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Galileo and the Leaning Tower of Pisa

*A*LTHOUGH many writers dismiss this tall tale as apocryphal, some writers, teachers, and physicists still claim that Galileo Galilei carried out experiments on gravity by dropping objects from the Leaning Tower of Pisa. Here is an old and dramatic version of the story:

Members of the University of Pisa, and other onlookers, are assembled in the space at the foot of the wonderful leaning tower of white marble in that city one morning in the year 1591. A young professor [Galileo] climbs the spiral staircase until he reaches the gallery surmounting the seventh tier of arches. The people below watch him as he balances two balls on the edge of the gallery, one weighing a hundred times more than the other. The balls are released at the same instant, and are seen to keep together as they fall through the air until they are heard to strike the ground at the same moment. Nature has spoken with no uncertain sound, and has given an immediate answer to a question debated for two thousand years.

“This meddling man Galileo must be suppressed,” murmured the University fathers as they left the square. “Does he think that by showing us that a heavy and a light ball fall to the ground together he can shake our belief in the philosophy which teaches that a ball weighing one hundred pounds would fall one hundred times faster than one weighing a single pound? Such disregard of authority is dangerous and we will see that

it goes no further.” So they returned to their books to explain away the evidence of their senses; and they hated the man who had disturbed their philosophic serenity. For putting belief to the test of experiment, and founding conclusions upon observation, Galileo’s reward in his old age was imprisonment by the Inquisition, and a broken heart. That is how a new scientific method is regarded by guardians of traditional doctrine.¹

A different writer claimed, “Galileo’s older colleagues knew nothing of experiments. The very idea implied to them a sort of hideous witchcraft—a profanation of the sanctity of the Aristotelian doctrine.”² Likewise, another account stated, “The Aristotelians ridiculed such ‘blasphemy,’ but Galileo determined to make his adversaries see the fact with their own eyes.”³

Most recent historians do not believe this elaborate, dramatic story because it is not based on any evidence; it is mainly the product of writers’ lively imaginations. Still, plenty of books and teachers still echo its basic elements.⁴ Therefore, fair questions remain: What fragments of the story are true? How did this story grow?

In a book of 1935, *Aristotle, Galileo, and the Tower of Pisa*, Professor Lane Cooper boldly denounced the story as false: he argued that Galileo did not drop objects from the tower. Nevertheless, some later historians have disagreed. For example, an expert scholar on Galileo, Stillman Drake, argued that the core of the story might be true, although Drake had no contemporary accounts stating that Galileo ever dropped anything from the tower of the cathedral at Pisa.⁵

The story about Galileo and the Lean-

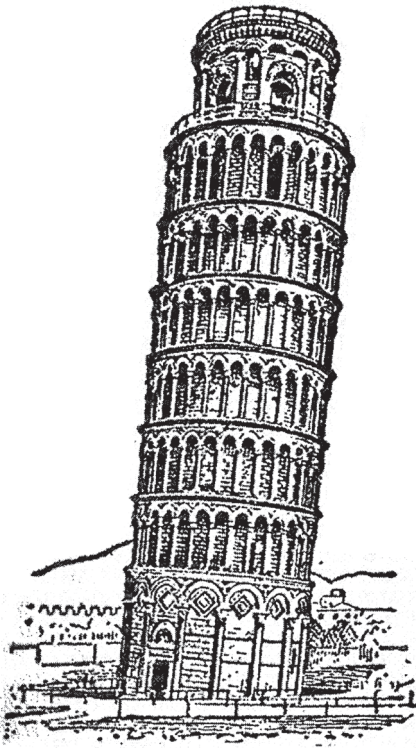


Figure 1.1. The Leaning Tower of Pisa.

ing Tower first appeared in a biography of Galileo written by Vincenzo Viviani, the young secretary who served him in his final years of blindness and home imprisonment, from 1639 until Galileo's death in 1642. Viviani, who apparently drafted his account sometime between 1654 and 1657 (although it was not published until 1717), described events that allegedly happened six decades earlier, but which he did not witness:

