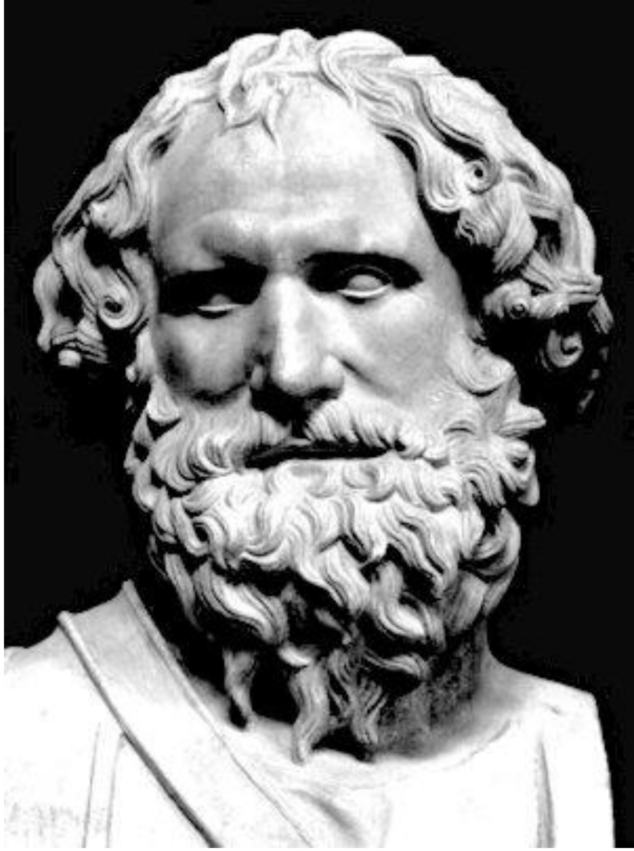
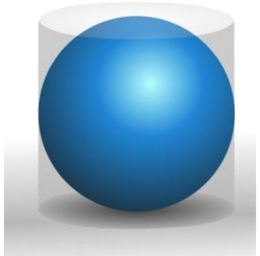
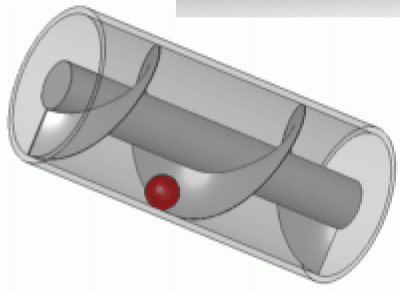
Historical Perspectives

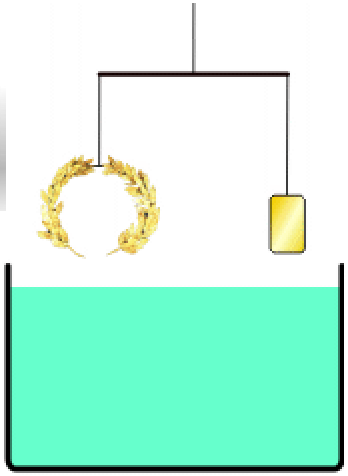
Archimedes of Syracuse (287-212 BC)

