GENERAL PATHS OF REASONING IN MAGNETOHYDRODYNAMICS.

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ABSTRACT.

The objective in this document is to establish a set of scientific competences in order to get the frontiers of research in magnetohydrodynamics mainly orientated to nuclear fusion.

FOUNDATIONS.

1. History.

According to Teller. E [82]: “It seems hard to believe that only half a century has passed since Atkinson and Houtermans (1929) proposed that the energy of the sun is released by thermonuclear reactions. Shortly after this important publication, a young and not yet renowned physicist, George Gamow, reported this suggestion at a meeting in Leningrad. After the meeting, Bukharin, a leading member of the Communist party, came to Gamow with a proposal. The whole electrical output of Leningrad could be made available to Gamow for one hour each night if he would undertake to reproduce on earth what was happening in the sun. Gamow, a physicist of unusual taste and common sense, did not accept the offer.” Extensive details of the history of nuclear fusion are in [20, 66, 89].

2. An introduction to general paths of reasoning in MHD.

Plasma physic has a considerable complexity, we give in this section a series of different paths of reasoning beginning with the most readable material, some of them of advanced nature.

A bridge between mathematicians and physicians is given by Artisimovich, L. A. in [7] where this are the main topics:

• Definition of plasma. • Motions of electrons and ions in plasmas in the absence of external fields. • Plasma behavior in electric field. • Plasma behavior in magnetic field. • The effect of the magnetic field on characteristics of the plasma. • Results derived from magnetohydrodynamic equations. • Developments of experimental targets. • Conditions for the existence of a plasma ring. • The theory of stability. • Plasma behavior in traps with magnetic mirrors. • Stability of plasmas configurations. • Shear stabilization. • Other plasma instabilities.

Also for you simplicity and detailed explanations we mention Nicholson, D. R. [70] Roberts, P. H. [73] and Thompson, W. B. [84].

A very important introduction of turbulence using a statistical approach is in Tystovich, V. N [87]:

• Comparison of plasma and liquid turbulence. • General problems of the theory of plasma turbulence. • The balance equation for a turbulent plasma. • Turbulent collisions and resonance broadening. • The spectrum and correlation functions of ion sound turbulence. • The spectrum and correlation functions of Langmuir turbulence. • Electromagnetic properties of a turbulent plasma. • The cosmic ray spectrum.

In [38] the authors Goldstone, R. J. and Rutherford, P. H. realize a comprehensive, understandable and advanced introduction to plasmas physics. They use Hamiltonian chaos:

• Introduction to plasmas. • Single particle motion. • Particle drifts in non-uniform magnetic fields. • Particle drifts in time-dependent fields. • Mappings (Hamiltonian chaos). • Plasmas as fluids. • Fluids equations for a plasma. • Relation between fluid equations and guiding-center drifts. • Single-fluid magnetohydrodynamics. • Magnetohydrodynamics equilibrium. • Collisional processes in plasmas. • Fully and partially ionized plasmas. • Collisions in fully ionized plasmas. • Diffusion in plasmas. • The Fokker-Planck equation for Coulomb collisions. • Collisions of fast ions in a plasma. • Waves in a fluid plasma. • Basic concepts of small-amplitude waves in anisotropic dispersive media. • Waves in an unmagnetized plasma. • High-frequency waves in a magnetized plasma. • Low-frequency waves in a magnetized plasma. • Instabilities in a fluid plasma. • The Rayleigh-Taylor and flute instabilities. • The resistive tearing instability. • Drift waves and instabilities. • Kinetic theory of plasmas. • Kinetics effects on plasma waves: Vlasov's treatment. • Kinetic effects on plasmas waves: Landau's treatment. • Velocity-space instabilities and nonlinear theory. • The drift-kinetic equation and kinetic drift waves.

A key steep is contained in Stix, T. H. [80]:

I. Wave normal surfaces: Introduction. • The susceptibility and dielectric tensors. • The dispersion relation. • Polarization and phase relations. • Cutoff and resonance. • Wave normal surfaces. • Transition of shapes and labels.

II. Waves in a cold uniform plasma: Introduction • Clemmow-Mullaly-Allys diagram for single ion species plasma. • Propagation parallel and perpendicular to B_0. • Hydromagnetic waves of Alfven and Astrom. • Ion cyclotron waves. • Ion cyclotron waves. • The hybrid resonances. The Altar-Appleton-Hartree dispersion relation. • Parallel current flow.