At this time [ca. 1590] it seemed to him [Galileo], that the investigation of natural effects necessarily require a true cognition of the nature of motion, there being a philosophical and popular axiom: *ignorance of motion, ignorance of nature*, he gave himself entirely to contemplate it: and then with great discord from all the philosophers, by means of experiences and good demonstrations and discourses he convinced them of the falsehood of many conclusions of Aristotle himself on the topic of motion, which up to that time were held as most clear, and indubitable, as among others, that the speeds of unequal weights of the same material, moving through the same medium, did not at all keep the proportion of their heaviness, assigned by Aristotle, but instead, these all moved with the same speed, he demonstrated this by repeated experiments made from the height of the Bell-Tower of Pisa, in the presence of all the Lecturers and Philosophers, and of all the Students.⁶

Stillman Drake argued that in this account: "Viviani was repeating his recollection of what Galileo himself had told him." But this kind of wording makes me doubt Drake. Really, we don't know what Galileo told Viviani, nor whether Viviani faithfully repeated it fifteen years later. Regardless, to make his case, Drake used more speculative words that make me part company with him: "would have been," "probably meant," "presumably argued," "it would then be natural," "more probably," and so forth.⁷ I think that there are no probabilities in the past; events either happened or they did not. In history, we either have enough evidence to claim that an event transpired, or we do not. Faced with uncertainty, one might choose to imagine whatever sounds most plausible, but it seems preferable to build our accounts of the past on the basis of evidence over conjecture.

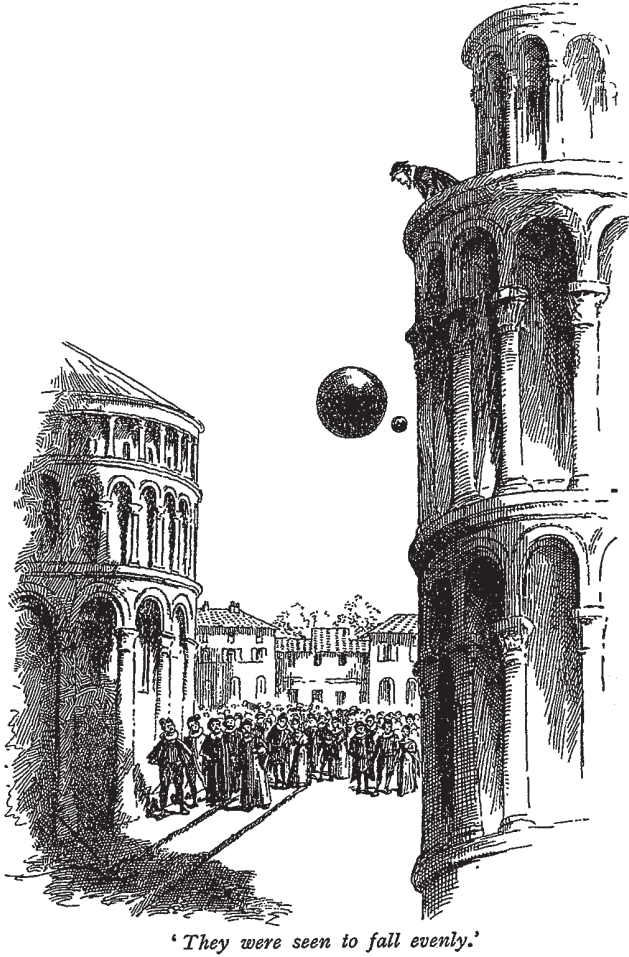


Figure 1.2. Apparently, one of the balls was very large.

By neglecting chronology, and presenting selected pieces of evidence in a contrived order, writers often convey whatever impressions they wish. As with other evolving stories in the history of science, this story benefits from establishing a chronology of events.

In 1544, the Florentine historian Benedetto Varchi alluded to experimental tests showing that traditional views on falling objects were wrong, in that heavier objects do not actually fall faster in proportion to their weight:

the custom of modern philosophers is to believe always, and never to test all that which is found written by the good authors, and above all in Aristotle, but that does not mean that it would not be more certain, and more delightful to do otherwise, and to sometimes descend to experience in some things, as for example, in the motion of heavy objects, about which Aristotle, and all other Philosophers, without ever doubting it, have believed and affirmed that as a body is more heavy, so much more quickly it descends, which evidence demonstrates is not true.⁸

Varchi opposed the claim that the heavier a body is, the faster it falls. So, *long before Galileo was even born*, Aristotle's claims on motion had already been challenged by experiments on falling objects.

