



Massive Neutrinos in  
**Physics and**  
**Astrophysics**  
Third Edition

Rabindra N. Mohapatra • Palash B. Pal

# Majorive Neutrinos In Physics And Astrophysics

**C. P. Burgess**



## **Massive Neutrinos In Physics And Astrophysics:**

*Massive Neutrinos in Physics and Astrophysics* Rabindra Nath Mohapatra, Palash B. Pal, 2004 An introduction to various issues related to the theory and phenomenology of massive neutrinos for the nonexpert also providing a discussion of results in the field for the active researcher All the necessary techniques and logics are included and topics such as supersymmetry are covered

**Massive Neutrinos In Physics And Astrophysics (Third Edition)** Rabindra N Mohapatra, Palash B Pal, 2004-03-09 The recent groundbreaking discovery of nonzero neutrino masses and oscillations has put the spotlight on massive neutrinos as one of the key windows on physics beyond the standard model as well as into the early universe This third edition of the invaluable book *Massive Neutrinos in Physics and Astrophysics* is an introduction to the various issues related to the theory and phenomenology of massive neutrinos for the nonexpert providing at the same time a complete and up to date discussion on the latest results in the field for the active researcher It is designed not merely to be a guide but also as a self contained tool for research with all the necessary techniques and logics included Specially emphasized are the various implications of neutrino discoveries for the nature of new forces Elementary discussions on topics such as grand unification left right symmetry and supersymmetry are presented The most recent cosmological and astrophysical implications of massive neutrinos are also dealt with

Neutrinos in Particle Physics, Astronomy and Cosmology Zhizhong Xing, Shun Zhou, 2011-06-08 Neutrinos in Particle Physics Astronomy and Cosmology provides a comprehensive and up to date introduction to neutrino physics neutrino astronomy and neutrino cosmology The intrinsic properties and fundamental interactions of neutrinos are described as is the phenomenology of lepton flavor mixing seesaw mechanisms and neutrino oscillations The cosmic neutrino background stellar neutrinos supernova neutrinos and ultrahigh energy cosmic neutrinos together with the cosmological matter antimatter asymmetry and other roles of massive neutrinos in cosmology are discussed in detail This book is intended for researchers and graduate students in the fields of particle physics particle astrophysics and cosmology Dr Zhizhong Xing is a professor at the Institute of High Energy Physics Chinese Academy of Sciences China Dr Shun Zhou is currently a postdoctoral fellow at the Max Planck Institute for Physics Germany

**Physics of Neutrinos** Masataka Fukugita, Tsutomu Yanagida, 2013-06-29 This book aims to provide a survey of the current state of research in the physics of neutrinos which has undergone dramatic development during the last decade in a form accessible to the nonspecialist and the graduate student The major issue during the last two decades has been the neutrino mass whereas the interaction of neutrinos was well understood within the framework of the standard theory which was established in the 1970s In 1994 we published a textbook format review article *Physics of Neutrinos in Physics and Astrophysics* in anticipation that the mass of the neutrino would be found in the near future It was indeed found thanks to the Super Kamiokande experiment four years after that book was written and a flurry of activity followed in the phenomenology of the neutrino mass From the theoretical point of view the importance of this discovery stems from the fact that it probably

indicates the presence of a new energy scale beyond the standard theory At the same time the formalism for massive neutrinos and the techniques to find the neutrino mass have now realistic importance and have become the subject of standard physics On the other hand experiment revealed that the pattern of the neutrino mass and mixing among generations appears in a way different from what has been speculated on the basis of existing theoretical models

**The Neutrino Story: One Tiny Particle's Grand Role in the Cosmos** Rabindra N. Mohapatra, 2020-11-05 Every second of every day we are exposed to billions of neutrinos emitted by the Sun and yet they seem to pass straight through us with no apparent effect at all Tiny and weakly interacting this subatomic particle may be but this book will show you just how crucial a role it has played in the evolution of the elements in the universe and eventually ourselves We first start with an introduction to the basics of subatomic physics including brief backgrounds on the discoveries that set the stage for major 20th century advances The author a distinguished theoretical physicist who has researched neutrinos for over thirty years next explains in nontechnical language how and why the neutrino fits into the wider story of elementary particles Finally the reader will learn about the latest discoveries in the past half century of neutrino studies This semi popular science book will appeal to any physics students or non specialist physicists who wish to know more about the neutrino and its role in the evolution of our universe

*Fundamentals of Neutrino Physics and Astrophysics* Carlo Giunti, Chung W. Kim, 2007-03-15 Our Universe is made of a dozen fundamental building blocks Among these neutrinos are the most mysterious but they are the second most abundant particles in the Universe This book provides detailed discussions of how to describe neutrinos their basic properties and the roles they play in nature