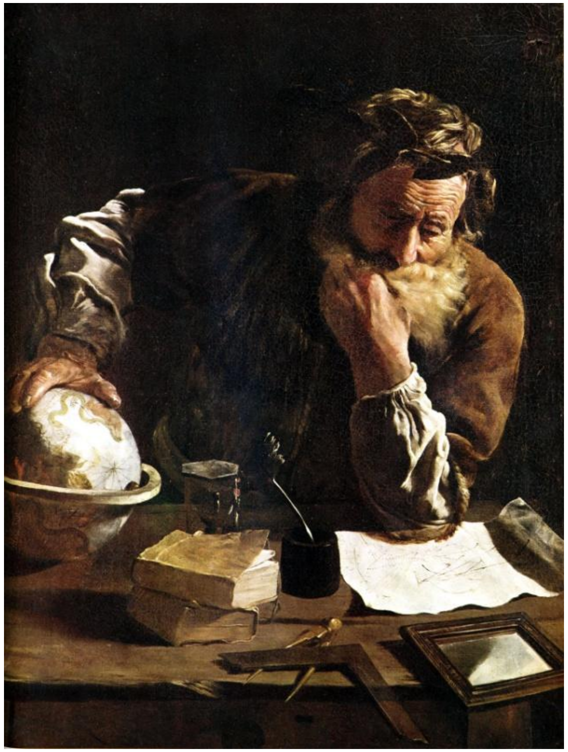


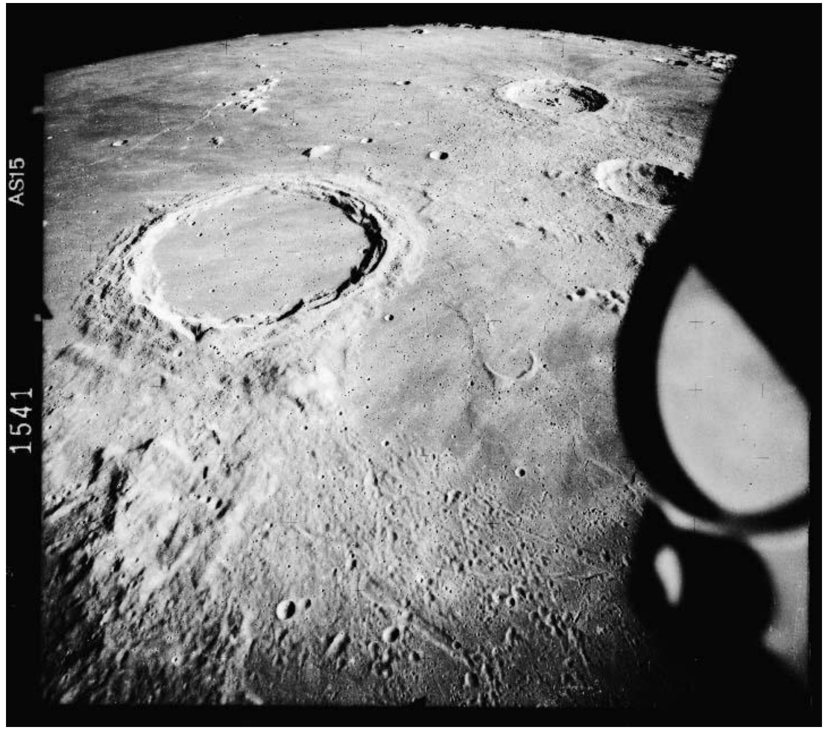
- Mathematician, physicist, engineer, inventor, astronomer
- Leading scientist of classical antiquity
- Originated hydrostatics, mechanics Archimedean screw, spiral, lever
- Discovered Archimedes' principle
- Used infinitesimals, approximated Pi
- Designed siege and naval weapons
- Invented large number notation







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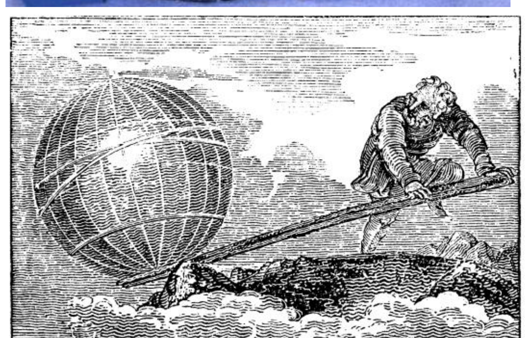
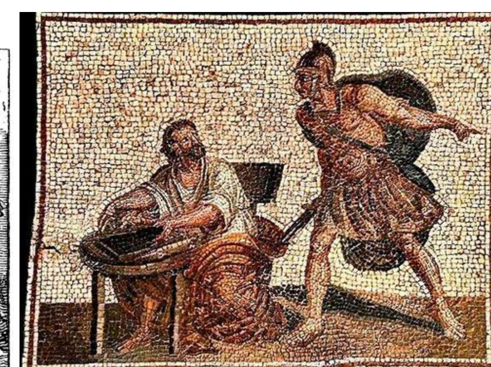
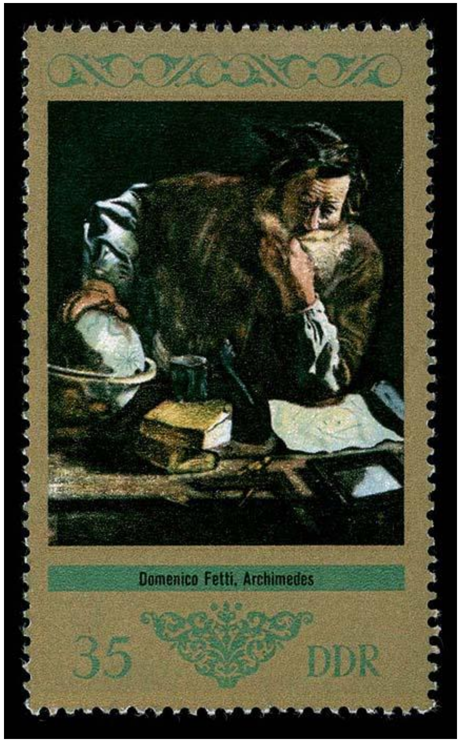
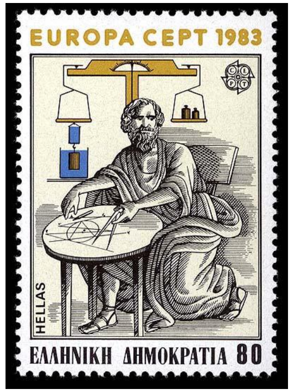





