Equilibrium Statistical Physics

This textbook gradually introduces students to the statistical mechanical study of the different phases of matter and to the phase transitions between them. It uses simple yet fully detailed models of both hard and soft matter systems to demonstrate core concepts, developing the subject matter in a thorough and accessible pedagogical manner throughout. Starting from an introduction to basic thermodynamics and statistical physics, the book progresses from ideal, non-interacting systems to real systems exhibiting classical interactions and phase transitions. It concludes with a selection of more advanced topics, such as the renormalisation group approach to critical phenomena, the density functional theory of interfaces, and kinematic aspects of the phase transformation process. This updated second edition features a considerably expanded study of the topology of the phases, including applications to modern problems such as topological defects of nematic liquid crystals and the topological phase transition of a two-dimensional spin system. Along with a complete introductory overview of the theory of phase transitions, this textbook provides students with ample material for deeper study. References include suggestions for more detailed treatments and six appendices supply overviews of the mathematical tools employed in the text.
Aimed at graduate students, this book explores some of the core phenomena in non-equilibrium statistical physics. It focuses on the development and application of theoretical methods to help students develop their problem-solving skills. The book begins with microscopic transport processes: diffusion, collision-driven phenomena, and exclusion. It then presents the kinetics of aggregation, fragmentation and adsorption, where the basic

phenomenology and solution techniques are emphasized. The following chapters cover kinetic spin systems, both from a discrete and a continuum perspective, the role of disorder in non-equilibrium processes, hysteresis from the non-equilibrium perspective, the kinetics of chemical reactions, and the properties of complex networks. The book contains 200 exercises to test students' understanding of the subject. A link to a website hosted by the authors, containing supplementary material including solutions to some of the exercises, can be found at www.cambridge.org/9780521851039.

Publisher Description

Statistical mechanics has been proven to be successful at describing physical systems at thermodynamic equilibrium. Since most natural phenomena occur in nonequilibrium conditions, the present challenge is to find suitable physical approaches for such conditions: this book provides a pedagogical pathway that explores various perspectives. The use of clear language, and explanatory figures and diagrams to describe models, simulations and experimental findings makes the book a valuable resource for undergraduate and graduate students, and also for lecturers organizing teaching at varying levels of experience in the field. Written in three parts, it covers basic and traditional concepts of nonequilibrium physics, modern aspects concerning nonequilibrium phase transitions, and application-orientated topics from a modern perspective. A broad range of topics is covered, including Langevin equations, Levy processes, directed percolation, kinetic roughening and pattern formation.

This third edition of one of the most important and best selling textbooks in statistical physics, is a graduate level text suitable for students in physics, chemistry, and materials science. Highlights of the book include a discussion of strongly interacting condensed matter systems with a thorough treatment of mean field and Landau theories of phase transitions. Discussions of the Potts model and the asymmetric exclusion process have been added. Along with traditional approaches to the subject such as the virial expansion and integral equations, newer theories such as perturbation theory and density functional theories are introduced. The modern theory of phase transitions occupies a central place in this book. A separate, largely rewritten, chapter is devoted to the renormalization group approach to critical phenomena, with detailed discussion of the basic concepts of this important technique and examples of both exact and approximate calculations given. The development of the basic tools is completed in an expanded chapter on computer simulations in which both Monte Carlo and molecular dynamics techniques are introduced.

Nonequilibrium statistical mechanics has a long history featuring diverse aspects. It has been a major research field in physics and will remain so in the future. Even regarding the concept of entropy, there exists a longstanding problem concerning its definition for a system in a state far from equilibrium. In this Special Issue, we offered the possibility to discuss and present up-to-date problems that were not necessarily restricted to statistical mechanics. Theoretical and experimental papers are both presented, in addition to unifying research works. As the entropy itself is the central element of nonequilibrium processes, papers discuss various formulations of the second law and its consequences. In this Special Issue, recent progress in kinetic approaches to hydrodynamics, rational extended thermodynamics, entropy in a strongly nonequilibrium stationary state, and related topics are reported as both review articles as well as original research works.

