molecules. The energy of the radiation field is transported by electromagnetic waves. While the transfer of energy by conduction and convection requires the presence of a material medium, radiation does not. In fact, radiation transfer occurs most efficiently in a vacuum.

* Consider radiation transfer processes for the surface of Figure. 1. 4. Radiation that is emitted by the surface originates from the thermal energy of matter bounded by the surface, and the rate at which the energy is released per unit area (W/m^2) is termed the surface emissive power E .

* There is an upper limit to the emissive power, which is prescribed by the Stefan-Boltzmann law | (1. 6) | * where T_s is the absolute temperature (K) of the surface and is the Stefan-Boltzmann constant ($= 5.67 \times 10^{-8} W/m^2K^4$). Such a surface is called an ideal radiator or black body. *