NEWTON AND THE GREAT WORLD SYSTEM

Peter Rowlands

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Mathematics is, in many ways, the most generic and abstract of all systems of human thought. Once Newton found he could describe dynamics and planetary motions using purely mathematical laws and deductive processes, he understood that there was no limit to what else could be explained — given time and ingenuity every aspect of Nature would find its mathematical roots. Newton himself repeatedly stated how aspects of chemistry, biology and even human thought could be accessed by his method. He also acknowledged how immense the task would be, involving many contributors over many centuries, however once the system was in place, it could be extended indefinitely. Although not fully understood during his lifetime, the Newtonian method has since been applied to many subjects outside of physics, including chemistry, physiology and philosophy. This book analyses the Newtonian method and demonstrates how it represents the very roots of our understanding of the great world system we live in today.

This unique book is published as the second of a three-part set for Newtonian scholars, historians of science, philosophers of science and others interested in Newtonian physics.

All Titles:

1. *Newton and Modern Physics*
2. *Newton and the Great World System*
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Preface

The first book in this series, *Newton and Modern Physics*, explored how Newton created an extraordinarily powerful method of scientific thinking based on taking concepts to the ultimate level of abstraction and generality, and used it in a penetrating analysis of many unexplained physical phenomena. The problems, however, because of their complexity, remained largely inaccessible to the equally powerful mathematical structures he had developed simultaneously. The modernity of the work was forced upon him because he had to use creative analytical thinking to make progress where there was no obvious deductive mathematical procedure leading from generic ideas to particular applications, while avoiding facile hypotheses in the search for the generic. It has much more resonance for the present than it could have had for his own time.

When he was faced with the problems of dynamics and planetary motion, however, he was investigating the phenomena most amenable to the mathematical techniques he had been developing from the beginning of his studies. In fact, the mathematics was itself created largely in the pursuit of solving the problems of 'motion', or, in modern terms, dynamics, and was ideally fitted to the use he made of it. Mathematics is, in many ways, the most generic and abstract of all systems of human thought, and once Newton found he could describe dynamics and planetary motions using abstract generic mathematical laws, he was able to present the world with a system which didn't require his powers of analysis and could progress using more deductive processes under its own momentum.

The special significance of this work was that, because Newton succeeded for the first time in discovering universal mathematical laws that applied to the entire system of the world, this could be considered as the moment in history when humans first realised that the whole of Nature was accessible to them using reasoning based on mathematics and experimental observation. Given time and ingenuity every aspect of Nature would find its explanation.

Newton himself clearly recognised this because he repeatedly stated how aspects of chemistry, biology and even human thought could be accessed by his method, and, almost immediately after his time, the Newtonian method began to be applied to many subjects outside of physics, including chemistry, physiology and philosophy. Newton also knew how immense the task would be, involving many contributors over a time period of many centuries, but the system was in place and it could be extended indefinitely.

The breakthrough was neither an obvious development nor an inevitable one. For all its employment of a powerful mathematical structure applicable to a wide variety of problems, the Newtonian world picture still required a quite unprecedented approach to the philosophy of physics which continues to have significance today. Appreciation of this has largely been lost for two reasons. The first is that the methodology largely succeeded and so became adopted as the standard one without needing further philosophical justification, even though this took another fifty years. The second is that the spectacular success of general relativity in the twentieth century, seemingly using an entirely different physical theory, meant that aspects of the Newtonian theory which are essential for the development of modern physics were thought to have been superseded by less fundamental approaches.

However, even though a 'revolution' was proclaimed in 1919, the reality was somewhat different, for Newtonian theory has remained an essential component of general relativity, and the use of a mathematics of curvature has nothing to say about the intrinsic nature of physical space or of gravity. It even has a Newtonian precedent. In addition, historical research shows that significant aspects of general relativity were anticipated by pre-relativistic physicists using minimal extensions to Newtonian methods. The true fundamental relation between Newtonian theory and general relativity has never been extensively studied, even though the lack of such a relation has been a major barrier to understanding the true basis of either theory. It will be proposed here that it is closely connected with the relation between gravity and inertia, a subject of particular interest to Newton himself.

As with *Newton and Modern Physics*, this book has benefited from the cooperation and support of many people, in particular Niccoló Guicciardini for his profound comments and suggestions on the mathematical sections, and also Mike Houlden, Colin Pask, Mervyn Hobden, John Spencer and my wife Sydney.

