Searching the Stars: Galileo Galilei

Randy Christensen

Salt Lake Community College

Abstract

Galileo Galilei (1564–1642) is one of the most fascinating scientific figures in history. He has played a key role in the history of science and is a vital figure of the scientific revolution of the 1600's. His work in physics as well as natural philosophy, astronomy, mathematics, and scientific methodology still is influential and controversial after four centuries. His scientific achievements, advancement of the Copernican theory and his storied trials with the Roman Church all highlight one of the most influential people in history. This article is a brief biography of the life, accomplishments and importance of Galileo Galilei.

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Early Life and Family

Born 15 February 1564 in Pisa (now Italy) (Most Influential), Galileo Galilei has been described as a physicist, astronomer, philosopher, inventor, professor and mathematician. His influence in these varied areas of study continues to be a vital part of these areas today. Though many of his concepts and ideas have since been shown to be incorrect and his inventions have been improved, Galileo's achievements illuminated a world that was typically influenced by the Roman Catholic Church. His work and changes in perception of the physical world and the universe brought about a new scientific outlook. By the time he died in 1642 he was as famous as any person the western world.

Galileo was the first son and child of Vincenzio Galilei and Giulia degli Ammannati. Vincenzio was a musician, "fine lute player" (Groups) and music teacher who was born in Florence in 1520. After studying music in Venice, Vincenzio carried out experiments, with Galileo in 1588-89, "making important contributions to the theory and practice of music on the relationship between pitch and the tension of strings" (Britannica). Galileo's mother, Guilia, whose family was from Pescia (Brunelleschi, p. 11), was born in Pisa in 1538 (Brunelleschi, Guilia). She married Vincenzo in 1563 and they made their home in the countryside near Pisa.

Though Galileo's family was of nobility they were not wealthy. The family moved from Pisa to Florence, Italy in 1572 (Stanford). Towards the end of 1574 Galileo moved to Florence to join his father. In Florence, where the Galilei family had lived for generations (Biography), Galileo attended a Jesuit monastery school to study the priesthood as a monk. This did not please his father, (Groups), who withdrew him (Most Influential, p. 41) in 1578 (Brunelleschi, p. 13). He remained in Florence for a few years, studying "the humanities, Greek and dialectics, as well as drawing and music" (Brunelleschi, p. 12) and like his father, he was a good lute player.

University Studies and Early Career

In 1581, Galileo enrolled at the University of Pisa to study for a medical degree (SJSU). He never completed a degree but studied mathematics (Stanford). He enjoyed the study of mathematics and decided to make mathematics and philosophy his profession (Rice), despite his father's protests and desire for him to study medicine, which was due to a family member from a century before being "a distinguished physician" (Groups). Galileo studied the Galen and Hippocrates medical writings to please his father. However, Galileo invited his geometry teacher Ostilio Ricci (Brunelleschi, p.17), the mathematician of the Tuscan Court, to meet his father "to persuade Vincenzo to allow his son to study mathematics since this was where his interests lay. Certainly Vincenzo did not like the idea and resisted strongly but eventually he gave way a little" (Groups). Galileo then began to study the mathematics of Euclid and Archimedes.

While he studied in Pisa, Galileo observed the oscillation of a hanging lamp in the Cathedral of Pisa in 1853 and wondered "whether the times of oscillation between two points, for large, medium and small arcs, were the same" (Brunelleschi, p.15-16). As he watched he had realized the constant period of the pendulum. He applied this knowledge to medicine and measuring a patient's heart rate and, due to the precision of its measurements, was able to establish the laws of motion (Brunelleschi).

He left the university without a degree in 1585 returning to teach in Florence (Most Influential, p.41). He began to teach Aristotelian philosophy and mathematics for several years, giving private lessons in the subjects in Florence (Biography); with several lectures surviving (Biography).

During the summer of 1586 (Rice) he designed a new form of hydrostatic balance for weighing small quantities of solids and wrote a circulated short manuscript, *La bilancetta* ("The Little Balance"), based on the Archimedes' method of finding specific gravities (Britannica).

