CAMBRIDGE

Cambridge University Press
978-1-107-01546-3 - The Cambridge Companion to Newton: Second Edition
Edited by Rob Iliffe and George E. Smith
Frontmatter
More information

The Cambridge Companion to Newton

Sir Isaac Newton (1642–1727) was one of the greatest scientists of all time, a thinker of extraordinary range and creativity who has left enduring legacies in mathematics and physics. While most famous for his *Principia*, his work on light and color, and his discovery of the calculus, Newton devoted much more time to research in chemistry and alchemy, and to studying prophecy, church history, and ancient chronology. This new edition of *The Cambridge Companion to Newton* provides authoritative introductions to these further dimensions of his endeavors as well as to many aspects of his physics and mathematics. It includes a revised bibliography, a new introduction, and six new chapters: three replacing previous chapters on Newton's mathematics, his chemistry and alchemy, and the reception of his religious views; and three on entirely new subjects, namely his religion, his ancient chronology, and the treatment of continuous and discontinuous forces in his second law of motion.

ROB ILIFFE is Professor of History of Science at the University of Oxford.

GEORGE E. SMITH is Professor of Philosophy at Tufts University.

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-1-107-01546-3 - The Cambridge Companion to Newton: Second Edition
Edited by Rob Iliffe and George E. Smith
Frontmatter
More information

Other Volumes in The Series of Cambridge Companions

ABELARD *Edited by* JEFFREY E. BROWER *and* KEVIN GUILFOY
ADORNO *Edited by* THOMAS HUHN
ANCIENT SCEPTICISM *Edited by* RICHARD BETT
ANSELM *Edited by* BRIAN DAVIES *and* BRIAN LEFTOW
AQUINAS *Edited by* NORMAN KRETZMANN *and* ELEONORE STUMP
ARABIC PHILOSOPHY *Edited by* PETER ADAMSON *and* RICHARD C. TAYLOR
HANNAH ARENDT *Edited by* DANA VILLA
ARISTOTLE *Edited by* JONATHAN BARNES
ARISTOTLE'S POLITICS *Edited by* MARGUERITE DESLAURIERS *and* PAUL DESTRÉE
ATHEISM *Edited by* MICHAEL MARTIN
AUGUSTINE 2ND EDITION *Edited by* DAVID MECONI *and* ELEONORE STUMP
BACON *Edited by* MARKKU PELTONEN
BERKELEY *Edited by* KENNETH P. WINKLER
BOETHIUS *Edited by* JOHN MARENBON
BRENTANO *Edited by* DALE JACQUETTE
CARNAP *Edited by* MICHAEL FRIEDMAN *and* RICHARD CREATH
CONSTANT *Edited by* HELENA ROSENBLATT
CRITICAL THEORY *Edited by* FRED RUSH
DARWIN 2ND EDITION *Edited by* JONATHAN HODGE *and* GREGORY RADICK
SIMONE DE BEAUVOIR *Edited by* CLAUDIA CARD
DELEUZE *Edited by* DANIEL W. SMITH *and* HENRY SOMERS-HALL
DESCARTES *Edited by* JOHN COTTINGHAM
DESCARTES' MEDITATIONS *Edited by* DAVID CUNNING
DEWEY *Edited by* MOLLY COCHRAN
DUNS SCOTUS *Edited by* THOMAS WILLIAMS
EARLY GREEK PHILOSOPHY *Edited by* A. A. LONG
EARLY MODERN PHILOSOPHY *Edited by* DONALD RUTHERFORD
EPICUREANISM *Edited by* JAMES WARREN
EXISTENTIALISM *Edited by* STEVEN CROWELL
FEMINISM IN PHILOSOPHY *Edited by* MIRANDA FRICKER *and* JENNIFER HORNSBY
FOUCAULT 2ND EDITION *Edited by* GARY GUTTING
FREGE *Edited by* TOM RICKETTS *and* MICHAEL POTTER
FREUD *Edited by* JEROME NEU
GADAMER *Edited by* ROBERT J. DOSTAL
GALEN *Edited by* R. J. HANKINSON

