Nicola Marras

Was There Life Before Computer?

the calculation before we went digital

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a new life for old instruments: ensuring the future by preserving the past

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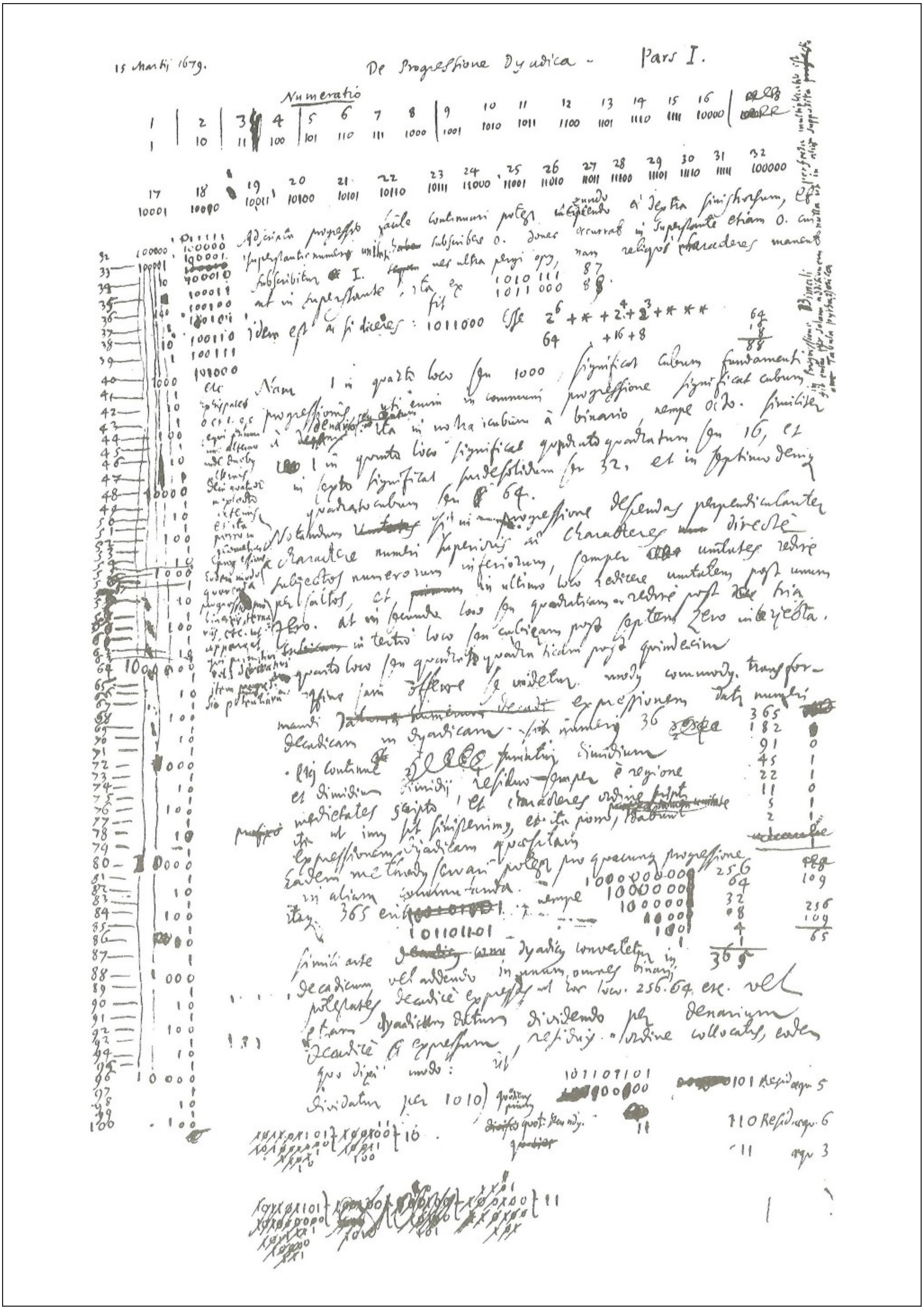
This English reduced version has the only purpose to show my program.



March 15, 1679 Leibniz presented *"De Progressione Dyadica"*: officially is born binary arithmetic, the basis of the computer

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Introduction

The old calculators were once new, used easily by everybody

Before the computer

The world of today, the landscape framed by skyscrapers, everything we associate with modernity was designed with calculators conceived in the seventeenth century.

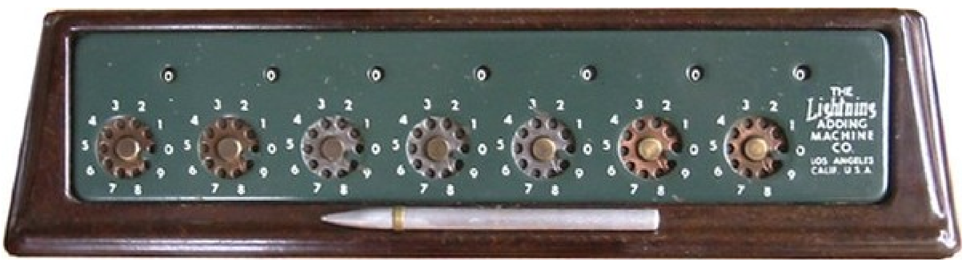
How were machines made without computers?

The LEM landed on the Moon carrying a slide rule, the same instrument used by Newton, Einstein and von Braun. The first nuclear submarine had onboard just a mechanical calculator.

The slide rule, invented in 1622, went to the Moon! This is a 1749 model year

The modern computer has been built on these ancient instruments that seemed irreplaceable:

Galileo's compass was still useful on board aircraft carriers, the calculating machines of Pascal and Leibniz were the driving force of the financial globalization and the logarithmic slide rule, invented in 1622, served to design everything: from the James Cook's flagship to the Jumbo Jet!



Pascalina, ca. 1940: patented in 1645 and built for more than 300 years

At the time nobody could imagine a world without them, but in 1972 appeared the first modern calculator and a whole fascinating world vanished in a flash, by 1980 was completely forgotten.

It was Leibniz's dream come true:

> *"It is unworthy of excellent men to lose hours like slaves in the labor of calculation which could be relegated to anyone else if machines were used"*

Rediscovering these ancient instruments ask yourself: what our technology will be tomorrow?

Digital and analog

I wrote "*The calculation before we went digital*", but the digital age started when the first man has counted some objects with the fingers (digitus in Latin means finger). Let see the differences with the analog.

The history of computing is divided into two major categories: the digital mechanical calculators, carrying out only the four operations, and the analog computers which carry out all the functions of a modern scientific calculator except for the addition and subtraction. In analog mode the operations are the result of a sum of measurements and the numerical quantities are represented by means of continuous physical quantities (scales). It works simulating *"by analogy"* the operation to be performed. To clarify: if I put 10 stones of 100 grams each on the balance I will read 1 kg; if I add other 10 I will read 2 kilos, as long as the scale is accurate and if I am able to read it properly. Two kilos are equivalent to 20 stones: I performed 10+10 in an analog way.

With the digital system the numbers are represented by single units, such as the bead of the abacus or a number:

counting the same stones I will have first 10 and doubling them 20. I have calculated digitally and the result is independent of the accuracy of the balance and the uniformity of the weights. It is impossible to make mistakes.

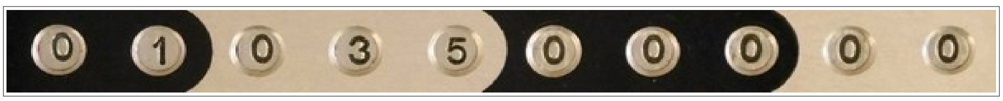
The anemometer on the left shows the same data represented in both ways. The needle measures a distance and is less easy to read than the digital information, but it is more intuitive to notice the measured quantity. It must be remembered that 15.9 m / s indicates a strong wind, but the position of the needle over half scale tells us the situation immediately. For this reason the speedometers of the cars are always of the traditional type.

Because the difficulty of reading the results seems inconvenient to use the analog system, but the logarithms permits to perform complex operations only marking them in form of scales. With the abacus, and later with mechanical calculators, you can perform only addition and subtraction. Multiply or extract roots in digital mode requires a long and tedious calculations.

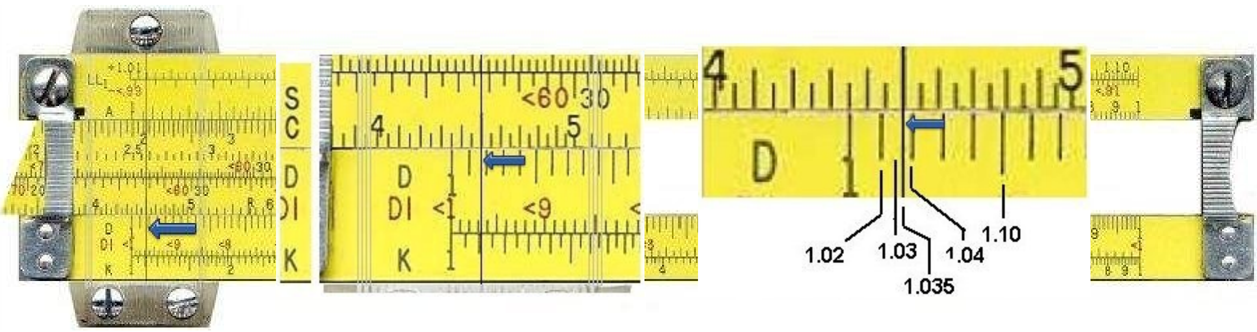
The computer, derivative of mechanical calculators, has a history of its own that goes beyond this booklet, but it should be remembered that the binary system was invented by Leibniz in 1679 just thinking to its use in a super computer and the first programmable machine, with punch cards, was built in 1801 by Jacquard for the production of fabrics. This system was then resumed by the first mechanical computer and then used until the 70s of the last century. Modern technology has ancient roots.

Reading the displays

In the digital display the result of an operation is immediately understandable, while in the analog one is a measurement and must be interpreted. Below the number 1,035,000 is expressed clearly, let's look at the same number on the slide rule: the reading is inaccurate but the engineers had such a good practice that errors hardly exceeded 2%. It was necessary to approximate, of course in excess, and the objects of the past were very robust creating the myth of the *"Olde Good Things"*.



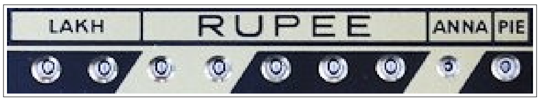
In digital the result is easy to read ...



… but on the slide rule can hardly be seen

The non-decimal systems

The construction of calculators is complicated by the existence of the duodecimal monetary system, borrowed from Roman Empire and spread throughout Europe by Charlemagne in 779, based on the pound (or lira) with decimal units divided into 20 shillings and 240 pence. France, after the Revolution, was the first country to adopt the decimal system, but the designers have always had to confront with the British currency and other weird systems. In the lower left we have a display in pounds, shillings and pennies, also known as LSD (!): the British are conservative and the symbols are still those of "Librae", "solidi" and "denarii" used by the Romans. Alongside there is a display in Rupees.



It was not easy: the pound was decimal, but divided into 20 shillings of 12 pence each and the penny was divided into two halfpennies and 4 farthings. If the price of an item is £ 1 7s.9 ¾ d. (1 pound, 7 shillings and 9 pence, one halfpenny, and 1 farthing) what it will cost to purchase three? £ 4 3s.5 ¼ d. of course!

Life was difficult for designers: lengths were measured in Imperial (12 inches = 1 foot; 3 feet = 1 yard; 22 yards = 1 chain, etc.), weights and volumes were complicated and calculators used in India had to show results in Lakh, Rupees, (1/100.000 Lak), Anna (1/16 rupee) and Pie (1/12 Anna). India adopted the decimal in 1957 and Britain in 1971, but the British argued that it was too hard to learn!

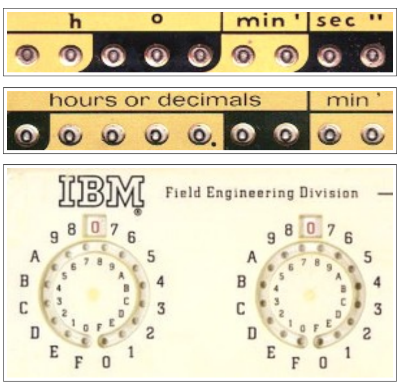
In Italy the decimal was introduced in 1806 by Napoleon, who designed the Italian lira immediately adopted in Lombardy and Piedmont. After the unification the Lira became legal in the country by replacing the chaos of the different currencies circulating in the pre-unification states, some with more complex divisions of duodecimal. An example for Tuscany: 1 Lira toscana = 20 soldi = 1.50 Paoli = 0.60 Fiorini (0.84 Lire italiane); 1 Crazia = 5 quattrini = 1 soldo e 8 denari = 0.125 Paoli = 0.083 Lire toscane (7 centesimi italiani); 1 Fiorino = 100 quattrini = 2.5 Paoli = 1.66 Lire toscane (1.40 Lire italiane).

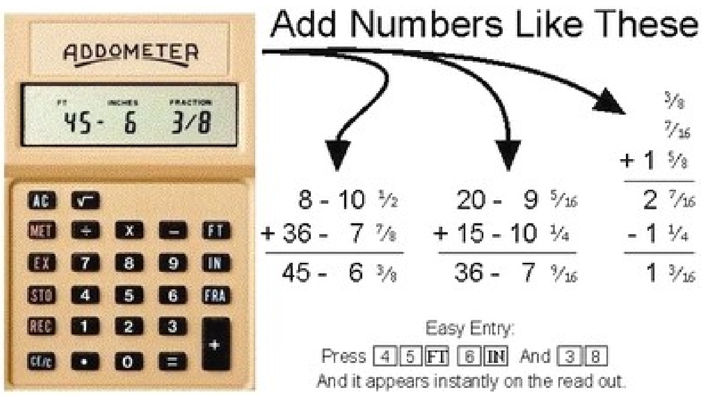
From 1861 were also unified weights and measures: they were dozens and changed at every border, often at each city. The Roman mile was shorter than the mile of Florence or Livorno, similar to the mile of Naples and in any case different from that of Genoa, Venice and Turin. The weights then ...

It 's funny to remember another eccentric monetary system: during the War of Independence, to protest against England, the Americans adopted the Spanish dollar divided into eighths. Hence the expression *"piece of eight"* to define an object of value but, despite having made the dollar decimal since 1776, the division in eighths remained in use until 1998: only in that year Wall Street forbade it in the transactions.

The Americans use the decimal only for the money and still measure in US. Standard, where an inch is divided into eighths or sixteenths. There is also a system in hexadecimal (base 16 digits and 10 letters from A to F in which you write 64 100 and 200 as C8): invented in 1859 is now used by programmers as the computer works in multiples of 8 bits.

In astronomy the time is sexagesimal while in many production processes is measured in decimal hours, but fortunately addiator and pascaline lend themselves to any kind of carryover. For each unit there is a specific calculator but the coexistence of different systems is confusing: in 1999, the *"Mars Climate Orbiter"* disintegrated into the orbit of Mars because the instruments measured the distances in US. Standard passing them to the control center, who believed to receive in decimal. The chief manager said *"People sometimes make errors"* and this expensive mistake became known as *"metric mix-up"*.





Displays in sexagesimal and decimal hours, and a modern US Standard calculator

On board of the first nuclear submarine were used exclusively mechanical calculators: the electronic revolution will come only in 1972

Digital calculators

A digital display of the sixteen century

“For the world and our country: 90 degrees north! The Nautilus had accomplished the impossible”

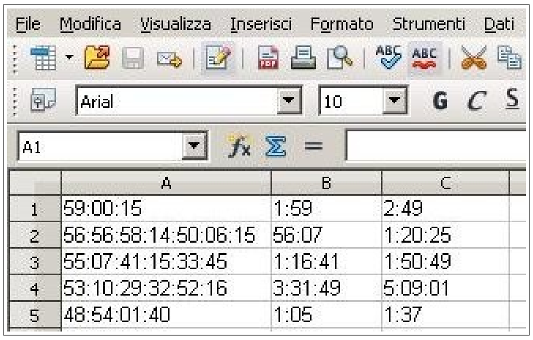
With these words, at 23:15 GMT on August 3, 1958, Captain Anderson announced to the crew that the first nuclear submarine had reached the North Pole navigating beneath the arctic ice cup. On board was still using a mechanical calculator, the latest in a series of machines designed in 1600. Let's look at its history.

The beginning of the calculus and the abacus

The first calculations were carried out with the fingers, in Latin *“digitus”* from which comes the word "*digital*", and were later used stones, marking the results on pieces of bone or wood. The oldest know calculation tool is the Ishango's bone, found in Africa and dated to 20,000 BC. There are marked groups of numbers that make up a sum, as they do even today the shepherds, and this way of representing the figures remained until recent times: the official use was abolished in England only in 1826!

The Ishango's bone

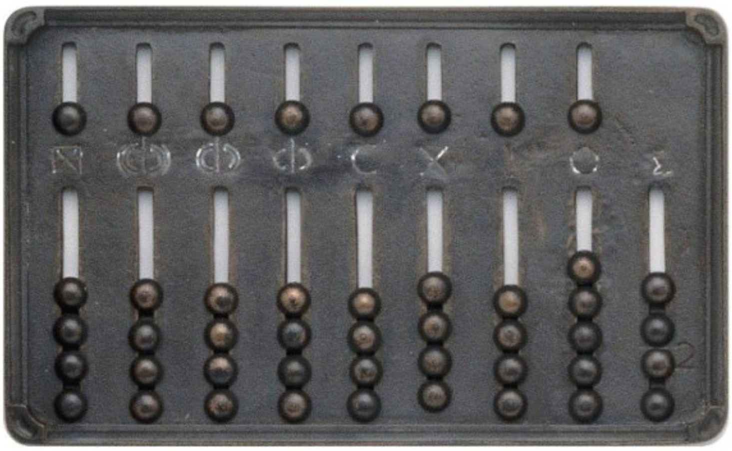
The next step was the abacus, a simple tool to organize piles of stones (in Latin *"calculi"* and hence the term *"calculate"*), while the numbers were now represented by symbols and recorded on clay tablets. Below you can see the attempt to solve the Pythagorean Theorem on a Babylonian tablet and in Excel, really very similar. The systems created by the use of the fingers are often in base 12 (10 fingers + 2 hands) or its multiples, the Babylonians counted in sexagesimal and trace remains in the division of time and angles.

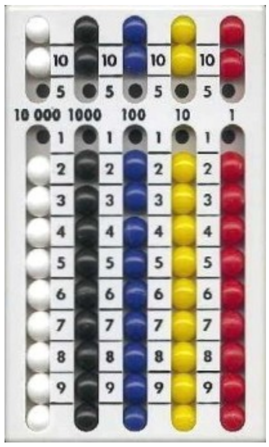


	A	B	C
1	59:00:15	1:59	2:49
2	56:56:58:14:50:06:15	56:07	1:20:25
3	55:07:41:15:33:45	1:16:41	1:50:49
4	53:10:29:32:52:16	3:31:49	5:09:01
5	48:54:01:40	1:05	1:37

Babylonian tablet (ca. 1800 BC) and the same calculation made in Excel

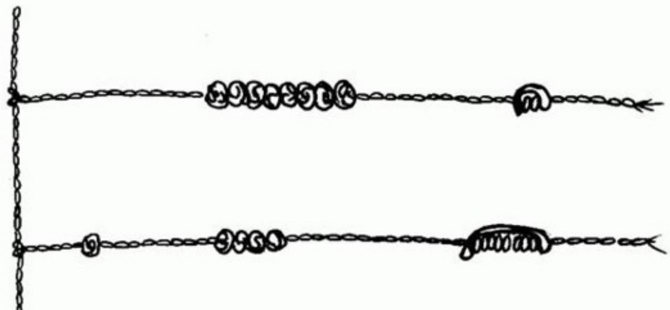
The abacus, invented around 2,500 BC in Mesopotamia, spread everywhere in various forms. The older models had the bottom filled with sand ('Abaq in Sumerian) to keep track of the operations: it was the first silicon memory!





Roman abacus and its modern equivalent

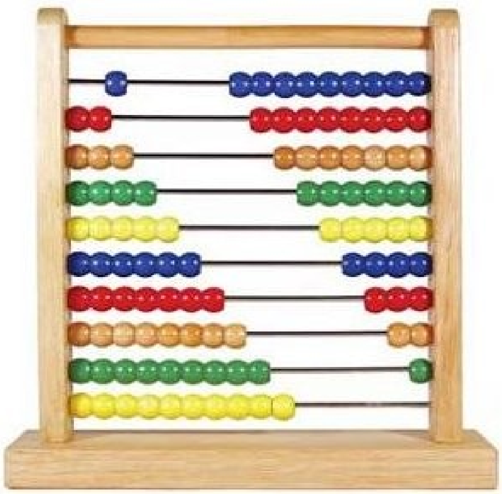
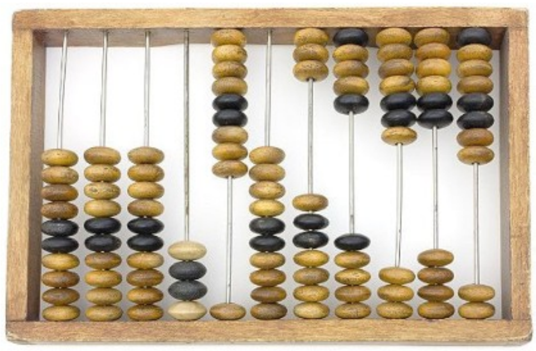
The abacus was adopted by all the people and the Incas had a particular model, composed of cords with knots, which allows to keep track of the transactions still used by the US. Special Forces in operational theaters climatically extremes because ... it works in every condition!




Quipu Inca and modern "Ranger Beads", used by US. Army

The abacus is not a real calculator because it merely assist the operator in performing the operations, but allows to add and subtract very quickly. It was abandoned by Europeans in the Middle Ages and only in Russia continued to be used in stores until the collapse of the Soviet Union.

Japanese' Soroban

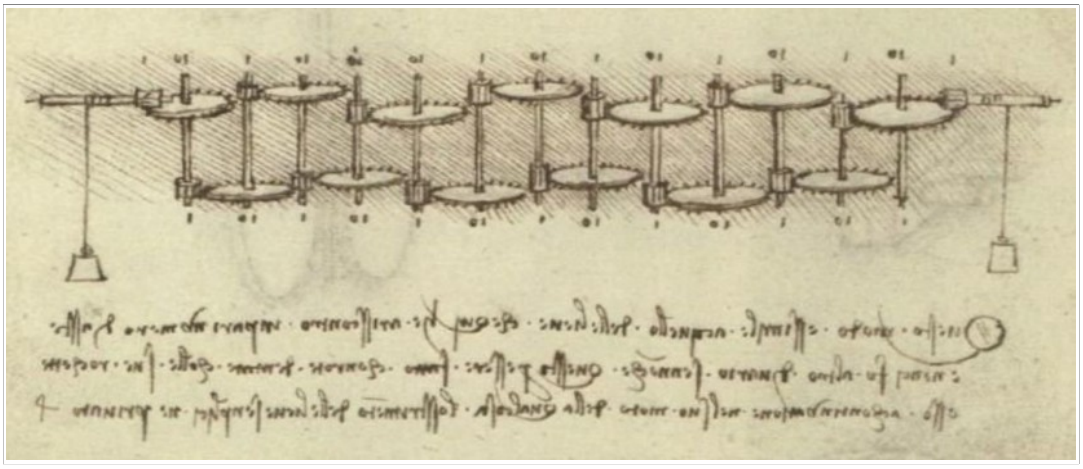
European* abacus *and Russian Schoty

There was also the abacus *"exchequer"* consisting of a board divided into squares on which were moved some small stones, called *"jetons"*. Hence the term *"Chancellor of the Exchequer"* which designates the English Minister of Finance: his predecessors kept the accounts of the crown thanks to an abacus of this type located in the London's tower.

With the development of trade, the Europeans needed more sophisticated tools. Luca Pacioli in 1494 published his *"Summa de Arithmetica"*, presenting in the *"Tractatus de computis et scripturis"* the modern concept of double-entry bookkeeping (give and take, budget, inventory) and proposing the use of Arabic numerals instead of Roman ones. To perform the bookkeeping of the new companies was necessary a calculator.

