Biography of Galileo Galilei

Abstract: Galileo Galilei was born on February 15, 1564 in Pisa, Italy. He was an Italian natural philosopher, astronomer, and mathematician who made fundamental contributions to the sciences of motion, astronomy, strength of materials, and to the development of the scientific method.

His formulation of (circular) inertia, the law of falling bodies, and parabolic trajectories marked the beginning of a fundamental change in the study of motion. His insistence that the book of nature was written in the language of mathematics changed natural philosophy from a verbal, qualitative account to a mathematical one in which repeatable, observable and measurable experimentation became a recognized method for discovering facts about nature. His discoveries with the telescope revolutionized astronomy and paved the way for acceptance of the Copernican Heliocentric System.

Galileo's advocacy of the Copernican Heliocentric System resulted in Inquisition by the Roman Catholic Church, and a sentence of house arrest for the rest of his life.

Childhood and Education

Galileo was the oldest son of Vincenzo Galilei, a musician who made important contributions to the theory and practice of music, and who may have performed experiments with Galileo on the relationship between pitch and the tension of strings.

In his teens Galileo attended the monastery school at Vallombrosa, near Florence, and in 1581 CE matriculated at the University of Pisa, where he planned to study medicine. However, he became enamored with mathematics and against the protests of his father decided instead to focus on mathematics and philosophy.

Early Career

Galileo began preparing to teach Aristotelian philosophy and mathematics, and several of these early lectures have survived. In 1585 CE Galileo left the university without having obtained a degree, and for several years he gave private lessons in the mathematical subjects. During this period he designed a new form of hydrostatic balance for weighing small quantities and wrote a short treatise, *La bilancetta ("The Little Balance").* He also began his studies on motion, which he pursued steadily for the next two decades.

Challenging Aristotle

By dropping objects of differing weights from the top of the Leaning Tower of Piza, Galileo demonstrated for all to see that, contrary to established beliefs since at least the time of Aristotle, the speed of fall of a heavy object is not proportional to its weight. The manuscript, *tract De motu (On Motion)*, finished during this period, shows that Galileo was abandoning Aristotelian notions about motion and was instead taking an Archimedean approach (boldness and originality of thought and extreme rigor of method) to the problem. But his attacks on Aristotle's ideas made him unpopular.

Telescopic Experiments

At this point Galileo's career took a dramatic turn. In 1609 he heard that in the Netherlands an instrument had been invented that showed distant things as though they were nearby. By trial and error with various arrangements of lenses, and perhaps with the help of his daughter, he figured out the secret of the invention and made his own three-powered spyglass from lenses for sale in local spectacle makers' shops.

Others had done the same; what set Galileo apart was that he quickly understood how to improve the instrument, taught himself the art of lens grinding, and produced increasingly powerful telescopes. In August of that year he presented an eight-powered ($\times$ 8) instrument to the Venetian Senate. He was rewarded with life tenure and a doubling of his salary, making him one of the highest-paid professors. In the fall of 1609 Galileo began observing the heavens with instruments that magnified up to 20 times. He was now discovering things in the night sky that no other human being in history had ever seen.

Challenging Conventional Beliefs

In December he drew the Moon's phases as seen through his telescope, showing that the Moon's surface was not smooth, as had been thought, but was in fact rough and uneven. In January 1610 he discovered four moons revolving around Jupiter. He also found that there were many more stars than are visible with the naked eye. Through his increasingly high-powered telescopes, Galileo discovered the puzzling appearance of Saturn, later to be shown as caused by a ring surrounding it, and that Venus goes through phases just as the Moon does.

Although these discoveries did not prove that Earth is a planet orbiting the Sun, they shook Galileo's faith in Aristotelian cosmology. His discoveries ultimately shook the foundations of deeply cherished belief systems, with consequences for society that are still playing out today.

Galileo's Copernicanism

1. The long accepted notion that there was an absolute difference between this 'corrupt earthly region' and the 'perfect and unchanging heavens' was proved wrong by the mountainous surface of the Moon.
2. The orbits of Jupiter's moons showed that there was more than one center of motion in the universe, which seriously contradicted the notion that the earth was the center of the universe.
3. The phases of Venus showed that it (and, by implication, Mercury) revolved around the Sun, not the Earth.

As a result, Galileo became convinced that the Sun was the center of the universe and that Earth was a planet orbiting the sun, as Copernicus had argued. Galileo's conversion to Copernicanism would be a key turning point in the Scientific Revolution.

Challenging Biblical Authorities

Galileo's increasingly overt Copernicanism began to cause trouble. In 1613 he wrote a letter to a student about the problem of squaring the Copernican theory with certain biblical passages. Inaccurate copies of this letter were sent by Galileo's enemies to the Inquisition in Rome, and he had to retrieve the letter and send an accurate copy.

Several Dominican fathers lodged complaints against Galileo, and Galileo went to Rome to defend the Copernican cause and his good name. Before leaving, he finished an expanded version of a letter in which he discussed the problem of interpreting biblical passages with regard to scientific discoveries Except for one example, he wisely refrained from interpreting the Bible—a task which in the wake of the Council of Trent (1545-63) and the beginnings of the Catholic Counter-Reformation was reserved only for "approved theologians".

