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ІЗИНҐІВСЬКІ ЧИТАННЯ–2002
(Львів, 12-14 березня 2002 р.)

ISING LECTURES–2002
(Lviv, March 12–14, 2002)

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ІЗИНҐІВСЬКІ ЧИТАННЯ–2002 (Львів, 12–14 березня 2002 р.)

за редакцією Юрія Головача

Анотація. Збірник містить анотації лекцій прочитаних 12–14 березня 2002 р. під час “Ізинґівських читань” – щорічного семінару із фізики фазових переходів і критичних явищ. Читання проводяться у Львові починаючи з 1997 року Інститутом фізики конденсованих систем НАН України спільно з кафедрою теоретичної фізики Львівського національного університету імені Івана Франка.

ISING LECTURES–2002 (Lviv, March 12–14, 2002)

edited by Yurij Holovatch

Abstract. Summaries of the lectures given on March 12–14, 2002 in Lviv in the frames of the "Ising lectures" (a workshop on phase transitions and critical phenomena). The workshop is organized annually by the Institute for Condensed Matter Physics of the National Academy of Sciences of Ukraine and the Chair for Theoretical Physics of the Ivan Franko National University of Lviv.

Подається в Журнал фізичних досліджень
Submitted to Journal of Physical Studies

Ernest Ising (10.05.1900 – 11.05.1998).

Introduction

The idea to set-up in Lviv an annual seminar on phase transitions and critical phenomena holding the name of “Ising lectures" appeared in 1997, when a group of Lviv physicists learned from Professor Sigismund Kobe about history of life of Ernest Ising (see S. Kobe, J. Stat.Phys. **88**, 991 (1997) and J.Phys.Stud. **2**, 1 (1998)). For many of us the name of Ising was deep in the beginning of history of phase transitions theory and we were really surprized learning that he was still in a good health then and hearing about his life and adventures during the period after the "Ising model" was born. The Ising model is one of the classical models in physics of phase transitions and it seemed for us quite natural to call the seminar by the name of Ising. Since 1997 the seminar is regularly organized by the Institute for Condensed Matter Physics of the National Acad. Sci. of Ukraine and Ivan Franko National University of Lviv. The seminar aims in promoting and deepening studies of critical phenomana as well as exchanging information between scholars working in this field. More detailed information may be achieved from our institute's server: http://www.icmp.lviv.ua following links "conferences" and “Ising Lectures".

This year the program of the seminar consisted of seven lectures given by the leading scholars in their fields. Each of the lectures contained both a review giving the comprehensive state-of-art in the subject chosen by the lecturer as well as the orinal part. The last was presented in the way which allowed also an understanding by students which widely attended the seminar. On behalf of the organizers I would like to express my warmest appreciation to the lecturers for their excellent work as well as to the Science Support Foundation (Lviv) and the Institute for Condensed Matter Physics of the National Acad. Sci. of Ukraine for the partial financial support. The abstracts of the lectures are given below in the order the letures were given. The texts of the lectures will apear separately.

Yurij Holovatch

Contents

Phase transitions in strongly correlated electron systems. Exactly solvable models

