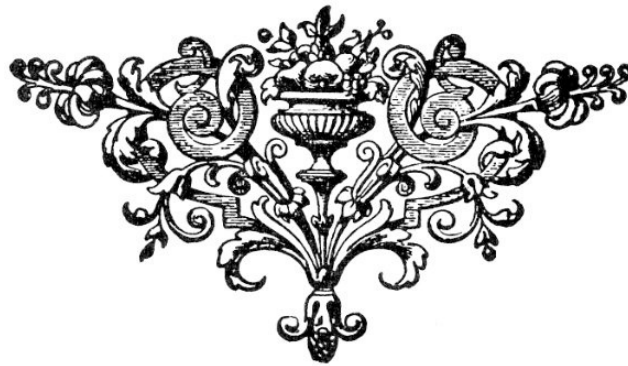


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Dialogues Concerning TWO NEW SCIENCES GALILEO GALILEI



TRANSLATED BY
Henry Crew & Alfonso de Salvio

WITH AN INTRODUCTION BY
Antonio Favaro

Galileo Galilei, *Dialogues Concerning Two New Sciences*, translated by Henry Crew & Alfonso de Salvio, with an introduction by Antonio Favaro, Dover Publications, Inc., New York, 1954. Originally published in 1904 by the MacMillan company.



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TRANSCRIBER'S NOTES (Added)

The present treatment of Galileo's *Two New Sciences* (1638) follows the condensed format of the 1954 Dover publication with a number of minor cosmetic changes intended to render the work slightly more readable. To this end the *Two New Sciences* has been split into shorter segments—here in separate parts—the *First* through *Fourth Day* plus the present *Introduction* from the Crew & De Salvio translation.

Denoted by {nnn} and [nnn] respectively, both modern and original page numbers have generally been incorporated *within* the text with the former also listed at the top of each page. For additional clarity and general consistency some figures have been redone and/or marginally repositioned.

Lastly, the bi-laterally dissimilar floral spira-form adornments and floral triangles from the title and end pages of the earlier publications have been retained here for necessary completeness. A link to Stillman Drake's Added (or "Fifth") Day (1974) is provided at the end. [jnh, 2014]



"La Dynamique est la science des forces accélératrices or retardatrices, et des mouvemens varies qu'elles doivent produire. Cette science *est* due entierement aux modernes, et Galilee est celui qui en a jete les premiers fondemens." Lagrange *Mcc. Anal.* 1. 221.

TRANSLATORS' PREFACE



OR more than a century English speaking students have been placed in the anomalous position of hearing Galileo constantly referred to as the founder of modern physical science, without having any chance to read, in their own language, what Galileo himself has to say. Archimedes has been made available by Heath; Huygens' *Light* has been turned into English by Thompson, while Motte has put the *Principia* of Newton back into the language in which it was conceived. To render the Physics of Galileo also accessible to English and American students is the purpose of the following translation.

The last of the great creators of the Renaissance was not a prophet without honor in his own time; for it was only one group of his country-men that failed to appreciate him. Even during his life time, his *Mechanics* had been rendered into French by one of the leading physicists of the world, Mersenne.

Within twenty-five years after the death of Galileo, his *Dialogues on Astronomy*, and those on *Two New Sciences*, had been done into English by Thomas Salusbury and were worthily printed in two handsome quarto volumes. The *Two New Sciences*, which contains practically all that Galileo has to say on the subject of physics, issued from the English press in 1665. {vi} It is supposed that most of the copies were destroyed in the great London fire which occurred in the year following. We are not aware of any copy in America : even that belonging to the British Museum is an imperfect one.

Again in 1730 the *Two New Sciences* was done into English by Thomas Weston; but this book, now nearly two centuries old, is scarce and expensive. Moreover, the literalness with which this translation was made renders many passages either ambiguous or unintelligible to the modern reader. Other than these two, no English version has been made.

Quite recently an eminent Italian scholar, after spending thirty of the best years of his life upon the subject, has brought to completion the great National Edition of the Works of Galileo. We refer to the twenty superb volumes in which Professor Antonio Favaro of Padua has given a definitive presentation of the labors of the man who created the modern science of physics.

