Magnetohydrodynamics Of The Sun

With ninety per cent of visible matter in the universe existing in the plasma state, an understanding of magnetohydrodynamics is essential for anyone looking to understand solar and astrophysical processes, from stars to accretion discs and galaxies; as well as laboratory applications focused on harnessing controlled fusion energy. This introduction to magnetohydrodynamics brings together the theory of plasma behavior with advanced topics including the applications of plasma physics to thermonuclear fusion and plasma- astrophysics. Topics covered include streaming and toroidal plasmas, nonlinear dynamics, modern computational techniques, incompressible plasma turbulence and extreme transonic and relativistic plasma flows. The numerical techniques needed to apply magnetohydrodynamics are explained, allowing the reader to move from theory to application and exploit the latest algorithmic advances. Bringing together two previous volumes: Principles of Magnetohydrodynamics and Advanced Magnetohydrodynamics, and completely updated with new examples, insights and applications, this volume constitutes a comprehensive reference for students and researchers interested in plasma physics, astrophysics and thermonuclear fusion.

Senior undergraduate and graduate textbook on key area in plasma physics and astrophysics.

Magnetohydrodynamics describes dynamics in electrically conductive fluids. These occur in our environment as well as in our atmosphere and magnetosphere, and play a role in the sun's interaction with our planet. In most cases these phenomena involve turbulences, and thus are very challenging to understand and calculate. A sound knowledge is needed to tackle these problems. This work gives the basic information on turbulence in nature, comtaining the needed equations, notions and numerical simulations. The current state of our knowledge and future implications of MHD turbulence are outlined systematically. It is indispensable for all scientists engaged in research of our atmosphere and in space science.

In September 1984 a Summer School on Solar System Plasmas was held at Imperial College with the support of the Science and Engineering Research Council. An excellent group of lecturers was assembled to give a series of basic talks on the various aspects of the subject, aimed at Ph. D. students or researchers from related areas wanting to learn about the plasma physics of the solar system. The students were so appreciative of the lectures that it was decided to write them up as the present book. Traditionally, different areas of solar system science, such as solar and magnetospheric physics, have been studied by separate communities with little contact. However, it has become clear that many common themes cut right across these distinct topics, such as magnetohydrodynamic instabilities and waves, magnetic reconnect ion , convection, dynamo activity and particle acceleration. The plasma parameters may well be quite different in the Sun's atmosphere, a cometary tailor Jupiter's magnetosphere, but many of the basic processes are similar and it is by studying them in different environments that we come to understand them more deeply. Furthermore, direct in situ measurements of plasma properties at one point in the solar wind or the magnetosphere complement the more global view by remote sensing of a similar phenomenon at the Sun.

A collection of papers edited by four experts in the field, this book sets out to describe the way solar activity is manifested in observations of the solar interior, the photosphere, the chromosphere, the corona and the heliosphere. The 11-year solar activity cycle, more generally known as the sunspot cycle, is a fundamental property of the Sun. This phenomenon is the generation and evolution of magnetic fields in the Sun’s convection zone, the photosphere. It is only by the careful enumeration and description of the phenomena and their variations that one can clarify their interdependences. The sunspot cycle has been tracked back about four centuries, and it has been recognized that to make this data set a really useful tool in understanding how the activity cycle works and how it can be predicted, a very careful and detailed effort is needed to generate sunspot numbers. This book deals with this topic, together with several others that present related phenomena that all indicate the physical processes that take place in the Sun and its exterior environment. The reviews in the book also present the latest theoretical and modelling studies that attempt to explain the activity cycle. It remains true, as has been shown in the unexpected characteristics of the first two solar cycles in the 21st century, that predictability remains a serious challenge. Nevertheless, the highly expert and detailed reviews in this book, using the very best solar observations from both ground- and space based telescopes, provide the best possible report on what is known and what is yet to be discovered. Originally published in Space Science Reviews, Vol 186, Issues 1-4, 2014.

