The roots of industrial engineering – Blaise Pascal and Pierre de Fermat

Compiled by Prof Paul Kruger

The history of human endeavour abounds with examples of the successful collaboration between two individuals leading to extraordinary achievements that they may not have reached as the sum of their individual efforts.

Examples are evident in a number of diverse fields: Pierre and Marie Curie (science), Frank and Lillian Gilbreth (engineering), Fischer Black and Myron Scholes (economics), Orville and Wilbur Wright (engineering), Francis Crick and James Watson, (science), Robert and Elizabeth Browning (literature), Richard Rodgers and Oscar Hammerstein (music) and Rudolf Nureyev and Margo Fonteyn (ballet), to name but a few. However, the world of mathematics/statistics is rather sparse in this regard. One possible exception is the collaboration between Blaise Pascal and Pierre de Fermat, a collaboration that led to the development of Probability Theory.

Pascal: the son of a tax farmer

Blaise Pascal (1623–1662) was born in Clermont-Ferrand, France, the third of four children and the only son of Etienne Pascal and Antoinette Begon. His mother died when he was only three years old. He was a child prodigy who was tutored in mathematics by his father, while the Jansenists (a Catholic sect) worked on his soul. Pascal's father was a judge and a "tax farmer". He bought the right to collect as much as possible of the outstanding taxes from tax defaulters from the government. His father had some unorthodox educational views and removed all the books on mathematics from the house, ostensibly to prevent Pascal from working too hard (a copy of Euclid's *Elements* was provided to Pascal when he was 12), thus only managing to intrigue the young Pascal. At the age of 16, he wrote a paper on the mathematics of the cone, which impressed even the great René Descartes (1596–1650), who helped him finish and publish the paper in 1640.

> "All men's miseries derive from not being able to sit in a quiet room alone. The heart has its reasons of which reason knows nothing."
>
> Blaise Pascal

In 1642, Pascal developed a mechanical calculator, which he called the Pascaline, to speed up arithmetic calculations for his father. Because of the Pascaline, Pascal is sometimes credited with inventing the first mechanical calculator – and by implication – starting the computer age. However, several similar attempts

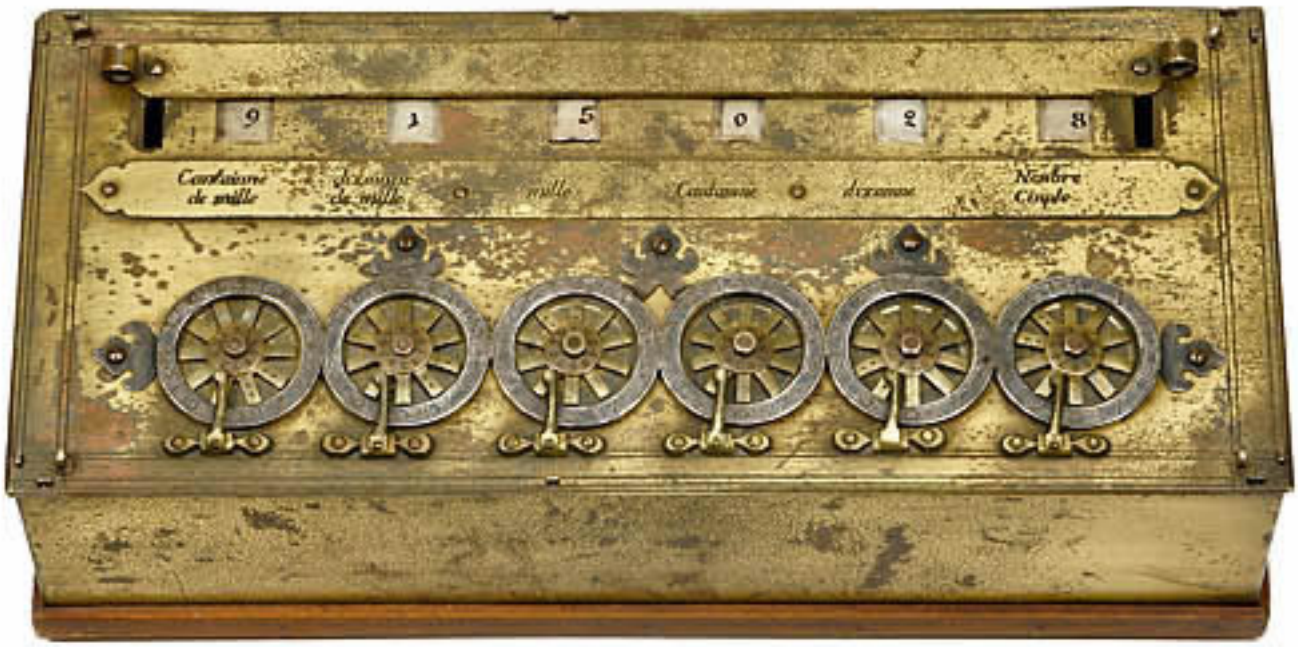
predated the Pascaline. In 1617, John Napier (1550–1617), the inventor of logarithms, designed a mechanical calculator known as "Napier's bones". Napier's bones was not based on logarithms, but on some rather old Arabic mathematical techniques. In 1622, William Oughtred (1574–1660) invented the first slide rule using Napier's logarithms to effect multiplication by addition. In 1623, Wilhelm Schickard (1592–1635) designed a calculator based on Napier's bones. Neither of the two machines that he built survived. Whether Schickard or Pascal was the inventor of the first mechanical calculator is still a contentious issue.