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-1-107-01546-3 - The Cambridge Companion to Newton: Second Edition
Edited by Rob Iliffe and George E. Smith
Frontmatter
More information

GALILEO *Edited by* PETER MACHAMER
GERMAN IDEALISM *Edited by* KARL AMERIKS
GREEK AND ROMAN PHILOSOPHY *Edited by* DAVID SEDLEY
HABERMAS *Edited by* STEPHEN K. WHITE
HAYEK *Edited by* EDWARD FESER
HEGEL *Edited by* FREDERICK C. BEISER
HEGEL AND NINETEENTH-CENTURY PHILOSOPHY *Edited by* FREDERICK C. BEISER
HEIDEGGER 2ND EDITION *Edited by* CHARLES GUIGNON
HOBBES *Edited by* TOM SORELL
HOBBES'S 'LEVIATHAN' *Edited by* PATRICIA SPRINGBORG
HUME 2ND EDITION *Edited by* DAVID FATE NORTON *and* JACQUELINE TAYLOR
HUSSERL *Edited by* BARRY SMITH *and* DAVID WOODRUFF SMITH
WILLIAM JAMES *Edited by* RUTH ANNA PUTNAM
KANT *Edited by* PAUL GUYER
KANT AND MODERN PHILOSOPHY *Edited by* PAUL GUYER
KANT'S 'CRITIQUE OF PURE REASON' *Edited by* PAUL GUYER, KEYNES ROGER E. BACKHOUSE *and* BRADLEY W. BATEMAN
KIERKEGAARD *Edited by* ALASTAIR HANNAY *and* GORDON DANIEL MARINO
LEIBNIZ *Edited by* NICHOLAS JOLLEY
LEVINAS *Edited by* SIMON CRITCHLEY *and* ROBERT BERNASCONI
LIFE AND DEATH *Edited by* STEVEN LUPER
LOCKE *Edited by* VERE CHAPPELL
LOCKE'S 'ESSAY CONCERNING HUMAN UNDERSTANDING' *Edited by* LEX NEWMAN
LOGICAL EMPIRICISM *Edited by* ALAN RICHARDSON *and* THOMAS UEBEL
MAIMONIDES *Edited by* KENNETH SEESKIN
MALEBRANCHE *Edited by* STEVEN NADLER
MARX *Edited by* TERRELL CARVER
MEDIEVAL JEWISH PHILOSOPHY *Edited by* DANIEL H. FRANK *and* OLIVER LEAMAN
MEDIEVAL PHILOSOPHY *Edited by* A. S. MCGRADE
MERLEAU-PONTY *Edited by* TAYLOR CARMAN *and* MARK B. N. HANSEN
MILL *Edited by* JOHN SKORUPSKI
MONTAIGNE *Edited by* ULLRICH LANGER
NEWTON 2ND EDITION *Edited by* ROB ILIFFE *and* GEORGE E. SMITH
NIETZSCHE *Edited by* BERND MAGNUS *and* KATHLEEN HIGGINS
NOZICK'S 'ANARCHY, STATE AND UTOPIA' *Edited by* RALF BADER *and* JOHN MEADOWCROFT
OAKESHOTT *Edited by* EFRAIM PODOKSIK

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-1-107-01546-3 - The Cambridge Companion to Newton: Second Edition
Edited by Rob Iliffe and George E. Smith
Frontmatter
More information

