HEP World's Classics

Mathematical Principles of Natural Philosophy

Volume One

自然哲学的数学原理

第一卷

ISAAC NEWTON

TRANSLATED INTO ENGLISH BY
ANDREW MOTTE IN 1729
THE TRANSLATIONS REVISED, AND SUPPLIED WITH AN HISTORICAL
AND EXPLANATORY APPENDIX BY FLORIAN CAJORI

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HEP World's Classics

There is a Chinese saying: "It is beneficial to open any book." It is even more fruitful to open and read classic books. The world is keeping on changing, but really fundamental and essential things stay the same since there is nothing new under the sun. Great ideas have been discovered and re-discovered, and they should be learnt and re-learnt. Classic books are our inheritance from all the previous generations and contain the best of knowledge and wisdom of all the people before us. They are timeless and universal. We cannot travel back in time, but we can converse with the originators of current theories through reading their books. Classic books have withstood the test of time. They are reliable and contain a wealth of original ideas. More importantly, they are also books which have not finished what they wanted or hoped to say. Consequently, they contain unearthed treasures and hidden seeds of new theories, which are waiting to be discovered. As it is often said: history is today. Proper understanding of the past work of giants is necessary to carry out properly the current and future researches and to make them to be a part of the history of science and mathematics. Reading classics books is not easy, but it is rewarding. Some modern interpretations and beautiful reformulations of the classics often miss the subtle and crucial points. Reading classics is also more than only accumulating knowledge, and the reader can learn from masters on how they asked questions, how they struggled to come up with new notions and theories to overcome problems, and answers to questions. Above all, probably the best reason to open classic books is the curiosity: what did people know, how did they express and communicate them, why did they do what they did? It can simply be fun!

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Higher Education Press has been the largest publisher in China. Besides the long tradition of providing high quality books for proper education and training of university and graduate students, she has also set out to provide research monographs and references books to people at all levels around the world. Higher Education Press considers it her duty to keep the world science and mathematics community informed of what has been achieved in their subjects in easy and accessible formats. This series of classic books is an integral part of this effort.

