

THE STANDARD MODEL OF FUNDAMENTAL PARTICLES AND INTERACTIONS

The Standard Model is a quantum theory that summarizes our current knowledge of the structure of matter and the interactions between its constituents. Fundamental interactions are mediated by forces and by bosons, units of exchange particles.

FERMIONS

matter constituents
spin = 1/2, 3/2, 5/2, ...

Leptons spin = 1/2			Quarks spin = 1/2		
Flavor	Mass (GeV/c ²)	Electric charge	Flavor	Approx. Mass (GeV/c ²)	Electric charge
ν_e electron neutrino	< 0.0000001	0	u up	0.0022	2/3
e^- electron	0.000511	-1	d down	0.0047	-1/3
ν_μ muon neutrino	< 0.0000000001	0	c charm	1.27	2/3
μ^- muon	0.10567	-1	b strange	0.0034	-1/3
ν_τ tauon neutrino	< 0.0000000000001	0	t top	172.7	2/3
τ^- tau	1.777	-1	b bottom	4.18	-1/3

*See the neutrino paragraph below.

Mass is the intrinsic energy contribution of particles. Spin is given in units of \hbar , which is the quantum unit of angular momentum where $\hbar = 1.054 \times 10^{-34}$ J·s and $\hbar = 1.054 \times 10^{-34}$ J·s.

Electric charge is given in units of the proton's charge, e . It is zero for electric charge of the proton is 1.602×10^{-19} coulombs.

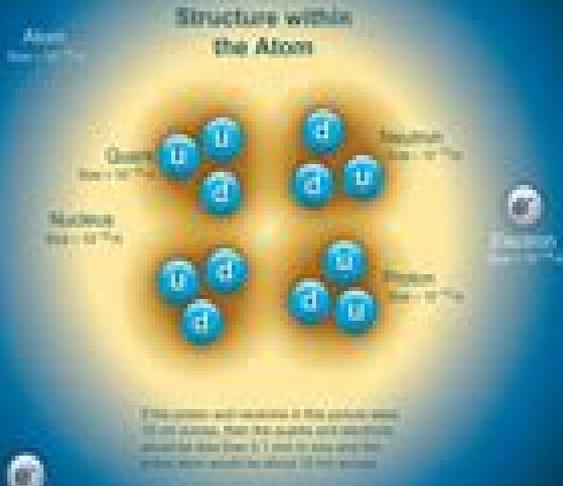
The energy unit of particle physics is the electronvolt (eV), the energy gained by one electron in one volt average difference of potential. Masses are given in GeV/c², where $1 \text{ GeV} = 10^9 \text{ eV} = 1.602 \times 10^{-10}$ joules. The mass of the proton is 0.938 GeV/c² or 1.672×10^{-27} kg.

Neutrinos

Neutrinos are produced in the sun, radioactive reactions, astrophysical processes, and many other processes. They produced neutrinos can be described as any of three flavors: electron neutrino, ν_e , μ neutrino, or ν_μ , the type of charged lepton associated with its production. Each is a different quantum number of the three different mass neutrinos ν_e , ν_μ , and ν_τ for which currently observed flavor eigenstates are chosen as the basis. Further, observation of the production of neutrinos does not guarantee that it is indeed that flavor and neutrinos can be produced in many and many different ways.

Matter and Antimatter

For every particle there exists a corresponding antiparticle with the opposite of its mass, the particle number (charge + or -), charge (e.g. electric), baryon number, lepton number, and other quantum numbers. Some elementary particles have mass (e.g. e^- , μ^- , and τ^-), but not ν particles have zero mass.



Electrons are scattered off the nucleus and only protons, that are points and extremely small, are visible. The nucleus is made of protons and neutrons.

Properties of the Interactions

The strength of the interaction, G , varies as the inverse of the strength of the electromagnetic force. G is the coupling constant for the specified interaction.

Property	Gravitational Interaction	Weak Interaction (G _F)	Electromagnetic Interaction	Strong Interaction
Acts on	Mass + Energy	Flavor	Electric Charge	Color Charge
Particles participating	All	Quarks, Leptons	Electrically Charged	Quarks, Gluons
Particles mediating	Graviton (not yet observed)	W^+ , W^- , Z^0	γ	Gluons
Strength at r	$\frac{1}{r^2}$ $\frac{1}{r^3}$	0.3 10^{-5}	1 0	20 10

BOSONS

force carriers
spin = 0, 1, 2, ...