Magnetohydrodynamics of the Sun is a completely new up-to-date rewrite from scratch of the 1982 book Solar Magnetohydrodynamics, taking account of enormous advances in understanding since that date. It describes the subtle and complex interaction between the Sun's plasma atmosphere and its magnetic field, which is responsible for many fascinating dynamic phenomena. Chapters cover the generation of the Sun's magnetic field by dynamo action, magnetoconvection and the nature of photospheric flux tubes such as sunspots, the heating of the outer atmosphere by waves or reconnection, the structure of prominences, the nature of eruptive instability and magnetic reconnection in solar flares and coronal mass ejections, and the acceleration of the solar wind by reconnection or wave-turbulence. It is essential reading for graduate students and researchers in solar physics and related fields of astronomy, plasma physics and fluid dynamics. Problem sets and other resources are available at www.cambridge.org/9780521854719.

The mapping of the surface of stars requires diverse skills, analysis techniques and advanced modeling, i.e. the collaboration of scientists in various specialties. This volume gives insights into new techniques allowing for the first time to obtain resolved images of stars. It takes stock of what has been achieved so far in Chile, on the ESO VLTI instrument or, in the States, on the CHARA instrument. In recent times interferometry, combined with adaptive optics has allowed to reconstruct images of stars. Besides the Sun (of course) by now five stars have been resolved in detail. In addition to interferometry, this book highlights techniques used for mapping the surfaces of stars using photometry made by space observatories; Zeeman- and Doppler Imaging; mapping the surface element abundances via spectroscopy. This book will also take stock of the best images of the solar surface, made by connecting the differential rotation to the underlying physical parameters derived from helioseismology. Recent measurements of flattening of the solar surface by SDO showed that the Sun’s shape is linked to the rotation of the core. It is shown how such a result is generalizable to the stars.

An introductory text on magnetohydrodynamics for advanced students, covering its broad range of applications in nature and in the laboratory.

Leading experts present the current state of knowledge of the subject of magnetoconvection from the viewpoint of applied mathematics.

The Sun as a Guide to Stellar Physics illustrates the significance of the Sun in understanding stars through an examination of the discoveries and insights gained from solar physics research. Ranging from theories to modeling and from numerical simulations to instrumentation and data processing, the book provides an overview of what we currently understand and how the Sun can be a model for gaining further knowledge about stellar physics. Providing both updates on recent developments in solar physics and applications to stellar physics, this book strengthens the solar–stellar connection and summarizes what we know about the Sun for the stellar, space, and geophysics communities. Applies observations, theoretical understanding, modeling capabilities and physical processes first revealed by the sun to the study of stellar physics Illustrates how studies of Proxima Solaris have led to progress in space science, stellar physics and related fields Uses characteristics of solar phenomena as a guide for understanding the physics of stars

Many approaches exist for scientific investigations and space research is no exception. The early approach during which each space plasma region within the Sun-Earth system was investigated separately with physics-based tools has now progressed to encompass investigations on coupling between these regions. Ample evidence now exists indicating the dynamic processes in these regions exhibit disturbances over a wide range of scales both in time and space. This new reckoning naturally leads to an emerging perspective of probing these natural phenomena with concepts and tools developed in modern statistical mechanics for physical processes governing the evolution of out-of-equilibrium and complex systems. These new developments have prompted a topical conference on Sun-Earth connection, held on February 9-13, 2004 at Kailua-Kona, Hawaii, USA, with the goal of promoting interactions among scientists practicing the traditional physics-based approach and those utilizing modern statistical techniques. This monograph is a product of this conference, a compilation of thirty-nine articles assembled into seven chapters: (1) multiscale features in complexity dynamics, (2) space storms, (3) magnetospheric substorms, (4) turbulence and magnetic reconnection, (5) modeling and coupling of space phenomena, (6) techniques for multiscale space plasma problems, and (7) present and future multiscale space missions. These articles show a diversity of space phenomena exhibiting scale free characteristics, intermittency, and non-Gaussian distributions of probability density function of fluctuations in the physical parameters of the Sun-Earth system. The scope covers the latest observations, theories, simulations, and techniques on the multiscale nature of Sun-Earth phenomena and underscores the usefulness in cross-disciplinary exchange needed to unravel the underlying physical processes, which may eventually lead to a possible unified description and prediction for space disturbances. * Extensive collection of state-of-the-art papers on multiscale coupling of Sun-Earth Processes * Present and future multiscale space missions * New techniques and models for performing multiscale analysis

An introduction to magnetohydrodynamics combining theory with advanced topics including the applications of plasma physics to thermonuclear fusion and plasma astrophysics.

