Physics and Philosophy

The Revolution in Modern Science

W.Heisenberg

October 7-11, 2009

Does this book contain any diatribes against the Jews? Does it extol the German race? If not there is no need to consign it to the general conflagration[1]. Heisenberg has a an ambiguous reputation[2], his conduct during the second world war was not heroic, if human, in the true and less exalted sense of the word. But this should not concern us at all. In this book, supposedly the written down version of a collection of lectures given in the late fifties, Heisenberg presents a surprisingly sophisticated philosophical analysis of the impact of modern physics. He is not a professional philosopher, but his text reveals an informed mind, and a personal perspective, the result no doubt of a sustained and intelligent reflection.

Both Physics and Mathematics underwent a crisis around the turn of the 20th century. While the mathematical crisis left no deeper impact on the pursuit of mathematics, in fact most mathematicians can safely forget the foundational stuff, regard Gdel as a curiosity and completely ignore higher cardinalities; the crisis in Physics on the other hand effected a real revolution, which physicists could only afford to ignore at their peril. And not only that, its ramifications reached well beyond the realm of physics, and made relativity theory and Heisenberg's uncertainty principle into household words. As the mathematician Manin has remarked, the crisis in mathematics was concerned with thought and thus led to introspection, the crisis in physics related to reality itself, and caused the far more exciting ride.

Heisenberg starts by pointing out the uncanny similarity between the visions of the pre-Socratic philosophers and modern physicists. Some simple translations appear to make the two look more or less isomorphic. Substitute for the fire of Heraclites the modern concept of energy, and for the atoms of the Greek materialists, the search for fundamental particles[3], and more to the point, compare the modern physicists mathematical models with those of Pythagoras and Plato. When it comes to the mathematical underpinnings of the real physical world, they have a respectable pedigree characterizing the essence of Western Philosophy. So what should we make of this? That the old Greeks anticipated the moderns by pure brain power and superior intuition? Heisenberg will of course have nothing of this. Their visions lacked the solid empirical foundation that provoked our modern one, and although they may on the purely poetic level rival the modern formulations, they

[1] The informed reader does not need to be reminded of the final and oft quoted paragraph of Hume's Treatise of which this is an obvious paraphrase.

[2] I recall Lipman Bers at Columbia, protesting maybe only half-jokingly, to a Colloquium speaker because he had referred to the Heisenberg group.

[3] One is reminded of the old quip. The Greeks thought that the atom was indivisible, we know better.

had no counterpart to the exact and quantitative predictions which raises modern physics above speculation and gives it its awesome utility. Yet, Heisenberg is sophisticated enough not to disparage them, on the contrary, seeing in them kindred spirits, of undeniable intelligence; and the similarities which are so striking, are indeed due to a similarity of outlook reflecting the human propensity of viewing nature in a unified (and mathematical?) way.

The real breakthrough in human intellectual development was the birth of empirical science in the 17th century. The scholastic philosophers of the medieval centuries are often made fun of. This is of course grossly unfair, they were highly intelligent and sophisticated individuals[4], whose conception of God was remarkably abstract, and who valued reason above anything else. The dialectical idea of empowerment through thought alone is a very seductive one, as is the subject given by the spiritual basis for all existence. Theology was clearly the most prestigious subject of them all, and daring speculation the dominant method of inquiry. According to Heisenberg the theological disputes of the Reformation made people tire, and a renewed interest in the natural world emerged. After all the Bible is just one source for knowing God, and an unreliable one at that being compiled by man, Nature on the other hand gives a more direct and more faithful access to divinity. And one that does not do away with speculation, which is very important to emphasize, only limiting it to the formulation of the questions, not the articulation of the answers. One may see in this the momentous split between the humanities and the natural sciences. Descartes had a crucial, and perhaps not fully beneficial impact, because with him there also followed a split between the material world and the spiritual, which initially provided a most fruitful impetus to the pursuit of science by separating the observer from the subject of observation[5]. Newton is of course the shining light, although a medieval character, the last of the old magicians as Keynes liked to characterize him as, Voltaire taught us long before to see him as the beacon of the enlightenment. With him was born the purely materialistic vision, in which small solid material bodies occupied well-defined extensions in a fixed space, subjected to laws of forceful interaction of remarkable simplicity and staggering complexity of ramification. In a sense everything in the world, or at least the material world apart from ourselves, could be explained. It is also in this context one should regard the attempts of Leibniz to create a formal language, reducing thought to mechanical physical objects thereby rendering them objective and amenable to manipulation and hence ultimately bring them into the realm of empirical study. The materialistic point of view reached its zenith during the 19th century, also the century which saw the industrial growth of science, both as regards to its magnitude of activity as to its applications. Towards the end of that century two things challenged this comfortable view of attaining closure. Two annoying details with no real practical consequences but of tremendous theoretical import as to the intrinsic consistency of theories. One was of course a negative one, the inability to detect an ether; the other was to find a mathematical explanation of black body radiation.

