Lecture Notes in Physics

Edited by J. Ehlers, München, K. Hepp, Zürich,
H. A. Weidenmüller, Heidelberg, and J. Zittartz, Köln
Managing Editor: W. Beiglböck, Heidelberg

54

Critical Phenomena

Sitges International School on
Statistical Mechanics, June 1976
Sitges, Barcelona/Spain
Director: L. Garrido

Edited by J. Brey and R. B. Jones

Springer-Verlag
Berlin · Heidelberg · New York 1976

Director

Luis Garrido
Instituto de Física Teórica
Diagonal, 647
Barcelona-14/Spain

Editors

Javier Brey
Universidade Sevilla
Facultad de Ciencias
Sevilla/Spain

Robert B. Jones
Queen Mary College
University of London
Mile End Road
London/Great Britain

Library of Congress Cataloging in Publication Data

Sitges International School of Statical Mechanics, 1976.
Critical phenomena.

(Lecture notes in physics ; 54)
Includes bibliographical references.

I. Critical phenomena (Physics)

I. Brey, Javier, 1947- II. Jones, Robert B.,
1940- III. Title. IV. Series.

QC173.4.C74S57 1976 536'.401 76-29038

ISBN 3-540-07862-2 Springer-Verlag Berlin Heidelberg New York
ISBN 0-387-07862-2 Springer-Verlag New York Heidelberg Berlin

This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned, specifically those of translation, re-printing, re-use of illustrations, broadcasting, reproduction by photocopying machine or similar means, and storage in data banks.

Under § 54 of the German Copyright Law where copies are made for other than private use, a fee is payable to the publisher, the amount of the fee to be determined by agreement with the publisher.

© by Springer-Verlag Berlin · Heidelberg 1976
Printed in Germany

Printing and binding: Beltz Offsetdruck, Hemsbach/Bergstr.

ACKNOWLEDGEMENTS

The Sitges International School of Statistical Mechanics was honored by the patronage of His Majesty the King, Juan Carlos I.

Acknowledgement must be made to those institutions without whose ready cooperation and financial assistance the School would not have been possible. I wish to express my particular gratitude to:

Ministerio de Educación y Ciencia
Ayuntamiento de Barcelona
Diputación de Barcelona
Rectorado de la Universidad de Barcelona
Ayuntamiento de Sitges

Finally I must not fail to thank all those who constantly encouraged and helped me and so ensured the success of this venture. I especially would mention Prof. de la Rubia, Dr. Martínez Sardá, Dr. Seglar and, in particular, my wife.

L. Garrido

CONTENTS

CRITICAL PHENOMENA AND SCALE INVARIANCE	F.J. WEGNER
I. Scaling: Phenomenological Description	3
II. Renormalization Group Equation	8
III. An Example	14
IV. Results on the Isotropic n-Vector Model	20
V. Scaling Fields and Universality	25
References	29
INVARIANCE PROPERTIES OF THE RENORMALIZATION GROUP	M.S. GREEN
I. Introduction	31
II. Differential Renormalization Transformation in Wegner Form	33
III. RG Linearized around Fixed Point	34
IV. Redundant Perturbations to $\mathcal{H}^*$	35
V. Flow Vector Containing a Parameter	37
VI. What Happens to Fixed Point	38
VII. What Happens to Eigenvalues	39
VIII. Conclusions	41
References	42
SCALE TRANSFORMATIONS IN DYNAMIC MODELS	SHANG-KENG MA
I. Review of Basic Ideas and Terminology	44
II. Simple Examples	56
III. Monte Carlo Study of the Renormalization Group	63
IV. Perturbation Methods	71
References	78
CRITICAL DYNAMICS IN FOKKER-PLANCK FORMALISM	C.P. ENZ
I. Classification of Models	80
II. Fokker-Planck Formalism	86
III. Perturbation Theory	98
IV. Application to Structural Phase Transitions	103
References	109

DYNAMIC CRITICAL PHENOMENA AND THE RENORMALIZATION GROUP - APPLICATION TO A LATTICE DYNAMIC MODEL P. SZÉPPALUSY

I. Introduction	112
II. The Dynamics of the Model in the $n \rightarrow \infty$ Limit	120
III. Hydrodynamics and Dynamic Scaling in the Lattice Dynamical Model	127
IV. Semimacroscopic Description of the System	133
V. Renormalization Group Analysis	142
References	153

