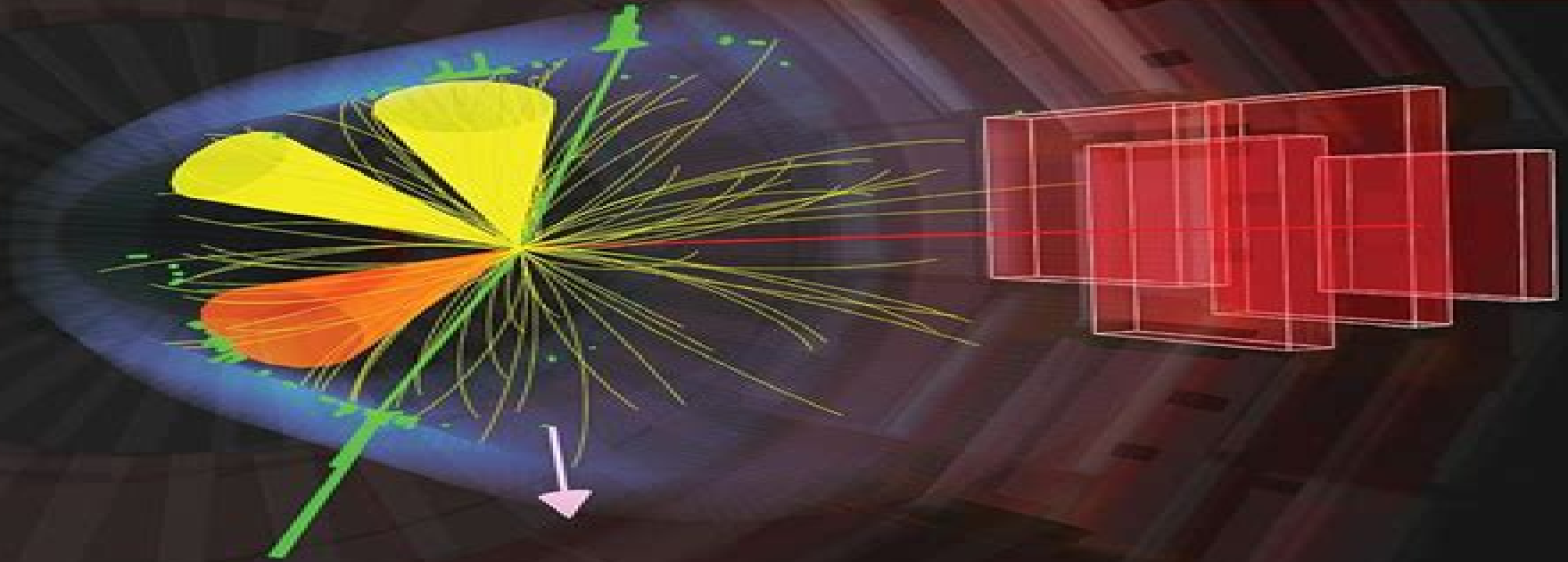


40<sup>TH</sup> ANNIVERSARY EDITION



# Gauge Theories in Particle Physics

FIFTH EDITION

## A Practical Introduction, Volume II

Non-Abelian Gauge Theories:  
QCD and The Electroweak Theory

**Ian J.R. Aitchison,**  
and **Anthony J.G. Hey**



CRC Press  
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# Gauge Theories In Particle Physics

**Ian Johnston Rhind Aitchison, Anthony  
J. G. Hey**



## **Gauge Theories In Particle Physics:**

**Gauge Theories in Particle Physics, Second Edition** Ian J.R. Aitchison, Anthony J.G. Hey, 1989 This book will provide you with a good practical understanding of quantum electrodynamics quantum chromodynamics and the electroweak theory which together make up the standard model The new edition includes over 50 diagrams showing experimental data allowing the reader to work through calculations in the three gauge theories and compare the results with experiment