The book is an introduction to the subject of fluid mechanics, essential for students and researchers in many branches of science. It illustrates its fundamental principles with a variety of examples drawn mainly from astrophysics and geophysics as well as from everyday experience. Prior familiarity with basic thermodynamics and vector calculus is assumed.

Alfven waves permeate the universe. They have been observed in the Sun, in the magnetosphere, as low frequency fluctuations in the Earth's magnetic field, and they are easily generated in laboratory plasmas. Alfven waves serve as a useful diagnostic tool to probe plasma conditions in both space and laboratory plasmas. In the quest for nuclear fusion they have been used with spectacular success to heat tokamak plasmas to temperatures exceeding 50 million Kelvin. This book aims to provide an introduction to the physics of Alfven wave propagation for postgraduate physicists and astrophysicists who are entering research on laboratory or space plasmas. In the early chapters the basic properties of Alfven waves are derived for homogeneous plasmas, using the ideal magnetohydrodynamic fluid equations. The essential differences between torsional and compressional wave types are highlighted by an examination of phase and group velocity surfaces, and by a discussion of recent experimental results obtained with small, 'point-source', antennae. Later chapters deal with cylindrical plasmas, Alfven waves in a plasma with two or more ion species, effects of plasma current, resistive damping and inhomogeneous plasmas. There are also two chapters about numerical and experimental techniques, topics which are often neglected in other books.

Following on from the companion volume Principles of Magnetohydrodynamics, this textbook analyzes the applications of plasma physics to thermonuclear fusion and plasma astrophysics from the single viewpoint of MHD. This approach turns out to be ever more powerful when applied to streaming plasmas (the vast majority of visible matter in the Universe), toroidal plasmas (the most promising approach to fusion energy), and nonlinear dynamics (where it all comes together with modern computational techniques and extreme transonic and relativistic plasma flows). The textbook interweaves theory and explicit calculations of waves and instabilities of streaming plasmas in complex magnetic geometries. It is ideally suited to advanced undergraduate and graduate courses in plasma physics and astrophysics.

This book revises the evolution of ideas in various branches of magnetohydrodynamics (astrophysics, earth and solar dynamos, pinch, MHD turbulence and liquid metals) and reviews current trends and challenges. Uniquely, it contains the review articles on the development of the subject by pioneers in the field as well as leading experts, not just in one, but in various branches of magnetohydrodynamics, such as liquid metals, astrophysics, dynamo and pinch.

This textbook, derived from courses given by three leading researchers, provides advanced undergraduates and graduates with up-to-date coverage of space physics, from the Sun to the interstellar medium. Clear explanations of the underlying physical processes are presented alongside major new discoveries and knowledge gained from space missions, ground-based observations, theory, and modelling to inspire students. Building from the basics to more complex ideas, the book contains enough material for a two-semester course but the authors also provide suggestions for how the material can be tailored to fit a single semester. End-of-chapter problems reinforce concepts and include computer-based exercises specially developed for this textbook package. Free access to the software is available via the book's website and enables students to model the behavior of magnetospheric and solar plasma. An extensive glossary recaps new terms and carefully selected further reading sections encourage students to explore advanced topics of interest.

