The Aharonov-Bohm Effect (Lecture Notes in Physics, Vol. 340)

by M Peshkin and A Tonomura

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Faraday and Maxwell introduced the concept of the electromagnetic field to describe electromagnetic effects in a space-time region – thereby unifying electrical and magnetic phenomena. The field strength F_{μ} describes electromagnetism. In 1959 Bohm and Aharonov presented a paper in which they pointed out the significance of electromagnetic potentials in quantum theory and actually suggested, interference experiments to detect how potentials would affect the passage of electrons through field free regions. In a multiply connected, region even if $F_{\mu}=0$ everywhere, there are physical experiments for which the outcome depends on the loop integral :

$$\frac{e}{hc}\oint A_{\mu}dx^{\mu}$$

around on unshrinkable loop. It has been realised that in fact only the *phase factor*

$$\exp\left(\frac{ie}{he}\oint A_{\mu}dx^{\mu}\right)$$

in meaningful and phase invariance (gauge invariance) is the correct quantum mechanical, characterisation of electromagnetism. The idea has in recent years been generalised by replacing the simple phase of complex numbers with more complicated phase – an element of a Lie group.

Few effects in physics have the distinctions of going through extensive debates and experimentations to settle the nuances as in AB effect. The controversial aspects of AB effect concern mainly its interpretation. To quote Bohm "Now in my view, the fact that our informal discussion of interaction in terms of forces has been shown to be irrevalent implies the need, for a new kind of informal discussion of this question. That is what I meant by saying that AB effect indicates the need to alter our informal terms of discussion of the vector potential as having a new kind of significance". This was expressed in a communication to one of the authors (M P) of the book under review. There is not much disagreement today as to the effect itself-well verified through delicate and precise measurements in which the state of the art has attained, astounding precision. However, questions concerning localisation and action at a distance remain alive.

So, it is in this backdrop that "The Aharonov-Bohm Effect" by M Peshkin and A Tonomura has to be examined. The book consists of two parts. The

Part I (Theory) by M Peshkin claims to give an exposition of that theoretical setting mainly with a view to highlight the background for experimentation. Peshkin has given a pedagogic treatment in his venture to explain the various aspects of AB effect. Starting with an introduction to the AB effect, he discusses, the classical theory, quantum theory, bound-state case, role of quantised angular momentum, scattering state case, locality and causality and the lessons from experiments. The four appendices to this part contain detailed derivations of the formulae needed in the text. However, the theoretical part is almost like a classroom lecture note in which deeper questions such as topological factors or the questions of locality are not adequately treated. However, the treatments given for the different topics mentioned above have been kept at a rather simple level, which will be very useful to students and beginners in research in this line.

The second part of the book consists mainly of the treatment of various aspects of the experimentation of AB-effect—the author (A. T.) being one of the very successful experiments in this line. However, this part also contains very lucid and rather adequate theoretical exposition of the various facets of AB effect. After giving a historical background, Tonomura discusses the basic aspects of the electric, magnetic and scattering state AB effects. Disputes regarding the significance of potentials are clearly discussed. He also considers the non-integrable phase factor and its generalisation of to Non-Abelian gauge fields. Tonomura goes through a very clear exposition of AB-effect including topological considerations and modern experiments by Deaver and Donaldson to demonstrate the winding number dp dependence of the AB-effect. Electron interference experiments to detect a single flux quantum is described. Then he passes on to the discussion of AB-effect and magnetic monopoles and non-locality of the AB-effect including the Van Kampeu experiment to find if AB-effect transit signals faster than light.

Tonomuras exposition of the standard experiments as also the proposed new experiments is very clear and interesting. Sufficient details are also given regarding down to the earth experimental requirements such as fabrication of samples. There is also an interesting section on experiments using toroidal, magnets. Following his exposition of the sophistication of experimental techniques and their possibilities one feels convinced that advanced technology and clarification of fundamental problems in physics are very much interrelated.

The book as a whole is very interesting though there are a number of overlapping areas in the two parts of the book. It seems to the reviewer that the part I might have been ommitted altogether.

The references cover wide regions of interest. I strongly recommend the book for inclusion in the library of academic institutions. Actually the book covers more ground than its name indicates.