The design of the Pascaline was somewhat unique and managed to overcome most of the problems of its predecessors. Although it was primarily intended as an adding machine, it could perform multiplication by successive addition, a rather laborious process. Between 1642 and 1645, Pascal manufactured and tested more than 50 prototypes before producing some 20 machines based on his "final" design, even attempting to sell them, albeit without much success. Nine of the original machines survived and are on display in various museums. The discovery of the tenth one is the "holy grail" of collectors of mechanical calculators. Numerous replicas are on the market and may sell for anything between $20 000 and $50 000. The mechanical calculators in general use during the first half of the 20th century rather closely resembled the Pascaline.

Pascal contributed significantly to science in the fields of hydrostatics and hydrodynamics, especially with regard to his numerous experiments expanding and generalising the work of Evangelista Torricelli (1608–1647) on atmospheric pressure. In 1647, Pascal became embroiled in a bitter dispute with other scientists, mainly because of his insistence on the possible existence of a vacuum, a notion that was abhorrent to most scientists and philosophers of the time. After all, the concept of "something" that is "nothing" is difficult to accept, even for a philosopher. In a letter to Christiaan Huygens (1629–1695) (the author of the first book on statistics), René Descartes even wrote that Pascal "... has too much vacuum in his head", but later – somewhat reluctantly – admitted that Pascal was probably correct.

Pascal was a very religious man who, in his old age (he died at the age of 39), was convinced that the practice of mathematics was a mortal sin, possibly due to the influence of the Jansenists. In an effort to atone for his "sins", he spent extended periods in the monastery were his one sister was a nun. It was during these periods that he wrote extensively on philosophy and religion, specifically his famous *Lettres Provinciales* and *Pensées,* which are considered to be literary masterpieces, which even a writer such as Voltaire used for inspiration. In this way, Pascal may be considered as one of only a few people who has contributed significantly to mathematics, statistics, philosophy and religion. *Pensées* contains the so-called "Pascal's wager", in which he could not refrain from bringing some mathematical logic to light, even on his religious writings: "If God does not exist, one will lose nothing by believing in Him, while if He does exist, one will lose everything by not believing ... we are compelled to gamble!" In this way, he formulated an important statistical concept, namely an "expected value", presently used widely in performing risk analyses.

Pascal's deep religious convictions are poignantly illustrated by the following, possibly apocryptical story: In 1654, he was



→ *An original Pascaline.*

"I have made this letter longer than usual, only because I have not had the time to make it shorter. Men never do evil so completely and cheerfully as when they do it from religious conviction."

Blaise Pascal

contemplating marriage when the horses of his carriage were frightened and jumped over the rail of a bridge. Pascal was only saved by the fact that all the traces broke, leaving him alive on the bridge. Interpreting this incident as a sign of divine origin, Pascal promptly decided never to get married, and he never did. He wrote this pledge on a piece of paper, which he sewed in the lining of his coat, transferring it carefully whenever he changed clothes.

Pascal had many diverse interests, even trying to create a perpetual motion machine. His complex personality has been described as "precocious, stubbornly persevering, a perfectionist, pugnacious to the point of bullying, ruthless, yet seeking to be meek and humble".

In honour of his scientific work, the name Pascal was given to the International System of Units (SI) unit of pressure, the programming language Pascal and the Pascal triangle, even though this triangle was known to the Chinese some centuries earlier.

Pascal was never a very healthy person and suffered from migraines and severe abdominal pains for most of his adult life. He died from what was probably some kind of tumour at the age of 39.