A good working knowledge of fluid mechanics and plasma physics is essential for the modern astrophysicist. This graduate textbook provides a clear, pedagogical introduction to these core subjects. Assuming an undergraduate background in physics, this book develops fluid mechanics and plasma physics from first principles. This book is unique because it presents neutral fluids and plasmas in a unified scheme, clearly indicating both their similarities and their differences. Also, both the macroscopic (continuum) and microscopic (particle) theories are developed, establishing the connections between them. Throughout, key examples from astrophysics are used, though no previous knowledge of astronomy is assumed. Exercises are included at the end of chapters to test the reader's understanding. This textbook is aimed primarily at astrophysics graduate students. It will also be of interest to advanced students in physics and applied mathematics seeking a unified view of fluid mechanics and plasma physics, encompassing both the microscopic and macroscopic theories.

I have felt the need for a book on the theory of solar magnetic fields for some time now. Most books about the Sun are written by observers or by theorists from other branches of solar physics, whereas those on magnetohydrodynamics do not deal extensively with solar applications. I had thought of waiting a few decades before attempting to put pen to paper, but one summer Josip Kleczek encouraged an im mediate start 'while your ideas are still fresh'. The book grew out of a postgraduate lecture course at St Andrews, and the resulting period of gestation or 'being with monograph' has lasted several years. The Sun is an amazing object, which has continued to reveal completely unexpected features when observed in greater detail or at new wavelengths. What riches would be in store for us if we could view other stars with as much precision! Stellar physics itself is benefiting greatly from solar discoveries, but, in tum, our understanding of many solar phenomena (such as sunspots, sunspot cycles, the corona and the solar wind) will undoubtedly increase in the future due to their observation under different conditions in other stars. In the 'old days' the solar atmosphere was regarded as a static, plane-parallel structure, heated by the dissipation of sound waves and with its upper layer expanding in a spherically symmetric manner as the solar wind. Outside of sunspots the magnetic field was thOUght to be unimportant with a weak uniform value of a few gauss.

This unique , authoritative book introduces and accurately depicts the current state-of-the art in the field of space storms. Professor Koskinen, renowned expert in the field, takes the basic understanding of the system, together with the pyhsics of space plasmas, and produces a treatment of space storms. He combines a solid base describing space physics phenomena with a rigourous theoretical basis. The topics range from the storms in the solar atmosphere through the solar wind, magnetosphere and ionosphere to the production of the storm-related geoelectric field on the ground. The most up-to-date information available ist presented in a clear, analytical and quantitative way. The book is divided into three parts. Part 1 is a phenomenological introduction to space weather from the Sun to the Earth. Part 2 comprehensively presents the fundamental concepts of space plasma physics. It consists of discussions of fundamental concepts of plasma physics, starting from underlying electrodynamics and statistical physics of charged particles and continuing to single particle motion in homogeneous electromagnetic fields, waves in cold plasma approximation, Vlasov theory, magnetohydrodynamics, instabilities in space plasmas, reconnection and dynamo. Part 3 bridges the gap between the fundamental plasma physics and research level physics of space storms. This part discusses radiation and scattering processes, transport and diffiusion, shocks and shock acceleration, storms on the Sun, in the magnetosphere, the coupling to the atmosphere and ground. The book is concluded wtih a brief review of what is known of space stroms on other planets. One tool for building this briege ist extensive cross-referencing between the various chapters. Exercise problems of varying difficulty are embedded within the main body of the text.

Electric currents are fundamental to the structure and dynamics of space plasmas, including our own near-Earth space environment, or “geospace.”This volume takes an integrated approach to the subject of electric currents by incorporating their phenomenology and physics for many regions in one volume. It covers a broad range of topics from the pioneers of electric currents in outer space, to measurement and analysis techniques, and the many types of electric currents. First volume on electric currents in space in over a decade that provides authoritative up-to-date insight on the current status of research Reviews recent advances in observations, simulation, and theory of electric currents Provides comparative overviews of electric currents in the space environments of different astronomical bodies Electric Currents in Geospace and Beyond serves as an excellent reference volume for a broad community of space scientists, astronomers, and astrophysicists who are studying space plasmas in the solar system. Read an interview with the editors to find out more: https://eos.org/editors-vox/electric-currents-in-outer-space-run-the-show

The book presents an advanced but accessible overview of some of the most important sub-branches of magnetohydrodynamics (MHD): stability theory, magnetic topology, relaxation theory and magnetic reconnection. Although each of these subjects is often treated separately, in practical MHD applications they are normally inseparable. MHD is a highly active field of research.The book is written for advanced undergraduates, postgraduates and researchers working on MHD-related research in plasma physics and fluid dynamics.