**Gauge Theories in Particle Physics, Volume II** I.J.R. Aitchison, A.J.G. Hey, 2003-12-01 This is the second volume of the third edition of a successful text now substantially enlarged and updated to reflect developments over the last decade in the curricula of university courses and in particle physics research Volume I covered relativistic quantum mechanics electromagnetism as a gauge theory and introductory quantum field theory and ended with the formulation and application of quantum electrodynamics QED including renormalization Building on these foundations this second volume provides a complete accessible and self contained introduction to the remaining two gauge theories of the standard model of particle physics quantum chromodynamics QCD and the electroweak theory The treatment significantly extends that of the second edition in several important respects Simple ideas of group theory are now incorporated into the discussion of non Abelian symmetries Two new chapters have been added on QCD one devoted to the renormalization group and scaling violations in deep inelastic scattering and the other to non perturbative aspects of QCD using the lattice path integral formulation of quantum field theory the latter is also used to illuminate various aspects of renormalization theory via analogies with condensed matter systems Three chapters treat the fundamental topic of spontaneous symmetry breaking the Bogoliubov superfluid and the BCS superconductor are studied in some detail one chapter is devoted to the implications of global chiral symmetry breaking in QCD and one to the breaking of local  $SU(2) \times U(1)$  symmetry in the electroweak theory Weak interaction phenomenology is extended to include discussion of discrete symmetries and of the possibility that neutrinos are Majorana rather than Dirac particles Most of these topics are normally found only in more advanced texts and this is the first book to treat them in a manner accessible to the wide readership that the previous editions have attracted

**Gauge Theories in Particle Physics: A Practical Introduction, Volume 2: Non-Abelian Gauge Theories** Ian J R Aitchison, Anthony J.G. Hey, 2012-12-17 Volume 2 of this revised and updated edition provides an accessible and practical introduction to the two non Abelian quantum gauge field theories of the Standard Model of particle physics quantum chromodynamics QCD and the Glashow Salam Weinberg GSW electroweak theory This volume covers much of the experimental progress made in the last ten y

**Gauge Theories in Particle Physics: A Practical Introduction, Volume 1** Ian J R Aitchison, Anthony J.G. Hey, 2012-12-17 Volume 1 of this revised and updated edition provides an accessible and practical introduction to the first gauge theory included in the Standard Model of particle physics quantum electrodynamics QED The book includes self contained presentations of electromagnetism as a gauge theory as well as relativistic quantum mechanics It provides a unique

**Gauge Theories in Particle Physics 40th Anniversary Edition** Ian J.R. Aitchison,Anthony J.G. Hey,2024-08-06 The fifth edition of this well established highly regarded two volume set continues to provide a fundamental introduction to advanced particle physics while incorporating substantial new experimental results especially in the areas of the Higgs and top quark sectors as well as CP violation and neutrino oscillations It offers an accessible and practical introduction to the three gauge theories comprising the Standard Model of particle physics quantum electrodynamics QED quantum chromodynamics QCD and the Glashow Salam Weinberg GSW electroweak theory The first volume provides a broad and self contained introduction to the first of these theories QED A unique feature is the elementary introduction to quantum field theory leading in easy stages to covariant perturbation theory and Feynman graphs thereby establishing a firm foundation for the formal and conceptual framework upon which the subsequent development of the three quantum gauge field theories of the Standard Model is based The second volume covers the two non Abelian gauge theories of QCD and the GSW theory A distinctive feature is the extended treatment of two crucial theoretical tools spontaneous symmetry breaking and the renormalization group The underlying physics of these is elucidated by parallel discussions of examples from condensed matter systems superfluidity and superconductivity and critical phenomena This new edition includes updates to jet algorithms lattice field theory CP violation and the CKM matrix and neutrino physics New to the fifth edition Tests of the Standard Model in the Higgs and top quark sectors The naturalness problem and responses to it going beyond the Standard Model The Standard Model as an effective field theory This revised and updated anniversary edition provides a self contained pedagogical treatment of the subject from relativistic quantum mechanics to the frontiers of the Standard Model For each theory the authors discuss the main conceptual points in both mathematical and physical aspects detail many practical calculations of physical quantities from first principles and compare these quantitative predictions with experimental results helping readers improve both their calculation skills and physical insight This set should serve as a valuable handbook for students and researchers in advanced particle physics looking for an introduction to the Standard Model of particle physics

