

LECTURE NOTES IN PHYSICS

J. Gemmer
M. Michel
G. Mahler

Quantum Thermodynamics

Emergence of Thermodynamic
Behavior Within Composite
Quantum Systems



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Quantum Thermodynamics Emergence Of Thermodynamic Behavior Within Composite Quantum Systems

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Thermodynamics Jochen Gemmer, Mathias Michel, Günter Mahler, 2004-12-14 This extended tutorial essay views thermodynamics as an incomplete description of quantum systems with many degrees of freedom The main goal is to show that the approach to equilibrium with equilibrium characterized by maximum ignorance about the open system of interest neither requires that many particles nor is it a precise way of partitioning relevant for the salient features of equilibrium and equilibration Moreover it is indeed quantum effects that are at work in bringing about universal thermodynamic behaviour of modestly sized open systems Von Neumann's concept of entropy thus proves to be much more widely useful than something to be feared and far beyond truly macroscopic systems in equilibrium Quantum Thermodynamics Jochen Gemmer, M.

Michel, Günter Mahler, 2009-08-29 Over the years enormous effort was invested in proving ergodicity but for a number of reasons confidence in the fruitfulness of this approach has waned Y Ben Menahem and I Pitowsky 1 Abstract The basic motivation behind the present text is threefold To give a new explanation for the emergence of thermodynamics to investigate the interplay between quantum mechanics and thermodynamics and to explore possible extensions of the common validity range of thermodynamics Originally thermodynamics has been a purely phenomenological science Early scientists Galileo Santorio Celsius Fahrenheit tried to give definitions for quantities which were intuitively obvious to the observer like pressure or temperature and studied their interconnections The idea that these phenomena might be linked to other fields of physics like classical mechanics e.g. was not common in those days Such a connection was basically introduced when Joule calculated the heat equivalent in 1840 showing that heat was a form of energy just like kinetic or potential energy in the theory of mechanics At the end of the 19th century when the atomic theory became popular researchers began to think of a gas as a huge amount of bouncing balls inside a box **Theory of Thermodynamic Measurements of Quantum Systems**

Far from Equilibrium Abhay Shastry, 2019-11-26 This thesis presents several related advances in the field of nonequilibrium quantum thermodynamics. The central result is an ingenious proof that the local temperature and voltage measurement in a nonequilibrium system of fermions exists and is unique, placing the concept of local temperature on a rigorous mathematical footing for the first time. As an intermediate step, a proof of the positivity of the Onsager matrix of linear response theory is given. A statement of the second law of thermodynamics that had lacked an independent proof for 85 years is also proposed, which could enable improvements to the spatial resolution of thermometry by several orders of magnitude. Finally, a new mathematically exact definition for the local entropy of a quantum system in a nonequilibrium steady state is derived. Several different measures of the local entropy are discussed, relating to the thermodynamics of processes that a local observer with varying degrees of information about the microstates of the system could carry out, and it is shown that they satisfy a hierarchy of inequalities. Proofs of the third law of thermodynamics for generic open quantum systems are presented, taking into account the entropic contribution due to localized states. Appropriately normalized per state local entropies are defined and are used to quantify the departure from local equilibrium.

Thermodynamics and Synchronization in Open Quantum Systems Gonzalo Manzano Paule, 2018-07-04 This book explores some of the connections between dissipative and quantum effects from a theoretical point of view. It focuses on three main topics: the relation between synchronization and quantum correlations, the thermodynamical properties of fluctuations, and the performance of quantum thermal machines. Dissipation effects have a profound impact on the behavior and properties of quantum systems, and the unavoidable interaction with the surrounding environment, with which systems continuously exchange information, energy, angular momentum, and matter, is ultimately responsible for decoherence phenomena and the emergence of classical behavior. However, there is a wide intermediate regime in which the interplay between dissipative and quantum effects gives rise to a plethora of rich and striking phenomena that has just started to be understood. In addition, the recent breakthrough techniques in controlling and manipulating quantum systems in the laboratory have made this phenomenology accessible in experiments and potentially applicable.