OCKHAM *Edited by* PAUL VINCENT SPADE
THE 'ORIGIN OF SPECIES' *Edited by* MICHAEL RUSE *and* ROBERT J. RICHARDS
PASCAL *Edited by* NICHOLAS HAMMOND
PEIRCE *Edited by* CHERYL MISAK
PHILO *Edited by* ADAM KAMESAR
THE PHILOSOPHY OF BIOLOGY *Edited by* DAVID L. HULL *and* MICHAEL RUSE
PIAGET *Edited by* ULRICH MÜLLER, JEREMY I. M. CARPENDALE *and* LESLIE SMITH
PLATO *Edited by* RICHARD KRAUT
PLATO'S REPUBLIC *Edited by* G. R. F. FERRARI
PLOTINUS *Edited by* LLOYD P. GERSON
PRAGMATISM *Edited by* ALAN MALACHOWSKI
QUINE *Edited by* ROGER F. GIBSON JR.
RAWLS *Edited by* SAMUEL FREEMAN
RENAISSANCE PHILOSOPHY *Edited by* JAMES HANKINS
THOMAS REID *Edited by* TERENCE CUNEO *and* RENÉ VAN WOUDENBERG
ROUSSEAU *Edited by* PATRICK RILEY
BERTRAND RUSSELL *Edited by* NICHOLAS GRIFFIN
SARTRE *Edited by* CHRISTINA HOWELLS
SCHOPENHAUER *Edited by* CHRISTOPHER JANAWAY
THE SCOTTISH ENLIGHTENMENT *Edited by* ALEXANDER BROADIE
ADAM SMITH *Edited by* KNUD HAAKONSSEN
SOCRATES *Edited by* DONALD MORRISON
SPINOZA *Edited by* DON GARRETT
SPINOZA'S 'ETHICS' *Edited by* OLLI KOISTINEN
THE STOICS *Edited by* BRAD INWOOD
LEO STRAUSS *Edited by* STEVEN B. SMITH
TOCQUEVILLE *Edited by* CHERYL B. WELCH
UTILITARIANISM *Edited by* BEN EGGLESTON *and* DALE MILLER
VIRTUE ETHICS *Edited by* DANIEL C. RUSSELL
WITTGENSTEIN *Edited by* HANS SLUGA *and* DAVID STERN

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-1-107-01546-3 - The Cambridge Companion to Newton: Second Edition
Edited by Rob Iliffe and George E. Smith
Frontmatter
More information

The Cambridge Companion to Newton

SECOND EDITION

Edited by

ROB ILIFFE
University of Oxford

GEORGE E. SMITH
Tufts University

CAMBRIDGE
UNIVERSITY PRESS

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-1-107-01546-3 - The Cambridge Companion to Newton: Second Edition
Edited by Rob Iliffe and George E. Smith
Frontmatter
More information

CAMBRIDGE
UNIVERSITY PRESS

University Printing House, Cambridge CB2 8BS, United Kingdom

Cambridge University Press is part of the University of Cambridge.

It furthers the University's mission by disseminating knowledge in the pursuit of education, learning and research at the highest international levels of excellence.

www.cambridge.org
Information on this title: www.cambridge.org/9781107015463

© Cambridge University Press 2002, 2016

This publication is in copyright. Subject to statutory exception and to the provisions of relevant collective licensing agreements, no reproduction of any part may take place without the written permission of Cambridge University Press.

First edition first published 2002
Second edition first published 2016

A catalogue record for this publication is available from the British Library

Library of Congress Cataloguing in Publication data

Names: Iliffe, Rob, editor. | Smith, George E. (George Edwin), 1938—editor.
Title: The Cambridge companion to Newton / edited by Rob Iliffe and George E. Smith.
Description: Second edition. | Cambridge : Cambridge University Press, 2016.| Includes bibliographical references and index.
Identifiers: LCCN 2015040735 | ISBN 9781107601741 (pbk. : alk. paper)
Subjects: LCSH: Newton, Isaac, 1642-1727. | Physics—Europe—History—17th century. | Physics—Europe—History—18th century. |Science—Europe—History—17th century. | Science—Europe—History—18th century.
Classification: LCC QC16.N7 C35 2016 | DDC 530.092—dc23 LC record available at http://lccn.loc.gov/2015040735

ISBN 978-1-107-01546-3 Hardback

Cambridge University Press has no responsibility for the persistence or accuracy of URLs for external or third-party internet websites referred to in this publication, and does not guarantee that any content on such websites is, or will remain, accurate or appropriate.

