Classical and Quantum Thermal Physics

Thermal physics deals with interactions of heat energy and matter. It can be divided into three parts: the kinetic theory, classical thermodynamics, and quantum thermodynamics or quantum statistics.

This book begins by explaining fundamental concepts of kinetic theory of gases, viscosity, conductivity, diffusion and laws of thermodynamics. It then goes on to discuss applications of thermodynamics to problems of physics and engineering. These applications are explained with the help of P-V and P-*s*-*h* diagrams. A separate section/ chapter on the application of thermodynamics to the operation of engines and to chemical reactions, makes the book especially useful to students from engineering and chemistry streams. An introductory chapter on the thermodynamics of irreversible processes and network thermodynamics provides readers a glimpse into this evolving subject.

Simple language, stepwise derivations, large number of solved and unsolved problems with their answers, graded questions with short and long answers, multiple choice questions with answers, and a summary of each chapter at its end, make this book a valuable asset for students.

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Dedicated to my parents

Late Smt. Mithlesh Mathur
&
Late Shri Ishwari Prasad Mathur

Contents

Figures

Tables

Preface

The book is designed to serve as a textbook on thermal physics / thermodynamic that may be prescribed to graduate students of physics, chemistry and engineering branches. The book covers all three components of thermal physics: namely the kinetic theory, classical thermodynamics and quantum thermodynamics (quantum statistical mechanics plus thermodynamics), with their applications. Some topics in the book may also be of interest to post graduate students. Since the focus of the book is on 85–90% average and below average students of the class, it is written in simple English with detailed and stepwise derivations starting from first principles. I hope that teachers of the subject and also readers other than the targeted audience, will also like the presentation.

Kinetic theory and transport properties of gases are covered in first two chapters of the book. Maxwell–Boltzmann velocity distribution for an ideal gas, which is mostly derived using the tools of quantum thermodynamics, is obtained in chapter-1 by the method originally used by Maxwell. The four laws of classical thermodynamics and their applications are discussed in chapters 3–8.

A special feature of the book is a separate chapter on the application of classical thermodynamics to chemical reactions (chapter-9), which is generally not covered in books on the subject. Though there are books on the application of thermodynamics to chemical reactions, unfortunately these books do not explain the underlying principles of physics associated with thermodynamics and are, therefore, incomplete. Since chemists use different notations and signs for thermodynamic parameters than those used by physicists and engineers, a separate chapter is included where these differences are clearly mentioned along with their reasons. Each application is explained through an example of an appropriate chemical reaction where technical terms are explained and mathematical derivations are worked out starting from the first principle.

Similarly, engineering applications of classical thermodynamics are discussed in a separate section. These applications are explained with the help of P–V and P–*s*–*h* diagrams wherever necessary and are followed by large number of solved and unsolved problems with answers.

Classical thermodynamics is an empirical science based on the behavior of macroscopic systems. On the other hand, quantum thermodynamics is a microscopic theory that uses laws of quantum statistic and the tools of thermodynamics to describe the behavior of systems made up of a large number of identical particles. Essentials of quantum thermodynamics are developed in chapter-10 and their applications to various physical systems are detailed in chapter-11. How quantum thermodynamic treatment of systems overcome the shortcomings found in their classical treatment, has also been elaborated in this chapter.

Formulations of both classical and quantum thermodynamics are applicable only to systems in equilibrium and to processes that are reversible and/or quasi-static. However, real systems are neither in equilibrium nor are processes taking place in the universe reversible. Hence, it is necessary to develop concepts that may be applied to non-equilibrium systems and to irreversible processes, i.e. thermodynamics applicable to real systems. Efforts in this direction have been made and thermodynamics of irreversible processes based on network theorems has been developed recently. Elements of thermodynamics of linear irreversible processes and of more general network thermodynamics are introduced in chapter-12 of the book.

Another distinctive feature of the book is the inclusion of a large number of worked out examples in each chapter. Further, there are sufficient number of unsolved problems with answers, questions with short and long answers and objective questions with multiple choices. Chapter contents are also followed with a summary for revision by students. It is hoped that these features will help students in preparing for examinations, viva and interviews.

Though considerable efforts have been made to remove all errors, I know it is not possible to achieve it, particularly for a project of this size. I, therefore, request readers to kindly point out the errors they find, so that the same may be corrected. I appreciate receipt of healthy and positive criticism that may further improve the presentation.

Acknowledgments

I owe this book to my students and colleagues who encouraged me to write. Few years after my superannuation I came to know that the class notes of my lectures are still being used by students. I am fortunate to have excellent students who not only appreciated my teaching but also persuaded me to write. In this context I would like to mention one Abbas Raza Alvi, who was in my class some thirty years back, and met me just by chance in Sydney, a couple of years back. Abbas, a multi-dimensional personality: engineer, poet, music composer, story writer etc., who had settled in Australia two decades back, surprised me by showing old class notes of my lectures when I visited him in Sydney. Dedicated students like him provided the necessary impetus required to complete such a huge task. I, therefore, thank all my wonderful colleagues and students including Abbas for their significant but not so visible contributions to this project.

I wish to put on record my sincere thanks to all members of my research group who helped in one way or the other in completing this work. As a matter of fact my strength lies in them. I will specially mention the name of Professor B. P. Singh who helped me at each step and in reading the manuscript, pointing out omissions and suggesting alterations. Thank you very much Professor Singh.

I spent the best part of my life at the Aligarh Muslim University: as a student, lecturer, reader, professor, the Chairman of the Department of Physics, and the Dean, Faculty of Science. It is here that I acquired whatever knowledge I have. I sincerely thank the Aligarh Muslim University for providing me with all the support during my stay.

This book was written in three parts at three different places; first four chapters were completed at Sydney, Australia; next six chapters at Boston, USA; and the remaining part was completed at Aligarh, India. I thank my wife Sushma and my daughters-in-law, Pooja and Chaitra, for being excellent hosts and providing congenial atmosphere and nice food, both of which I feel are essential for any creative work.

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I dedicate this book to my parents—my mother, Late Smt. Mithlesh Mathur and my father, Late Shri Ishwari Prasad Mathur. They encouraged me to undertake higher learning and acquire competence.