Thermodynamics in the Quantum Regime Felix Binder, Luis A. Correa, Christian Gogolin, Janet Anders, Gerardo Adesso, 2019-04-01 Quantum thermodynamics is a novel research field which explores the emergence of thermodynamics from quantum theory and addresses thermodynamic phenomena which appear in finite size, non-equilibrium, and finite time contexts. Blending together elements from open quantum systems, statistical mechanics, quantum many-body physics, and quantum information theory, it pinpoints thermodynamic advantages and barriers emerging from genuinely quantum properties such as quantum coherence and correlations. Owing to recent experimental efforts, the field is moving quickly towards practical applications such as nano-scale heat devices or thermodynamically optimised protocols for emergent quantum technologies. Starting from the basics, the

present volume reviews some of the most recent developments as well as some of the most important open problems in quantum thermodynamics. The self-contained chapters provide concise and topical introductions to researchers who are new to the field. Experts will find them useful as a reference for the current state of the art. In six sections the book covers topics such as quantum heat engines and refrigerators, fluctuation theorems, the emergence of thermodynamic equilibrium, thermodynamics of strongly coupled systems as well as various information theoretic approaches including Landauer's principle and thermal operations. It concludes with a section dedicated to recent quantum thermodynamics experiments and experimental prospects on a variety of platforms ranging from cold atoms to photonic systems and NV centres.

Emergent Quantum Mechanics Jan Walleczek, Gerhard Grössing, Paavo Pylkkänen, Basil Hiley, 2019-04-02. Emergent quantum mechanics explores the possibility of an ontology for quantum mechanics. The resurgence of interest in deeper level theories for quantum phenomena challenges the standard textbook interpretation. The book presents expert views that critically evaluate the significance for 21st century physics of ontological quantum mechanics, an approach that David Bohm helped pioneer. The possibility of a deterministic quantum theory was first introduced with the original de Broglie-Bohm theory, which has also been developed as Bohmian mechanics. The wide range of perspectives that were contributed to this book on the occasion of David Bohm's centennial celebration provide ample evidence for the physical consistency of ontological quantum mechanics. The book addresses deeper level questions such as the following: Is reality intrinsically random or fundamentally interconnected? Is the universe local or nonlocal? Might a radically new conception of reality include a form of quantum causality or quantum ontology? What is the role of the experimenter-agent? As the book demonstrates, the advancement of quantum ontology as a scientific concept marks a clear break with classical reality. The search for quantum reality entails unconventional causal structures and non-classical ontology, which can be fully consistent with the known record of quantum observations in the laboratory.

Thermal Physics and Thermal Analysis Jaroslav Šesták, Pavel Hubík, Jiří J. Mareš, 2017-03-24. Features twenty-five chapter contributions from an international array of distinguished academics based in Asia, Eastern and Western Europe, Russia and the USA. This multi-author contributed volume provides an up-to-date and authoritative overview of cutting-edge themes involving the thermal analysis applied solid-state physics, micro and nano crystallinity of selected solids and their macro and microscopic thermal properties. Distinctive chapters featured in the book include, among others, calorimetry, time scales from days to microseconds, glass transition phenomena, kinetics of non-isothermal processes, thermal inertia and temperature gradients, thermodynamics of nanomaterials, self-organization, significance of temperature and entropy. Advanced undergraduates, postgraduates and researchers working in the field of thermal analysis, thermophysical measurements and calorimetry will find this contributed volume invaluable. This is the third volume of the triptych volumes on thermal behaviour of materials, the previous two receiving thousand of downloads, guaranteeing their worldwide impact.