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-1-107-01546-3 - The Cambridge Companion to Newton: Second Edition
Edited by Rob Iliffe and George E. Smith
Frontmatter
More information

Contents

		Page
	List of figures	ix
	List of contributors	xi
	Preface to the second edition	xv
	Introduction ROB ILIFFE AND GEORGE E. SMITH	1
1	Newton's philosophical analysis of space and time ROBERT DISALLE	34
2	Newton's concepts of force and mass, with notes on the laws of motion I. BERNARD COHEN	61
3	Instantaneous impulse and continuous force: the foundations of Newton's *Principia* BRUCE POURCIAU	93
4	The methodology of the *Principia* GEORGE E. SMITH	187
5	Newton's argument for universal gravitation WILLIAM HARPER	229
6	Newton and celestial mechanics CURTIS WILSON	261
7	Newton's optics and atomism ALAN E. SHAPIRO	289

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-1-107-01546-3 - The Cambridge Companion to Newton: Second Edition
Edited by Rob Iliffe and George E. Smith
Frontmatter
More information

8 Newton's metaphysics 321
HOWARD STEIN

9 A brief introduction to the mathematical work of Isaac Newton 382
NICCOLÒ GUICCIARDINI

10 Newton, active powers, and the mechanical philosophy 421
ALAN GABBEY

11 A preliminary reassessment of Newton's alchemy 454
WILLIAM R. NEWMAN

12 The religion of Isaac Newton 485
ROB ILIFFE

13 Isaac Newton, historian 524
MORDECHAI FEINGOLD

14 Newton and eighteenth-century Christianity 554
SCOTT MANDELBROTE

15 Newton and the Leibniz–Clarke correspondence 586
DOMENICO BERTOLONI MELI

Bibliography 597
Index 615

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-1-107-01546-3 - The Cambridge Companion to Newton: Second Edition
Edited by Rob Iliffe and George E. Smith
Frontmatter
More information

Figures

2.1 Newton's parallelogram rule for motions produced by impulsive forces. 71
2.2 The area law for uniform rectilinear motion. 76
2.3 Newton's polygonal path (from the first edition of the *Principia*, 1687). 77
2.4 The trajectory of a moving body that has received a blow or has been struck by an impulsive force. 84
3.1 The figure illustrating Lemma 7 in the *Principia*. 102
3.2 The moving deflection $\overrightarrow{LQ}$ measures the deviation from uniform straight line motion. 106
3.3 The moving deflection $\overrightarrow{LQ}$ generated in a given time by an instantaneous impulse acting on a body at P. 110
3.4 Newton's original figure and a redrawn version, illustrating the meaning of the second law, for the continuous force case. 117
3.5 Illustrating the Compound Second Law for a continuous force and an instantaneous impulse. 119
3.6 The figure that Huygens drew to illustrate his second and third hypotheses in the *Horologium oscillatorium* and the figure that Newton drew to illustrate his second law. 127
3.7 The redrawn figure that Huygens drew to illustrate the application of his three hypotheses to gravity acting in the direction of motion and the reproduced figure that Newton drew to illustrate the application of his first two laws to a force in the direction of motion. 127
3.8 The figure used in the *Principia* to illustrate Corollary 1 of the laws. 130
3.9 The Compound Second Law applied to the motion of a body that describes a line under the influence of a force that remains parallel to that line. 133

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-1-107-01546-3 - The Cambridge Companion to Newton: Second Edition
Edited by Rob Iliffe and George E. Smith
Frontmatter
More information

