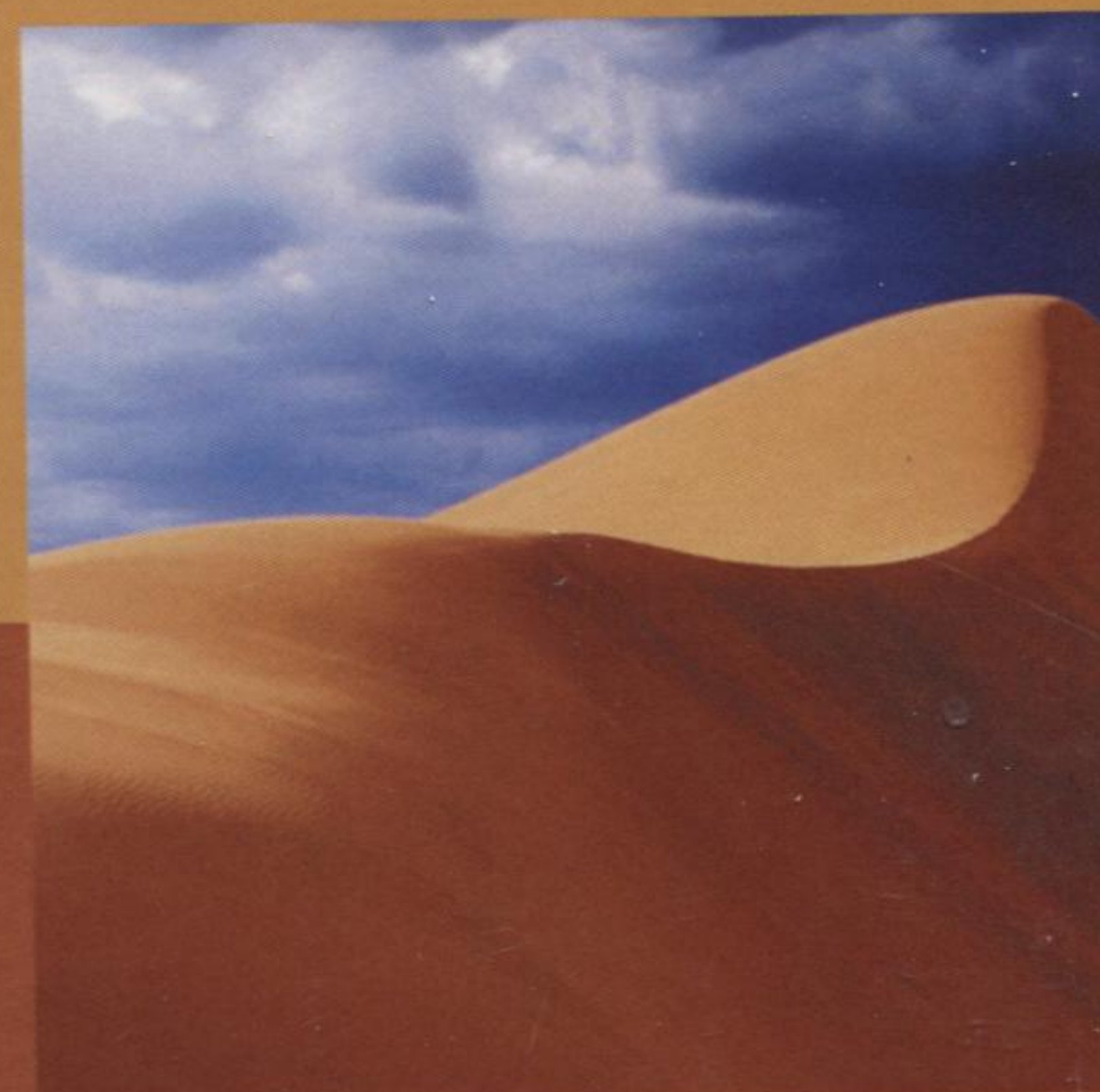


Statistical physics has its origins in attempts to describe the thermal properties of matter in terms of its constituent particles, and has played a fundamental role in the development of quantum mechanics. It describes how new behavior emerges from interactions of many degrees of freedom, and as such has found applications outside physics in engineering, social sciences, and, increasingly, in biological sciences. This textbook introduces the central concepts and tools of statistical physics. It includes a chapter on probability and related issues such as the central limit theorem and information theory not usually covered in existing texts. The book also covers interacting particles, and includes an extensive description of the van der Waals equation and its derivation by mean-field approximation. A companion volume, *Statistical Physics of Fields*, discusses non-mean-field aspects of scaling and critical phenomena, through the perspective of the renormalization group.



Based on lectures for a course in statistical mechanics taught by Professor Kardar at Massachusetts Institute of Technology (MIT), this textbook contains an integrated set of problems, with solutions to selected problems at the end of the book. It will be invaluable for graduate and advanced undergraduate courses in statistical physics. Additional solutions are available to lecturers on a password-protected website at www.cambridge.org/9780521873420.

