Chapter 5

Summary and Conclusions

In this concluding chapter, we summarize the work presented in this thesis. The objective of this study was to understand fermion mass hierarchy and the origin of quark mixing within the domain of the SM and the possible extensions of SM that are allowed phenomenologically. This thesis consists of two distinct but connected parts. The first part deals with quarks whereas the second part is devoted to neutrinos. The results are summarized below.

5.1 Studies related to quarks

We study the quark masses within the framework of the SM given the CKM quark mixing matrix to be symmetric. First it was shown that if the CKM matrix is symmetric then the top quark mass has to be heavier than 180 GeV, to be consistent with the experimental results of ϵ_K, the parameter describing the indirect CP violation in the interactions changing strangeness by two units ($\Delta S = 2$), and the measurement on B_d–$\overline{B_d}$ mixing parameter x_d (which gives the time-integrated probability of a $\overline{B_d}$ appearing in a B_d beam) for the Bag constant $B_K = 1, 2/3$; if the Bag constant $B_K = 1/3$ then $m_t > 275$ GeV. The parameters q and δ(CP violating phase) are constrained to be in the range

$$.113 \leq q \leq .130 \qquad 8.0^\circ \leq \delta \leq 31.1^\circ$$

for the symmetric CKM matrix over the allowed range of the top quark mass $80GeV \leq m_t \leq 270GeV$. To get a comparative idea it should be noted that accurate measurements, especially at LEP of the properties of Z^0, together with the collider and ν data yield an indirect value for m_t :

$$m_t = 164^{+16}_{-17} \ {}^{+18}_{-21} GeV.$$

Secondly, we address the important question of how to derive the symmetric quark mixing starting from the Yukawa couplings in a natural way. In this regard we tried to find the constraints on the quark mass matrices for the symmetric CKM matrix. The symmetry constraint was written as an equation involving the parameters of the mass matrices using flavour projection operators in a basis where M_u is diagonal. The numerical ranges for the mod elements of

M_d were given in this basis. This procedure was repeated in the basis where M_d is diagonal. Then, the necessary condition for having a symmetric V in terms of the matrices U and D was derived. A particularly interesting basis was chosen where $U = D^*P$; P being a phase matrix and the ranges for the mod elements of M_u, M_d in that basis was found out using a convenient parametrization for V. It was noticed that none of the off-diagonal elements of M_u and M_d is consistent with zero for a symmetric V, which means such forms for mass matrices cannot be obtained from any symmetry. But, in principle there exists infinite number of other bases related to each other by similarity transformations. So it is apparent that the numbers provided for the allowed ranges of the mod elements of mass matrices are not basis independent. Finally the symmetry constraint was presented in a basis-independent form.

Then, we cheked the phenomenological validity of a new scheme, in which there was an attempt to obtain an approximately symmetric CKM matrix starting from mass matrices of the type $M_{U,D} = \kappa_{U,D}M_0 + X_{U,D}$ where $\kappa_{U,D}$ are numerical constants; M_0 is a real $3X3$, rank-one matrix and the matrices X_U and X_D are correction terms that have to be added to M_0 to obtain the non-zero masses of the light two generation quarks since the rank-one mass matrix M_0 has only one non-vanishing eigenvalue. We have shown that out of the three interesting solutions of the symmetric CKM matrix discussed in this scheme one is inconsistent with experiments, whereas another one requires a very heavy top quark mass ($m_t \approx 255GeV$) to be consistent.

5.2 Studies related to neutrinos

We studied the phenomenological consequences of massive neutrinoes. First, we have made an analysis of the spontaneous symmetry breaking for the Higgs sector taking various Higgs representations in the context of generalised ($g_L \neq g_R$) left-right symmetric model, including the higgs field $\xi = (2,2,15)$ that predicts the correct low energy ratio of $\frac{m_b}{m_\tau}$ and a singlet field η which breaks the left-right parity. As special cases we also include $\xi' = (2,2,15)$ and $\chi = (2,2,6)$ (which are interesting in the context of the three lepton decay mode of the proton) and field $\delta = (3,3,0)$ none of which acquire vev. We show that the linear couplings of these fields upon minimization put fine tuning conditions on the parameters of the model. We carry out the minimization of these potentials explicitly. In all the cases the relationship between the vev s of the left and right handed triplets v_L and v_R are given. The phenomenological consequences of this minimization regarding the neutrino masses are also studied.

Secondly, we studied constraints on the neutrino mixing matrix from the various oscillation data, neutrinoless double beta decay and the limit on the ν_e, ν_μ and ν_τ masses assuming only three generations of left-handed neutrinos and no sterile neutrinos to accomodate a 17 keV neutrino without extending the fermion sector. In the limit when all the three eigenvalues are nondegenerate and the mass differences are larger than $100eV^2$, we identify ν_τ with the 17 keV neutrino and vary the mixing probability between 3% and 0 3%. We found a very narrow allowed region for the various mixing angles. The allowed values of m_{ν_μ} lie between 145 keV and 205 keV for 1% mixing and between 135 keV and 240 keV for 3% mixing (our result differs from the earlier similar works with 3% mixing, where some approximations were made). The

$\nu_e \rightarrow \nu_\mu$ oscillation probability is found to lie between .001 and .002 for consistency. We then considered the allowed amount of the symmetry breaking when ν_μ and ν_τ form a pseudo-Dirac particle. We found the mass difference to be less than $9 \times 10^{-8} eV$, which puts stringent limits on the symmetry breaking effect on the neutrino mass matrix