

## Galileo Galilei: Father of Modern Science

A striking feature of the writings of Galileo Galilei is that all of them with one exception – *Sidereus Nuncius* or *The Sidereal Message* – are in Italian, his native tongue, rather than in Latin as was customary in his time, and even till much later. Not only that, he wrote in a very lively and dramatic style too. His two principal works – *Dialogue Concerning the Two Chief World Systems, Ptolemaic & Copernican*, and *Dialogues Concerning Two New Sciences* – are in the nature of a conversation between three persons, Simplicio representing the Aristotelian school of thought, Salviati representing Galileo and Sagredo, an intelligent layman (see the excerpt from *Dialogues Concerning Two New Sciences* in Box 1 at the end). It is in these works of Galileo that his most significant contribution to the modern scientific thought shines through – ‘its method of enquiry’ and ‘its criterion of truth.’ He championed the method of pursuing research through observation and experiment.

Vincenzo Galilei, Galileo’s father, was a talented musician and was well versed in the theory of music as well. He studied with Zarlino who was an exponent of the Pythagorean tradition that ascribed all consonance of sounds to the governance of numerical ratios. Vincenzo believed in what a ‘trained ear’ could recognise rather than in what the underlying numerical ratios would dictate. Since the semitone is represented by the ratio 9:8 whose square root is not a rational number, Zarlino’s school believed that a semitone cannot be divided into two equal parts (for such a division would correspond to the square root of 9/8). But Vincenzo’s argument was that such a division was necessary and that trained ears of a musician would certainly help in effecting this division. Finally, in 1588 Vincenzo

carried out experiments to conclusively destroy the idea that ‘sonorous numbers’ ruled musical consonance. There is evidence to believe that Galileo Galilei had participated in these experiments which involved hanging weights on strings and then sounding them. It is hard to miss the ‘simple pendulum’ during these experiments and, perhaps, we also recognise the seeds of Galileo’s contribution to the modern scientific thought – ‘its method of enquiry’ and ‘its criterion of truth.’

Galileo Galilei was born on February 15, 1564 to Vincenzo Galilei and Giulia Ammannati in the countryside near Pisa. The family later moved to Florence where many generations of the Galilei family had lived. Here Galileo attended the monastery school at Vallombrosa from 1575-78 and matriculated from the University of Pisa in 1581. Vincenzo wanted his son to study Medicine and so enrolled him at the same university. Two things prevented Galileo from completing his medical education. Firstly, his impatience with the works of Galen and Aristotle which he had to study. In the margin of a book Galileo left a record of his objections to the Aristotelian rule that the speed of a falling body was proportional to its size; he had seen large and small hailstones striking the ground at the same time but couldn’t believe that the larger ones had originated farther up or that they started falling later than the smaller ones. Secondly, early in 1583 he chanced upon a lecture on Euclid by Ostilio Ricci, mathematician to grand duke of Tuscany, the position which Galileo acquired in 1610. Fascinated, he returned to listen to further lectures and became engrossed in the study of Euclid on his own. Alarmed by this turn of events, Vincenzo threatened to stop supporting him unless he dropped these studies to complete his medical education. Galileo re-



### Box 1

Salviati. ... *I greatly doubt that Aristotle ever tested by experiment whether it be true that two stones, one weighing ten times as much as the other, if allowed to fall, at the same instant, from a height of, say, 100 cubits, would so differ in speed that when the heavier had reached the ground, the other would not have fallen more than 10 cubits.*

Simplicio. *His language would seem to indicate that he had tried the experiment, because he says: We see the heavier; now the word see shows that he had made the experiment.*

Sagredo. *But I, Simplicio, who have made the test can assure you that a cannon ball weighing one or two hundred pounds, or even more, will not reach the ground by as much as span ahead of a musket ball weighing only half a pound, provided both are dropped from a height of 200 cubits. ... ..*

Salviati. *But if this is true, and if a large stone moves with a speed of, say, eight while a smaller moves with a speed of four, then when they are united, the system will move with a speed less than eight; but the two stones when tied together make a stone larger than that which before moved with a speed of eight. Hence the heavier body moves with less speed than the lighter; an effect which is contrary to your supposition. ...*

Simplicio. *I am all at sea because it appears to me ... ..*

quested, and got, his support for just one more year after which he said he would take care of himself. In 1885 he left Pisa without a degree and taught mathematics privately at Florence and Siena for a couple of years. In 1589 he was appointed to the chair of mathematics at the University of Pisa which he held till 1592. By this time his scholarship had been noticed and he had acquired patrons who secured for him the chair of mathematics at University of Padua which he held for eighteen years, 1592-1610. Galileo later referred to this period as the most enjoyable time of his life. His father died in 1591 and the burden of looking after the family fell on Galileo. He seems to have discharged his duties very well, arranging for his two sisters' marriage with good dowries and helping his brother make a career in music. He did not marry but had a stable relationship with a Venetian woman, Marina Gamba; main reason for Galileo not entering into mar-

riage seems to be his already strained financial situation. They had two daughters and a son. Galileo and Marina seem to have parted ways when he moved out of Padua in 1610. Though his daughters joined the convent of San Matteo at Arcetri his eldest daughter, Sister Maria Celesta, remained close to him till her death in 1634 (see the book review on pp.93); she made fair copies of many writings of Galileo for publication.

In 1610 he returned to Florence as Chief Mathematician and Philosopher to the Grand Duke of Tuscany, a position he retained till his death on January 8, 1642 at Arcetri. In 1632 *Dialogue Concerning the Two Chief World Systems, Ptolemaic & Copernican* appeared and immediately brought him into conflict with Vatican which imposed a ban on it. Notwithstanding his proximity to the Pope and the unqualified support of the Duke and many influential persons, Galileo



### Milestones in Galileo's Scientific Work.

1585-88: Designed a new form of hydrostatic balance and wrote *La Bilancetta* or *The Little Balance*. Participates in his father's experiments on vibrations of strings.

1588: First note by Galileo on isochronism of pendulums (he had been fascinated by swinging of a lamp in the cathedral of Pisa and had observed the uniformity of their vibrations in 1583).

1604: Announces law of falling bodies.

1609: Arrives at the correct theory of falling bodies. Builds a telescope and begins observations of the sky.

1610: Publishes *Sidereus Nuncius* containing his discoveries through the telescope.

1613: Publishes *Letters on Sunspots*.

1623: Publishes *The Assayer*, a brilliant polemic on physical reality and an exposition of the new scientific method.

1625-30: Begins and completes *Dialogue Concerning the Two Chief World Systems, Ptolemaic & Copernican*.

1638: *Dialogues Concerning Two New Sciences*, first great work of modern physics published in Leyden.

was sentenced to indefinite imprisonment after humiliating abjuration. He was permitted to get back to Arcetri and remain in house arrest till his death. After the death of Sister Maria Celeste in 1634 Galileo's health declined rapidly and he became totally blind in 1637. In 1638 Pope flatly refused requests to free him from house arrest and when Galileo died the Pope forbid the Grand Duke to erect a monument in Galileo's honour.

Thus Galileo died a man condemned by the church and so he remained for another 350 years. Fi-

nally, in 1992 it was reported that Galileo has been 'rehabilitated' by Pope John Paul II. In his biography, *Galileo, Decisive Innovator*, Michael Sharaat has this to say about this: "But it was generally understood that it was not Galileo who needed to rehabilitated."!

C S Yogananda  
Department of Mathematics  
Indian Institute of Science  
Bangalore 560 012, India.

