

# TORRICELLI: a man who achieved the IMPOSSIBLE!

There are people who can see things most of us don't see, ask questions that don't strike all of us, feel forces that many miss and, therefore, draw conclusions that often come as a surprise. The strange thing is that these surprises slowly become a part of the thinking of every person, until they no longer seem so unusual – indeed, one even begins to enquire why no one ever thought of this before!

If you are wondering what I am talking about: then just imagine that you are standing on a hillock, looking down on the valley below you. Standing all alone, you look up at the heavens above and are awestruck by the vast expanse of emptiness above you. Other than an occasional and gentle breeze, you feel no movement at all in your immediate environment. Your mind is calm: no chatter that is its usual characteristic.

Now, what if you were asked the following question: what are the forces pressing down on you and the hillock?

"Forces? Huh? Nothing! I feel so free and light!" Your response would probably go something like that, right?

But way back in 1644, Torricelli declared that "*We live submerged at the bottom of an ocean of the element air, which by unquestioned experiments is known to have weight.*"<sup>2</sup>

But what's so special about that? Of course we all know that air has weight! So what? Well, this was something that people did *not* know until then. Torricelli was the first to declare this.

What's more, for centuries people had believed that *a vacuum cannot exist*. After all, none less than Aristotle had said so! "Nature abhors a vacuum," are said to be his words.

But Torricelli discovered that this was untrue. And in so doing, he invented a very useful instrument: the barometer.

On 15 October, 1608, Torricelli was born into a fairly poor family in Italy. His father was a textile worker and he had two younger brothers who later went on to join their father's profession. But young Torricelli showed unusual signs of brilliance right from a young age, and so, his parents sent him to live with his uncle – so that he could get a good education.

So that is how Evangelista Torricelli learned mathematics and physics – and even had to take over teaching these subjects when his own teacher was absent for some time.

Around this time, the now famous Galileo was hesitantly putting forth his revolutionary ideas about a heliocentric universe, which went against the tenets of the Bible. People were most unwilling to let go of their belief that the Earth was at the centre of the Universe, and the story of Galileo's tussle with the Church is common knowledge today. It therefore took a lot of courage for anyone to publicly declare that they supported Galileo: which Torricelli came close to doing! In a letter to Galileo he showed his support, but as it became increasingly clear that it would be dangerous to continue

traversing that road, Torricelli turned his attention to mathematics. His sharp mind led him to do some pioneering work in geometry, calculus and his most famous work was in the area of indivisibles.

Torricelli became Professor of Mathematics in Florence in 1642.

But he carried on his investigations into atmospheric pressure even as he taught mathematics. Galileo had shown that water in a well could not be pumped up to a height greater than 30 feet. Torricelli thought about the possible reason for this: and concluded that the weight of the atmosphere pressing down on the water of the well produced a pressure that could support only this high a column of water.

*We saw that an empty space was formed and that nothing happened in the vessel where this space was formed ... I claim that the force which keeps the mercury from falling is external and that the force comes from outside the tube. On the surface of the mercury which is in the bowl rests the weight of a column of fifty miles of air. Is it a surprise that into the vessel, in which the mercury has no inclination and no repugnance, not even the slightest, to being there, it should enter and should rise in a column high enough to make equilibrium with the weight of the external air which forces it up? Torricelli* Source: <https://mathshistory.st-andrews.ac.uk/Biographies/Torricelli/>

In 1644, he wrote of his curiosity to explore the resistance to a vacuum that thus far, people had claimed existed. His starting premise was: if there is truly some resistance to a vacuum, can we not find *the source of that resistance*?

He challenged the long-held belief of the impossibility of creating a vacuum through simple experimentation. The significant part of this experiment is *the predictive power of science*: building on Galileo's observation with water, Torricelli predicted that if he used mercury instead of water, the column of mercury should settle at roughly 2 feet, since mercury is roughly 14 times heavier than water. Incidentally, this effort ended up by creating a vacuum as well.

Taking long tubes completely filled with mercury (called quicksilver, at that time), he inverted and immersed them in a trough of mercury.

*We have made many vessels of glass like those shown as A and B and with tubes two cubits long. These were filled with quicksilver, the open end was closed with the finger, and they were then inverted in a vessel where there was quicksilver C; then we saw that an empty space was formed and that nothing happened in the vessel where this space was formed;<sup>2</sup>*

The remarkable finding – which was repeatable – was that the heights AD and BD were *always largely the same*! [And yes, his prediction about the height of the column of mercury as compared to that of water proved right!]

If he detected small variations from one day to another, he ascribed it to differing atmospheric pressures from day to day. Building on this work, he measured the height of the column of mercury at higher altitudes (on the top of a mountain, for instance) and found it to be significantly less.

His conclusion was that the atmospheric air is pushing down on the mercury in the trough such that it can rise up the tube only to the height shown in the figure.

But was it really EMPTY SPACE above the column of mercury inside the tube?

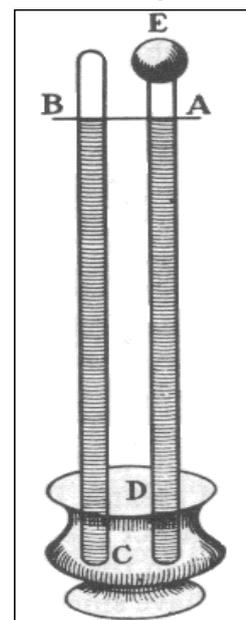


Figure 1 Experiment done by Torricelli (Source: Ref 2)

In order to verify if the space above B and A was truly a vacuum, he filled the vessel with pure water upto D, and then *raising the tube little by little, we saw that, when the opening of the tube reached the water, the quicksilver fell out of the tube and the water rushed with great violence up to the mark E.*<sup>2</sup>

If the space was not empty, water would not rush to fill it!

So do you see how this was a man who could penetrate the invisible? The intangible?

Torricelli had created a vacuum – something that was thus far considered to be impossible! And in so doing, he had invented a very useful instrument too: the barometer. To this day, the unit of atmospheric pressure is the *torr*: in honour of this scientist.

Torricelli was also an expert lens grinder: he seems to have learned this during his time with Galileo. Much of his earnings came from grinding lenses of high quality. He was the first person to explain how winds are produced: *... winds are produced by differences of air temperature, and hence density, between two regions of the earth.*<sup>4</sup>

Sadly, Torricelli died of typhoid at the young age of 39. How much more he could have contributed to the world had he lived longer! In fact, much of his work was lost as it was never published. He may well have made many other contributions which we do not know of today, as some of his manuscripts were destroyed in the Torricelli Museum 1944.

Small wonder that his parents saw in this child a very unusual mind! A mind that even enquired what causes a breeze, something hardly anyone questions!

## References

1. <https://mathshistory.st-andrews.ac.uk/Biographies/Torricelli/>
2. <https://web.lemoyne.edu/giunta/torr.html>
3. Science: A History By JOHN GRIBBIN
4. <https://mathshistory.st-andrews.ac.uk/Biographies/Torricelli/>