**Gauge Theories in Particle Physics, 40th Anniversary Edition: A Practical Introduction, Volume 2** Ian J R Aitchison,Anthony J.G. Hey,2024-06-19 The fifth edition of this well established highly regarded two volume set continues to provide a fundamental introduction to advanced particle physics while incorporating substantial new experimental results especially in the areas of Higgs and top sector physics as well as CP violation and neutrino oscillations It offers an accessible and practical introduction to the three gauge theories comprising the Standard Model of particle physics quantum electrodynamics QED quantum chromodynamics QCD and the Glashow Salam Weinberg GSW electroweak theory Volume 2 of this updated edition covers the two non Abelian gauge theories of QCD and the GSW theory A distinctive feature is the extended treatment of two crucial theoretical tools spontaneous symmetry breaking and the renormalization group The underlying physics of these is elucidated by parallel discussions of examples from condensed matter systems superfluidity

and superconductivity and critical phenomena This new edition includes updates to jet algorithms lattice field theory CP violation and the CKM matrix and neutrino physics New to the fifth edition Tests of the Standard Model in the Higgs and top quark sectors The naturalness problem and responses to it going beyond the Standard Model The Standard Model as an effective field theory Each volume should serve as a valuable handbook for students and researchers in advanced particle physics looking for an accessible introduction to the Standard Model of particle physics Ian J R Aitchison is Emeritus Professor of Physics at the University of Oxford He has previously held research positions at Brookhaven National Laboratory Saclay and the University of Cambridge He was a visiting professor at the University of Rochester and the University of Washington and a scientific associate at CERN and SLAC Dr Aitchison has published over 90 scientific papers mainly on hadronic physics and quantum field theory He is the author of two books and joint editor of further two Anthony J G Hey is now Honorary Senior Data Scientist at the UK's National Laboratory at Harwell He began his career with a doctorate in particle physics from the University of Oxford After a career in particle physics that included a professorship at the University of Southampton and research positions at Caltech MIT and CERN he moved to Computer Science and founded a parallel computing research group The group were one of the pioneers of distributed memory message passing computers and helped establish the MPI message passing standard After leaving Southampton in 2001 he was director of the UK's eScience initiative before becoming a Vice President in Microsoft Research He returned to the UK in 2015 as Chief Data Scientist at the UK's Rutherford Appleton Laboratory He then founded a new Scientific Machine Learning group to apply AI technologies to the Big Scientific Data generated by the Diamond Synchrotron the ISIS neutron source and the Central Laser Facility that are located on the Harwell campus He is the author of over 100 scientific papers on physics and computing and editor of *The Feynman Lectures on Computation*

*Gauge Theories in Particle Physics* Ian Johnston Rhind  
Aitchison,Anthony J. G. Hey,1982      *Gauge Theories in Particle Physics* I.J.R. Aitchison,A.J.G. Hey,2002-09-01 *Gauge Theories in Particle Physics* Volume 1 From Relativistic Quantum Mechanics to QED Third Edition presents an accessible practical and comprehensive introduction to the three gauge theories of the standard model of particle physics quantum electrodynamics QED quantum chromodynamics QCD and the electroweak theory For each of them the authors provide a thorough discussion of the main conceptual points a detailed exposition of many practical calculations of physical quantities and a comparison of these quantitative predictions with experimental results For this two volume third edition much of the book has been rewritten to reflect developments over the last decade both in the curricula of university courses and in particle physics research Substantial new material has been introduced that is intended for use in undergraduate physics courses New introductory chapters provide a precise historical account of the properties of quarks and leptons and a qualitative overview of the quantum field description of their interactions at a level appropriate to third year courses The chapter on relativistic quantum mechanics has been enlarged and is supplemented by additional sections on scattering

theory and Green functions in a form appropriate to fourth year courses Since precision experiments now test the theories beyond lowest order in perturbation theory an understanding of the data requires a more sophisticated knowledge of quantum field theory including ideas of renormalization The treatment of quantum field theory has therefore been considerably extended so as to provide a uniquely accessible and self contained introduction to quantum field dynamics as described by Feynman graphs The level is suitable for advanced fourth year undergraduates and first year graduates These developments are all contained in the first volume which ends with a discussion of higher order corrections in QED the second volume is devoted to the non Abelian gauge theories of QCD and the electroweak theory As in the first two editions emphasis is placed throughout on developing realistic calculations from a secure physical and conceptual basis **An**