In any case, the tide in Rome was turning against Galileo and the Copernican theory. In 1615, when the cleric Paolo Antonio Foscarini published a book arguing that the Copernican theory did not conflict with scripture, Inquisition consultants examined the question and pronounced the Copernican theory heretical. Foscarini's book was banned, as were more technical and nontheological works, such as Johannes Kepler's *Epitome of Copernican Astronomy*. Copernicus's own 1543 book, *De revolutionibus orbium coelestium libri vi* ("Six Books Concerning the Revolutions of the Heavenly Orbs"), was suspended until "corrected".

Galileo was not mentioned directly in the decree, but a document placed in the Inquisition files at this time states that Galileo was admonished "not to hold, teach, or defend" the Copernican theory "in any way whatever, either orally or in writing."

> *"Philosophy is written in this grand book, the universe, which stands continually open to our gaze. But the book cannot be understood unless one first learns to comprehend the language and read the letters in which it is composed. It is written in the language of mathematics, and its characters are triangles, circles, and other geometric figures without which it is humanly impossible to understand a single word of it."*

Galileo's Inquisition

In time, Galileo again spoke out, directly challenging the authority of the Bible as the only word of God, as well as the authority of those who presumed to be the Bible's only true interpreters.

Galileo's approach to cosmology was fundamentally spatial and geometric, i.e., mathematical rather than theological: Earth's axis retains its orientation in space as Earth circles the Sun, and bodies not under a force retain their velocity (although this inertia is ultimately circular). He also drew a distinction between the properties of external objects and the sensations they cause in us—i.e., the distinction between primary and secondary qualities, or what we might call "subjective and objective reality".

Reaction against such ideas was swift. In 1633 CE, Galileo was summoned to Rome to appear before the Inquisition. During his first appearance, he was confronted with the 1616 edict recording that he was forbidden to discuss the Copernican Theory. In his defense Galileo

produced a letter from Cardinal Bellarmine, by then dead, stating that he was admonished only to not hold or defend the theory. The case was at an impasse. In what can only be interpreted as a 'plea bargain', Galileo confessed to having overstated his case. He was pronounced to be vehemently suspect of heresy, was condemned to life imprisonment, and was made to formally abjure.

Despite rumors, there is no historical evidence that he whispered, *"Eppur si muove" ("And yet it moves").* On the other hand, such dangerous statements are rarely recorded in historically verifiable form.

Dialogues Concerning Two New Sciences

Galileo was then 70 years old, yet he kept working. He had begun a new book on the sciences of motion and strength of materials. In it he reworked unpublished studies that had been interrupted by his interest in the telescope. The finished manuscript was secretly carried out of Italy and published in Leiden, the Netherlands in 1638 under the title *Discorsi e dimostrazioni matematiche intorno a due nuove scienze attenenti alla meccanica (Dialogues Concerning Two New Sciences).* In this book Galileo wrote for the first time about the bending and breaking of beams and summarized his mathematical and experimental investigations of motion, including the law of falling bodies and the parabolic path of projectiles as a result of the mixing of two motions—constant speed and uniform acceleration.

Galileo's Passing

The now blind Galileo continued working up to his final days. He collaborating with a young student, Vincenzo Viviani, who was with him when he died on January 8, 1642, in the tiwb if Arcetri near the city of Florence.

Galileo's Legacy

In 1992 CE, 359 years after Galileo's Inquisition, the Catholic Church finally admitted that they had been wrong. At a ceremony in Rome, Pope John Paul II officially declared that Galileo had been correct, and that the Inquisition had acted in good faith, but had been wrong.

Modern Echoes

The form of the Inquisition's verdict is strikingly similar to obfuscating statements made by entrenched powers regarding more current scientific debates, such as the dangers of cigarette smoking, the dangers o pesticide use, the impact of navel sonar systems on marine mammals, and predictions of global greenhouse warming. The Inquisition had ruled that because Galileo could not prove 'beyond doubt' that the Earth orbits the Sun, there was no reason for them to change their opinions.

Some of Galileo's Achievements

1. A "Renaissance Man" who contributed to a variety of fields, including natural philosophy, instrument making, astronomy, physics, materials science, mathematics and foundations of the modern scientific method.
2. Contributed greatly to the foundation of the modern scientific method by summarizing experimental findings mathematically.
3. Demonstrated that Aristotle had been wrong about the speed of falling objects.

4. Fundamentally changed the study of motion with his formulations for (circular) inertia, the law of falling bodies, and parabolic trajectories.
5. Changed natural philosophy from a verbal, qualitative study to one based mathematics by insisting that the 'book of nature' was written in the language of mathematics.
6. Improved the design of telescopes.
7. Discovered that the surface of the moon was rough.
8. Discovered that there were many more stars than could be seen with the naked eye.
9. Discovered that Jupiter had moons, and that they orbited Jupiter, not the earth.
10. Discovered that Saturn had rings.
11. Discovered that the planets Venus and Mercury orbited the sun, and not the earth.
12. Founded the modern science of Cosmology and successfully challenged Church authorities and long established dogma by focussing research on spatial and geometric (mathematical) principles.
13. Revolutionized astronomy and paved the way for acceptance of the Copernican Heliocentric System.
14. Performed original research on the bending and breaking of beams, which lead to the discipline of materials science.
15. Published *La bilancetta ("The Little Balance")*
16. Secretly published *Discorsi e dimostrazioni matematiche intorno a due nuove scienze attenenti alla meccanica (Dialogues Concerning Two New Sciences)*

Sources and Further Reading

https://www.britannica.com/biography/Galileo-Galilei/Galileos-Copernicanism

https://en.wikipedia.org/wiki/Equations_for_a_falling_body