**Physics of Massive Neutrinos** Felix Boehm, Petr Vogel, 1992-06-26 Neutrinos play a decisive part in nuclear and elementary particle physics as well as in astrophysics and cosmology Some of their most basic properties such as their mass and charge conjugation symmetry are largely unknown This book focuses on what we know and may hope to know about the mass of the neutrino and its particle antiparticle symmetry Topics include neutrino mixing neutrino decay neutrino oscillations double beta decay solar neutrinos supernova neutrinos and related issues The authors stress the physical concepts and discuss both theoretical and experimental techniques This updated second edition differs from the first in that it contains an expanded coverage of experimental results and theoretical advances Since publication of the first edition many issues that were at that time unresolved such as tritium beta decay and reactor neutrino oscillations have been clarified and are discussed here Also included is an expanded coverage of solar and supernova neutrinos This book deals with one of the most intriguing issues in modern physics and will be of value to researchers graduate students and advanced undergraduates specializing in experimental and theoretical particle physics and nuclear physics

*Massive Neutrinos in Astrophysics and in Particle Physics* J. Thanh Van Tran, 1984

[Introduction to the Physics of Massive and Mixed Neutrinos](#) Samoil Bilenky, 2010-09-14 For many years neutrino was considered a massless particle The theory of a two component neutrino which played a crucial role in the creation of the theory of

the weak interaction is based on the assumption that the neutrino mass is equal to zero. We now know that neutrinos have non-zero small masses. In numerous experiments with solar, atmospheric, reactor, and accelerator neutrinos, a new phenomenon, neutrino oscillations, was observed. Neutrino oscillations, periodic transitions between different flavors of neutrinos, are possible only if neutrino mass squared differences are different from zero and small, and if neutrinos are mixed. The discovery of neutrino oscillations opened a new era in neutrino physics, an era of investigation of neutrino masses, mixing, magnetic moments, and other neutrino properties. After the establishment of the Standard Model of the electroweak interaction at the end of the seventies, the discovery of neutrino masses was the most important discovery in particle physics. Small neutrino masses cannot be explained by the standard Higgs mechanism of mass generation. For their explanation, a new mechanism is needed. Thus, small neutrino masses are the first signature in particle physics of a new physics beyond the Standard Model. It took many years of heroic efforts by many physicists to discover neutrino oscillations. After the first period of investigation of neutrino oscillations, many challenging problems remained unsolved. One of the most important is the problem of the nature of neutrinos with definite masses: Are they Dirac neutrinos possessing a conserved lepton number, which distinguishes neutrinos and antineutrinos, or Majorana neutrinos, identical to neutrinos and antineutrinos? Many experiments of the next generation and new neutrino facilities are now under preparation and investigation. There is no doubt that exciting results are ahead.

*Massive Neutrinos in Particle Physics and Astrophysics*, 1986. The concepts of Majorana and Dirac neutrinos are reviewed from an operational point of view, and survey the experimental search for neutrino mass. Also reviewed are the work of Mikheyev and Smirnov on the enhancement of neutrino oscillations via the mechanism of Wolfenstein matter oscillations. Results of an extensive computation of MSW effects in the sun are described. 41 refs, 6 figs.

**Massive Neutrinos: Flavor Mixing Of Leptons And Neutrino Oscillations** Harald Fritzsch, 2015-08-28. Since the discovery of neutrino oscillations, neutrino physics has become an interesting field of research in physics. They imply that neutrinos must have a small mass and that the neutrinos coupled to the charged leptons are mixtures of the mass eigenstates, analogous to the flavor mixing of the quarks. The mixing angles for the quarks are small, but for the leptons, two of the mixing angles are large. The masses of the three neutrinos must be very small, less than 1 eV, but from the oscillation experiments, we only know the mass differences; the absolute masses are still unknown. Also, we do not know if the masses of the neutrinos are Dirac masses, as the masses of the charged leptons and of the quarks, or whether they are Majorana masses. In this volume, an overview of the present state of research in neutrino physics is given by well-known experimentalists and theorists. The contents originated from talks and discussions at a recent conference addressing some of the most pressing open questions in neutrino physics, ranging from the oscillation experiments to CP violation for leptons, to texture-zero mass matrices, and to the role of neutrinos in astrophysics and cosmology.