Spheromaks are easily formed, self-organized magnetized plasma configurations that have intrigued plasma physicists for over two decades. Sometimes called magnetic vortices, magnetic smoke rings, or plasmoids, spheromaks first attracted attention as a possible controlled thermonuclear plasma confinement scheme, but are now known to have many other applications. This book begins with a review of the basic concepts of magnetohydrodynamics and toroidal magnetic configurations, then provides a detailed exposition of the 3D topological concepts underlying spheromak physics, namely magnetic helicity, Taylor relaxation, force-free equilibria, and tilt stability. It then examines spheromak formation techniques, driven and isolated configurations, dynamo concepts, practical experimental issues, diagnostics, and a number of applications. The book concludes by showing how spheromak ideas are closely related to the physics of solar prominences and interplanetary magnetic clouds. Contents: Basic ConceptsMagnetic HelicityRelaxation of an Isolated Configuration to the Taylor StateRelaxation in Driven ConfigurationsThe MHD Energy Principle, Helicity, and Taylor StatesSurvey of Spheromak Formation SchemesClassification of Regimes: An Imperfect Analogy to ThermodynamicsAnalysis of Isolated Cylindrical SpheromaksThe Role of the WallAnalysis of Driven Spheromaks: Strong CouplingHelicity Flow and DynamosConfinement and Transport in SpheromaksSome Important Practical IssuesBasic Diagnostics for SpheromaksApplications of SpheromaksSolar and Space Phenomena Related to Spheromaks Readership: Graduate students and advanced undergraduates who have taken a course in plasma magnetohydrodynamics, laboratory plasma physicists, solar & space plasma physicists, and scientists interested in the topological dynamics of self-organizing configurations. Keywords:Spheromak;Magnetohydrodynamics (MHD);Plasma;Self-Organization;Magnetic Helicity;Fusion;Solar;Coronal;Tokamak;Astrophysics;Relaxation;Taylor;Reversed Field Pinch (RFP);Dynamo

Develops a fresh mathematical approach to coronal seismology, explaining oscillatory phenomena by drawing upon original research and complex modelling techniques.

This advanced textbook reviews the complex interaction between the Sun's plasma atmosphere and its magnetic field.

Magnetic energy release plays an important role in a wide variety of cosmic objects such as the Sun, stellar coronae, stellar and galactic accretion disks and pulsars. The observed radio, X-ray and gamma-ray emission often directly results from magnetic `flares', implying that these processes are spatially fragmented and of an impulsive nature. A true understanding of these processes requires a combined magnetohydrodynamical and plasma physical approach. Fragmented Energy Release in Sun and Stars: the Interface between MHD and Plasma Physics provides a comprehensive, interdisciplinary summary of magnetic energy release in the Sun and stars, in accretion disks, in pulsar magnetospheres and in laboratory plasmas. These proceedings include papers on both theoretical and observational aspects. Fragmented Energy Release in Sun and Stars: the Interface between MHD and Plasma Physics is for researchers in the fields of solar physics, stellar astrophysics and (laboratory) plasma physics and is a useful resource book for graduate level astrophysics courses.

The authors explore solar flares by applying physics and theoretical investigations.

This text provides a comprehensive introduction to space physics.

This book gives a concise description of the phenomenon of plasma relaxation from the point of view of resistive magnetohydrodynamic (MHD) theory. Magnetized plasmas relax when they seek their natural state of lowest energy subject to certain topological constraints imposed by the magnetic field. Relaxation may be fast and dynamic or slow and gradual depending on the external environment in which the magnetoplasma system evolves. Relaxation occurs throughout the universe and may describe such diverse phenomena as dynamos, solar flares, and the operation of magnetic fusion energy experiments. This book concentrates on the dynamic, rather than variational aspects of relaxation. While the processes described are general, the book focuses on the reversed-field pinch experiment as a paradigm for plasma relaxation and dynamo action. Examples from other branches of plasma physics are also discussed. The authors draw upon their extensive experience in numerical and experimental studies of relaxation.

