CHAPTER I

INTRODUCTION

The main purpose of this thesis is to study a quantum Brownian motion. Brownian motion phenomenon[7],[10]-[12] was significantly mentioned by an English botanist, Robert Brown in 1829. Having investigated a suspension of plant pollens dispersed in water through a microscope, he observed that a tiny particle executed an irregular fluctuating motion. Physical theories of this phenomenon was first considered by Einstein and Smoluchowski, and later further developed by Langevin and others. The important of this phenomenon comes from the reason that it is can serve as a prototype problem whose analysis provides considerable insight into the mechanisms responsible for the existence of fluctuation and dissipation of energy.

It is not only a classical particle like a plant pollen can behave as a Brownian motion but also quantum particles. In the case of quantum particles, the Feynman path integrals, the nonrelativistic quantum theory proposed by Feynman,[1],[2] is used to analyze the problem. The idea of Feynman path integrals is to sum or average the probability amplitudes from all possible paths. This sum is called propagator, the total transition probability. Feynman postulated that a contribution from each path to the total transition amplitude is equally in magnitudes but difference in phases. Each phase equals an classical action of that path in the unit of $\hbar$. Feynman path integrals is equivalently to the matrix mechanics of Heisenberg and wave mechanics of Schrödinger. Thus Feynman path integrals does not gives any new fundamental results. Some problem, however, can be solved more conveniently by using Feynman's method than the others.[1],[2],[4]-[9] For example, two non-relativistic quantum mechanical systems, say, A and B are coupled together. If we are interested in the system A but not in B then we can be eliminated all coordinates of system B from the equation of motion of the system A. The interaction with system B is represented by a change in the formula for the probability amplitude associate with a motion of system A. It is analogous to a classical situation in which the effect of system B can be represented by a change in the equation of motion of A by introduced the terms representing force acting on system A. Feynman extensively applied the techniques of this method to study problems in quantum electrodynamics. Thus, in a problem of several charge particles interacting with electromagnetic field, he found that it was possible to eliminate the coordinates of the field and recast the problem in terms of the coordinates of the particles alone. The effect of the field was included as a delayed interaction between the particles.

On the dynamics of dissipative quantum particle problems, the Feynman path integrals implies a compact and suggestive method to take account of fluctuation in dynamical processes. Feynman and Vernon had developed a theory the so-called of a general quantum system interacting with a linear dissipative system,[4] Feynman-Vernon theory, treating the problem based on the Feynman path integrals. The idea of the Feynman-Vernon theory comes from the reason that we wish to describe the behavior of the interesting system in terms of its parameters alone. On this idea one parted the whole system of the problem into the interesting system and the rest, the heat bath, which surrounds and can perturb the interesting system. This theory show that all parameters of the heat bath can be eliminated from the formula of the probability associated with the motion of the interesting system. All effects of the heat bath which influence on the system of interested are kept in a functional, the influence functional. The powerful influence functional can be analogous to a force term in a Newton equation of motion. However, the influence functional contain more information of interaction between the system of interested and the heat bath than the force term in the Newton equation. Because the force term does not contain exactly the effect from the motion of the interesting system to the heat bath, but the influence functional does. This effect is very important because it may be sent back to the interesting system in a later time.

In this thesis, we investigate a quantum system interacting with a linear dissipative system. We model the whole system in such a way that it has two parts, an interesting system and a heat bath. The interesting system composes of a particle, a Brownian particle, and the heat bath compose of a set of harmonic oscillators. Using this specific model, we can obtain the influence functional, the density matrix for the Brownian particle and the probability transition or the propagator of the density matrix. The result can cover to the classical Brownian motion, when we take the limit $\hbar$ go to zero.

This thesis will also contain the next five chapters as summaried as follows:

Chapter II Investigation on the Brownian Motion: This chapter is for surveying the theory of the classical Brownian motion and putting some notions before going to the quantum case.

Chapter III Feynman Path Integrals: We introduce the Feynman path integrals which is a powerful tool to describe the behavior of the quantum system. The basic concept of this theory will be discussed while we explore some of its properties. Also path integrals of statistical mechanics will be mentioned in this chapter.

Chapter IV Feynman-Vernon theory: This chapter shows how our problem may be formulated. We define an influence functional and explore some of its properties. We also show that any parameters of a heat bath can be eliminated and kept in this influence functional.

Chapter V Quantum Mechanical Model: We use the idea of an interesting system and a heat bath to describe our problem. Our problem is considered as a particle moving through some medium which is called a heat bath. We model our problem in a way that the heat bath is a set of harmonic oscillators. From this model, we can derive the density matrix of the particle and a propagator of the density matrix

Chapter VI Discussion and Conclusion