EVANGELISTA TORRICELLI (October 15, 1608 – October 25, 1647)

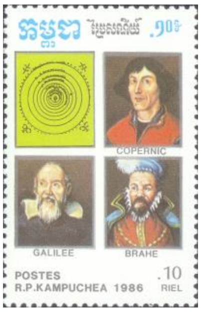
by HEINZ KLAUS STRICK, Germany

Born the son of a simple craftsman in Faenza, EVANGELISTA TORRICELLI was fortunate that his uncle, a monk, recognised the boy's great talent at an early age and prepared him to attend the local Jesuit secondary school. At the age of 16, he was allowed to attend lectures in mathematics and philosophy there for a few months. In 1626 he was sent to Rome for further education.

There, BENEDETTO CASTELLI (1577 – 1643), a pupil of GALILEO GALILEI (1564 – 1642), had just been appointed professor of mathematics at the papal university *La Sapienza*.

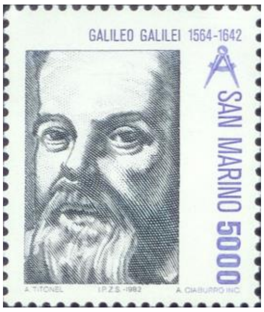
TORRICELLI did not enrol at the university but rather CASTELLI became his "private" teacher in mathematics, mechanics, hydraulics and astronomy. TORRICELLI worked for him as a secretary and took over CASTELLI's lectures in his absence.

From 1632 onwards TORRICELLI corresponded with GALILEO on behalf of CASTELLI. He too was convinced of the correctness of the theories of COPERNICUS and the revolutionary observations and theories of GALILEO. However, when GALILEO was put on trial by the *Inquisition* the following year, he shifted the focus of his investigations to less dangerous areas ...



He spent the next years with studies and experiments, among others with GALILEO's treatise *Discorsi e Dimostrazioni Matematiche, intorno a due nuove scienze* about the parabolic motion of projectiles. In 1641 he presented the manuscript *De motu gravium naturaliter descendentium* to CASTELLI, who was so enthusiastic about it that he forwarded it to GALILEO. In the autumn of the same year, TORRICELLI travelled to Arcetri to work as an assistant to GALILEO, who was now almost blind and was living there under house arrest by orders of the Church.

GALILEO died the following January and TORRICELLI was appointed his successor as court mathematician to the Grand Duke of Florence and professor of mathematics and physics at the Florentine University.



In 1644, TORRICELLI's only work, the three-volume *Opera geometrica*, appeared. It contained the further development of the draft *De motu gravium naturaliter descendentium* as the second volume. Taking up GALILEO's ideas, he examined the trajectories of projectiles and gave tables with the help of which gunners could determine the correct launch angle for their intended targets. It also contained the first theories and laws of hydrodynamics. He discovered that the outflow velocity of liquids was proportional to the square root of the height of the liquid column.

From 1643 onwards, together with VINCENZO VIVIANI (1622 – 1703), he investigated the behaviour of mercury and other liquids in tubes. TORRICELLI became famous for the invention of the mercury barometer in 1644. With it he proved the existence of atmospheric pressure: a mercury column of approximately 760 mm was balanced by atmospheric pressure.

He thus refuted the ideas of ARISTOTELES (384 - 322 BC), who regarded the existence of a vacuum as a logical contradiction, and also GALILEO, who still held the opinion that the vacuum prevented the pumping of water over a height difference of 10 metres.

Like other contemporaries, the latter conceded that the vacuum existed, but that nature "resisted" its existence (*horror vacui:* "Nature abhors a vacuum").

In the last years of his life, TORRICELLI made considerable extra income by building optical instruments (telescopes and simple microscopes). His lenses, which still survive today, show great craftsmanship.

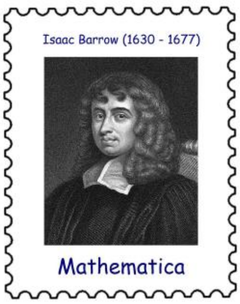
After his early and sudden death (he died presumably due to a typhoid infection), his friends did not succeed in arranging and evaluating the letters and manuscripts he left behind and this did not happen until the 20th century.

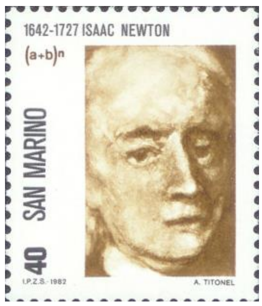
However, most of the original manuscripts were destroyed during the Second World War.

As a mathematician, TORRICELLI dealt above all with the theories of BONAVENTURA CAVALIERI (1598 – 1647), professor of mathematics at the University of Bologna. In 1635, CAVALIERI's main work *Geometrica indivisibilibus continuorum nova quadam ratione promota* was published, in which he further developed methods of ARCHIMEDES and KEPLER.

It contained the (today) so-called CAVALIERI principle:

- *If cuts are made in two bodies at the same but arbitrary height and if the resulting cut surfaces are the same size, then the two bodies have the same volume.*

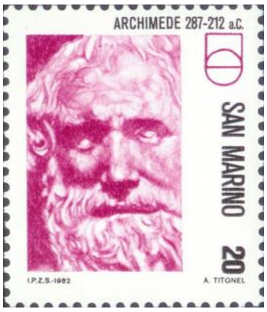




According to CAVALIERI's ideas, straight lines were created by the movement of a point, planes by the movement of a straight line – an idea that was later also found in the work of ISAAC BARROW (1630 – 1677), ISAAC NEWTON (1642 – 1727) and GOTTFRIED WILHELM LEIBNIZ (1646 – 1716) and which thus had a significant influence on the development of infinitesimal calculus.