Domenico Fetti, Archimedes
35
DDR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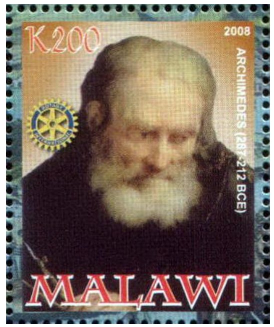
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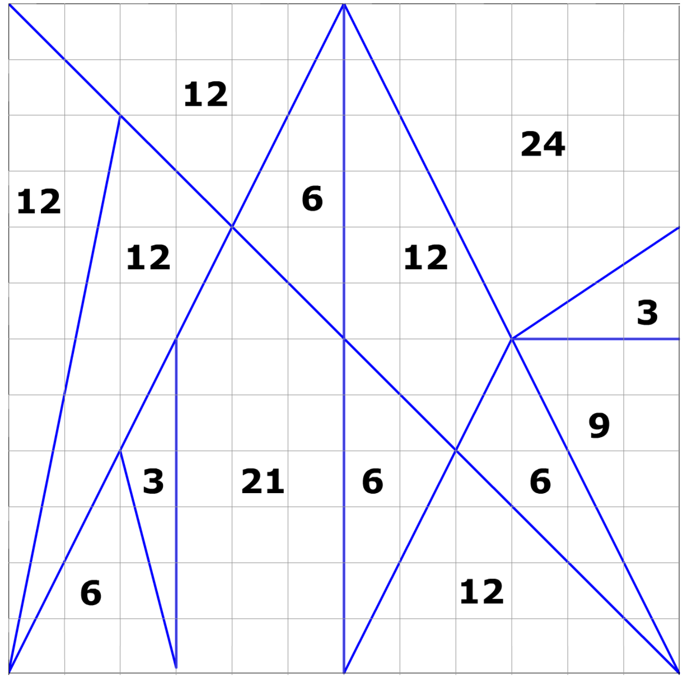
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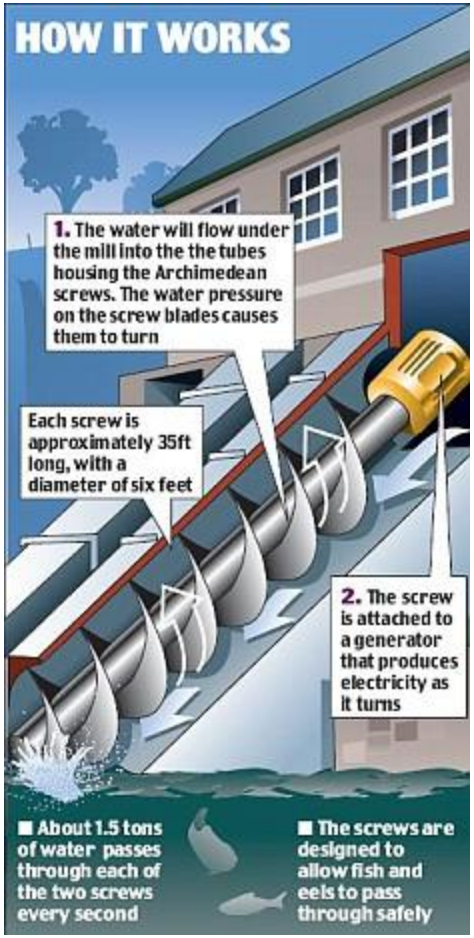
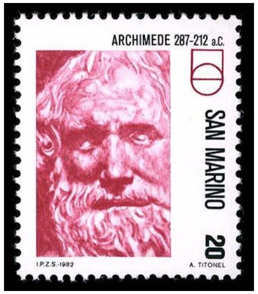

HOW IT WORKS
1. The water will flow under the mill into the the tubes housing the Archimedean screws. The water pressure on the screw blades causes them to turn
Each screw is approximately 35ft long, with a diameter of six feet
2. The screw is attached to a generator that produces electricity as it turns
About 1.5 tons of water passes through each of the two screws every second
The screws are designed to allow fish and eels to pass through safely


NICARAGUA
LEY DE ARQUIMEDES
AEREO
2
CORDOBAS
DE LA RUE
LAS 10 FORMULAS MATEMATICAS QUE CAMBIARON LA FAZ DE LA TIERRA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CORREOS
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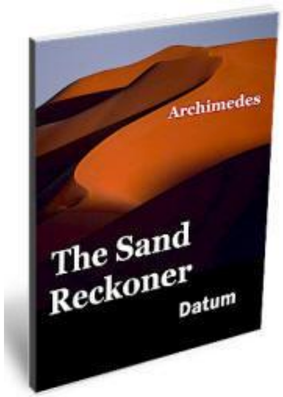
Archimedes
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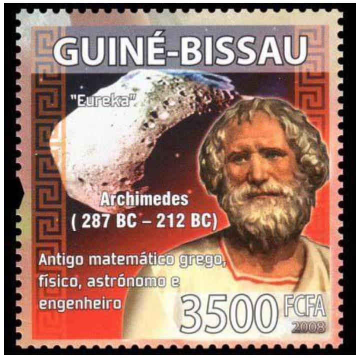
GUINÉ-BISSAU
"Eureka"
Archimedes
(287 BC – 212 BC)
Antigo matemático grego, físico, astrónomo e engenheiro
3500 FCFA
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€ 0,41
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ITALIA
ANNO MONDIALE DELLA MATEMATICA


ARCHIMEDES
is my homeboy


EUREKA!


ARCHIMEDES
83 km / 2150 m
97 / 10 / 09
D=254mm f/D=10
Moon "LIGHT"
© António J. Cidadão
8
B/W QuickCam
a.cidadao@mail.telepac.pt