**Introduction to Gauge Theories and Modern Particle Physics** Elliot Leader, Enrico Predazzi, 1996-03-14 This work presents in two volumes a comprehensive and unified treatment of modern theoretical and experimental particle physics at a level accessible to beginning research students The emphasis throughout is on presenting underlying physical principles in a simple and intuitive way and the more sophisticated methods demanded by present day research interests are introduced in a very gradual and gentle fashion Volume 1 covers electroweak interactions the discovery and properties of the new particles the discovery of partons and the construction and predictions of the simple parton model Volume 2 deals at some length with CP violation but is mainly devoted to QCD and its application to hard processes A brief coverage of soft hadronic physics is included This work will provide a comprehensive reference and textbook for all graduate students and researchers interested in modern particle physics [Gauge Theories in Particle Physics](#), 2003 **Gauge Theories in Particle Physics, 40th**

**Anniversary Edition: A Practical Introduction, Volume 2** Ian Johnston Rhind Aitchison, Anthony J. G. Hey, 2024 The fifth edition of this well established highly regarded two volume set continues to provide a fundamental introduction to advanced particle physics while incorporating substantial new experimental results especially in the areas of Higgs and top sector physics as well as CP violation and neutrino oscillations It offers an accessible and practical introduction to the three gauge theories comprising the Standard Model of particle physics quantum electrodynamics QED quantum chromodynamics QCD and the Glashow Salam Weinberg GSW electroweak theory Volume 2 of this updated edition covers the two non Abelian gauge theories of QCD and the GSW theory A distinctive feature is the extended treatment of two crucial theoretical tools spontaneous symmetry breaking and the renormalization group The underlying physics of these is elucidated by parallel discussions of examples from condensed matter systems superfluidity and superconductivity and critical phenomena This new edition includes updates to jet algorithms lattice field theory CP violation and the CKM matrix and neutrino physics New to the fifth edition Tests of the Standard Model in the Higgs and top quark sectors The naturalness problem and responses to it going beyond the Standard Model The Standard Model as an effective field theory Each volume should serve as a valuable handbook for students and researchers in advanced particle physics looking for an accessible introduction to the Standard

Model of particle physics Ian J R Aitchison is Emeritus Professor of Physics at the University of Oxford He has previously held research positions at Brookhaven National Laboratory Saclay and the University of Cambridge He was a visiting professor at the University of Rochester and the University of Washington and a scientific associate at CERN and SLAC Dr Aitchison has published over 90 scientific papers mainly on hadronic physics and quantum field theory He is the author of two books and joint editor of further two Anthony J G Hey is now Honorary Senior Data Scientist at the UK s National Laboratory at Harwell He began his career with a doctorate in particle physics from the University of Oxford After a career in particle physics that included a professorship at the University of Southampton and research positions at Caltech MIT and CERN he moved to Computer Science and founded a parallel computing research group The group were one of the pioneers of distributed memory message passing computers and helped establish the MPI message passing standard After leaving Southampton in 2001 he was director of the UK s eScience initiative before becoming a Vice President in Microsoft Research He returned to the UK in 2015 as Chief Data Scientist at the U K s Rutherford Appleton Laboratory He then founded a new Scientific Machine Learning group to apply AI technologies to the Big Scientific Data generated by the Diamond Synchrotron the ISIS neutron source and the Central Laser Facility that are located on the Harwell campus He is the author of over 100 scientific papers on physics and computing and editor of The Feynman Lectures on Computation