The first calculators

In 1966 were found in Madrid some of Leonardo's manuscripts considered lost. A drawing seems to represent a calculator but it is probably just a *"ratio machine"* that, like a speedometer or a watch, every turn of a wheel advances the wheel on the side of one step. Is thus solved the problem of carryover that in the abacus is performed manually.



Leonardo design, Codex Madrid, ca. 1500 (Biblioteca Nacional, Madrid)

A reproduction of Leonardo's computer was built by IBM in the 60s, but the original could not work due to excessive friction and the first mechanical calculator can be attributed to the German scientist Wilhelm Schickard in 1623. His calculator was destroyed by a fire in 1640 and was Pascal who finally succeeded in make a working adding machine. In 1673 Leibniz designed a sophisticated computer while the architect Perrault had already designed a couple of years before a practical pocket calculator: the era of mechanical calculation was beginning.

These prototypes were too complex for the technology of the time and could only be built by hand in pieces almost unique, but the patent of Pascal gave life to economic pascaline, that of Perrault to a line of small arithmographs, and the project of Leibniz, later improved by Odhner, was adopted by the major brands for the most prestigious models. The keyboards appeared in the last years of 1800 and the story ends in 1956 with the innovative Olivetti Divisumma, a perfect epitome of all the features always wanted. In the early 70s the appearance of electronic computers wiped out these machines on the market.

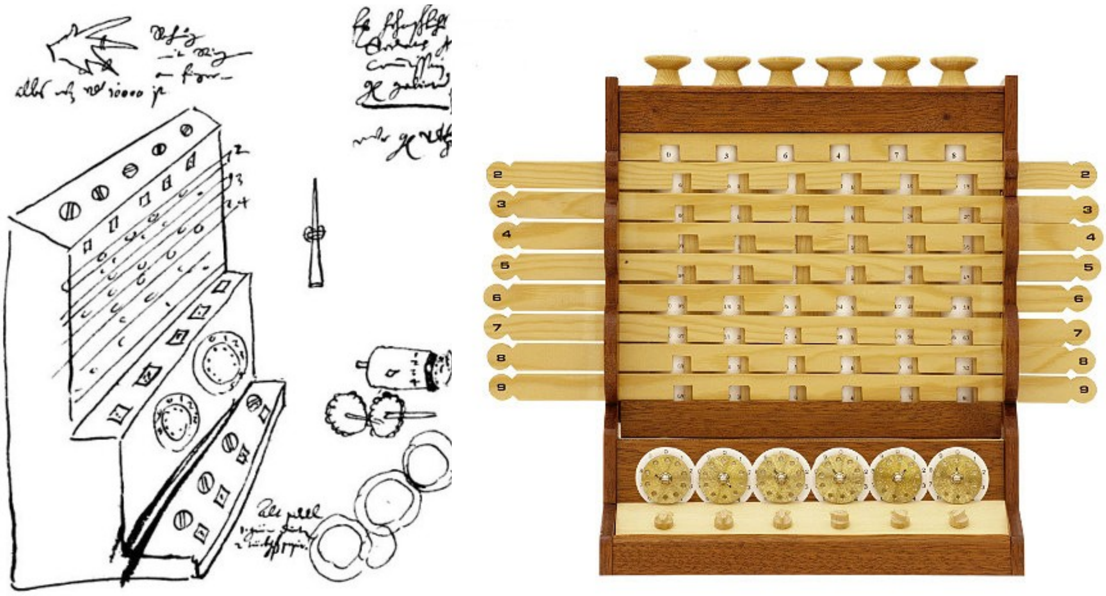
This big calculator, ca 1650 and the little Curta, 1952, are very similar

The mechanical calculators, except the Olivetti Divisumma, are derived from inventions of 1600 and were built until the mid 70s. The history of computing is formed by hundreds of inventors that helped to create the basis for future developments. I am compelled to mention only the most important: it is impossible to mention them all.

Wilhelm Schickard

After Leonardo da Vinci the first real attempt to build a calculation tool can be attributed to the German mathematician Wilhelm Schickard, who in 1623 devised a machine based on the movement of gears. It was destined to Kepler and was able to perform mechanically addition and subtraction, while for multiplication and division used an adaptation of the Napier's rods.

Schickard's letters to Kepler reported that the machine was destroyed in a fire when it was still incomplete and remain only sketches of the project, discovered in 1912, which made possible to realize a functional reconstruction but Kepler had to calculate the orbits of the planets only with the Napier's bones. The main problem was clear: the mechanical calculators do not perform easily multiplications and it is necessary to use mixed systems or mathematical tricks.



The original sketch and the modern reconstruction

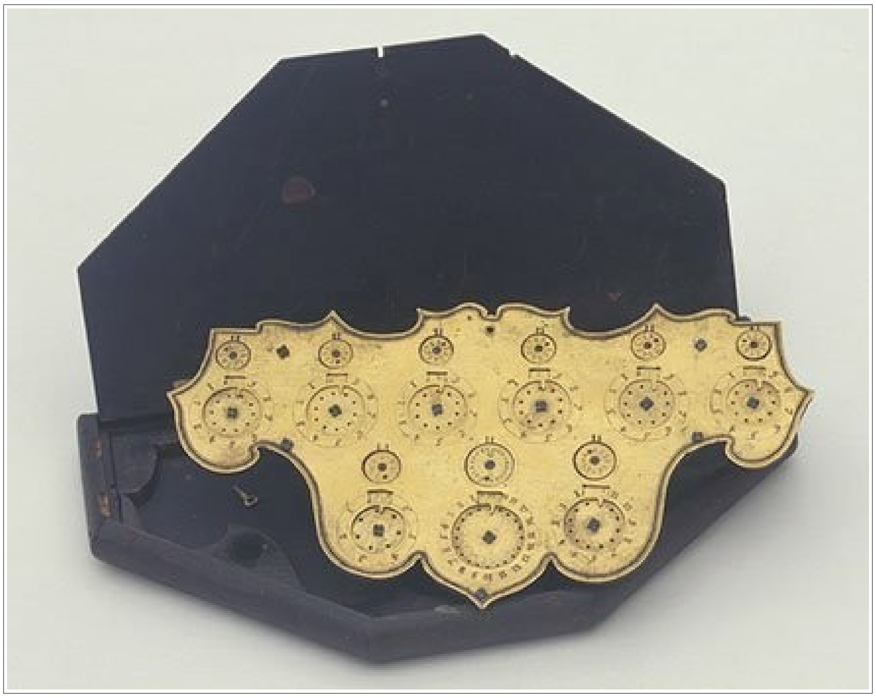
Blaise Pascal and the pascaline

In 1642, at the age of 19, Blaise Pascal built the first commercial calculator. This machine, designed for the French monetary system and called by everyone *"pascaline"*, performed quickly the sum, but for subtract was necessary to use the method of complement to 10 and multiply or divide was not easy. With the Revolution France was converted to the decimal system, but traditions die hard: flowers and eggs are still sold by dozens! In the pascaline shown below the display is split in Thousands, Hundreds, Tens, Nombres Simples (unit), Sols (20 Sols = 1 Nombre Simple) and Deniers (12 Deniers = 1 Sol).

Pascalina, 1650 (replica made by R. Guatelli - Museo Leonardo - Milano)

The invention of Pascal was not immediately successful: at the time was impossible to solve the problem of friction and many tried to improve this machine, often creating beautiful pieces by fancy names, but the pascaline was little used until the advances in technology allowed the development of reliable models.

The most beautiful examples inspired by the design of Pascal were executed by Tito Livio Burattini and Samuel Morland, both given as gifts to Cosimo III de'Medici, but the pascaline remained in the shadows until the strong economic development of the United States pushed the inventors to redraw it rationally.



The wonderful Burattini's Ciclografo, ca. 1660 (© Museo Galileo - Firenze)

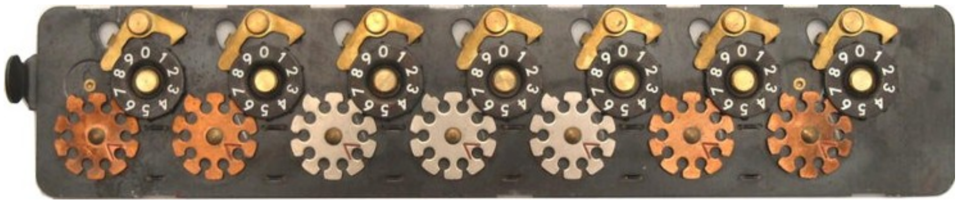
In 1901 appeared on the US. market *"The Calcumeter"*, the first pascaline really cheap and functional. This machine met with great success and was copied by many manufacturers even though it was always difficult to perform subtractions, multiplications and divisions.

The Calcumeter, 1901, one of the first working Pascalines

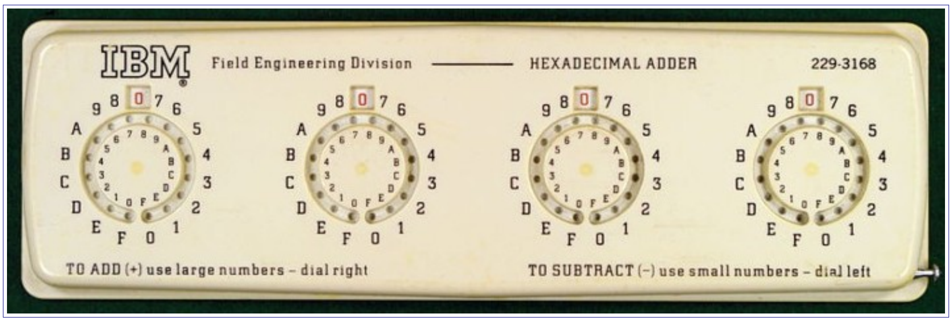
In the 1930 it was finally realized that, by turning the wheel in the opposite direction and using a second reversed numerical scale, it was possible to perform the subtraction as negative addition. The pascaline changed little over the years and the production ended around 1975: it had been built in more than 5 million units.

Still in the 30's models are traditional, but from 1945 …

… subtract is became easy (see the small inverted scale)



In the gears you can see the long teeth that permit the carry

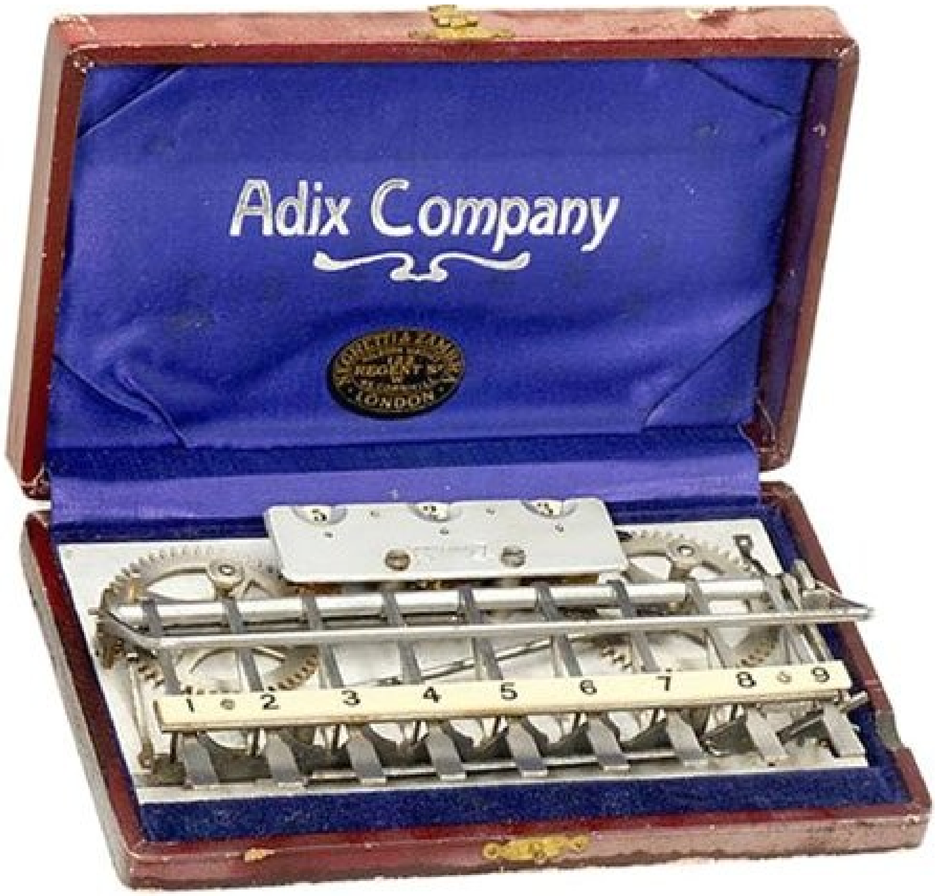


Pocket model in hexadecimal, ca. 1965

The single column pascaline

At the end of the 1800 was very successful a model of pascaline with the display of only two or three digits, able to add just the numbers of each column performing the carry with memory. There were many funny models: the Webb Adder was controlled by sliding it in the thumb, the Stephenson was smaller and thinner than a modern credit card and the Adix had a rudimentary keyboard. All were very successful and some were marketed for over 50 years.

Webb Adder, ca. 1891: a very simple machine



The small Adix had a simple keyboard, ca. 1901

Credit card size: Stephenson Adder, ca. 1890

How to calculate in single column

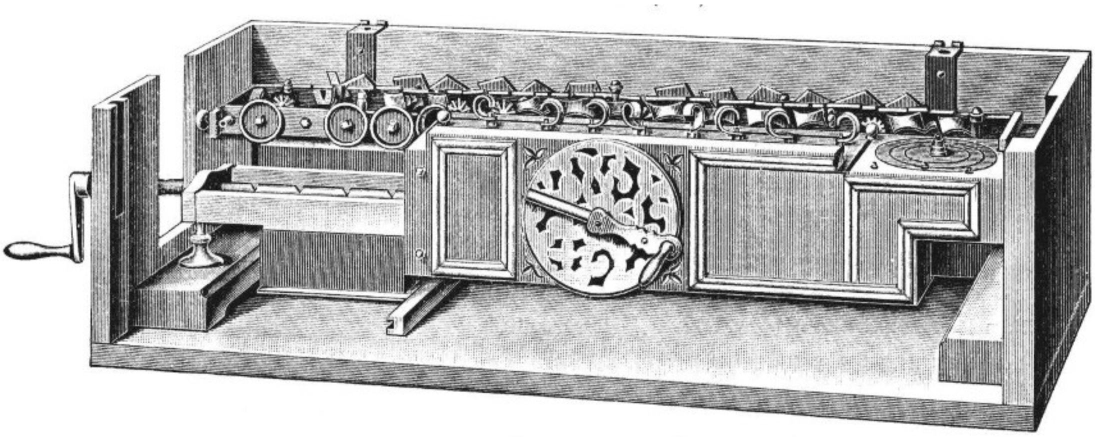
Suppose you have to do this:

   743 +
 1,226 +
 2,365 =
 4,334

Perform the sum of units in the last column, in this case 14, take note of the result, 4, reset, and proceed to the sum of the tens in the adjacent column by adding 1 of carryover. Take note of the result, 13, reset and continue in the same way for hundreds, etc..
In banks and office the managers were very fond of this method: not being able to act quickly employees were forced to pay attention, writing carryovers in margins for future controls. Of course, the subtraction must be performed by the method of complement.

Leibniz and followers

Leibniz in 1673, inspired by the patent of Pascal, designed a sophisticated computer using its innovative *"drum"* (or stepped drum). Addition and subtraction are performed as in the pascaline, the multiplication is carried out by repeated additions: to get the result of 15×4 we must add 15+15+15+15, subtracting we can divide. The technology involved is complex, it is enough to know that we do not need to perform all the sums because the process is mechanized. In the pascaline the numbers are immediately added and the drum saves them in a mechanical memory that allows re-use. Furthermore the drums, one for each column, can sliding in the side allowing to multiply automatically by powers of 10: wanting to perform 540×123 does not need to perform 123 additions, but simply set on the cylinders 540, summing it 3 times, move the drums one position to the left, add 2 times, move and add once. The number of additions or subtractions consecutive is controlled by a lancet: to perform a multiplication it is sufficient to point the lancet on the number of additions desired that the calculator will then perform autonomously.



Leibniz 's calculator in an old print

Imagining a super calculator Leibniz also invented the binary system, presented March 15, 1679 in the manuscript of only three pages *"De Progressione Dyadica"*. Too modern for the time was not understood and the first machine of this type was built in 1936. Today it is the mathematical basis of computer, designed for this purpose when the electricity was not yet known.

The Leibniz's calculator was difficult to build but had many emulators as Poleni, Leupold and Braun, who produced works of art even if not very functional.

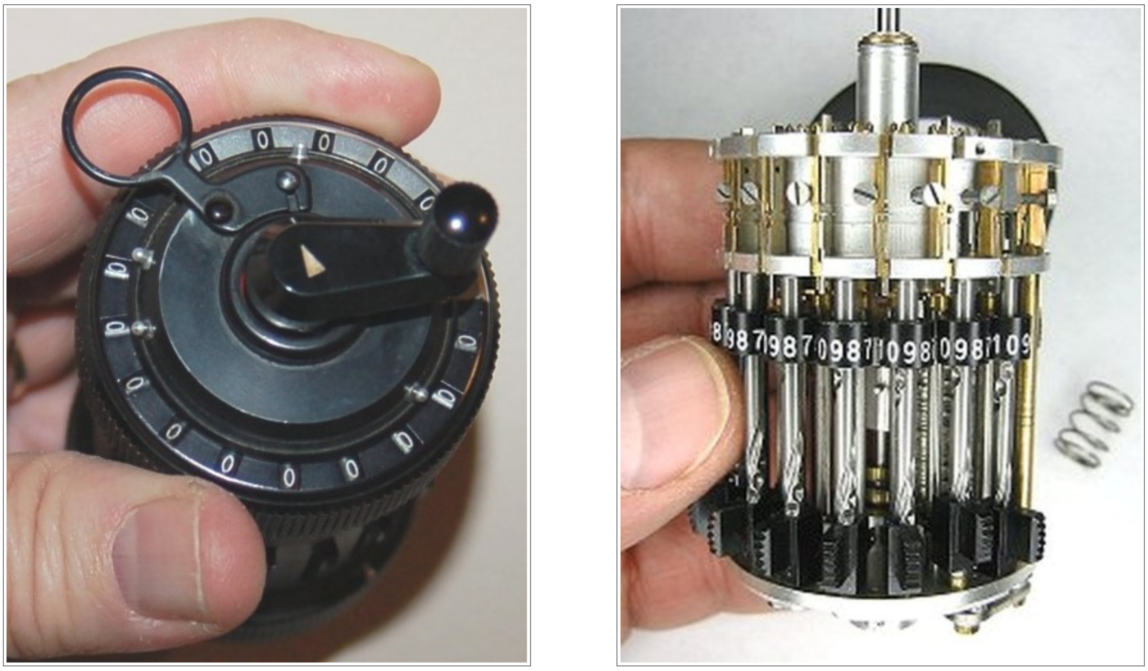
Braun's calculator, 1736

The Arithmomètre, ca 1855

Thomas de Colmar improved the Leibniz's calculator in 1820. Cumbersome and expensive its Arithmomètre, however, was very reliable and was produced until 1915 in 1,500 units.

The Arithmomètre had no followers because Odhner was now flooding the market with its new model of calculator, more light and practical to use.

Finally we can not forget the little Curta, designed by Kurt Herzstark during World War II: 230 grams to perform the four operations with a display of 11 digits, a miniature jewel of great success in spite of the prohibitive cost. The principles of large machines designed 300 years before they were finally realized thanks to modern construction technology. Composed of more than 600 pieces still using the Leibniz's drum but it is the best mechanical calculator ever existed and remained in production until the first half of the 70s.



The fantastic technology of the Curta

Willgodt Odhner

Willgodt Odhner, Swedish engineer and entrepreneur, worked in St. Petersburg in the factory of Alfred Nobel's brother. In 1871, while repairing an Arithmomètre, he realized that it was possible to redesign the Leibniz's drum in a more practical way: it took 19 years before starting production, but his calculator was an instant success. The factory passed soon to his sons who built some 23,000 units before being expelled from Russia during the revolution. This machine is based on the *"Pin Wheel",* ingenious modification to the Leibniz's drum, which speeds up the repeated additions necessary to multiply.

Odhner calculator, ca. 1920 (© Kees Nagtegaal)

It was copied by many companies, the main were: Brunsviga, Triumphator, Walther, Thales, Muldivo, Felix, Tiger and Busicom. The latter has been famous as, in 1970, asked the Intel to create a chip for a modern machine designed to replace the old Odhner project. Federico Faggin, at the time technical director of the Intel, developed the revolutionary 4004 microprocessor and the new Busicom141-PF was the first small electronic calculator: the tiny signature *"FF"*, hidden deep inside, certified the Italian origin.

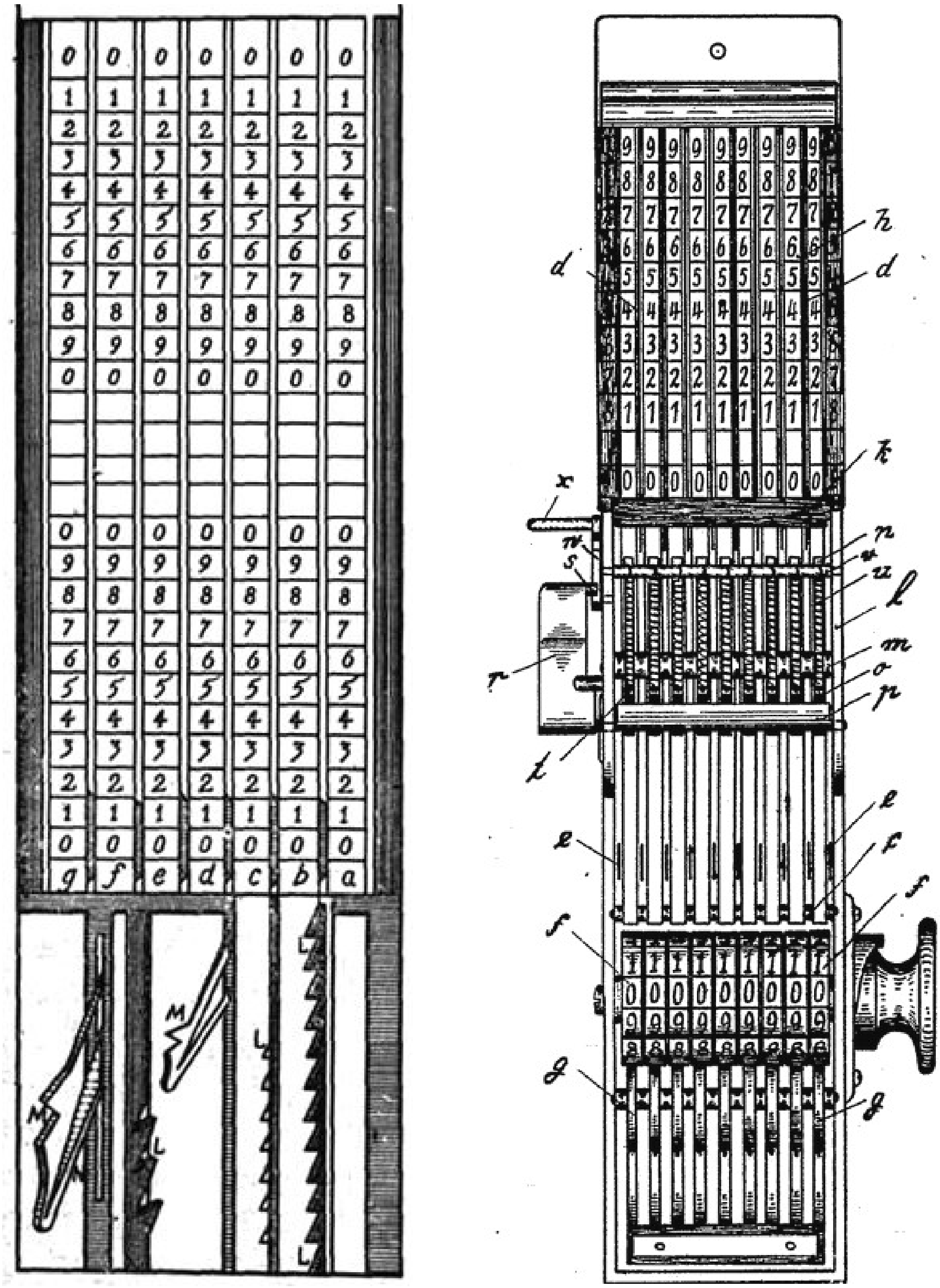
In the 50s, with millions of units built by different companies, the successor of the Leibniz's machine was one of the best-selling calculators and the production increased up to 10,000 units per day in 1970. With the appearance of the new electronic calculators the decline was immediate and in 1972 were no longer marketed.

