Chapter 7
A Mesoscopic Analysis for Diffusion Transport Phenomena

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ABSTRACT

A mesoscopic study of linear irreversible transport phenomena is proposed. This chapter takes a phenomenological and statistical approach to non-equilibrium phenomena. At thermodynamic equilibrium, the intensive physical quantities of a system are uniform in space and time. These quantities can be defined at any point and at any time, and are referred to as local thermodynamic equilibrium. Otherwise, the system is out of thermodynamic equilibrium. This is the case for all irreversible phenomena, which are generally induced by an external input of energy and/or matter to the system. In this chapter, we will be focusing on the phenomenon of transport, which is a key process in non-equilibrium physics. There are various transport phenomena. Each is characterized by macroscopic properties. A microscopic approach is taken to study the transport phenomena. However, we are particularly interested in the phenomenon of particle diffusion and of the thermal diffusion.

1. INTRODUCTION

In the last years, understanding the transport phenomena become one of the most interesting issue for its physical significance of an advance in industrial technology.

Transport equations for heat and mass can be investigated on three scales. The first scale is the macroscopic scale for which partial differential equations (PDE) are used such as Navier-Stokes equation (N.S). These equations are hard to solve. In fact, due to the non-linearity terms and complex geometry, it is difficult to achieve the analytical solution. However, through computational fluid dynamic method, such

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as the finite volume method (FVM), the ordinate discrete method (ODM), the finite difference method (FDM), finite element method (FEM) and others, the PDE are changed to a system of algebraic equations that are solved by an iterative procedure until reaching the convergence of the results. The second scale is a microscopic scale. The microscopic equation of motion of particle is governed by the Hamilton's equation. Therefore, with systems of a great number of particles we have to identify the position and the velocity of every particle to describe the motion of the each single particle. This task is difficult so we have to use several variables in order to describe the system properties. To the contrary, mesoscopic scale is an association among the microscopic and macroscopic scales. The LBM is a statistical model. It is based on the mesoscopic approach that provides its origin from kinetic theory (Liao & Jen, 2011; Mohamad, 2011; Sukop, 2006; Wolf-Gladrow, 2004).

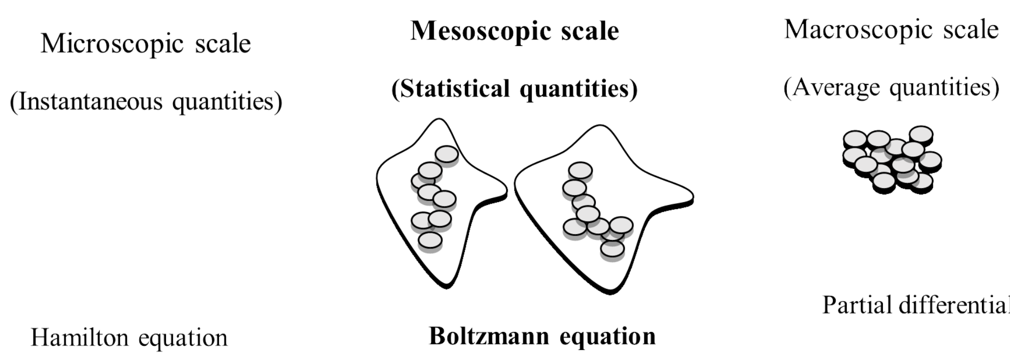
In the last years, several works have been developed in the LBM, the method has received prodigious attention as an alternative and enhancing numerical scheme for simulating complex fluid flows.

The property of the assembly of particles is described by a distribution function. For that reason, LBM it has recognized to be an efficient method for simulating complex flow and it is becoming more current in the field of the numerical conventional method.

In the present chapter, a statistical study of transport phenomenon particularly molecular mass transport phenomenon and thermal diffusion transport phenomenon is devoted for which the microscopic approach is used to evaluate macroscopic quantities. The breakdown of this chapter is as follows:

In sections 2 and 3, the physical background of diffusion involving a microscopic analysis of diffusion phenomenon is presented. Next, the fundamental of LBM is detailed in section 4. Section 5 is dedicated to the application of LBM to energy and mass transport equation solution by using LBM.

Figure 1. Microscopic, mesoscopic, and macroscopic scales of fluid flows



2. MASS TRANSPORT PHENOMENON: PARTICLE DIFFUSION IN PLASMA

Transport processes in plasma physics result from particle and energy transport. The first diffusion phenomenon corresponds to the movement of particles from higher density region to lower density region due to the internal energy of the plasma medium. Fick's law governs this phenomenon. The second is the convection phenomenon, which corresponds to the movement of particles into different regions of the plasma. This is due to the external forces applied to the system.

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