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Heisenberg on Schrodinger's theory - An Overview

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Abstract

This paper deals with works of Heisenberg and Schrodinger famous physicists entitled Ueber den anschaulichen Inhalt der quantentheoretischen Kinematik und Mechanik. A (partial) translation of this title is: "On the anschaulich content of quantum theoretical kinematics and mechanics". Here, the term anschaulich is particularly notable. Apparently, it is one of those German words that defy an unambiguous translation into other languages. Heisenberg's title is translated as "On the physical content …" by Wheeler and Zurek (1983). His collected works translate it as "On the perceptible content …", while Cassidy's biography of Heisenberg, refers to the paper as "On the perceptual content …". Literally, the closest translation of the term anschaulich is "visualizable". But, as in most languages, words that make reference to vision are not always intended literally. Seeing is widely used as a metaphor for understanding, especially for immediate understanding. Hence, anschaulich also means "intelligible" or "intuitive" How, then, does one explain Erwin Schrodinger? At the age of 38, positively geriatric for a theorist, Schrodinger changed forever the face of physics with four exquisite papers, all written and published in a six-month period of theoretical research that is without parallel in the history of science.They are interpretable independently of these concepts and, further, their validity on the empirical level still provides the physical content of the theory.

Key words: quantum theory, Schrodinger, Heisenberg, quantum mechanics, Paul Dirac.

Introduction

Enter Werner Heisenberg, at the age of 24 already considered, next to Einstein, the most brilliant physicist in the world. Heisenberg, with help from Max Born and Pascual Jordan, came up with a matrix theory, which supposedly explained the travels of the electron by a complex form of mathematics called matrices. There remained some problems, however. Heisenberg's solution did not allow one to visualize what was happening inside the atom. Also, the smartest physicists in the world found the equations impossible to solve.Along came Louis de Broglie. This young French physicist presented a most unusual thesis for his doctoral degree at the University of Paris. He put forth the proposition that, at certain velocities, an electron behaves more like a wave than a particle. De Broglie's thesis examiners couldn't make head or tail out of this concept and neither could most theorists, with the exception of two: Albert Einstein, who applauded it, and Erwin Schrodinger, who exploited it.

The physical basis of Schrodinger's theory was this: Ordinarily, one can think of a particle as a dot; but one should really visualize it as a little clump of waves, a "standing wave" in today's parlance. Don't bother thinking of electrons as particles, Schrodinger said, and forget about this quantum-leap business. Just apply rules of wave interactions. Beyond constructing a mechanism for particle interactions, Schrodinger linked the quantum world of the microscopic to the classical world of macroscopic objects. Waves now existed, figuratively speaking, in atoms as well as in oceans. Physicists could understand waves, which they had endlessly studied. Schrodinger's wave mechanics saved quantum theory and at the same time threatened its underpinnings. It utilized continuous phenomena, waves, to explain the discontinuous quantum world of the atom.

For this, Schrodinger earned the Nobel Prize in Physics (in 1933) and the undying enmity of the great Werner Heisenberg. Schrodinger had destroyed Heisenberg's precious matrices. Schrodinger was old. He was an outsider from Zurich, not part of the Gottingen-Copenhagen quantum clique. Worst of all, he was right. The clique felt compelled to retaliate. Pauli referred to Schrodinger's views as "Zurich superstitions." Heisenberg was less charitable, calling the theory "abominable" and worse. Heisenberg would later eat his words. In 1927 he incorporated Schrodinger's wave functions as an integral part of his uncertainty principle.

Objective:

This paper intends to understand the works of Schrodinger and Heisenberg and their contribution to the society. From artists and determined dreamers to daredevils and studious scientists, here we look at 10 of humanity's greatest innovators, and the special attributes which helped them to help the world progress.