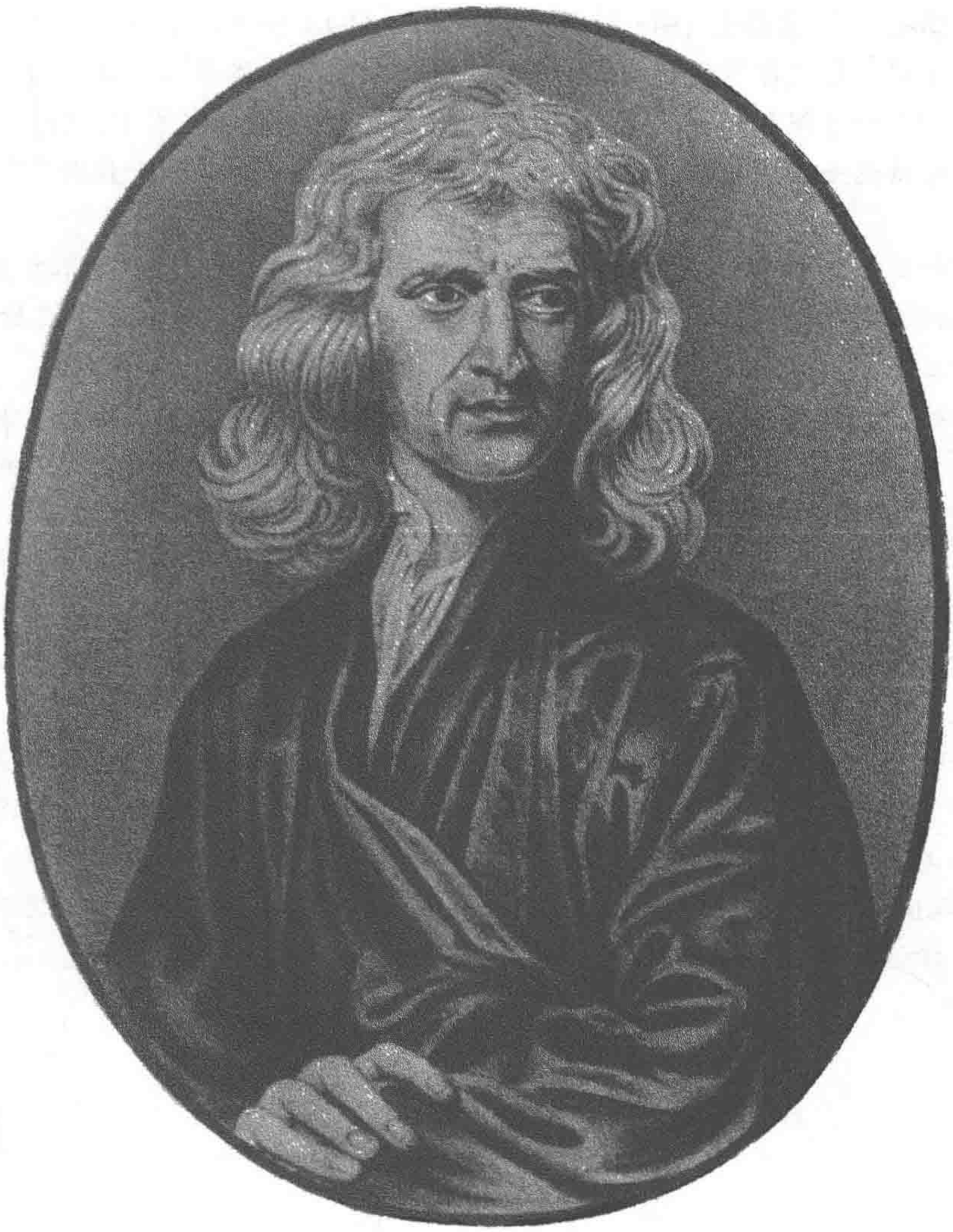
内容简介

《自然哲学的数学原理》是牛顿一生中最重要的科学著作, 对物理学、数学、天文学和哲学等领域的研究和发展产生了巨大影响。

牛顿在世时共发表了 3 个版本的《自然哲学的数学原理》, 分别于 1687 年、1713 年及 1726 年出版, 均为拉丁文版本。第一个英文译本由莫特 (Andrew Motte) 根据该书的第三版翻译而来, 出版于 1729 年; 1802 年又出现了根据《自然哲学的数学原理》第一版翻译的英文译本。1930 年, 美国学者、科学史家卡约里 (Florian Cajori) 在莫特的英译本基础上用现代英文对《自然哲学的数学原理》进行了校订出版, 从而成为 20 世纪读者群最大的版本。本书也采用此版本重排而成。

《自然哲学的数学原理》共五部分, 分为两卷。本书为第一卷, 内容主要包括: 物质的量、时间、空间、向心力等的定义; 包括著名的运动三定律在内的公理或运动的定律; 第一、二编 (BOOK I、BOOK II) 的标题均为论物体的运动, 第一编研究在无阻力的自由空间中物体的运动, 第二编研究在阻力给定的情况下物体的运动、流体力学以及波动理论。第二卷主要内容包括: 第三编 (BOOK III) 宇宙的系统 (使用数学的论述)、宇宙体系以及附录, 附录中的内容是卡约里对牛顿《自然哲学的数学原理》进行的历史和解释性注释。

《自然哲学的数学原理》提出了经典力学的三个基本定律和万有引力定律, 在科学史上, 它是经典力学的第一部经典著作, 是人类掌握的第一个完整的科学的宇宙论和科学理论体系, 影响力遍及经典自然科学的所有领域。



SIR ISAAC NEWTON

(See Appendix, Note 1, page 627)

