BOOK REVIEW

Plasma Physics and Fusion Energy

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Reviewer Thomas J. Dolan

The Preface states, "*Plasma Physics and Fusion Energy* is a textbook about plasma physics, although it is plasma physics with a mission—magnetic fusion energy. The goal is to provide a broad, yet rigorous, overview of the plasma physics necessary to achieve the half century dream of fusion energy." In 671 pages the book achieves this goal remarkably well. Inertial confinement fusion is outside the scope of the book.

Part I (Chapters 1 through 5) deals with nuclear fusion power. Chapters 1 through 3 discuss world energy supply, fusion reactions, reaction rates, collision frequencies, and bremsstrahlung radiation losses. Radiation losses due to line radiation and cyclotron radiation are not discussed. Chapter 4 presents a simple model to calculate reactor power balance, ignition, energy gain, thermal stability, and required external heating power.

Chapter 5 develops a simplified model of a generic toroidal fusion reactor. It shows how specification of seven parameters (electrical power output, neutron wall load, maximum magnetic field, maximum coil stress, reaction rate parameter/plasma temperature, and neutron cross sections for slowing down and for tritium breeding) plus a desire to minimize the reactor cost per watt can lead directly to reasonable estimates of blanket-shield thickness, plasma minor radius, major radius, coil thickness, plasma pressure, plasma density, energy confinement time, and required beta. This chapter derives these vital estimates with brilliant simplicity.

Part II (Chapters 6 through 16) deals with the plasma physics issues of nuclear fusion research. Chapters 6 through 12 describe plasma fundamentals, the guiding center approximation, Coulomb collision effects, a two-fluid model, magnetohydrodynamic (MHD) equilibrium, and MHD stability.

Chapter 13 (115 pages long) describes the main magnetic confinement concepts: the levitated dipole, field-reversed configuration (including magnetized target fusion), reversed field pinch, spheromak, tokamak, and stellarator, with assessments of their achievements and problems. The conclusion is that current tokamak performance is superior but that current drive requirements limit the attainable power gain ratio and feedback stabilization of resistive wall modes may be required. A stellarator could in principle achieve steady-state operation without current drive or disruptions, but its modular coils would be complex and expensive. The chapter then compares the beta values required for power balance with the MHD beta limits. The chapter does not describe tandem mirrors, bumpi tori, rotating plasma, or some older fusion concepts. I believe that a couple of concepts termed relatively new (levitated dipole, low aspect ratio tokamak) are more than 20 years old.

Chapter 14 describes transport equations, neoclassical transport, empirical scaling, ignition, and bootstrap current. Chapter 15 assesses various types of plasma heating and current drive (ohmic, neutral beam injection, ion cyclotron heating, electron cyclotron heating, lower hybrid current drive), including plasma waves, cutoff, penetration, damping, accessibility, and efficiency. The final Chapter 16 discusses the future of fusion research, including plans for ITER and DEMO. Appendices discuss $\langle \sigma v \rangle$, radiation, Boozer coordinates, and the Poynting theorem.

The book is well illustrated and has few errors. Each chapter finishes with a summary of the main points, a bibliography, and problems for students. I have only one substantial criticism of the book: Many of the problems are suitable for physics students but are too highly mathematical for some of our nuclear engineering students.

This book is the most modern and thorough introductory textbook on plasma physics for fusion research that I have seen, providing rigorous mathematical descriptions for most of the concepts. I highly recommend it.

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