The following rendition includes neither *Le Mechaniche* of Galileo nor his paper *De Motu Accelerate*, since the former of these contains little but the Statics which was current before the time of Galileo, and the latter is essentially included in the Dialogue of the Third Day. Dynamics was the one subject to which under various forms, such as Ballistics, Acoustics, Astronomy, he consistently and persistently devoted his whole life. Into the one volume here translated he seems to have gathered, during his last years, practically all that is of value either to the engineer or the physicist. The historian, the philosopher, and the astronomer will find the other volumes replete with interesting material.

It is hardly necessary to add that we have strictly followed the text of the National Edition—essentially the Elzevir edition of 1638. All comments and annotations have been omitted save here and there a foot-note intended to economize the reader's time. To each of these footnotes has been attached the signature [*Trans.*] in order to preserve the original as nearly intact as possible.

Much of the value of any historical document lies in the language employed, and this is doubly true when one attempts to {vii} trace the rise and growth of any set of concepts such as those employed in modern physics. We have therefore made this translation as literal as is consistent with clearness and modernity. In cases where there is any important deviation from this rule, and in the case of many technical terms where there is no deviation from it, we have given the original Italian or Latin phrase in italics enclosed in square brackets. The intention here is to illustrate the great variety of terms employed by the early physicists to describe a single definite idea, and conversely, to illustrate the numerous senses in which, then as now, a single word is used. For the few explanatory English words which are placed in square brackets without italics, the translators alone are responsible. The paging of the National Edition is indicated in square brackets inserted along the median line of the page.

The imperfections of the following pages would have been many more but for the aid of three of our colleagues. Professor D. R. Curtiss was kind enough to assist in the translation of those pages which discuss the nature of Infinity; Professor O. H. Basquin gave valuable help in the rendition of the chapter on Strength of Materials; and Professor O. F. Long cleared up the meaning of a number of Latin phrases.

To Professor A. Favaro of the University of Padua the translators share, with every reader, a feeling of sincere obligation for his Introduction.

H. C.
A. DE S.

EVANSTON, ILLINOIS,
15 February, 1914.





INTRODUCTION



RITING to his faithful friend Elia Diodati, Galileo speaks of the "New Sciences" which he had in mind to print as being "superior to everything else of mine hitherto published"; elsewhere he says "they contain results which I consider the most important of all my studies"; and this opinion which he expressed concerning his own work has been confirmed by posterity: the "New Sciences" are, indeed, the masterpiece of Galileo who at the time when he made the above remarks had spent upon them more than thirty laborious years.

One who wishes to trace the history of this remarkable work will find that the great philosopher laid its foundations during the eighteen best years of his life—those which he spent at Padua. As we learn from his last scholar, Vincenzo Viviani, the numerous results at which Galileo had arrived while in this city, awakened intense admiration in the friends who had witnessed various experiments by means of which he was accustomed to investigate interesting questions in physics. Fra Paolo Sarpi exclaimed: To give us the Science of Motion, God and Nature have joined hands and created the intellect of Galileo. And when the "New Sciences" came from the press one of his foremost pupils, Paolo Aproino, wrote that the volume contained much which he had "already heard from his own lips" during student days at Padua.

Limiting ourselves to only the more important documents which might be cited in support of our statement, it will suffice to mention the letter, written to Guidobaldo del Monte on the 29th of November, 1602, concerning the descent of heavy bodies {x} along the arcs of circles and the chords subtended by them; that to Sarpi, dated 16th of October, 1604, dealing with the free fall of heavy bodies; the letter to Antonio de' Medici on the nth of February, 1609, in which he states that he has "completed all the theorems and demonstrations pertaining to forces and resistances of beams of various lengths, thicknesses and shapes, proving that they are weaker at the middle than near the ends, that they can carry a greater load when that load is distributed throughout the length of the beam than when concentrated at one point, demonstrating also what shape should be given to a beam in order that it may have the same bending strength at every point," and that he was now engaged "upon some questions dealing with the motion of projectiles"; and finally in the letter to Belisario Vinta, dated 7th of May, 1610, concerning his return from Padua to Florence, he enumerates various pieces of work which

were still to be completed, mentioning explicitly three books on an entirely new science dealing with the theory of motion. Although at various times after the return to his native state he devoted considerable thought to the work which, even at that date, he had in mind as is shown by certain fragments which clearly belong to different periods of his life and which have, for the first time, been published in the National Edition; and although these studies were always uppermost in his thought it does not appear that he gave himself seriously to them until after the publication of the *Dialogue* and the completion of that trial which was rightly described as the disgrace of the century. In fact as late as October, 1630, he barely mentions to Aggiunti his discoveries in the theory of motion, and only two years later, in a letter to Marsili concerning the motion of projectiles, he hints at a book nearly ready for publication in which he will treat also of this subject; and only a year after this he writes to Arrighetti that he has in hand a treatise on the resistance of solids.