Gauge Theories in Particle Physics, Third Edition - 2 volume set Ian J.R. Aitchison, I.J.R. Aitchison, A.J.G. Hey, Anthony J.G. Hey, 2004-01-01 This two volume set provides an accessible practical and comprehensive introduction to the three gauge theories of the standard model of particle physics quantum electrodynamics QED quantum chromodynamics QCD and the electroweak theory For each of them the authors provide a thorough discussion of the main conceptual points a detailed exposition of many practical calculations of physical quantities and a comparison of these quantitative predictions with experimental results For this third edition much has been rewritten to reflect developments over the last decade both in the curricula of university courses and in particle physics research On the one hand substantial new material has been introduced that is intended for use in undergraduate physics courses New introductory chapters provide a precise historical account of the properties of quarks and leptons and a qualitative overview of the quantum field description of their interactions at a level appropriate to third year courses The chapter on relativistic quantum mechanics has been enlarged and is supplemented by additional sections on scattering theory and Green functions in a form appropriate to fourth year courses On the other hand since precision experiments now test the theories beyond lowest order in perturbation theory an understanding of the data requires a more sophisticated knowledge of quantum field theory including ideas of renormalization The treatment of quantum field theory has therefore been considerably extended to provide a uniquely accessible and self contained introduction to quantum field dynamics as described by Feynman graphs The level is suitable for advanced fourth year undergraduates and first year graduates These developments are all contained in the first volume which ends with a discussion of higher order corrections

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**Gauge Theories in Particle Physics: Non-Abelian gauge theories : QCD and the electroweak theory** Ian Johnston Rhind Aitchison, 2013 The first volume of this updated fourth edition includes self contained presentations of electromagnetism as a gauge theory as well as relativistic quantum mechanics It provides a unique elementary introduction to quantum field theory establishing the essentials of the formal and conceptual framework upon which the subsequent development of the three gauge theories is based The text also describes tree level calculations of physical processes in QED and introduces ideas of renormalization in the context of one loop radiative corrections for QED Provided by publisher

Gauge Theory of Elementary Particle Physics Ta-Pei Cheng, Ling-Fong Li, 1994-08-02 This is a practical introduction to the principal ideas in gauge theory and their applications to elementary particle physics It explains technique and methodology with simple exposition backed up by many illustrative examples Derivations some of well known results are presented in sufficient detail to make the text accessible to readers entering the field for the first time The book focuses on the strong interaction theory of quantum chromodynamics and the electroweak interaction theory of Glashow Weinberg and Salam as well as the grand unification theory exemplified by the simplest SU 5 model Not intended as an exhaustive survey the book nevertheless provides the general background necessary for a serious student who wishes to specialize in the field of elementary particle theory Physicists with an interest in general aspects of gauge theory will also find the book highly useful

Gauge Theories in Particle Physics, Third Edition - 2 volume set Ian J.R. Aitchison, I.J.R. Aitchison, A.J.G. Hey, Anthony J.G. Hey, 2004-01-01 This two volume set provides an accessible practical and comprehensive introduction to the three gauge theories of the standard model of particle physics quantum electrodynamics QED quantum chromodynamics QCD and the electroweak theory For each of them the authors provide a thorough discussion of the main conceptual points a detailed exposition of many practical calculations of physical quantities and a comparison of these quantitative predictions with experimental results For this third edition much has been rewritten to reflect developments over the last decade both in the curricula of university courses and in particle physics research On the one hand substantial new material has been introduced that is intended for use in undergraduate physics courses New introductory chapters provide a precise historical account of the properties of quarks and leptons and a qualitative overview of the quantum field description of their interactions at a level appropriate to third year courses The chapter on relativistic quantum mechanics has been enlarged and is supplemented by additional sections on scattering theory and Green functions in a form appropriate to fourth year courses On the other hand since precision experiments now test the theories beyond lowest order in perturbation theory an understanding of the data requires a more sophisticated knowledge of quantum field theory including ideas of renormalization The treatment of quantum field theory has therefore been considerably extended to provide a uniquely



accessible and self contained introduction to quantum field dynamics as described by Feynman graphs The level is suitable for advanced fourth year undergraduates and first year graduates These developments are all contained in the first volume which ends with a discussion of higher order corrections in QED The second volume is devoted to the non Abelian gauge theories of QCD and the electroweak theory As in the first two editions emphasis is placed throughout on developing realistic calculations from a secure physical and conceptual basis