In his calculus, he added distances to obtain an area. TORRICELLI recognised that this approach was flawed, because according to this method one could "prove" for any triangle that an altitude would bisect the area.

CAVALIERI therefore changed his concept so that he no longer added d*istances* but *threads* – non-divisible surface pieces of infinitesimal width. (*Surfaces* are *fabrics* of parallel *threads* and in space: *bodies* are *books* consisting of *leaves*).



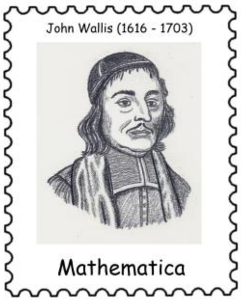
With the help of this calculus, CAVALIERI derived the relations

$$V_{\text{Sphere}} = V_{\text{Cylinder}} - V_{\text{Cone}} \quad \text{and} \quad V_{\text{Cylinder}} = 3 \cdot V_{\text{Cone}}$$

for bodies of equal height and concluded from this:

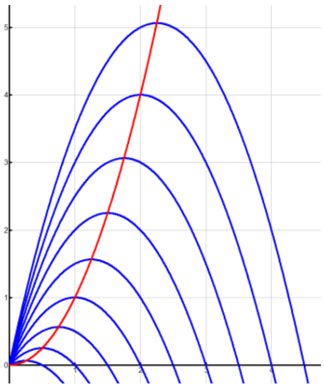
$V_{\text{Sphere}} = \frac{2}{3} \cdot V_{\text{Cylinder}}$ (which was already known to ARCHIMEDES).

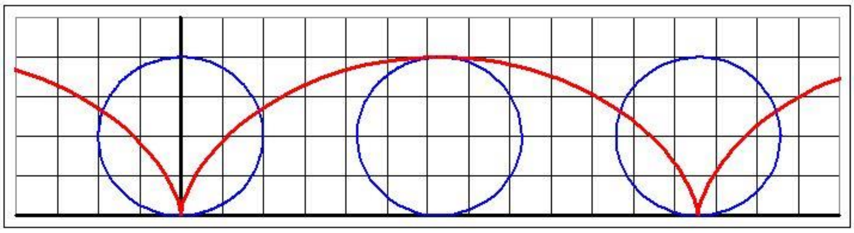
He performed calculations of the areas under the parabola with $y = x^2$ as well as $y = x^4$ and these were calculated at the same time by PIERRE DE FERMAT (1608 – 1665) and JOHN WALLIS (1616 – 1703) using other methods.



TORRICELLI proved that families of parabolas are "enveloped" by parabolas and that the locus of the vertices of a family of parabolas is also a parabola.

At the same time as GILLES PERSONNE DE ROBERVAL (1620 – 1675), he developed a method of constructing tangents to cycloids (which are the curves that a point of a circle passes through when it is unrolled). He also calculated – like ROBERVAL – the measures of areas under cycloids.

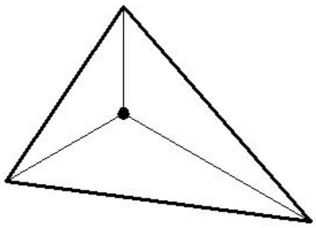




Furthermore, he determined the arc length of the logarithmic spiral and the centres of gravity of surfaces.

In 1644, the Minorite priest MARIN MERSENNE (1588 – 1648) visited him on his pilgrimage to Rome and reported on a problem posed by FERMAT:

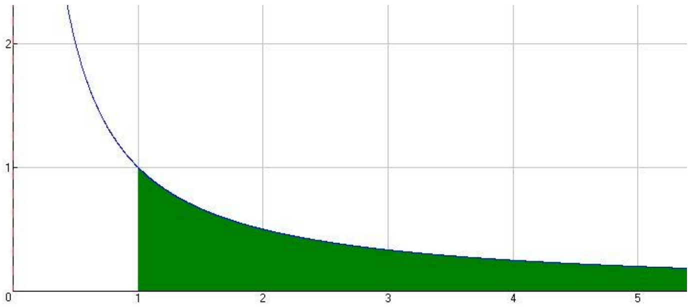
- *At which point in the interior of a triangle with angles less than 120° is the sum of the distances to the three corner points minimal?*



He found a solution (constructed with the help of ellipses), which is why this point he was looking for is often called the FERMAT-TORRICELLI point today.

While dealing with the volume of a body of revolution, TORRICELLI discovered something that even made him doubt the correctness of mathematics in the first place:

- *If the surface (with infinite area) under the hyperbola with* $y = \frac{1}{x}$ *for* $x \geq 1$ *is rotated around the x-axis, then one obtains a finite measure as the volume of the body extending to infinity – in today's notation:* $V = \pi \cdot \int_1^{\infty} \left(\frac{1}{x}\right)^2 dx = \pi$ *.*



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https://www.spektrum.de/wissen/evangelista-torricelli-1608-1647/967719

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