Compendium of Quantum Physics Daniel Greenberger, Klaus Hentschel, Friedel

Weinert,2009-07-25 With contributions by leading quantum physicists philosophers and historians this comprehensive A to Z of quantum physics provides a lucid understanding of key concepts of quantum theory and experiment It covers technical and interpretational aspects alike and includes both traditional and new concepts making it an indispensable resource for concise up to date information about the many facets of quantum physics Bioenergetics Davor Juretic,2021-12-23 Bioenergetics deals with the very first energy transformation steps performed by living cells Increased dissipation is the primary effect of processing external energy packages Enzyme supported charge separation is the minor but essential outcome for maintaining life This book explores the usefulness of dissecting the entropy production of enzymes involved in cellular defenses fermentation respiration and photosynthesis assuming that tightly regulated dissipation is the hallmark of life Researchers educators and students of life sciences can find in this text many examples of how we can use the interdisciplinary approach to study cells virtuoso ability to connect the microscopic to the macroscopic world Each chapter is a self contained unit with a glossary and selected references for further reading **Quantum Engineering** A. M. Zagoskin,2011-07-14 Quantum engineering the design and fabrication of quantum coherent structures has emerged as a field in physics with important potential applications This book provides a self contained presentation of the theoretical methods and experimental results in quantum engineering The book covers topics such as the quantum theory of electric circuits theoretical methods of quantum optics in application to solid state circuits the quantum theory of noise decoherence and measurements Landauer formalism for quantum transport the physics of weak superconductivity and the physics of two dimensional electron gas in semiconductor heterostructures The theory is complemented by up to date experimental data to help put it into context Aimed at graduate students in physics the book will enable readers to start their own research and apply the theoretical methods and results to their current experimental situation Differential Geometric Foundations of Non-Equilibrium Thermodynamics Marcus Hildebrandt,2025-02-19 While all field theories are nowadays available in a modern differential geometric coordinate free formulation on manifolds this has been so far only rudimentary accomplished in general non equilibrium thermodynamics In this work it is shown how a fitting geometric structure can be derived for arbitrary compact discrete Schottky Systems thermodynamic systems such as stars and black holes using only a few thermodynamic principles This leads to deep geometric insights Some central results are the following while in the theory of relativity the energy momentum tensor determines the geometry of the space in non equilibrium thermodynamics the 1 form of the entropy production rate is responsible for the emergence of a well known geometric structure the contact geometry Relaxation processes remain in the fibers in which they start and end on an attractor manifold that can be identified with the classical equilibrium subspace of thermostatics One then proves that outside this attractor manifold there are no reversible process directions As a consequence of this the 2nd Law of thermodynamics lives mainly on the fibers of the state manifold the so called vertical geometric structure while the 1st Law of thermodynamics is formulated on the horizontal components

of the state manifold The internal energy provides a physical gauge for each fiber The 1st and 2nd Law of thermodynamics are coupled via the representation of the entropy flux 1 form that can be represented in the dual basis of exchange 1 forms such as the heat 1 form This fact can be used to provide a coordinate free invariant definition of non equilibrium temperature Finally it is shown that probably the most general geometric structure to model non equilibrium thermodynamics of compact discrete Schottky systems systems is given by a composite fibred cocontact phase manifold that includes time as an explicit dimension

Quantum Information Science Riccardo Manenti, Mario Motta, 2023 This book explains quantum information the science at the basis of the new quantum revolution of this century Aimed at students who are about to begin a master s program or their graduate studies it teaches the reader to build and program a quantum computer and leverage its potential

Physics Fixes All the Facts Liam Graham, 2025-01-16 Complex systems seem to magically emerge from the interactions of their parts A whirlpool emerges from water molecules A living cell from organic molecules You emerge from the cells of your body Not since chaos has a concept from physics spread like wildfire to other disciplines Emergence can be found from chemistry to economics from psychology to ecology At its heart is the alluring idea that there s more to the world than physics that there is a holistic component to nature an edge of mystery Physics Fixes All the Facts starts by taking you on a tour through a fascinating world of complexity exploring phenomena from the inside of an atomic nucleus to bacterial behaviour to the ability of your thoughts to affect the world These examples are used along with a thorough exploration of the philosophical literature to untangle the notoriously poorly defined concept of emergence This reveals something surprising the term emergence is redundant In its weak form it is so weak that it applies to everything In its strong form it is so restrictive that it is like the belief that there are pixies in your garden impossible to exclude but not worth spending your time on Emergence either applies to all systems or to none Rather than telling us something about the nature of the world it is an illusion an artefact of our cognitive limitations The past decade has seen a dozen or so monographs and collections about emergence almost all resolutely supportive of the concept This book aims to redress the balance But it is more than just a campaign against the idea of emergence Graham presents a framework called Austere Physicalism and argues that it is the only coherent way to view the world He uses this framework to reinterpret so called emergent phenomena and investigates its wider implications for science In this radically materialist view we are nothing but physical systems among others Physics Fixes All the Facts ends by exploring what this means for our sense of free will and consciousness The book will appeal to academics in fields which use the concepts of complexity or emergence Scientists and philosophers alike will find unexpected and exciting ideas in these pages But the target audience is much broader including students who want to add context to their studies and the intellectually curious with some scientific background

