Topic: Heat and mass transfer

1.1 Conduction and convection

Synthesising information from different sources

- **Using information from all excerpts, write a paragraph of not more than 170 words discussing the most important features of conduction and convection.**

Remember that you need to:
- **Use information from all sources.**
- **Cite your sources appropriately.**
- **Use your own words! You must not plagiarise!**

Excerpt 1

At mention of the word *conduction*, we should immediately conjure up concepts of *atomic* and *molecular activity* because processes at these levels sustain this mode of heat transfer. Conduction may be viewed as the transfer of energy from the more energetic to the less energetic particles of a substance due to interactions between the particles.
The physical mechanism of conduction is most easily explained by considering a gas and using ideas familiar from thermodynamics. Consider a gas in which a temperature gradient exists, and assume that there is *no bulk, or macroscopic, motion.* The gas may occupy the space between two surfaces that are maintained at different temperatures. We associate the temperature at any point 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. 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 a temperature gradient, energy transfer by conduction must then occur in the direction of decreasing temperature. This would be true even in the absence of collisions. 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 higher temperature than those from below, in which case there must be a *net* transfer of energy in the positive x-direction. Collisions between molecules enhance this energy transfer. We may speak of the net transfer of energy by random molecular motion as a *diffusion* of energy.

Examples of conduction heat transfer are legion. The exposed end of a metal spoon suddenly immersed in a cup of hot coffee is eventually warmed due to the conduction of energy through the spoon. On a winter day, there is significant energy loss from a heated room to the outside air. This loss is principally due to conduction heat transfer through the wall that separates the room air from the outside air *(1, pp. 3-4)*.

Excerpt 2

The convection heat transfer *mode* is comprised of *two mechanisms.* In addition to energy transfer due to *random molecular motion* (*diffusion*), energy is also transferred by the *bulk*, or *macroscopic, motion* of the fluid. This fluid 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 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. The term *convection* is customarily used when referring to this cumulative transport, and the term *advection* refers to transport due to bulk fluid motion.

Convection heat transfer may be classified according to the nature of the flow. We speak of *forced convection* when the flow is caused by external means, such as by a fan, a pump, or atmospheric winds. As an example (1), consider the use of a fan to provide forced convection air cooling of hot electrical components on a stack of printed circuit boards. In contrast, for *free* (or *natural*) *convection*, the flow is induced by buoyancy forces, which are due to density differences caused by temperature variations in the fluid. An example (2) is the free convection heat transfer that occurs from hot components on a vertical array of circuit boards in air. Air that makes contact with the components experiences an increase in temperature and hence a reduction in density. Since it is now lighter than the surrounding air, buoyancy forces induce a vertical motion for which warm air ascending from the boards is replaced by an inflow of cooler ambient air *(1, pp. 6-8)*.

Excerpt 3

Heat transfer is commonly encountered in engineering systems and other aspects of life, and one does not need to go very far to see some application areas of heat transfer. In fact, one does not need to go anywhere. The human body is constantly rejecting heat to its surroundings, and human comfort is closely tied to the rate of this heat rejection. We try to control this heat transfer rate by adjusting our clothing to the environmental conditions.

Many ordinary household appliances are designed, in whole or in part, by using the principles of heat transfer. Some examples include the electric or gas range, the heating and air-conditioning system, the refrigerator and freezer, the water heater, the iron, and even the computer, the TV, and the VCR. Of course, energy-efficient homes are designed on the basis of minimizing heat loss in winter and heat gain in summer. Heat transfer plays a major role in the design of many other devices, such as car radiators, solar collectors, various components of power plants, and even spacecraft. The optimal insulation thickness in the walls and roofs of the houses, on hot water or steam pipes, or on water heaters is again determined on the basis of a heat transfer analysis with economic consideration. [2, p. 3]

Excerpt 4

The interaction of conduction and convection is a relatively poorly explored subject, and no references dealing with the problem treated in this paper were found during the search of the literature. Two related studies, however, should be mentioned. Sidorov [l], by assuming that the fluid has everywhere the temperature of the outer boundary of the thermal boundary layer, estimated the contribution of radiation and then solved the energy equation for flow of a radiating fluid along a flat plate in a very approximate manner. Kadanoff [2] treats the transport of energy in an ablating body which absorbs, emits, and scatters thermal radiation. He used the integrated form of the equation of transfer, known as the Milne-Eddington approximation, to simplify the energy equation. A book by Konakov, et al. [3] reviews radiant heat-transfer studies related to furnaces and combustion chambers. [3, p. 318]

References

1. Bergman, T. L.; Lavine, A. S.; Incropera, F. P.; Dewitt, D. P. *Introduction to Heat Transfer*, (6th ed.); Wiley: New York, 2011.

2. Çengel, Y. A. *Heat Transfer: A Practical Approach;* McGraw-Hill: Boston, Mass, 1998.

3. Viskanta, R. Interaction of Heat Transfer by Conduction, Convection, and Radiation in a Radiating Fluid *J. Heat Transfer*, **1963,** *85*(4), 318-328.