THE ALGEBRAIC APPROACH TO QUANTUM STATISTICAL MECHANICS. EQUILIBRIUM STATES AND HIERARCHY OF STABILITY R. HAAG

I. Introduction	156
II. Basic Concepts	158
III. Equilibrium States. Stability Condition. KMS-Condition	168
IV. Direct Computation of Equilibrium States from the Stability Condition for the Free Bose- and Fermi Gas	176
V. Hierarchy of Stability	184
Appendix	186
References	188

THEOREMS ON PHASE TRANSITIONS WITH A TREATMENT FOR THE ISING MODEL S. MIRACLE-SOLÉ

Introduction	190
I. Notations and Definitions	191
II. First Remarks on the Equilibrium States	194
III. Statement of the Results	197
IV. Uniqueness of the Equilibrium State	198
V. Critical Temperature and Spontaneous Magnetization	199
VI. Two Phase Coexistence at Low Temperature	202
VII. Two Phase Coexistence below T_c	204
VIII. Sharpness of the Interface Surface	209
IX. Interface Profile in Two Dimensions	211
References	213

STATISTICAL MECHANICS OF EQUILIBRIUM SYSTEMS: SOME RIGOROUS RESULTS J.L. LEBOWITZ

I. Introduction	216
II. The Canonical Ensemble: Thermodynamic Limit of the Free Energy	219
III. Phase Transitions for Systems with Long Range Potentials	225
IV. Grand Canonical Ensemble	232
V. Lattice Systems	238
References	246

PROBABILISTIC ASPECTS OF CRITICAL FLUCTUATIONS	G. GALLAVOTTI
I. Generalities	250
II. Macroscopic Fluctuations Theory	259
III. Applications to Field Theory	263
IV. Remarks	271
References	273
THE APPLICATION OF RENORMALIZATION GROUP TECHNIQUES TO QUARKS AND STRINGS	L.P. KADANOFF
Introduction	276
I. Statistical Variables and Statistical Sums	278
II. Symmetries	288
III. Renormalization Theory: A Point of View and a Calcula- tional Method	298
IV. Properties of the Quark-String Model	317
V. Approximation Methods for Lattice Systems	328
References	346
THE ROLE OF SPONTANEOUS BROKEN SYMMETRY	R. BROUT
I. Spontaneous Broken Symmetry and the Nambu-Goldstone Theorem	350
II. Application of the Nambu-Goldstone Theorem to Particle Theory	360
III. Spontaneous Broken Gauge Theory	369
IV. Quantum Flux Lines: Type II Superconductivity: The Dual String	377
V. Odds and Ends	380
References	383

LECTURERS

Prof. R. BROUT, Brussels, Belgium
Prof. Ch. ENZ, Geneva, Switzerland
Prof. G. GALLAVOTTI, Rome, Italy
Prof. M.S. GREEN, Philadelphia, USA
Prof. R. HAAG, Hamburg, Germany
Prof. L.P. KADANOFF, Providence, USA
Prof. J.L. LEBOWITZ, New York, USA
Prof. S.K. MA, Saclay, France
Prof. S. MIRACLE-SOLE, Zaragoza, Spain
Prof. P. SZEPPFALUSY, Budapest, Hungary
Prof. F. WEGNER, Heidelberg, Germany

PARTICIPANTS

Mr. K. AMSLER, Bern, Switzerland
Miss M. AUBERSON, Neuchâtel, Switzerland
Dr. M. AUSLOOS, Liège, Belgium
Dr. P. AUSLOOS-CLIPPE, Liège, Belgium
Dr. G. BASKARAN, Bangalore, India
Dr. J. BASTEN, Petten, Holland
Prof. A. BERNALTE, Bilbao, Spain
Dr. J. BIEL, Barcelona, Spain
Prof. L.J. BOYA, Zaragoza, Spain
Mr. J. BRICMONT, Louvain-le-Neuve, Belgium
Dr. A. BUNDE, Antwerp, Belgium
Mr. C. CAMAROTTA, Naples, Italy
Mr. V. CANIVELL, Barcelona, Spain
Mr. H. CAPES, Fontenay-aux-Roses, France
Dr. P. CHANDRA SEKHAR, Bangalore, India
Dr. N. CLAVAGUERA, Barcelona, Spain
Dr. A. CORDOBA, Sevilla, Spain
Dr. P. DAMAY, Lille, France
Dr. F. DEBACKER-MATHOT, Louvain-le-Neuve, Belgium

