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Kant and the Exact Sciences

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Kant and the Exact Sciences

For my philosophical parents

Norman Friedman Zelda Nathanson Friedman

Es bewies mehr wie alles andere Platons, eines versuchten Mathematikers, philosophischen Geist, daß er über die große, den Verstand mit so viel herrlichen und unerwarteten Prinzipien in der Geometrie berührende reine Vernunft in eine solche Verwunderung versetzt werden konnte, die ihn bis zu dem schwärmerischen Gedanken fortriß, alle diese Kenntnisse nicht für neue Erwerbungen in unserm Erdenleben, sondern für bloße Wiederaufweckung weit früherer Ideen zu halten, die nichts geringeres, als Gemeinschaft mit dem göttlichen Verstande zum Grunde haben könnte. Einen bloßen Mathematiker würden diese Produkte seiner Vernunft wohl vielleicht bis zur Hekatombe erfreuet, aber die Möglichkeit derselben nicht in Verwunderung gesetzt haben, weil er nur über seinem Object brütete, und darüber das Subject, so fern es einer so tiefen Erkenntniß desselben fähig ist, zu betrachten und zu bewundern keinen Anlaß hatte. Ein bloßer Philosoph, wie Aristoteles, würde dagegen den himmelweiten Unterschied des reinen Vernunftvermögens, so fern es sich aus sich selbst erweitert, von dem, welches, von empirischen Prinzipien geleitet, durch Schlüsse zum allgemeinern fortschreitet, nicht genug bemerkt und daher auch eine solche Bewunderung nicht gefühlt, sondern, indem er die Metaphysik nur als eine zu höhern Stufen aufsteigende Physik ansahe, in der Anmaßung derselben, die sogar aufs Übersinnliche hinausgeht, nichts Befremdliches und Unbegreifliches gefunden haben, wozu den Schlüssel zu finden so schwer eben seyn sollte, wie es in der That ist.

Welches sind die wirklichen Fortschritte, die die Metaphysik seit Leibnitzens und Wolf's Zeiten in Deutschland gemacht hat? Beilage No. I

The philosophical spirit of Plato, an experienced mathematician, was demonstrated above all else by the fact that he could be transported into such a wonderment by the greatness of pure reason—which concerns the understanding with so many magnificent and unexpected principles in geometry—that he was carried away even to the fantastic thought that all this knowledge was not to be taken for a new acquisition in our earthly life, but rather for a mere reawakening of much earlier ideas which could have no less of a basis than community with the divine understanding. A mere mathematician would no doubt have delighted and perhaps even rejoiced in these products of his reason, but their possibility would not have set him into wonderment, because he was intent only on his object and had no cause to consider and to wonder about the subject—in so far as it is capable of such a deep cognition thereof. On the other hand, a mere philosopher, such as Aristotle, would not sufficiently have noted the vast difference of the *pure* faculty of reason—in so far as it amplifies itself from itself alone—from that which, guided by empirical principles, progresses through inferences to more general [principles]; and therefore he would also not have felt such a wonderment, but rather, in that he viewed metaphysics only as a physics ascending to a higher level, he would have found nothing strange and incomprehensible in its presumption, which aims even at the supersensible—the key to which must be precisely as difficult to find as it in fact is.

What Real Progress Has Metaphysics Made in Germany since the Time of Leibniz and Wolff? Supplement No. I

Preface

Immanuel Kant was deeply engaged with the science of his time—with the mathematical physics of Newton, in particular—during his entire philosophical career. His first published work, *Thoughts on the True Estimation of Living Forces* (1747), initiates a fundamental philosophical reconsideration of Newtonian physics which is then continued throughout the so-called pre-critical period: we here see Kant attempting to redefine the nature and method of metaphysics in light of the recent breathtaking advances in mathematics and mathematical physics. In the great period of the critical works (1781–1790) Kant achieves this metaphysical revolution by self-consciously following "the examples of mathematics and natural science, which through a suddenly accomplished revolution have become what they now are" (Bxv–xvi). Accordingly, in the *Prolegomena to Any Future Metaphysics* (1783) Kant explicitly addresses the question "How is metaphysics in general possible?" by way of the questions "How is pure mathematics possible?" and "How is pure natural science possible?" And it is no accident that the *Metaphysical Foundations of Natural Science* (1786), which presents Kant's most developed account of the foundations of Newtonian mathematical physics, is written at the height of the critical period. In Kant's post-critical reflections contained in his unpublished *Opus postumum* (1796–1803), moreover, we see a final reconsideration of the philosophical foundations of the sciences as Kant contemplates a new work, intended to complete his philosophy, entitled *Transition from the Metaphysical Foundations of Natural Science to Physics*.