This first volume of Statistical Physics is an introduction to the theories of equilibrium statistical

mechanics, whereas the second volume (Springer Ser. Solid-State Sci., Vol. 31) is devoted to non equilibrium theories. Particular emphasis is placed on fundamental principles and basic con cepts and ideas. We start with physical examples of probability and kinetics, and then describe the general principles of statistical mechanics, with appli cations to quantum statistics, imperfect gases, electrolytes, and phase tran sitions, including critical phenomena. Finally, ergodic problems, the me chanical basis of statistical mechanics, are presented. The original text was written in Japanese as a volume of the Iwanami Series in Fundamental Physics, supervised by Professor H. Yukawa. The first edition was published in 1973 and the second in 1978. The English edition has been divided into two volumes at the request of the publisher, and the chapter on ergodic problems, which was at the end of the original book, is included here as Chapter 5. Chapters 1,2,3 and part of Chapter 4 were written by M. Toda, and Chapters 4 and 5 by N. Saito. More extensive references have been added for further reading, and some parts of the final chapters have been revised to bring the text up to date. It is a pleasure to express my gratitude to Professor P. Fulde for his detailed improvements in the manuscript, and to Dr. H. Lotsch of Springer Verlag for his continued cooperation.
A completely modern approach to statistical mechanics Gene Mazenko presents an introduction to statistical mechanics from the modern condensed matter physics point of view. Emphasizing symmetry principles, conservation laws, and the consequences of broken symmetry, all of which are crucial to a fundamental understanding of statistical physics, this volume discusses the role of broken translational symmetry in treating solids.Professor Mazenko develops a firm basis for the choice of macrovariables or thermodynamic variables, stressing the importance of Nambu-Goldstone modes. He develops this theory beyond the

usual examples of simple fluids with discussions of magnets, superfluids, and solids. Based on the author's more than 30 years of experience with this subject, Equilibrium Statistical Mechanics: * Develops the structure of statistical mechanics and thermodynamics from fundamentals * Highlights the approach of coarse graining in statistical mechanics * Discusses ergodic theory and information theory * Treats phase transitions in a number of specific applications * Includes copious examples and end-of-chapter problems * Gives full development to the rich history of this topic Look for Mazenko's forthcoming volumes, Fluctuations, Order, and Defects; Nonequilibrium Statistical Mechanics; and Field Theory Methods in Statistical Mechanics. Combined with this self-contained volume, these works span the entire graduate-level program.

This title builds from basic principles to advanced techniques, and covers the major phenomena, methods, and results of time-dependent systems. It is a pedagogic introduction, a comprehensive reference manual, and an original research monograph--

This third edition of one of the most important and best selling textbooks in statistical physics, is a graduate level text suitable for students in physics, chemistry, and materials science. The discussion of strongly interacting condensed matter systems has been expanded. A chapter on stochastic processes has also been added with emphasis on applications of the Fokker–Planck equation. The modern theory of phase transitions occupies a central place. The chapter devoted to the renormalization group approach is largely rewritten and includes a detailed discussion of the basic concepts and examples of both exact and approximate calculations. The development of the basic tools includes a chapter on computer simulations in which both Monte Carlo method and molecular dynamics are introduced, and a section on Brownian dynamics added. The theories are applied to a number of important systems such as liquids, liquid crystals, polymers, membranes, Bose condensation, superfluidity and superconductivity. There is also an extensive treatment of interacting Fermi and Bose systems, percolation theory and disordered systems in general.

This book encompasses our current understanding of the ensemble approach to many-body physics, phase transitions and other thermal phenomena, as well as the quantum foundations of linear response theory, kinetic equations and stochastic processes. It is destined to be a standard text for graduate students, but it will also serve the specialist-researcher in this fascinating field; some more elementary topics have been included in order to make the book self-contained. The historical methods of J Willard Gibbs and Ludwig Boltzmann, applied to the quantum description rather than phase space, are featured. The tools for computations in the microcanonical, canonical and grand-canonical ensembles are carefully developed and then applied to a variety of classical and standard quantum situations. After the language of second quantization has been introduced, strongly interacting systems, such as quantum liquids, superfluids and superconductivity, are treated in detail. For the connoisseur, there is a section on diagrammatic methods and applications. In the second part dealing with non-equilibrium processes, the emphasis is on the quantum foundations of Markovian behaviour and irreversibility via the Pauli–Van Hove master equation. Justifiable linear response expressions and the quantum-Boltzmann approach are discussed and applied to various condensed matter problems. From this basis the Onsager–Casimir relations are derived, together with the mesoscopic master equation, the Langevin equation and the Fokker–Planck truncation procedure. Brownian motion and modern stochastic problems such as fluctuations in optical signals and radiation fields briefly make the round.