As an example, he considered the measurement of the position of an electron by a microscope. The accuracy of such a measurement is limited by the wave length of the light illuminating the electron. Thus, it is possible, in principle, to make such a position measurement as accurate as one wishes, by using light of a very short wave length, e.g., \(\gamma\)-rays. But for \(\gamma\)-rays, the Compton effect cannot be ignored: the interaction of the electron and the illuminating light should then be considered as a collision of at least one photon with the electron. In such a collision, the electron suffers a recoil which disturbs its momentum. Moreover, the shorter the wave length, the larger is this change in momentum. Thus, at the moment when the position of the particle is accurately known, Heisenberg argued, its momentum cannot be accurately known:

At the instant of time when the position is determined, that is, at the instant when the photon is scattered by the electron, the electron undergoes a discontinuous change in momentum. This change is the greater the smaller *the wavelength of the light employed, i.e., the more exact the determination of the position. At the instant at which the position of the electron is known, its momentum therefore can be known only up to magnitudes which correspond to that discontinuous change; thus, the more precisely the position is determined, the less precisely the momentum is known, and conversely. (Heisenberg 1927: 174–5)*

The interpretation of Heisenberg's uncertainty relations

Heisenberg's relations were soon considered to be a cornerstone of the Copenhagen interpretation of quantum mechanics. Just a few months later, Kennard (1927) already called them the "essential core" of the new theory. Taken together with Heisenberg's contention that they provide the intuitive content of the theory and their prominent role in later discussions on the Copenhagen interpretation, a dominant view emerged in which the uncertainty relations were regarded as a fundamental principle of the theory.

The interpretation of these relations has often been debated. Do Heisenberg's relations express restrictions on the experiments we can perform on quantum systems, and, therefore, restrictions on the information we can gather about such systems; or do they express restrictions on the meaning of the concepts we use to describe quantum systems? Or else, are they restrictions of an ontological nature, i.e., do they assert that a quantum system simply does not possess a definite value for its position and momentum at the same time? The difference between these interpretations is partly reflected in the various names by which the relations are known, e.g., as "inaccuracy relations", or: "uncertainty", "indeterminacy" or "unsharpness relations". The debate between these views has been addressed by many authors, but it has never been settled completely. Let it suffice here to make only two general observations.

First, it is clear that in Heisenberg's own view all the above questions stand or fall together. Indeed, we have seen that he adopted an operational "measurement=meaning" principle according to which the meaningfulness of a physical quantity was equivalent to the existence of an experiment purporting to measure that quantity. Similarly, his "measurement=creation" principle allowed him to attribute physical reality to such quantities. Hence, Heisenberg's discussions moved rather freely and quickly from talk about experimental inaccuracies to epistemological or ontological issues and back again.

However, ontological questions seemed to be of somewhat less interest to him. For example, there is a passage (Heisenberg 1927: 197), where he discusses the idea that, behind our observational data, there might still exist a hidden reality in which quantum systems have definite values for position and momentum, unaffected by the uncertainty relations. He emphatically dismisses this conception as an unfruitful and meaningless speculation, because, as he says, the aim of physics is only to describe observable data. Similarly, in the Chicago Lectures, he warns against the fact that the human language permits the utterance of statements which have no empirical content, but nevertheless produce a picture in our imagination. He notes, *One should be especially careful in using the words "reality", "actually", etc., since these words very often lead to statements of the type just mentioned. (Heisenberg 1930: 11)*

So, Heisenberg also endorsed an interpretation of his relations as rejecting a reality in which particles have simultaneous definite values for position and momentum.

Conclusion

Newtonian macroworld of everyday objects that obey hard-and-fast rules of causality. Put a cat in a box, Schrodinger said, with a flask of lethal acid. In a Geiger tube, place a small quantity of radioactive material, so little that in the course of an hour one atom has a 50-50 chance of disintegrating, setting off the Geiger counter, which will trigger a hammer that shatters the flask of acid that will kill the cat. So, after one hour is the cat dead or alive? Schrodinger said that if one used the quantum wave function to describe the entire system, "the living and the dead cat" would be "smeared out (pardon the expression) in equal parts." Schrodinger intended his paradox as a sarcastic comment on quantum probability or "blurred variables." One can resolve the uncertainty, he explained, by looking in the box. Schrodinger himself, however, must always remain somewhat blurred, despite Walter Moore's heroic efforts in this important book about the century's most enigmatic scientist. For the average reader, "Schrodinger" may be tough going, but it serves up a wonderfully frank and unglamorized, albeit narrow, history of the development of quantum mechanics. Much of the science in this book is only opaquely explained, but explaining science is not the book's main function.

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