Yet there has been a marked tendency to downplay and even to dismiss the philosophical relevance of Kant's engagement with contemporary science, particularly among twentieth-century English-language commentators. The reason for this is not far to seek: to read Kant in close connection with the specifics of the mathematics and physics of his time would seem inevitably to diminish his relevance to our current concerns. Much of twentieth-century philosophy finds its starting point and inspiration in the overthrow of Euclidean geometry and Newtonian physics by Einstein's theory of relativity. Hence from our present point of view geometry and physics certainly do not have the fixed, and indeed the synthetic a priori, status attributed to them by Kant. If Kant's philosophical achievement is still to have significance for us, therefore, it must be read in terms of more general epistemological principles that transcend the specifics of Euclidean-Newtonian science. Indeed, even commentators who have attempted to take seriously Kant's philosophy of science (and have thus not rested content with general epistemology) have also sought to extract a more general conception of science that would be as acceptable in the twentieth as in the eighteenth century.

Although this attempt to read Kant, as far as possible, in independence from the details of his scientific context is therefore understandable, I believe it is also profoundly mistaken. Kant's philosophical achievement consists precisely in the depth and acuity of his insight into the state of the mathematical exact sciences as he found them, and, although these sciences have since radically changed in ways that were entirely unforeseen (and unforeseeable) in the eighteenth century, this circumstance in no way diminishes Kant's achievement. For, on the one hand, Kant had an astonishing grasp of the philosophical foundations of the exact sciences of his time—a grasp that we, with all our increase in purely scientific sophistication, have hardly been able to match vis-à-vis twentieth-century exact science. So Kantian thought stands as a model of fruitful philosophical engagement with the sciences. On the other hand, our current philosophical predicament evolves directly from the breakdown of the Kantian philosophy in light of twentieth-century scientific developments (via the development of logical positivism and its aftermath): it is precisely because Kantian philosophy is so well adapted to eighteenth-century science—and not, therefore, to twentieth-century science—that our present philosophical situation has the specific shape it does. A better understanding of Kant's thought within its eighteenth-century context is therefore most relevant indeed to our twentieth-century problems.

This book is an attempt to provide detailed support for the above claims—especially concerning the depth and acuity of Kant's philosophical insight into the foundations of the sciences—by developing a reading of Kant's engagement with the exact sciences in all three periods: the pre-critical period of the *Thoughts on the True Estimation* through the *Inaugural Dissertation* (1770); the critical period of the *Prolegomena*, the *Metaphysical Foundations*, and the *Critique of Pure Reason* (1781, 1787); and finally the post-critical period of the *Opus postumum*. My aim throughout is to show that and how central aspects of the Kantian philosophy are shaped by—are responses to—the theoretical evolution and conceptual problems of contemporary mathematical science. I do not mean to suggest, however, that the Kantian philosophy can be thereby seen as wholly parasitic on the exact sciences—so that, for example, one can simply read off the content of that philosophy from the scientific developments in question. On the contrary, Kant's achievement consists rather in adapting and radically transforming independently given philosophical and metaphysical ideas—ideas stemming largely from the Leibnizean philosophical tradition he inherited—within the essentially new scientific context wrought by Newton. In this way, philosophy and the exact sciences are set into a fruitful interaction with one another that illuminates both the nature and function of the former and the conceptual foundations of the latter.