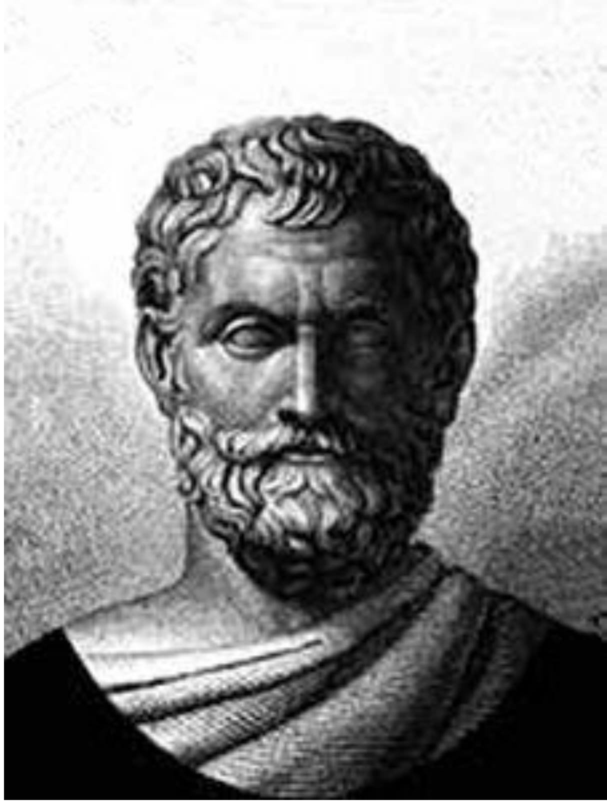

S. Harris
"THERE GOES ARCHIMEDES WITH HIS CONFOUNDED LEVER AGAIN"

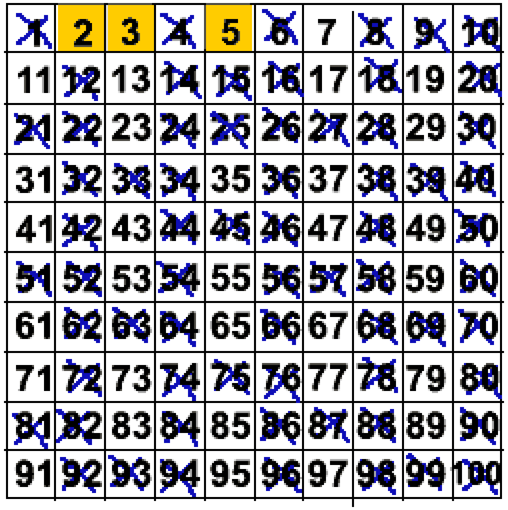
"The periodic table."

Historical Perspectives

Eratosthenes (276BC-194BC)

- Chief librarian at Library of Alexandria
- Measured the Earth’s size (<1% error!)
- Calculated the Earth-Sun distance
- Invented latitude and longtitude
- Primes - “Sieve of Eratosthenes”
- Chronology of ancient history
- Wrote on astronomy, geography, history, mathematics, philosophy, and literature





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61	62	63	64	65	66	67	68	69	70
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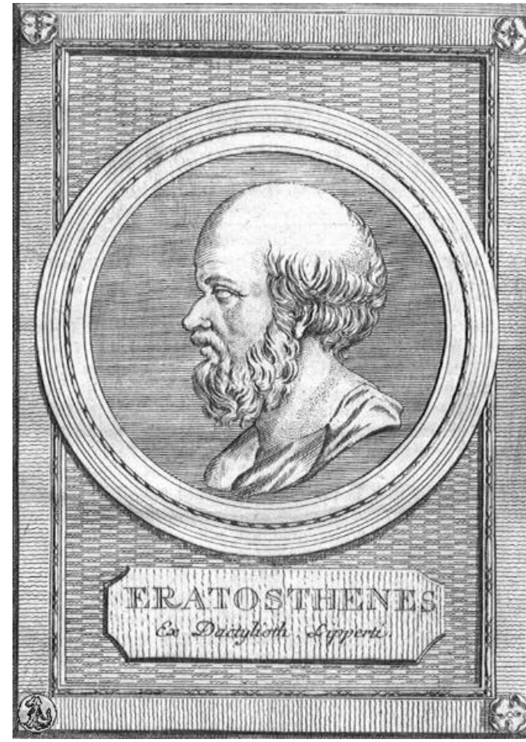
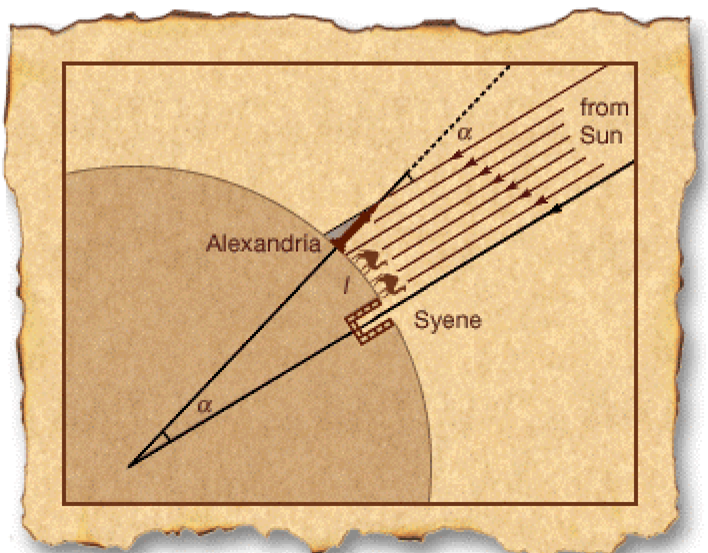
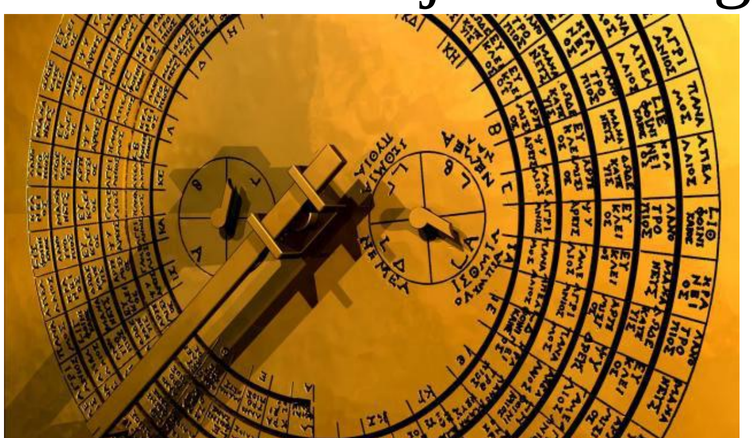
Prime numbers

