The Infamous Boundary – Seven Decades of Controversy in Quantum Physics. David Wick. Birkhaüser Verlag, AG Klasterberg, P. O. Box 133, CH-4010. Basel, Switzerland. 1996. Price: DM 88, SFr 78. 244pp.

John Stewart Bell was one of the keenest critics of the orthodox Copenhagen interpretation of quantum mechanics. He was also an exceptionally clear thinker and contributed decisively to the progress of the decades old debate on the meaning of quantum mechanics, and its bearing on the general notions of realism and locality in physics. Despite its stunning and practical successes – in applications to elementary particle physics, nuclear and atomic and molecular physics, condensed matter physics and chemistry, weak and electromagnetic and strong interaction phenomena – a basic problem for quantum mechanics has always been the location of the divide between the quantum microworld and the classical macroworld, the smooth transition from the one to the other, the relation between observed system and observing apparatus. In a famous 1971 article titled 'Introduction to the hidden-variable question', Bell referred to this hard-to-pin-down point of separation as 'the infamous boundary between classical and quantum worlds'.

David Wick's book is inspired not only in its title but also in its overall motivation and content by the spirit and the points of view expressed by Bell so sharply and strikingly on innumerable occasions. Wick's aim is to trace the early development of quantum mechanics; the struggles of the founding fathers in fashioning an interpretation; the emergence of the orthodox version based on Heisenberg's uncertainty principles and Bohr's complementarity principle; and then the attempts to construct alternative interpretations with an account of the generally hostile way in which these were received and treated by the 'establishment'.

An attractive feature of Wick's treatment is that the individual sections – twenty in all – are brief, focussed, each one devoted to one major theme or concept or historical development. Formal mathematics is kept at a minimum, technical points being relegated to numerous footnotes at the end of sections. In the beginning he sets the stage by recalling the evidence for the reality of atoms, the emergence of quanta, the magical discoveries of matrix and wave mechanics, and the ways in which Heisenberg and Bohr arrived respectively at the uncertainty and complementarity principles. Brief life sketches of Heisenberg, Schrodinger, von Neumann and Bell and the other principal characters are included at the appropriate places. Then follow accounts of events at the two Solvay Congresses of 1927 and 1930, which saw the opening of the Bohr–Einstein debate. At these two meetings, Einstein tried respectively to show that the position–momentum and the time–energy uncertainty principles could be 'beaten' – had it worked out, quantum mechanics or at least the proffered interpretation would have been shown to be inconsistent. The answers Bohr presented on the two occasions are well known. Einstein's third and final attack came in 1935 with the Einstein–Podolsky–Rosen argument – that quantum mechanics while possibly internally consistent gives an incomplete description of physical reality. On the way Wick recounts the von Neumann theorem of 1932: based on stated assumptions, no hidden variable extension of quantum mechanics restoring determinism is possible.

After this essentially historical recollection of the early period, Wick moves on to post-World War II developments. As he points out, while all along there had been some voices raised against the Copenhagen interpretation from the very beginning – witness Schrodinger and the early work of de Broglie apart from Einstein – the work of Bohm in 1952 and then by Bell beginning in the 1960s raised the intensity of the opposition, until today it seems child's play to express one's astonishment at and disagreements with the views of the founding fathers! The reviewer cannot help recalling a statement by Einstein in 1951 in a somewhat different context: 'All the fifty years of conscious brooding have brought me no closer to the answer to the question, "What are light quanta?" Of course today every rascal thinks he knows the answer, but he is deluding himself'.

Wick's treatment of Bell's theorems, the attempts to test them and the analysis of experimental results are illuminating and well-done. In particular the account of the ways in which Clauser, Shimony, Horne, Holt and Freedman each came to know of Bell's work, their individual motivations, and how they were drawn into collaborative efforts to test quantum mechanics is valuable and interesting. Loopholes in the interpretation of experiments displaying violations of Bell's inequalities are discussed. The concluding sections discuss the problems in finding a well-defined set of principles on which one can base quantum mechanics in its entirety, the philosophical standpoints of many of the leading figures, recent developments, and guesses for the future.

The book concludes with an excellently written elementary account of the relation of classical probability theory to quantum mechanics, and a derivation of the two Bell theorems, by William Faris.

Overall the book is stimulating and timely. It is an honest, irreverent and deliberately provocative account. (In contrast, the appendix is sober and to the point, avoiding all polemics). It does bring out the difficulty of the issues involved, and shows how easily one may succumb to prejudices of one kind or the other. However at several points the author seems needlessly harsh in his criticism of the ways in which the early pioneers expressed themselves and treated opposing views. He repeatedly comes down especially hard on both Bohr and Feynman, of course for different reasons. Beyond a point these diatribes, also against Heisenberg and Delbruck, do seem overdone. However one must grant the author's point that the Bohm interpretation of quantum mechanics, available since 1952, has not been given the attention it deserved, and for so long has been just ignored by so many. Wick argues that the 'establishment' adopted a generally bullying attitude to the opposition, at least partly because of its own underlying uneasiness on the foundations!

Speaking of the difficulty in overcoming prejudices, the reviewer could not help noticing that in one of Wick's parables, the two spies in the story are (of course) Boris and Natasha; it was the Buddha who abolished the real world; and Schrödinger's views could be respected and trusted just so far as he did not bring in Vedanta! In many places there is an avoidable flippancy and frivolity of expression, and sometimes factual errors. Thus while in 1925 Heisenberg took the 'leap beyond logic' and represented position and momentum by square arrays, one should remember that Born in 1924 had foreseen the role of 'two index quantities' in a future quantum mechanics. And Heisenberg's rule for multiplying arrays was motivated by the Ritz Combination Law of spectroscopy. Similarly the author of the time–energy uncertainty relation – so most of us have been taught – was Bohr and not Heisenberg. The discussion on the various alternative ways to understand the uncertainty principle is well motivated but finally leaves one uncertain. And Wick's confident assertion about Wigner – 'unlike most physicists, Wigner did not think the Copenhagen interpretation had settled the matter' – seems somewhat at variance with Wigner's own statement: 'The orthodox view is very specific in its epistemological implications. . . . A large group of physicists finds it difficult to accept these conclusions and, *even though this does not apply to the present writer*, he admits that the far-reaching nature of the epistemological conclusions makes one uneasy'.