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Disorder and Nonlinearity (Springer Proceedings in Physics, Vol. 39)

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edited by A R Bishop, D K Campbell and S Pnevmatikos

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viii+143 pages, 66 figures ; price : DM 75 (Hard cover) ; ISBN 3-540-51374-4

The role of nonlinearity in physical sciences needs hardly be overemphasised. In fact over the last few decades the development of nonlinear dynamics initiated by the pioneering work of Kolmogorov in early sixties has profoundly affected the course of research in various disciplines, e.g. optics, fluid mechanics, solid state physics, electronics and even in biology. Following these developments several age-old 'belief's were subjected to thorough revision and serious rethinking on the longtime prediction in dynamics on the basis of equations of motion and the concept of ergodicity was necessary. The result is the dramatic development of deterministic chaos which implies that even some of the simplest nonlinear dynamical systems may exhibit truely random-iike time evolution.

Parallel to these developments considerable progress was made in understanding the role of disorder in classical and quantum systems. This field was initiated by the pioneering work of Anderson. The disorder due to random potential leads to localization of electronic states – the consequence of which was deeply felt in the wide arena ot solid state and other branches.

It seems that although the early development of the two fields was independent by their own nature, the interconnection between nonlinearity and disorder or even the formal similarity in the related issues may be very important. For example, the formal similarity of the problems between some aspects of quantum chaos and Anderson localization in kicked rotator poses interesting questions. Also one may legitimately ask what happens to Anderson localization in presence of nonlinearity and also various other questions.

The present Springer proceedings under review brings some of these aspects to our attention in fifteen articles. These are arranged in three sections. The first section devoted to the problems of localization and nonlinearity contains seven articles. In the first two of them the nonlinear one-dimensional optical media with random inhomogeneties have been studied to see the effect of interplay between nonlinearity and disorder on optical bistability by classical Helmotz equation and nonlinear Schrodinger equation in the tight-binding form. In another interesting article Anderson localization has been derived in terms of a generalized master equation with a nearest neigh'our memory function. The two articles discuss quantum transport problem in terms of the nonlinear quantum evolution equation. Sutherland has given a brief account of some features of physics of quasiperiodic systems where one can follow the dynamics in terms of a simple trace map. In

the last article of the first section the density of states in disordered two-dimensional system has been calculated.

The four articles in part two of the book are devoted to solitons and disorder. The first two deal with spatial disorder due to impurity and space stochastic perturbations. In the third article chaotization of soliton and breather motion of perturbed Sine-Gordon has been investigated. The last one deals with a two-component soliton model in a H-bonded network.

The part III of the book starts with a study on statistics of back scattering generated when an acoustic plane wave pulse is incident on a randomly layered half-space. The next two articles are on localization of light. The experimental realization of weak localization have given new impetus in the field of Anderson localization of light. The last one discusses the nonresonant effect with ultrashort light pulses. The book ends with a brief remark on disorder and nonlinearity by Krunhanst.

The book is mainly devoted to some borderline issues on nonlinearity and disorder. One could have equally well add the aspect of phase transitions, a few more articles on quasiperiodic systems.

Although primarily designed for the specialists the book is a wellcome addition in the field of nonlinear science, in general.

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1989 CERN School of Computing

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CERN 90-06

edited by C Verkerk

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viii+347 pages ; ISBN 92-9083-025-5

The CERN publication 90-06, about three hundred and fifty pages long, contains the proceedings of the twelfth school of Computing organised by CERN at Bad Herrenalb in the FRG.

For over 30 years CERN has been a leading civilian user of computers. It began with the acquisition of the Ferranti Mercury system in 1958, and now has in its inventory CRAY XM-P 48, DEC VAX 8600/8650/8700/8800, IBM3090 FUJITSU M382, aside from a large number workstations, and of course, the PCs. Coupled with the networks that connect the machines to centers across the globe,

and the library of softwares and programs, it is an asset that allows the organisation to take on projects as complex as the LEP.