Kant's pre-critical period is the main subject of the Introduction. In these years Kant self-consciously seeks to refashion the Leibnizean (Leibnizean-Wolffian) tradition so as better to harmonize metaphysics with Newtonian natural philosophy. The notions of substance, the active force of substance, and the interaction of substances are the central metaphysical concepts at issue. The problem of interaction—as expressed in the well-known conflict among the systems of physical influx, occasionalism, and pre-established harmony—is Kant's philosophical starting point. In particular, Kant attempts throughout the pre-critical period to defend a modified version of physical influx—according to which distinct substances really do interact with one another via genuine "transuent forces"—explicitly modeled on the Newtonian theory of universal gravitation; and this effort then leads him to a radically new conception of the relationship between (phenomenal) space and the underlying (noumenal) realm of ultimate substances. The pre-critical period is also noteworthy for Kant's attempt to reformulate the proper method of metaphysics. In explicit agreement with the Newtonianism of Euler, Kant argues that metaphysics must begin with—must take as its "data"—the far more certain and secure results of the mathematical exact sciences. Indeed, it is only in this way that metaphysics can possibly aspire to a properly scientific status for itself.

The critical period is the subject of Part One. The great innovations of this period are explained as revolving around two central ideas. The first, explored in detail in Chapters 1 and 2, involves a sharp distinction of the faculties of the mind into a conceptual or intellectual faculty, on the one hand, and a sensible or intuitive faculty, on the other. This division of the faculties of understanding and sensibility is here traced back to Kant's extraordinary insight into the logic and proof-structure of Euclid's *Elements* (including the arithmetic of Books VII–IX and the theory of proportion of Book V). In Euclid existence assumptions are represented not via propositions formulated in modern quantificational logic but rather by constructive operations—generating lines, circles, and so on in geometry—which can then be iterated indefinitely. Such indefinite iteration of constructive operations takes the place, as it were, of our use of quantificational logic, and it is essentially different, moreover, from the inferential procedures of traditional syllogistic logic. From Kant's perspective, then, mathematical reasoning—which necessarily involves such indefinite iteration in geometry, in arithmetic, and in "algebra" as well—thereby must involve non-logical, and hence non-conceptual elements; and this appeal to "construction in pure intuition" underlies Kant's radical division of the faculties of the mind. Perhaps the most important result is the characteristically critical theory of space: space is no longer constituted by the interactions among intellectually conceived ultimate substances (as it was for the pre-critical Kant); rather, it is an autonomous "form of sensible intuition" governed by *sui generis* (non-intellectual) laws of its own—namely, the laws of Euclidean geometry.

The second great innovation of the critical period is explored in Chapters 3 and 4. Not only is the sensible faculty fundamentally distinct from the intellectual faculty, but the concepts and principles of the intellectual faculty themselves have "sense and meaning" only when applied to the sensible faculty and thus to space (and time). In particular, the intellectual concepts of substance, active force (or causality), and interaction (or community) now have genuine content only as applied to the spatio-temporal world of sense. This spatio-temporal "schematism" of the pure intellectual concepts or categories marks a profoundly new conception of their nature and function: such metaphysical concepts no longer characterize an underlying (noumenal) intellectual realm located somehow beneath or behind the (phenomenal) world of sensible experience; rather, their function now is precisely to constitute the conditions of possibility of sensible experience itself. From the present point of view, the spatio-temporal application of the pure concepts or categories is exemplified, above all, by Kant's penetrating analysis, developed in the *Metaphysical Foundations of Natural Science,* of Newton's law of universal gravitation. Here Kant starts from a rejection of Newtonian absolute space, but still attempts, nonetheless, to do justice to Newton's central distinction between "true" and "apparent" motion. Kant views the argument of Book III of the *Principia* as first defining or constructing a privileged frame of reference—an empirical counterpart of absolute space—and, at the same time, as constructing or deducing the law of universal gravitation from the "phenomena." This procedure then exemplifies how the categories discharge the function of "as it were prescribing laws to nature and even making nature possible" (B159).

Kant's post-critical reflections in his *Opus postumum* are the subject of

Part Two (Chapter 5). The problem underlying Kant's attempt to formulate the *Transition from the Metaphysical Foundations of Natural Science to Physics* is understood in the following way. In the critical period, as indicated above, Kant is able to show how the understanding "prescribes laws to nature," and thus makes experience possible, in the case of the Newtonian theory of universal gravitation. But the rest of the phenomena of nature—chemical phenomena especially—remain entirely unaccounted for. Indeed, in the critical period Kant explicitly despairs of the properly scientific status of chemistry. If we are truly to see how experience—experience as a whole—is possible, therefore, some kind of extension of the argument of the *Metaphysical Foundations* is needed. The *Transition* project takes its inspiration from the new developments in the science of heat and in chemistry that constitute Lavoisier's chemical revolution, and this project is therefore based on Kant's appreciation of the emerging scientific status of chemistry. In particular, Kant wrestles with the central theoretical construct of Lavoisier's new chemistry—the imponderable caloric fluid or aether—and ultimately attempts to show that it has an a priori, not merely hypothetical, status. In the course of the *Transition* project Kant's conception of the faculties of the mind and their relation—this time, the faculties of understanding and judgement—is once again fundamentally transformed.