III. Causality, acoustic waves and simper drift waves: Introduction. • Nonlocal behavior. • The electrostatic and electromagnetic approximations. • Finite parallel electron temperature. • Thermal corrections and ion acoustic waves. • Lower-hybrid waves. • Drift waves.

IV. Energy flow and accessibility: • Introduction. • Energy transfer. • Energy density, energy flux and group velocity. • Energy transfer for electrostatic waves. • Some geometrical waves. • Surfaces of constant phase and Lighthill's theorem. • Ray tracing in inhomogeneous media. • The kinetic equation for waves. • Amplitude transport for a well-defined wave packet. • Radiation transfer. • Accessibility. • Calculation of accessibility.

V. Kruskal-Schwarzschild solutions for a bounded plasma: Introduction. • The boundary equations. • An equilibrium solution. • Linearization of the equations. • Solution of the first-order boundary equations. • Solution of the first-order plasma equations. • The Rayleigh-Taylor instability.

VI. Oscillations in bounded plasmas: Introduction. • Alfven and ion cyclotron waves in a cylindrical plasma. • The vacuum and the boundary equations. • Solution of the steady state problem. • Forced oscillations. • Toroidal eigenmodes. • Density of the modes. • Resonance cones.

VII. Plasma models with discrete structure: Introduction. • The two stream instability. • The beam equations. • The Dawson modes for a plasma of many beams. • The trapping of charged particles. • A nonlinear plasma wave. • Beam-exited plasma oscillations.

VIII. Longitudinal oscillations in a plasma of continuous structure: Introduction. • A physical picture of Landau damping. • Landau damping as viscosity. • The plasma kinetic equations. • A simple kinetic model of Landau damping. • Environments for valid Landau damping. • The collisionless Boltzmann equation. • Analytic continuation of the integrals. • The dispersion relation. • The Van Kampen modes. • The Nyquist criterion for instability. • The two stream instability in a hot plasma. • Electrostatic waves in a Maxwellian unmagnetized plasma. • The plasma dispersion plasma. • Asymptotic behavior of the dispersion function.

IX. Absolute and convective instability: Introduction. • An intuitive picture. • Further analysis and discussion. • Pulse shape, convective and absolute instability. • Convective instability and amplifying waves. • Absolute instability by residue theorem.

X. Susceptibilities for a hot plasma in a magnetic field: Introduction. • A physical picture of cyclotron damping. • Electromagnetic trapped particle modes. • Solution of Vlasov equation. • Transformation from Lagrangian to Eulerian coordinates.

XI. Waves in magnetized uniform media. Introduction. • Introduction. • Propagation parallel to Bo. • Cyclotron harmonic damping. • Transit time damping. • Propagation perpendicular to Bo, $\omega \neq n\Omega$. • Propagation approximately perpendicular to Bo, $\omega \approx n\Omega$. • The marginal state for the magnetosonic wave. • Power absorption by collisionless processes. • Cyclotron overstability due to pressure anisotropy. • Electrostatic waves in a magnetic field.

XII. Effect on waves from weak collisions: Introduction. • Random walk in velocity space. • Model Fokker-Planck equation; decay of singular perturbations. • The function $C(\xi)$. • Gyrophase and gyrocenter diffusion. • Conservation of momentum. • Damping of Alfven waves. • Particle conservation; electrostatic waves. • Hybrid Resonances. • Stabilization of simple drift waves.

XIII. Reflection, absorption and mode conversion. Introduction. • Zeros and infinities in the refractive index. • Solutions to the wave equation near a turning point. • Asymptotic solutions. • The Budden tunneling factors. • The absorption layer. • Applicability of singular turning point theory. • Mode conversion: the Alfven resonance. • The hybrid resonance. • The standard equation. • The ICRF equation. • The low frequency Alfven resonance. • Matched asymptotic expansions.

XIV. Non-uniform plasmas: Introduction. • The Vlasov equation. • The electrostatic approximation. • Susceptibilities. • The drift kinetic regime. • Small Larmor radius kinetic theory of drift waves. • Drift wave instability. • Flute like drift waves.