In this much-needed modern text, Kardar presents a remarkably clear view of statistical mechanics as a whole, revealing the relationships between different parts of this diverse subject. In two volumes, the classical beginnings of thermodynamics are connected smoothly to a thoroughly modern view of fluctuation effects, stochastic dynamics, and renormalization and scaling theory. Students will appreciate the precision and clarity in which difficult concepts are presented in generality and by example. I particularly like the wealth of interesting and instructive problems inspired by diverse phenomena throughout physics (and beyond!), which illustrate the power and broad applicability of statistical mechanics. **Leon Balents, Department of Physics, University of California, Santa Barbara**

... *Statistical Physics of Particles* is the welcome result of an innovative and popular graduate course Kardar has been teaching at MIT for almost 20 years. It is a masterful account of the essentials of a subject which played a vital role in the development of twentieth-century physics ... *Statistical Physics of Fields* builds on the foundation laid by the *Statistical Physics of Particles*, with an account of the revolutionary developments of the past 35 years, many of which were facilitated by renormalization group ideas. Much of the subject matter is inspired by problems in condensed matter physics, with a number of pioneering contributions originally due to Kardar himself. **David R. Nelson, Arthur K. Solomon Professor of Biophysics, Harvard University**

If Landau and Lifshitz were to prepare a new edition of their classic statistical physics text they might produce a book not unlike this gem by Mehran Kardar. Indeed, Kardar is an extremely rare scientist, being both brilliant in formalism and an astoundingly careful and thorough teacher. He demonstrates both aspects of his range of talents in this pair of books, which belong on the bookshelf of every serious student of theoretical statistical physics. **H. Eugene Stanley, Director, Center for Polymer Studies, Boston University**

This is one of the most valuable textbooks I have seen in a long time. Written by a leader in the field, it provides a crystal clear, elegant and comprehensive coverage of the field of statistical physics. I'm sure this book will become the reference for the next generation of researchers, students and practitioners in statistical physics. I wish I had this book when I was a student, but I will have the privilege to rely on it for my teaching. **Alessandro Vespignani, Center for Biocomplexity, Indiana University**

Cover designed by Zoe Naylor

CAMBRIDGE
UNIVERSITY PRESS
www.cambridge.org

ISBN 978-0-521-87342-0



9 780521 873420 >

Preface

page ix

1 Thermodynamics

1.1	Introduction	1
1.2	The zeroth law	2
1.3	The first law	5
1.4	The second law	8
1.5	Carnot engines	10
1.6	Entropy	13
1.7	Approach to equilibrium and thermodynamic potentials	16
1.8	Useful mathematical results	20
1.9	Stability conditions	22
1.10	The third law	26
	Problems	29

2 Probability

2.1	General definitions	35
2.2	One random variable	36
2.3	Some important probability distributions	40
2.4	Many random variables	43
2.5	Sums of random variables and the central limit theorem	45
2.6	Rules for large numbers	47
2.7	Information, entropy, and estimation	50
	Problems	52

3 Kinetic theory of gases

3.1	General definitions	57
3.2	Liouville's theorem	59
3.3	The Bogoliubov–Born–Green–Kirkwood–Yvon hierarchy	62
3.4	The Boltzmann equation	65
3.5	The H-theorem and irreversibility	71
3.6	Equilibrium properties	75
3.7	Conservation laws	78

3.8	Zeroth-order hydrodynamics	82
3.9	First-order hydrodynamics	84
	Problems	87
4	Classical statistical mechanics	98
4.1	General definitions	98
4.2	The microcanonical ensemble	98
4.3	Two-level systems	102
4.4	The ideal gas	105
4.5	Mixing entropy and the Gibbs paradox	107
4.6	The canonical ensemble	110
4.7	Canonical examples	113
4.8	The Gibbs canonical ensemble	115
4.9	The grand canonical ensemble	118
	Problems	120
5	Interacting particles	126
5.1	The cumulant expansion	126
5.2	The cluster expansion	130
5.3	The second virial coefficient and van der Waals equation	135
5.4	Breakdown of the van der Waals equation	139
5.5	Mean-field theory of condensation	141
5.6	Variational methods	143
5.7	Corresponding states	145
5.8	Critical point behavior	146
	Problems	148
6	Quantum statistical mechanics	156
6.1	Dilute polyatomic gases	156
6.2	Vibrations of a solid	161
6.3	Black-body radiation	167
6.4	Quantum microstates	170
6.5	Quantum macrostates	172
	Problems	175
7	Ideal quantum gases	181
7.1	Hilbert space of identical particles	181
7.2	Canonical formulation	184
7.3	Grand canonical formulation	187
7.4	Non-relativistic gas	188
7.5	The degenerate fermi gas	190

7.6 The degenerate bose gas	194
7.7 Superfluid He ⁴	198
Problems	202

Solutions to selected problems	211
---------------------------------------	------------

Chapter 1	211
Chapter 2	224
Chapter 3	235
Chapter 4	256
Chapter 5	268
Chapter 6	285
Chapter 7	300

Index	318
--------------	------------