

# Galileo Galilei

## And Yet It Moves!

Advanced

**Galileo Galilei** (1564 – 1642) was an early Italian scientist, working in physics, math, astronomy and so on. In those times you called yourself not a scientist but a philosopher. Galileo certainly was among the first humans who did science the way we perceive it now. It would not be wrong to state that he is one of the **inventors of science**. Galileo is, as you know, still famous for those immortal words: "E pur si muove" (**And yet it moves!**).

Supposedly he uttered those words in 1633, when he was forced by the **Inquisition** to recant his sincere belief that the earth moves around the sun. There is, however, no firm evidence that he really uttered those words.

What has happened? Galileo essentially defended the view of **Copernicus** that the earth and so on moves around the sun and not the sun and so on around the earth.

Copernicus had written his "De revolutionibus orbium coelestium" (On the Revolutions of the Celestial Spheres)" just before his death in 1543, establishing a first version of the **heliocentric system**. That, of course, must have caused an uproar in theological and "scientific" circles. No, it didn't.

Copernicus' new "theory" was originally slow to catch on. Sixty years after the publication of "The Revolutions" there were only around 15 astronomers, including **Giordano Bruno** (burned on the stake by the church) **Tycho Brahe**, **Johannes Kepler** and Galileo, who subscribed to Copernicus' view, at least partially. They also added to it, including some major BS. To be fair to the church, none of them could really *prove* with mathematical rigor that the heliocentric system was right and the old view wrong. Of, course, the church couldn't prove the correctness of its view either.

While the heliocentric system was mathematically much simpler than the old-fashioned (essentially Ptolemaic) view of the sun and so on whizzing around the earth, it could not really explain anything that had been observed so far that the old system could not.

So why should one *believe* in the new system? The Bible, after all, unequivocally states for example:

"The world is firmly established, it cannot be moved." (Psalm 93:1, 96:10, and 1 Chronicles 16:30),

"The Lord set the earth on its foundations; it can never be moved." (Psalm 104:5),

"And the sun rises and sets and returns to its place" (Ecclesiastes 1:5).

Believers in this particular holy book thus were not inclined to give up their deep-seated convictions. That would have been fine - but unfortunately these guys had the power to force others to give up their deep-seated convictions.

By the way, Copernicus, who like all early scientists dabbled in anything, also wrote a study on the **value of money** in 1526. His essential thesis runs along the line that "bad" (debased) coinage drives "good" (un-debased) coinage out of circulation.

In 2011 this seems to be prophetic. Which coinage is worse? The Dollar or the Euro? We shall see.