XV. The straight trajectory approximation: Introduction. • A long wavelength loss cone instability. • The straight line trajectory approximation. • The enhanced straight line trajectory dispersion relation. • Ion Berstein waves. • Short wavelength loss cone instabilities. • Drift cyclotron instability. • Drift cyclotron loss cone instability.

XVI. Quasilinear diffusion: Introduction. • Quasilinear analysis. • Conservation of energy and momentum. • Quasilinear evolution. • Cross-B transport. . • Wave associated drag. • Collisional relaxation and rf current drive. • Stochasticity. • Superadiabaticity. • Anomalous viscosity for parallel current.

XVII. Quasilinear diffusion in a magnetized plasma: Introduction. • Cyclotron heating. • Heating in tokamak geometry. • Rf induced radial transport in tokamaks. • Quasilinear diffusion in a magnetic field. • Wave associated drag. • Electromagnetic quasilinear theory. • Resonant particle diffusion. • Test particle Fokker-Planck equation. • The Coulomb diffusion coefficients. • Steady state solution for $f(v)$. • $f(v)$ for steady state isotropic ion injection. • Superadiabaticity and decorrelation.

XVIII. Bounce average quasilinear diffusion: Introduction. • Bounce averaging. • Particle conservation in E, μ coordinates. • The bounce average integrals. • The phase integral.

Further material [11, 19, 22, 25, 30, 34, 35, 37, 42, 50, 53, 65, 75, 77, 96]

The source of lineage of paths of reasoning in MHD: Lectures notes of schools and reviews.

Perhaps one of the main streams in our subject was given in The Culham Summer School on Plasma Physics. Gill R. D. (editor) [36] offer a carefully chosen set of lectures notes from the period 1978-1980:

Section I. Introduction: • Nuclear fusion. • Introduction to plasma physics.

Section II. Theory: Magnetohydrodynamics. • Particle orbit theory. • Plasma waves. • Kinetic theory. • MHD stability theory. • Plasma radiation.

Section III. Advanced theory: Microinstabilites. • Plasma turbulence. • Anomalous transport theory. • Nonlinear laser plasma interaction.

Section IV. Experimental devices: Tokamak confinement devices. • Stellerator confinement devices. • The next generation tokamaks. • Fusion reactor studies.

Section V. Heating and diagnosis: Neutral injection plasma heating. • The theory of radio frequency plasma heating. • Radio frequency plasma heating experiments. • Plasma diagnosis using lasers. • X-ray and particle diagnosis.

In The Nagoya Lecture Notes in Plasma Physics and Controlled Fusion Ichikawa, Y. H. and Kamimura, T. editors [48], we encounter the subjects:

• Development of nuclear fusion research. • A few perspectives in nonlinear dynamics. • Time dependent drift Hamiltonian. • Adventures in magnetohydrodynamics. • Introduction to the theory of fluid and magnetofluid turbulence. • Topics in magnetic reconnection and transport in fusion devices. • Turbulent transport in tokamaks. • Advanced fusion reactors.

Also we mention:

Advanced School on Waves and Instabilities in Plasmas September 1993, International Centre for Mechanical Sciences in Udine, editor Cap, F. [21].

International Summer School on Magnetohydrodynamics June 1999. International Centre for Mechanical Sciences in Udine, editors and IUTAM, editors Davison, P. A. and Thess, A. [26].

International School of Plasma Physics Varenna, Como Italy, 1971. The MHD Approach to the Problem of Plasma Confinement in Closed Magnetic Configuration. Lectures notes by Mercier, H. and Luc, H. [63].

Physics of magnetically confined plasmas. Boozer, A. H. Reviews of Modern Physics, vol. 76, October 2004, [18].

Summer University of Plasma Physics. September 27-October 1, 2004 Max Planck Institut fur Plasma Physics, edited by Konies, A. and Krieger, K. [60].

ICTP Summer College on Plasmas Physics, 2007. Proceedings New Aspects of Plasma Physics. Shukla, P. K., Stenflo, L. and Eliasson, B. editors. World Scientific 2008 [76].

THE FRONTIERS OF RESEARCH.

1. Mathematical paths of reasoning in MHD.

The use of functional analysis is extensive in Lifschitz, A. E [62], where the writer study mainly spectral problems arisen in magnetohydrodynamics, it is demonstrated that the ideal MHD equations can be obtained by means of a variational principle from the actional functional whose explicit form is found, the use of advanced mathematical concepts like Poincare's map, manifolds with magnetic properties is wide, a carefully description of waves also is given.

