Preface

Neutrinos have played a key role in the evolution of our understanding of particles, forces and the universe and most likely the next step in this process of exploration of physics beyond the standard model will come from new properties of the neutrino revealed in many on going experiments such as the solar neutrino experiments, neutrino mass measurements, double beta decay searches etc. In the absence of any solid experimental clues regarding this new direction, many interesting theoretical speculations have been advanced with implications for collider as well as non-collider experiments. The central theme of most of these speculations in the possibility of a massive neutrino which in turn impacts on our thinking about the universe past and present. Most of these ideas will be put to test by the same kind of experiments discussed.

We therefore felt that it may be an appropriate time to summarize the theoretical, phenomenological and astrophysical implications of the massive neutrino so that first, a person starting out in the field will have a ready reference to the major existing ideas and, secondly, an expert in the field may be spared frequent trips to the library to clarify simple points in his or her thinking. In this spirit, we have not attempted a complete, exhaustive survey of all the details in various areas of neutrino physics but rather an introduction to the important major ideas in the field. We have tried to restrain our personal prejudices in the presentation to the extent humanly possible. We have most certainly left out some ideas as we must have missed citing some important works. While some of it is perhaps unavoidable because of the size of the book, mostly it is inadvertant and will be included in subsequent editions if brought to our attention with sufficient conviction. We have, however, given references to review articles where additional references can be obtained. For articles originally published in languages other than English, we have given reference to the English translation if we knew of one. The reader can easily find out the original reference by looking at the translated material.

A suggestion for new comers to the area trying to read this book : a necessary pre-requisite is a course on field theory, group theory and basic concepts in particle physics, and a right attitude. We have added some exercises at the end of the book to help the new comers. Our notations regarding the metric and gamma matrices etc are the same as the standard text books on Quantum Field theory such as the book by Bjorken and Drell or by Itzykson and Zuber, with the following comments or exceptions:

- Our normalization of spinor solutions to Dirac equation is different. It has been described in §4.3 and has the advantage that it applies equally well to massive as well as massless fields.

- To denote antiparticles, we do not use the customary bar since it is easy to confuse it with the operation of hermitian conjugation followed by multiplication of the Dirac matrix γ^0. Neither do we use the notation, which is used in some modern literature, of attaching a superscript c to the particle since it might lead to the misconception that the antiparticle is the C conjugate of the particle. For particles like the neutrinos whose interactions violate C by large amounts, the antiparticle can be defined only through the operation CPT. We use a hat to denote antiparticles and hope that this symbol will find acceptance in the community.

- We have used the summation convention for repeated indices when the index denotes space-time, but not when it labels different particles or represents elements of internal symmetry groups.

Over the years, both the authors have learned a great deal about the subjects discussed in the book from many of their colleagues – either through collaboration or through discussions. Specifically we would like mention K. S. Babu, Riccardo Barbieri, Darwin Chang, Nilendra

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