Earlier versions of some of the chapters were published previously, as detailed below. In the present book I have revised these earlier versions substantively. In particular, I have now attained greater clarity and consistency, I hope, on the very delicate question of the relationship between geometry and physics, between sensibility and understanding, and between "form of intuition" and "formal intuition." It is also my hope that the recurrence of some themes and texts, approached from different directions in different chapters, will both facilitate access to the book (which can be read starting with any chapter of special interest) and prove to be philosophically illuminating.

Several pages from the Introduction are reprinted from "Causal Laws and the Foundations of Natural Science," in P. Guyer, ed., *The Cambridge Companion to Kant* (Cambridge University Press, 1992). I am grateful to Paul Guyer and Cambridge University Press for permission to reproduce this material.

An earlier version of Chapter 1 appeared as "Kant's Theory of Geometry," *Philosophical Review* 94 (1985): 455–506. I am grateful to the editors of *The Philosophical Review* for permission to publish the present version.

An earlier version of Chapter 2 appeared as "Kant on Concepts and Intuitions in the Mathematical Sciences," *Synthese* 84 (1990): 213–257,

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An earlier version of Chapter 3 appeared as "The Metaphysical Foundations of Newtonian Science," in R. Butts, ed., *Kant's Philosophy of Physical Science* (D. Reidel, 1986). I am grateful to Robert Butts and D. Reidel for permission to publish the present version.

An earlier version of Chapter 4 appeared as "Kant on Space, the Understanding, and the Law of Gravitation: *Prolegomena* §38," *Monist* 72 (1989): 236–284. I am grateful to the editor of *The Monist* for permission to publish the present version.

My intellectual debts incurred in writing this book are many and various.

Reading Gerd Buchdahl's *Metaphysics and the Philosophy of Science* (1969) in 1980 first awoke my interest in Kant's philosophy of science. Before this my interest in Kant had taken a more traditional direction, as I had assumed (as have many others) that Kant's commitment to the science of his time presented a formidable obstacle to the twentieth-century relevance of his scientific thought. In the meantime I had pursued independently studies of the conceptual foundations of space-time physics. Buchdahl's rich and suggestive treatment of Kant in the context of the development of seventeenth- and eighteenth-century science first showed me how to combine my interests in Kant and in the foundations of physics and formed the starting point for my ensuing investigations.

During this same period I benefited greatly from the encouragement and advice of Thomas Ricketts, who urged me to forge links between my study of Kant and my study of the philosophy of space and geometry. In attempting to do so I have since profited repeatedly from Ricketts's philosophical insights.

My first efforts focused on Kant's philosophy of mathematics and geometry. Here I drew inspiration from the work of Jaakko Hintikka, Charles Parsons, and Manley Thompson. I also benefited from the comments and advice of Parsons and Thompson—and later, in this connection especially, from extensive conversations with William Tait. I am further indebted to Thompson for his fundamental criticisms of my 1985 version of Chapter 1.

In the Spring of 1984 I held a Canada Council Visiting Foreign Scholars Fellowship at the University of Western Ontario. This invaluable opportunity allowed me to begin to work out my ideas on the *Metaphysical Foundations of Natural Science,* which I presented in a series of seminars. I am indebted to the participants, particularly Richard Arthur, Robert Binkley, Robert Butts, Philip Catton, William Demopoulos, Malcolm Forster, William Harper, Clifford Hooker, Thomas Lennon, Ausonio Marras, John Nicholas, Kathleen Okruhlik, and Graham Solomon. Since then I

have returned yearly to Western Ontario and have continued to present my evolving ideas there. I am grateful for the support and encouragement of Butts, Demopoulos, Lennon, and Marras, who have made this continuing relationship possible.