**Current Aspects of Neutrino Physics** David O. Caldwell, 2013-11-11. This is a particularly exciting time for neutrino physics. Now providing the first experimental evidence for new physics beyond the Standard Model of particle

physics neutrino studies are leading that larger field in new directions As a probe for discovery neutrinos are unique among particles Being leptons neutrinos are as far as one knows true elementary particles but in addition they are unencumbered by charge and of course they do not have complicating strong interactions Their unusually small mass also points to their novelty and possibly to their providing a window onto very high energy scales The emphasis for neutrino physics at this time is on their masses and mixing with each other as well as on their basic nature and their role in the Universe While they have been important tools for studying particle properties such as structure functions and the nature of the weak interaction at present this is not the thrust of most research and hence is not covered in this book Rather the topics are those currently of most interest at the frontier of particle physics

**Neutrinos** Arnold S. Lavro, 2002 Neutrinos are one of the most abundant particles in the universe Because they have very little interaction with matter however they are incredibly difficult to detect Neutrinos are similar to the more familiar electron with one crucial difference neutrinos do not carry electric charge Because neutrinos are electrically neutral they are not affected by the electromagnetic forces which act on electrons Three types of neutrinos are known Each type or flavour of neutrino is related to a charged particle which gives the corresponding neutrino its name Hence the electron neutrino is associated with the electron and two other neutrinos are associated with heavier versions of the electron called the muon and the tau The book presents citations from the literature for the last three years from the journal literature and the existent book literature Access is provided by subject author and title indexes **A**

**Modern Introduction to Neutrino Physics** Frank F Deppisch, 2019-11-07 A deeper understanding of neutrinos with the goal to reveal their nature and exact role within particle physics is at the frontier of current research This book reviews the field in a concise fashion and highlights the most pressing issues and areas of strongest topical interest It provides a clear self contained and logical treatment of the fundamental physics aspects appropriate for graduate students Starting with the relevant basics of the SM neutrinos are introduced and the quantum mechanical effect of oscillations is explained in detail A strong focus is then set on the phenomenon of lepton number violation especially in  $0\nu\beta\beta$  decay as the crucial probe to understand the nature of neutrinos The role of neutrinos in astrophysics expected to be of increasing importance for future research is then described Finally models to explain the neutrino properties are outlined The central theme of the book is the nature of neutrino masses and the above topics will revolve around this issue [The Physics of Massive Neutrinos](#) Boris

Kayser, Françoise Gibrat-Debu, 1989 This book explains the physics and phenomenology of massive neutrinos The authors argue that neutrino mass is not unlikely and consider briefly the search for evidence of this mass in decay processes before they examine the physics and phenomenology of neutrino oscillation The physics of Majorana neutrinos neutrinos which are their own antiparticles is then discussed This volume requires of the reader only a knowledge of quantum mechanics and of very elementary quantum field theory

**Unfolding the Matter of Nuclei** Società italiana di fisica, 1998 The nucleus and its constituents are a challenging problem The lectures collected in this book present a broad and comprehensive review of

the current knowledge about nuclei They cover topics such as searching for signatures of the quarks in nuclei with electromagnetic probes and at much higher energies for signatures of the quark gluon plasma in ultrarelativistic nuclear collisions The attempts to obtain new nuclei in the laboratory are also discussed as well as the central role played by nuclear physics in the development of weak interactions Progress in all these areas rests on a deeper theoretical handling of the nuclear and nucleon s structure The latter can also be addressed by relying on numerical solutions of QCD on a discrete space time lattice The advancement of computational capabilities has spurred a growing interest in this approach Finally the book deals with different paths toward solving non perturbative QCD      Massive Neutrinos Orrin Fackler,Gérard Fontaine,J. Thanh Van Tran,1991

**The Standard Model and Beyond** Paul Langacker,2017-06-26 This new edition of The Standard Model and Beyond presents an advanced introduction to the physics and formalism of the standard model and other non abelian gauge theories It provides a solid background for understanding supersymmetry string theory extra dimensions dynamical symmetry breaking and cosmology In addition to updating all of the experimental and phenomenological results from the first edition it contains a new chapter on collider physics expanded discussions of Higgs neutrino and dark matter physics and many new problems The book first reviews calculational techniques in field theory and the status of quantum electrodynamics It then focuses on global and local symmetries and the construction of non abelian gauge theories The structure and tests of quantum chromodynamics collider physics the electroweak interactions and theory and the physics of neutrino mass and mixing are thoroughly explored The final chapter discusses the motivations for extending the standard model and examines supersymmetry extended gauge groups and grand unification Thoroughly covering gauge field theories symmetries and topics beyond the standard model this text equips readers with the tools to understand the structure and phenomenological consequences of the standard model to construct extensions and to perform calculations at tree level It establishes the necessary background for readers to carry out more advanced research in particle physics Supplementary materials are provided on the author s website and a solutions manual is available for qualifying instructors

**Introduction to Effective Field Theory** C. P. Burgess,2020-12-10 This advanced accessible textbook on effective field theories uses worked examples to bring this important topic to a wider audience      **Neutrino Physics** Kai Zuber,2011-08-03 When Kai Zuber s pioneering text on neutrinos was published in 2003 the author correctly predicted that the field would see tremendous growth in the immediate future In that book Professor Zuber provided a comprehensive self contained examination of neutrinos covering their research history and theory as well as their application to particle p

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