Plasmas

The First State of Matter

Vinod Krishan

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To my parents
Shri Om Prakash Pabbi
and
Shrimati Raj Dulari Pabbi
who continue to adore me, educate me and inspire me.

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Preface

Plasma physicists are initiated into the field with the line that plasma is the fourth state of matter since it is produced by the three-stage process of melting a solid into a liquid, evaporating a liquid into a gas, and ionizing a gas into a plasma. Astronomers have long known that the universe originated from a very hot soup of plasma and radiation. The other three states of matter, namely gas, liquid, and solid, came into being, in that order, as the universe expanded and cooled. It is high time that we set the record straight and coronate plasma as the first state of matter. Some may ask: Does it make a difference? It just might. Plasmas are already playing a tremendous role in creating new materials. In the face of rapidly depleting conventional energy sources, plasmas emerge as the last hope for mankind to generate green energy. This paradigm shift from solid–liquid–gas–plasma to plasma–gas–liquid–solid is likely to usher in a completely novel way of dealing with the material world. The universality of plasmas has however not made it any easier to understand them. Astronomers consider plasmas, at best, an unavoidable presence and reluctantly accept the plasma often without the plasma phenomena. Here, in this book, I have attempted to introduce the subject of physics of the plasmas to graduate and undergraduate students in an accessible style in the hope of catching them young. Each chapter stands on its own for the most part.

The first chapter is essentially an inventory of the first state of matter in the cosmos and on terra firma. The reader is introduced to the phenomenal variety of plasmas and their purposes. The second chapter consists of ways and means of making plasmas, followed by their defining properties. Confinement techniques of often extremely hot natural and man-made plasmas are discussed in the third chapter. 'What are the wild waves saying'? Plasmas are known by the waves they can support. The wave properties of single-fluid Magnetohydrodynamics waves and two fluid waves, electrostatic, electromagnetic, and the combination thereof, make up the stuff of Chapter 4. Radiation and plasmas, the embryonic fluid of the universe, is the subject of Chapter five. This Chapter has been made completely self-sufficient at the cost of some repetition.

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A little extra help never hurts. Detailed derivations of a few important equations are provided in Chapter 6.

I have written this book after my retirement from office. It is only natural that my thoughts race back to my beginnings. I gratefully recall the family and the friends, the colleagues, and the collaborators who have nourished and nurtured me with their indulgence and instruction. Among the many colleagues and collaborators, I wish to particularly record my deep gratitude toward Drs Rufus Ritchie, Ed Harris, Professor Vainu Bappu, Ch.V. Sastry, S.M. Chitre Ram Varma, Paul Wiita, H.S. Sawant, Swadesh Mahajan, Zensho Yoshida, Padma Shukla, R.T. Gangadhara, Santoshi Masuda and Baba Varghese. I have been extremely fortunate to have found my first teacher of plasma physics and my life partner in my husband Dr Som Krishan who continues to stoically bear with my idiosyncracies. My daughter Dr Monika Krishan has always been my total support system and I feel blessed with her presence in my life. There is one person who has been there for me much longer than my immediate family. And this is my younger sister Saroj Ishwarlal who flows like a subsoil stream and nourishes my roots.

I wish to place on record my deep gratitude to the Raman Research Institute for providing me with all possible support to enable me to continue my work after my retirement from the Indian Institute of Astrophysics.

I shall ever remain indebted to my home institution, the Indian Institute of Astrophysics.

I hope the book will serve as a primer for students who wish to have a taste of the embryonic fluid of the universe.

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