That it all began in a modest way in the mid-fifties, and the strides since then has been aptly captured in the leading article by Zanella of CERN. The story of CERN Computing Center in a way mirrors the state of affairs in the computer industry – the early attempts in the mid fifties when the "European computer industry was still competitive", the unreliability of the 'big machines' of that era, onto the development of FORTRAN, the IBM development of reliable computer, the user-friendly systems from the DEC, the powerful Cybers of the seventies giving way to the CRAY, and the demise of supercomputing at the CDC. The CERN obviously had little interaction with the Japanese systems, except for the machines distributed in European labels by companies such as the Siemens, but designed and manufactured in Japan.

This publication is, however, more than the history of computing at CERN, and contains a total of fifteen specialised and contemporary articles on the subject of computers, networks, and even galliumarsenide vis-a-vis silicon in supercomputer chips. H M Wacker's outline on the present and the future configuration of computers and networks connecting the DFVLR establishments in the FRG may be of conderable use for agencies planning and executing similar nets here. Hey and Bowler discuss the transputers and parallel computing. Development of parallel machines based on these systems have been reported here by C-DAC, Pune, and is certainly of great interest in this country as C-DOT, ANURAG, NAL and others travel similar routes.

Treleven presents an introductory glimpse of the hardwares and softwares for neural computer, and Wacker discusses the ways to measure the performance of the vector machines. This is followed by a set of five articles related to the use of computers, expert systems and artificial intelligence in data collection, diagnosis of accelerators, analysis of tracks and vertices in high-energy physics. The European high-energy physics net is also one of the topics.

The last four pieces introduces the readers to ciphering algorithms, operating systems, gallium arsenide in supercomputers, and a brief abstract on the subject of future high speed networks in Europe.

The slow but steady development of facilities spread over several decades, sharing resources of several countries, CERN has built up a strong infrastructure in the area of computing. Experimental high-energy physics requires technology that is demanding ; requires input from a wide range of industries of which computing one. This publication from CERN gives a view of this incremental development and the coming technologies.

It is to be noted that even though member countries of the CERN lag way behind in the development of computing technology, the organisation has built through acquisitions, and in-house development of user-specific software, a

contemporary civilian outfit. The publication 90-06 touches on a broad set of specialized subjects, and should also be of interest to a wide range of experts outside the high-energy community.

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Wave Propagation in Solids and Fluids

by Julian L Davis

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X+386 pages, 58 figures ; price : DM 148 (Hard cover) ; ISBN 3-540-96739-7

The book contains a good exposition of the various types of waves in a continuous nonconducting medium and includes nonlinear effects as well. The author starts with a brief summary of harmonic vibration. The eigenvalue equation for a system of coupled oscillator is then discussed and the concept of normal coordinates is introduced.

In chapter 3 of the book the author presents a general discussion on the methods of solution of the various types of partial differential equations which one come across in connection with the study of wave propagation, the physical foundation for which is laid down in chaptar 2. This mathematical introduction will be very helpful for further reading of the book. In the fourth chapter the vibrations of strings are discussed. The discussion on the vibration of strings as a limiting case of vibrations of a coupled system of particles emphasizes the use of finite difference method for solving wave equations in continuous medium.

The three subsequent chapters deal with the wave propagation in incompressible and compressible fluids. Brief discussion on the non-linear problems of current interest, such as solitary wave, shallow water wave, shock wave and supersonic wave propagation in air also included. In the second part of the seventh chapter the author introduces the viscous fluid and briefly discusses the Navier-Stoke's equation. Stoke's flow, which is a linearization of the Navier-Stoke's equation for steady flow is also discussed.

Chapter 8 begins with a nice introduction to the history development of the wave propagation in continuous medium and deals with the wave propagation in continuous medium. However the author confines his discussions to wave propagation in isotropic medium only.

In the concluding section the author introduced the Hamilton Jacobi theory and gives the readers a brief introduction to the fascinating field of asymptotic

expansion and shows the relationship between the classical mechanics, geometrical optics and quantum mechanics.

The book is well written and self-contained and is a good venture by the author in unifying the divergent facts relating to wave propagation by clarifying the common features and pointing out the interconnections. The book will be helpfui to students of different disciplines interested in the theory of wave propagation and to workers in the field alike.