This book provides an introduction to topics in non-equilibrium quantum statistical physics for both mathematicians and theoretical physicists. The first part introduces a kinetic equation, of Kolmogorov type, which is needed to describe an isolated atom (actually, in experiments, an ion) under the effect of a classical pumping electromagnetic field which keeps the atom in its excited state(s) together with the random emission of fluorescence photons which put it back into its ground state. The quantum kinetic theory developed in the second part is an extension of Boltzmann's classical (non-quantum) kinetic theory of a dilute gas of quantum bosons. This is the source of many interesting fundamental questions, particularly because, if the temperature is low enough, such a gas is known to have at equilibrium a transition, the Bose–Einstein transition, where a finite portion of the particles stay in the quantum ground state. An important question considered is how a Bose gas condensate develops in time if its energy is initially low enough.

Statistical Physics I discusses the fundamentals of equilibrium statistical mechanics, focussing on basic physical aspects. No previous knowledge of thermodynamics or the molecular theory of gases is assumed. Illustrative examples based on simple materials and photon systems elucidate the central ideas and methods.

Classic monograph treats irreversible processes and phenomena of thermodynamics: non-equilibrium thermodynamics. Covers statistical foundations and applications with chapters on fluctuation theory, theory of stochastic processes, kinetic theory of gases, more.

This self-contained volume introduces modern methods of statistical mechanics in turbulence, with three harmonised lecture courses by world class experts.

This textbook concentrates on modern topics in statistical physics with an emphasis on strongly interacting condensed matter systems. The book is self-contained and is suitable for beginning graduate students in physics and materials science or undergraduates who have taken an introductory course in statistical mechanics. Phase transitions and critical phenomena are discussed in detail including mean field and Landau theories and the renormalization group approach. The theories are applied to a number of interesting systems such as magnets, liquid crystals, polymers, membranes, interacting Bose and Fermi fluids; disordered systems, percolation and spin of equilibrium concepts are also discussed. Computer simulations of condensed matter systems by Monte Carlo-based and molecular dynamics methods are treated.
"There is a symbiotic relationship between theoretical nonequilibrium statistical mechanics on the one hand and the theory and practice of computer simulation on the other. Sometimes, the initiative for progress has been with the pragmatic requirements of computer simulation and at other times, the initiative has been with the fundamental theory of nonequilibrium processes. This book summarises progress in this field up to 1990"--Publisher's description.
Groundbreaking monograph by Nobel Prize winner for researchers and graduate students covers Liouville equation, anharmonic solids, Brownian motion, weakly coupled gases, scattering theory and short-range forces, general kinetic equations, more. 1962 edition.

This book encompasses our current understanding of the ensemble approach to many-body physics, phase transitions and other thermal phenomena, as well as the quantum foundations of linear response theory, kinetic equations and stochastic processes. It is destined to be a standard text for graduate students, but it will also serve the specialist-researcher in this fascinating field; some more elementary topics have been included in order to make the book self-contained.The historical methods of J Willard Gibbs and Ludwig Boltzmann, applied to the quantum description rather than phase space, are featured. The tools for computations in the microcanonical, canonical and grand-canonical ensembles are carefully developed and then applied to a variety of classical and standard quantum situations. After the language of second quantization has been introduced, strongly interacting systems, such as quantum liquids, superfluids and superconductivity, are treated in detail. For the connoisseur, there is a section on diagrammatic methods and applications.In the second part dealing with non-equilibrium processes, the emphasis is on the quantum foundations of Markovian behaviour and irreversibility via the Pauli-Van Hove master equation. Justifiable linear response expressions and the quantum-Boltzmann approach are discussed and applied to various condensed matter problems. From this basis the Onsager-Casimir relations are derived, together with the mesoscopic master equation, the Langevin equation and the Fokker-Planck truncation procedure. Brownian motion and modern stochastic problems such as fluctuations in optical signals and radiation fields briefly make the round.

This is the definitive treatise on the fundamentals of statistical mechanics. A concise exposition of classical statistical mechanics is followed by a thorough elucidation of quantum statistical mechanics: postulates, theorems, statistical ensembles, changes in quantum mechanical systems with time, and more. The final two chapters discuss applications of statistical mechanics to thermodynamic behavior. 1930 edition.
This is a presentation of the main ideas and methods of modern nonequilibrium statistical mechanics. It is the perfect introduction for anyone in chemistry or physics who needs an update or background in this time-dependent field. Topics covered include fluctuation-dissipation theorem; linear response theory; time correlation functions, and projection operators. Theoretical models are illustrated by real-world examples and numerous applications such as chemical reaction rates and spectral line shapes are covered. The mathematical treatments are detailed and easily understandable and the appendices include useful mathematical methods like the Laplace transforms, Gaussian random variables and phenomenological transport equations.
The International Encyclopedia of Physical Chemistry and Chemical Physics, Volume 1: Equilibrium Statistical Mechanics covers the fundamental principles and the development of theoretical aspects of equilibrium statistical mechanics. Statistical mechanical is the study of the connection between the macroscopic behavior of bulk matter and the microscopic properties of its constituent atoms and molecules. This