In two years the world had really changed.

The last mechanical Busicom, ca. 1972

Perrault and the aritmographs

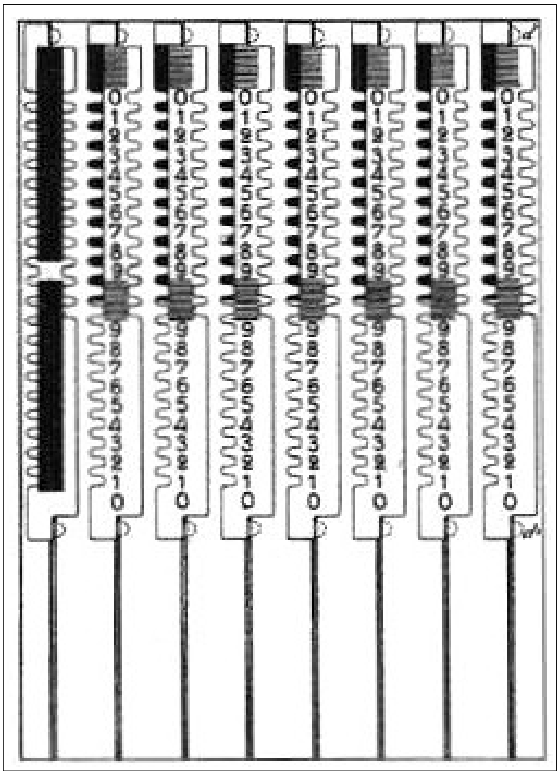
Let's go back a little back in time: the architect Claude Perrault, famous for the facade of the Louvre, designed around 1670 a pocket adding machine, the *“Abaque Rhabdologique”*, passed unnoticed at the time despite his description had been published in 1699. At the end of the 1800 this project formed the basis for a whole series of small Slide and Chain Adder, in which the numbers are inserted by sliding some sliders with the help of a stylus. The differences between the two models are just techniques: Slide Adder use a movable cursor, the Chain Adder a small chain.

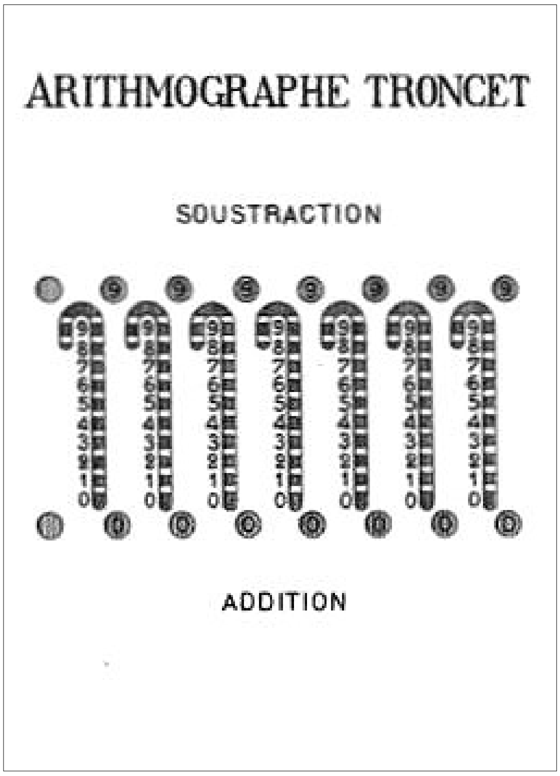


The original patent of Perrault, 1669, and of the Comptator, 1911

The design of Perrault was simplified in 1847 by Kummer, but only in 1889 Louis Troncet managed to successfully commercialize this change. Thus was born a line of small and very practical aritmographs, copied by many companies under the name of “addiator”, and built with no changes until 1988.

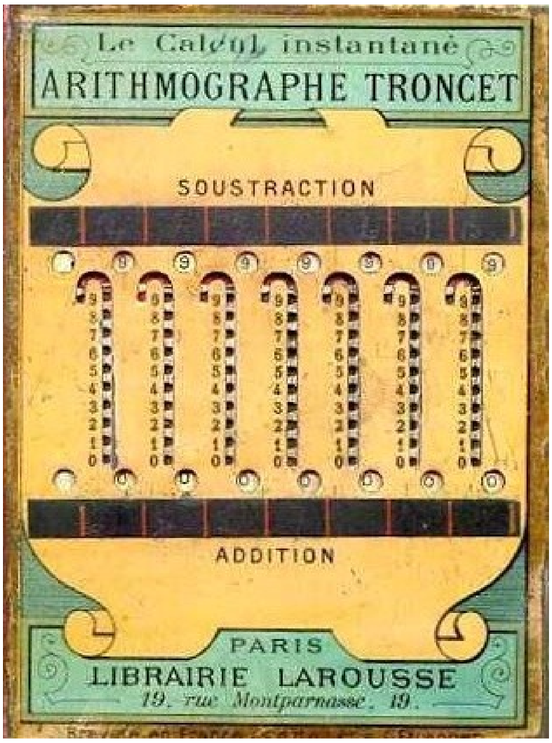
A long life for a simple and ingenious instrument: in those days did not come out something new every 6 months.

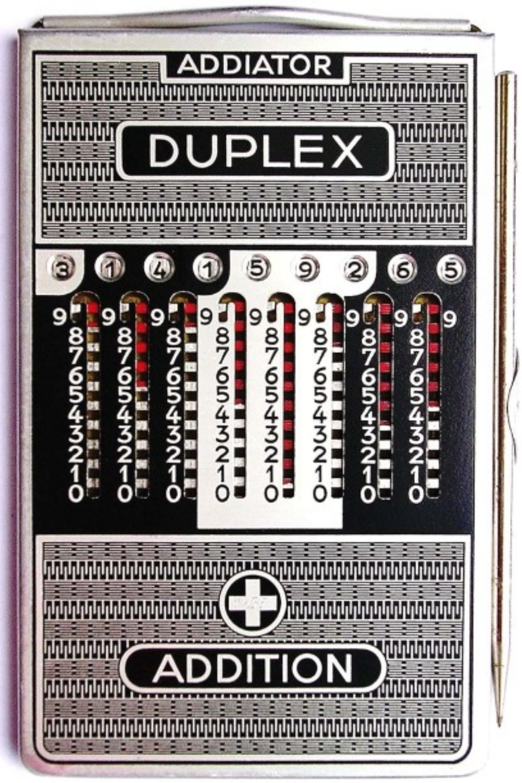




Two draws from the patent of the Troncet, 1889

The addiators normally have two windows to enter the numbers: in the front to add and in the back, with reverse numbering, to subtract or simply one above the other.





The Troncet of 1889 and the Addiator of 1979 does not have appreciable differences

The arithmographs were extremely popular for almost 100 years. They were no longer marketed in Europe after 1979, but remained in production for the Soviet market until 1988 and inventories were still on sale in the early 90s. The Russians, in fact, did not have batteries for the new electronic calculators!

Multiplication tables

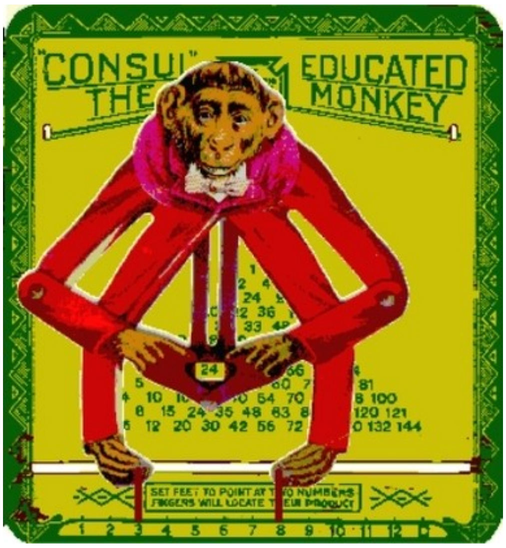
With arithmographs and pascalines it is difficult to multiply and were often accompanied by multiplication tables that allow you to easily make the four operations with a limited investment. There were pocket models and large books very precise: they were used by the Third Reich to set up offices in occupied areas without having qualified personnel. It is sufficient a little care to avoid errors, but the calculation speed is very low.

The Consul Monkey

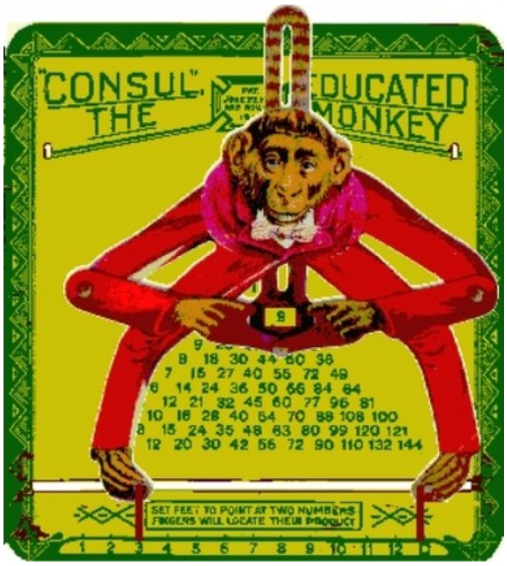
In the early years of '900 had great success this amazing multiplication table, made by the Educational Novelty Company of Dayton, USA. Early example of mathematical toy, it allows the children to learn the multiplication tables without effort, as the advertising said: *"No matter if the students are lazy or careless, the monkey never loses patience"*. Why the name? *Consul* was a trained monkey of the time, well known in all the circuses of USA and Europe.

Set the feet on the numbers to multiply and the result magically appears between the "hands". Of course it also performs divisions: dividend fits between the "hands", divisor fits at right or left foot and the result is read at the other foot. As showed in the example below there is also a square function, but in any case you can"t enter any number bigger than 12.

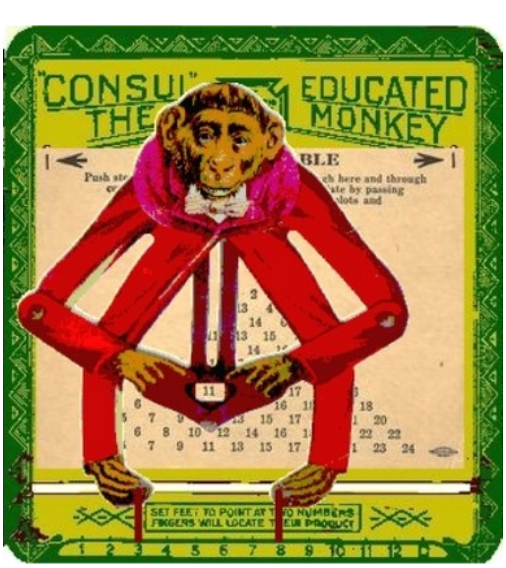
Can also be inserted a card that allows to add and subtract: in this way the children can easily understand the relationship between addition and multiplication, It' a true programmable calculator! Still in commerce and is used in many schools.



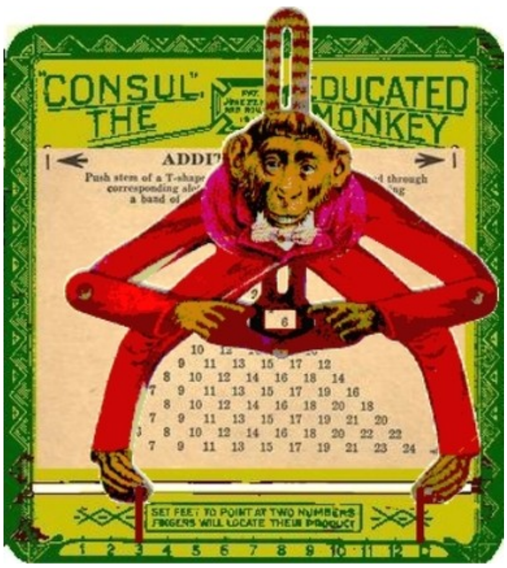
3×8=24 or 8×3=24 or 24÷8=3 or 24÷3=8



$3^2=9$ or $\sqrt{9}=3$



3+8= 11 or 8+3=11 or 11-8=3 or 11-3=8

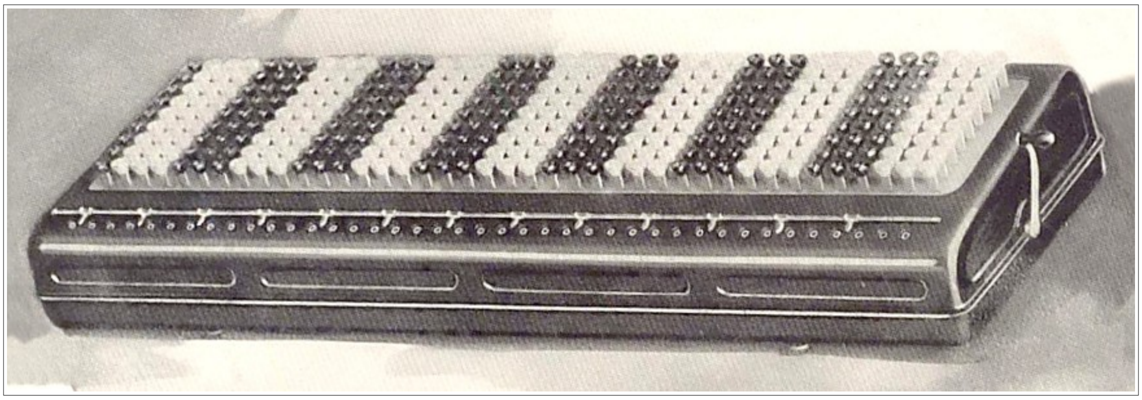


3+3=6 or 6-3=3

Felt and the full keyboard

After several attempts, such as those of Louis Torchi and Tito Gonnella, in 1887 a new category of calculators was born: the Key Driven, equipped with a large keypad that directly actuates the mechanism and the crank only serves to reset. The keys are arranged in columns, one for each decimal point, with the numbers 1 to 9.

A calculator with 6 columns calculates up to 999,999; with 10 to 9,999,999,999; and the Burroughs Duodecillion arrived at this incredible number: 9,999,999,999,999,999. 999,999,999,999,999,999,999,999!



360 keys for the Burroughs Duodecillion, 1915

The project, inspired by the pascaline, was patented by the American Dorr Felt. Funny to remember that the prototype of its Comptometer was built inside a wooden box for spaghetti bought at the grocery store and these machines are remembered as *"Macaroni Box"*. Felt set up its factory with his friend and financier Robert Tarrant, coming soon in dispute with William Bourroghs that in1905 had begun to produce very similar machines.

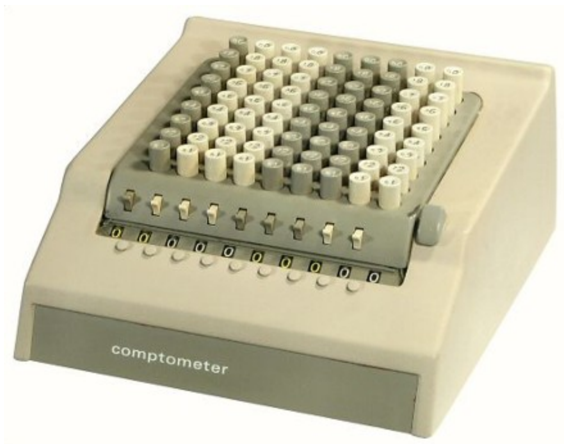
In the Key Driven pressing a button gives the sum of the corresponding value in the correct decimal place, to input the zero must simply jump the column, and all figures are released simultaneously with both hands.

An expert Comptometrist is very fast in executing long series of additions and this keyboard was in use for nearly a century, even in the first electronic calculators.

The Comptometer can also perform multiplication and division, but the procedure is quite complicated. This is an example from the manual:

"To multiply 1364×57 place the first finger of the left hand on the 50 key and the first finger of the right hand on the 7 key. Strike the 57 in this position as many times as the right hand figure of the multiplicand (in this case 4) indicates. Move both finger one column to the left and strike as many times as indicated by the second figure of the multiplicand (in this case 6). Continue to move to the left, striking in each column the multiplier as many times as indicated by the successive figures of the multiplicand".

Very little instinctive and operators must be well trained, but who had the need to run long series of multiplications used specific machines called *"direct multiplication calculators"*.



One of the first comptometers (© Mark Richards) and the model year 1960 (© John Wolff)

The extended keyboards were so complex and expensive that were also realized calculators *"Half Keyboard"* with the numbers on the keyboard only up to 5. This system saved half machine and half price, but 7 had to be typed as 4 + 3. Imagine to perform 6,789.77 + 9,876.96 + 8,690.89: very easy to make mistakes!
The major suppliers were Felt & Tarrant, Burroughs and Bell Punch, but all models were called by the name Comptometer designed by Felt in 1887.

Half-keyboard calculator, ca. 1947 (© John Wolff)

The modern keyboard

The modern keyboard was invented in 1914 by David Sundstrand for its adders and this layout was taken up in many economic machines. In 1945 it was adopted by Olivetti for the Divisumma, the best calculator ever built, thus becoming the undisputed global standard while not particularly practical. The keyboard of the phone is different, it dates back to the dial discs that had the numbers arranged in a row.

Sundstrand's keyboard, touchpad, dial disc and layout of modern phone

The printers

Except that on pascalines and arithmographs printers were mounted on all models of calculators. First was the Felt & Tarrant Comptograph of 1889. Over time were improved, electrified and made smaller.

Old and modern printers

The direct multiplication

All the calculators that we have seen are simple adders that can, with repeated addition and subtraction, perform the four operations. It required a great deal of attention by the operator and many people tried to overcome this limitation. The Spaniard Ramón Verea and the French León Bollée, the last known as the creator of the *"24 hours"* of Le Mans, built some machines that multiplied directly but was the Swiss Hans W. Egli who, inspired by the principles of Leibniz, patented in 1893 the first calculator able to multiply effectively. His *"Millionaire"* was moderately successful and in 1913 he began to produce a new model called MADAS (Multiplication, Automatic Division, Addition and Subtraction). The Millionaire ended his career in 1920, but for its extreme robustness remained in use for over 30 years in many offices. This kind of calculators are heavy to operate by handle and were equipped with electric servo motor.

The Millionaire with the servo motor, ca. 1910 (© John Wolff)

Trying to improve the performance of the MADAS, the American J.R. Monroe built from 1914 his own line of calculators. Composed of more than 4,000 pieces were obviously very expensive and were mainly used in scientific laboratories or where there was need for many multiplications with untrained operators. At the time the offices chose different models depending on the task to perform, and a full functionality in all operations was reached only in 1956 with the Olivetti Divisumma. The direct multiplication was also developed by other factories like Friden and the Italian Lagomarsino.

The first and the last Monroe calculators, 1920 - 1970 (© John Wolff)

Olivetti and the Divisumma

Natale Capellaro joined Olivetti in 1916 as an apprentice worker, in 1943 became Director of Projects and from 1960 was Technical Chief. Two years later he was awarded of an honorary degree in engineering and for his extraordinary achievements deserves a prominent place among the great inventors.

In the early days he was assigned to the assembly of typewriters but later will be the creator of almost all calculators. His first model was the Elettrosumma of 1945, which was followed in 1956 by the fantastic Divisumma that poses the Olivetti at the top of the world market. It was the first calculator capable of performing the four operations without the need for skilled workers, with modern features without deriving from the principles of 1600. The goal of many inventors had finally realized, unfortunately late, and these machines, with built-in printer and keyboard type Sundstrand, were short-lived: the electronics was now reaching maturity and the latest Divisumma models were no longer mechanical.

The series included the Multisumma (addition, subtraction and multiplication), the Divisumma (including division) and the Tetractys, equipped with a mechanical memory, electric motor and double totalizer, which represented the state of the art. None had the display, the numbers entered and the results could be read only after they are printed. The secret of their speed (very briefly) was this: they found the quickest way to operate according to the requested operation, reducing for example 3 x 99,999 to 3 x 100,000 - 1, then using a very short time. Nothing like it had ever been conceived before and Marcello Nizzoli, Ettore Sottsass and Mario Bellini oversaw the design, creating works of reference for the style of the period.

They were complex mechanism to build but were marketed up to 10 times the cost of production and, despite the very high price, more than a million and a half were sold: the Divisumma was therefore essential for the prosperity of Olivetti and was jokingly called *"The goose that lays the golden eggs"*. The high gains slowed the company in the development of electronic calculators because the management was convinced, as Henry Ford with his "T", that traditional calculators would always be sold without the need for further investment. A missed opportunity for Olivetti, where at the time was employed the brilliant Pier Giorgio Perotto. He was considered *"a hunter of butterflies that would never do anything"* but in 1965 introduced with these words his *"Perottina"*, the first personal computer in history, at the Bema Show in New York::

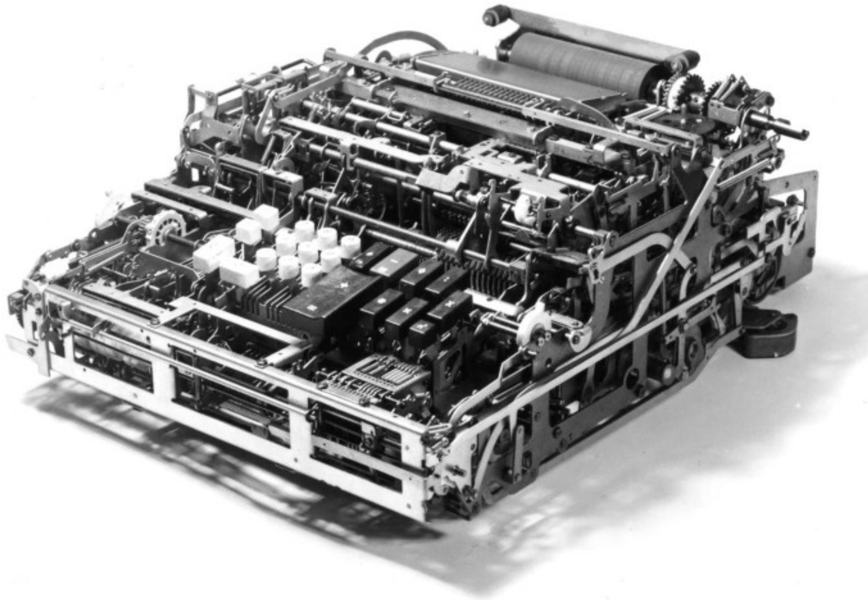
"I dreamed of a friendly machine which delegate those tasks that are due to mental fatigue and error, a machine who could learn and then perform obediently, the use of which is within the reach of all. For these reasons I created a new electronic language that needs no interpreter". Leibniz or Bill Gates would not have been able to tell it better.

No one had ever come so close to the goal, but the project was not supported by the management and the history of the computer went on another continent. The competitors had realized its potential and began to copy: in 1967 the innovative Desk Top HP 9100 proved to be a clone of Perottina and HP had to pay a fine of $ 900,000 to Olivetti, which then gave to Perotto a symbolic dollar: this was the thank for having started the electronic revolution. Today the Olivetti Programma 101, the official name of Perottina, is exposed in the MoMA of New York along with the Divisumma.

Olivetti Divisumma, ca. 1960 (© John Wolff) and the "Perottina", 1965

The end of an era

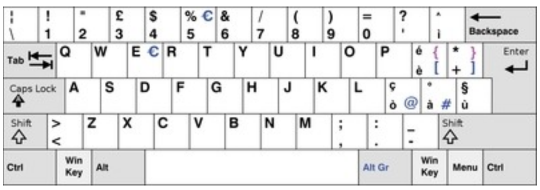
In the 60s the mechanical calculators were used in all commercial and financial applications: data processing centers had the direct multiplication models, in large offices there were the Odhner type, derived from the project of Leibniz and the Key Driven invented to the 1800. Small shops had the pascalines, the aritmographes designed by Perrault in 1600 were always present in all the pockets and the Olivetti, although arrived later on the market, were quickly conquering it. The first electronic calculators had excessive costs and there was no competition until 1970, when the spread of transistors and LED's allowed the creation of small and affordable equipment.



