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BOOK REVIEWS

Magnetohydrodynamic Turbulence, by Dieter Biskamp. Cambridge University Press, 2003. 298+xii pages. ISBN 0 521 81011 6. £65.
DOI: 10.1017/S0022377804213083

Magnetohydrodynamic (MHD) turbulence is one of the most interesting and important areas of plasma physics. However, since it is a very broad and difficult subject, normal plasma physics textbooks usually only mention it briefly, if at all. On the other hand, up to now there has not been any monograph devoted solely to MHD turbulence. This gap has now been filled by the book by D. Biskamp who is an expert in the field. MHD is the appropriate description for large-scale plasma systems such as those occurring in astrophysics. Turbulence, in particular, has been recognized as playing a major role in our understanding of many of the physical processes taking place in these systems. Also, MHD turbulence is interesting in its own right as a theoretical challenge to understand scaling and universality concepts in turbulent magnetized fluids. This book covers both the theoretical aspects and astrophysical applications, namely solar wind, accretion disks and interstellar turbulence.

There are in all 12 chapters, which can be grouped into four major parts: an introductory part consisting of Chapters 2 and 3 (Chapter 1 is an overview of the whole treatise); incompressible turbulence (Chapters 4–7); two-dimensional and compressible turbulence (Chapters 8 and 9, respectively); and astrophysical applications (Chapters 10–12).

In Chapter 2 the basic concepts of MHDs are introduced. The MHD equations are derived following a heuristic approach and other important related subjects are discussed, such as incompressibility, rotating and stratified systems, conservation laws, equilibrium configurations and linear waves.

Chapter 3 deals with the transition from a smooth flow to turbulence. There is an initial discussion of the problem of finite time singularities of ideal equations, followed by an overview of basic instabilities, like Kelvin–Helmholtz, Rayleigh–Taylor and the tearing instability. The nonlinear evolution of the instabilities is also briefly discussed.

Chapters 4–7 represent the core of the book and address the statistical theory of incompressible turbulence. One- and two-point closure theories are discussed in great detail. Scaling arguments are clearly explained, highlighting the similarities and differences between MHDs and hydrodynamic turbulence. Chapter 7 is entirely devoted to the important problem of intermittency.

Two-dimensional MHD turbulence is treated in Chapter 8. Again a large part of the chapter is devoted to the hydrodynamic case in order to compare it with the MHD case. Compressible turbulence, which is of great importance in astrophysics, is considered in Chapter 9, together with turbulent convection, passive scalar turbulence and magnetoconvection.

I particularly enjoyed the last three chapters discussing the applications. They contain a general introduction to each subject and can be read independently of the other parts of the book.

Strong emphasis is placed throughout on results from numerical computations, which are often the only way to verify the validity of theoretical modeling. Considering the large variety of topics covered in the book, the readers, especially if students, will occasionally need to supplement the material in the book by additional reading (e.g. more basic textbooks or some of the referenced papers). The large bibliography includes many sources for further reading. The material is up to date and several chapters provide references up to 2001.

In conclusion, I would recommend this book to all those who would like to undertake a serious study of MHD turbulence, be it from a theoretical point of view or because they are interested in applications. The book is also suitable for researchers working in the field of MHD turbulence, as an up to date account of the current status of research.

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Plasma and Fluid Turbulence, Theory and Modelling, by A. Yoshizawa, S.-I. Itoh and K. Itoh. IOP Publishing, Bristol, 200X, Series in Plasma Physics. Editors: S. Cowley, P. Stott and H. Wilhelmsson. ISBN 07503 08710.
DOI: 10.1017/S002237780422308X

This monograph is well written and has been beautifully produced by IOP Publishing. In this reviewer's view, it constitutes a worthy addition to the literature on the technologically and scientifically important fields of fluid and plasma turbulence. It is unusual in its wide scope, encompassing both traditional fluid dynamics, which seeks to describe flow phenomena in neutral gases and liquids, and plasma physics. The latter is a relatively recent off shoot of fluid dynamics, which attempts to describe fully ionized gases subjected to electromagnetic fields obeying Maxwell's equations. The authors are well known for their many contributions to these subjects and are thus well qualified to write this monograph. They present their work in an attractive and pedagogically accessible manner. Indeed, the book would also make a good graduate level text book. In this connection, the omission on the authors' part of not including worked examples and problems for the student seems rather unfortunate.