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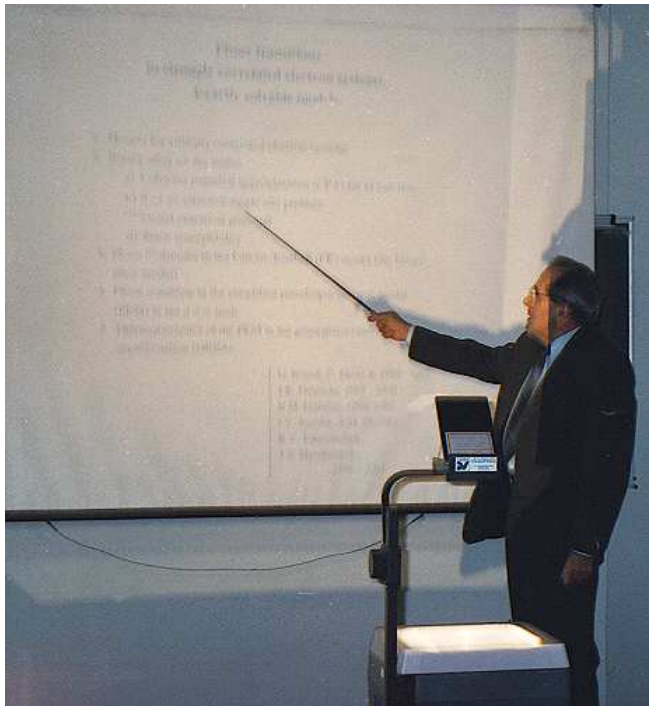

Some problems of the theory of strongly correlated electron systems are discussed in the lecture. A brief review of the history of the main ideas and model development (from the Bogoliubov polar model of the metal, Hubbard model and its extensions to the Falicov-Kimball and pseudospin-electron models) is given.

The dynamical mean field theory (DMFT) approach, which is exact in the limit of the infinite dimension of space, is presented on the example of the binary alloy lattice model. It provides a derivation of equations for the coherent potential and electron Green's function in an analytic

form as well as expressions for the grand canonical potential and static susceptibilities in the cases of the exactly solvable models.

Besides the binary alloy model the pseudospin-electron model (PEM) and Falicov-Kimball (FK) one belong to the models of this kind. The results of recent investigations of the FK model performed by various groups are discussed. The main features of the energy spectrum and thermodynamics of the model as well as phase transitions into modulated or segregated phases are considered.

Special attention is paid in the lecture to the pseudospin-electron model which appeared in the last few years in connection with the investigation of the high-Tc superconductors and systems with hydrogen bonds (the model is closely related to the FK model but differs by the regime of the thermodynamical averaging procedure). The results of investigation of the equilibrium states of PEM (using its various versions) within the DMFT scheme and by means of the generalized random phase approximation are analyzed and compared. The possibilities of application of the PEM to description of the inhomogeneous states and structure instabilities in the high-Tc superconducting systems are discussed.

The random Potts model

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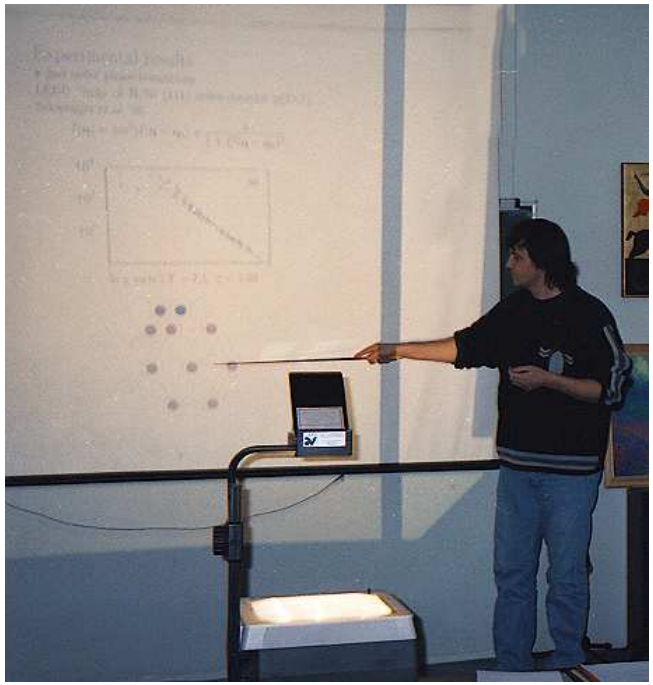

Influence of uncorrelated, quenched disorder on the phase transition of two dimensional Potts models will be reviewed. After an introduction where the conditions of relevance of quenched randomness on phase transitions are exemplified by some experimental measurements, the results of perturbative and numerical investigations in the case of the Potts model will be presented. The Potts model is of particular interest, since it can have in the pure case a second-order or a first-order transition, depending on the number of states per spin. In 2d, transfer matrix calculations and Monte Carlo simulations are used in order to check the validity of conformal invariance methods in disordered systems. These techniques are then used to investigate the universality class of the disordered Potts model, in both regimes of the pure model phase transitions. A test of replica symmetry is made possible through a study of multiscaling properties.