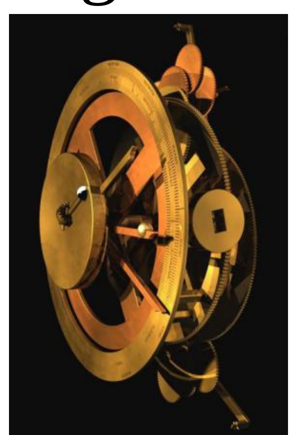


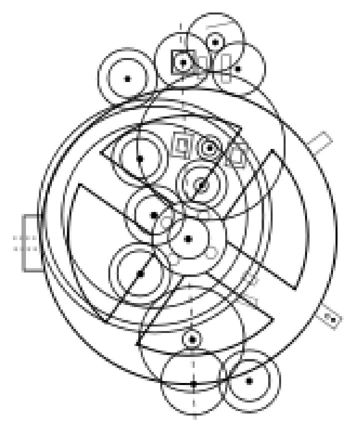


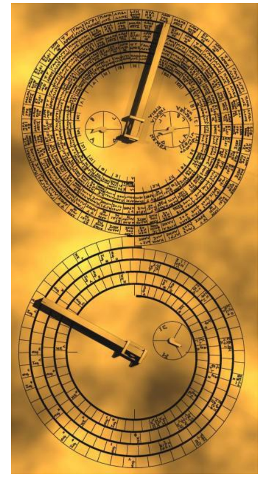
An Ancient Computer: The Antikythera

- Oldest known mechanical computer
- Built around 150-100 BCE !
- Calculates eclipses and astronomical positions of sun, moon, and planets
- Very sophisticated for its era
- Contains dozens of intricate gears
- Comparable to 1700's Swiss clocks
- Has an attached "instructions manual"
- Still the subject of ongoing research





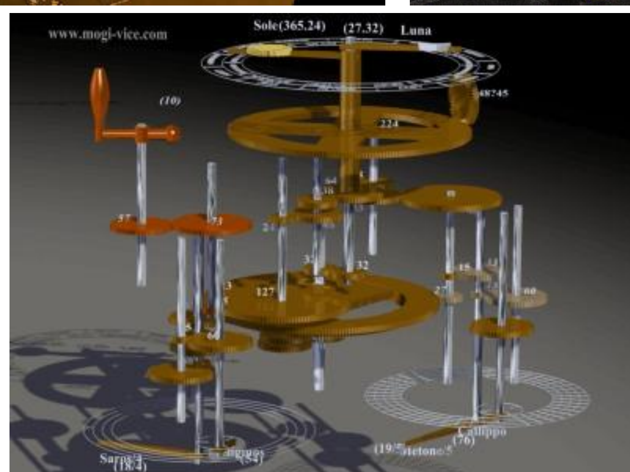









www.mogi-vice.com
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Callippo
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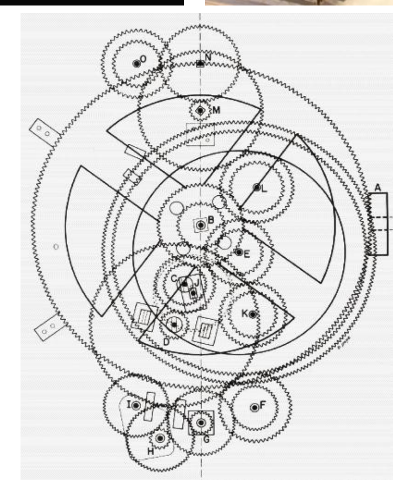
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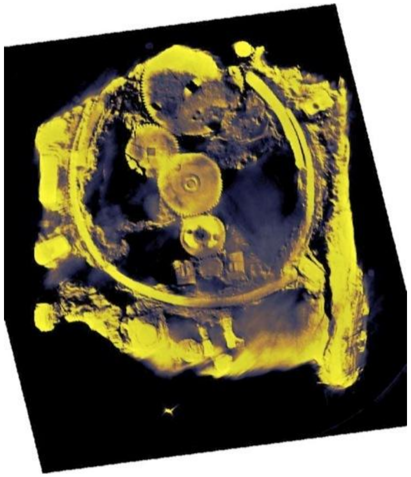
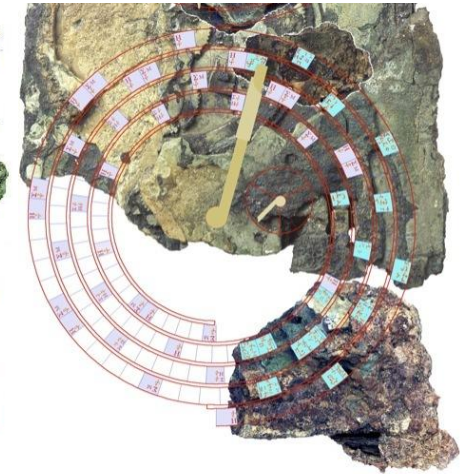
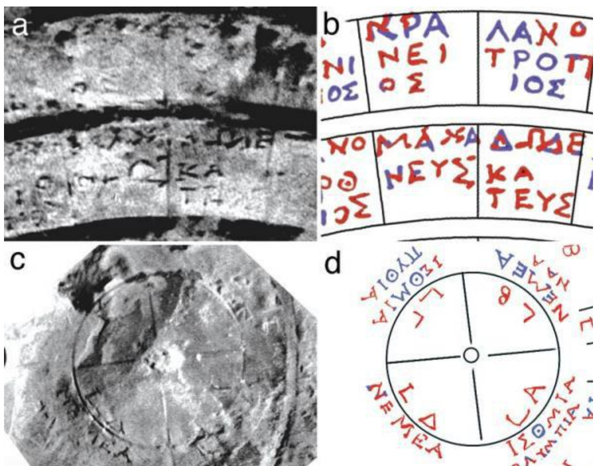