Gauge Field Theories Mike Guidry, 2008-07-11 Acquaints readers with the main concepts and literature of elementary particle physics and quantum field theory In particular the book is concerned with the elaboration of gauge field theories in nuclear physics the possibility of creating fundamental new states of matter such as an extended quark gluon plasma in ultra relativistic heavy ion collisions and the relation of gauge theories to the creation and evolution of the universe Divided into three parts it opens with an introduction to the general principles of relativistic quantum field theory followed by the essential ingredients of gauge fields for weak and electromagnetic interactions quantum chromodynamics and strong interactions The third part is concerned with the interface between modern elementary particle physics and applied disciplines such as nuclear physics astrophysics and cosmology Includes references and numerous exercises

Gauge Theories in Particle Physics: A Practical Introduction, Fourth Edition - 2 Volume set Ian J.R. Aitchison, Anthony J.G. Hey, 2012-12-17 The fourth edition of this well established highly regarded two volume set continues to provide a fundamental introduction to advanced particle physics while incorporating substantial new experimental results especially in the areas of CP violation and neutrino oscillations It offers an accessible and practical introduction to the three gauge theories included in the Standard Model of particle physics quantum electrodynamics QED quantum chromodynamics QCD and the Glashow Salam Weinberg GSW electroweak theory In the first volume a new chapter on Lorentz transformations and discrete symmetries presents a simple treatment of Lorentz transformations of Dirac spinors Along with updating experimental results this edition also introduces Majorana fermions at an early stage making the material suitable for a first course in relativistic quantum mechanics Covering much of the experimental progress made in the last ten years the second volume remains focused on the two non Abelian quantum gauge field theories of the Standard Model QCD and the GSW electroweak theory A new chapter on CP violation and oscillation phenomena describes CP violation in B meson decays as well as the main experiments that have led to our current knowledge of mass squared differences and mixing angles for neutrinos Exploring a new era in particle physics this edition discusses the exciting discovery of a boson with properties consistent with those of the Standard Model Higgs boson It also updates many other topics including jet algorithms lattice QCD effective Lagrangians and three generation quark mixing and the CKM matrix This revised and updated edition provides a self contained pedagogical treatment of the subject from relativistic quantum mechanics to the frontiers of the Standard Model For each theory the authors discuss the main conceptual points detail many practical calculations of physical quantities from first principles and compare these quantitative predictions with

experimental results helping readers improve both their calculation skills and physical insight

**Gauge Theories in Particle Physics** Ian Johnston Rhind Aitchison, Anthony J. G. Hey, 2003

An Introduction to Gauge Theories Nicola Cabibbo, Luciano Maiani, Omar Benhar, 2017-07-28

Written by world leading experts in particle physics this new book from Luciano Maiani and Omar Benhar with contributions from the late Nicola Cabibbo is based on Feynman's path integrals. Key elements of gauge theories are described: Feynman diagrams, gauge fixing, Faddeev-Popov ghosts as well as renormalization in Quantum Electrodynamics. Quarks and QCD interactions are introduced. Renormalization group and high momentum behaviour of the coupling constants is discussed in QED and QCD with asymptotic freedom derived at one loop. These concepts are related to the Higgs boson and models of grand unification: an excellent introduction to the quantum theory of gauge fields and their applications to particle physics. It will be an excellent book for the serious student and a good reference for the professional practitioner. Let me add that scattered through the pages we can find occasional traces of Nicola Cabibbo's style. John Iliopoulos, CNRS Ecole Normale Supérieure. The volume ends with an illuminating description of the expectation generated by the recent discovery of the Higgs boson combined with the lack of evidence for supersymmetric particles in the mass range 0.6–1 TeV. Arturo Menchaca Rocha, FinstP Professor of Physics, Mexico's National Autonomous University. Former President of the Mexican Academy of Sciences, Presidential Advisor. The reader is masterfully guided through the subtleties of the quantum field theory and elementary particle physics from simple examples in Quantum Mechanics to salient details of modern theory. Mikhail Voloshin, Professor of Physics, University of Minnesota.

**Gauge Theories in Particle Physics: From relativistic quantum mechanics to QED** Ian Johnston Rhind Aitchison, 2003

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