The book is divided into four parts. Part I is a general introduction to fluids and plasmas. The authors discuss the notion of 'structure formation' (sometimes known as morphogenesis in nonlinear dynamics). Part II is concerned with fluid turbulence covered in three chapters. Part III deals with magnetohydrodynamic (MHD) turbulence, exemplified by the dynamo. The authors devote four chapters to this topic. Part IV takes up the second half of the book and is devoted to plasma turbulence which the authors discuss in no less than 16 chapters. By the authors' own admission, an encyclopedic coverage is not attempted. This is a wide decision in this reviewer's opinion. However, the treatment is generally clear and relatively easy-paced. References to some of the vast literature is provided at the end of each chapter.

Chapter 2 on 'Structure Formation in Fluids and Plasmas' gives a qualitative account of why turbulence occurs in fluids and plasmas. The examples given are not necessarily ones which would be intuitive for the student (perhaps they could have begun with Rayleigh–Taylor, thermal-convective and Kelvin–Helmholtz instabilities which can be more simply explained than the subtle nonlinear instability of Poiseuille flow?). Chapter 3 moves on to the 'fundamentals of Fluid Turbulence'. This subject is well served by many classics, some of which are found in the reference list. I was somewhat disappointed to miss references to Monin and Yaglom's two volume treatise, as well as books by C. C. Lin and Drazin and Reid (on hydrodynamic stability). In my view, the treatment of transition to turbulence should have been more systematic than the authors are prepared to discuss, and forms a necessary prelude to any study of 'full-developed' turbulence.

Chapter 4 takes up the important practical matter of turbulence modelling. Here the authors give a good general account of various models, without, however, discussing the rationale and experimental justification for the various models in detail. The work of such fluid turbulence-modelling pioneers like D. B. Spalding is passed over in silence. The next chapter on the statistical theory of turbulence is rather formal and presents long calculations but seems weak on results. This may not be the fault of the authors but of the approach: little empirical value seems to have come out of this 'statistical mechanics of fluids' apart from general results based on dimensional arguments like the Kolmogorov spectrum for the inertial sub-range.

In Part III, the authors apply the techniques developed previously to give an account of dynamo theory within the MHD model. There are a lot of formal manipulations leading to (7.20), which expresses the electric field generated by MHDs in terms of the mean magnetic field (so-called 'alpha effect'), mean current density (so-called 'turbulent resistivity') and the mean vorticity (in the authors' notation, a 'gamma effect'). The *real* difficulty with all theories is the lack of a systematic calculation of the coefficients involved in terms of the characteristics of the decidedly anisotropic and inhomogeneous turbulence. The authors do not treat this question (effectively a 'closure problem') in any detail. In Chapter 8, they do provide some model equations based on heuristic closures. These are then applied in Chapters 9 and 10 to solar, geomagnetic, accretion-disk, reversed-field pinch and tokamak problems. Some of these results are indeed interesting, if somewhat speculative. What is not clear is if the methods used are truly predictive of the phenomena they are supposed to explain. In other words, have the models genuinely predicted a new result where one was not initially expected and not already revealed experimentally?

Part IV begins with some remarks where the authors state clearly that plasma turbulence (unlike fluid turbulence) usually involves kinetic effects and it is not at all obvious that a 'fluid-like' theory to which they restrict themselves is sufficient to satisfactorily describe experiment. The authors state some of the many well-known sets of fluid equations derived by various workers omitting others. Unfortunately, this is not a critical survey of the approximations used in these models. Even the key concept of quasi-neutrality of most plasmas encountered in applications and the nature of the electric field in such conditions is not discussed. Since many students are confused by the role played by Gauss' law in quasi-neutral plasma physics (this, despite excellent texts like that of Francis Chen which explain the matter thoroughly and accurately!), it would have been useful to at least motivate why plasma turbulence encountered in practice can be so treated. However, the authors do give a good discussion of why plasma turbulence is generated: it is quintessentially characteristic of a *driven, dissipative* system. The 'turbulence' in a completely conservative model is constrained by the integral invariants of the system and is much more like a system of nonlinearly interacting random waves in a frictionless fluid confined in a bounded domain.

Chapter 12 introduces the reader to some well-know linear instabilities. In an appendix, the quasi-linear transport theory is treated. A key point about the quasi-linear estimates of transport is the actual meaning of the average when the amplitudes are supposed to be linearly (usually rapidly) growing modes. Why then is the resultant 'transport matrix' (say (12A.3)) valid as it will be a very rapidly growing (at twice the linear growth rate!) object? Yet when quasi-linear theory estimates are used, this key point is conveniently forgotten. The real fact is of course that the averages are only relevant to the very earliest stages of any linear instability and the transport coefficients obtained by the procedure have no necessary connection to the final saturated turbulent state which is what the authors are concerned with. This criticism has been made by many authors (e.g. P. Diamond amongst others) and deserves a careful discussion in a monograph such as this. Quasi-linear estimates often give the 'correct' experimental order of magnitudes of experimentally measured transport quantities, but this depends upon several acts of faith about the non-dimensional constants which involve saturation amplitudes. Conclusions about real experiments based on such estimates should be treated with suspicion and great caution. An alert reader of this book might well be tempted to ask 'if quasi-linear theory is supposed to be effective in plasma turbulence theory, why then is it never used or introduced in fluid turbulence theory?'.