[4] Although Tomas of Aquinas is perhaps the most well-known and the most representative, Occam with his razor, is probably the most impressive, and perhaps the only one who has received some lasting recognition.

[5] One may argue that the historian and philosopher Collingwood was still caught in this Cartesian point of view, as he regarded the study of nature as a spectacle, and was more intrigued by the historical realm, in which observers and the observed were indeed inseparably intertwined.

The first soon achieved a beautiful solution in the form of special relativity theory (later to be complemented by a theory of general relativity, for which Heisenberg at the time of writing still has some doubts as to empirical verifications) which revolutionized our ideas of time and space, and which led to such startling consequences as the equality between energy and mass, i.e. that one could be transformed into the other, and thus in a sense doing away with the distinction between mass and force. The second got its own mathematical formalism, for which Heisenberg himself was largely responsible, but while relativity theory forms a unified whole, whose ontology presents no real hurdles to the open mind, quantum theory went against common sense and the deterministic character of classical materialistic philosophy. And in addition both theories were not even compatible. This is an embarrassment that remains to this day fifty years later, but due to the local successes, not to say triumphs of modern physics, such embarrasment of contradictions is something physicists have learned to live with.

Heisenberg spends for obvious reasons most of his time on quantum theory. Apart from his own involvement, quantum theory effected the greatest rupture from classical theory necessitating a totally new philosophy of physics, nay even of logic itself, and in addition also turned out to be far more useful. The greatest hurdle connected with quantum effects is to make ontological sense of it. It is one thing to cook-up a mathematical formalism that works, or at least gives all the right answers, and quite another to really understand it. For one thing is an electron a particle or a wave? The wisest answer is probably neither and both. An electron is an electron. Depending on the situation either viewpoint can be the most convenient. This led Bohr and his co-workers to propose the Copenhagen interpretation, in particular to introduce the notion of complementarity, an interpretation which was met with a lot of opposition and provoked much resistance, even among such giants of physics as Einstein himself. It is important to realize that what is at stake is not the mathematical formalism as such, as long as it gives the right answers it is more or less objective and useful, but the purely philosophical ambition of formulating an understanding along the lines of classical traditions. Complementarity is the result of a resignation that the classical language cannot capture everything, a realization which is quite common in the humanities, where say, to give an example of or quoted by Heisenberg, to the effect that a piece of art can either be enjoyed emotionally and aesthetically or analyzed intellectually. What is at stake in Quantum theory is that classical interpretations can be applied at the onset and at the final interpretation of the result of the experiment, without that Quantum theory would be too strange to be grafted on traditional science; but it does not make sense in the interim. We can know what happens at A and what happens at B, but we have no way of knowing what happened along the way. Somehow the continual chain of cause and effect is no longer present (and the young Hume would have been delighted). Whether that is due to our ignorance or simply because there is no chain (epistemology versus ontology) is a popular bone of contention. Does a particle really have a precise position and velocity, and the uncertainty is just apparent, due to our limited powers of observation and measurement[6]? Maybe we need to develop a new language, our traditional language served other purposes appropriate to daily life, or mayve we will be forced to change our

[6] It reminds me of the American tourist, who thought that all those people speaking French did it just to spite him, once he was not looking (and listening) they reverted to English.

logic, the basis for our understanding? But that is a tricky business indeed, even if some limited attempts have been made. Heisenberg particular reports on Weizscker's attempt to provide a constructivist logic in which the excluded middle *tertium non dator* no longer holds. Another related solution bringing in the complementary principle of Bohr, is to speak about levels of languages. Such as 'the atom is in the left half' as opposed top 'it is true that the atom is in the left half'. In classical logic the statements are equivalent, at least as to truth values. Either both are true or both are false. But in quantum logic the latter statement maybe false without the first being false, it might just be undecided. As far as I understand fancy logics has not had any success in the intervening fifty years, and the situation is still logically shaky, but this does not disturb physicists as much as mathematicians.

In the last pages, Heisenberg reflects on the political situation that the modern advances physics has created. He is of course thinking of the Atom Bomb, which unfortunately has not made wars obsolete, far from it, but potentially far more devastating. The actual fact of the Bomb raises the stakes of Physics in particular and intellectual endeavors in general. Thoughts matter, and the Bomb is actually going to have a devastating effect on traditional societies, because no society can afford to be ignorant of such modern developments.

October 11, 2009 **Ulf Persson:** *Prof.em, Chalmers U.of Tech., Göteborg Sweden* ulfp@chalmers.se