book contains eight chapters, and begins with a presentation of the master equation used for the calculation of the fundamental thermodynamic functions. The succeeding chapters highlight the characteristics of the partition function and its application to the analysis of perfect and imperfect gases, solids, and dense fluids. These topics are followed by discussions on the fundamentals of quantum statistics, with particular emphasis on its application in certain media. The last chapter outlines the derivation of the relations between the partition functions and the thermodynamic quantities. This book will be of value to physical chemists, chemical physicists, mathematicians, and researchers in the allied fields of statistical mechanics.

This book provides a gentle introduction to equilibrium statistical mechanics. The particular aim is to fill the needs of readers who wish to learn the subject without a solid background in classical and quantum mechanics. The approach is unique in that classical mechanical formulation takes center stage. The book will be of particular interest to advanced undergraduate and graduate students in engineering departments.

Equilibrium Statistical PhysicsWorld Scientific

Key features include an elementary introduction to probability, distribution functions, and uncertainty; a review of the concept and significance of energy; and various models of physical systems. 1968 edition.

This textbook is the result of the enhancement of several courses on non-equilibrium statistics, stochastic processes, stochastic differential equations, anomalous diffusion and disorder. The target audience includes students of physics, mathematics, biology, chemistry, and engineering at undergraduate and graduate level with a grasp of the basic elements of mathematics and physics of the fourth year of a typical undergraduate course. The little-known physical and mathematical concepts are described in sections and specific exercises throughout the text, as well as in appendices. Physical-mathematical motivation is the main driving force for the development of this text. It presents the academic topics of probability theory and stochastic processes as well as new educational aspects in the presentation of non-equilibrium statistical theory and stochastic differential equations.. In particular it discusses the problem of irreversibility in that context and the dynamics of Fokker-Planck. An introduction on fluctuations around metastable and unstable points are given. It also describes relaxation theory of non-stationary Markov periodic in time systems. The theory of finite and infinite transport in disordered networks, with a discussion of the issue of anomalous diffusion is introduced. Further, it provides the basis for establishing the relationship between quantum aspects of the theory of linear response and the calculation of diffusion coefficients in amorphous systems.

This book contains solutions to the problems found in Equilibrium Statistical Physics, 2nd Edition, by the same authors. Request Inspection Copy

In recent years the interaction between dynamical systems theory and non-equilibrium statistical mechanics has been enormous. The discovery of fluctuation theorems as a

fundamental structure common to almost all non-equilibrium systems, and the connections with the free energy calculation methods of Jarzynski and Crooks, have excited both theorists and experimentalists. This graduate-level book charts the development and theoretical analysis of molecular dynamics as applied to equilibrium and non-equilibrium systems. Designed for both researchers in the field and graduate students of physics, it connects molecular dynamics simulation with the mathematical theory to understand non-equilibrium steady states. It also provides a link between the atomic, nano, and macro worlds. The book ends with an introduction to the use of non-equilibrium statistical mechanics to justify a thermodynamic treatment of non-equilibrium steady states, and gives a direction to further avenues of exploration.
A self-contained, mathematical introduction to the driving ideas in equilibrium statistical mechanics, studying important models in detail.
This is a textbook which gradually introduces the student to the statistical mechanical study of the different phases of matter and to the phase transitions between them. Throughout, only simple models of both ordinary and soft matter are used but these are studied in full detail. The subject is developed in a pedagogical manner, starting from the basics, going from the simple ideal systems to the interacting systems, and ending with the more modern topics. The textbook provides the student with a complete overview, intentionally at an introductory level, of the theory of phase transitions. All equations and deductions are included.

This classic book marks the beginning of an era of vigorous mathematical progress in equilibrium statistical mechanics. Its treatment of the infinite system limit has not been superseded, and the discussion of thermodynamic functions and states remains basic for more recent work. The conceptual foundation provided by the Rigorous Results remains invaluable for the study of the spectacular developments of statistical mechanics in the second half of the 20th century. Contents:Thermodynamic Behavior. EnsemblesThe Thermodynamic Limit for Thermodynamic Functions: Lattice SystemsThe Thermodynamic Limit for Thermodynamic Functions: Continuous SystemsLow Density Expansions and Correlation FunctionsThe Problem of Phase TransitionsGroup Invariance of Physical StatesThe States of Statistical MechanicsAppendix: Some Mathematical Tools Readership: Statistical and theoretical physicists. Keywords:Equilibrium Statistical Mechanics;Thermodynamic Limit;Pure Phase;Phase Transition;Activity Expansion;Virial Expansion;Ergodic State;Gibbs Phase Rule;KMS ConditionReviews: "… it continues to be a classical reference where researchers and students find information, enlightenment and inspiration … In addition, Ruelle's presentation of many of the issues of the book has become the standard treatment … Rueller's Statistical Mechanics remains the leading reference for a motivated informed reader, or lecturer, wishing to grasp, in a concise but complete manner, the supporting arcs of this beautiful mathematical theory." Mathematical Reviews