The later chapters go on to discuss various approximate turbulence theories which have been developed. This part of the book is a useful compendium of what passes for currently received wisdom with selective references. Whether this type of theory is actually able to account for phenomena in a predictive way is an entirely different question. The key difficulty, as I see it, is this: turbulence and plasma profiles are intimately, *dynamically* linked. There is no clear separation between the mesoscale and the macroscale. Just as traditional theories of fluid turbulence are not very effective in highly inhomogeneous experimental situations, approaches based on evaluating linear growth rates on fixed profiles miss most of the essential features such as 'corrugations' in the current and temperature profiles routinely seen in global numerical simulations. To be really relevant to experiment, linear theories must be carried out on profiles which are rapidly varying on the spatio-temporal mesoscales. This is well-nigh impossible (indeed, just about as difficult as solving the full nonlinear equations!) and hence realistic turbulence theories must be essentially computational and should not be based on quasi-linear guesstimates.

The authors put forward theories of zonal flow generation and their suppression effects and of bifurcations in plasmas. The most interesting examples are to be found in Chapters 16–22. The coverage here seems somewhat parochial and restricted to models developed largely by the authors. For example, little or no account of other ideas of zonal flow generation based on the modulational instability mechanism for zonal flow generation is given. There are similar selection effects apparent in other parts of the book. The reader should be aware of this tendency of the authors to avoid critical discussions of approaches significantly different from their own ideas. In a monograph which purports to give a balanced account of current research in the fields it treats, this neglect seems hard to justify.

In spite of these remarks, I believe this book should prove useful to the readership it addresses. The authors deserve to be congratulated for taking a very difficult and multi-faceted subject and giving a relatively straightforward, no-nonsense account of its many subtleties and ramifications. The editors and publishers have done an excellent job of production. In later editions, the authors should seriously consider reducing at least some of the largely redundant formalism (e.g. Green's functions, perturbation expansions and elaborate formulas which cannot be evaluated in any given application, with little or no meaningful function and which ultimately lead to no practically useful results which can be tested against experiment) to a minimum and to introduce more comparisons between different approaches (including numerical ones) on the one hand and with experimental data on the other. The inclusion of a set of judiciously chosen problems should make this treatise a more effective and useful pedagogic tool.

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Collisional Transport in Magnetized Plasmas, by Per Helander and Dieter J. Sigmar, Cambridge Monograph on Plasma Physics, Cambridge University Press (2002).
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The transport of particles and energy in a magnetized plasma is of considerable importance to diverse fields such as space physics, astrophysics and of crucial importance to magnetic fusion devices. The neoclassical theory of transport is a highly developed body of work which began in the late 60s and continues to be an extremely active area of research. The term neoclassical refers to purely collisional transport with full allowance for the effects of a toroidal magnetic field. No turbulent effects are included so that the theory should provide the irreducible minimum level of transport to be expected in a toroidal plasma. The theory predicted the existence of the "bootstrap" current which is a vital ingredient for present and planned magnetic confinement devices.

Collisional Transport in Magnetized Plasmas by Per Helander and Dieter J. Sigmar emerged from over two decades of graduate courses at MIT. The book is of a readable length of 275 pages, consists of 14 chapters and aims to bridge the gap between the basic text of Braginskii and the research literature. The first two (introductory) chapters discuss collision frequencies, random walks and diffusion and contrast the kinetic and fluid pictures. A clear and thorough account of the many different forms of collision operator is given in which the authors stress the physics of the various interactions.

The reader is then taken through a more detailed account of the fluid description leading to a discussion of the transport of particles, momentum and heat in a cylindrical plasma. In preparation for the complexities of toroidal magnetic fields a chapter on particle orbits is provided containing an elegant and relevant description of Whitham's averaged Lagrangian approach, a discussion of adiabatic invariants and a derivation of the drift kinetic equation.

The key topic of an axisymmetric toroidal magnetic field is introduced through a discussion of magnetohydrodynamic equilibrium and guiding centre orbits. The chapter concludes with a brief discussion of the extension of the theory to non-axisymmetric systems.

The general principles of transport in toroidal plasmas are first of all discussed. These principles do not depend on the details of the collisionality of the plasma. Three chapters are then devoted to the collisional regime, known as the

Pfirsch-Schluter, and the two long mean free path regimes known as the plateau and "banana" (after the orbits of magnetically trapped particles). The Pfirsch-Schluter regime is adequately described by a fluid theory whereas the second and third require the drift kinetic equation. These three chapters contain the key results of the neoclassical theory.