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About the Author

Dr. Peter Rowlands obtained his BSc and PhD degrees from the University of Manchester, UK. He then spent some time working in industry and further education. He became a Research Fellow at the Department of Physics, University of Liverpool in 1987, and still works there. He has also been elected as Honorary Governor of Harris Manchester College, University of Oxford, a post he has held since 1993. Dr. Rowlands has published around 200 research papers and 12 books. Some of his recent works, published by World Scientific, include *Zero to Infinity The Foundations of Physics* (2007), *The Foundations of Physical Law* (2014), and *How Schrödinger's Cat Escaped the Box* (2015). As a theoretical physicist, his research interests include, but are not limited to, foundations of physics, quantum mechanics, particle physics, and gravity. He has also done extensive work on the subjects of history and philosophy of science, and has published several books on these topics.

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Chapter 1

Metaphysics and Methodology

1.1. Newton and Hypotheses

To work at the most fundamental concepts with the sustained success shown by Newton over a period of more than 50 years would be impossible without both a powerful methodology and a strong metaphysical basis. Great science at this level cannot be done without a powerful system of philosophy which goes beyond the usual scientific method. Newton certainly had such a system, and, without it, he would not have created the unique style of science with which he has always been credited, but, unlike, say, his contemporary Leibniz, he has never had independent recognition as a philosopher. Robert DiSalle, who credits Newton with a general system of philosophy, says that: 'Because Newton never drafted a treatise on, or even a digest of, this general system, his stature as one of the great philosophers of the seventeenth century, indeed, of all time, is no longer widely appreciated'.[1]

Newton's metaphysics, however, is one of his most remarkable achievements, and his desire to attain ultimate metaphysical truth can be seen as the real driver behind his science.[2] Consequently, his views on space, time and motion, and their interpretation in a metaphysical context, are the essential basis of everything he achieved in physics, as well as being an extremely profound approach to the most fundamental truth that a human intelligence can hope to attain. Earlier commentators, confident that the science had developed its own truth beyond any previous philosophical origins, looked on the metaphysical background as an accident of history, now superseded, and saw little significance for such philosophy in the autonomous discipline of modern physics. However, the seemingly continual reversion of modern

[1]DiSalle (2004).

[2]Newton, however, would not have used the term 'metaphysics' in this context, as to him it seemingly referred to attempts at a direct explanation of how God acted in the world, and so, in this sense, was always to be rejected (Levitin, 2013).

physics to prototypes with a manifestly Newtonian origin — what we may call a 'Newtonian attractor' — suggests otherwise, as the common basis for all this work seems to be the Newtonian metaphysics. In addition, the metaphysics was also the basis for Newton's scientific *methodology*, which was also profoundly innovative but which was so successful in its effects that subsequent physicists had no option but to adopt it if they wanted to achieve successes of a similar kind.

The *Principia* and *Opticks* undoubtedly reveal that Newton was a most remarkable scientific thinker; but the manuscripts reveal one who was even more remarkable, a daring speculator whose extraordinary intuitions require an idea of science far beyond a procedure dominated by the rigid application of some established order and method. Philosophy of science has not yet developed a language adequate to deal with them. According to a philosophy of science much in vogue today, science advances by a 'hypothetico-deductive' process: hypotheses are suggested to explain observed facts and are then tested by their experimental predictions; hypotheses which fail in their predictions are discarded, hypotheses which succeed in their predictions are retained. Newton would not have recognised this as a valid process for fundamental physics, and, though he did put forward hypotheses, these were not the main sources of his creative thought.

Much of our knowledge of Newton's methodology comes from a revealing episode early in his career. This came after Newton made the ground-breaking discovery that a prism *dispersed* white light into the rainbow colours of the spectrum because the rays producing each colour had a different refractive index, and so a different velocity in a dispersive medium. This idea that white light is *intrinsically* composite is so familiar today that it is hard to believe that it was ever controversial, but at the time it caused a storm of criticism of such ferocity that Newton threatened to give up science altogether. Newton himself felt that his discovery of the different refrangibilities of the components of white light, and his proof that they were intrinsic to the light rays creating the sensations of different colours, was an outstanding contribution; he knew that he had made a discovery of an entirely new kind, 'the oddest if not the most considerable detection w^{ch} hath hitherto beene made in the operations of Nature'.[3] Everything that we know about Newton's early career suggests that at this period he was content to lead the life of a private scholar, and that he had no desire to seek publicity for his discoveries, but by 1671 the Royal Society had news of his reflecting

[3] Newton to Oldenburg, 18 January 1672; *Corr.* I, 82.

