Steve Faulkner

The Underlying Machinery of Quantum Indeterminacy

The Answer to a Century of Questions

Steve Faulkner
Glasgow
Scotland UK.
stevefaulkner@protonmail.com

Review Edition. Published by Steve Faulkner.
Document typesetting and preparation, TEX, LATEX 2_ε and LYX.
Printed by Bell & Bain Ltd, 303 Burnfield Road, Glasgow G46 7UQ

... but Steve, you're meant to use Quantum Theory,
not take it to bits ...

Ian Halliday, Sheffield Hallam University

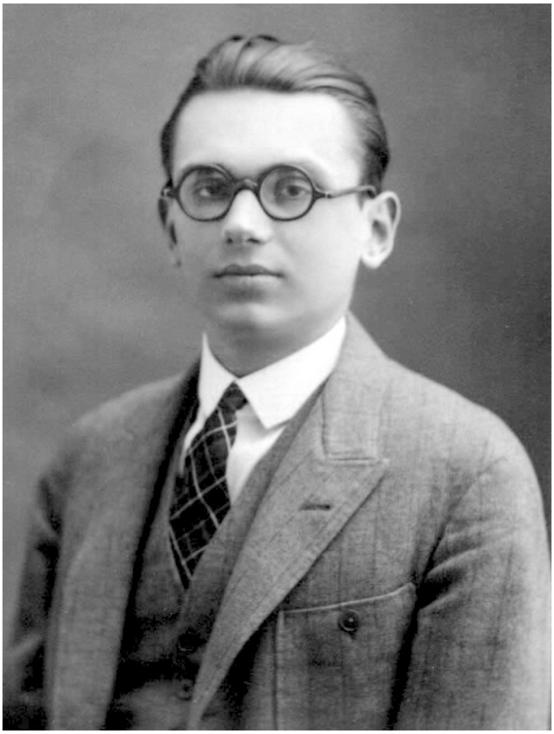

Fig. 0.1: **Kurt Gödel as a student in 1925, age 19.**

In the early 20th century Physics suffered two crises: first, Special Relativity and then Quantum Mechanics. Then, from 1930 onward, Mathematics suffered its own shattering crisis, after Gödel announced his First Incompleteness Theorem. Its consequence today is that there are statements in Applied Mathematics that are *true* but *not provable.* One such statement concerns existence of the square root of minus one. Knowing precisely what drives necessity for this number's presence in Quantum Theory resolves the question of quantum indeterminacy.

Preface

In the main, physicists have long since given up any expectation of ever making sense of quantum indeterminacy, at least in *their* lifetimes. University professors regularly teach undergraduates that indeterminacy is an utterly amazing, but yet unresolvable artifact. Those especially close to the subject, debate whether or not indeterminacy is an *irreducible* fundamental.

Thanks to this lack of any answer, professors designing physics courses, tend to position quantum indeterminacy as occupying only a short descriptive chapter of their undergraduate curriculum. This status quo is well-established as mainstream: we are into the *sixth generation* of physicists being taught the subject. And it might even be said that indeterminacy is discussed to greater depth in philosophy departments; though not for the sake of progressing Physics, but for its empirical challenge to what might be called 'natural rules of inference and deduction'.

However, physicists continuing to teach indeterminacy as *answerless*, are doing their students a misleading injustice.

Since the late 1990s a few researchers have focused on processes that convey mathematical information through experiments, paying special attention to *mathematical freedoms* within algebraic systems, that permit the propagation of indefinite ambiguities — as opposed to *implied logical consequences* which govern definite certainties. Both freedoms and consequences play their part.

This book tells the full story. Scientists reading it will find the tools they need in making intuitive good-sense of unintuitive facts, witnessed in quantum experiments; and find that indeterminacy is a mathematically technical subject, whose mathematics is inherent in the algebras of textbook Quantum Mechanics. This is revelation in the detail of mathematical intricacies, rather than the new discovery of some previously unknown *missing* physical theory.

This book is not a text for learning Quantum Mechanics; its purpose is insight. In the first instance, the book's material is aimed at researchers and graduate students, whose special interest is quantum indeterminacy; and to a lesser extent, researchers aiming to resolve The Measurement Problem. But equally, its findings will interest all who study physics, all students of Quantum Mechanics, and all philosophers researching Foundations of Physics.

Readers should find this book's material covers enough ground to make sense, self-contained. It reports on research investigating the processes and mechanisms that are the workings of quantum indeterminacy. In it, the reader is shown structure in Quantum Mathematics, logically isomorphic with quantum indeterminacy, expressing indeterminacy's *uncausedness* and *indefiniteness.*

The enquiry was originally motivated in 1997 by a thought experiment posed by the author, suggesting that quantum indeterminacy has origins in axiom systems, Mathematical Logic and computability; which promised to agree with the *3–valued logic* of Hans Reichenbach. Independently of that endeavour, such a connection was subsequently *demonstrated* in 2008, in experiments performed by Tomasz Paterek et al in Vienna. Indeed, the book explains what is actually going on in the propagation of the Paterek density operator.

Readers are given the evidence, and shown the arguments supported by that evidence. This starts with known facts taken from those Vienna Experiments and from Mathematical Logic; with additional evidence, argued from Quantum Mathematics itself.

Implied in requirements to consistently satisfy that evidence is uncaused self-referential circularity, conveying information around transformations whose combined resultant is stable perfect symmetry.