An extensive use of Fourier, Laplace and Hilbert transforms is in Jones, W. D. et al. [54]. Tensor calculus is reviewed in Hazeltine, R. D. and Meiss, J. D. [44] .In Abdullaev, [1] we have methods to study Hamiltonian systems and mathematical aspects of Dynamical Chaos. The use of intrinsic coordinates is a key ingredient in Mercier, L and Luc. L. [63].

Heisenberg-Weyl groups, the theory of operator symbols, Lie groups, Lie algebras, representations and the Weyl symbols calculus appears in Tracy, E. R. et al [86]. In Yoshizawa, A. Itoh, S-I and Itoh, K. [95], perhaps the main mathematical tools are: Kolmogorov's spectrum, renormalization and statistical methods, bifurcation and systems with hysteresis, self-organized dynamics, statistical picture of bifurcation and transition probabilities.

2. Tokamaks and confined plasmas: [1, 6, 10, 17, 29, 45, 63, 68, 69, 79, 82, 83, 90, 91, 92, 93, 97].

3. Technology of nuclear fusion: [24, 31, 32, 39, 41, 78]

4. Turning the wheel of turbulence and chaos in MHD: [15, 28, 33, 43, 46, 55, 59, 61, 67, 94, 95]

5. Waves in MHD: [2, 3, 4, 5, 9, 52, 54, 72, 81, 86].

6. Anomalous transport in MHD: [8].

7. Computational MHD: [10, 12, 17, 40, 51, 58].

8. Further material: [14, 27, 16, 27, 30, 47, 71]

9. Conclusion.

Finally we are in the frontiers of research in nuclear fusion, just go to: https://fusion.gat.com/theory/Home.

Bibliography.

1. Abdullaev, S. Magnetic Stochasticity in Magnetically Confined Fusion Plasmas. Springer 2014.
2. Akhiezer, A. I. et al. Collective Oscilations in a Plasma. Pergamon Press 1967.
3. Akhiezer A. I. et al. Plasma electrodynamics vol I. Linear Theory. Pergamon Press 1975.
4. Akhiezer et al. Plasma electrodynamics vol II. Nonlinear Theory and Fluctuations. Pergamon Press 1975.
5. Anderson, J. E. Magnetohydrodynamic Shock Waves. MIT Press 1973.
6. Ariola, M and Pironti, M. Magnetic control of tokamaks. Springer 2008.
7. Artisimovich, L. A. A physicist's abc-plasma. Mir Publishers 1978.
8. Balesc, R. Aspects of Anomalous Transport in Plasmas. IOP Publishing 2005.
9. Basov, N. G. The Dissipation of Electromagnetic Waves in Plasmas. Consultants Bureau New York 1982.
10. Bauer, F. Betancourt, O. and Garabedian, P. Magnetohydrodynamic Equilibrium and Stability of Stellerators. Springer Verlag 1984.
11. Bellan, P. M. Fundamentals of Plasma Physics. Cambridge University Press 2006.
12. Birdsall, C. K. and Langdon, A. B. Plasma Physics via Computer Simulation. IOP 1991
13. Birn, J. and Priest, E. R. Reconnection of Magnetic Fields. Cambridge University Press 2007.
14. Biskamp, D. Magnetic Reconnection in Plasmas. Cambridge University Press 2000.
15. Biskamp, D. Magnetohydrodynamic Turbulence. Cambridge University Press 2003.
16. Biskamp, D. Nonlinear Magnetohydrodynamics. Cambridge University Press 1992.
17. Blum, J. Numerical Simulation and Optimal Control in Plasmas Physics with Applications to Tokamaks. John Wiley & Sons 1989.
18. Boozer, A. H. Physics of magnetically confined plasmas. Reviews of Modern Physics, Vol. 76, October, 2004.