© Antikythera Mechanism Research Project

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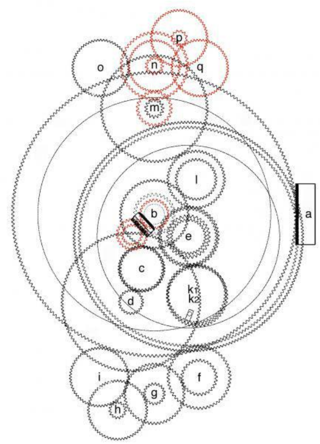
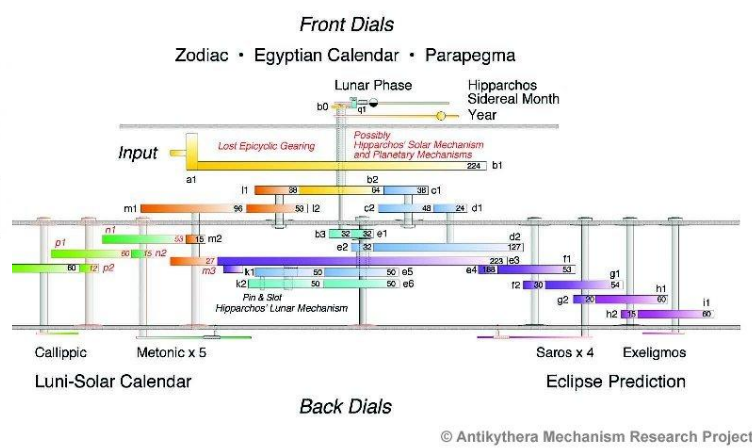
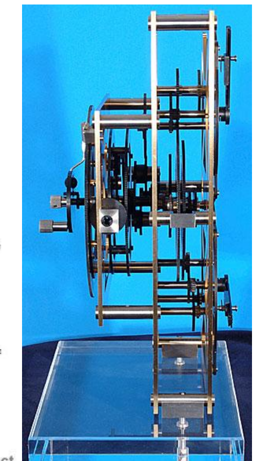


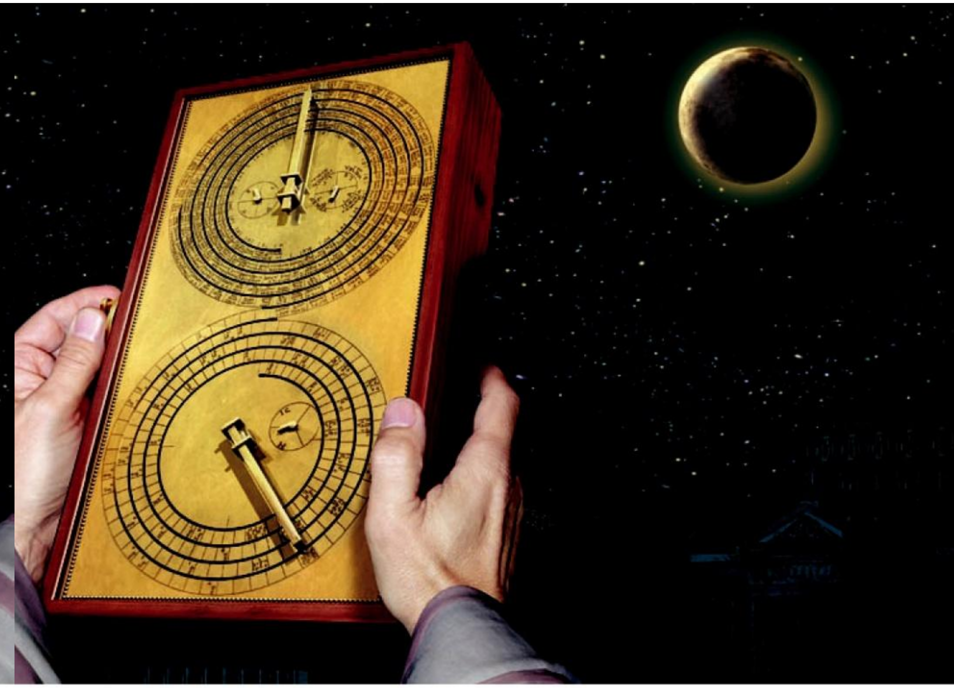

Front Dials
Zodiac • Egyptian Calendar • Parapegma
Lunar Phase
Hipparchos Sidereal Month
Year
Input
Lost Epicyclic Gearing
Possibly Hipparchos' Solar Mechanism and Planetary Mechanisms
Pin & Slot Hipparchos' Lunar Mechanism
Callippic
Metonic x 5
Saros x 4
Exeligmos
Luni-Solar Calendar
Eclipse Prediction
Back Dials
© Antikythera Mechanism Research Project