Two-dimensional polymers, the Edwards model and O(n=0) field theory

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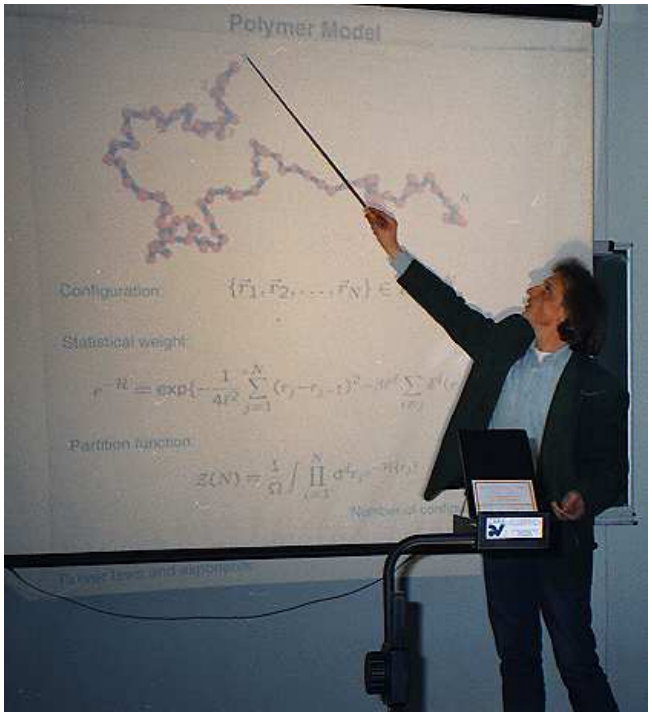

In this lecture, we discuss the scaling properties of long flexible polymer chains in two dimensions. We compare perturbative expansions of the Edwards model, lattice Monte Carlo simulations, and exact results using conformal invariance and 2D quantum gravity for the (scaling) properties of random walks with self and/or mutual avoidance interactions. We are especially interested in the question of the universality of the problem of self and mutually avoiding walks in two dimensions (2D), as well as in validating multifractality found in these situations by field theoretic methods based on the Edwards model and by a conformal theory.

We focus on model star copolymers in two dimensions: walks or polymers of different species with a common starting point; the species avoid each other mutually.

In our field theoretic approach we mapped the problem of finding the scaling properties of the copolymer star to that of determining the anomalous dimensions of appropriate local field operator products. Resummation of the perturbation series for these dimensions provides reliable numeric values for a family of exponents that displays multifractal behavior.

A recent extension of the conformal theory for 2D polymers to random graphs using methods of 2D gravity has revealed an exact derivation of this multifractal spectrum which is in remarkable coincidence with the perturbative results for a number of situations.

To further investigate this coincidence with respect to universality and moreover to uncover the reasons for deviations, we have undertaken a series of MC simulations on the lattice where the implementation of avoidance and topological restrictions of 2D polymers is most natural. While we confirm the universality of the 2D star copolymer problem of walks with topological avoidance it appears to constitute a class separate from the 2D Edwards and $O(n)$ models with repelling interactions.

Field theoretical approaches in the superconducting phase transition

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Several field theoretical approaches to the superconducting phase transition are discussed. Emphasis is given to theories of scaling and renormalization group in the context of the Ginzburg-Landau theory and its variants. Also discussed is the duality approach, which allows the access to the strong coupling limit of the Ginzburg-Landau theory.

