SOCIETA ITALIANA DI FISICA

RENDICONTI
DELLA
# SCUOLA INTERNAZIONALE DI FISICA « ENRICO FERMI »

IL CORSO

## *Fondamenti di meccanica quantistica*

ACADEMIC PRESS · NEW YORK AND LONDON

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## IL Corso

a cura di B. D'ESPAGNAT
Direttore del Corso

VARENNA SUL LAGO DI COMO
VILLA MONASTERO
29 GIUGNO - 11 LUGLIO 1970

# *Fondamenti di meccanica quantistica*

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# Letter to the Participants.

B. D'ESPAGNAT

*Laboratoire de Physique Théorique et Particules Elémentaires*
*Université de Paris XI, Centre d'Orsay - Orsay*

Dear participant,

Like the Delphic oracle theoretical physics rests on three legs: experience, mathematics and a workable set of general ideas.

Some would like to cut this third leg away. They hope to increase thereby the stability of the whole construction but we, who will gather in Varenna, know that of course they are quite wrong! We are all convinced that a mere collection of wholly or partially successful recipes—be they even beautifully formal—cannot be a substitute for a genuine understanding.

Unfortunately (or in view of the necessary diversity of human conceptions should we perhaps say « happily »?) the standpoints of the physicists greatly differ from one another on the question of what these workable ideas should be. In our daily professional life this truth is hushed down without damage, since we all practically agree on how to apply the quantum recipes. But it will probably become quite clear, in a few days, that under a superficial agreement on how to use the rules we have learnt, we entertain real differences of opinion as to what these rules refer to. Rather hectic discussions can thus be hoped to develop; especially since, purposedly, lecturers are invited who represent quite a broad spectrum of ideas. This is an excellent thing. In order that we should take full advantage of it, let me suggest to you the following agreement: that we should not take as our goal the conversion of the heretic but rather a better understanding of his standpoint; that we should not suggest that we consider as a stupid fool anybody in the audience (lest the stupid fools should in the end appear clearly to be ourselves!); that we should try to cling to facts; and that nevertheless we should be prepared to hear without indignation very nonconformist views which have no *immediate* bearing on facts.

We shall also enjoy some nice pieces of mathematical formalism. Not many of them, since the danger is that when a man has understood a bit of nontrivial mathematics applied to physics he is so happy with himself that he may forget to try to make clear in his mind what conceptual ideas are underlying the whole thing. However, on mathematics, it is usually possible to agree. These mathematical developments were carefully selected for their relevance to the problems at hand. They will also serve as the pillow on which we can reconcile with one another after having quarrelled on allegedly « trivial » points.

It is not usual that such matters should be discussed at length in lectures or in seminars. The large number of applications that came in has convinced me that the members of the Italian Physical Society who were at the origin of the course had a very good idea after all.

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# The Subject of Our Discussions.

E. WIGNER

*Physics Department, Princeton University - Princeton, N. J.*

## 1. – Physics and philosophy.

Our task during the present session of the Enrico Fermi Institute will not be an easy one. We'll discuss a subject on the borderline between physics and philosophy and, since most of us are not philosophers, we may say things which appear dilettantish to true philosphers. Also, few of us are truly familiar with the ideas and accomplishments of philosophers, earlier and contemporaneous. We may unnecessarily invent a new terminology, flaunting well established custom and neglecting to establish connection with past thinking. It is good that there are some true philosophers among us who, I hope, will correct our errors.

Since we shall be thinking about questions on the borderline between physics and philosophy, it may be well to say a few words on the essence of these disciplines and how they differ from each other. Let us begin with physics. Physics, it is often said, explains the phenomena of inanimate nature. I find this definition a bit hollow and more than a bit boastful. The great progress of physics was initiated by Newton's division of the determinants of our surroundings into two categories: initial conditions and laws of nature. Physics, as we know it, deals only with the second category and Newton gave up Kepler's idea to derive the sizes of the planetary orbits from simple rules. What he gave, rather, were rules on how to obtain the position of a planet at any given time, using as input its positions at two earlier times. More generally, we can say that physics establishes regularities in the behavior of inanimate objects. That these regularities can be described by means of beautiful and conceptually simple mathematical models has often been commented on as a near miracle. But we need not be concerned with this now.

