SOCIETA' ITALIANA DI FISICA

RENDICONTI

DELLA

SCUOLA INTERNAZIONALE DI FISICA «ENRICO FERMI»

LXXII CORSO

Problems in the Foundations of Physics

ITALIAN PHYSICAL SOCIETY

PROCEEDINGS
OF THE
INTERNATIONAL SCHOOL OF PHYSICS
« ENRICO FERMI »

COURSE LXXII

edited by G. TORALDO DI FRANCIA
Director of the Course

VARENNA ON LAKE COMO
VILLA MONASTERO

Problems in the Foundations of Physics

1979

NORTH-HOLLAND PUBLISHING COMPANY, AMSTERDAM - NEW YORK - OXFORD

Library of Congress Cataloging in Publication Data

Varenna, Italy. Scuola internazionale di fisica.
Problems in the foundations of physics.
(Proceedings of the International School of Physics « Enrico Fermi »; course 72).
At head of title: Italian Physical Society.
Added t.p.: Problemi dei fondamenti della fisica.
Course held July 25-Aug. 6, 1977.
Bibliography: p.
1. Physics—Congresses. I. Toraldo di Francia, Giuliano, 1916. II. Società Italiana di Fisica. III. Title. IV. Title: Problemi dei fondamenti della fisica.
QC1.V29 1979 530.1 79-13069
ISBN 0-444-85285-9

Printed in Italy

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LXXII Corso

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Direttore del Corso

VARENNA SUL LAGO DI COMO
VILLA MONASTERO
25 LUGLIO - 6 AGOSTO 1977

Problemi dei fondamenti della fisica

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SOCIETÀ ITALIANA DI FISICA
BOLOGNA - ITALY

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LXXII CORSO - VARENNA SUL LAGO DI COMO - VILLA MONASTERO - 25 Luglio - 6 Agosto 1977

Foreword.

« *Allez en avant, la foi viendra* ». This exhortation attributed to D'ALEMBERT seems to reflect very well the attitude taken by many of the great founders of science. Some of them were perhaps even unaware of the unfirm ground they were treading on; they just went boldly forward, and their success seemed to represent the best justification for the starting assumptions.

Somebody has even remarked that science is not founded upon its foundations. That remark certainly contains a great deal of truth; but it is not the entire story.

It is true that a good many, perhaps the majority, of the great achievements of science were not the result of a brick-by-brick construction, gradually carried out from the foundations to the top, like the construction of an old-time building. Pythagoras' theorem was discovered much before the time when EUCLID settled geometry as a well-founded science. Differential calculus yielded the most brilliant results in celestial mechanics much before CAUCHY, RIEMANN and WEIERSTRASS set out to justify its procedures. Today quantum mechanics can be said to have perfectly fulfilled the task for which it was first introduced: *i.e.* to interpret with great precision all atomic phenomena and radiation processes. Yet the foundations of quantum mechanics still present a number of puzzling problems that are currently challenging the ingenuity of many workers. Ironically, it can be said that in several cases physicists have obtained full success and exciting results before they knew exactly what they were talking about.

It would nevertheless be wrong to derive from these and other countless examples the conclusion that the study of the foundations is « useless », and represents only an academic pastime. The foundational problems of a discipline are likely to arise only when the discipline is fully developed and ripe. But, when finally the scientific community becomes aware of them and subjects them to a critical appraisal, a major breakthrough can occur and a more advanced discipline can arise.

Mechanical clocks of comparatively high precision had existed for centuries, when Einstein's keen examination of how time is measured and simultaneity is ascertained paved the way to special relativity. Euclidean geometry had provided for millennia the firm basis for science, when a critical analysis of its foundations led to a conceptual revolution, and eventually to general relativity. As a third example, let us recall that, if physicists had gone on taking for granted the elementary and « evident » fact that any quantity can in principle be measured with any precision, independently of other quantities, we would never have built quantum mechanics.

There is a sort of feed-back in the construction of physical science. First a new chapter is built on shaky grounds; then, when it is fully developed, it starts to react on its own foundations. It is only at this later stage that workers begin to realize what these foundations are and to pinpoint the more delicate questions of principle. Perhaps, the increasing interest in the foundational problems of physics which we are witnessing today is due to the unprecedented developments which physics has experienced in this century and to the vast amount of knowledge which is at our disposal today. An increasing number of physicists are becoming more and more critical and want to know « what it is all about ».

The present volume, a response to this demand, cannot encompass, for obvious reasons, all the foundations of physics. It contains the lectures given at the LXXII Course of the International School of Physics « Enrico Fermi ». The topics and the speakers were selected so as to give at least the highlights of several critical subjects which are currently debated today, but no attempt was made to reach completeness.