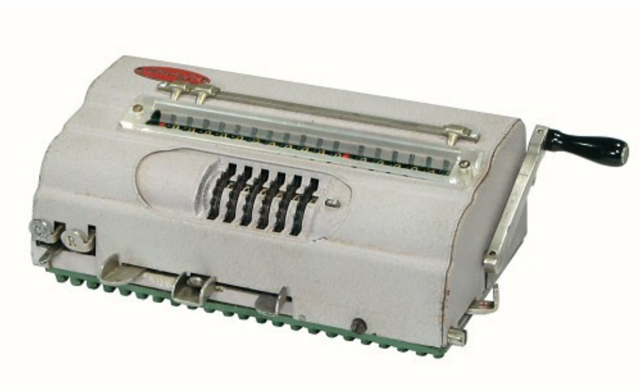
Olivetti Logos, sometimes still surviving in the Post Offices (© John Wolff)

However the transition was slow: engineers and scientists have replaced immediately their slide rules, but in the offices these machines were changed only when they broke. There was in fact a generation of workers well trained to use them, and for this reason we still to write with the same keyboard invented in 1878.

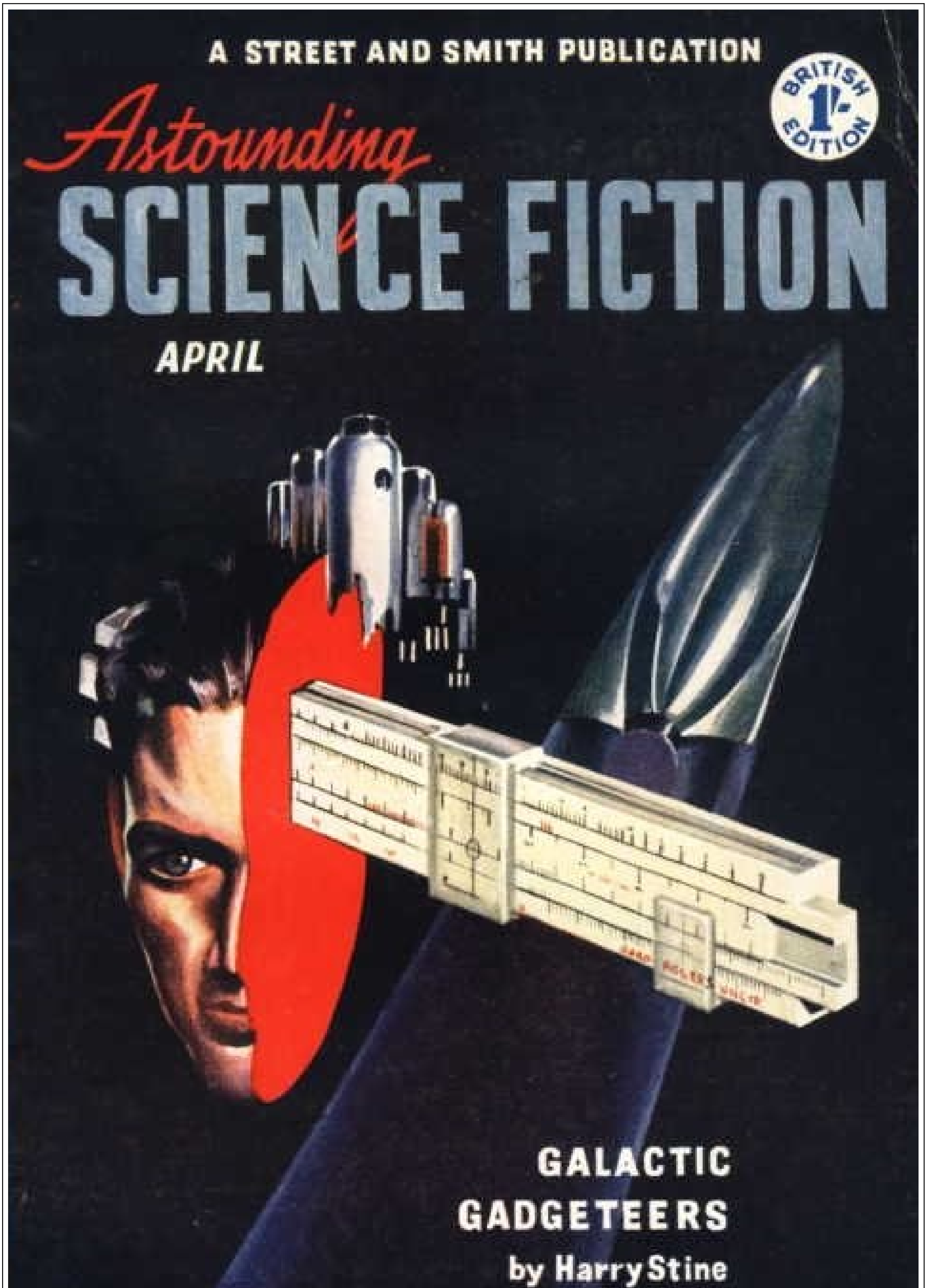
Using a more modern one we would not be faster, but only confused: would you like to change the old one on the right with the new?



Keyboard "qwerty",1878, and modern ergonomic model, 2004

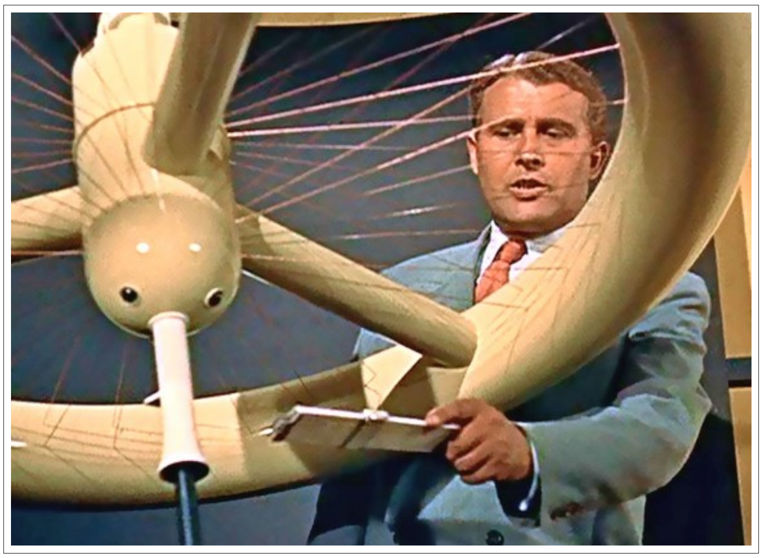


Mini mechanical calculators and an electronic model, ca. 1970



The analog calculators were considered irreplaceable and their use was imagined also far into the future: what will be tomorrow of our computers?

Analog calculators



von Braun with his slide rule (Courtesy of Disney Studios)

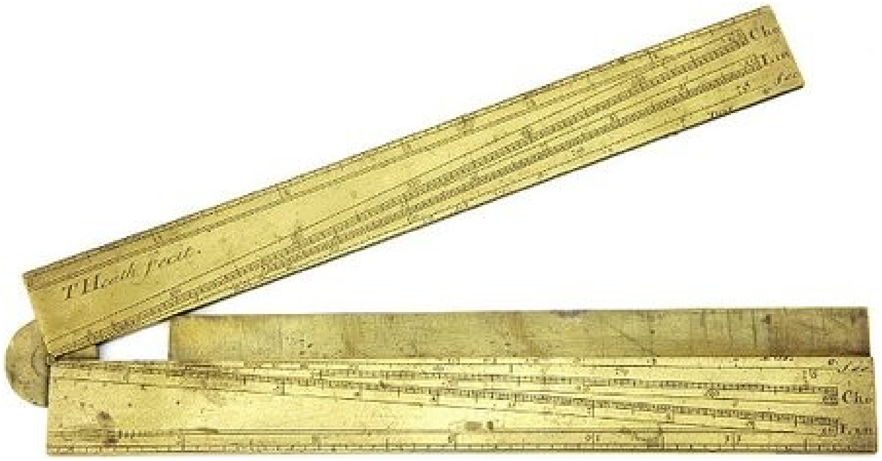
“Houston, Tranquility Base here. The Eagle has landed”

with these words Neil Armstrong announced the landing on the Moon. One of the on-board computers was a pocket slide rule, supplied to all the Apollo missions. Invented in 1622 this tool reached the outer space: a history long time forgotten, overtaken by a digital age that seems to exist since forever.

Galileo's compass

In the sixteenth century for the development of science was necessary to calculate with big numbers and the old systems were no longer sufficient. Many searched for a solution, but at the end of 1500 Galileo was perhaps the first to develop a tool that help to solve mathematical operations: multiplication, division, roots, calculation of areas and volumes, measuring gauges of guns. His *"Compasso geometrico et militare"*, based on the proportionality of corresponding sides of two triangles, was very convenient for aiming artillery pieces and Galileo advertised it with modern methods, selling throughout Europe accompanied by a comprehensive instruction's booklet entitled *"Le operazioni del Compasso"*.

Around 1620 Edmund Gunter added to it a logarithmic scale, to help in solving multiplications and divisions. This model, known as *“Sector”,* was used in the Royal Navy until the Second World War.



Pied de Roy, ca. 1770, the French model of the Galileo's compass

The use of the compass involved many steps, to be performed with the help of a pair of dividers, and this system was too slow for the mathematicians. No one could find a better solution until the invention, made by John Napier, of the famous *“Napier's bones”*. They were presented in his book *"Rabdologiæ"* (from the Greek *rabdos* and *logos*: calculation with sticks) in 1617. Kepler used them immediately in order to calculate the orbits of the planets, stating that they had shortened his work at least 400 years: the adventure of the scientific computing had finally begun.

For this work Napier was inspired by a type of multiplication system invented in India, widespread in medieval Europe and still used in Turkey, where the operations are performed by filling some boxes, divided in half by a diagonal.

Napier synthesized this system printing the products on sticks of wood or bones: the boxes were precomputed and to perform the multiplications was needed only to add.

At the time even the educated people had difficulty with multiplication and this calculator was produced in many variations until the first half of the twentieth century.

The bones does not work good with decimals and to solve this problem Napier made a great intellectual effort finding logarithms, which truly revolutionized mathematics: let's see this brilliant idea in detail.

A wooden set of Napier's bones

Logarithms and Gunter's Scale

The mathematician John Napier argued *"Perform calculations are slow and often difficult task and the boredom that ensues is the main cause of the alienation that people feel towards mathematics"*. He found a solution in 1614 by inventing the logarithms, published in the book *Mirifici logarithmorum canonis descriptio*, capable of expressing any positive number using powers. Since the product of two powers with the same base is a power with the same base and exponent given by the sum of the exponents, with logarithms multiplications and divisions can be made as simple additions and subtractions.

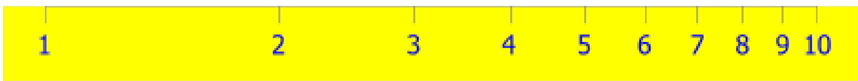
To multiply two numbers just look out for their logarithms and add them together: the result is the number whose logarithm correspond to the sum. In practice the logarithm of a number in a certain base is the exponent to which the base must be raised to obtain the number. The logarithm of 10,000 in base 10 is 4 (10^4 = 10,000) and 10,000×1,000 become $10^4 \times 10^3 = 10^{4+3} = 10^7$ = 10,000,000. Multiplication and division of exponents allow to find squares, cubes and roots.

Things get hard when dealing numbers other than 10: we need a volume with more than a million values, but the tables had a very long life as they were cheap and precise; publications ceased around 1975.

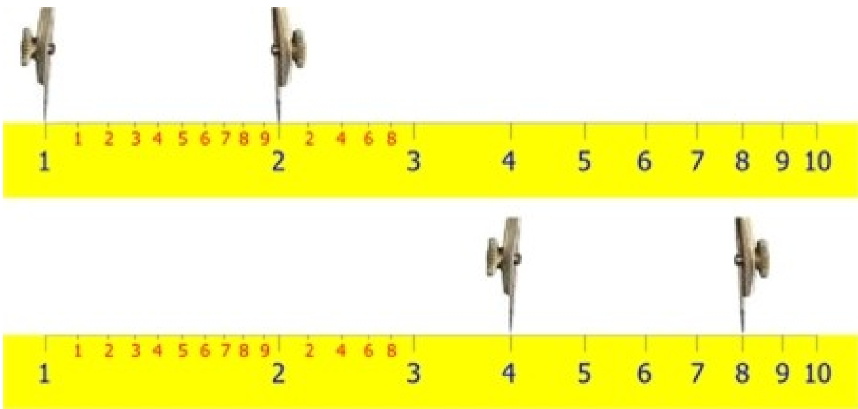
Calculate with the table is slow and in 1620 Edmund Gunter, to make it faster, designed the logarithmic scale by marking the numbers on a ruler at a distance from the origin proportional to the value of their logarithm:

1	2	3	4	5	6	7	8	9	10
0	0,301	0,477	0,602	0,699	0,778	0,845	0,903	0,954	1

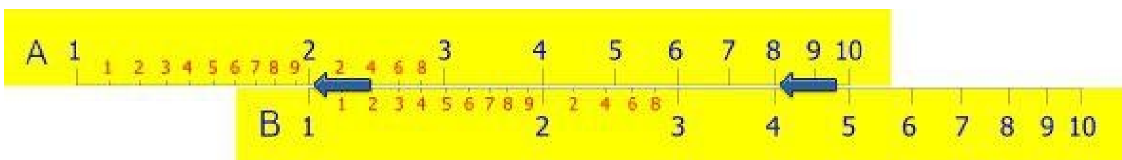
Now we can construct the scale: the 1 is the starting point, the 2 is located at 3.01 cm, the 3 at 4.77 and so on up to 10. We can therefore represent each number as we can read, for example, the number 3 as 30, 300, 3,000, 0.3, etc. With this system the results are less accurate than using of the tables, but the work is easier.



Instead of search the logarithms in the tables we can simply add them with the help of a compass. To perform 2×4 we open the compass between 1 and 2 and then, keeping the same opening, we put a tip on 4: the other tip will indicate the result and to divide we use the opposite proceeding.



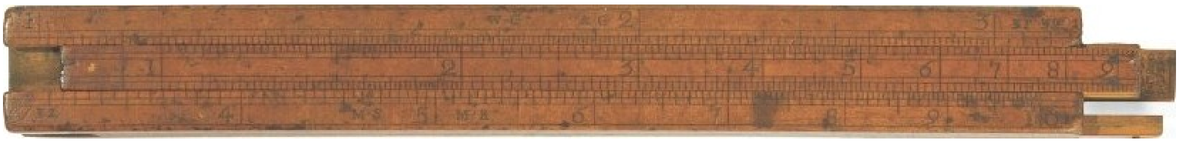
The Gunter's Scale remained in use for 300 years despite the slide rule was invented in 1622. In that year William Oughtred marked the logarithmic scales on two sliding parallel rulers: to perform 2×4 we align the 1 of scale B in correspondence of 2 in scale A and the result can be read on the same scale above the 4 of scale B; to perform 8÷4 we just put the 4 of scale B under the 8 of scale A and read the result on the same scale above the 1 in scale B.



The calculation has finally become fast and this tool will reach the Moon!

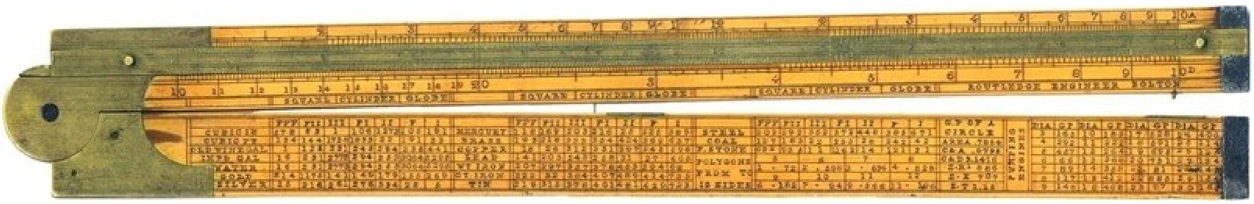
The slide rule

In 1654, just few years after the invention of Oughtred, Robert Bissaker made the *"Gauging Rule"*, with 4 slides, specialized in measuring the contents of the barrels of wine, beer or spirits and calculate the tax burden. A very successful instrument that was marketed for over 300 years.



The Gauging Rule of Thomas Everard, half of the eighteenth century

In 1677 Henry Coggeshall created the *"Carpenter's Slide Rule"*, mounted on two wooden rulers with the gradation in inches, the central sliding scale in bronze and several other scales to solve various problems. It is a combined instrument that has allowed the common people to measure and calculate, remained in use until the beginning of 1900 especially in shipyards and workshops.

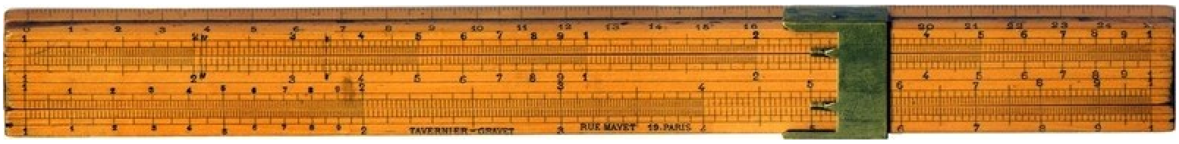


Carpenter's Slide Rule, ca. 1840

At the beginning of 1700 there were slide rules specific to all the needs of the time: the Carpenter's Slide Rule was used to find the volume and weight of shipments of timber, the Gauging Rule to calculate the taxation of beer barrel, while the Gunter's Scale allowed a great work: the mapping of the United States.

Towards mid-800, however, there was a pressing need for computational tools not only specialized in tax or workshop use and, essentials for the design of steam engines and the development of railroads, generic slide rules began to appears, soon becoming the secret weapons of the Industrial Revolution.

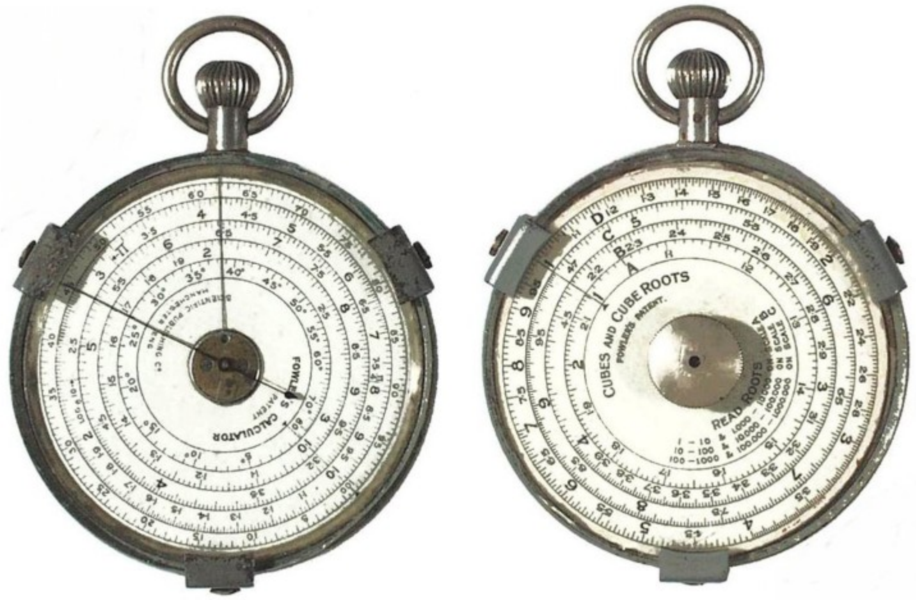
In 1859 the French artillery lieutenant Amédée Mannheim perfected the scales introducing the movable cursor: the modern slide rule was born.



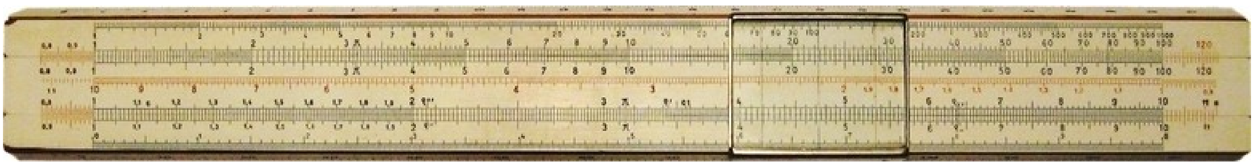
With the Mannheim slide rule appears the cursor, ca. 1860

Around 1920 the slide rule had assumed its final form: Einstein used it to develop the theory of relativity, Marconi for the radio, Fermi for the atomic bomb, Korolev for the Sputnik program and von Braun for the engines of the Saturn V, the Apollo vector. In order to improve accuracy, proportional to the length of the scales, where produced very large models also circular or cylindrical.

Fuller's cylindrical slide rule, ca. 1915



Fowler's round pocket slide rule, front and rear, ca. 1920



Classic Nestler 23 slide rule, the model preferred by Einstein, ca. 1930

The first computers appeared around 1946, but they were huge and expensive, the same IBM planned to sell up to four a year, and the slide rules seemed irreplaceable. Nobody imagined a world without them: they served to housewives in the kitchen, to tracing the routes on the *Star Trek Enterprise*, appeared on the cover of Playboy, were also proposed in the form of cuff links and tie clips.

COOKING

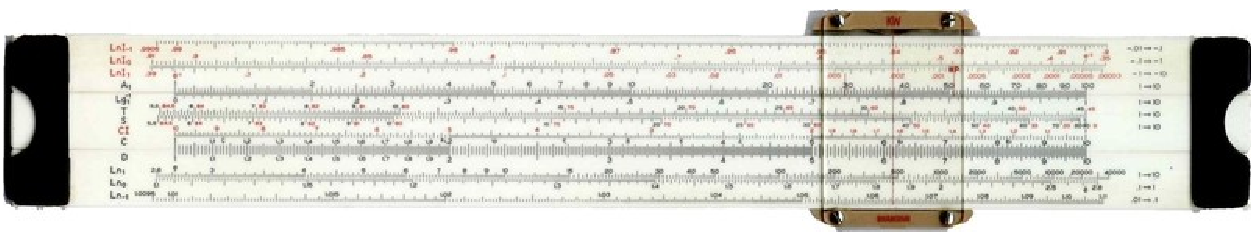
If a roast of beef should be roasted 12 minutes to the pound, how long will it take to cook a 5¾ pound roast?

Answer: $12 \times 5.75 = 69$ minutes.

$= \frac{69}{60} = 1$ hour, 9 minutes.

Tie clip and instruction for use the slide rule to cook, ca. 1950

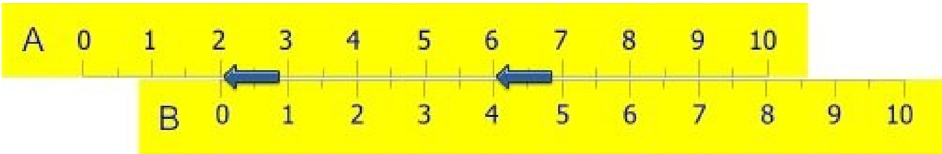
Walt Disney had a simplified model for the children, was built in Braille for the blind, with scales dedicated to solving statistical problems and also in hexadecimal, octal or binary for computer programmers: it was the laptop of the era, always sticking out of engineers' pocket. A true sign to identify the category.



Modern slide rule, ca. 1960

The basis of the slide rule

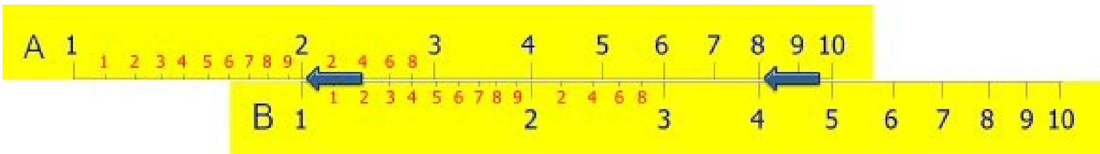
The slide rule, being an analog instrument, replace the mathematical functions with linear measurements. To show how it works let's start to see how we can execute an addition using two common metric rules: to add 2 and 4, align first the 0 of the rule B with the 2 of the rule A. We have set 2+ and the sum can be read on the mark of slide A corresponding to the second addendum.