Whereas it is easy to characterize the objective of physics as the search for, and description of, regularities in the behavior of inanimate objects, philosophy is more difficult to define. It is the search for an encompassing view of nature and life, for an elevated picture of the world and our role therein. Naturally, the interface between physics and philosophy covers only a small part of all this and consists, essentially, of an analysis of the character and significance of the regularities established by physicists. One of the tasks of philosophy is the assimilation of the information which other sciences produce and one of the tasks of physics is to provide such information by exploring the unifying principles underlying its many detailed results.

All of this shows that physics is, fundamentally, a much more modest discipline than philosophy. This also has rewards. Physical theories are often superseded and replaced by more accurate, by more general and deeper theories. However, the superseded theory still retains validity as an approximation, applicable in a perhaps restricted but still multifaceted set of circumstances. As far as the original domain of the theory is concerned, the superseding theory does, as a rule, little more than to delineate more sharply the boundaries of that domain. Also, the new theory owes, almost invariably, a great deal to the older one—it usually could not have been invented without a knowledge thereof.

On the contrary, the different philosophical pictures seem to represent *alternatives* and do not have a space in each other as do successive physical theories. Different philosophies represent different images of the world, conflicting images. As a result, philosophers often dislike each others' theories. It will be good to keep in mind this difference between the relations of physical theories, and of philosophical theories, to each other. In this regard, the ideas on the epistemological implications of quantum theory resemble more the philosophical than the physical theories.

## 2. – Common applications *vs.* fundamental problems of quantum mechanics.

As was implied before, and as is well known, there is no full unanimity among physicists concerning the fundamental principles which underlie quantum mechanics. This is very surprising at first, and remains surprising even after it is explained away to a certain extent. One of the reasons that the basic principles affect the day-to-day work of the physicist rather little is that quantum mechanics is used very rarely to establish the regularities between events direcly. It is used more frequently in conjunction with classical, that is macroscopic, theories by providing material constants for these, such as cohesive strength, viscosity, chemical affinity, etc.—quantities which are arbitrary material constants as far as classical, macroscopic theory is concerned. The most important exception to this rule is collision theory and we shall speak a good deal about idealized collisions, measurements, or observations. However, all collisions, not only the idealized ones, are in this category—they are events rather than properties and their description uses the equations of motion of quantum mechanics rather than calculate characteristic values. Collision theory is closely tied to the fundamental, epistemological problems of quantum mechanics and the work on the foundations of collision theory is more dependent on, and supports more directly, the epistemology of quantum mechanics than other applications of that theory. This will be, no doubt, discussed further by others in the course of our study here.

## 3. – Epistemology and everyday life.

There is a very instructive joke in the Introduction to Boltzmann's *Kinetic Theory of Gases*. He tells us, in his story, that he was, as a young man, very critical of the logical rigor of the books on physics with which he became familiar. He was quite elated, therefore, when he heard about a physics book wich was, he was told, strictly logical. He rushed to the library—only to find, first, that the book was out and, second, that it was all in English. Boltzmann spoke no English at that time. He went home, quite down-hearted and complained to his brother. His brother, however, told him that, if the book was all that good it was surely worth waiting for it until it would be returned to the library. As to its being in English, Boltzmann's brother said, that surely will be immaterial. If the book is entirely logical, the authors won't use any term before having defined and explained it carefully.

Incidentally, HEISENBERG, in his *The Whole and Its Parts*, also points to the impossibility of strict logical rigor in scientific work.

What follows from all this? Simply, that the statements and conclusions of science are, and have to be, expressed in common language, that science cannot be independent from everyday experience, the concepts and information we acquired in babyhood. The homo scientificus who bases his actions and knowledge on science alone does not, and cannot, exist. In fact, we feel that the more primitive the notions are which one uses to express the regularities observed, the more fundamental can the theory be. This does not mean that science accepts or needs all notions which we acquired as children, or that it accepts them uncritically—relativity theory showed that this is not the case—but that it cannot exist without the notions and has to use some of them as a fundament. Boltzmann's anecdote brings this point home most clearly.

## 4. – The basic quantities of various physical theories.

What, then, are the concepts which physics, in its different stages of development, uses to describe the regularities which are its subject? Newtonian mechanics' primitive concepts were the positions of objects at different times;