The foundational problems of physics are certainly all connected with one another. But in many cases the connection is subtle and hidden at a profound level. This makes it very difficult to give a logical succession to the different topics. Accordingly, the Editor has decided to publish the contributions in the alphabetical order of the names of the authors.

G. TORALDO DI FRANCIA

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物理学的基础问题

(英 2-3/7081)

A 00410

Tipografia Compositori - Bologna - Italy

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Radioactivity, a Pragmatic Pillar of Probabilistic Conceptions.

E. AMALDI

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When, years ago, I read the book by Max JAMMER *The Conceptual Development of Quantum Mechanics* [1], I found very interesting and stimulating the presentation he gives of this fundamental subject. I should say, however, that I was slightly disappointed from Chapter 4, devoted to *The transition to quantum mechanics*, since it appeared to me too short, incomplete and in some way one-sided.

The chapter consists of three sections. The first one, entitled *Applications of quantum conceptions to physical optics*, summarizes very effectively the work and conceptual background of A. FRESNEL, J. J. THOMSON, A. H. COMPTON, G. BARKLA, W. H. BRAGG and W. L. BRAGG, P. DEBYE and a few others. The second section, devoted to *The philosophical background of nonclassical interpretations*, can be, in some way, summarized by the following sentence by JAMMER himself: « certain philosophical ideas of the late ninteenth century not only prepared the intellectual climate for, but contributed decisively to the formation of the new conceptions of the modern quantum theory » [2]. The people quoted are C. RENOUVIER, E. BOUTROUX, F. EXNER, S. KIERKEGAARD, H. HØFFDING, and also H. POINCARÉ, L. DE BROGLIE, N. BOHR, C. G. DARWIN and a few others. The new conceptions are probabilistic conceptions which « differ fundamentally from the traditional notions of probability as used, for example, in classical statistical mechanics. In classical physics probability statements were but an expression of human ignorance of the exact details of the individual event, either because of the insufficient resolving power of our measuring instrument or because of the large number of events involved: the individual physical process, however, was always regarded as strictly obeying the law of cause and effect and the result was always considered as uniquely determined.

The new conception of probability, on the other hand, assumed not only that macroscopic determinism is a statistical effect but also that the individual microscopic and submicroscopic event is purely contingent » [3].

The third and last section of Chapter 4, entitled *Nonclassical interpretation of optical dispersion*, deals with the early work by N. BOHR, J. C. SLATER,

H. A. KRAMERS and by M. BORN, A. LANDÉ, R. LADENBURG and a few others.

With this presentation of the first attempts to solve the fundamental problem of optical dispersion, Chapter 4 is closed and the discussion of the transition to the new probabilistic conceptions is practically finished.

My first impression that this presentation is too hastly and too one-sided did not find further support from successive Jammer works such as the book on the *Philosophy of Quantum Mechanics* [4], since, in this case, an emphasis (or perhaps an over-emphasis) of the philosophical aspects of the subject is justified by the same title of the book.

My original impression was, on the contrary, strengthened by the article of P. FORMAN on *Weimar culture, causality and quantum theory, 1918-1927* [5], where the author states: ... « Jammer did not go very far towards demonstrating his propositions ... » the most important of which is « that extrinsic influences led physicists to ardently hope for, actively search for, and willingly embrace an acausal quantum mechanics ».

The aim of Forman's article (according to him) is not « to fill the gap left by Jammer » between « a variety of late ninteenth century philosophers » and « the development of quantum mechanics by German speaking central European physicists circa 1925 ». His aim is « rather to examine closely the lay of the land on the far side ... » with the result of a « overwhelming evidence that in the years after the end of the First World War, but before the development of an acausal quantum mechanics, under the influence of 'currents of thought' large numbers of German physicists, for reasons only incidentally related to developments in their own discipline, distanced themselves from, or explicitly repudiated, causality in physics ».

One of the main conclusions of Forman is that the « extrinsic influences » suggested by JAMMER are demonstrated in his article « but only for the German cultural sphere ».

Certainly I am not here to deny the interest of Jammer's point of view and the suggestiveness of the above propositions nor the cultural value of Forman's article, which deeply analyses the interrelations between the development of physical sciences in those years and their cultural and philosophical craddle and environment. What I would like to express in the following is my impression that, by looking at the problem of « repudiation of causality in physics » from the most general and far away point of view, one can be brought to over-estimate the « extrinsic influences » outlined above and overlook « intrinsic arguments » inherent to two parallel, almost independent developments. The first one starts from the kinetic theory of gases and passes through statistical mechanics, Planck original definition of quantum, the photons conceived as particles and the relations between emission and absorption of photons by atoms.

The other path, also intrinsic to physics, starts with the accidental discovery of radioactive substances, passes through the experimental recognition