To perform 2+6 we don't need to move again the rule (set on 2+), but just read the sum directly on the figure 6 of the B rule. To subtract we use the opposite proceeding.

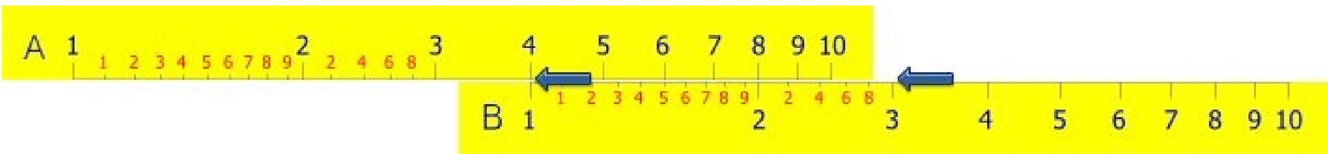
From the accuracy of the construction depends the precision of the results but, also dividing further the scales, it is not possible to operate with numbers greater than 100. It 'is therefore clear that, as regards the addition and subtraction, the slide rule is much less practical than the abacus and to any other type of calculator. This system, however, becomes very powerful if the scales are drawn using the logarithmic succession that we have seen previously.

To perform 2×4 we align the 1 of scale B in correspondence of 2 in scale A and the result can be read on the same scale above the 4 of scale B.

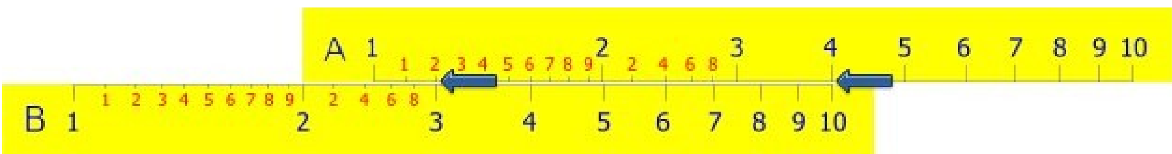


We now have a tool that can perform multiplication (2x with this setting); the previous picture also shows how to perform 8÷4: just put the 4 of scale B under the 8 of scale A and read the result on the same scale above the 1 in scale B.

There are also some disadvantages: if we want process 4×3 the slides are positioned as follows:



The total is now located out of the scale. To solve this problem, we need to use the 10 of the rule B, instead of the previous 1:



So we obtain 1.2, but the right total is 12: the slide rule gives only the numbers and how to locate the dot or how to add tens or hundreds we must find by ourselves.

$$\frac{\sqrt{\sqrt{\sqrt{(0.424 \times 6.13)^3}}}}{2.63 \times 0.41 \times 3.27} \times \frac{\left[\frac{0.008}{21 \times 63}\right]^3}{0.000000278}$$

This was just a brief outlook on how the system work, but the slide rule has many other scales and can reach the computing power of a modern calculator. His only flaw is the poor readability, but an equation such as this on the left can be solved in few minutes. The secret is: practice and to start you can download from my website several paper templates of slide rules very easy to build.

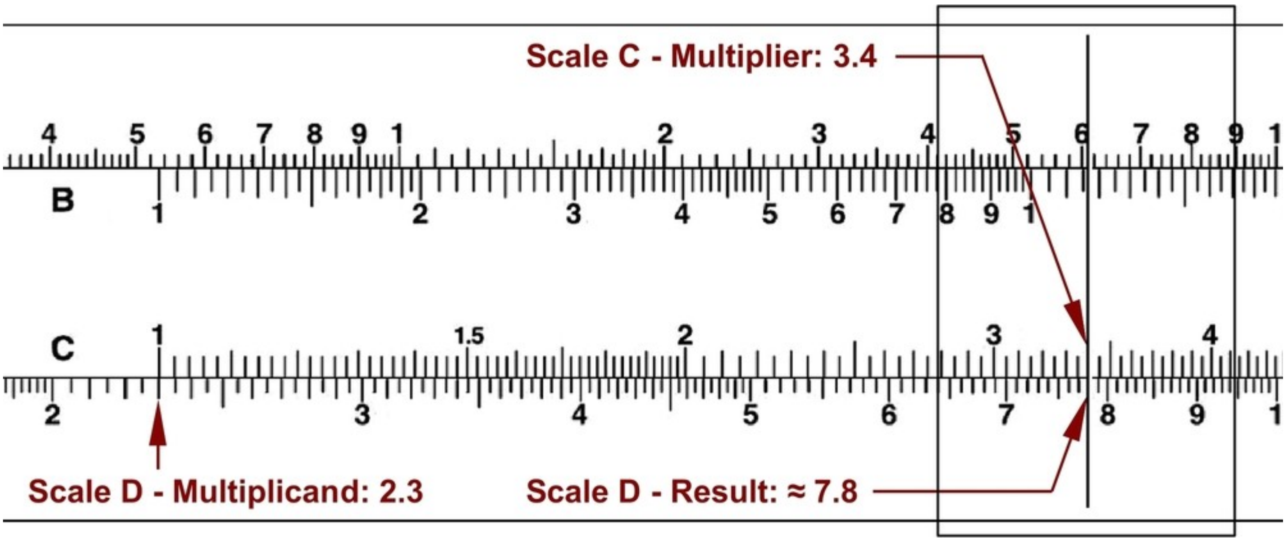
The slide rule - Examples to practice

In the slide rules the scales are indicated by letters: the two most important are on the slide (C) and on the body (D). The others are used to simplify the calculations when you are in the presence of square roots (A and B), cubes and cube roots (K), exponential (LL), etc. up to more than 30. In this simple slide rule we find only the essentials: A-B-C-D. As cursor we will use just a clip, then the numbers should not be placed under it, but immediately to his left side.

Multiplication (uses C and D scales)

Example: 2.3×3.4

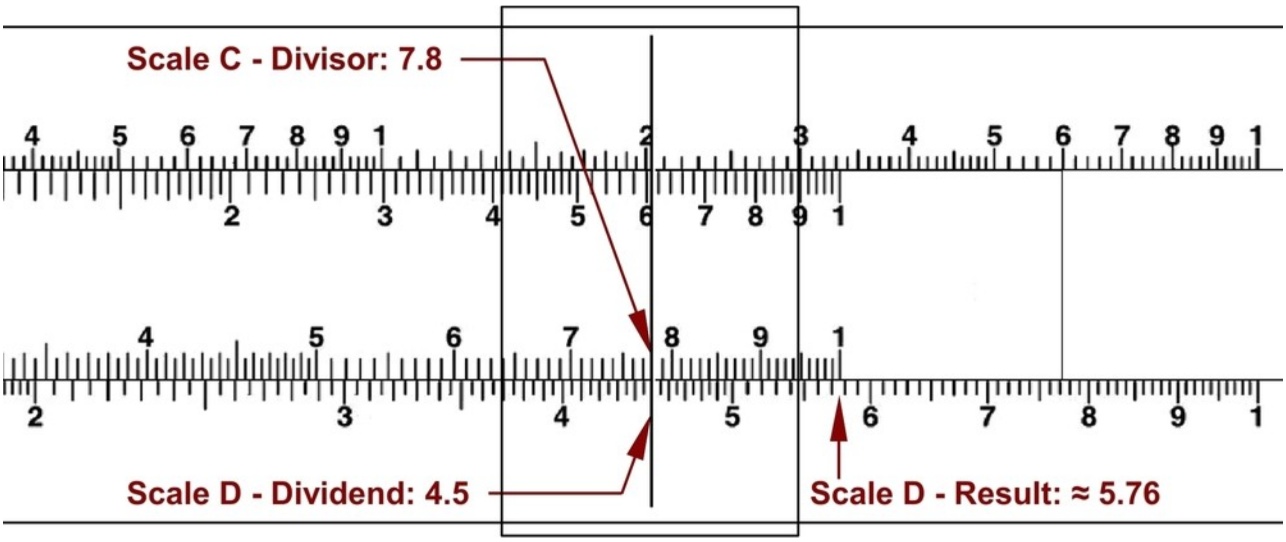
- slide the **C** leftmost '1' on by side 2.3 on the **D scale**;
- move the cursor by side 3.4 on the **C scale**;
- the cursor is on the **D scale** just a bit over 7.8. The correct answer is 7.82.



Division (uses C and D scales)

Example: 4.5÷7.8

- move the cursor by side 4.5 on the **D scale**;
- slide 7.8 on the **C scale** by side the cursor;
- the **C** rightmost '1' is now at 5.76 on the **D scale**. We know that the result of 4/8 is near 0.5, so we adjust the decimal place to get 0.576. The correct answer is 0.576.



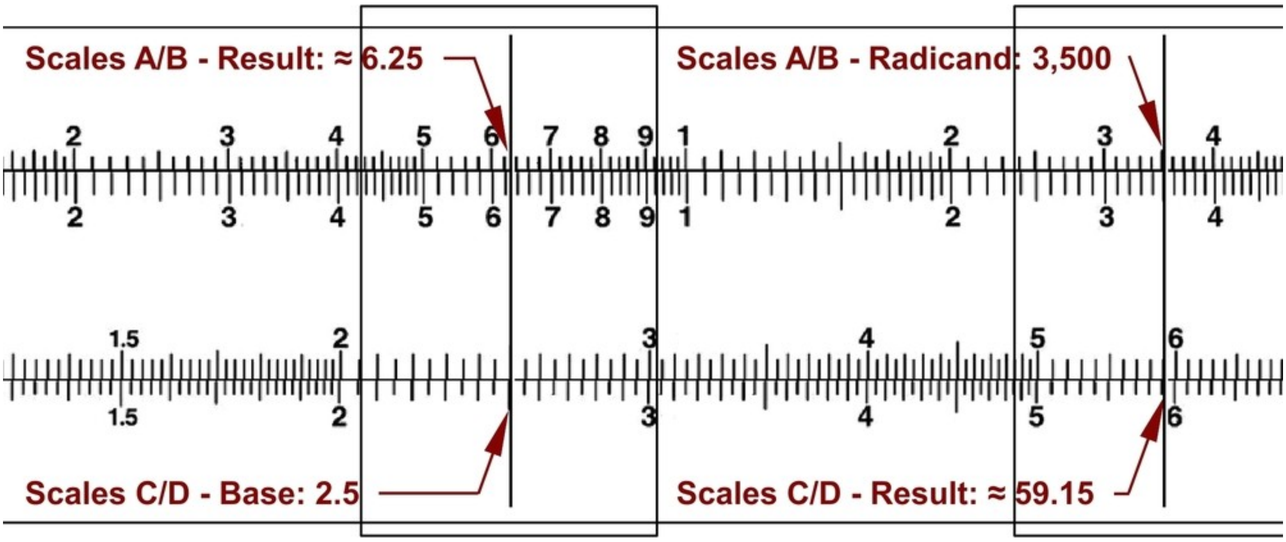
Squares and Square roots (uses A and D or B and C scales)

Example: 2.5^2

- moving the cursor by side 2.5 on the **C scale**; we get on the **B scale** ca. 6.25; The correct answer is 6,25.

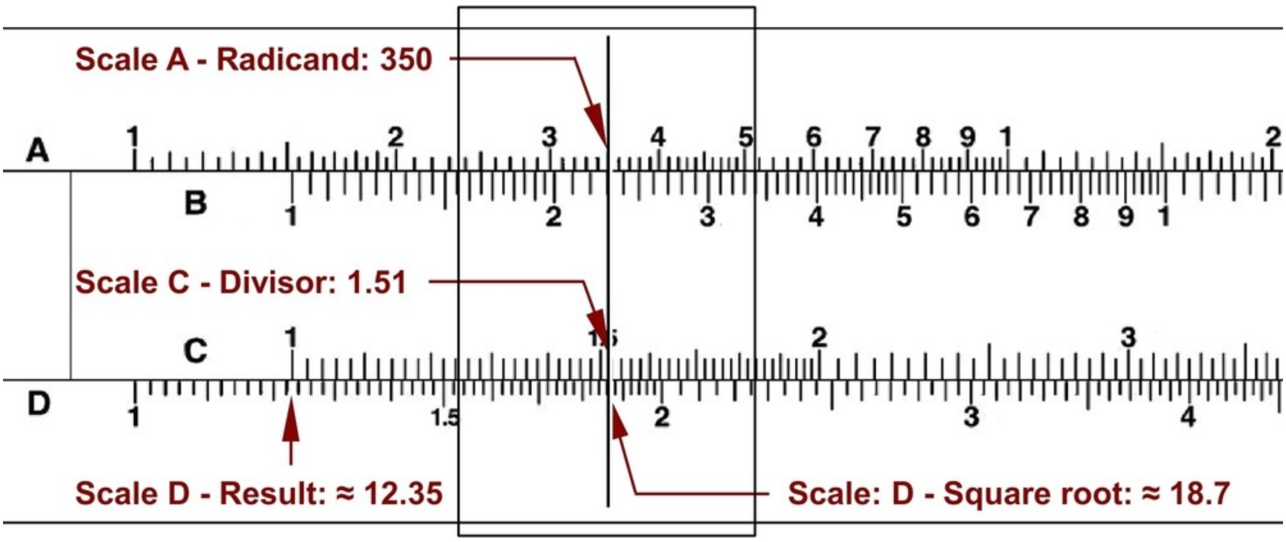
Example: $\sqrt{3.500}$

- the **A and B scales** have two similar halves. The left half is used to find the square root of numbers with odd numbers of digits; the right half is used for numbers with even numbers of digits. Since 3.500 has an even number of digits we'll use the right half of the scale. Moving the cursor by side 3,5 of the **A/D scales** we get on the **C/D scales** ca. 59,15. The correct answer is 59,16.



Now we can try this operation: $\sqrt{350} \div 1{,}51$

- moving the cursor by side the 350 of the **A scale** (odd number of digits, then the left side) we get its square root, 18.7, on the **D scale**;
- now we match 18.7 with 1.51 of the **C scale**: on the **D scale**, in correspondence with the **C** leftmost index '1', we can read the answer: ca. 12.35.



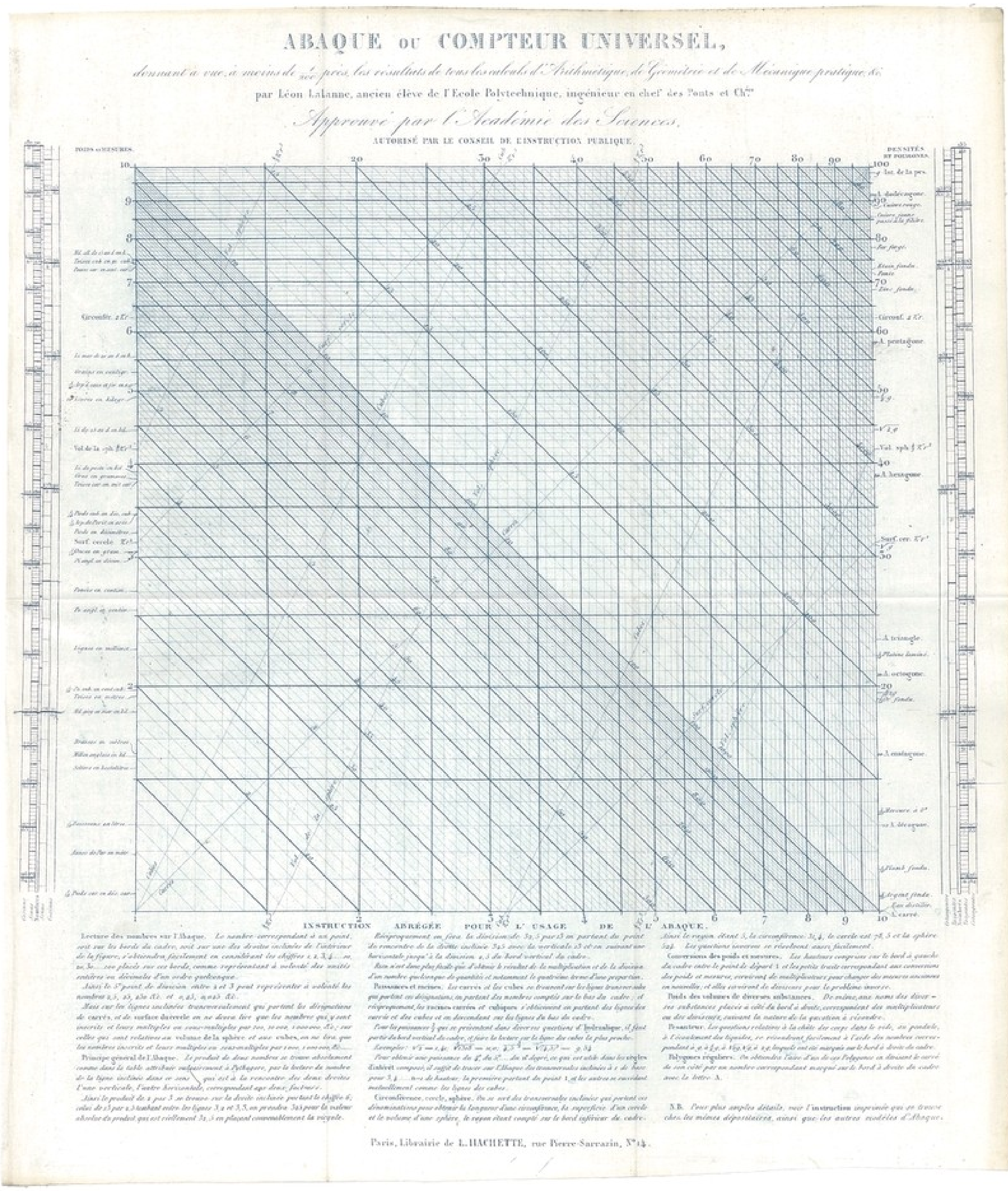
Not bad in a couple of seconds, armed only with a piece of paper and a paper clip! An electronic calculator would have been just a little more precise, finding 12.3896. This slight approximation has not prevented von Braun to send Man on the Moon: the slide rule is in fact less difficult than it sounds, the secret is just to practice, to practice and to practice ...

The Abaques

In 1844 Léon Lalanne created the first log graph table, calling it *"Abaque Compteur Universelle"*. The product of x and y is found from their intersection with the 45° lines. In the other side there is its simplified graphic.

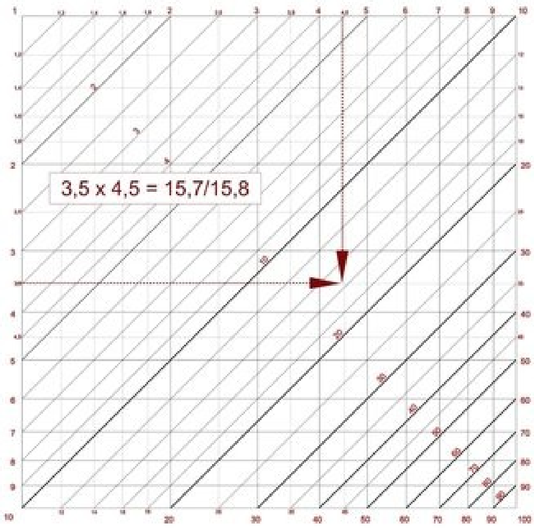
The *Abaque* was adopted by the French Railways and distributed in various versions, designed to solve specific problems. Indispensable for the construction of bridges, which now no one would design without 8 decimal digits at hand, at its time was widespread but today is very rare. I think less than 15 copies survived, included mine.

This interesting system had little success and was abandoned for the more easy and practical nomography, but the proportions between the numbers are harmonious and some *Abaques* are really beautiful.



One of the few surviving copies of the *Abaque Compteur*: how many would be able today to design a railway bridge with no other help?

Calculating with the Abaque Compteur

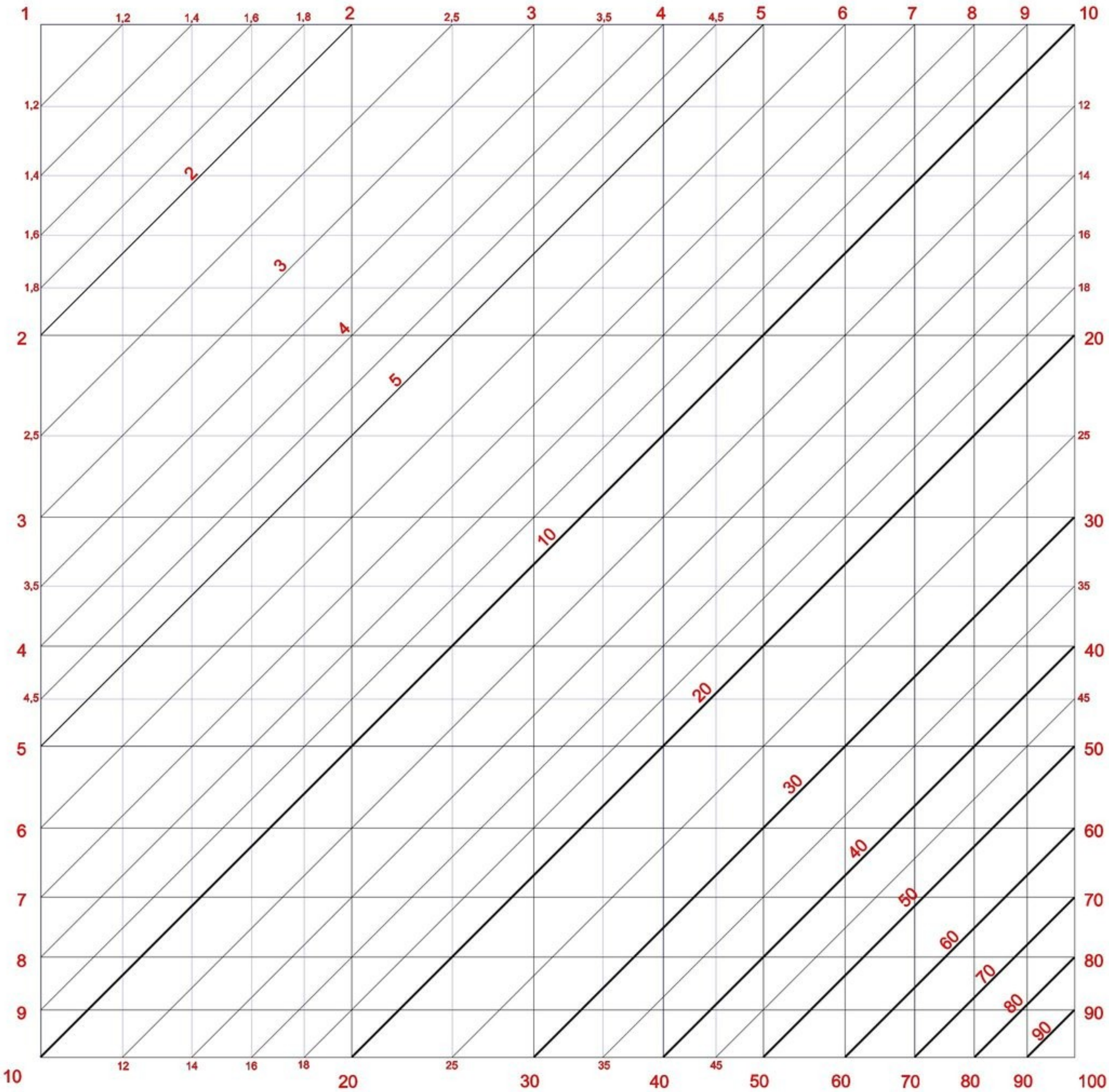


The Lalanne's *Abaque* allows to operate very quickly at the expense of a small loss of precision. To perform 3.5×4.5 just search for the two factors on the lateral scales, look for their intersection on the diagonal and read the result. In this case the intersection is close to 16 and we can evaluate the result in ca. 15.7-8. The exact result is 15.75, within the accuracy range of 2% considered acceptable by Lalanne.

