CHAPTER I. THE STATES OF AN ATOMIC SYSTEM

1. Preliminary Considerations

It is well established that many phenomena exhibited by atomic systems (where an atomic system may be an atom, a molecule or an aggregate of atoms forming a solid, a liquid, a gas, or a plasma) cannot be explained in terms of classical mechanics and classical electrodynamics. An important aspect of these phenomena is that some physical quantities are found to have only discrete (*i.e.*, quanta of) values. The branch of physics, which seeks to explain these atomic phenomena, is called quantum mechanics. In this monograph, we present the physical principles of quantum mechanics. This approach is, of course, nonrelativistic.

An atomic system consists of electrons and nuclei where nuclei themselves are composite entities consisting of protons and neutrons. Mass of an electron is about 10^{-27} g and that of a proton, as well as of a neutron, is about 10^{-24} g. Because of their small mass they are referred to as microscopic entities. It is experimentally well established that in the presence of electric and/or magnetic fields a free electron or a free proton moves in matter-free space in accordance with the laws of classical electrodynamics; similarly, it is well established that a free neutron falls under gravity in matter-free space in accordance with the laws of classical mechanics. From this we infer that (i) the basic interactions between these physical entities and the external (electromagnetic and gravitational) fields are the same as in classical physics, and (ii) only the laws of quantum mechanics which govern atomic phenomena are different from the laws of classical mechanics. Since a large aggregate of microscopic entities leads to a macroscopic entity, the laws of quantum mechanics should lead to the laws of classical mechanics in the appropriate limit. So we first consider the basic features of classical mechanics (or, more aptly, particle dynamics) that are necessary for developing the theory of quantum mechanics.

1.1. Dynamical States of a Classical Mechanical System

Let us consider a simple classical system consisting of a macroscopic entity of mass m_0 subjected to a force field. So far as the linear motion of the entity is concerned, we may identify the entity as a particle whose position is identical with the centre of mass of the entity and mass equal to the mass of the entity. Particle is a basic concept of physics. By definition a particle exists at only one point in space at any instant of time and the position of the particle is necessarily a finite, single-valued and continuous function of time. At an instant of time the particle (subjected to a force field) has well defined values of certain physical quantities such as velocity, momentum, kinetic energy, potential energy, total energy, etc. The sum total of all the quantities the system has at any instant of time is said to specify the “state” of the system at that instant; we refer to such a state as an “instantaneous state”. As time passes the position of the particle and the values of some of these quantities change continuously with time and the system evolves through a unique sequence of successive instantaneous states; we refer to such a unique sequence as a “dynamical state”.