DECODING AN *Ancient Computer*

New explorations have revealed how the Antikythera mechanism modeled lunar motion and predicted eclipses, among other sophisticated tricks

By Tony Freeth



ANCIENT GREEKS **knew how to calculate the recurring patterns of lunar eclipses thanks to observations made for centuries by the Babylonians. The Antikythera mechanism would have done those calculations for them—or perhaps for the wealthy Romans who could afford to own it. The depiction here is based on a theoretical reconstruction by the author and his collaborators.**

KEY CONCEPTS

- The Antikythera mechanism is a unique mechanical calculator from second-century B.C. Greece. Its sophistication surprised archaeologists when it was discovered in 1901. But no one had anticipated its true power.
- Advanced imaging tools have finally enabled researchers to reconstruct how the device predicted lunar and solar eclipses and the motion of the moon in the sky.
- Inscriptions on the mechanism suggest that it might have been built in the Greek city of Syracuse (now in modern Sicily), perhaps in a tradition that originated with Archimedes.

—The Editors

If it had not been for two storms 2,000 years apart in the same area of the Mediterranean, the most important technological artifact from the ancient world could have been lost forever.

The first storm, in the middle of the 1st century B.C., sank a Roman merchant vessel laden with Greek treasures. The second storm, in A.D. 1900, drove a party of sponge divers to shelter off the tiny island of Antikythera, between Crete and the mainland of Greece. When the storm subsided, the divers tried their luck for sponges in the local waters and chanced on the wreck. Months later the divers returned, with backing from the Greek government. Over nine months they recovered a hoard of beautiful ancient Greek objects—rare bronzes, stunning glassware, amphorae, pottery and jewelry—in one of the first major underwater archaeological excavations in history.

One item attracted little attention at first: an undistinguished, heavily calcified lump the size of a phone book. Some months later it fell apart, revealing the remains of corroded bronze gearwheels—all sandwiched together and with teeth just one and a half millimeters long—along with plates covered in scientific scales and Greek inscriptions. The discovery was a shock: until then, the ancients were thought to have made gears only for crude mechanical tasks.

Three of the main fragments of the Antikythera mechanism, as the device has come to be known, are now on display at the Greek National Archaeological Museum in Athens. They look small and fragile, surrounded by imposing bronze statues and other artistic glories of ancient Greece. But their subtle power is even more shocking than anyone had imagined at first.

I first heard about the mechanism in 2000. I was a filmmaker, and astronomer Mike Edmunds of Cardiff University in Wales contacted me because he thought the mechanism would make a great subject for a TV documentary. I learned that over many decades researchers studying the mechanism had made considerable progress, suggesting that it calculated astronomical data, but they still had not been able to fully grasp how it worked. As a former mathematician, I became intensely interested in understanding the mechanism myself.

Edmunds and I gathered an international collaboration that eventually included historians, astronomers and two teams of imaging experts. In the past few years our group has reconstructed how nearly all the surviving parts worked and what functions they performed. The mechanism calculated the dates of lunar and solar eclipses, modeled the moon's subtle apparent motions through the sky to the best of the available knowledge, and kept track of the dates of events of social significance, such as the Olympic Games. Nothing of comparable technological sophistication is known anywhere in the world for at least a millennium afterward. Had this unique specimen not survived, historians would have thought that it could not have existed at that time.

Early Pioneers

German philologist Albert Rehm was the first person to understand, around 1905, that the Antikythera mechanism was an astronomical calculator. Half a century later, when science historian Derek J. de Solla Price, then at the Institute for Advanced Study in Princeton, N.J., described the device in a *Scientific American* article, it still had revealed few of its secrets.

The device, Price suggested, was operated by turning a crank on its side, and it displayed its output by moving pointers on dials located on its front and back. By turning the crank, the user could set the machine on a certain date as indicated on a 365-day calendar dial in the front. (The dial could be rotated to adjust for an extra day every four years, as in today's leap years.) At the same time, the crank powered all the other gears in the mechanism to yield the information corresponding to the set date.

A second front dial, concentric with the calendar, was marked out with 360 degrees and with the 12 signs representing the constellations of the zodiac [*see box on pages 80 and 81*]. These are the constellations crossed by the sun in its apparent motion with respect to the "fixed" stars—"motion" that in fact results from Earth's orbiting the sun—along the path called the ecliptic. Price surmised that the front of the mechanism probably had a pointer showing where along the ecliptic the sun would be at the desired date.

