Heat and Thermodynamics - Course PI 25

MECHANISMS OF HEAT TRANSFER

Objectives

1. Briefly explain heat transfer by:

   (a) conduction
   (b) natural convection
   (c) forced convection
   (d) radiation.

2. State the factors that affect the rate of heat transfer by each mechanism from (1).

3. Briefly describe two examples of each mechanism from (1) in a CANDU generating station.

In this module you will be considering the four mechanisms by which heat can be transferred: conduction, convection - both natural and forced, and radiation. It is by combinations of these mechanisms that electricity generation in a CANDU station is made possible.

Conduction

Heat transfer by conduction involves the movement of heat energy without a net mass movement. In effect, heat is passed through a substance from one molecule to the next with no overall movement of the substance from one place to another.

There are four factors that affect the rate of conduction:

(1) The type of substance involved. Since the structures of different substances are different, heat energy will be passed through these substances with varying degrees of difficulty. This effect is expressed by the thermal conductivity.

(2) The surface area of the substance that is conducting heat. As area increases, so does rate of conduction.

(3) The temperature difference across the substance. Heat will be transferred through the substance as long as there is a high temperature source on one side of the substance and a low temperature sink on the other side. The larger the temperature difference, the higher is the rate of conduction.

(4) The thickness of the substance. As the distance between the high temperature side and the low temperature side increases, the rate of conduction decreases.

Thermal conductivity of substance is normally expressed in watts conducted per square meter of surface per metre thickness per degree Celsius temperature difference.

⟶ Answer questions 5.1 and 5.2 in the space provided, then check your answers with those in the "TEXT ANSWERS".

5.1) Briefly explain heat transfer by conduction.

5.2) State the factors that affect the rate of conduction.

——► Answer question 5.3 in the space provided before you proceed. Discuss your answer with someone else in the class or with the course manager.

5.3) Briefly describe two examples of conduction in a CANDU station.

Convection

Heat transfer by convection is heat transfer due to movement of a fluid. Typically, the fluid gains heat as it flows past a higher temperature surface. The fluid then transports the heat from the surface as it flows.

Convection is divided into two types: natural and forced.

Natural Convection

In natural convection, the flow of fluid is accomplished by density differences that occur as the heat is transferred. As the fluid is heated, it expands and becomes less dense. Under the influence of gravity this less dense fluid will rise and be replaced by cooler, more dense fluid. A flow is set up which transfers heat as the flow occurs.

There are three factors that influence the rate of heat transfer by natural convection:

(1) The area of the surface in contact with the fluid. As this area increases, so does the rate of convection.

(2) The temperature difference between the surface and the fluid. As this difference increases, the rate of heat transfer increases.

(3) A heat transfer coefficient that expresses specific conditions associated with the substances in the system. Examples of the conditions expressed are: amount of turbulence in fluid, conductivity of the fluid, fluid density, slope of the surface, fluid viscosity, etc. As the coefficient increases, so does the rate of heat transfer.

——→ Answer the following questions in the space provided. Check your answers for questions 5.4 and 5.5 with those in the "TEXT ANSWERS". For question 5.6, discuss your answer with someone else in the class or with the course manager before you continue.

5.4) Briefly explain heat transfer by natural convection.

5.5) State the factors that affect the rate of heat transfer by natural convection.

5.6) Briefly describe two examples of natural convection in a CANDU station.

Forced Convection

Forced convection involves fluid movement due to external means. The fluid flow is usually accomplished using a mechanical device such as a pump, fan, blower, or compressor.

The factors that influence the rate of heat transfer by forced convection are the same as those you considered in natural convection: surface area, temperature differential, and heat transfer coefficient.

5.7) Briefly describe heat transfer by forced convection.

5.8) State the factors that affect the rate of heat transfer by forced convection.

5.9) Briefly describe two examples of heat transfer by forced convection in a CANDU station.

——→ Answer the above questions in the space provided. Check your answers to the first two questions with those in the "TEXT ANSWERS". Discuss your answer to question 5.9 with someone else in your class or with the course manager before you proceed.

Radiation

Heat transfer by radiation can be described as emission of electromagnetic energy from a substance that is at a higher temperature than its surroundings. This energy usually is in the infrared part of the electromagnetic spectrum.

There are three factors that affect the rate of heat transfer by radiation:

1) The surface area presented by the emitting substance to the surroundings. The larger the surface area, the higher the rate of heat transfer by radiation.

2) The temperature differential between the substance and the surroundings. This differential is expressed by the difference between the fourth powers of the absolute temperatures of the substance and the surroundings. Note that as the temperature of the substance increases relative to the surroundings, the rate of heat transfer by radiation increases more and more quickly.

3) A property of the emitting substance called emissivity. The emissivity is influenced by such things as surface colour and smoothness. The higher the emissivity the greater the rate of heat transfer by radiation.

(Note that heat can not only be emitted but also be absorbed due to radiation.)

⟶ Answer questions 5.10, 5.11, and 5.12 in the space provided before you proceed. Check your answers for questions 5.10 and 5.11 with those in the "TEXT ANSWERS". Discuss your answer to question 5.12 with someone from your class or with the course manager.

5.10) Briefly explain heat transfer by radiation.

5.11) State the factors that affect the rate of heat transfer by radiation.

5.12) Briefly describe two examples of heat transfer by radiation in a CANDU station.

⟶ You have now completed module 5. If you feel confident you can answer the objectives, obtain a criterion test and complete it. If you feel you need more practice, go back and answer the assignment questions on separate paper. Check your answers with the "TEXT ANSWERS" and with your own corrected answers in the module.

PI 25-5 TEXT ANSWERS

5.1) Heat transfer by conduction is the transfer of heat energy from one particle to the next through a substance. There is no net movement of mass in conduction.

5.2) The factors that affect rate of conduction are:

(a) thermal conductivity (which expresses the type of substance)

(b) surface area of the conducting substance

(c) temperature difference between the hot and cool sides of the conducting substance

(d) thickness of the conducting substance.

5.3) Discuss your answer with the course manager.

5.4) Heat transfer by natural convection is heat transfer by fluid movement, where the fluid movement is due to density differences that occur as heat is tranferred.

5.5) The factors that influence the rate of heat transfer by natural convection are:

(a) surface area of the substance in contact with the fluid

(b) temperature difference between the surface and the fluid

(c) heat transfer coefficient (which is influenced by the conditions of the system).

5.6) Discuss your answer with the course manager.

5.7) Forced convection is a means of transferring heat by fluid movement, where the movement is caused by some external means. Examples of external means are pumps, fans, blowers and compressors.

PI 25-5 TEXT ANSWERS

5.8) The factors that affect the rate of heat transfer by forced convection are:

(a) surface area of the substance in contact with the fluid

(b) temperature difference between the surface and the fluid

(c) heat transfer coefficient (expressing the conditions of the system).

5.9 Discuss your answer with the course manager.

5.10 In heat transfer by radiation, the particles of a substance emit electromagnetic energy because they are at a higher temperature than their surroundings. This energy, usually in the infrared light range, transfers heat from the substance.

5.11) The factors which affect the rate of heat transfer by radiation are:

(a) surface area of the emitting substance

(b) temperature difference between the fourth power of the absolute temperature of the emitting substance and the fourth power of the absolute temperature of the surroundings

(c) emissivity of the surface of the emitting substance (expressing colour, texture, etc.).

5.12) Discuss your answer with the course manager.