艾萨克 · 牛顿爵士 (Sir Isaac Newton, 1643—1727), 英国著名物理学家、数学家、自然哲学家和天文学家, 经典物理学理论体系的建立者。牛顿是剑桥大学三一学院硕士和院士, 卢卡斯数学讲座教授, 英国皇家学会会员, 法国科学院外籍院士, 英国皇家学会主席, 被册封为英国历史上第一个自然哲学家爵士。

牛顿对代数学、数论、古典几何学与分析几何学、曲线分类、计算方法与近似求解以及概率论等都有重要贡献, 他最重要的贡献是微积分和无限级数理论, 特别是二项式展开式。

牛顿曾致力于颜色的现象和光的本性的研究, 他的重要发现成为光谱分析的基础。牛顿的最高科学成就体现在运动学和天体力学中, 1684 年, 牛顿的论文《论轨道上物体的运动》证明了天上与地上的物体服从完全相同的运动规律, 引力的存在使得行星及其卫星必定沿椭圆轨道运动, 展示出一种全新的力学理论框架, 这篇论文成为写作名著《自然哲学的数学原理》的必要准备。1687 年,《自然哲学的数学原理》的出版震动了整个英国和欧洲学术界, 使牛顿一跃成为当时欧洲最负盛名的数学家、天文学家和自然哲学家。

牛顿是经典力学基础的牛顿运动定律的建立者。他发现的运动三定律和万有引力定律为近代物理学和力学奠定了基础, 他的万有引力定律和哥白尼的日心说奠定了现代天文学的理论基础, 实现了人类对自然认识的巨大飞跃。直到今天, 人造地球卫星、火箭、宇宙飞船的发射升空和运行轨道的计算, 仍以牛顿运动定律作为理论根据。

PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA.

Autore *J. S. NEWTON*, *Trin. Coll. Cantab. Soc.* Matheseos Professore *Lucasiano*, & Societatis Regalis Sodali.

IMPRIMATUR.
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LONDINI,

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TITLE PAGE OF THE FIRST EDITION OF THE PRINCIPIA

(See Appendix, Note 2, page 627)

Editor's Note to the Present Revision

Professor FLORIAN CAJORI died August 15, 1930. In May of the following year I was invited by the University of California Press to edit this work. After much delay, due in part to unavoidable circumstances and in part to the time consumed in the extraordinary care taken in reading, checking, and rereading the proofs, this edition of Newton's *Principia* is now ready to be run off the press.

The manuscript as presented to the Press contained no Preface. Much of the material that would be included in the usual Preface is contained in the first few notes of the Appendix, pages 627 ff. Professor Cajori probably intended to prepare a Preface while the book was in the process of manufacture. There being none, the customary acknowledgment of thanks to various persons who assisted him in one way or another is lacking. Lest I unknowingly omit some to whom thanks are due, I refrain from attempting any such acknowledgment on behalf of the author.

As the title page states, this is a revision of Motte's translation of the *Principia*. From many conversations with Professor Cajori, I know that he had long cherished the idea of revising Newton's immortal work by rendering certain parts into modern phraseology (e.g., to change the reading of "reciprocally in the subduplicate ratio of" to "inversely as the square root of") and to append historical and critical notes which would provide instruction to some readers and interest to all. This is his last work; one most fitting to crown a life devoted to investigation and to writing the history of the sciences in his chosen field.

R. T. CRAWFORD

Berkeley, California,
March 31, 1934.

The Ode Dedicated to Newton by Edmund Halley

THIS ODE PREFIXED TO THE PRINCIPIA OF NEWTON IS HERE TRANSLATED BY LEON J. RICHARDSON, PROFESSOR OF LATIN, IN THE UNIVERSITY OF CALIFORNIA, FROM THE VERSION AS GIVEN IN THE FIRST EDITION.