Relaxation in quantum spin chains

Dragi Karevski
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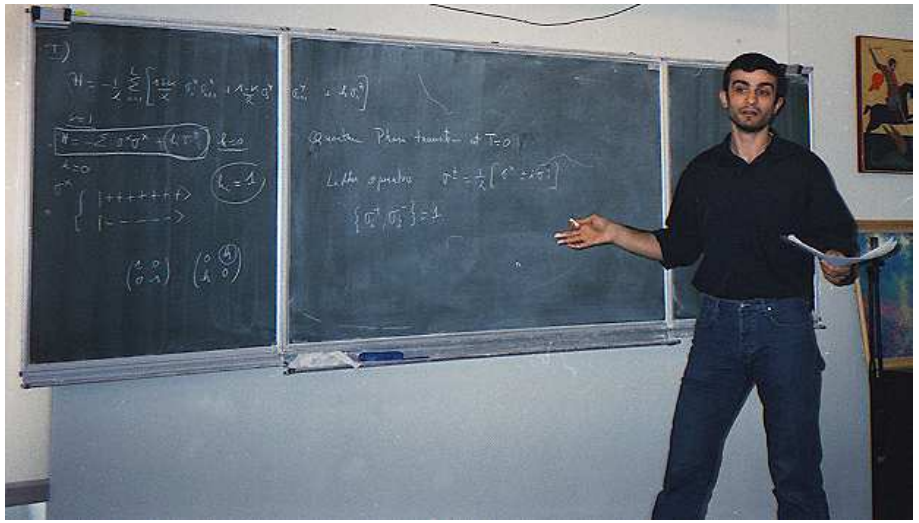

The aim of this lecture is to give a pedagogical introduction to the exact equilibrium and nonequilibrium properties of free fermionic quantum spin chains. In a first part we present in full details the canonical diagonalisation procedure and review quickly the equilibrium dynamical properties. The phase diagram is analysed and possible phase transitions are discussed.

The remaining part is devoted to the nonequilibrium dynamical behaviour of such quantum chains relaxing from a nonequilibrium pure initial state. In particular, a special attention is made on the relaxation of transverse magnetization. Two-time linear response functions and correlation functions are also considered, giving insights on the nature of the final nonequilibrium stationary state. The possibility of aging is also discussed.

Some facts about the mathematical theory of the Ising model and its generalizations

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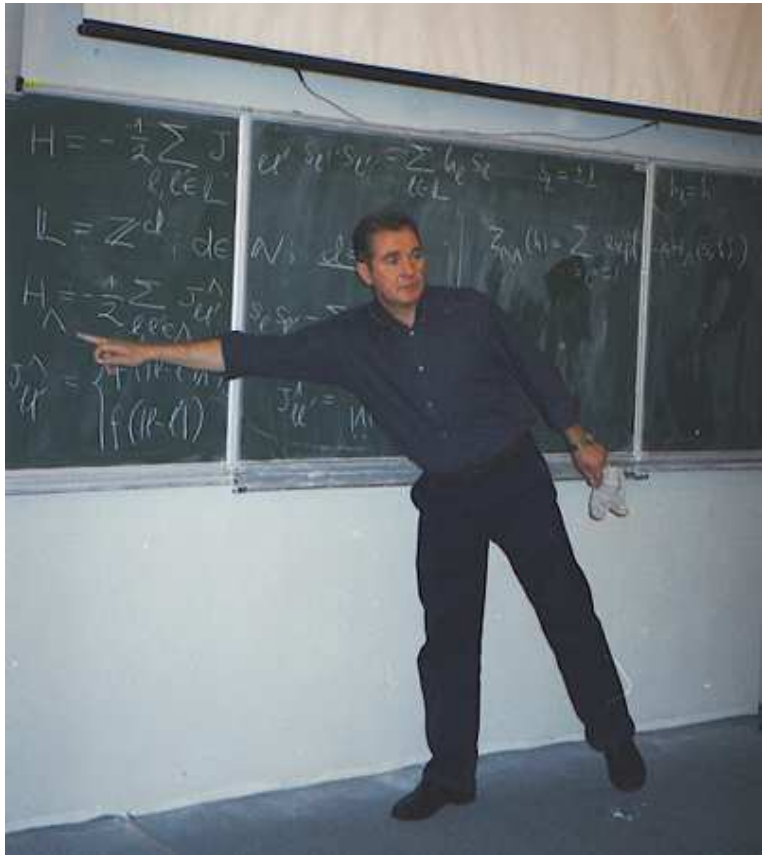
Marie Sklodowska University, Lublin, POLAND