If the two factors are not between 1 and 10 (e.g. 172×37) we must first reduce them (e.g. 1.72×3.7) and then add the zeros to the result.

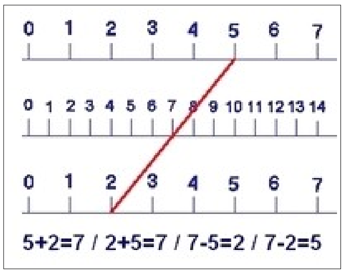
To perform 35/8 go on the diagonal value of 35 and seek for the intersection with the horizontal line of value 8: this point is close to the vertical line 4.5, and we can read 4.3-4. The exact result is 4.375, again an error of less than 2%.

This is a simplified graphic, the original *Abaque* allows also to raise powers and extract roots.



The nomography

The *nomography* was invented in 1884 by Maurice d'Ocagne, who replaced the Cartesian Coordinates of the first calculating table created by Leon Lalanne with a system of parallel scales.

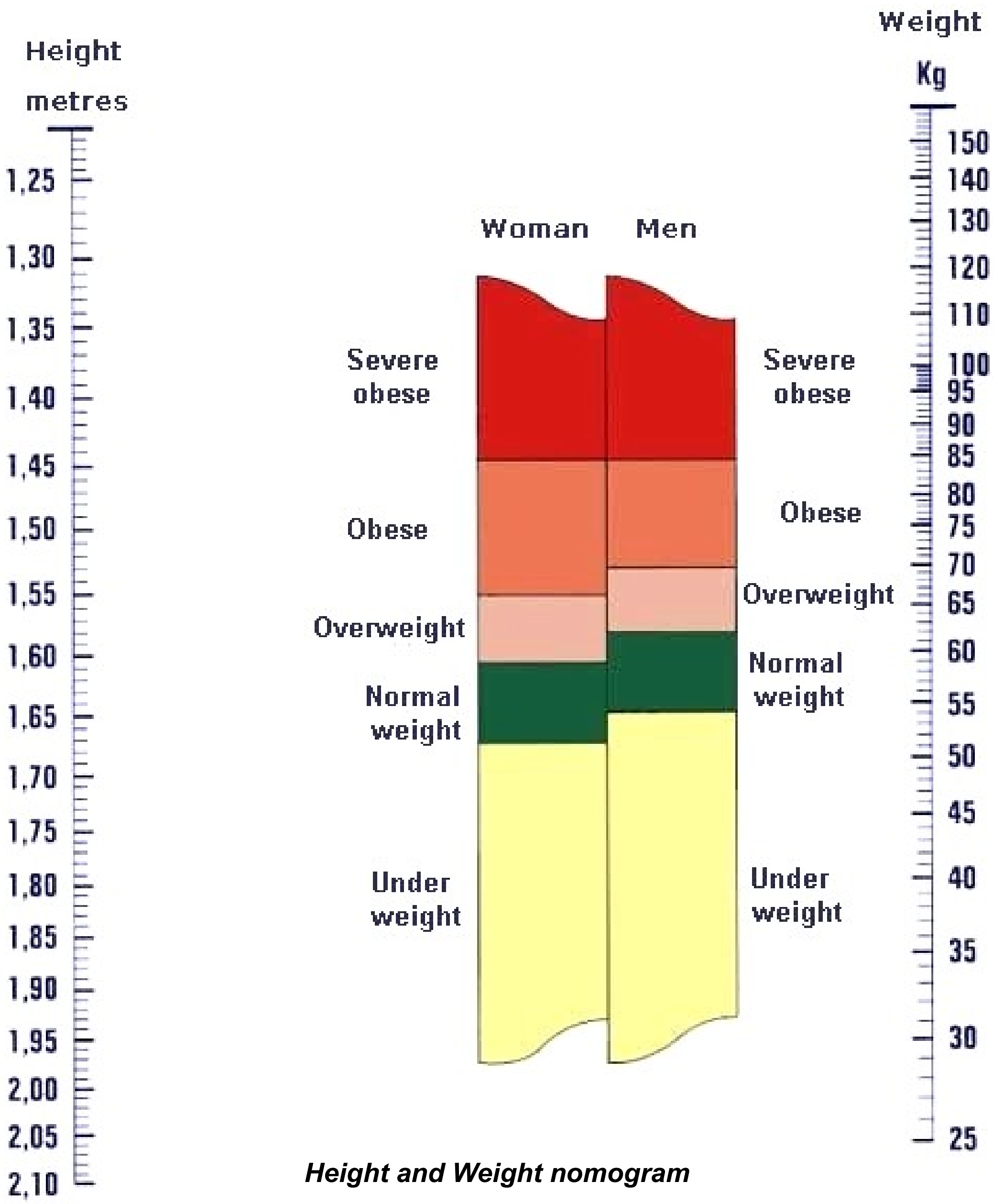


The *nomogram*, or *nomograph*, in its simplest form consists of three parallel scales: two for identify the values of the problem to solve and, connecting them with a ruler, the result can be read in the intersection with the third one. The scales may be metric or logarithmic, normally are parallel but it's some-times necessary to draw them in different shapes.

The *nomography* allowed everyone to perform calculations with ease, it is sufficient to draw one or more lines without even having to know the equation to solve. A great help before the advent of the modern calculators.

As the slide rules, the *nomograms* are analog instruments whose precision is limited by the resolution with which the scales can be printed. They can be easily programmed to solve specific problems and often are placed in sliding tables called *Slide Charts*.

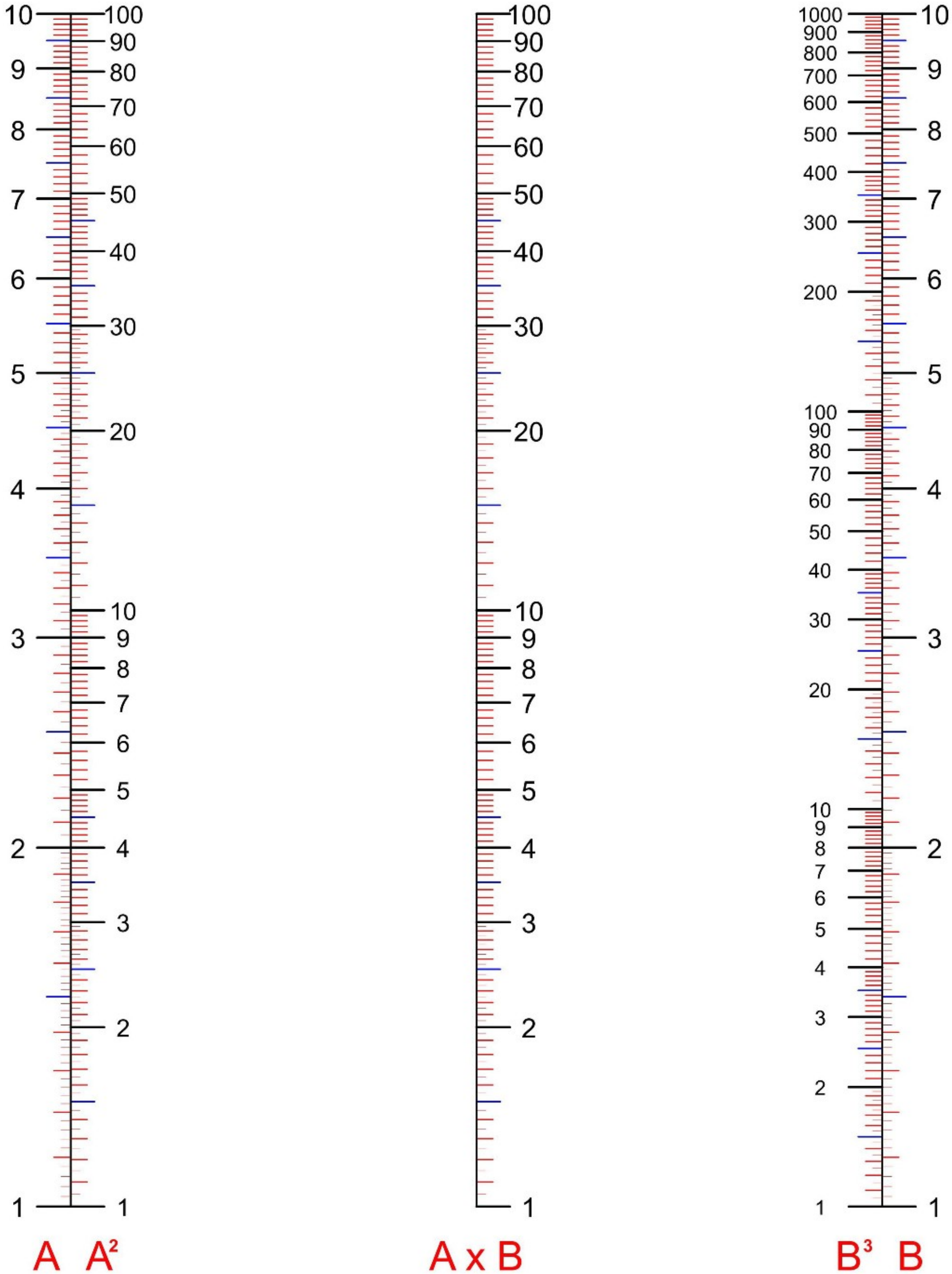
The *nomograms* are still widely used for military uses, in medicine and in aviation: they are easy to use and the results are sufficiently precise; for the solution of specific problems are unsurpassed. This represented below is extremely intuitive: simply combine with a ruler the values of our weight and our height to know if we must start a diet.



Height and Weight nomogram

Calculating with the nomography

To multiply connect with a ruler the two factors A and B of the outer scales and read the result in the central scale, to divide reverse the process. You can also square and cube a number (or do the square and cubic root). Graphic by Alvaro Gonzales – *arc.reglasdecalculo.org*.

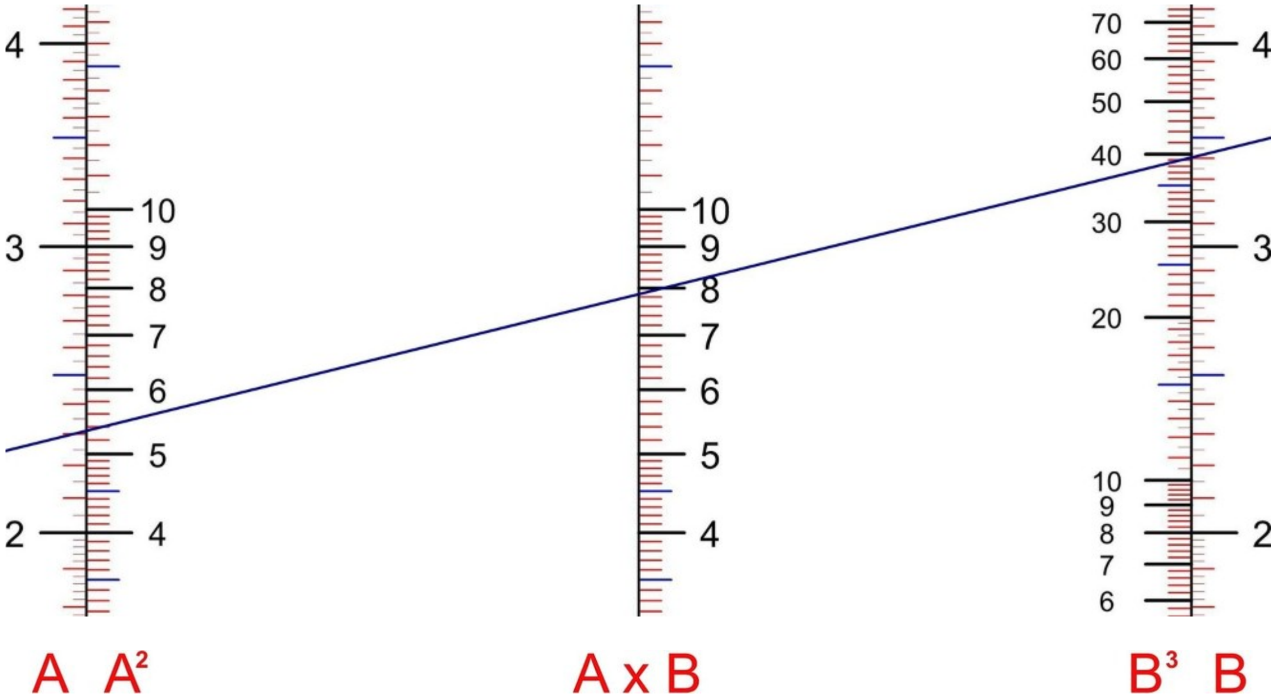


Nomography - Examples to practice

Multiplication

Example: 2.3×3.4

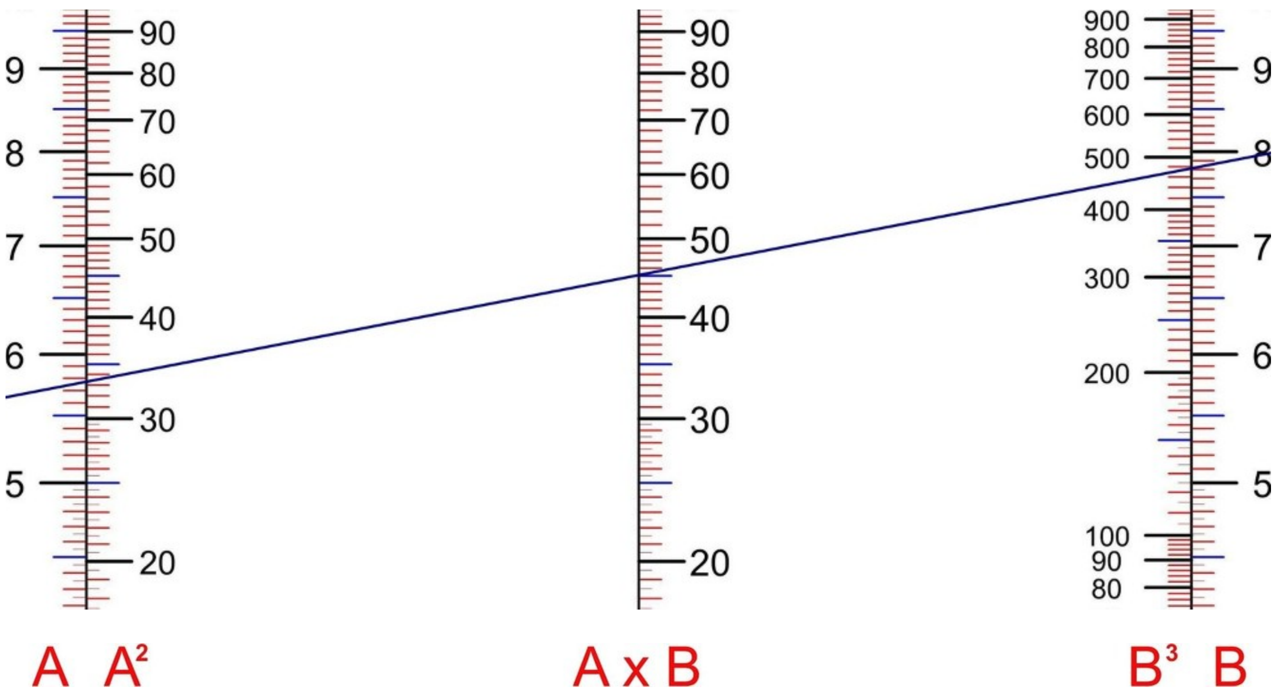
- connect with a ruler 2.3 of the **A** scale with 3.4 of the **B** scale;
- read the answer (ca. 7.81) in the **AxB** scale. The correct answer is 7.82.



Division

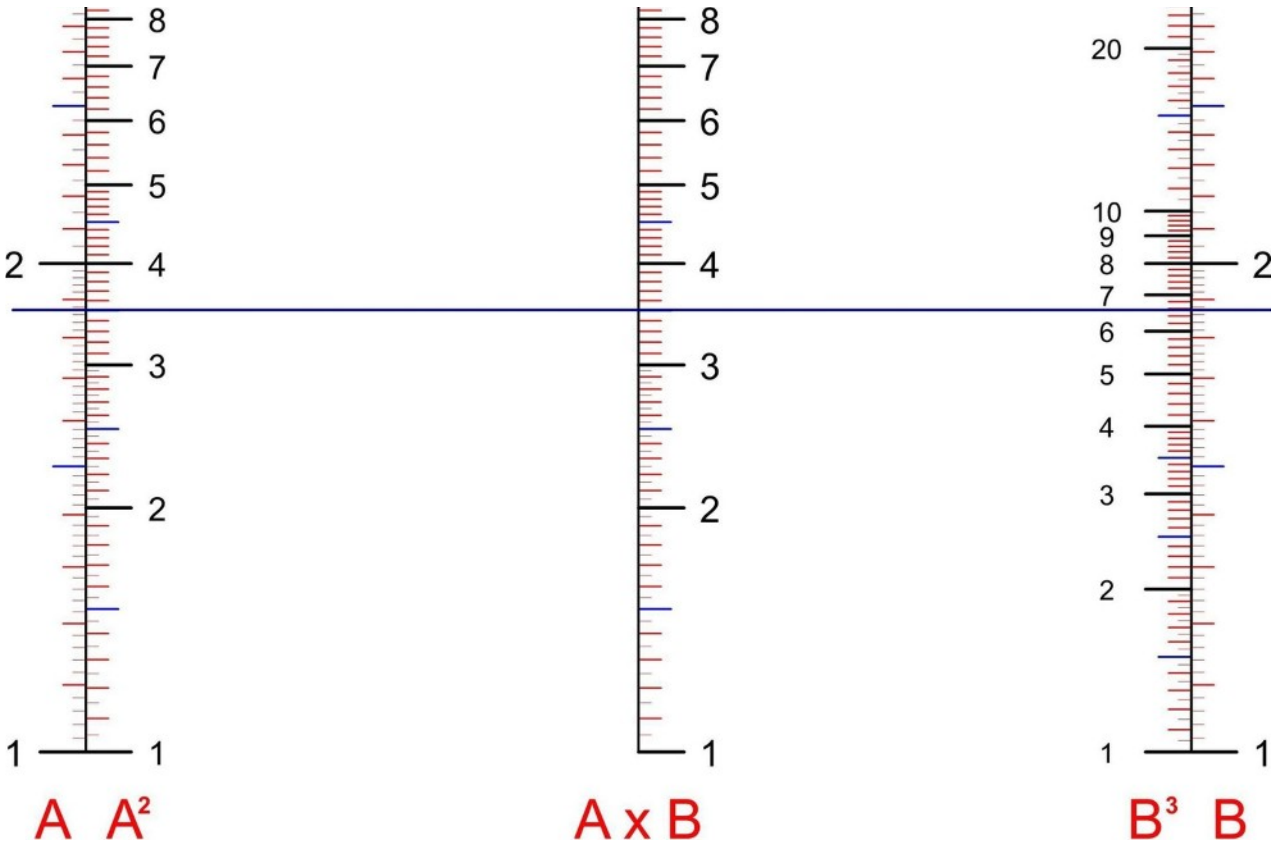
Example: 4.5÷7.8

- connect with a ruler 4.5 of the **AxB** scale with 7.8 of the **B** scale;
- read the answer (ca. 5.76) on the **A** scale. We know that the result of 4/8 is near 0.5, so we adjust the decimal place to get 0.576. The correct answer is 0.576.

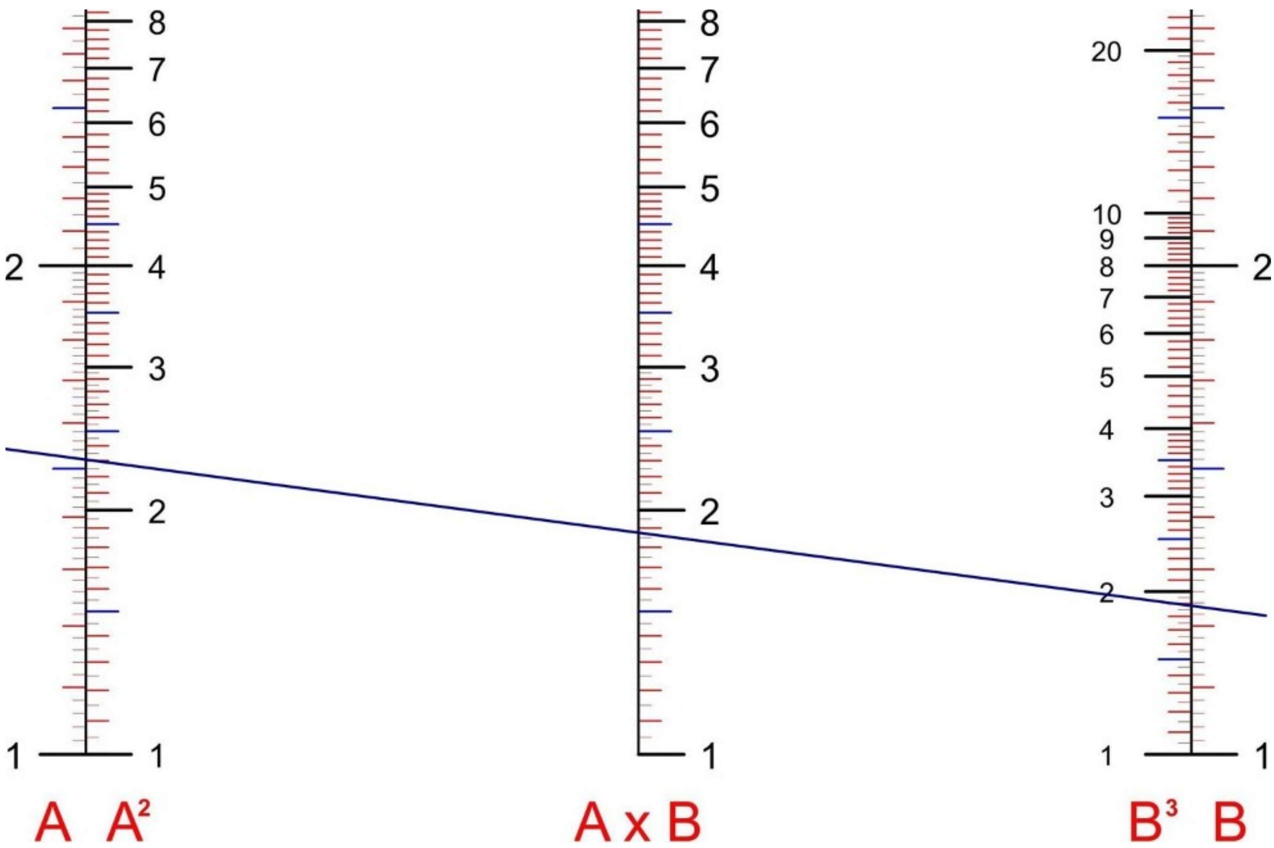


Now we can try this operation: √350 / 1,51

- to the left of 3.5 of the **A²** scale we find on the **A** scale the square root of 350: 18.7;



- now we connect 18.7 on the **AxB** scale with 1.51 of the **A** scale: on the **B** scale we can read the answer: ca. 12.39. A calculator would have been just a little more precise, finding 12.3896.



Volvelles and slide charts

The volvelles are formed by two concentric disks, normally made of cardboard. The top one has a perforated mask, which displays the information marked on the lower part depending on the rotation. The slides charts are the same instrument, but in rectangular shape where two cardboard sheets slide one over the other.

They replace the manual exploration of the tables needed to identify the stars, to help in first aid, to calibrate mixtures of colors or to choose the wine for an elegant meal.

Matthew Paris, a Benedictine monk of 1200, was the inventor. At the time the books were very heavy and to consult the circular tables, used to calculate religious holidays, he had to walk around them: Paris realized that it was more comfortable to turn the tables instead walk up and down!

Petrus Apianus in 1500 created true works of art, with hand-painted engravings, but only with the introduction of the printing press the production of smaller and cheaper models became possible.