Later, Giuseppe Moletti, a professor of mathematics at the University of Padua, carried out experiments on falling objects, and in 1576 he reported that falling objects composed of the same material but having different weights reach the ground together.

Aristotle . . . [seems to argue that] if from the top of a tower we release two balls, one of lead of twenty pounds and the other equally of lead but of one pound, the motion of the larger will be twenty times greater than that of the smaller. . . . My dear sir, you would err; they both arrive at the same time and I have made the test of it not once but many times. And there is more: a ball of wood more or less the same size as a lead one, and released from the same height, descends and reaches the ground soil in the same moment of time.⁹

Moletti thus claimed that objects of roughly the same volume but of different materials and weights reach the ground simultaneously. However, more recent experimenters have shown that this is not necessarily the case. If they are released by hands [palms down], the lighter ball is usually released slightly prior to the heavier ball, and thus the two do not fall quite side by side, the lighter ball moves ahead initially.¹⁰

During his time at the University of Pisa (1589–1592), Galileo began

to write *On Motion*, a book that was published long after his death. In that work, he included a question about hurling objects from a tower:

How ridiculous is this opinion [Aristotle's] is clearer than daylight: Because who would ever believe, for example, that if two lead balls were dropped from the orb of the moon, one a hundred times larger than the other, if the larger reached Earth in one hour, the smaller would take a hundred hours in its motion? Or also, if from a high tower two stones, one stone twice the size of the other, were flung simultaneously, that when the smaller was halfway down the tower, the larger would have already reached the ground?¹¹

In this manuscript, Galileo repeatedly referred to objects falling from a tower, but he did not specify the Leaning Tower of Pisa, and he did not describe any experiments in detail. Moreover, Galileo there argued explicitly that objects of different weights fall at different speeds! He claimed that he dropped two objects, one of wood and one of lead from the top of a high tower, and that “the lead one moves far out in front. This is something I have often tested.”¹² Galileo then believed that the speed of falling objects is proportional to their density (instead of their weight, as Aristotle seemed to argue).

Sometime in the late 1500s, Simon Stevin, a Flemish mathematician and engineer, apparently became convinced that falling objects of different weights hit the ground at the same time. He claimed to let two balls of lead, one ten times heavier than the other, “from a point about 30 feet high” to a plank below, and that “the lighter one falls not ten times later than the heavier, but that both seem to hit the plank in a single thump.”¹³ In 1605, Stevin published a book in which he claimed that he had carried out this experiment “long ago” with his friend John Grotius, with the aim of showing that Aristotle was mistaken in his *Physics* and *On the Heavens*.

In 1597, Jacopo Mazzoni, a friend of Galileo, published a book in which he advocated Galileo's early ideas on motion, against Aristotle's; but he did not mention any experiments at any tower.¹⁴

In 1604, Galileo sent a letter to Paolo Sarpi, in which he stated that different objects fall at the same rate.¹⁵ At the time, Galileo mistakenly thought that speed is proportional to distance of fall (instead of time).

In 1612, Giorgio Coresio, a professor of Greek, attacked Mazzoni's claims by complaining that Mazzoni had experimented with falling objects from an insufficient height. Coresio then briefly noted that *by dropping objects from the top of the Tower of Pisa*, Coresio himself had shown Aristotle to be correct: a whole body falling faster than a separate piece of it:

Mazzoni commits anew two other errors of no slight importance. First, he denies a matter of experiment, that, with one and the same material, the whole moves more swiftly than the part. Herein his mistake arose because, perhaps, he made his experiment from his window, and because the window was low all his heavy substances went down evenly. But we did it from the top of the cathedral tower of Pisa, actually testing the statement of Aristotle that the whole of the same material in a figure proportional to the part descends more quickly than the part. The place, in truth, was very suitable, since, if there were wind, it could by its impulse alter the result; but in that place there could be no danger. And thus was confirmed the statement of Aristotle, in the first book of *On the Heavens*, that the larger body of the same material moves more swiftly than the smaller, and in proportion as the weight increases so does the velocity.¹⁶

Coresio did not attribute any experiments at the Tower of Pisa to Galileo.