De Fermat: the prince of amateurs

Dominique Fermat, the father of Pierre de Fermat (1601–1665), was a wealthy leather merchant and second consul of Beaumont-de-Lomagne in France. His mother was either Francoise Cazeneuve or Claire de Long. He had a brother and two sisters, and attended the universities of Toulouse and Bordeaux where he studied mathematics, producing important work on maxima and minima. He moved to the University of Orléans where he received a degree in civil law. He purchased the offices of the Councillor of the Parliament in Toulouse and became a lawyer and government official. Because of the office he held, he was entitled to change his name from Pierre Fermat to Pierre de Fermat. In 1638, he was appointed to a higher chamber, and in 1652, he was promoted to the highest level in the criminal court with further promotions following in quick succession. This meteoric rise through the ranks may have been at least partly due to the prevailing custom of awarding promotions on the basis of seniority, and De Fermat's colleagues and seniors were dying of the plague in droves. De Fermat himself was struck down by the plague in 1653. As in the case of Mark Twain (1835–1910), it was reported that he had died, but this report proved to be wrong and he managed to survive.

De Fermat is sometimes credited with the invention of calculus, and his work on minima and maxima and tangents certainly laid the foundations for the efforts of Isaac Newton (1643–1727) and Gottfried Wilhelm von Leibniz (1646–1716).

De Fermat was a successful and rich lawyer, for whom mathematics was a sideline and something to be used to exercise and amuse his extraordinary mathematical genius. Most of his work was communicated by way of letters to friends, often as theorems, statements or even puzzles, without providing the solutions, leaving it to Leonard Euler (1707–1783) to find them 100 years later. This was at least partly due to the fact that he experienced severe problems in publishing his work for the simple reason that he had a total disinterest in editorial polish. He even once asked Pascal to help him prepare a paper for publication, but Pascal promptly refused to act as De Fermat's editor.

Shortly before his death, De Fermat was reading in the famous *Arithmetica* of Diophantus about a problem that may be summarised as follows: It is well known that the equation, $x^2 + y^2 = z^2$ has an infinite number of positive integer solutions, the so-called Pythagoras triplets. However, is this also true for $x^n + y^n = z^n$ for $n > 2$? In the margin of the book, De Fermat wrote: "I have discovered a truly remarkable proof of this theorem, which this margin is too small to contain." This statement became known as "De Fermat's last theorem" and provided numerous mathematicians with a challenge – and some irritation and frustration – to either prove or disprove De Fermat's last theorem for 357 years. Ironically, Carl Friedrich Gauss (1777–1855), "the prince of mathematics", declared somewhat peevishly that he had very little interest in De Fermat's theorem, since "... I could easily lay down a multitude of such propositions, which one could neither prove nor disprove". Andrew Wiles, the British mathematician

→ *Blaise Pascal.*

→ *Pierre de Fermat.*

from Princeton, only recently (1993) proved the correctness of "De Fermat's last theorem". Wiles's proof is almost certainly not the same as the one De Fermat had in mind, simply because De Fermat could not have had any knowledge of the mathematics used and developed by Wiles. Recently (2014), Tom Ballard claimed to have discovered a so-called "short-form" proof to De Fermat's last theorem, which has not been accepted or rejected to date. If it is declared to be acceptable, it may be similar to what De Fermat had in mind, since it seems to be based mainly on geometry and number theory, both subjects with which De Fermat was well acquainted. Some doubt exists as to whether De Fermat ever had "proof". He made a habit of teasing the mathematical community by confronting them with bold mathematical statements and theorems without providing any proof. Therefore, De Fermat's last theorem may be no more than a mischievous hoax. However, De Fermat's statement motivated numerous mathematicians to spend countless hours working on a possible proof and, in the process, developed a significant body of new mathematical theory. Thus, in this way, whether a hoax or not, "De Fermat's last theorem" may be seen as De Fermat's lasting legacy.

Pierre de Fermat died of unknown causes at the age of either 57 or 58 in Castres, France.

Both Pascal and De Fermat are rightfully famous and respected for their individual accomplishments, but their greatest and lasting contribution may be found in their mutual achievements in establishing the mathematics of probability theory. Chevalier de Méré, a nobleman with an insatiable appetite for gambling, solicited Pascal's help in "improving the odds in gambling". The problem, as stated by De Méré, albeit somewhat innocuous and facetious, was how to divide the "pot" among the players if a game of chance is prematurely terminated. Pascal turned to De Fermat for support, and thus started an amazing journey of discovery into the mathematics of chance. Between the two of them and by way of the exchange of 24 letters, all but the first one have survived. They not only put the principles of probability theory on a firm scientific basis, but finally got rid of the medieval notion that the roll of a die was in some way controlled by the gods.

Nowadays, probability theory is an integral part of many topics in engineering and science, including reliability engineering, quality control, stochastic modelling, forecasting, actuarial science, quantum mechanics, particle physics and – obviously – lotteries and gambling.

This article is dedicated to the memory of Prof Kristiaan Adendorff, who not only initiated, but also kindled and shared my interest in the history of mathematics over many years.

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