Unified Electroweak spin = 1			Strong (color) spin = 1		
Name	Mass (GeV/c ²)	Electric charge	Name	Mass (GeV/c ²)	Electric charge
γ photon	0	0	g gluon	0	0
W^- W boson	80.36	-1	Higgs Boson spin = 0		
W^+ W boson	80.36	+1	Name	Mass (GeV/c ²)	Electric charge
Z^0 Z boson	91.188	0	H Higgs	125.20	0

Higgs Boson
The Higgs boson is a crucial component of the Standard Model. The associated Higgs field provides the mechanism by which fundamental particles get mass. Particles that interact more strongly with the Higgs field are more massive.

Color Charge
The strong force governs only "strong charge" (also called "color charge") and not those strong interactions that occur between those types of color charge. These charges have nothing to do with the color of visible light, and are completely orthogonal quantum charges by exchanging gluons, in strong interactions, color-charged particles, except by exchanging gluons.

Quarks Confined in Mesons and Baryons

Quarks and gluons combine to form hadrons - they are confined in color-neutral particles called hadrons. The confinement (binding) results from multiple exchanges of gluons among the color-charged constituents. As color charges are carried away and gluons have spin, the energy in the interaction field between them increases. The energy eventually is contained into additional quark-antiquark pairs. The quarks and antiquarks then combine into hadrons. There are the particles seen in nature.

The types of hadrons that have been observed in nature consist of all baryons and mesons. Among the many types of baryons observed are the proton (uud), antiproton ($\bar{u}\bar{u}\bar{d}$), and neutron (udd). Quarks change color in just a way as to make the proton have charge +1 and the neutron charge 0. Among the many types of mesons are the pion ($u\bar{d}$), kaon ($u\bar{s}$), and K^0 ($d\bar{s}$).

Learn more at ParticleAdventure.org

Particle Processes

These diagrams are an artist's conception. Charge (red) and color (green) are conserved.



Unsolved Mysteries

Drawn by two scientists in our understanding of the physical world, particle physicists are following paths to new theories and starting theories. Experiments may reveal the more dimensions of space, fundamental laws, hidden forces, and the existence of string theory.

Why is the Universe Accelerating?

The acceleration of the universe's expansion is the accelerating expansion. It is the rate at which the universe's expansion is increasing. This is an accelerating expansion. It is a rate of increase of the rate of expansion of space.

Why No Antimatter?

Matter and antimatter were created in the Big Bang. Why do we see only matter today? For the tiny amounts of antimatter that we have in the lab and observed in cosmic rays?

What is Dark Matter?

Visible forms of matter make up most of the mass observed in galaxies and clusters of galaxies. But the dark matter makes up the rest of the mass. How much dark matter is there?

Are there Extra Dimensions?

All attempts to unify quantum mechanics with the general relativity of gravity combined with the other three fundamental forces, gravity, and electromagnetism, failed. A small region of space is called the neighborhood of Earth's gravity.

A Level Physics Nuclear Physics And Fundamental Particles

Ashok Das, Thomas Ferbel



A Level Physics Nuclear Physics And Fundamental Particles:

Introduction to Nuclear and Particle Physics Ashok Das, Thomas Ferbel, 1994 Stresses the reasoning chain of experimental observation the development of physical principles and how to make math quantitative models Includes more modern material than its competitors Chapters on the techniques of the fields provide a unique perspective and connect the methodologies of nuclear and particle physics In addition explanations of the connection between formalism of theory and more classical concepts bring the theory down to a more understandable level *Nuclear Physics and Fundamental Particles* Roger Muncaster, 1995 Its large format allows for the clear presentation of topics Illustrations and charts are used wherever possible to convey information and enhance the text Student friendly language is used throughout Consolidation sections stress key points Definitions and fundamental points are highlighted Worked examples are included throughout Questions are included at relevant points in the text allowing students to test immediately their understanding of a topic In addition each chapter ends with a selection of questions the majority of which are taken from past examination papers