Decades later, in March 1641, Vincenzo Renieri, professor of mathematics at Pisa, sent a letter to Galileo stating that he (Renieri) had carried out experiments by dropping objects from the Leaning Tower of Pisa, and he asked Galileo to interpret them. Renieri wrote:

We have had occasion here to make an experiment of two weights falling from a height, of diverse material, namely one of wood and one of lead, but of the same size; because a certain

Jesuit [Niccolò Cabeo] writes that they descend at the same time, and with equal velocity reach the earth; and a certain Englishman affirms that Liceti here set a problem, and gave the explanation of it. But finally we have found the fact in the contrary, because from the summit of the Campanile of the Cathedral [at Pisa], between the ball of lead and the ball of wood there occur at least three cubits of difference. Experiments also were made with two balls of lead, one of a bigness equal to a cannon-ball and the other to a musket-ball, and there was observed the biggest and the smallest, from the height of the same Campanile, to be a good palm's difference by which the biggest preceded the smallest.¹⁷

Not all the letters in the correspondence between Renieri and Galileo still exist, but those that exist show no evidence that Galileo ever conducted any such experiments himself.

At that very time, when Renieri wrote to the old, blind Galileo about experiments from the Leaning Tower, Viviani was Galileo's secretary. A year later, Galileo died. Fifteen years later, Viviani claimed that Galileo dropped objects from the Tower of Pisa. In two drafts, Viviani followed his claim about Galileo's experiments from the Leaning Tower by noting that Galileo discussed the subject in his work on the *Two New Sciences*. But really, Galileo there did not refer to any specific tower and he discussed only *thought-experiments*.¹⁸

None of the many letters and manuscripts that Galileo wrote over decades claim that he dropped anything from the Leaning Tower. And none of his contemporaries who would have witnessed that event reported any such thing. None of Viviani's alleged lecturers, philosophers, or the many students at Pisa seem to have left any clue that they were aware of such an experiment carried out by anyone in the 1590s.

Historians have found that Viviani was not entirely credible. For example, in accord with the Pythagorean idea of the transmigration of souls, Viviani misrepresented the date of Galileo's birth, as being not on

February 15, 1564, but four days later—so that it would seem to follow the death of the great artist Michelangelo, on February 18, 1564.¹⁹

Regardless, some prominent historians chose to believe Viviani's account about the tower. In particular, Antonio Favaro, the prestigious editor of the collected works of Galileo, claimed that Viviani "must have heard it from the lips of Galileo himself, affirmed in a manner so certain and explicit that it cannot be called into question."²⁰

Must have? And, it *cannot* be questioned?

Lane Cooper traced how various versions of the tale added details that were not even present in Viviani's story. Some writers claimed that the demonstration happened "in the morning."²¹ Why in the morning? Was it the dawn of a new era? Others claimed that Galileo dropped one ball that weighed a pound and another that weighed a hundred pounds. Another writer claimed that Galileo placed different materials in "exactly similar boxes," before dropping them. Fiction. And yet another writer claimed that the results were "epoch-making."²² Cooper rightly complained: "Why 'epoch-making'? I have yet to learn what communal scientific advance arose out of Galileo's alleged experimentation from the tower of Pisa; there was no mention of it that can be traced before 1654; and if indeed the thing took place, it seems to have been overlooked by the world at large for sixty years and more."²³ Even at Pisa, Galileo's own admirer, Renieri, made claims quite contrary to Galileo's.

Lane Cooper was not a historian, nor a physicist. He was a professor of English. Hence, when he published his book showing that the story about the tower is not supported by evidence, many historians just dismissed it. For decades they belittled him and ignored his book. But Cooper used evidence to make his argument. It is encouraging that outsiders can contribute to a professional field such as history, especially by focusing on documentary facts rather than speculations. Legends about Galileo have propagated partly because people were willing to parrot the claims of specialists, believing authority, rather than evidence. Thus, the irony of this myth is that whereas it purports to *criticize* philosophers who blindly believed in the authority of Aristotle, in actuality it instead

