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TABLE OF CONTENTS

PREFACE	VII
I. The Statistical Algorithm of Quantum Mechanics	1
I. Remarks	1
II. Early Formulations	3
III. Hilbert Space	8
IV. The Statistical Algorithm	15
V. Generalization of the Statistical Algorithm	24
VI. Compatibility	28
II. The Problem of Completeness	32
I. The Classical Theory of Probability and Quantum Mechanics	32
II. Uncertainty and Complementarity	36
III. Hidden Variables	46
III. Von Neumann's Completeness Proof	49
IV. Lattice Theory: The Jauch and Piron Proof	55
V. The Imbedding Theorem of Kochen and Specker	65
VI. The Bell-Wigner Locality Argument	72
VII. Resolution of the Completeness Problem	84
VIII. The Logic of Events	92
I. Remarks	92
II. Classical Logic	93
III. Mechanics	105
IX. Imbeddability and Validity	108
X. The Statistics of Non-Boolean Event Structures	119
XI. The Measurement Problem	128
XII. The Interpretation of Quantum Mechanics	142
BIBLIOGRAPHY	151
INDEX OF SUBJECTS	153

PREFACE

This book is a contribution to a problem in foundational studies, the problem of the interpretation of quantum mechanics, in the sense of the theoretical significance of the transition from classical to quantum mechanics.

The obvious difference between classical and quantum mechanics is that quantum mechanics is statistical and classical mechanics isn't. Moreover, the statistical character of the quantum theory appears to be irreducible: unlike classical statistical mechanics, the probabilities are not generated by measures on a probability space, i.e. by distributions over atomic events or classical states. But how can a theory of mechanics be statistical and complete?

Answers to this question which originate with the Copenhagen interpretation of Bohr and Heisenberg appeal to the limited possibilities of measurement at the microlevel. To put it crudely: Those little electrons, protons, mesons, etc., are so tiny, and our fingers so clumsy, that whenever we poke an elementary particle to see which way it will jump, we disturb the system radically – so radically, in fact, that a considerable amount of information derived from previous measurements is no longer applicable to the system. We might replace our fingers by finer probes, but the finest possible probes are the elementary particles themselves, and it is argued that the difficulty really arises for these. Heisenberg's γ -ray microscope, a thought experiment for measuring the position and momentum of an electron by a scattered photon, is designed to show a reciprocal relationship between information inferable from the experiment concerning the position of the electron and information concerning the momentum of the electron. Because of this necessary information loss on measurement, it is suggested that we need a new kind of mechanics for the microlevel, a mechanics dealing with the dispositions for microsystems to be disturbed in certain ways in situations defined by macroscopic measuring instruments. A God's-eye view is rejected as an operationally meaningless abstraction.

Now, it is not at all clear that the statistical relations of quantum mechanics characterize a theory of this sort. After all, the genesis of quantum mechanics had nothing whatsoever to do with a measurement problem at the microlevel, but rather with purely theoretical problems concerning the inadequacy of classical mechanics for the account of radiation phenomena. Bohm and others have proposed that the quantum theory is incomplete, in the sense that the statistical states of the theory represent probability distributions over 'hidden' variables. Historically, then, the controversy concerning the completeness of quantum mechanics has taken this form: A majority view for completeness, understood in the sense of the disturbance theory of measurement, and a minority view for incompleteness.

An interpretation of quantum mechanics should show in what fundamental respects the theory is related to preceding theories. I propose that quantum mechanics is to be understood as a 'principle' theory, in Einstein's sense of the term. The distinction here is between principle theories, which introduce abstract structural constraints that events are held to satisfy (e.g. classical thermodynamics), and constructive theories, which aim to reduce a wide class of diverse systems to component systems of a particular kind (e.g. the molecular hypothesis of the kinetic theory of gases). For Einstein, the special and general theories of relativity are principle theories of space-time structure.

I see quantum mechanics as a principle theory of logical structure: the type of structural constraint introduced concerns the way in which the properties of a mechanical system can hang together. The propositional structure of a system is represented by the algebra of idempotent magnitudes – characteristic functions on the phase space of the system in the case of classical mechanics, projection operators on the Hilbert space of the system in the case of quantum mechanics. Thus, the propositional structure of a classical mechanical system is isomorphic to the Boolean algebra of subsets of the phase space of the system, while the logical structure of a quantum mechanical system is represented by the partial Boolean algebra of subspaces of a Hilbert space. In general, this is a non-Boolean algebra that is not imbeddable in a Boolean algebra. As principle theories, classical mechanics and quantum mechanics specify different kinds of constraints on the possible events open to a physical system, i.e. they define different possibility structures of events.

This view arises naturally from the Kochen and Specker theory of partial Boolean algebras, which resolves the completeness problem by properly characterizing the category of algebraic structures underlying the statistical relations of the theory. Kochen and Specker show that it is not in general possible to represent the statistical states of a quantum mechanical system as measures on a classical probability space, in such a way that the algebraic structure of the magnitudes of the system is preserved. Of course, the statistical states of a quantum mechanical system can be represented by measures on a classical probability space if the algebraic structure of the magnitudes is *not* preserved. But such a representation has no theoretical interest *in itself* in this context. The variety of hidden variable theories which have been proposed all involve some such representation, and are interesting only insofar as they introduce new ideas relevant to current theoretical problems. Invariably, the reasons proposed for considering a new algebraic structure of a specific kind are plausibility arguments derived from some metaphysical view of the universe, or arguments which confuse the construction of a hidden variable theory of this sort with a solution to the completeness problem.

I reject the Copenhagen disturbance theory of measurement and the hidden variable approach, because they misconstrue the foundational problem of interpretation by introducing extraneous considerations which are completely unmotivated theoretically, and because they stem from an inadequate theory of logical structure. With the solution of the completeness problem, all problems in the way of a realist interpretation of quantum mechanics disappear, and the measurement problem is exposed as a pseudo-problem.

The short bibliography lists only works directly cited, and since the sources of the ideas discussed will be obvious throughout, I have not thought it necessary to introduce explicit references in the text, except in the case of quotations.