Cambridge International AS and A Level Physics Coursebook with CD-ROM David Sang, Graham Jones, Gurinder Chadha, Richard Woodside, 2014-08-07 Fully revised and updated content matching the Cambridge International AS A Level Physics syllabus 9702 Endorsed by Cambridge International Examinations the Second edition of the AS A Level Physics Coursebook comprehensively covers all the knowledge and skills students need for AS A Level Physics 9702 first examination 2016 Written by renowned experts in Physics the text is written in an accessible style with international learners in mind The Coursebook is easy to navigate with colour coded sections to differentiate between AS and A Level content Self assessment questions allow learners to track their progression and exam style questions help learners to prepare thoroughly for their examinations Contemporary contexts are discussed throughout enhancing the relevance and interest for learners *The Basics of Nuclear and Particle Physics* Alexander Belyaev, Douglas Ross, 2021-11-08 This undergraduate textbook breaks down the basics of Nuclear Structure and modern Particle Physics Based on a comprehensive set of course notes it covers all the introductory material and latest research developments required by third and fourth year physics students The textbook is divided into two parts Part I deals with Nuclear Structure while Part II delves into Particle Physics Each section contains the most recent science in the field including experimental data and research on the properties of the top quark and Higgs boson Detailed mathematical derivations are provided where necessary to help students grasp the physics at a deeper level Many of these have been conveniently placed in the Appendices and can be omitted if desired Each chapter ends with a brief summary and includes a number of practice problems the answers to which are also provided *Introduction to Nuclear and Particle Physics* Ashok Das, 2003 Annotation Readership Advanced undergraduates and researchers in nuclear and particle physics **University of Michigan Official Publication** University of Michigan, 1989 Each number is the catalogue of a specific school or college of the University *Specialized Discourses and Their Readerships* David

Banks, Emilia Di Martino, 2019-07-05 This volume studies the relationship between the writers of specialized text and their readers in a broad range of settings including research popularization and education It offers younger researchers an insight into the targeting process helping them consider the impact their work can have and showing them how to achieve greater exposure Further it offers an invaluable reflective instrument for beginning and experienced researchers drawing on a veritable treasure trove of their colleagues experience As such it represents a way for researchers and students in linguistics and related disciplines to access issues from a different insider perspective Reader targeting has become a very sophisticated process with authors often addressing their potential readers even in video Compared to other forms of writing academic writing stands out because authors are in the majority of cases also consumers of the same type of products which makes them excellent targeters

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Nuclear and Particle Physics Brian R. Martin, 2011-08-31 An accessible introduction to nuclear and particle physics with equal coverage of both topics this text covers all the standard topics in particle and nuclear physics thoroughly and provides a few extras including chapters on experimental methods applications of nuclear physics including fission fusion and biomedical applications and unsolved problems for the future It includes basic concepts and theory combined with current and future applications An excellent resource for physics and astronomy undergraduates in higher level courses this text also serves well as a general reference for graduate studies

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Atomic and Nuclear Physics Thomas Albert Littlefield, 2012-12-06 After the death of Dr Littlefield it was decided that I should undertake the revision of the whole of Atomic and Nuclear Physics an Introduction for the third edition and it was soon apparent that major changes were necessary I am confident that these changes would have had Dr Littlefield's approval The prime consideration for the present edition has been to modernize at a minimum cost As much as possible of the second edition has therefore been retained but where changes have been made they have been fairly drastic Thus the chapters on fine structure wave mechanics the vector model of the atom Pauli's principle and the Zeeman effect have been completely restructured The chapters on nuclear models cosmic rays fusion systems and fundamental particles have been brought up to date while a new chapter on charm and the latest ideas on quarks has been included It is hoped that the presentation of the last named will give readers a feeling that physics research can be full of adventure and surprises

Society Membership 1980 Profile Beverly Fearn Porter, Roman Czujko, 1981 This 1980 profile provides an overview of

employment stability and change among a small random sample of U S and Canadian members of The American Institute of Physics AIP member societies The American Physical Society Optical Society of America Acoustical Society of America The Society of Rheology American Association of Physics Teachers American Astronomical Society American Crystallographic Society American Association of Physicists in Medicine and American Vacuum Society Specific topics presented in the text and illustrated in charts and graphs include employment 1980 subfields salaries employment 1979 80 salary increases 1979 80 employment and salary changes 1979 80 and society membership profiles Five appendices include 1 detailed statistical tables on 1980 demographic and employment characteristics 1980 salaries and 1979 80 salary comparisons 2 a list of geographic regions 3 dropping society membership 4 methodology used in the survey and 5 a list of definitions and technical notes SK **Catalogue** Kansas State Agricultural College, Kansas State College of Agriculture and Applied Science, Kansas State University, 1972 *Technical Information Pilot* , 1951

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This book is crafted in an easy-to-understand language and is complemented by engaging illustrations. It is highly recommended for anyone seeking to gain a comprehensive understanding of A Level Physics Nuclear Physics And Fundamental Particles.

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