Mr. B. DEMOEN, Heverlee, Belgium
 Mr. E. ELIZALDE, Barcelona, Spain
 Prof. R. FERNANDEZ ALVAREZ-ESTRADA, Madrid, Spain
 Dr. R. FIGARI, Naples, Italy
 Miss M. FILIPE, Oxford, England
 Dr. R. FOLK, Linz, Austria
 Dr. B. GIDAS, Seattle, USA
 Mr. E. GLOTZL, Linz, Austria
 Dr. H. GRABERT, Stuttgart, Germany
 Dr. J. GOMIS, Barcelona, Spain
 Prof. J.D. GUNTON, Philadelphia, USA
 Prof. H. HAHN, Braunschweig, Germany
 Mr. D. HELLWIG, Essen, Germany
 Mrs. D. HERRMAN-RONZAUD, Grenoble, France
 Dr. A. HUBER, Kiel, Germany
 Mr. D. JOU MIRABENT, Barcelona, Spain
 Mr. H. KING, Essen, Germany
 Prof. N. KUMAR, Trieste, Italy
 Dr. M. LEAL, Valladolid, Spain
 Dr. K. LENDI, Zürich, Switzerland
 Prof. F. di LIBERTO, Naples, Italy
 Mr. A. MAC LEOD, St. Andrews, Scotland
 Mr. J.M. MARCAIDE, Zaragoza, Spain
 Miss M. MARQUES, Porto, Portugal
 Dr. J. MARRO, Barcelona, Spain
 Mr. J. MATEOS, Zaragoza, Spain
 Dr. D. MAYER, Bures-sur-Yvette, France
 Dr. N. MENYHARD-SZEPFALUSY, Budapest, Hungary
 Dr. A. MESSENGER, Marseille, France
 Dr. G. MONROY, Naples, Italy
 Prof. M.T. MORA, Valladolid, Spain
 Dr. R. MORF, Zürich, Switzerland
 Dr. M. MURMANN, Heidelberg, Germany
 Dr. Ch. NAPPI, Naples, Italy
 Dr. J. NAUDTS, Antwerp, Belgium
 Dr. M. PARAMIO, Zaragoza, Spain
 Mr. J.M. PARRA, Barcelona, Spain
 Prof. A. PAVLOVIC, Grenoble, France
 Mr. L. PESQUERA, Valladolid, Spain
 Dr. E.B. POHLMAYER, Hamburg, Germany
 Dr. M. QUIROS, Madrid, Spain

Dr. M. RAMON, Madrid, Spain
Dr. D. REISETBAUER, Linz, Austria
Dr. G. REITER, Göteborg, Sweden
Mrs. M. REYNAERT, Heverlee, Belgium
Dr. M. RIVAS, Bilbao, Spain
Prof. E. ROJAS, Sevilla, Spain
Dr. V. RUIZ, Valencia, Spain
Mr. J.M. SANCHE, Barcelona, Spain
Mr. M. SAN MIGUEL, Barcelona, Spain
Prof. E. SANTOS, Valladolid, Spain
Miss M. SANTOS, Birmingham, England
Dr. J. SARBACH, Zürich, Switzerland
Dr. J. SCHOUTEN, Amsterdam, Holland
Dr. P. SEGLAR, Barcelona, Spain
Dr. P. SHEPHERD, Exeter, England
Dr. P. SHUKLA, Oxford, England
Mr. L. SNEDDON, Oxford, England
Prof. P. TOMBESI, Rome, Italy
Miss K. UZELAC, Zagreb, Yugoslavia
Dr. S. VELASCO, Salamanca, Spain
Prof. M. ZANNETTI, Salerno, Italy
Mr. T. ZIMAN, Oxford, England

DIRECTOR

Prof. L. GARRIDO, Barcelona, Spain

EDITORS

Prof. J. BREY, Sevilla, Spain
Dr. R.B. JONES, London, England

SECRETARIES

Mrs. Ch. BALY, Geneva, Switzerland
Mrs. R. CHESTER, Edinburgh, Scotland
Miss P. UDINA, Barcelona, Spain