The implications of the kinetic theory of the long mean free path regimes are analysed in terms of moment equations. This sheds light on the physics behind neoclassical transport but also decouples the kinetics of different particle species (including impurities) from each other, greatly simplifying the calculations. The book concludes with a discussion of some advanced topics and a brief summary of experimental evidence for neoclassical transport theory. Poloidal and toroidal rotation and non-linear transport in steep plasma profiles are described. Poloidal rotation has become a topic of considerable interest since it is believed to be relevant to the formation of transport barriers. If additional poloidal flows are produced (for example, by turbulence) the collisional effects will try to restore the flow to the neoclassical value. The most important validation of neoclassical theory is the observation of the "bootstrap" current in TFTR, JET,JT-60, DIII-D and other machines.

Students, theoreticians and experimentalists in both fusion and space plasma physics should gain from a serious reading of all (or parts) of this book. In their preface, the authors refer to the "committed" student. This is the important qualification. Collisional transport in a magnetically confined toroidal plasma is an extremely complex subject. The authors have given a thorough and systematic account of this difficult subject. The physics of the mathematical analysis is discussed whenever possible. The equations are approximated whenever appropriate in order to make the theory as accessible as possible. The reader is lead progressively towards the goal of collisional transport in a magnetically confined plasma. The more committed the reader, the more he or she will benefit from a study of this book. It is a very welcome addition, indeed asset, to the subject.

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The Physics of Plasmas, by T. J. M. Boyd and J. J. Sanderson. Cambridge University Press, 2003. Hardback: ISBN 0 521 45290 2. Paperback: ISBN 0 521 45912 5. DOI: 10.1017/S0022377804243082

Having used Plasma Dynamics (1969), by the same authors, as a favourite textbook to support my own lectures in plasma physics for several years, until eventually that earlier book went out of print, I looked forward to reading this latest book. Although this text has both a different title and publisher, the authors explain in the Preface that it does have its origins in the earlier book. Having now read it I am pleased to say that "The Physics of Plasmas" has immediately gone on to the recommended reading list for my students.

The text has a direct, clear and unfussy style that achieves a good physical understanding, while retaining a firm mathematical framework. It treats the core topics of fundamental plasma physics. In the intervening years since the authors' earlier book there have been significant developments in plasma physics. Where these developments are relevant to the exposition of the basic theory of plasmas they are included and are supported by several references drawn from the 1970's, 80's and 90's.

This book is best suited for advanced undergraduate, or graduate level students. Professionals working in plasma physics, or those needing to retrain in plasma physics will also find it a valuable book. There are useful exercises at the ends of most chapters, which enhances the book's value. Whereas the authors' earlier book had used Gaussian cgs units, this text uses SI units, which is the sensible choice and will be popular with today's students.

The treatment of the various models of plasmas namely single particle, fluid and kinetic is good. Essentially the first 8, or 9, Chapters provide a core syllabus for a study of plasma physics, where the plasma theory mostly tends to be linear, homogeneous and unbounded. Chapter 10 introduces a variety of important non-linear effects and Chapter 11 demonstrates the effects of inhomogeneity and physical boundaries. Chapter 12 completes the book with the classical theory of plasmas which provides a comprehensive mathematical structure upon which the various models used earlier in the text are based. In a logical sequence of development this could have been the first Chapter but placing it as the final Chapter is much wiser for the majority of readers. Most readers will find the final Chapter more mathematical and the physics of the earlier Chapters can be appreciated without needing to access this final Chapter. For those who wish to gain an understanding of the basis of the plasma models, their motivation is built up through the earlier Chapters and the fuller picture is then made available in Chapter 12.

The material covered would suit plasma physicists with intentions of entering just about any of the plasma specialisations, including magnetic confinement fusion, inertial confinement fusion, and space plasmas. Some of the examples and illustrations are taken from these plasma specialisations but having introduced the reader to these specialised areas of plasma physics, the authors intentionally do not go on to delve into the finer details of these specialisations. These details can be found in several specialised monographs and "The Physics of Plasmas" retains its focus on treating the core plasma physics material that provides the foundations for all plasma specialisations.

Those intending to become technological plasma specialists may find less examples illustrating their field, although many of the plasma fundamentals covered in this text would still be relevant to them. Similarly those seeking information on plasma diagnostic methods and plasma experimental techniques will only find the means to equip themselves with a good understanding of the fundamental physics that supports such diagnostics and experimental techniques, rather than any detailed descriptions.

This book is so well-structured and excellently written that it is a joy to read. It is highly recommended and it should become a classic just like its predecessor.

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