TO THE ILLUSTRIOUS MAN

ISAAC NEWTON

AND THIS HIS WORK
DONE IN FIELDS OF THE MATHEMATICS AND PHYSICS
A SIGNAL DISTINCTION OF OUR TIME AND RACE

Lo, for your gaze, the pattern of the skies!
What balance of the mass, what reckonings
Divine! Here ponder too the Laws which God,
Framing the universe, set not aside
But made the fixed foundations of his work.

The inmost places of the heavens now gained,
Break into view, nor longer hidden is
The force that turns the farthest orb. The sun
Exalted on his throne bids all things tend
Toward him by inclination and descent,
Nor suffers that the courses of the stars
Be straight, as through the boundless void they move,
But with himself as centre speeds them on
In motionless ellipses. Now we know
The sharply veering ways of comets, once
A source of dread, nor longer do we quail

Beneath appearances of bearded stars.

At last we learn wherefore the silver moon
Once seemed to travel with unequal steps,
As if she scorned to suit her pace to numbers—
Till now made clear to no astronomer;
Why, though the Seasons go and then return,
The Hours move ever forward on their way;
Explained too are the forces of the deep,
How roaming Cynthia bestirs the tides,
Whereby the surf, deserting now the kelp
Along the shore, exposes shoals of sand
Suspected by the sailors, now in turn
Driving its billows high upon the beach.

Matters that vexed the minds of ancient seers,
And for our learned doctors often led
To loud and vain contention, now are seen
In reason's light, the clouds of ignorance
Dispelled at last by science. Those on whom
Delusion cast its gloomy pall of doubt,
Upborne now on the wings that genius lends,
May penetrate the mansions of the gods
And scale the heights of heaven. O mortal men,
Arise! And, casting off your earthly cares,
Learn ye the potency of heaven-born mind,
Its thought and life far from the herd withdrawn!

The man who through the tables of the laws
Once banished theft and murder, who suppressed
Adultery and crimes of broken faith,
And put the roving peoples into cities
Girt round with walls, was founder of the state,
While he who blessed the race with Ceres'gift,
Who pressed from grapes an anodyne to care,
Or showed how on the tissue made from reeds
Growing beside the Nile one may inscribe
Symbols of sound and so present the voice
For sight to grasp, did lighten human lot,
Offsetting thus the miseries of life
With some felicity. But now, behold,
Admitted to the banquets of the gods,

We contemplate the polities of heaven;
And spelling out the secrets of the earth,
Discern the changeless order of the world
And all the aeons of its history.

Then ye who now on heavenly nectar fare,
Come celebrate with me in song the name
Of Newton, to the Muses dear; for he
Unlocked the hidden treasuries of Truth:
So richly through his mind had Phoebus cast
The radiance of his own divinity.
Nearer the gods no mortal may approach.

Newton's Preface to the First Edition

Since the ancients (as we are told by *Pappus*) esteemed the science of mechanics of greatest importance in the investigation of natural things, and the moderns, rejecting substantial forms and occult qualities, have endeavored to subject the phenomena of nature to the laws of mathematics, I have in this treatise cultivated mathematics as far as it relates to philosophy. The ancients considered mechanics in a twofold respect; as rational, which proceeds accurately by demonstration, and practical. To practical mechanics all the manual arts belong, from which mechanics took its name. But as artificers do not work with perfect accuracy, it comes to pass that mechanics is so distinguished from geometry that what is perfectly accurate is called geometrical; what is less so, is called mechanical. However, the errors are not in the art, but in the artificers. He that works with less accuracy is an imperfect mechanic; and if any could work with perfect accuracy, he would be the most perfect mechanic of all, for the description of right lines and circles, upon which geometry is founded, belongs to mechanics. Geometry does not teach us to draw these lines, but requires them to be drawn, for it requires that the learner should first be taught to describe these accurately before he enters upon geometry, then it shows how by these operations problems may be solved. To describe right lines and circles are problems, but not geometrical problems. The solution of these problems is required from mechanics, and by geometry the use of them, when so solved, is shown; and it is the glory of geometry that from those few principles, brought from without, it is able to produce so many things. Therefore geometry is founded in mechanical practice, and is nothing but that part of universal mechanics which accurately proposes and demonstrates the art of measuring. But since the manual arts are chiefly employed in the moving of bodies, it happens that geometry is commonly referred to their magnitude, and mechanics to their motion. In this sense rational mechanics will be the science of motions resulting from any forces whatsoever, and of the forces required to produce any motions, accurately proposed and demonstrated. This part of mechanics, as far as it extended to the five powers which relate to manual arts, was cultivated by the ancients, who considered gravity (it not being a manual power) no otherwise than in moving weights by those powers. But I consider philosophy rather than arts and write not concerning manual but natural powers, and consider chiefly those things which relate to gravity, levity, elastic force, the resistance of fluids, and the like forces, whether attractive or impulsive; and therefore I offer this work as the mathematical principles of philosophy, for the whole burden of philosophy seems to consist in this—from the phenomena of motions to investigate the forces of nature,