But the work was given definite form by Galileo during his enforced residence at Siena: in these five months spent quietly with the Archbishop he himself writes that he has completed "a treatise on a new branch of mechanics full of interesting and useful ideas"; so that a few months later he was able to send {xi} word to Micanzio that the "work was ready"; as soon as his friends learned of this, they urged its publication. It was, however, no easy matter to print the work of a man already condemned by the Holy Office: and since Galileo could not hope to print it either in Florence or in Rome, he turned to the faithful Micanzio asking him to find out whether this would be possible in Venice, from whence he had received offers to print the *Dialogue on the Principal Systems*, as soon as the news had reached there that he was encountering difficulties. At first everything went smoothly; so that Galileo commenced sending to Micanzio some of the manuscript which was received by the latter with an enthusiasm in which he was second to none of the warmest admirers of the great philosopher. But when Micanzio consulted the Inquisitor, he received the answer that there was an express order prohibiting the printing or reprinting of any work of Galileo, either in Venice or in any other place, *nullo excepto*.

As soon as Galileo received this discouraging news he began to look with more favor upon offers which had come to him from Germany where his friend, and perhaps also his scholar, Giovanni Battista Pieroni, was in the service of the Emperor, as military engineer; consequently Galileo gave to Prince Mattia de' Medici who was just leaving for Germany the first two Dialogues to be handed to Pieroni who was undecided whether to publish them at Vienna or Prague or at some place in Moravia; in the meantime, however, he had obtained permission to print both at Vienna and at Olmiitz. But Galileo recognized danger at every point within reach of the long arm of the Court of Rome; hence, availing himself of the opportunity offered by the arrival of Louis Elzevir in Italy in 1636, also of the friendship between the latter and Micanzio, not to mention a visit at Arcetri, he decided to abandon all other plans and entrust to the Dutch publisher the printing of his new work the manuscript of which, although not complete, Elzevir took with him on his return home.

In the course of the year 1637, the printing was finished, and at the beginning of the following year there was lacking only the index, the title-page and the dedication. This

last had, {xii} through the good offices of Diodati, been offered to the Count of Noailles, a former scholar of Galileo at Padua, and since 1634 ambassador of France at Rome, a man who did much to alleviate the distressing consequences of the celebrated trial; and the offer was gratefully accepted. The phrasing of the dedication deserves brief comment. Since Galileo was aware, on the one hand, of the prohibition against the printing of his works and since, on the other hand, he did not wish to irritate the Court of Rome from whose hands he was always hoping for complete freedom, he pretends in the dedicatory letter (where, probably through excess of caution, he gives only main outlines) that he had nothing to do with the printing of his book, asserting that he will never again publish any of his researches, and will at most distribute here and there a manuscript copy. He even expresses great surprise that his new Dialogues have fallen into the hands of the Elzevirs and were soon to be published; so that, having been asked to write a dedication, he could think of no man more worthy who could also on this occasion defend him against his enemies.

As to the title which reads: *Discourses and Mathematical Demonstrations concerning Two New Sciences pertaining to Mechanics and Local Motions*, this only is known, namely, that the title is not the one which Galileo had devised and suggested; in fact he protested against the publishers taking the liberty of changing it and substituting "a low and common title for the noble and dignified one carried upon the title-page."

In reprinting this work in the National Edition, I have followed the Leyden text of 1638 faithfully but not slavishly, because I wished to utilize the large amount of manuscript material which has come down to us, for the purpose of correcting a considerable number of errors in this first edition, and also for the sake of inserting certain additions desired by the author himself. In the Leyden Edition, the four Dialogues are followed by an "*Appendix containing some theorems and their proofs, dealing with centers of gravity of solid bodies, written by the same Author at an earlier date*" which has no immediate connection with the subjects treated in the Dialogues; these theorems were found by Galileo, as he tells us, "at the age of twenty-two and {xiii} after two years study of geometry" and were here inserted only to save them from oblivion.