Later in 1587 (Groups), he visited and started a correspondence with the Roman Jesuit mathematicians Christopher Clavius and Guildobaldo del Monte. A very popular topic amongst the

mathematicians at the time was centers of gravity and Galileo brought to Rome some of his discoveries on the topic (Groups). He applied and was turned down for a mathematics professorship position in Bologna but a few years later in 1589, after receiving great compliments for his 1588 lectures at the Academy in Florence of Dante's *Inferno*, and through his association with Clavius and del Monte, he was appointed to the mathematics chair in Pisa (Stanford).

While at the University of Pisa, Galileo showed that the speed of fall of a heavy object is not proportional to its weight, as Aristotle had claimed. He demonstrated this by his "repeated experiments, made from the top of the Leaning Tower of Pisa in the presence of other teachers and philosophers and the entire student body" (Brunelleschi) by dropping bodies of different weights, according to biographer Vincenzo Viviani (Biography). Galileo spent three years teaching mathematics at the University of Pisa.

The never published (Groups) manuscript tract *De motu* (*On Motion*) shows that Galileo was abandoning Aristotelian ideas and instead taking an Archimedean approach to motion (Britannica). Perhaps the most important new ideas which *De motu* contains is that one can test theories by conducting experiments and the important idea that one could test hypotheses about falling bodies using an inclined plane (Groups).

Galileo, shortly after being appointed mathematics chair at the University of Pisa, was compelled to support his mother and siblings with the death of his father Vincenzo in 1591 (Brunelleschi, Guilia). Since Galileo was the eldest son of Vincenzo he had to provide financial support for the rest of the family including providing dowries for his two younger sisters (Groups). He earned enough to live on and also make a contribution to his family (Brunelleschi).

Galileo's discoveries on motion, however, made him unpopular with his University colleagues because the views were moving away from Aristotle. In 1592 his contract was not renewed (Biography). However, he was appointed chair of mathematics at the University of Padua later that same year (SJSU), due to strong recommendations from friend del Monte; at a salary of three times what he had received at

Pisa. “On 7 December 1592 he gave his inaugural lecture and began a period of eighteen years at the university, years which he later described as the happiest of his life” (Groups). Because he was supporting his family after the death of his father, Galileo was always pressed for money and was forced to take in wealthy boarding students whom he tutored privately (Rice). Many of these pupils would remain lifelong friends (Brunelleschi).

At Padua his teaching duties were mainly to teach Euclid's geometry and geocentric astronomy to medical students. However, with the appearance of a new star (now known as 'Kepler's supernova') in 1604 (Groups), Galileo argued against Aristotle's and the popularly held view of astronomy and natural philosophy in three public lectures. In a 1598 letter written to the German mathematician and astronomer Johannes Kepler, Galileo stated that he was a supporter of the Copernicus’ theories, although this was not made public until many years later (Groups). He also had his first legal difficulties, having been accused of “drawing up various horoscopes for various people” (Brunelleschi, p.30) that same year.

While teaching at Padua, Galileo began a long term relationship with Maria Gamba from Venice but they never married (Britannica). In 1600 their first child Virginia was born, a second daughter Livia was born in 1601, with their son Vincenzo born in 1606 (Stanford).

Discoveries

Even with his busy life Galileo continued his research on motion, and by 1609 he had determined the law of falling bodies (that the distance fallen by a body is proportional to the square of the elapsed time) and that the trajectory of a projectile is a parabola. Both of these concepts contradicted Aristotelian physics (Britannica). Galileo was most likely influenced by the observations of ballistics engineers who had realized that a projectile, such as a bullet, was pulled down by the earth (Most Influential). His experiments with a ball rolling off a table agreed with these observations.

In May 1609, Galileo was made aware of a spyglass instrument made by a Dutchman (Groups). After reading of descriptions and the reports of others, he started working on optics, creating his own telescopes and eventually creating better versions than the Dutch instrument (Groups). The telescope already existed before Galileo built his first version and he never claimed to have invented it (Brunelleschi, p. 33).