Most of the visible matter in the universe exists in the plasma state. Plasmas are of major importance for space physics, solar physics, and astrophysics. On Earth they are essential for magnetic controlled thermonuclear fusion. This textbook collects lecture notes from a one-semester course taught at the K.U. Leuven to advanced undergraduate students in applied mathematics and physics. A particular strength of this book is that it provides a low threshold introduction to plasmas with an emphasis on first principles and fundamental concepts and properties. The discussion of plasma models is to a large extent limited to Magnetohydrodynamics (MHD) with its merits and limitations clearly explained. MHD provides the students on their first encounter with plasmas, with a powerful plasma model that they can link to familiar classic fluid dynamics. The solar wind is studied as an example of hydrodynamics and MHD at work in solar physics and astrophysics.

The reconnection of magnetic fields is one of the most fascinating processes in plasma physics, responsible for phenomena such as solar flares and magnetospheric substorms. The concept of reconnection has developed through recent advances in exploring the magnetospheres of the Sun and Earth through theory, computer simulations and spacecraft observations. The great challenge in understanding it stems from balancing the large volumes of plasma and magnetic fields involved with the energy release with the physical mechanism which relies on the strongly localized behavior of charged particles. This book, edited by and with contributions from leading scientists in the field, provides a comprehensive overview of recent theoretical and observational findings concerning the physics of reconnection and the complex structures that may give rise to, or develop from, reconnection. It is intended for researchers and graduate students interested in the dynamics of plasmas.

This volume is devoted to the dynamics and diagnostics of solar magnetic fields and plasmas in the Sun’s atmosphere. Five broad areas of current research in Solar Physics are presented: (1) New techniques for incorporating radiation transfer effects into three-dimensional magnetohydrodynamic models of the solar interior and atmosphere, (2) The connection between observed radiation processes occurring during flares and the underlying flare energy release and transport mechanisms, (3) The global balance of forces and momenta that occur during flares, (4) The data-analysis and theoretical tools needed to understand and assimilate vector magnetogram observations and (5) Connecting flare and CME phenomena to the topological properties of the magnetic field in the Solar Atmosphere. The role of the Sun’s magnetic field is a major emphasis of this book, which was inspired by a workshop honoring Richard C. (Dick) Canfield. Dick has been making profound contributions to these areas of research over a long and productive scientific career. Many of the articles in this topical issue were first presented as talks during this workshop and represent substantial original work. The workshop was held 9 – 11 August 2010, at the Center Green campus of the National Center for Atmospheric Research (NCAR) in Boulder, Colorado. This volume is aimed at researchers and graduate students active in solar physics, solar-terrestrial physics and magneto-hydrodynamics. Previously published in Solar Physics journal, Vol. 277/1, 2012.

A thorough introduction to solar physics based on recent spacecraft observations. The author introduces the solar corona and sets it in the context of basic plasma physics before moving on to discuss plasma instabilities and plasma heating processes. The latest results on coronal heating and radiation are presented. Spectacular phenomena such as solar flares and coronal mass ejections are described in detail, together with their potential effects on the Earth.

Most of the solar system is in the plasma state and its subtle non-linear interaction with the magnetic field is described by the equations of magnetohydrodynamics (MHD). This book examines the basic MHD topics, such as equilibria, waves, instabilities and reconnection, and examines each in a context of different areas that utilize MND.

Data from spacecraft such as Pioneer, Vela and Voyager have revealed the interstellar medium to be a remarkable physical system, which has served as a laboratory for the study of turbulent, supersonic, ideal magnetohydrodynamic (MHD) flows. The results of these studies provided confirmation of many theoretical models of the interstellar medium.