19. Boyd, T. J. M. and Sanderson, J. J. The Physics of Plasmas. Cambridge University Press 2003.
20. Braams, C. M. and Stott, P. E. Nuclear Fusion Half a Century of Magnetic Confinement Research. IOP 2002.
21. Cap, F. Waves and Instabilities in Plasmas. Springer 1994.
22. Chen, F. F. Introduction to Plasma Physics and Controlled Fusion vol I. Plenum Press New York, 1985.
23. Clark, R. E. H. and Reiter, D. H. Nuclear Fusion Research Understanding Plasma Surface Interactions. Springer 2005.
24. Crosswait, K. M. A Passively Safe Fusion Reactor Blanket wth Helium Coolant and Steel Structure. PhD Thesis MIT 1994.
25. Davidson, P. A. An Introduction to Magnetohydrodynamics. Cambridge University Press 2001.
26. Davison, P. A. and Thess, A. Magnetohydrodynamcs. Springer Verlag 2002
27. Davidson, R. C. Methods in Nonlinear Plasmas Theory. Academic Press 1972.
28. Diamond, P. H. Itoh, S. and Itoh, K. Modern Plasma Physics. Volume 1 Physical Kinetics of Turbulent Plasmas. Cambridge University Press 2010.
29. Dinklage, A et al. editors. Plasma Physics Confinement, Transport and Collective Effects. Springer 2005.
30. Diver, D. A. Plasma Formulary for Physics, Technology and Astrophysics. Wiley VCH 2001.
31. Dolan, T. J. editor. Magnetic Fusion Technology. Springer 2013.
32. Dolan, T. J. Fusion Research Principles, Experiments and Technology. Pergamon Press Corrected edition 2000.
33. Elskens Y. and Elscande, D. Microscopic Dynamics of Plasmas and Chaos. IOP 2003.
34. Freidberg, J. Ideal MHD. Cambridge University Press 2014.
35. Freidberg, J. Plasma Physics and Fusion Energy. Cambridge University Press 2007.
36. Gill, R. D. editor. Plasma Physics and Nuclear Fusion Research. Academic Press 1981.
37. Goedbloed, H. P. and Poedts S. Principles of Magnetohydrodynamics. Cambridge University Press 2004.
38. Goldston, R. J. and Rutherford P. H. Introduction to Plasma Physics. IOP 1995
39. Griem, H. R. Principles of Plasma Spectrocopy. Cambridge University Press 1997.
40. Gruber, R. and Rappaz, J. Finite Element Methods in Linear Ideal Magnetohydrodynamics. Springer Verlag 1985.
41. Guest, G. Electron Cyclotron Heating of Plasmas. Wiley-VCH 2009.
42. Harms, A. A. et al. Principle of Nuclear Fusion. World Scientific 2002.
43. Hauff, T. Transport of energetic particles in turbulent plasmas. Dissertation zur Erlangung des Doktorgrades Dr. rer. Nat der Fakultat fur Naturwissenschaften der Universitat Ulm 2009.
44. Hazeltine, R. D. and Meiss, J. D. Plasma Confinement. Addison Wesley 1992.
45. Helander, P. and Sigmar, D. J. Collisional Transport in Magnetized Plasmas. Cambridge University Press 2005.
46. Horton, W and Ichikawa, Y. H. Chaos and Structures in Nonlinear Plasmas. World Scientific 1996.
47. Huba, J. D. NRV Plasma Formulary. The Office of Naval Research 2000.
48. Ichikawa, Y. H. and Kamimura, T. editors. Nagoya Lecture Notes in Plasma Physics and Controlled Fusion. Tokai University Press 1989.
49. Ichimaru, S. Statistical Plasma Physics Vol 1. Addison Wesley 1992.
50. Inan, U. and Golkowski, M. Principles of Plasma Physics for Engineers and Scientists. Cambridge University Press 2011.
51. Jardin, S. Computational Methods in Plasma Physics. CRC Press 2010.
52. Jeffrey, A and Taniuti, T. Non-linear Wave Propagations with Applications to Physics and Magnetohydrodynamics. Academic Press 1964.
53. Jeffrey, A. Magnetohydrodynamics. John Wiley 1964.
54. Jones, W. D. Doucet H. J. and Buzzi, J. M. Linear Theories and Methods of Electrostatics Waves in Plasmas. Plenum Press New York 1985.
55. Kadomtsev B. B. Plasma Turbulence. Academic Press 1965.
56. Kadomtsev, B. B. Tokamak Plasma A complex Physical System. IOP 1992.
57. Kikuchi, M. Frontiers in Fusion Research. Springer 2010.
58. Killeen, J. Kerbel, G. D. McCoy, M. G. and Mirin, A. A. Computational Methods for Kinetics Models of Magnetically Confined Plasmas. Springer Verlag 1985.
59. Klimontovich, Y. L. The Statistical Theory of Nonequilibrium Process in Plasmas. Pergamon Press 1967.
60. Konies, A and Krieger, K. editors. Summer University of Plasma Physics. Max Planck Institut fur Plasma Physick 2004.
61. Krommes, J. A. Fundamental Statistical Descriptions of Plasma Turbulence in Magnetic Fields. Princeton Plasma Physics Laboratory 2001.
62. Lifschitz, A. E. Magnetohydrodynamics and Spectral Theory. Kluwer Academic Publishers 1987.