Unopposed by axioms and free to perpetuate, that unprevented freedom explains quantum indeterminacy's *uncausedness.* And *referentially ambiguous epistemology* of the stable perfect symmetry explains indeterminacy's *indefiniteness.*

This self-referential machinery is not an invention or contrivance, or taken from any 'toy theory'; it is implicit in the Vienna Experiments; has basis in Mathematical Logic; and reliance on the distinction between *true* and *provable* statements, made famous through the work of Kurt Gödel. In the sense of Gödelian Incompleteness, referential ambiguity is resolved only through the supply of information brought in from outside the system. This is machinery that removes any reason there may have been to view quantum randomness and quantum indeterminacy as *fundamental* and *irreducible.*

In exposing this machinery, a typical line of attack employed is to lay bare the *mathematical* content of Quantum Theory by attempting to *replicate* its formulae. Axioms are laid down; then quantum formulae are derived from them, in order to reveal the necessary items of information needed in proving them. This method identifies whatever information-shortfall there is, that axioms have no way of providing, which must be provided extra from *outside* the axiom system, in order to complete their proof — from the standpoint of the axiom system, these items of outside information are statements which are *'true–but–unprovable'*

The reader will be challenged by a profoundly momentous revelation; shown to be the case, in this book: that the *a priori* unitary|Hermitian ontology of standard theory — asserted *'by Quantum Postulate'* in textbooks — is *mathematically redundant*, as well as also being *contradicted* by the Vienna Experiments. Historically, this unitary|Hermitian condition has been wrongly understood, as needing to be imposed *a priori;* when in fact, its true logical status is *a posteriori* under axioms already accounted for; being a consistency consequence of complementarity. The effect of this *wrong* is to cover up a pre-existing mathematical system, possessing intricate structure, by dominating and obscuring it with an even coating of all-the-same. Historically, this *a priori* condition on Quantum Mathematics has been the obstacle blocking progress in the advancement of Indeterminacy Theory. If indeterminacy is to reveal itself in the mathematics, the *a posteriori* behaviour must be allowed to propagate its effects.

Followup on the Vienna Experiments exposes density operator propagation as necessitating *information loss*; which is denied by the *a priori* unitarity of standard theory. This may resolve the *Black Hole Information Paradox.*

The book was embarked upon immediately research material covered enough ground to make sense as a self-contained body of work. Its purpose is to resolve a Quantum Theory conundrum. Once accepted, the book's material will likely be seen as groundbreaking. That experts may scrutinise its individual sections and chapters; and review its story as a whole, is my first duty in writing. That physicists and philosophers should benefit from it, is my primary motivation. Yet, my strongest and overriding wish is that teachers may pass on to their students, a more complete picture of Quantum Mechanics.

For those investigating The Measurement Problem or EPR paradox, techniques should hopefully shed some light. Of incidental use possibly, for those hoping to find quantisable curved spacetime metrics, there are techniques used in regard to $\mathsf{su}(2)$ which show promise of being helpful.

The inspiration for taking a direction involving *circularity*, into the quantum mechanical enquiry, stemmed originally from two related ideas. Both make it difficult to picture 'The Universe' not incorporating some form of self-reference. The first is the proposition that: any *'cause'*, in the reductionist sense, is itself an *'effect'* stemming from some prior cause, deeper rooted. From which may be inferred — *'chains of cause'* must be infinite, or; chains begin in uncaused effects, or; chains loop back on themselves to form *'causal loops'* that have no beginning. To me, only the second and third of these can science make any sense of, even if unintuitive.

Even more compelling is a thought-experiment, contemplating computer simulation of 'The Universe'. Ignoring entirely the fantastic complexity, logical anomalies arise if the computer program itself is to be regarded as part of that Universe — and if such a simulator be expected to boot itself from cold. Analogous anomalies arise in considering the Laws of Physics, if they are to be regarded as part of The Universe they govern — and not outside it.

These anomalous self-referential systems led me to study the theorems of Kurt Gödel. In turn, that led to the study of *mathematical undecidability (undecidable statements)* and from there to *axiom systems* and *logical independence*. It took some years before realising that logical independence of the imaginary unit is key to uncovering the machinery of indeterminacy, despite the fact I had been aware of the imaginary unit's independence, for some years before.

The book is an in-depth examination of Quantum Mathematics, for *freedoms* it imposes on Quantum Theory, not seen as important in textbook theory. It brings to bare the advantages of quantifier logic into the realms of Quantum Theory; furnishing existential formulae, as opposed to equations. The theory provided, then, is a theory of existence. The approach offered relies strictly and exactingly on the *mathematical content* of Quantum Theory, far more heavily than is instructed in standard textbooks. For instance, special note is made of the distinction separating information that is *consistent* — as distinct from information asserting *implication*. Particular care is paid in avoiding unnoticed assumptions made by the mathematician. An issue of note is the epistemic nature of perfect symmetry. For example, the algebra of scalars does not differentiate left|right handedness, and it is customary for mathematicians to agree on a convention of right handed reference frames in setting out problems. That agreement is in the minds of the mathematicians only, and not asserted in the mathematics; the mathematics itself conveys ambiguity in this regard. This kind of ambiguity is a freedom, unavoidable in *actual* quantum systems, which mathematicians inadvertently suppress in the *theory*. Another issue arises where it is customary to declare, *by Postulate*, certain scalars *real* and others *complex*, where the mathematics itself does not assert this distinction.

As said, the algebra of scalars does not differentiate left|right handedness, and because density operator processes at measurement rely on orientation being encoded in terms of scalars, followed by that, scalar information being encoded back as orientation, there is ingression of ambiguity at measurement.

The reader will encounter mathematical disciplines of Abstract Algebra and Group Theory; Model Theory — a branch of Mathematical Logic — and Cantor's Diagonal Argument in conjunction a Fixed-Point Theorem.

All comment welcome.

Steve Faulkner 2020