3.10 Newton's hand-drawn figures illustrating the Compound Second Law for motion along a line moved by a force in (above) and opposite to (below) the direction of motion. 134
3.11 The figure, redrawn with our notation, used in the *Principia* to illustrate the motion of a body projected along the line $\overrightarrow{PL}$ and acted on by uniform gravity. 138
3.12 From Euler's *Theoria motus corporum solidorum seu rigidorum*, published in 1765, a figure drawn to illustrate what he calls the basic "ground of measuring" forces. 140
3.13 Newton's figure for Proposition 1 and its demonstration in the *Principia*. 143
3.14 Newton's original figure for Proposition 1, adapted to illustrate his polygonal impulse strategy applied to a given arbitrary centripetal motion. 147
3.15 Uncovering the meaning of Newton's "sagitta" in Proposition 6. 163
3.16 Newton's "sagitta" $\overrightarrow{PX}$, from the center P (with respect to time) of the arc qQ to the center X (with respect to length) of the chord qQ. 166
5.1 Log mean distances versus log periodic times for the planets. 235
7.1 Refraction at the surface EG decomposes a ray of sunlight OF into rays of different degrees of refrangibility and color. 293
7.2 Newton's dispersion model from his *Optical Lectures*. 297
7.3 Newton's derivation of Snell's law of refraction in the *Principia*, Book 1, Proposition 94. 299
7.4 Newton's method for determining the thickness d of a thin film of air formed between a spherical lens and a plane. 303
7.5 One quadrant of Newton's rings produced with light of a single color. 309
7.6 A compound corpuscle of matter illustrating Newton's hierarchical conception of the structure of matter. 313

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-1-107-01546-3 - The Cambridge Companion to Newton: Second Edition
Edited by Rob Iliffe and George E. Smith
Frontmatter
More information

Contributors

DOMENICO BERTOLONI MELI is a professor in the Department of History and Philosophy of Science at Indiana University. He specializes in seventeenth- and eighteenth-century science and medicine and is the author of a number of books, including *Equivalence and Priority: Newton versus Leibniz*.

I. BERNARD COHEN was Victor S. Thomas Professor of the History of Science Emeritus at Harvard University. He is the author of numerous books in the history of science generally and on Newton in particular, including *The Newtonian Revolution*, and is co-editor of the Variorum Latin edition of Newton's *Principia* and co-author of the new English translation.

ROBERT DISALLE is a professor in the Department of History and Philosophy of Science at the University of Western Ontario. He has published several papers on Newton, Einstein, and Mach, especially on their respective treatments of space, time, and motion.

MORDECHAI FEINGOLD is Professor of History at Caltech. He is the editor of the journal *History of Universities* and author of a number of books including *The Mathematicians' Apprenticeship: Science, Universities and Society in England, 1560–1640* (Cambridge, 1984), *The Newtonian Moment: Isaac Newton and the Making of Modern Culture* (2004), and *Isaac Newton and the Origin of Civilization* (2013), written with Jed Buchwald.

ALAN GABBEY is Professor of Philosophy at Barnard College, New York. He has published numerous papers on seventeenth-century mechanics and philosophy.

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-1-107-01546-3 - The Cambridge Companion to Newton: Second Edition
Edited by Rob Iliffe and George E. Smith
Frontmatter
More information

NICCOLÒ GUICCIARDINI teaches history of science at the University of Bergamo. He is author of *The Development of Newtonian Calculus in Britain, 1700–1800* and *Reading the Principia: The Debate on Newton's Mathematical Methods for Natural Philosophy from 1687 to 1736, and Isaac Newton on Mathematical Certainty and Method*.

WILLIAM HARPER is Professor of Philosophy at Western Ontario University. He has written extensively on Newton's methodology and the relationship between Newton's and Einstein's theories of gravity, as well as on Kant and on causal decision theory.

ROB ILIFFE is Professor of History of Science at the University of Oxford. He is author of the *Very Short Introduction to Newton* (Oxford, 2007) and *Priest of Nature: the Religious Life of Isaac Newton* (Oxford, 2016). He was director of the AHRC Newton Theological Papers Project from 1999 to 2014, is a General Editor of the Newton Project, and is currently co-editor of the journal *Annals of Science*.

SCOTT MANDELBROTE is Official Fellow and Director of Studies in History at Peterhouse, Cambridge. He is the author of many articles in the history of early modern scholarship, and is a General Editor of the Newton Project.