Energy Limits in Computation Craig S. Lent, Alexei O. Orlov, Wolfgang Porod, Gregory L. Snider, 2018-08-03 This book is a single source reference to the issues involved in the Landauer principle which has gained new prominence recently due to the large

amount of heat generated by today's computers. If Landauer's principle is correct, there may be ways to build computers that dissipate far less power corresponding to heat generated than today's computers. This book brings together all sides of the discussions regarding Landauer's principle, both theoretical and experimental, empowering readers to gain better understanding of dissipation in computation and the limits, if any, to progress in computation related to energy dissipation. It represents the best and most thorough examination of the important issue of Landauer's principle that is available in one volume. Provides an in-depth investigation of the Landauer principle and how it relates to the possible existence of lower bounds on dissipation in computation. Gathers together both sides of the discussion: those who agree with Landauer and his conclusions and those who think that Landauer was not correct, offering a fresh perspective on the issues in the new light of experiments. Offers insight into the future of silicon CMOS and the limits, if any, to progress in computation related to energy dissipation.

Mathematical Reviews, 2007 **American Book Publishing Record**, 2005 *Einsteins trojanisches Pferd* Norbert Olah, 2012-08-31 Die Quantenthermodynamik bietet eine konsistente und entmystifizierende Deutung der Quantenmechanik. Die Auffassung des Quantenobjekts als thermodynamisches System ermöglicht eine tiefere statistische Fundierung der Quantentheorie und eröffnet neue Wege zur Überwindung des Wellenteilchen Dualismus und des Paradoxons der Zeitumkehrinvarianz. Die Quantentheorie wird aus einer statistischen Thermodynamik abgeleitet. Damit wird die aktuelle Literatur zur Quantenthermodynamik und Dekohärenz um eine neue Sichtweise ergänzt. Die Schrödinger-Gleichung wird aus einer thermodynamischen Lagrange-Funktion hergeleitet. Quanteneffekte entstehen durch ein Zusammenspiel von Entropieproduktion und Entropiediffusion. Die thermodynamische Stabilität erzwingt die Energiequantisierung gebundener Zustände und eine Nullpunktsenergie. Die Dekohärenz der Überlagerungszustände wie auch die Dissipationsfreiheit der Eigenzustände kann thermodynamisch begründet werden. Die Heisenbergsche Unschärferelation wird auf den zweiten Hauptsatz zurückgeführt.

Evolution and Emergence Nancey Murphy, William R. Stoeger, 2007-04-05 A collection of essays by experts in the field exploring how nature works to produce systems of increasing complexity from simple components and how our understanding of this phenomenon of emergence can lead us to a deeper appreciation of both our humanity and our relationship with God.

Metabolism and Medicine Brian Fertig, 2022-01-25 Chronic disease states of aging should be viewed through the prism of metabolism and biophysical processes at all levels of physiological organization present in the human body. This book describes the building blocks of understanding from a reasonable but not high-level technical language viewpoint employing the perspective of a clinical physician. It brings together concepts from five specific branches of physics relevant to biology and medicine: namely, biophysics, classical electromagnetism, thermodynamics, systems biology, and quantum mechanics.

Key Features: Broad and up-to-date overview of the field of metabolism, especially connecting the spectrum of topics that range from modern physical underpinnings with cell biology to clinical practice. Provides a deeper basic science and interdisciplinary understanding of biological systems that broaden the perspectives and therapeutic

problem solving Introduces the concept of the Physiological Fitness Landscape which is inspired by the physics of phase transitions This first volume in a two volume set primarily targets an audience of clinical and science students biomedical researchers and physicians who would benefit from understanding each other s language

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