One of the first volvelle, inserted in a book, Petrus Apianus ca. 1540

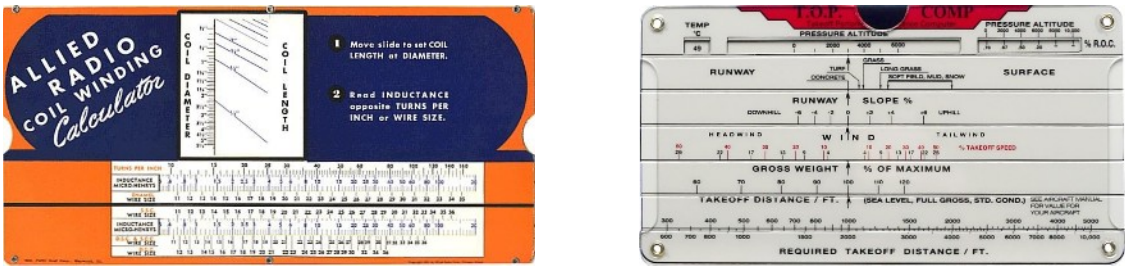
From the end of '800 the volvelles were widespread and today still are very popular, in fact they can found quick and instinctive solution to an endless number of practical problems.

Volvelles for agricultural and navvy use, ca. 1945

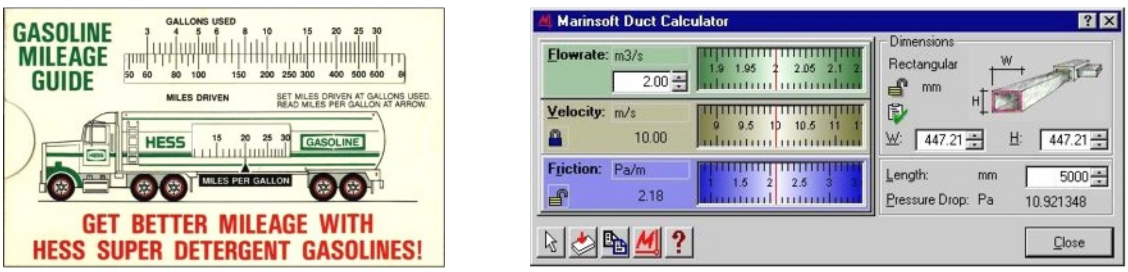
Parking disc with fuel consumption computer and volvelle for the calculation of the DNA

Modern volvelle, inserted in a magazine, 2012

The slide chart are commonly called perrygraf from its main producer. They are Ideal as advertising support and their graphics are so intuitive that is used in many applications and computer programs.



Perrygraf, 1940, and modern slide chart with takeoff nomogram



Slide chart for fuel calculation, 1958, and a software with analog interface

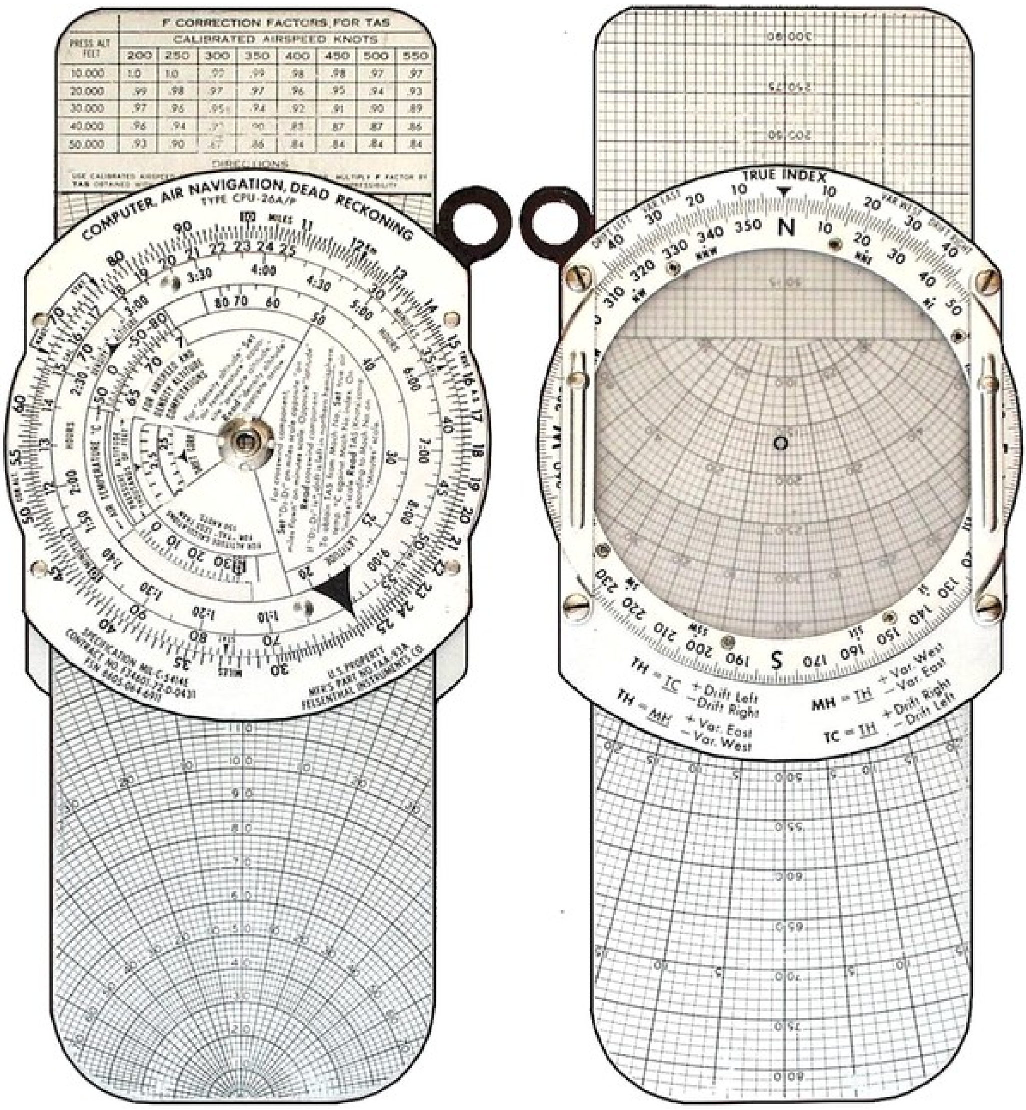
The flight computer

The slide rules, also known colloquially as "*slip sticks*", were the only calculators available before the electronic age, traveled with the Apollo 11 on the Moon and, essentials on board aircraft for the dead reckoning, are still required as a means of emergency.

1969: the slide rule with "Buzz" Aldrin on board Apollo 11

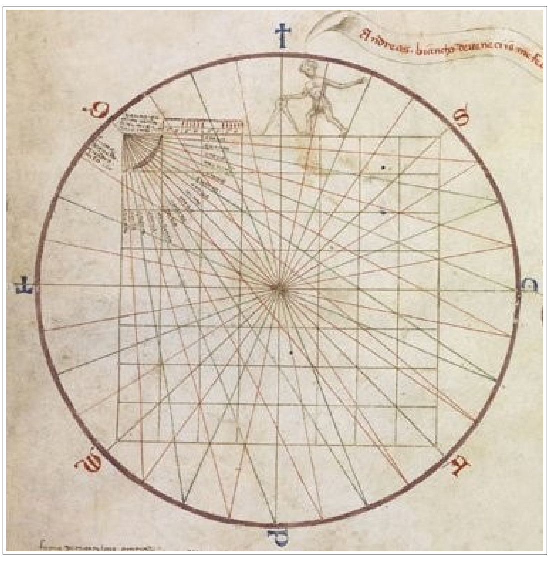
2269 (star date 4978.5): with Mr. Spock onboard Enterprise

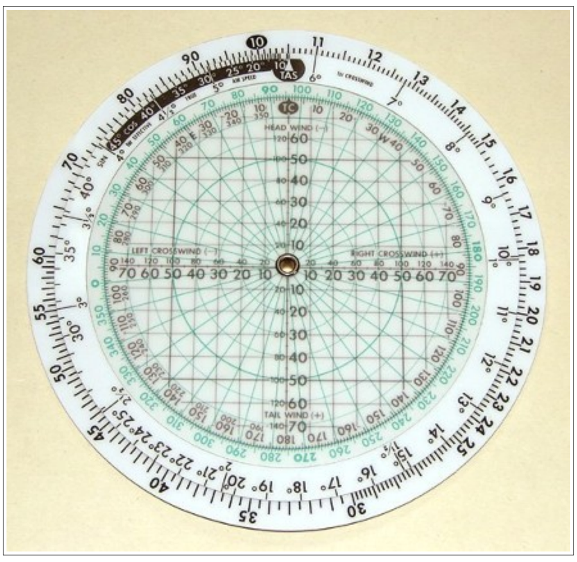
The navigation's problems are always the same from immemorial time and a modern aircraft slide rule is not so different from the graphs drawn in the Middle Ages to determine the ship's position. The pilots have to find their location and perform various conversions of measures with great rapidity: in this task the slide rules are unbeatable. As you can see Mr. Spock used a slide rule on board Star Trek's Enterprise and nobody thought that its use was anachronistic in a highly technological future. The interface of the aero-nautical slide rule has no equal for dead reckoning and its graphic is used in many navigation software.



One of the most popular flight computer

The aircraft type was invented in the '30s and its use is so instinctive that is often preferred to electronic computers: solves all the problems of flight, finds the angle of drift caused by the wind and it is essential to convert the jungle of measures in which the pilot must unravel. In the Air Force are used interchangeably meters, feet, nautical miles, statute miles, kilometers, liters, gallons, etc.

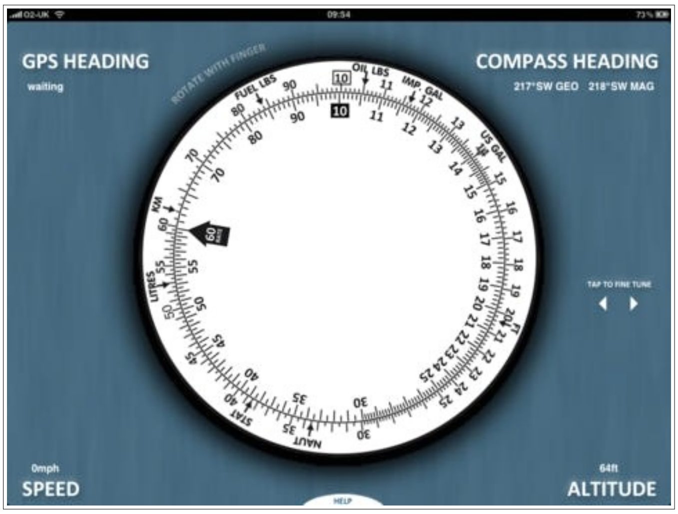




Raxon de Martelojo, chart of 1430 to determine the route, and a modern aeronautical slide rule

Since the 50s the E6-B, in a simplified form, has been included in the outer ring of watches especially designed for pilots. The most popular models are the Breitling's “Navitimer” and “Cosmonaute”, the last built for the NASA with the display divided in 24 hours as in space is impossible to distinguish day from night. It was the first watch to make an orbital flight, at the wrist of Scott Carpenter in Mercury-Atlas 7 mission of 1962, but it was not waterproof being soon replaced by the Omega Speedmaster. Although they lack of the graphic for the correction of the routes and of some specialized functions, such as determining the Mach number, are useful in solving problems of travel time, speed, fuel consumption and to perform conversions between different units of measure or currency.

Easy to buy one: over the timeless (and expensive) Breitling there are excellent models cheaply priced, like Casio, Seiko, Citizen and many others, and the fun is guaranteed.



The E6-B mounted in the Breitling Cosmonaute and a computer interface with its graphic

These watches are useful when traveling to convert currencies or measurements, they have two sliding scales: in the inner one we will found the number 60 (*Speed Index)* marked with a red arrow to help the calculations. Remember that, as in a standard slide rule, "0.9", "9", "90", "900", "9,000" are always read as "9" and how to locate the dot or add tenths we must find by ourselves, but it's always instinctive to know if we are dealing with tens, hundreds or thousands.

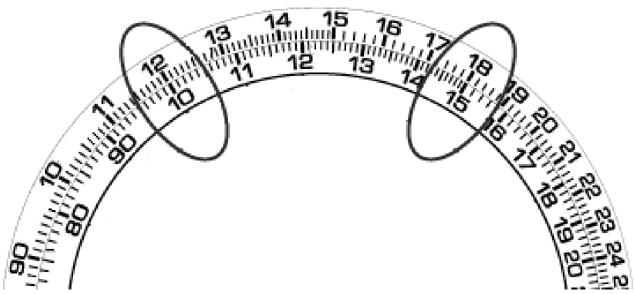
Calculating with the flight computer

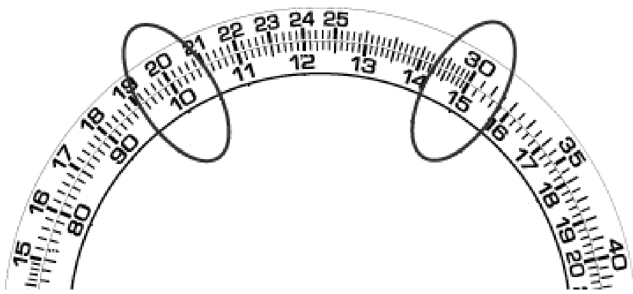
Here some examples, the complete instructions, can be found at the end of this book or downloaded from my website with a template to build a paper E6-B slide rule: an easy *“Flight Computer”* to start practice.

Example (bottom left)**:** 12×15.

Align 12 on the outer scale with 10 on the inner scale. Then 15 on the inner scale corresponds to 18 on the outer scale. Take into account the position of the decimal point and add one zero to obtain 180.

Remember always that with all slide rules the position of the decimal point cannot be obtained automatically.



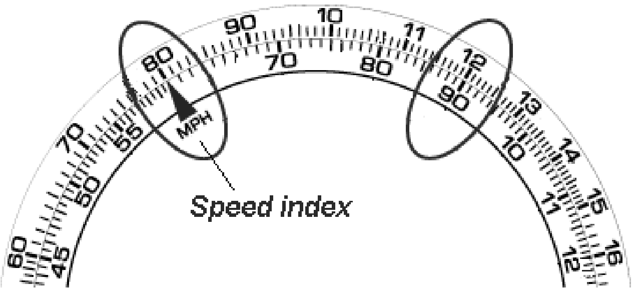


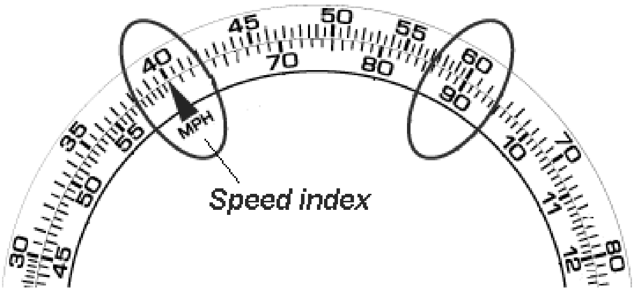
Example (upper right)**:** 300/15.

Align 30 on the outer scale with 15 on the inner scale. Then 10 on the inner scale corresponds to 20 on the outer scale. Take into account the position of the decimal point to obtain 20.

Example (bottom left)**:** obtain the average speed (km/h) needed to travel 120 km in 1:30 hours.

- Align 12 on the outer scale with 90 (minutes) on the inner scale. Then the *Speed Index* (MPH) corresponds to 80. Thus the average speed is 80 kilometers per hour.



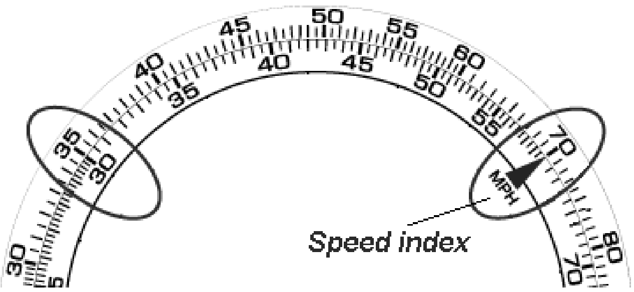


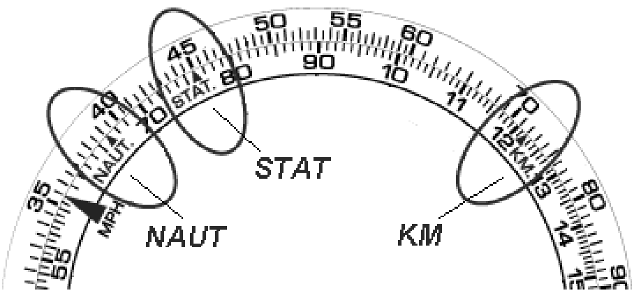
Example (upper right)**:** obtain the mileage when the speed is 40 km/h and the running time is 1:30 hours.

- Align 40 on the outer scale with the *Speed Index* (MPH). Then 90 (the minutes) on the inner scale corresponds to 60 on the outer scale. Thus the mileage is 60 kilometers.

Example (bottom left)**:** obtain the rate of fuel consumption (liters/hour) when the running time is 5 hours and the total fuel consumption is 35 liters.

- Align 35 on the outer scale with 30 on the inner scale (300 minutes = 5 hours). Then the Speed I*ndex* (MPH) corresponds to 70. Thus the fuel consumption rate is 7 liters per hour.





Example (upper right)**:** convert 45 miles into nautical miles and kilometers.

- Align 45 with *STAT* . Then *NAUT* corresponds to about 39 nautical miles and *KM* to about 72 km.

This simplified paper E6-B can be downloaded from my website

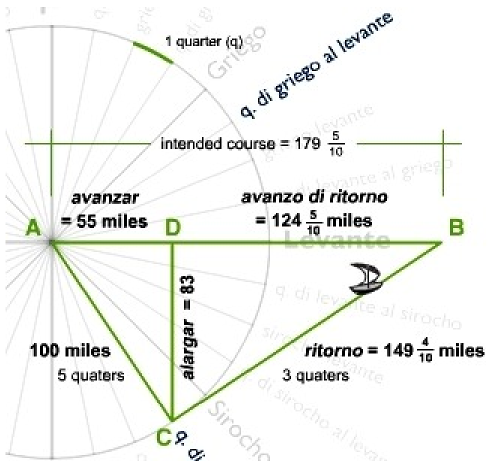
The navigation with the flight computer

We have seen how the front of the aeronautical slide rule serves to calculate times, distances, rates, conversions, etc. The back, inspired by the graphic *Raxon de Martelojo** shown before, is used to solve the problems of reckoning: we see how determine the changes of direction and speed needed to compensate the wind.

Try to solve a problem with the Martelojo:

You had to sail straight to the east from A to B, but the wind has allowed only a route to *"sirocho all' ostro"* where you covered 100 NM.

How many miles you have to navigate to *"griego al levante"* to reach B?



Answer: 149.4 miles.

Example: you have laid out a course on a chart and measured it to be 090° true. The winds aloft forecast calls for the wind at your chosen altitude to be 230° at 18 knots, and the performance data for the airplane says that you can expect a true airspeed of 125 knots at that altitude.

1. Set 230° at the TRUE INDEX.
2. Using any convenient starting point, measure 18 units up from the grommet toward the True Index and make a dot at 18 units (Fig. 1).
3. Rotate the transparent disk to bring 090° to the TRUE INDEX.
4. Move the slide until the wind dot falls on the arc for 125 knots (Fig. 2).
5. Read the ground speed of 138 knots under the grommet; the fact that the wind dot is below the grommet indicates a tailwind.
6. The wind dot is 5° to the right, indicating that the true heading should be 095°. Now all you have to do is apply local magnetic variation to correct the compass.
7. We are a bit faster than planned and we can slow down of 13 Knots to respect the time of the flight plan.

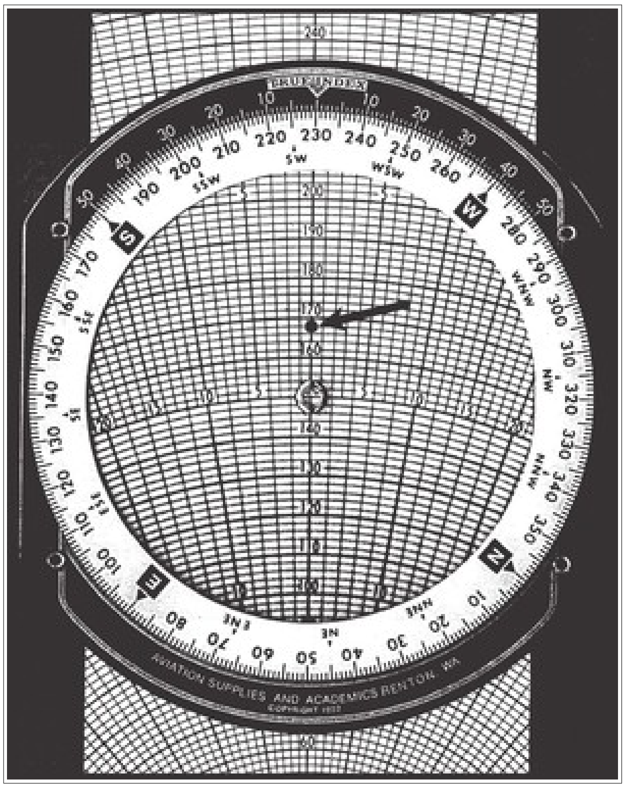


Fig.1

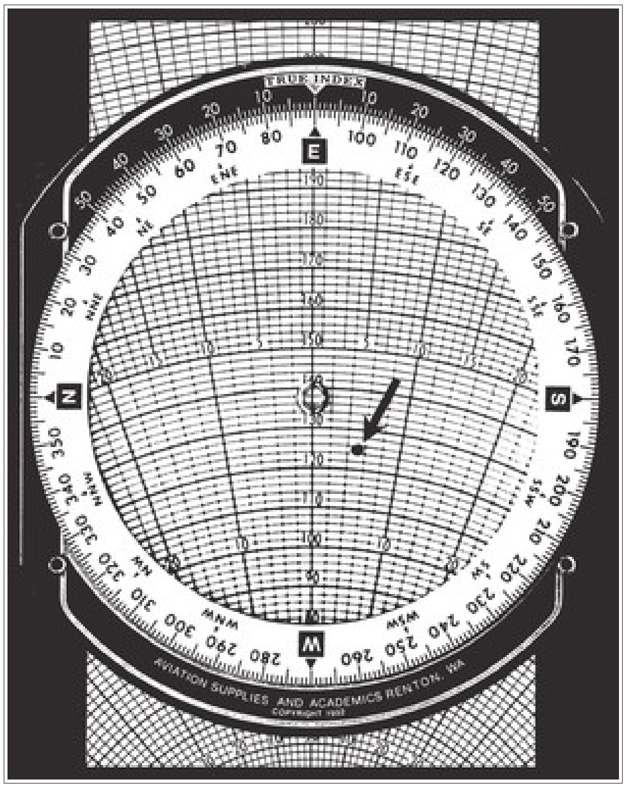
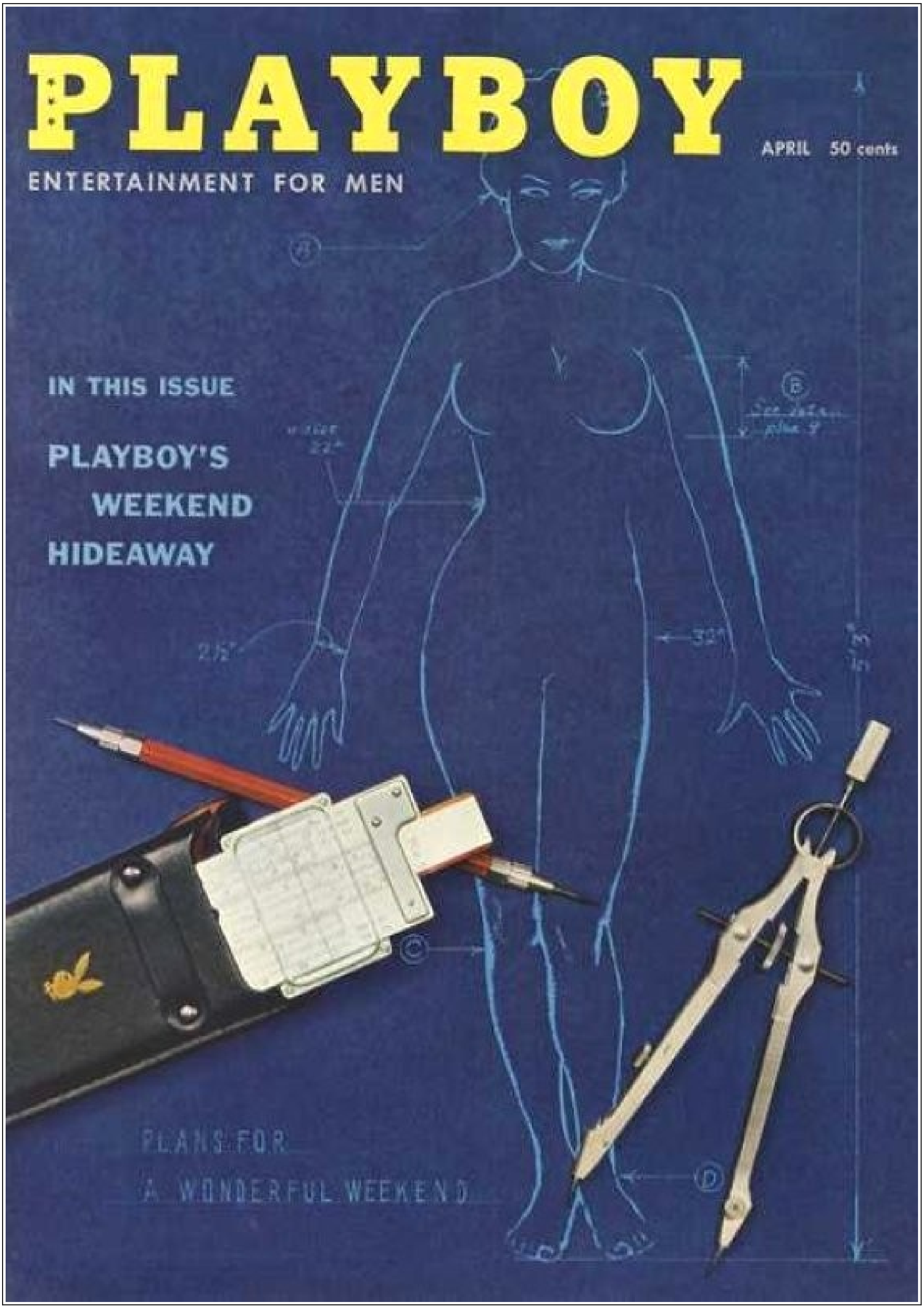


Fig.2

* *"Raxon de Martelojo"* in Venetian dialect means *"Rule of Hammer"*: the graph was in fact used at the beginning of each hour (indicated by a hammer blow on the bell) to check the route.