The first part of the lecture gives an outlook of the main aspects of the mathematical theory of the Ising model. The existance and differentiability of the infinite volume free energy density, including the properties connected with the Lee-Yang theorem, are discussed. Then the equilibrium state of the model as a probability measure on the space of configurations is introduced, a number of its properties are described. In particular, the nonuniqueness/phase transitions properties are discussed

on the base of Dobrushin's criterium, as well as of the Lebowitz/Martin-Löf analiticity results. In the second part of the lecture, the above scheme is applied to the Ising model with a transverse field (De Gennes model), which contains non-comutative operators. Here the Euclidean approach, in which quantum states are represented by probability measures, is employed.

Quantum phase transitions in alternating transverse Ising chains

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We start from recalling generally known topics of the phase transition theory: phase transitions of the first and the second order in classical systems at nonzero temperature, the Onsager solution of the square-lattice

Ising model, critical behaviour of the physical quantities, universality, scaling, renormalization group. Then we turn to the basic concepts of quantum phase transition theory discussing the experiment of Bitko, Rosenbaum and Aeppli (1996) on Ising system ($LiHoF_4$) placed in a magnetic field transverse to the magnetic axis and the phase diagram of the Ising spin model in the plane temperature - transverse field. One-dimensional spin-$\frac{1}{2}$ Ising model in a transverse field is a simplest model exhibiting the second-order quantum phase transition. We discuss a relation of that model to the square-lattice Ising model and present the 'old' results of rigorous calculation derived by Pfeuty (1970). The essential tool in this solution is the Jordan-Wigner fermionization. We briefly explain how the fermionic description can be introduced and thus how the results of Pfeuty (and some other results) were derived. We contrast quantum and classical transverse Ising chains emphasizing that the zero-temperature continuous phase transition driven by the transverse field occurs in the quantum chain only.

The second part of the lecture deals with the effects of regular alternation of the Hamiltonian parameters (i.e., the intersite exchange interaction and on-site field) on the quantum phase transition. We elaborate an approach based on continued fractions for rigorous calculation of the thermodynamic quantities. The spin correlation functions for regularly alternating transverse Ising chains can be obtained numerically. We discuss in detail the case of a chain of period 2 comparing exact analytical and exact numerical results for the ground state properties. Moreover, we demonstrate how the ground state (and therefore all spin correlation functions) can derived for special parameter values. We complete the analysis of the effects of regular alternation examining the low-temperature behaviour of the specific heat. We sketch the phase diagram for a chain of period 3. We end up with conclusions emphasizing the effects of regular alternation on the second-order quantum phase transition in the transverse Ising chain.

Препринти Інституту фізики конденсованих систем НАН України розповсюджуються серед наукових та інформаційних установ. Вони також доступні по електронній комп'ютерній мережі на WWW-сервері інституту за адресою http://www.icmp.lviv.ua/

The preprints of the Institute for Condensed Matter Physics of the National Academy of Sciences of Ukraine are distributed to scientific and informational institutions. They also are available by computer network from Institute's WWW server (http://www.icmp.lviv.ua/)

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