CHAPTER I

INTRODUCTION

In classical electromagnetism, it is well known that the electric dipole moment (EDM) of a charge distribution $\rho(\mathbf{x})$ is defined by

$$\mathbf{d} = \int \mathbf{x}\rho(\mathbf{x})d^3x.$$

Therefore the EDM of a point charge located at the origin of the coordinate system vanishes identically. In quantum theory, however, it is possible for a point charge to have its "intrinsic" electric dipole moment if Nature violates time reversal (T) and parity (P) symmetries. To see how this is possible, we first note that the only vector quantity associated with a particle at rest is its spin. So if the particle were to have a non-vanishing EDM which is a vector quantity, its EDM must be proportional to its spin. Explicitly, for a particle with spin $\mathbf{S}$, its EDM can be written as

$$\mathbf{d} = d\frac{\mathbf{S}}{|\mathbf{S}|}.$$

Usually the coefficient d is referred to as the electric dipole moment instead of $\mathbf{d}$. That the presence of a nonzero d signifies the time reversal and parity violation was argued by Landau in 1957 [1]. The reason behind this is that $\mathbf{d}$ is even under T and odd under P, while the spin is odd under T and even under P. So for the above relation to hold, the coefficient d must change its sign under both T and P. As the quantum field theories describing elementary particle interactions generally respect CPT invariance, they will predict a non-vanishing EDM only if their P and CP symmetries are broken. In general, a fermion EDM is a quantum effect and arises only in the loop calculations.

In the Standard Model (SM) of elementary particles, the predictions for the lepton EDMs are extremely small and therefore unable to be observed by experiments in the near future. For example, the EDM of the electron is predicted to be of the order $10^{-38}e$ cm, while its current experimental limit is $d_e \leq 1.6 \times 10^{-27}e$ cm [2]. The supersymmetric extensions of the Standard Model with softly broken supersymmetry, however, contain more complex parameters responsible for CP violation than the SM. This makes possible for the fermion EDMs to be generated even at one-loop quantum corrections in the supersymmetric theories [3, 4, 5, 6, 7, 8, 9, 10, 11] and their values are within the reach of next generation experiments.

The purpose of this thesis is to review the prediction of lepton electric dipole moments from the supersymmetric theories. The organization of this thesis is as follows. In Chapter 2, we explore the Standard Model of particle physics and its source of CP violation. The supersymmetric extension of the SM known as the Minimal Supersymmetric Standard Model (MSSM) is discussed in Chapter 3. In Chapter 4, the EDM of the electron in the MSSM is calculated by performing one-loop calculations. Finally, the conclusion will be made in Chapter 5.