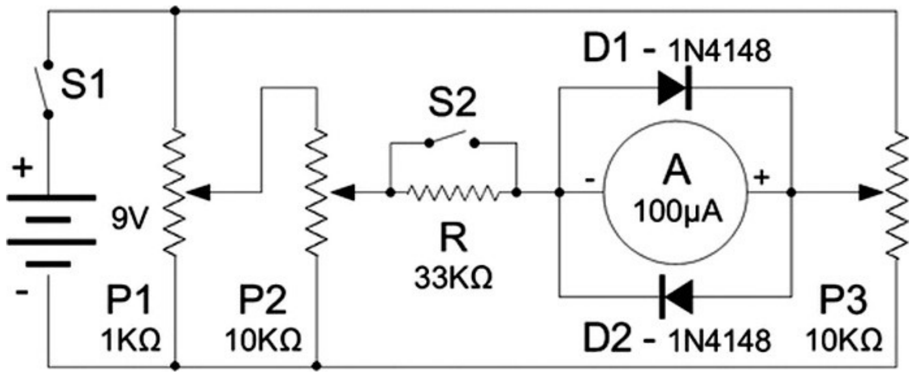
The slide rule was so well known to appear on the cover of Playboy: calculators can sometimes be sexy!

The electric slide rule

The analog electric slide rules, often distributed in kit for self-construction and pompously called analog computers, had a brief golden age in the early 60s. You can easily build one: it's cheap and funny.

How it works

The scheme I propose is inspired by the articles *"An introduction to analog computers"* by J. Sienkiewicz (Popular Mechanics, December 1961) and *"Archimede, calcolatore elettronico"* (Sperimentare, July 1968), without the addition and subtraction circuit, which requires a complicated voltage stabilization. At the time it was necessary to grade the scales by hand according to the characteristics of each potentiometer, but now they can be purchased with ready-made and precise pot-knobs.



The circuit diagram: just three potentiometers and an ammeter

Let's have a look at the diagram: the battery and the central zero ammeter are connected in one side through the potentiometers P1 and P2, on the other through P3, all graduated with scales from 1 to 10. When all are settled to the same value the instrument will read zero.

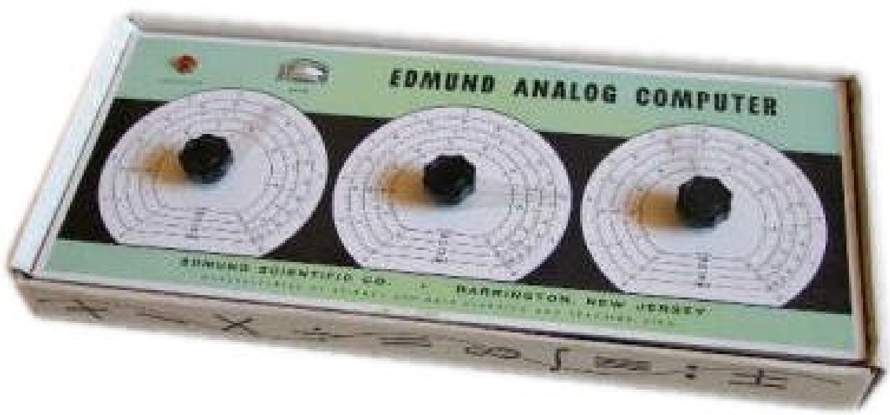
To perform 8×5 we set P1 on 8 (20% of the resistance) and at the output we will have 80% of the input current which will feed P2 positioned on 5 (50% of the resistance). At its output the original current will be 50% of 80% (40%) and will move the instrument's needle from the central zero.

Now we rotate P3 until the instrument reads zero: this will happen when the potentiometer is at 40% of the scale, 4, and its output perfectly balances the 40% of P1 and P: 40 is just the result of 5×8! All the operations are settled like in a classic slide rule, decimals and commas being calculated by mind as usual.

To perform a multiplication we need just to set multiplicand and multiplier on P1 and P2, turning after P3 until the instrument marks zero and then read the result on its scale.

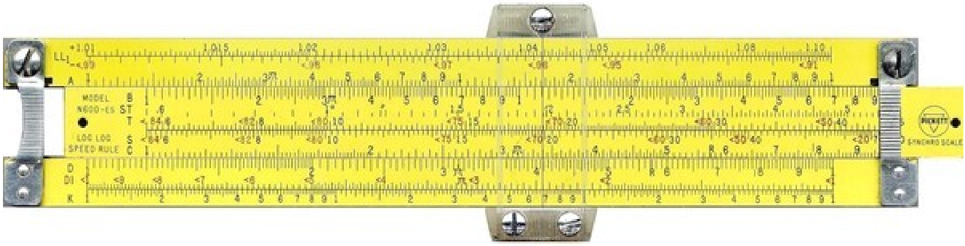
Because we treat percentages the results will always be correct, whatever the input voltage. All the operations can be done, but it's difficult to made addition and subtraction because in this case the voltage must always be accurate and stable: 1.5 volt + 1.5 volt will read 3 volts on a voltmeter.

The error in the calculations (ca. 2.5%) is higher than on standard slide rules, despite today we have economic and precise potentiometers which instead in the 60s were expensive but without guarantee a good linearity (the relationship between angle of rotation and resistance). Due to the unreliability of these components the analog calculators met very little success.



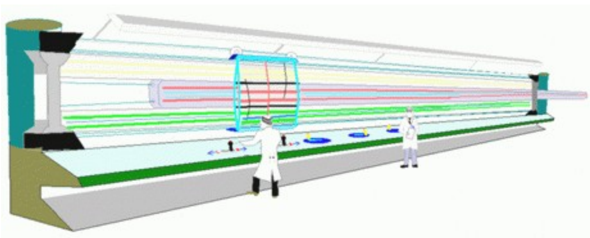
In the '60 large scales were needed due the imprecision of the pots

The twilight of the analog era



The Pickett ES 600 supplied to the Apollo missions

In 1969 the slide rule was landed on the Moon on-board the Apollo 11: a very long career which began more than 350 years before. However these tools are only accurate to three decimal places and the engineers had to make continuous estimates with the help of their experience. Approximating the calculations for excess created the myth of the *"Olde Good Things"*, but the modern structural analysis required now exact results, thus promoting the development of small electronic calculators. These were of course designed using slide rules: Robert Ragen said to have literally consumed two to realize in 1963 its revolutionary *"Friden 130"*. It was still too cumbersome and increasing complex slide rules continued to be built: in the Soviet Union it was constructed one, electromechanical, of 14 meters in length. Made in the Kalashnikov's workshops was baptized with the name of the biblical monster Behemoth, really appropriate for such a giant.



Finally in 1972 the Helwett Packard, advertising it as *"Innovative electronic slide rule"*, put on sale the first economic scientific calculator, 50 times smaller than the competitors and so modern that it is still on the market. The capabilities of the new HP 35 were indispensable, Forbes cites it among the 20 objects that have changed the world, and analog computers disappeared from the market in a flash.

The new HP-35, so called "the slide rule killer"

Shortly before 1972 the president of a very old slide rules factory had declared:
"No matter what aspect of the future we consider, we can see a continuing and important role for the company that supplies the engineering profession with the tools it needs. We have been that company for over 100 years, and we intend to be that company for the next 100 years".
Never somebody were less prophetic: only two years after his company closed and the slide rules, produced over the centuries in more than 60 million units, came out of the story. But our *"hero"*, reliable and environmentally friendly, it is always necessary to pilots and military and perhaps the adventure is not over yet, as in the Asimov' science fiction novel *"The feeling of power"* that, assuming a return to the old methods of calculation, ends with these words: *"Nine times seven, thought Shuman with deep satisfaction, is sixty-three, and I don't need a computer to tell me so. The computer is in my own head. And it was amazing the feeling of power that gave him"*.

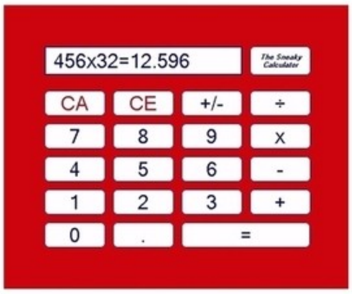
The first computers were bulky and not very powerful, but they were able to replace 150 engineers equipped with slide rule: their time had come

Creativity in science education

SCIENCE ON STAGE 2015 LONDON

Old Calculators & Democracy

a new life for old instruments: ensuring the future by preserving the past



You may have noticed the error ..

.. but not everyone care to check!

The old world was complex. How was it made without computers?

A lesson of old calculators keeps the students sharp and informed

I think teaching mathematics without teaching how calculations were made in the past is useless. This would be comparable to teaching history only from 1970.

Only a few minutes are required to communicate the existence of a world before computers, a world where Man reached the Moon!

Nicola Marras

Calcolatoria: educational solutions, exhibits and conferences on the history of calculus

History of calculating devices, private collector of slide rules and mechanical calculators

Contact Information

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www.facebook.com/calcolatoria
calcolatoria@nicolamarras.it

The Lost Art of Numeracy

Nowadays calculations are delegated to electronic devices and the results uncritically read on the display, without any idea of how they are produced. People punch numbers into a calculator and expect it to provide the correct answer: the Art of Numeracy is no longer practiced and the world before computers almost forgotten. Now students learn mathematics being illiterate about its history, which is a false start.

Step Back to Move Forward

The electronic aids should not blindly be trusted, with the old calculating devices the operators were always aware of their actions and used to check the results.

Today instead many people think *"I don't need to check, the computer knows better than me"*. Sadly this is the base of the Authority Principle, which leads to mental slavery.

Not by chance democracy was born in the same country in which maths and geometry were born, but Scientific Thinking isn't a natural product of intelligence and must be cultivated steadily. A simple lesson about traditional calculation may help: a rational mind produces better decisions, better citizens and a better world.

With my e-book *"Was There Life Before Computer?"*, complete of educational material and *freely downloadable* from my website, the teachers can easily illustrate this history in their classroom.

cagliari festivalscienza www.festivalscienzacagliari.it

arc.reglasdecalculo.org ARC

THE OUGHTRED SOCIETY WWW.OUGHTRED.ORG

against mindless use of computers

Poster for the international fair *Science on Stage London 2015*

Conclusions

The modern world has short memory and soon the remembrance of the ancient calculating instruments will disappear. Aiming to preserve the 300-year history of calculation I organize exhibits, conferences and lectures where ancient analog and mechanical calculators can be tested by the public. Using my collection I explain the most significant calculators, from the abacus to the HP 35.

Demonstrations of slide rules and small mechanical calculators

I think teaching mathematics without teaching how calculations were made in the past is useless. This would be comparable to teaching history only from 1970. Now students learn mathematics, while being illiterate about its history, which is a false start. Only a few minutes are required to communicate the existence of a world before computers, a world where Man reached the Moon!

For many students the result of 2+3×4 is 20 (not 14!), but with *slide rules* they learn to recognize the order of operations. With *pascalines* and *addiators* children understand easily the addition and the Consul Monkey is the best way to teach the multiplication table.

For a better vision of mathematics my exhibits aim to:

- arouse curiosity about ancient computers;
- illustrate their history and use;
- demonstrate the need to use computers critically.

My typical stand, with ancient calculators and navigational devices

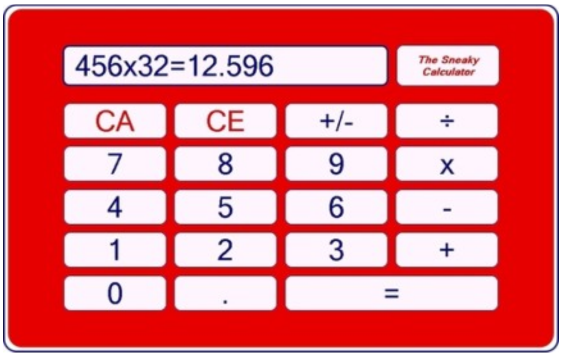
As a static exposition of scientific instruments cause just a mild curiosity, I make a *dynamic* exhibit focused in quickly teaching *how to* use them. Math on the move!
Since 2008 I show every year at *Cagliari Festival Scienza*, an Italian science fair sponsored by the U.N.E.S.C.O. with more than 14,000 visitors, a brief history of computing.

Was there life before computer? was one of 10 educational projects that have represented Italy at the Science on Stage Europe Festival 2013 and *"Old Calculators & Democracy"* done the same in 2015. The exhibit was also displayed in San Francisco, London, Berlin, Delft, Poznań, Trent, etc.

Different locations for the history of computing

The *Old Calculators & Democracy* project

Nowadays calculations are delegated to electronic devices and the results uncritically read on the display, without any idea of how they are produced. People punch numbers into a calculator and expect it to provide the correct answer: the Art of Numeracy is no longer practiced and the world before computers almost forgotten.



This result is wrong, you noticed?

The electronic aids should not blindly be trusted, we need to understand and criticize what we do; software could be buggy and the results have to be critically reviewed. In the past, with the old calculating devices, the operators were always aware of their actions and used to check their work.

Today instead many people think *"I don't need to check, the computer knows better than me"*. Sadly, the thinking that *"if an expert states it, then it must be true" is* the basis of the Authority Principle, which leads to mental slavery.

Teaching the traditional calculating instruments as a school of democracy may seem an overstatement, but nobody can be a free citizen if unaware of what he does or willing to discuss it. Not by chance democracy was born in the same country in which math and geometry were born, but uncritical use of the computer can lead people to press buttons mindlessly.

Scientific thinking and independence of ideas are not a natural product of intelligence, they must be cultivated steadily. A simple lesson about traditional calculation may help: a rational mind produces better decisions, better citizens and a better world.

I hope my work will help to remember the old calculators and those who created the modern world using technology, not dependent on it for survival. Today, instead, we often use electronic calculator as the alcoholic uses with the street lamp: to lean on, not to use the light to read!

I'm just a collector, there are no funds nor organizations supporting me: all I can do is to awake the interest of the public, but slide rules aren't easy to explain in 5 minutes and their teaching must be inserted in the official school programs, this is my main target.

Have you been involved in the history of computing? Have fun working as engineers, airmen or sailors of a past with my *Teaching Aids,* freely downloadable from www.nicolamarras.it. We landed on the Moon with just brain power and slide rules: *there was life before computer*, after all

Nicola Marras

BC: © & TM Ida Hart Trust

The Web before the Web Age

By Nicola Marras – www.nicolamarras.it
Ghetto degli Ebrei, Cagliari - 7/12 November

The culture of instant information sharing was born in the 1800s: Back then, news would have already traveled in real time and from 1930 you could chat online by means of HAM Radio Net.

When we re-discover these outdated technologies, we should ask ourselves: How our present world will be viewed in the future?

THE MELTING FACTOR

Cartography and Celestial Navigation: the Tools that Connected People & Cultures

4/11 May 2018 – ACCIMO Convention Center, Via G. Natta 21 – Z. I. Est – Elmas, Cagliari

'And if you arrive on the shores of another sea, in a far country inhabited by barbarians, remember you this: the only hope lies not with fires but in the quicksilver hearts of men'. Sailing Directions, London 1744.

educational solutions Nicola Marras *make learning easier* **www.nicolamarras.it**

OnLine: Communication Before The Internet

Cagliari FestivalScienza – ExMa Center, 5/11 novembre 2018

The concepts of *Social Networks*, *Global Village*, *Real Time* and *Broadband* appear very modern, but they are all 19th century achievements. Let's now rediscover the roots of our technology: the first online chess game dates back to 1844!

Calcolatoria Educational Solutions Nicola Marras *make learning easier* **www.nicolamarras.it/calcolatoria**

To complete my exhibits on the calculators, I also expose the history of communication and celestial navigation

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Countless websites visited, for convenience I report only the most important ones:

Inglese

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International Slide Rule Museum: www.sliderulemuseum.com
The Slide Rule Universe: www.sphere.bc.ca
Rechenmaschinen Illustrated: www.rechenmaschinen-illustrated.com
John Wolff's Web Museum: www.johnwolff.id.au
Andries de Man: sites.google.com/site/calculatinghistory
Vintage Calculators Web Museum: www.vintagecalculators.com
The Museum of HP Calculators: www.hpmuseum.org
Retrocalculators: retrocalculators.com
David M. Riches: www.mathsinstruments.me.uk
Kees Nagtegaal: www.mechanicalculator.com
Rod Lovett: sliderules.lovett.com

Spagnolo

ARC: arc.reglasdecalculo.org
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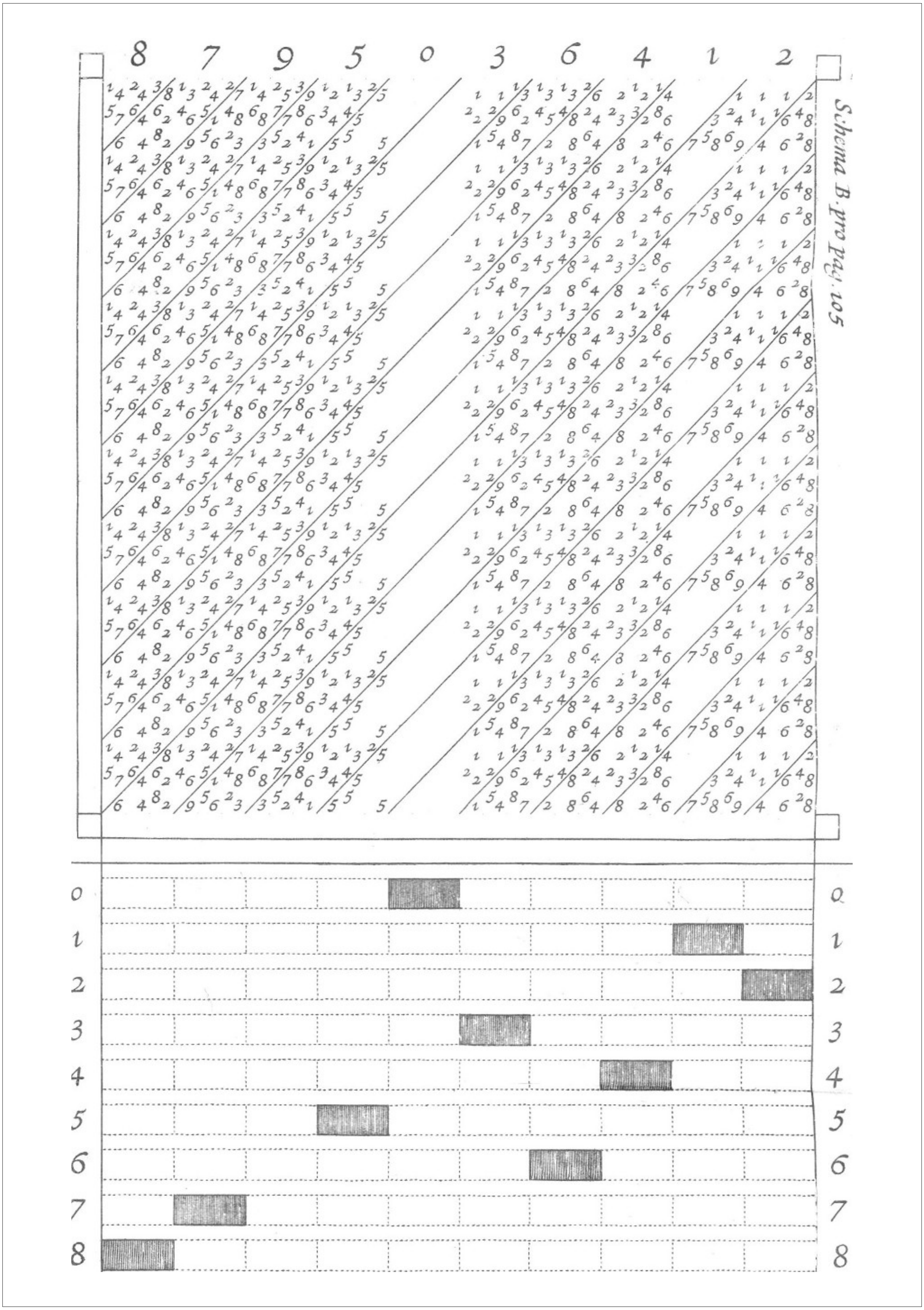

In 1617 John Napier's "Rabdologiæ" was printed: the first scientific calculator is born, used for over 300 years

Nicola Marras

Was There Life Before Computer?

the calculation before we went digital

The world of today,

the landscape framed by skyscrapers, everything we associate with modernity was designed with calculators conceived in the seventeenth century.

The LEM landed on the Moon carrying a slide rule, the same instrument used by Newton, Einstein and von Braun. the first online chess game dates back to 1844!

The modern computer has been built on these ancient instruments that

seemed irreplaceable:

Galileo's compass was still useful on board aircraft carriers, the calculating machines of Pascal and Leibniz were the driving force of the financial globalization and the logarithmic slide rule, invented in 1622, served to design everything: from the James Cook's flagship to the Jumbo Jet!

At the time nobody could imagine a world without them,

but in 1972 ...

... appeared the first modern calculator and a whole fascinating world vanished in a flash, by 1980 was completely forgotten.

It was Leibniz's dream come true

it is unworthy of excellent men to lose hours like
slaves in the labor of calculation which could be
relegated to anyone else if machines were used

Rediscovering these computing instruments ask yourself:

what our technology will be tomorrow?

The Oughtred Society

ARC

Science on Stage Europe

International Slide Rule Museum

cagliari festivalscienza

Nicola Marras – Italy, 1954. Collector, member of ARC and fellow of the Oughtred Society, promotes through exhibits and educational courses the memory of old calculating, navigation and communication systems.
Nicola wants young people to know that the world as we see it now, with its sky-scrapers, space exploration, real time communication and computer, was only possible because of technologies conceived in the 17th century.
Since 2008 he participates at the Italian Fair FestivalScienza. His projects were presented at the international Science on Stage Festival, in various European countries and in the US. Nicola's website is: www.nicolamarras.it.