In attempting to come to terms with Kant's analysis of Newton's remarkably subtle argument for the law of universal gravitation I am indebted, above all, to the writings and advice of Howard Stein. Without the benefit of Stein's understanding of the intricacies of the Newtonian argument I simply would not have been able to pursue Kant's analysis as far as I have. As comments from Stein, and also especially from Robert DiSalle, have made clear, my account still needs to be developed further.

My work on the *Opus postumum* has benefited particularly from the writings of Eckart Förster and Burkhard Tuschling. I am also indebted to Förster for his comments on an earlier draft of Chapter 5.

I developed the ideas on the pre-critical period articulated in the Introduction while working with Alison Laywine on her dissertation on this topic. There is no doubt that I learned as much from her as she did from me.

For comments on the penultimate draft I am indebted to an anonymous referee for Harvard University Press and also, once again, to William Harper.

In addition to those already named, I am indebted for comments, conversations, and criticisms over the years to Henry Allison, Karl Ameriks, Gordon Brittan, John Carriero, Richard Cartwright, Alberto Coffa, Joshua Cohen, Graciela De Pierris, Burton Dreben, Hannah Ginsborg, Warren Goldfarb, Anil Gupta, Paul Guyer, Peter Hylton, Philip Kitcher, Thomas Kuhn, Ernan McMullin, Ralf Meerbote, Carl Posy, John Rawls, Roberto Torretti, Daniel Warren, Scott Weinstein, Margaret Wilson, and Mark Wilson. I regret that I became acquainted with the *scharfsinnig* work of Martin Carrier on Kant's scientific thought only as the present book was already in press—I hope to benefit from it in future work.

For support of my work on this book I am indebted, in addition, to the Institute for the Humanities at the University of Illinois at Chicago for a Fellowship in the academic year 1984–1985 (I am also grateful to Gene Ruoff, the Director of the Institute, for technical assistance in the preparation of the manuscript), to the Department of Philosophy at Harvard University for a George Santayana Fellowship in the Fall of 1986, to the University of Illinois for a Senior University Scholars Award from 1987 to 1990, to the National Science Foundation for a Grant (SES 86-19813) in 1988, and to the John Simon Guggenheim Memorial Foundation for a Fellowship in the academic year 1988–1989.

Kant and the Exact Sciences

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Metaphysics and Exact Science in the Evolution of Kant's Thought

Kant began his philosophical career as an enthusiastic student of Leibnizean-Wolffian metaphysics and Newtonian natural philosophy. As is well known, Kant's interest in both systems of thought was inspired and nurtured by his teacher Martin Knutzen at Königsberg, a moderate Wolffian revisionist who was one of the first in Germany to accept Newtonian attraction.[1] Kant himself accepts Newtonian attraction as an immediate action-at-a-distance throughout his career, and, in fact, he consistently takes the law of universal gravitation as his paradigm of a well-established physical law.[2] Yet Kant also consistently holds that, whereas the Newtonian natural philosophy is correct as far as it goes, it does not go far enough: a true natural science requires a grounding in metaphysics—a metaphysics based on the prior notions of *substance* and *active force*. The following passage from the *Physical Monadology* of 1756 is typical in this regard:

1. See Erdmann [23]; Tonelli [110]; Cassirer [18]; Beck [5], p. 430. Knutzen's revisionism consisted primarily in a defense of physical influx as opposed to the Leibnizean system of pre-established harmony, and it is probable that Knutzen influenced Kant decisively in this regard (Erdmann, for example, argues on p. 143 of [23] that Knutzen is the "certain clear-sighted author" to whom Kant alludes in §6 of *Thoughts on the True Estimation of Living Forces:* 1, 21.3–4). For Knutzen and Newtonian attraction see Tonelli [110], p. 67 and n. 200 thereto on p. 117.

2. Kant's consistent acceptance of Newtonian attraction as a true and immediate action-at-a-distance actually represented a rather extreme position, as compared with the position of Newton himself and the majority of continental Newtonians of Kant's day. Euler, for example, who was certainly no friend otherwise of Leibnizean-Wolffian metaphysics, notoriously rejected action-at-a-distance, and even such staunch Newtonians as Maupertuis and Voltaire expressed themselves extremely cautiously on the matter. Kant's position corresponds to that of the second generation English Newtonians, especially to that of John Keill. See Tonelli [110], pp. 66–69.