Chapter 10
Particle Physics – II

10.1 Basic Concepts and Formulae

Classification of particles
Table 10.1 gives the mass, mean lifetimes ($\tau$) and common decay modes of elementary particles excluding resonances. Their classification into hadrons, photon and leptons is also indicated. Further subdivision of hadrons into mesons (pions and kaons) and baryons (nucleons and hyperons) is also shown. Electron ($e^-$), muon ($\mu^-$), Tauon ($\tau^-$), and the three neutrinos $v_e$, $v_\mu$, and $v_\tau$ constitute the class of leptons. A hadron stands for a strongly interacting particle distinguished from lepton which has only weak or electromagnetic interactions. Photon is the massless carrier of the electromagnetic field.

In the fourth family, graviton a massless particle of spin 2, the quantum of gravitation is not yet discovered.

Mesons and photon are Bosons (a particle of integral spin, $0\hbar, 1\hbar, 2\hbar, \ldots$). Bosons obey Bose-Einstein statistics, the wave function describing two identical bosons is symmetric under particle exchange. The baryons and leptons are Fermions (a particle with half integral spin, $\frac{1}{2}\hbar, \frac{3}{2}\hbar, \ldots$). Fermions obey Fermi-Dirac statistics, for which the wave function of two identical particle is anti symmetric (changes sign under particle exchange).

Antiparticle: Every particle has in association an antiparticle, with exactly the same mass and lifetime but opposite values of electric charge, magnetic moment, baryon number, lepton number, and flavor. Thus positron ($e^+$) is the anti particle of electron ($e^-$), antiproton ($p^-$) that of proton ($p$), $\bar{v}_e$ that of $v_e$ etc. Photon is the antiparticle of itself, so also $\pi^0$.

Fundamental interactions
1. Strong (nuclear) interaction
2. Electromagnetic interaction
3. Weak (nuclear) interaction
4. Gravitational interaction.
Here we will be concerned with only the first three types. Table 10.2 summarizes the characteristics of the interactions.

**Coupling constant**: Particles interact through strong electromagnetic or weak charges. The square of the charge is known as the coupling constant. It enters the interaction matrix which determines the cross-sections and decay rates. Strictly speaking, the coupling constants are not constant but vary very gradually with the particle energy. They are called running constants.

**QED** (*quantum electrodynamics*) is the quantum field theory of the electromagnetic interaction whose predictions have been verified to a precision of one part in a billion.

**QCD** (*quantum chromodynamics*) is the field theory of the strong color interaction between quarks.