His telescope brought objects as much as a thousand times closer than they were to the naked eyes (Most Influential, p. 41) and with this he looked at the surface of the moon, discovering that it was pockmarked along with peaks and valleys and what he thoughts were seas (Brunelleschi, p. 35). In January 1610 he discovered four moons revolving around Jupiter (Britannica). These discoveries were published in the book *Siderus nunicus (The Starry Messenger)* (Most Influential) which became quite popular and moved the Copernican idea of a heliocentric system forward.

With the publication of *The Starry Messenger*, Galileo became well-known and was invited into palaces and lived the life of a gentleman (Biography). He continued to observe planets and stars, discovering the strange appearance of Saturn (later to be shown to be caused by rings), and that Venus goes through phases just as the Moon does, again proving the fallacy of the Aristotelian theories of astronomy (Britannica). With this, Galileo was convinced of his Copernican belief that the Sun was the center of the universe and the Earth was a planet orbiting the Sun as were the other planets.

In 1612 Galileo established the theorems of hydrostatics, publishing *Discoveries on Floating Bodies* (Most Influential). In 1613 he published many of his letters that confirmed public his Copernican beliefs and showed his initial thoughts on the principle of inertia (Biography).

Trouble with the Vatican

During his time at the University of Pisa Galileo's discoveries began to create problems with the Roman Catholic Church. In 1616 when he visited Rome, he was cautioned to not teach the Copernican views of astronomy (Most Influential). Inaccurate copies of some of his letters were sent to Rome

(Britannica) and he had to correct them by going to Rome to defend his views. Many church fathers from Florence lodged complaints against Galileo (Biography). He was not the only astronomer that was muzzled by the Inquisition, with Kepler and even Copernicus' book *De revolutionibus orbium coelestium libri vi* (*Six Books Concerning the Revolutions of the Heavenly Orbs*) being suspended until it was corrected (Britannica). In his treatise, *Il saggiatore* (*The Assayer*), Galileo defended his breakthroughs and the scientific method (Rice).

Galileo met six times with Pope Urban II, who was an admirer of Galileo's work, through which the Pope gave him permission to publish the book, *Dialogo sopra i due massimi sistemi del mondo, tolemaico e copernicano* (*Dialogue Concerning the Two Chief World Systems, Ptolemaic & Copernican*) (Biography). Due to the outbreak of the plague, the publication was postponed and the censorship was done in Florence, not Rome. The book was published in 1632, with a preface stating it contained hypothetical theories (Britannica).

The book was examined in more detail by the Vatican church and a special commission created by the Pope. The papal commission found the book had not really treated the Copernican theory hypothetically and recommended that the book be banned and ordered Galileo to appear in Rome before them (Most Influential). Galileo was summoned to Rome in 1633. During his first appearance before the Inquisition, he was pressed with the 1616 decree that forbade him to discuss the Copernican theory (Britannica).

Galileo was found guilty and condemned to lifelong imprisonment, but the sentence was carried out by house arrest rather than a prison sentence. When Galileo had completed work on the *Discourses and mathematical demonstrations concerning the two new sciences*, it was smuggled out of Italy and taken to Holland where it was published (Groups). Near the end of his life, around 1640, he designed a pendulum clock, thus in effect causing his life's discoveries and inventions to swing from one end of the

arc to the other and back, as the swinging lamp he observed. The Vatican officially recognized the validity of Galileo's work in 1993 (Infoplease).

Very few, if any, individuals have been more influential on human understanding of the universe than Galileo. For more than 1,200 years prior to Galileo, there was limited scientific advancement; and because of Galileo's work, he is arguably the father of modern science (Western). By the time he died in 1642, science was well on its way to becoming its own discipline with its concepts and methods becoming a whole philosophical system (Stanford). The leap forward in science today is built upon the foundation of the ancient Greco-Roman science and the Galilean scientific methodology of the "systematic use of experimentation and mathematics" (Western).

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