But it was not the intention of Galileo that the *Dialogues on the New Sciences* should contain only the four Days and the above-mentioned appendix which constitute the Leyden Edition; while, on the one hand, the Elzevirs were hastening the printing and striving to complete it at the earliest possible date, Galileo, on the other hand, kept on speaking of another Day, besides the four, thus embarrassing and perplexing the printers. From the correspondence which went on between author and publisher, it appears that this Fifth Day was to have treated "of the force of percussion and the use of the catenary"; but as the typographical work approached completion, the printer became anxious for the book to issue from the press without further delay; and thus it came to pass that the *Discorsi e Dimostrazioni* appeared containing only the four Days and the Appendix, in spite of the fact that in April, 1638, Galileo had plunged more deeply than ever "into the profound question of percussion" and "had almost reached a complete solution."

The "New Sciences" now appear in an edition following the text which I, after the most careful and devoted study, determined upon for the National Edition. It appears

GALILEO: *TWO NEW SCIENCES*, INTRODUCTION (TRANS. CREW & DE SALVIO, 1954: xi–xii)

also in that language in which, above all others, I have desired to see it. In this translation, the last and ripest work of the great philosopher makes its first appearance in the New World: if toward this important result I may hope to have contributed in some measure I shall feel amply rewarded for having given to this field of research the best years of my life.

ANTONIO FAVARO.

UNIVERSITY OF PADUA,
27th of October, 1913.



TO THE MOST ILLUSTRIOUS LORD COUNT OF NOAILLES

*Counsellor of his Most Christian Majesty, Knight of the Order
of the Holy Ghost, Field Marshal and Commander,
Seneschal and Governor of Rouergue, and His
Majesty's Lieutenant in Auvergne, my
Lord and Worshipful Patron*



OST ILLUSTRIOUS LORD:–

In the pleasure which you derive from the possession of this work of mine I recognize your Lordship's magnanimity. The disappointment and discouragement I have felt over the ill-fortune which has followed my other books are already known to you. Indeed, I had decided not to publish any more of my work. And yet in order to save it from complete oblivion, it seemed to me wise to leave a manuscript copy in some place where it would be available at least to those who follow intelligently the subjects which I have treated. Accordingly I chose first to place my work in your Lordship's hands, asking no more worthy depository, and believing that, on account of your affection for me, you would have at heart the preservation of my-studies and labors. Therefore, when you were returning home from your mission to Rome, I came to pay my respects in person as I had already done many times before by letter. At this meeting I presented to your Lordship a copy of these two works which at that time I happened to have ready. In the gracious reception which you gave these I found assurance {xviii} of their preservation. The fact of your carrying them to France and showing them to friends of yours who are skilled in these sciences gave evidence that my silence was not to be interpreted as complete idleness. A little later, just as I was on the point of sending other copies to Germany, Flanders, England, Spain and possibly to some places in Italy, I was notified by the Elzevirs that they had these works of mine in press and that I ought to decide upon a dedication and send them a reply at once. This sudden and unexpected news led me to think that the eagerness of your Lordship to revive and spread my name by passing these works on to various friends was

the real cause of their falling into the hands of printers who, because they had already published other works of mine, now wished to honor me with a beautiful and ornate edition of this work. But these writings of mine must have received additional value from the criticism of so excellent a judge as your Lordship, who by the union of many virtues has won the admiration of all. Your desire to enlarge the renown of my work shows your unparalleled generosity and your zeal for the public welfare which you thought would thus be promoted. Under these circumstances it is eminently fitting that I should, in unmistakable terms, gratefully acknowledge this generosity on the part of your Lordship, who has given to my fame wings that have carried it into regions more distant than I had dared to hope. It is, therefore, proper that I dedicate to your Lordship this child of my brain. To this course I am constrained not only by the weight of obligation under which you have placed me, but also, if I may so speak, by the interest which I have in securing your Lordship as the defender of my reputation against adversaries who may attack it while I remain under your protection.

And now, advancing under your banner, I pay my respects to you by wishing that you may be rewarded for these kindnesses by the achievement of the highest happiness and greatness.

I am your Lordship's
Most devoted Servant,
GALILEO GALILEI.