Table 1.1 Experiments and explanations, actual or imagined, about falling objects and the Leaning Tower of Pisa

| | | |
|-----------|--|--|
| 1589–1592 | Galileo Galilei | Taught mathematics at the University of Pisa. |
| 1612 | Giorgio Coresio | By dropping objects from the Tower of Pisa, I have shown that Aristotle's theory of motion is <i>correct</i> : a body falls faster than a piece of it. |
| 1638 | Galileo's fictional dialogue <i>Two New Sciences</i> | Salviati: "Aristotle says that an iron ball of one hundred cubits, reaches the ground before a one-pound ball has fallen a single cubit." [Actually, Aristotle did not specify this.] ... "I [Salviati] say that they arrive at the same time." |
| 1638 | Galileo's fictional dialogue <i>Two New Sciences</i> | Aristotle is refuted by a logical contradiction [<i>a thought-experiment</i>]: the sum of a smaller stone and a larger stone should slow down the larger body, but they should also make a larger, faster body. |
| 1646–1647 | Niccolò Cabeo and Giovanni Baliani | Prior to Galileo, the experiments of Giovanni Battista Baliani (1630s) showed that two objects of different weights take the same amount of time to fall to the ground, irrespective of the medium. |
| 1641 | Vincenzo Renieri | From the top of the Tower of Pisa, I have dropped wood objects and lead objects, of different weights but the same size, and the heavier ball hit the ground first. I have also dropped a large lead ball, and a small lead ball, and the larger one hit the ground first. |
| 1651 | Giovanni Riccioli | Cabeo is wrong, because in 1634, I noticed that the heavier stone dropped from a tower reached the ground slightly faster. |
| 1650s | Vincenzio Viviani | When Galileo taught at Pisa, he repeatedly demonstrated by experiments, in front of all the lecturers, philosophers, and students, that objects dropped from the bell tower of Pisa landed on the ground simultaneously, proving that Aristotle was wrong. All this is treated by Galileo in his <i>Two New Sciences</i> [Not true]. |
| 1717 | Vincenzio Viviani | Viviani's claim about the Tower (above) is finally printed, but without the footnote mistakenly claiming that Galileo himself reported it in <i>Two New Sciences</i> . |
| 1890s | Rafaello Caverni | Galileo lied to Viviani about the Leaning Tower. |
| 1916 | Richard Gregory | In 1591, the young Galileo dropped balls of different weights from the Tower of Pisa, proving that they land together, and thus Nature clearly and instantly answered a debate that had lasted two thousand years. |
| 1934 | Lane Cooper | There is no evidence that Viviani's account was true. |
| 1978 | Stillman Drake | "Viviani was repeating his recollection of what Galileo himself had told him." |

exhibits the gullibility of persons who repeat the tale, their readiness to believe on the basis of authority.

The story of the Leaning Tower of Pisa captured people's imagination, I think, because it conveyed the dramatic illusion that in a single moment, one young man publicly dared to challenge an arbitrary tradition that had dominated for over a thousand years, and supposedly, his successful experiment abruptly and clearly revealed the truth. Allegedly, this simple, dramatic event constituted a turning point in the history of science; nature had spoken, delivering the death-blow to an arbitrary traditional belief. This epic mythical image was conveyed well in the early 1900s:

As Galileo's statement was flouted by the body of professors, he determined to put it to a public test. So he invited the whole University to witness the experiment which he was about to perform from the leaning tower. On the morning of the day fixed, Galileo, in the presence of the assembled University and townsfolk, mounted to the top of the tower, carrying with him two balls, one weighing one hundred pounds and the other weighing one pound. Balancing the balls carefully on the edge of the parapet, he rolled them over together; they were seen to fall evenly, and the next instant, with a loud clang, they struck the ground together. The old tradition was false, and modern science, in the person of the young discoverer, had vindicated her position.²⁴

In the 1990s, experimental physicist Leon Lederman wrote a section of a book titled "The Truth of the Tower." Lederman embraced the story, and described it as a media happening, the first great scientific publicity stunt: "Galileo knew in advance how it was going to come out. I can see him climbing the tower in total darkness at three in the morning and tossing a couple of lead balls down at his postdoc assistants."²⁵

Sixty years prior to Lederman's narrative, Lane Cooper, perplexed by the widespread currency of the Leaning Tower story, commented on people's willingness to believe across the centuries:

Again, there are many who as aforesaid believe the story about Galileo and the tower of Pisa, and have no better ground for accepting the story than hearsay. They have read or vaguely heard that it was so just as they believe that Aristotle said a certain thing about falling bodies of different weights, and that every one down to Galileo believed the same thing on the authority of Aristotle. As casual readers accept some modern authority for an opinion about the speed of bodies heavy and light in falling, so they accept upon authority, however vague, the tale about Galileo at Pisa.²⁶