Part Two

Principles

The purpose of this Part of the text is to present the principles of heat transfer. Although a host of principles are introduced, the primary focus will be on the three heat transfer mechanisms: conduction, convection, and radiation. A brief description of these mechanisms is given in the next paragraph.

A difference in temperature between two bodies in close proximity, or between two parts of the same body, results in a flow of heat from the higher temperature to the lower temperature. There are three different mechanisms by which this heat transfer can occur: the aforementioned conduction, convection, and radiation. When heat transfer is the result of molecular motion (e.g., the vibrational energy of molecules in a solid being passed along from molecule to molecule), the mechanism of transfer is *conduction*. An example is the conduction of heat through the brick wall of a furnace. When the heat transfer results from macroscopic motion, such as currents in a fluid, the mechanism is *convection*. An example is the flow of heat when hot air flows across a bank of cold tubes. If fluid flow is the result of the temperature difference in the fluid (which causes buoyancy currents), the solid-to-fluid heat transfer is termed *free* or *natural* convection. If a mechanical device (e.g., fan, pump, or compressor) causes the motion of the fluid, it is termed *forced* convection. The rate of heat transfer is proportional to the temperature difference in both conduction and convection. When heat is transferred by electromagnetic waves, the mechanism is *radiation*. Radiation may be transmitted, reflected, or absorbed, depending upon the medium and the receiving surface. A transmittance example is the incidence of solar radiation on glass. Most of the solar energy is transmitted through glass as electromagnetic waves. Generally, radiation becomes important only at high temperatures.

Summarizing, heat is the transfer of energy occurring as a result of a driving force referred to as a temperature difference. There are three mechanisms by which heat transfer can occur:

1. Conduction—Heat is transferred by the energy of motion between adjacent molecules.
2. Convection—Heat is transferred due to both motion and mixing of macroscopic elements of materials. Because the motion of a fluid is involved, heat transfer by convection is partially governed by the laws of fluid mechanics. If convection is induced by a density difference which arises due to temperature differences, then the mechanism is referred to as natural or free convection.

If convection occurs due to an external force (e.g., pump or fan), the mechanism is defined as forced convection.

3. Radiation—This mechanism transfers energy by electromagnetic radiation or photons having a certain range of wavelength. Although energy can be transferred by radiation through gases, liquids, and solids, these media absorb some or all of the energy. Therefore, energy is radiated most efficiently through empty space. The most obvious example of the radiation mechanism is the transport of heat from the Sun to the Earth; the contributions from conduction and convection are obviously negligible because of the distance separating the two.

The remainder of this part deals with heat transfer principles and fundamentals. Chapter topics include:

Steady-State Heat Conduction: Chapter 7

Unsteady-State Heat Conduction: Chapter 8

Forced Convection: Chapter 9

Free Convection: Chapter 10

Radiation: Chapter 11

Condensation and Boiling: Chapter 12

Refrigeration and Cryogenics: Chapter 13

The reader should note that sections detailing the microscopic approach are included within the first three chapters (i.e., steady-state conduction, unsteady-state conduction, and forced convection). This will complement the presentation for some. However, this material can be bypassed, particularly by those not interested or concerned with a more theoretical treatment of these topics.