

Scaling And Renormalization In Statistical Physics - Cambridge Lecture Notes In

Statistical physics is a branch of physics that deals with the behavior of large collections of particles based on statistical laws. It provides a framework to study the properties of matter and physical systems at various scales. Scaling and renormalization are two important concepts in statistical physics that help us understand the behavior of systems across different length and energy scales. In this article, we will explore these concepts and their relevance in understanding complex systems.

What is Scaling?

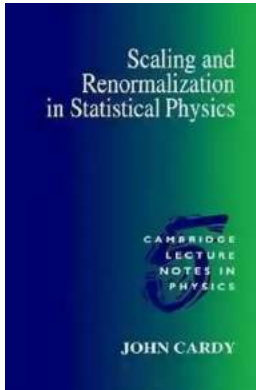
Scaling refers to the study of how the properties of a system change as we change the length or energy scale at which we observe it. Many physical systems exhibit scaling behavior, which means their properties remain invariant under certain transformations. For example, if we consider the behavior of a ferromagnetic material near its critical temperature, we find that certain properties like magnetic susceptibility or heat capacity exhibit scaling behavior.

In statistical physics, scaling is often characterized by power laws. Power laws describe how a certain property of a system changes as a function of a relevant parameter. For example, the heat capacity of a ferromagnetic material near its critical temperature follows a power law dependence on temperature. This power law behavior is a signature of scaling in the system.

Scaling and Renormalization in Statistical Physics (Cambridge Lecture Notes in Physics Book 5)

by Alina A. Dumitrescu (1st Edition, Kindle Edition)

★★★★★ 5 out of 5



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Renormalization: From Microscopic to Macroscopic

Renormalization is a powerful technique used in statistical physics to understand systems across different length scales. It allows us to relate the behavior of a system at a microscopic level to its macroscopic properties. The basic idea behind renormalization is to coarse-grain a system, i.e., to average out the details at a smaller scale and write down effective equations that describe the behavior of the system at a larger scale.

Renormalization is particularly useful when dealing with systems that exhibit strong correlations or collective phenomena. These systems often have complex behavior that cannot be directly understood from their microscopic constituents. By coarse-graining the system, renormalization helps us simplify the problem and identify the relevant macroscopic degrees of freedom.

The process of renormalization involves integrating out degrees of freedom at a smaller scale. This integration is done by performing suitable mathematical operations such as averaging or summing over all possible configurations of the microscopic degrees of freedom. The result of this integration is an effective

action or effective Hamiltonian that describes the behavior of the system at a larger scale.

Applications of Scaling and Renormalization

Scaling and renormalization have found numerous applications in various branches of physics. Some prominent examples include the study of phase transitions in condensed matter systems, the theory of critical phenomena, and the behavior of complex networks.

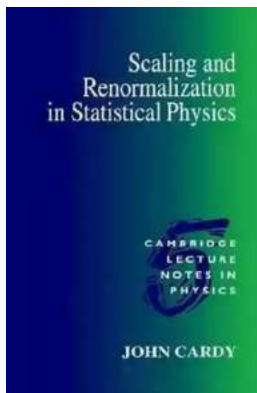
Phase transitions, such as the transition between liquid and gas phases or the transition between ferromagnetic and paramagnetic phases, are described by scaling laws. Scaling and renormalization help us understand these transitions and predict their critical exponents, which provide valuable information about the universality class of the transition.

Critical phenomena, which occur at phase transitions, are characterized by long-range correlations and scaling behavior. The renormalization group, a powerful technique closely related to renormalization, allows us to study the behavior of critical systems and classify them into different universality classes.

Complex networks, such as social networks or the internet, exhibit scaling behavior in various properties like degree distribution or clustering coefficient. Scaling and renormalization techniques have been applied to study the properties of these networks and understand their robustness, vulnerability, and evolution.

Scaling and renormalization are important concepts in statistical physics that allow us to understand the behavior of complex systems at different length and energy scales. These concepts have applications in various fields, from condensed matter physics to network science. By studying scaling laws and

performing renormalization, we can uncover universal properties of physical systems and gain insights into their collective behavior.



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This text provides a thoroughly modern graduate-level to the theory of critical behaviour. Beginning with a brief review of phase transitions in simple systems and of mean field theory, the text then goes on to introduce the core ideas of the renormalization group. Following chapters cover phase diagrams, fixed points, cross-over behaviour, finite-size scaling, perturbative renormalization methods, low-dimensional systems, surface critical behaviour, random systems, percolation, polymer statistics, critical dynamics and conformal symmetry. The book closes with an appendix on Gaussian integration, a selected bibliography, and a detailed index. Many problems are included. The emphasis throughout is on providing an elementary and intuitive approach. In particular, the perturbative method introduced leads, among other applications, to a simple derivation of the epsilon expansion in which all the actual calculations (at least to lowest order) reduce to simple counting, avoiding the need for Feynman diagrams.



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