**Galileo's tomb (Santa Croce, Florence)**

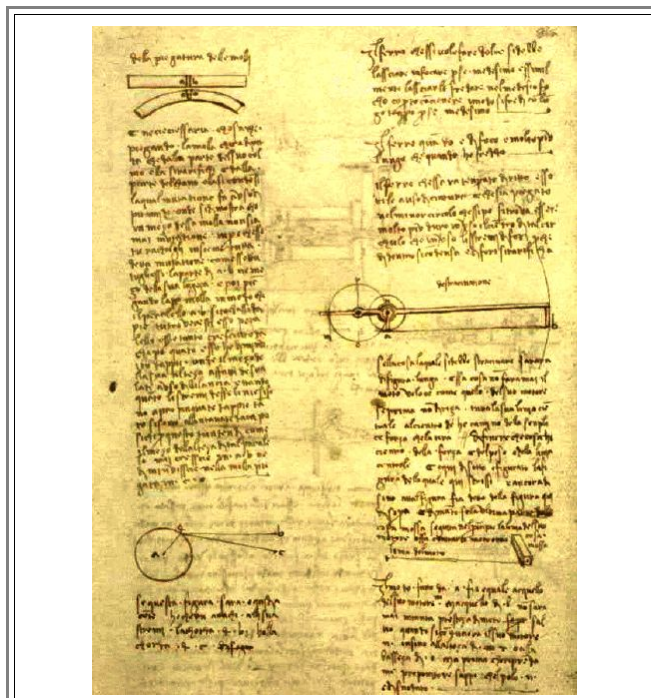
Source: Photographed 2018 in Florence

- That (maybe) Galileo's *body* is in his casket and not just his *ashes*, is due to him abjuring, cursing and detesting his firmly held opinions - upon be asked to do so by the inquisition or else. Good move on his part.
- ▣ Anyway, Galileo, defending Copernicus' view all the time, finally wrote the "Dialogue Concerning the Two Chief World Systems", published in 1632 - with formal authorization from the Inquisition and papal permission. The book, if read a bit between the lines, made fun of the Pope (one Urban VIII), which the Pope didn't like at all. And, to be fair once more, Galileo also couldn't supply an irrefutable proof of the correctness of the **heliocentric view**. Things went from bad to catastrophic. In 1633 he was sentenced to formal imprisonment at the pleasure of the inquisition, and required to "abjure, curse and detest" his opinions or else. Abjure he did, and thus could stay alive until 1642 - under conditions of house arrest. All his works were put on the index and thus forbidden, including any he might write in the future.
- The Catholic Church, by the way, eventually did see the light - bit by bit. It dropped general "heliocentric books" from the index as early as 1758 - but not Copernicus' or Galileo's books; that took until 1835. In 1992 the Church formally and finally adopted the heliocentric view. In 2000, Pope John Paul II issued a formal apology to Galileo and others. To put that in perspective: **Newton** published his "*Principia*" in 1687, proofing the heliocentric view to all with a brain. The first man on the moon, sort of finally proofing the heliocentric view even to the imbecile, stomped around up there in 1969.

### Galileo and Beam Bending

▣ Now that we have the "And yet it moves" issue out of the way, I will focus on Galileos' contribution to Material Science, department Mechanical Testing.

- It seems that there was a long-standing consensus that Galileo Galilei made the first attempt at developing a theory of beam bending. However, more recent studies try to ~~put the blame~~ put the fame on Leonardo da Vinci. (If you ever [bent a beam](#) with the full math apparatus needed to do that and suffered through the infamous "technical mechanics" exams all of us aspiring physicists had to go through, you understand why "blame" comes more easily to my mind than "fame"). So what's the score? Here is Leonardo's part from about 1493:



#### What Leonardo has to say about beam bending

This is a mirror image of the relevant Codex page because Leonardo, as always, wrote in mirror script. Now you can read it.

[Source](#): Historical Library. Cornell University, USA

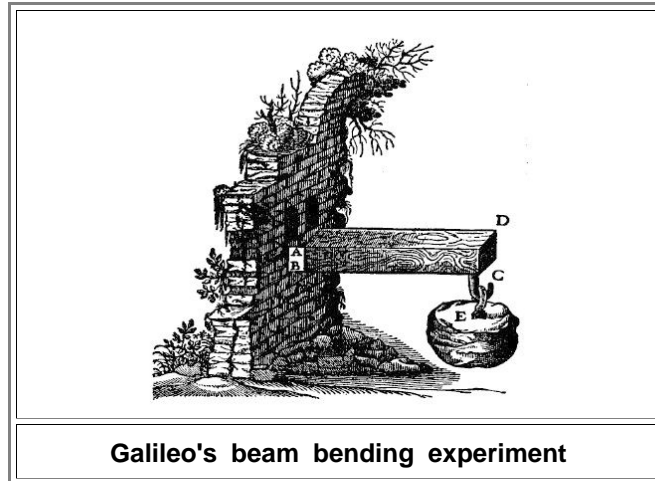
▣ Well, I'm not good at deciphering hand-written old Italian or possibly Latin either, but it is clear that a few lines do not constitute a "theory" of anything, not to mention beam bending.

- To say it with "Newton, Excel, Bach - An Excel blog for engineers and scientists, and an engineering and science blog for Excel users" [1](#):

"He (*Leonardo*) did not provide any way of assessing the strength of a beam, knowing its dimensions, and the tensile strength of the material it was made of".

Well, da Vinci lacked **Hooke's law** and calculus to come up with a good theory but we won't hold that against him.

- ▣ Galileo, in his well known "Dialogues concerning two new sciences", addressed the questions from above some 140 years later in 1638. Galileo assumed that the beam rotates about the base at its point of support, and that there was a **uniform tensile stress** (*wrong*) across the beam section, equal to the tensile strength of the material. He illustrated that with cantilever beam supported by a wall that looks alarmingly unstable as shown below:



- Galileo's basic assumption of **uniform** stress across the cross-section of the beam is wrong! The results he got from from calculations thus must be wrong too. In short, the "bending strength" he calculated is about three times larger than the actual one.

That was not so bad, however, given the fact that proper calculations are **rather tricky**.

It took another 75 years before **Antoine Parent** came up in 1713 with proper result. He correctly assumed a central neutral axis and a **linear stress distribution** from tensile at the top face to compression at the bottom. Unfortunately, Parent's work has not been recognized; I've never heard of the guy before I wrote this module. It still took a long time after he published his work before beam bending was treated properly and scientifically.

That's a bit amazing, considering that beam bending is a the very root of static analysis of almost anything, and thus of prime importance to mechanical engineering.

- ▣ Finally, let's not forget that Galileo did far more in early science than just bending beams and moving the earth around the sun. Since science has many fathers (and a few mothers), calling him the "Father of Science" is overdoing it a bit - but not very much!

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1) <http://newtonexcelbach.wordpress.com/>

2) [http://historical.library.cornell.edu/kmoddl/toc\\_leonardo1.html](http://historical.library.cornell.edu/kmoddl/toc_leonardo1.html)