telescope, and he resolved on presenting them with a much more extensive account of his optical discoveries, written in a bold and forthright style. He sent to the Society a paper on 'A New Theory of Light and Colours',[4] which was read on 8 February 1672, 'with a singular attention and an uncommon applause'.[5]

The paper was a brilliant account of his discovery of the analysis of white light, presented as a chain of deductive inferences from an ordered sequence of experiments. Though we may feel that this is how science is supposed to happen, we know, in fact, that presentation of results in this style is merely part of the didactic process which is necessary to the acceptance of a scientific discovery. The engagingly autobiographical style gives the impression that the paper was a straightforward account of work undertaken with no theoretical preconceptions, but with logical inferences derived directly from experimental results. The autobiographical' sections are quite famous and often quoted verbatim as an historical account of his work: 'in y^{e} beginning of y^{e} year 1666.... I procured me a triangular glass Prisme, to try there wth y^{e} celebrated phaenomena of colours', and so forth.[6]

While the individual autobiographical facts may be true, the account connecting them is a fiction, a classic example of the reconstruction of a scientific discovery in the form most likely to convince a new audience — a procedure which is now fundamental in the writing of all scientific papers. Newton wrote that he was 'surprised' to find that the spectrum of light from his prism and circular slit was oblong rather than circular, though it was exactly what he had expected and had carefully positioned his apparatus to produce. He then outlined a series of tests made in a logical and systematic order leading to an 'experimentum crucis' in which specifically coloured rays from the first prism were separately passed through a second prism and shown to refract at different angles. 'Colours', he concluded, 'are not *Qualifications of Light* derived from Refractions or Reflections of natural Bodies (as *'tis* generally believed), but *Original and connate properties*, which in divers Rays are divers'.[7] The conclusion, however, was shocking to its targeted audience. For 2000 years, philosophers had followed Aristotle in proclaiming whiteness as a symbol of purity and simplicity; colouration was held to be due to a modification by the medium, in this case the glass of

[4] *Corr.* I, 92–102.
[5] Oldenburg to Newton, 8 February 1672; *Corr.* I, 107.
[6] *Corr.* I, 92–102, text as quoted from CUL Add. 3970, ff. 460^{r}–466^{v} in *OP*, I, 10.
[7] '*A New Theory*', 1672, *Corr.* I, 92–102.

the prism. Newton was now claiming that white light was heterogeneous and coloured light pure. The roles of colour and whiteness had been reversed.

Newton knew that his conclusion was boldly original, but, as an author entirely new to scientific publishing, he was completely unprepared for what followed. The paper was rightly praised for its ingenious experiments, but Robert Hooke, the Royal Society's curator of experiments, immediately attacked the 'hypothesis' on which Newton's theoretical treatment was based, supposedly the corpuscular theory which he had mentioned in passing as part of a mechanism which he immediately discarded.[8] In a pattern which has repeated itself all too often in the history of science, there was more than a hint in Hooke's remarks of the experienced metropolitan scientist putting the provincial amateur in his place, and, again, in a pattern which would repeat itself all too often with Hooke himself, the Royal Society curator tried to make out that Newton's novel experiments were merely variations on his own. For all his importance to the Royal Society, Hooke was a rather insecure man, keenly aware of his physical deformities and his status as a Society 'employee', and Newton's work had, in effect, undermined the views on light and colour that he had recently put forward in his *Micrographia*, which was that white light was 'nothing but a pulse or motion propagated through an homogeneous, uniform and transparent medium', and that 'colour was nothing but the disturbance of yt light by the communication of that pulse to other transparent mediums, that is by the refraction thereof".[9] So, a ray incident obliquely on a refracting surface created an obliquity in the light pulse. A red sensation was produced when the strongest part of the pulse preceded, and the weakest followed; a blue sensation when the position was reversed; the other colours were produced by combinations lying between these extremes.

Newton was shocked by this damaging 'peer review' from such an influential person. Like many later authors in the same position, he resolved to write a devastating reply, and spent three months carefully composing a letter addressed to the Society's Secretary, Henry Oldenburg. 'I was a little troubled', he wrote, 'to find a person so much concerned for an *Hypothesis*, from whom in particular I most expected an unconcerned & indifferent examination of what I propounded'.[10] Newton would not be the last scientist to fail to receive an 'unconcerned & indifferent examination' of his work, but

[8]Hooke to Oldenburg, 15 February 1672; *Corr.* I, 110–114; first published, Birch (1756–1757), 3: 10–15.

[9]Hooke (1665, 54–67), esp. 62–64; *Corr.* I, 110.

[10]11 June 1672; *Corr.* I, 171–188, 171.