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Fundamentals of Statistical Mechanics : Manuscript and Notes of Felix Bloch
prepared by John Dirk Walecka
Stanford, California : Stanford University Press, 1989
302 pages ; price : $ 39.50 (Hard cover)

From 1933 right upto 1976, Felix Bloch taught statistical mechanics at Stanford University. He had planned to write a book based on his course – a task that was, unfortunately, not finished. The title under discussion is a labour of love and respect undertaken by J D Walecka who has used the manuscript left by Bloch as well as the detailed notes taken by students in his course, and has fashioned them into a book. In order to give us a flavour of Bloch's writing, sections taken verbatim from his notes have been marked with asterisks. The text, together with five appendices and a large collection of problems, purports to be a book on the principles of statistical mechanics rather than their applications.

In planning his course and the text, Bloch gave precedence to "insight into important concepts" over mere "acquisition of techniques" (to borrow a few phrases from Weisskopf's foreword to the Pauli Lectures on Physics). The results is a masterly exposition of the fundamentals of statistical mechanics that is accessible to students with a background of classical mechanics at the level of Goldstein. Although the basics are available in many excellent textbooks, in going over the same ground with Bloch the reader is struck by the clarity, lucidity, economy of expression and fresh insights characteristic of the truly outstanding teacher that he was.

As to the contents, chapters I and II introduce basic concepts including a review of classical mechanics. The notion of phase space is discussed leading to a proof of Liouville's theorem. Interestingly, the proof of the theorem given here is Bloch's own. The next two chapters discuss the concept of an ensemble. Thermal equilibrium is related to the constancy of the distribution function, averages are discussed and finally the canonical ensemble is arrived at.

The thermodynamic functions are related to the partition function. Applications in chapter V deal with the ideal and non-ideal gas, rotations and vibrations of diatomic molecules, specific heats of solids, radiation in a cavity and magnetism.

Chapters VI and VII deal with quantum statistics and their applications. Quantum phase space and the density matrix are introduced. Gibbs' canonical ensemble is again derived and the thermodynamic functions are related to the quantum partition function. The examples discussed in the classical context are reviewed and the theory of Fermi and Bose gases is developed.

In summary, we agree with J D Walecka when he says that Bloch's insight into the fundamental principles of statistical mechanics is worth sharing with students. The more exciting and modern applications of statistical mechanics are really untouched in this book. But the merit of the book as a companion text along with more well known expositions make it a really useful acquisition for teachers and students alike.

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Electricity and Magnetism
by A S Mahajan and A A Rangwala
Tata McGraw Hill Publishing Company Ltd.

The book gives an excellent disposition of classical electricity and magnetism for undergraduate students of Indian Universities and Indian Institute of Technologies. This is also of partial help to students doing Master's degree, although for the latter very standard text books are available. At the beginning a chapter is devoted to vector algebra and vector calculas which are absolutely necessary for a proper understanding of the basic principles of electrostatics, magnetostatics and electromagnetism. The authors adopted MKSA system of units which is convenient from macroscopic point of view and is of more practical utility.

Chapters 2 and 3 are devoted to step by step development of basic electrostatic principles, their related concepts and some of their practical applications. Solution of one dimensional Laplace's equation with simple boundary conditions is aimed at and multipolar expansion of a charge distribution is dealt with from simple considerations. In chapters 4 and 5 the authors describe the properties of conductors and dielectrics in such a way that is more suitable for application purpose, especially for engineering students. Chapter 6 gives a brief description of the properties of charges in motion with special emphasis for solving network problems including resistances and capacitors. With a short but lucid introduction

to magnetostatics and magnetic induction due to currents in chapter 7, the authors describe in chapters 8 and 9, the features that arise due to the motion of charged particles in electromagnetic fields along with different aspects of electromagnetic induction. LCR circuits have been discussed in detail in Chapter 10. Chapter 11 deals with properties of macroscopic magnetic fields. The last chapter is devoted to an well thought discussion on Maxwell's electromagnetic field equations understandable from beginners point of view.

The beauty of the present book is the problem oriented approach throughout. A large number of interesting examples have been solved and a number of problems have been set up. This gives a good grasp on the subject and sets up a proper background for advanced study on electromagnetism and for solving more general boundary value problems. This book is an important addition to the standard text books existing at present.

Perhaps a short introduction to electromagnetic radiations arising from atoms and nuclei would have been incorporated in this book.

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