and then from these forces to demonstrate the other phenomena; and to this end the general propositions in the first and second Books are directed. In the third Book I give an example of this in the explication of the System of the World; for by the propositions mathematically demonstrated in the former Books, in the third I derive from the celestial phenomena the forces of gravity with which bodies tend to the sun and the several planets. Then from these forces, by other propositions which are also mathematical, I deduce the motions of the planets, the comets, the moon, and the sea. I wish we could derive the rest of the phenomena of Nature by the same kind of reasoning from mechanical principles, for I am induced by many reasons to suspect that they may all depend upon certain forces by which the particles of bodies, by some causes hitherto unknown, are either mutually impelled towards one another, and cohere in regular figures, or are repelled and recede from one another. These forces being unknown, philosophers have hitherto attempted the search of Nature in vain; but I hope the principles here laid down will afford some light either to this or some truer method of philosophy.

In the publication of this work the most acute and universally learned Mr. *Edmund Halley* not only assisted me in correcting the errors of the press and preparing the geometrical figures, but it was through his solicitations that it came to be published; for when he had obtained of me my demonstrations of the figure of the celestial orbits, he continually pressed me to communicate the same to the *Royal Society*, who afterwards, by their kind encouragement and entreaties, engaged me to think of publishing them. But after I had begun to consider the inequalities of the lunar motions, and had entered upon some other things relating to the laws and measures of gravity and other forces; and the figures that would be described by bodies attracted according to given laws; and the motion of several bodies moving among themselves; the motion of bodies in resisting mediums; the forces, densities, and motions, of mediums; the orbits of the comets, and such like, I deferred that publication till I had made a search into those matters, and could put forth the whole together. What relates to the lunar motions (being imperfect), I have put all together in the corollaries of Prop. LXVI, to avoid being obliged to propose and distinctly demonstrate the several things there contained in a method more prolix than the subject deserved and interrupt the series of the other propositions. Some things, found out after the rest, I chose to insert in places less suitable, rather than change the number of the propositions and the citations. I heartily beg that what I have here done may be read with forbearance; and that my labors in a subject so difficult may be examined, not so much with the view to censure, as to remedy their defects.

Is. NEWTON

Cambridge, Trinity College, May 8, 1686.[1]

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[1] Appendix, Note 3.

Newton's Preface to the Second Edition

In this second edition of the *Principia* there are many emendations and some additions.[1] In the second section of the first Book, the determination of forces, by which bodies may be made to revolve in given orbits, is illustrated and enlarged. In the seventh section of the second Book the theory of the resistances of fluids was more accurately investigated, and confirmed by new experiments. In the third Book the lunar theory and the precession of the equinoxes were more fully deduced from their principles; and the theory of the comets was confirmed by more examples of the calculation of their orbits, done also with greater accuracy.

Is. NEWTON

London, March 28,1713.

[1] Appendix, Note 4.