# Abstract

The Standard Model (SM) in spite of its many success, fails to explain many observed phenomena like origin of neutrino mass, matter-antimatter asymmetry of the Universe, Dark matter etc. To explain these issues, the particle contents of the SM must be extended. Exploration of the origin of neutrino masses and its hierarchy pattern (whether normal or inverted) are the major goals for the particle physics community for the last few decades.

The main objective of this thesis is to offer some theoreticals as well as phenomenological study of the neutrino mass models in the context of observed neutrino and cosmology data. This includes the study of different $\mu - \tau$ symmetric neutrino mass models in the light of baryogenesis within the framework of type I+II seesaw mechanism. Then one and two texture zero Majorana mass matrices have been studied in the context of recent neutrino oscillation and cosmology data. Another aspect of this thesis is to generate non-zero $\theta_{13}$ in MSSM with broken $A_4$ flavor symmetry. This includes the study of the stability criteria of the neutrino mass models in terms of their predictions under the running of RGE's of gauge couplings, neutrino masses and mixing angles from high to low energy scale.

In **Chapter 1**, we present a literature survey on present status of neutrino physics. Then we briefly discuss the theories to describe the neutrino masses. We also depict a review of neutrino oscillation, neutrino oscillation in vacuum as well as matter and lastly ended with a summary of different neutrino experiments which

includes solar neutrino experiments, atmospheric neutrino experiments and reactor experiments. The latest results of these experiments are also summarized.

In **Chapter 2**, We study the possibility of generating non-zero reactor mixing angle $\theta_{13}$ by perturbing the $\mu-\tau$ symmetric neutrino mass matrix. The leading order $\mu - \tau$ symmetric neutrino mass matrix originates from type I seesaw mechanism whereas the perturbations to $\mu - \tau$ symmetry originate from type II seesaw term. We consider four different realizations of $\mu-\tau$ symmetry: BM, TBM, HM and GRM all giving rise to $\theta_{13} = 0, \theta_{23} = \frac{\pi}{4}$ but different non-zero values of solar mixing angle $\theta_{12}$. We assume a minimal $\mu-\tau$ symmetry breaking type II seesaw mass matrix as a perturbation and calculate the neutrino oscillation parameters as a function of type II seesaw strength. We then consider the origin of non-trivial leptonic $CP$ phase in the charged lepton sector and calculate the lepton asymmetry arising from the lightest right handed neutrino decay by incorporating the presence of both type I and type II seesaw. We constrain the type II seesaw strength as well as leptonic $CP$ phase (and hence the charged lepton sector) by comparing our results with experimental neutrino oscillation parameters as well as Planck bound on baryon to photon ratio.

In **Chapter 3**, We study all possible texture zeros in the Majorana neutrino mass matrix which are allowed from neutrino oscillation as well as cosmology data when the charged lepton mass matrix is assumed to take the diagonal form. In the case of one-zero texture, we write down the Majorana phases which are assumed to be equal and the lightest neutrino mass as a function of the Dirac $CP$ phase. In the case of two-zero texture, we numerically evaluate all the three $CP$ phases and lightest neutrino mass by solving four real constraint equations. We then constrain texture zero mass matrices from the requirement of producing correct baryon asymmetry through the mechanism of leptogenesis by assuming the Dirac neutrino mass matrix to be diagonal. Adopting a type I seesaw framework, we consider the $CP$-violating out of equilibrium decay of the lightest right-handed neutrino as the source of lepton asymmetry. Apart from discriminating between the texture zero mass matrices and light neutrino mass hierarchy, we also constrain the Dirac and Majorana $CP$ phases so that the observed baryon asymmetry can be produced. In two-zero texture, we further constrain the diagonal form of the Dirac neutrino mass matrix from the requirement of producing correct baryon asymmetry.

In **Chapter 4**, We study the renormalization group effects on neutrino masses and mixing in Minimal Supersymmetric Standard Model (MSSM) by considering a $\mu-\tau$ symmetric mass matrix at high energy scale giving rise to Tri-Bi-Maximal (TBM) type mixing. We outline a flavor symmetry model based on $A_4$ symmetry giving rise to the desired neutrino mass matrix at high energy scale. We take the three neutrino mass eigenvalues at high energy scale as input parameters and compute the neutrino parameters at low energy by taking into account of renormalization group effects. We observe that the correct output values of neutrino parameters at low energy are obtained only when the input mass eigenvalues are large $|m_{1,2,3}| = 0.08-0.12$ eV with a very mild hierarchy of either inverted or normal type. A large inverted or normal hierarchical pattern of neutrino masses is disfavored within our framework. We also find a preference towards higher values of $\tan\beta$, the ratio of vacuum expectation values (vev) of two Higgs doublets in MSSM in order to arrive at the correct low energy output. Such a model predicting large neutrino mass eigenvalues with very mild hierarchy and large $\tan\beta$ could have tantalizing signatures at oscillation, neutrinoless double beta decay as well as collider experiments.

In **Chapter 5**, we summarize the major conclusion achieved from our present works. Finally, the future scope of research in the field of neutrino physics has been discussed.