In conclusion, the book is well worth reading to learn interesting points of history, to see the pressure of philosophical prejudices in every position or point of view, and to appreciate the utter nontriviality of the problems involved. One also understands that just as Bohr and Heisenberg were pioneers, so were Bohm and Bell in a later day. And in each case the courage and persistence shown by the pioneers made the way for those who followed deceptively easy.

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Yakov Ilich Frenkel: His Work, Life and Letters. Alexander S. Gilbergleit, ed. Birkhaüser Verlag, Postfach 133, CH-4010, Basel. 1996. Price: DM 198, SFr 168. 323pp.

Victor Frenkel's *Yakov Ilich Frenkel: His Work, Life and Letters* is a thoughtfully compiled biography of the great Soviet theoretical physicist, J. I. Frenkel (1894–1952) who lived and worked through what has come to be known as the golden age of the twentieth century physics. This biography is, however, not just about the many scientific achievements of J. I. Frenkel, the physicist, but also about Frenkel, the man (or J. I., as he is affectionately referred to throughout the book) – about his worldview and the civic convictions upheld by him through the tumultuous decades that followed the October revolution when the scientific ideas of Quantum Mechanics and the Relativity Theory were held suspect by the State.

In this book we are re-told of Frenkel's well-known contributions to theoretical physics which are deep and, indeed, far too many for any one individual. This fact stands acknowledged in terms of the diverse physical phenomena and effects that now bear his name. Thus, we have the Frenkel defects in crystalline lattices; the Frenkel excitons in semiconductors; the Frenkel–Kontorova equation for the plastic deformation giving Frenkel solitons; the Frenkel Saw, or the Double-Saw model for the elastic limit of crystals and for dry friction; the Frenkel-fields of quantum electrodynamics; and, of course, the Frenkel theory of the liquid state, the last mentioned being closest to his heart, and considered by many his abiding contribution to theoretical physics. Some others, however, viewed his idea of the exciton (the photo-excited mobile electron-hole pairs *sans* photoconductivity) as 'the pearl of his creative legacy'. Then there are the less known works traceable to Frenkel for which he did not quite get the credit that was rightly his. This includes his work on the superdense stars – the White Dwarfs – which, he had argued, were stabilized against gravitational collapse by the electronic degeneracy pressure, rather than by a high temperature as the great Eddington would have it. And similarly for his work on the theory of metals with 'collectivized' electrons obeying Pauli's 'residence law'; his theory of the superdense nuclear matter; or his dynamo theory of Earth's magnetic field. Even the electron-paramagnetic resonance (EPR) was in fact one of his sound theoretical guesses. So was his idea of the lattice-polaron. He had, perhaps, expressed these seminal ideas just in passing. Some of his ideas were simply ahead of his time, e.g., the Ioffe–Frenkel idea of tunneling was realized in Tunnel Diodes, long after his death.

The biographer has provided insight into the working of Frenkel's mind, his method, and his style of pursuing scientific enquiry. Frenkel belonged to 'the theoreticians of the experimentalist type'. His method was, we are told, 'to come forward with a kind of "catch" and then with its help to approach the truth'. He was known to have bemoaned the 'unhealthy passion for formal mathematical apparatus, a formal approach to physics that brings more damage than profit by tempting physicists to be satisfied with cheap mathematical trophies and to forget about the true essence of the problem considered'. The biographer hastens to clarify, however, that Frenkel was merely objecting to 'shooting guns at sparrows'. To him, introduction of new ideas remained the single greatest service one can render to science. It has been said of him that 'sometimes not even a model, but a precise, clear imaginative (if anthropomorphic, or terramorphic) expression by J. I. Frenkel, actually provided the formulation of some problem, later solved by other theoreticians'. This is well illustrated by his remark that '. . . the surface layer of every solid may be considered even in the absence of any alien adsorbed particles, as itself having been adsorbed with respect to the substrating mass'. One has only to read through his arguments as to why a liquid is kinetically closer to a solid than to the gas, that it naively resembles most, to be left in no doubt about its truth. The biography is, however, quite candid about some of Frenkel's intuitive remarks that may now seem untenable. Thus, for instance, Frenkel felt the gravitational field to be too 'macroscopic' to be quantized. But, precisely this and such otherwise inaccessible asides have added great value to this book for a discerning reader.

Last but not the least, this is a biography of an illustrious father by an affectionate son, not just filed from some archives but compiled with care from personal recollections and letters and familial anecdotes that go far beyond the usual public domain. Through reading these, a curious reader may even deconstruct the mind and the personality of J. I. Frenkel. From this record, J. I. emerges as a creative first-principle scientist, an encyclopaedic thinker, a kindly warm hearted professor with friends all over the world, and an artist. Some of the paintings/portraits by him reproduced in the book are simply disarming in their appeal. His students loved him, and there was no 'theoretical minimum' at his Physical-Technical Institute, that Landau, for one, would have insisted upon. For all his varied interests he was no great reader, or collector of books. But, he had read Jim Corbett's *Man-eaters of Kumaon* and *Leopard Man-eater from Rudraprayag*.