An introduction to statistical mechanics which aims to relate microscopic properties of matter to observed macroscopic, or bulk, behaviour of physical systems.
This modern textbook provides a complete survey of the broad field of statistical mechanics. Based on a series of lectures, it adopts a special pedagogical approach. The authors, both excellent lecturers, clearly distinguish between general principles and their applications in solving problems. Analogies between phase transitions in fluids and magnets using continuum and spin models are emphasized, leading to a better understanding. Such special features as historical notes, summaries, problems, mathematical appendix, computer programs and order of magnitude estimations distinguish this volume from competing works. Due to its ambitious level and an extensive list of references for technical details on advanced topics, this is equally a must for researchers in condensed matter physics, materials science, polymer science, solid state physics, and astrophysics. From the contents Thermostatics: phase stability, phase equilibria, phase transitions; Statistical Mechanics: calculation, correlation functions, ideal classical gases, ideal quantum gases; Interacting Systems: models, computer simulation, mean-field approximation; Interacting Systems beyond Mean-field Theory: scaling and renormalization group, foundations of statistical mechanics "The present book, however, is unique that it both is written in a very pedagogic, easily comprehensible style, and, nevertheless, goes from the basic principles all the way to these modern topics, containing several chapters on the various approaches of mean

field theory, and a chapter on computer simulation. A characteristic feature of this book is that often first some qualitative arguments are given, or a "pedestrians's approach", and then a more general and/or more rigorous derivation is presented as well. Particularly useful are also "supplementary notes", pointing out interesting applications and further developments of the subject, a detailed bibliography, problems and historical notes, and many pedagogic figures."

This book offers a comprehensive picture of nonequilibrium phenomena in nanoscale systems. Written by internationally recognized experts in the field, this book strikes a balance between theory and experiment, and includes in-depth introductions to nonequilibrium fluctuation relations, nonlinear dynamics and transport, single molecule experiments, and molecular diffusion in nanopores. The authors explore the application of these concepts to nano- and biosystems by cross-linking key methods and ideas from nonequilibrium statistical physics, thermodynamics, stochastic theory, and dynamical systems. By providing an up-to-date survey of small systems physics, the text serves as both a valuable reference for experienced researchers and as an ideal starting point for graduate-level students entering this newly emerging research field.

Most interesting and difficult problems in equilibrium statistical mechanics concern models which exhibit phase transitions. For graduate students and more experienced researchers this book provides an invaluable reference source of approximate and exact solutions for a comprehensive range of such models. Part I contains background material on classical thermodynamics and statistical mechanics, together with a classification and survey of lattice models. The geometry of phase transitions is described and scaling theory is used to introduce critical exponents and scaling laws. An introduction is given to finite-size scaling, conformal invariance and Schramm—Loewner evolution. Part II contains accounts of classical mean-field methods. The parallels between Landau expansions and catastrophe theory are discussed and Ginzburg--Landau theory is introduced. The extension of mean-field theory to higher-orders is explored using the Kikuchi--Hijmans--De Boer hierarchy of approximations. In Part III the use of algebraic, transformation and decoration methods to obtain exact system information is considered. This is followed by an account of the use of transfer matrices for the location of incipient phase transitions in one-dimensionally infinite models and for exact solutions for two-dimensionally infinite systems. The latter is applied to a general analysis of eight-vertex models yielding as special cases the two-dimensional Ising model and the six-vertex model. The treatment of exact results ends with a discussion of dimer models. In Part IV series methods and real-space renormalization group transformations are discussed. The use of the De Neef—Enting finite-lattice method is described in detail and applied to the derivation of series for a number of model systems, in particular for the Potts model. The use of Pad\'e, differential and algebraic approximants to locate and analyze second- and first-order transitions is described. The realization of the ideas of scaling theory by the renormalization group is presented together with treatments of various approximation schemes including phenomenological renormalization. Part V of the book contains a collection of mathematical appendices intended to minimise the need to refer to other mathematical sources.