63. Mercier, C. and Luc, H. The MHD Approach to the Problem of Plasma Confinement in Closed Magnetic Configuration. Commission of the European Communities, Luxembourg 1974.
64. Mikhailovskii. A. B. Instabilities in a Confined Plasma. IOP 1998.
65. Miyamoto, K. Plasma Physics and Controlled Nuclear Fusion. Springer 2005.
66. Molokov, S. Moreau, R. and Moffatt, H. K. Magnetohydrodynamics Historical Evolution and Trends. Springer 2007.
67. Morozov, A. I. Introduction to Plasmas Dynamics. CRC Press 2013.
68. Naujoks, D. Plasma Material Interaction in Controlled Fusion. Springer 2006.
69. Nersisyan, H. Toepffer Ch. and Zwicknagel, G. Interactions between Charged Particles in a Magnetic Field. Springer 2007.
70. Nicholson, D. R. Introduction to Plasma Theory. John Wiley & Sons 1983.
71. Leontovich, M. A. et al. editors. Reviews of Plasma Physics Volumes 3, 5, 8, 13, 21, 22, 23, and 24. Consultants Bureau, New York.
72. Pecseli, H. L. Waves and Oscillations in Plasmas. CRC 2013.
73. Roberts, P. H. An Introduction to Magnetohydrodynamics. Longmans, London, 1967.
74. Salzmann, D. Atomic Physics in Hot Plasmas. Oxford University Press 1998.
75. Schnack, D. D. Lectures in Magnetohydrodynamics. Springer 2009.
76. Shukla, P. K., Stenflo, L. and Eliasson, B. editors. New Aspects of Plasma Physics. World Scientific 2008.
77. Stacey, W. M. Fusion Plasma Physics. Wiley VCH 2005.
78. Stacey, W. M. Fusion. Wiley VCH 2007.
79. Stangeby, P. C. The plasma boundary of magnetic fusion. IOP 2000.
80. Stix. T. H. Waves in Plasmas. American Institute of Physics 1992.
81. Swanson, D. G. Plasma Waves. IOP 2003.
82. Teller, E. editor. Fusion vol I Magnetic Confinement Part A. Academic Press 1981.
83. Teller, E. editor. Fusion vol I Magnetic Confinement Part B. Academic Press 1981.
84. Thompson, W. B. An Introduction to Plasma Physics. Pergamon Press 1964
85. Tidman, D. A. and Krall N. A. Shock Waves in Collisionless Plasmas. Wiley 1971.
86. Tracy, E. R. et al. Ray Tracing and Beyond Phase Space Methods in Plasma Wave Theory. Cambridge University Press 2014.
87. Tystovich, V. N. An Introduction to the Theory of Plasma Turbulence. Pergamon Press 1972.
88. Tystovich, V. N. Theory of Turbulent Plasma. Consultant Bureau 1977.
89. Voronov, G. S. Storming the Fortress of Fusion. Mir 1988.
90. Weiland, J. Stability and Transport in Magnetic Confinement Systems. Springer 2012.
91. Wesson, J. Tokamaks. Clarendon Press Oxford 2004.
92. White, R. B. The Theory of Toroidally Confined Plasmas. Imperial College Press 2001.
93. Woods. L. C. Theory of Tokamak Transport. Wiley VCH 2006.
94. Yoshizawa, A. Hydrodynamic and Magnetohydrodynamic Turbulent Flows Modelling and Statistical Theory. Springer 1998.
95. Yoshizawa, A. Itoh, S-I and Itoh, K. Plasma and Fluid Turbulence Theory and Modelling IOP 2002.
96. Zheng, L. editor. Topics in Magnetohydrodynamics. InTech 2012.
97. Zohm, H. Magnetohydrodynamic Stability of Tokamaks. Wiley VCH 2015.