WILLIAM R. NEWMAN is a professor in the Department of History and Philosophy of Science at Indiana University. His work on early chemistry and alchemy includes *The "Summa Perfectionis" of Pseudo-Geber: A Critical Edition, Translation, and Study*, and *Gehennical Fire: The Lives of George Starkey, An American Alchemist in the Scientific Revolution*.

BRUCE POURCIAU is Professor of Mathematics at Lawrence University, Appleton, Wisconsin. His research has focused on optimization theory and global analysis in mathematics, the mathematical and logical foundations of Newton's *Principia* and Newton's mathematical work

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-1-107-01546-3 - The Cambridge Companion to Newton: Second Edition
Edited by Rob Iliffe and George E. Smith
Frontmatter
More information

more generally, as well as the philosophy of mathematics, particularly Brouwer's intuitionism and Bishop's constructivism.

ALAN E. SHAPIRO is Professor of the History of Science and Technology at the University of Minnesota. He is author of *Fits, Passions, and Paroxysms: Physics, Method, and Chemistry* and *Newton's Theories of Colored Bodies and Fits of Easy Reflection*, and is the editor of Newton's optical papers.

GEORGE E. SMITH is Professor of Philosophy at Tufts University. He specializes in the development of evidence in the advanced sciences and engineering and is the author of several papers on Newton.

HOWARD STEIN is a professor emeritus in the Department of Philosophy of the University of Chicago. His research has focused on the philosophical foundations of physics and mathematics, and he has published several highly influential papers on Newton, as well as on Huygens, Maxwell, and Einstein.

CURTIS WILSON was a tutor at St. John's College, Annapolis. His writings on the history of science reach from the Middle Ages through the nineteenth century, most extensively on astronomy; he was coeditor of the two parts of *Planetary Astronomy from the Renaissance to the Rise of Astrophysics*, the second volume of *The General History of Astronomy*.

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-1-107-01546-3 - The Cambridge Companion to Newton: Second Edition
Edited by Rob Iliffe and George E. Smith
Frontmatter
More information

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-1-107-01546-3 - The Cambridge Companion to Newton: Second Edition
Edited by Rob Iliffe and George E. Smith
Frontmatter
More information

Preface to the second edition

The task of compiling *The Cambridge Companion to Newton* was originally taken on by Richard S. Westfall. After he died in 1996, it fell to the late I. Bernard Cohen and George E. Smith, who started it afresh. The first edition was published in 2002 and has received wide circulation. In the case of several of its chapters, research since then has not yielded sufficient reasons to make substantial revision to them. In several other cases, however, subsequent research has greatly advanced our knowledge of Newton, rendering the original chapters out of date. The goal of the second edition is to correct this situation, bringing *The Companion to Newton* more up to date.

Most notable in this regard has been research on Newton's extensive manuscripts concerning theology, many of which had scarcely been examined at all at the time of the first edition. Scott Mandelbrote's chapter in that edition focused largely on the reaction among theologians to Newton's conception of Christianity as it emerged in snippets during the years after he died. Mandelbrote has updated that chapter by incorporating new research carried out over the last decade. Rob Iliffe has added a new chapter surveying Newton's efforts in theology, while Mordechai Feingold has added an essay on Newton's efforts in chronology that extends the critical analysis of *The Chronology of Ancient Kingdoms Amended* that he and Jed Buchwald present in their book *Newton and the Origin of Civilization*.

Another area in which research during the last decade has greatly expanded and refined our understanding of what Newton was up to is the effort he devoted to alchemy and chemistry. William Newman has been analyzing the experiments Newton recorded in his notes, even reproducing some of them, and he, along with others, has continued his systematic study of alchemy

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-1-107-01546-3 - The Cambridge Companion to Newton: Second Edition
Edited by Rob Iliffe and George E. Smith
Frontmatter
More information

in the period. On the basis of this work, Newman has supplied an entirely new chapter on Newton's efforts in alchemy and chemistry, replacing the essays in the first edition by him and the late Karin Figala.