THE PUBLISHER TO THE READER



INCE society is held together by the mutual services which men render one to another, and since to this end the arts and sciences have largely contributed, investigations in these fields have always been held in great esteem and have been highly regarded by our wise forefathers. The larger the utility and excellence of the inventions, the greater has been the honor and praise bestowed upon the inventors. Indeed, men have even deified them and have united in the attempt to perpetuate the memory of their benefactors by the bestowal of this supreme honor.

Praise and admiration are likewise due to those clever intellects who, confining their attention to the known, have discovered and corrected fallacies and errors in many and many a proposition enunciated by men of distinction and accepted for ages as fact. Although these men have only pointed out falsehood and have not replaced it by truth, they are nevertheless worthy of commendation when we consider the well-known difficulty of discovering fact, a difficulty which led the prince of orators to exclaim: *Utinam tarn facile possem vera reperire, quam falsa commncere** And indeed, these latest centuries merit this praise because it is during them that the arts and sciences, discovered by the ancients, have been reduced to so great and constantly increasing perfection through the investigations and experiments of clear-seeing minds. This development is particularly evident in the case of the mathematical sciences. Here, without mentioning various men who have achieved success, we must without hesitation and with the {xx} unanimous approval of scholars assign the first place to Galileo Galilei, Member of the Academy of the Lincei. This he deserves not only because he has effectively demonstrated fallacies in many of our current conclusions, as is amply shown by his published works, but also because by means of the telescope (invented in this country but greatly perfected by him) he has discovered the four satellites of Jupiter, has shown us the true character of the Milky Way, and has made us acquainted with spots on the Sun, with the rough and cloudy portions of the lunar surface, with the threefold nature of Saturn, with the phases of Venus and with the physical character of comets. These matters were entirely unknown to the ancient astronomers and philosophers; so that we may truly say that he has restored to the world the science of astronomy and has presented it in a new light.

Remembering that the wisdom and power and goodness of the Creator are nowhere exhibited so well as in the heavens and celestial bodies, we can easily recognize the great

merit of him who has brought these bodies to our knowledge and has, in spite of their almost infinite distance, rendered them easily visible. For, according to the common saying, sight can teach more and with greater certainty in a single day than can precept even though repeated a thousand times; or, as another says, intuitive knowledge keeps pace with accurate definition.

But the divine and natural gifts of this man are shown to best advantage in the present work where he is seen to have discovered, though not without many labors and long vigils, two entirely new sciences and to have demonstrated them in a rigid, that is, geometric, manner: and what is even more remarkable in this work is the fact that one of the two sciences deals with a subject of never-ending interest, perhaps the most important in nature, one which has engaged the minds of all the great philosophers and one concerning which an extraordinary number of books have been written. I refer to motion [*moto locale*], a phenomenon exhibiting very many wonderful properties, none of which has hitherto been discovered or demonstrated by any one. The other science which he has also developed from {xxi} its very foundations deals with the resistance which solid bodies offer to fracture by external forces [*per violenza*], a subject of great utility, especially in the sciences and mechanical arts, and one also abounding in properties and theorems not hitherto observed.

In this volume one finds the first treatment of these two sciences, full of propositions to which, as time goes on, able thinkers will add many more; also by means of a large number of clear demonstrations the author points the way to many other theorems as will be readily seen and understood by all intelligent readers.

* Cicero, *de Natura Deorum*, I, 91. [Trans.]





APPENDIX

Containing some theorems, their proofs, dealing with centers of gravity of solid bodies, written by the same Author at an earlier date.*

* Following the example of the National Edition, this Appendix which covers 18 pages of the Leyden Edition of 1638 is here omitted as being of minor interest. [*Trans*]

[FINIS]



Galileo Galilei, *Dialogues Concerning Two New Sciences*, translated by Henry Crew & Alfonso de Salvio with an introduction by Antonio Favaro, Dover Publications, Inc., New York, 1954 (INTRODUCTION). Originally published in 1904 by the MacMillan company.

INTRODUCTION [FIRST DAY](#) [SECOND DAY](#) [THIRD DAY](#) [FOURTH DAY](#)

* * *

THE [ADDED](#) (OR “FIFTH” DAY) BY STILLMAN DRAKE (1974)

Galileo Galilei, *Discourses and Mathematical Demonstrations Concerning Two New Sciences Pertaining to Mechanics and Local Motions*. Translated by Stillman Drake, University of Wisconsin Press, Madison, 1974: 281–303. (ADDED DAY)