Niccolò Guicciardini's chapter on Newton's mathematics in the first edition, "Analysis and synthesis in Newton's mathematical work," centered on the topic announced in its title, and hence provided readers with a perspective of Newton's efforts in the area, but not a comprehensive overview of efforts that stretched over four decades. In the meantime Guicciardini has continued his research on the subject, producing his recent book *Isaac Newton on Mathematical Certainty and Method* that focuses heavily on Newton's conception of truth and certainty in mathematics. This has also led to an entirely new essay in this edition, which provides a comprehensive overview of Newton's efforts in mathematics and the significance he attached to it.

Finally, a new chapter by Bruce Pourciau has been added on a long-time controversial issue within the foundations of Newton's mechanics in the *Principia*, namely his appearing to go back and forth between discrete (or impulse) forces and continuous forces without laying a foundation for doing so. On the one hand, the phrasing of the statement of his second law of motion in all editions of the *Principia* appears to limit it to discrete forces, and this is consistent with such initial applications of it as the first corollary to the laws of motion and Propositions 1 and 2; on the other hand, the second law is cited repeatedly throughout the *Principia* in conjunction with continuous forces that are characterized in terms of an incremental displacement from uniform motion in a straight line and the square of an increment of time inversely – a claim that makes no sense in the case of discrete forces. In a series of articles since the first edition of this *Companion*, Pourciau has argued that Newton himself provided a way of resolving this conflict in an unpublished manuscript from the early 1690s that lays out "the

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-1-107-01546-3 - The Cambridge Companion to Newton: Second Edition
Edited by Rob Iliffe and George E. Smith
Frontmatter
More information

meaning of the law." Under this meaning of the law, it clearly applies to both discrete and continuous forces and hence makes it consistent with all the applications and citations of the law in the *Principia*. There nevertheless appears to be no textually authorized way to reconcile this unpublished statement of the meaning of the law with its express statement in all editions.

Bernard Cohen, who was fully aware of the manuscript from the early 1690s, elected to ignore it in his chapter in the first edition of this *Companion* and chose instead to restrict himself to the actual statement of the law in the *Principia*, leaving him with the difficult task of explaining how Newton thought of continuous forces as derivative from discrete ones. In his new chapter, Pourciau makes the case that Newton always understood his second law in the way he explicated it in the early 1690s, so that the only source of confusion has been the unfortunate phrasing of the law in the *Principia*. This leaves him with the difficult task of reconciling the explication from the early 1690s with the statement of the law not only in the 1687 edition of the *Principia*, but in the 1713 and 1726 editions as well. We decided that the appropriate way to deal with this situation is to include both Cohen's and Pourciau's chapters in the second edition, thereby enabling readers to see the complexity of the issue raised by the second law, as regards both Newton and the subsequent history of mechanics.

The addition of three completely new chapters by Pourciau, Iliffe, and Feingold has unfortunately necessitated our dropping of three chapters from the first edition, "Curvature in Newton's dynamics" by the late Bruce Brackenridge and Michael Nauenberg, "Newton versus Leibniz: from geometry to metaphysics" by the late A. Rupert Hall and "Newton on prophecy and the Apocalypse" by the late Maurizio Mamiani. Hall's chapter was to a large extent a summary of his book *Philosophers at War: The quarrel between Newton and Leibniz*, and hence readers can always turn to it if they want to go beyond the discussion of the priority dispute in

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-1-107-01546-3 - The Cambridge Companion to Newton: Second Edition
Edited by Rob Iliffe and George E. Smith
Frontmatter
More information

Guicciardini's chapter. The real loss, therefore, is the long chapter by Brackenridge and Nauenberg and its account of how Newton's investigations into curvature informed his writing of the *Principia* in ways not readily evident in the book itself. Our choice in this case reflects both the length of the paper and its more technically demanding analysis (in comparison with the other chapters in the *Companion*), but we encourage readers interested in the evolution of Newton's approach to curvilinear motion to turn to it.

© in this web service Cambridge University Press www.cambridge.org