In the surviving fragments, Price identified the remains of a dozen gears that had been part of the mechanism's innards. He also estimated their tooth counts—which is all one can do given that nearly all the gears are damaged and incomplete. Later, in a landmark 1974 study, Price described 27 gears in the main fragment and provided improved tooth counts based on the first x-rays of the mechanism, by Greek radiologist Charalambos Karakalos.

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[THE PLACES]

The Greek and Roman worlds, circa 145 B.C.

Where Was It From?

The Antikythera mechanism was built around the middle of the 2nd century B.C., a time when Rome was expanding at the expense of the Greek-dominated Hellenistic kingdoms (*green*). Divers recovered its corroded remnants (*including fragment at left*) in A.D. 1901 from a shipwreck near the island of Antikythera. The ship sank around 65 B.C. while carrying Greek artistic treasures, perhaps from Pergamon to Rome. Rhodes had one of the major traditions of Greek astronomy, but the latest evidence points to a Corinthian origin. Syracuse, which had been a Corinthian colony in Sicily, is a possibility: the great Greek inventor Archimedes had lived there and may have left behind a technological tradition.

Tooth counts indicate what the mechanism calculated. For example, turning the crank to give a full turn to a primary 64-tooth gear represented the passage of a year, as shown by a pointer on the calendar dial. That primary gear was also paired to two 38-tooth secondary gears, each of which consequently turned by 64/38 times for every year. Similarly, the motion relayed from gear to gear throughout the mechanism; at each step, the ratio of the numbers of gear teeth represents a different fraction. The motion eventually transmitted to the pointers, which thus turned at rates corresponding to different astronomical cycles. Price discovered that the ratios of one of these gear trains embodied an ancient Babylonian cycle of the moon.

Price, like Rehm before him, suggested that the mechanism also contained epicyclic gearing—gears spinning on bearings that are themselves attached to other gears, like the cups on a Mad Hatter teacup ride. Epicyclic gears extend the range of formulas gears can calculate beyond multiplications of fractions to additions and subtractions. No other example of epicyclic gearing is known to have existed in Western technology for another 1,500 years.

Several other researchers studied the mechanism, most notably Michael Wright, a curator at the Science Museum in London, in collaboration with computer scientist Allan Bromley of the University of Sydney. They took the first three-dimensional x-rays of the mechanism and showed that Price's model of the mechanism had to be wrong. Bromley died in 2002, but Wright persisted and made significant advances. For example, he found evidence that the back dials, which at first look like concentric rings, are in fact spirals and discovered an epicyclic mechanism at the front that calculated the phase of the moon.

Wright also adopted one of Price's insights, namely that the dial on the upper back might be a lunar calendar, based on the 19-year, 235-lunar-month cycle called the Metonic cycle. This calendar is named after fifth-century B.C. astronomer Meton of Athens—although it had been discovered earlier by the Babylonians—and is still used today to determine the Jewish festival of Rosh Hashanah and the Christian festival of Easter. Later, we would discover that the pointer was extensible, so that a pin on its end could follow a groove around each successive turn of the spiral.

BladeRunner in Athens

As our group began its efforts, we were hampered by a frustrating lack of data. We had no access to the previous x-ray studies, and we did not even have a good set of still photographs. Two images in a science magazine—x-rays of a goldfish and an enhanced photograph of a Babylonian clay tablet—suggested to me new ways to get better data.

We asked Hewlett-Packard in California to perform state-of-the-art photographic imaging and X-Tek Systems in the U.K. to do three-dimensional x-ray imaging. After four years of careful diplomacy, John Seiradakis of the Aristotle University of Thessaloniki and Xenophon Moussas of the University of Athens obtained the required permissions, and we arranged for the imaging teams to bring their tools to Athens, a necessary step because the Antikythera mechanism is too fragile to travel.

Meanwhile we had a totally unexpected call from Mary Zafeiropoulou at the museum. She had been to the basement storage and found boxes of bits labeled "Antikythera." Might we be interested? Of course we were interested. We now had a total of 82 fragments, up from about 20.

The HP team, led by Tom Malzbender, assembled a mysterious-looking dome about five feet across and covered in electronic flashbulbs that provided lighting from a range of different angles. The team exploited a technique from the computer gaming industry, called polynomial texture mapping, to enhance surface details. Inscriptions Price had found difficult to read were now clearly legible, and fine details could be enhanced on the computer screen by controlling the reflectance of the surface and the angle of the lighting. The inscriptions are essentially an instruction manual written on the outer plates.

A month later local police had to clear the streets in central Athens so that a truck carrying the BladeRunner, X-Tek's eight-ton x-ray machine, could gain access to the museum. The BladeRunner performs computed tomography similar to a hospital's CT scan, but with finer detail. X-Tek's Roger Hadland and his group had specially modified it with enough x-ray power to penetrate the fragments of the Antikythera mechanism. The resulting 3-D reconstruction was wonderful: whereas Price could see only a puzzle of overlapping gears, we could now isolate layers inside the fragment and see all the fine details of the gear teeth.

Unexpectedly, the x-rays revealed more than 2,000 new text characters that had been hidden deep inside the fragments. (We have now identified and interpreted a total of 3,000 characters out of perhaps 15,000 that existed originally.) In Athens, Moussas and Yanis Bitsakis, also at the University of Athens, and Agamemnon Tselikas of the Center for History and Palaeography be-

Historians would have thought that SOMETHING SO COMPLEX *could not have existed at the time.*

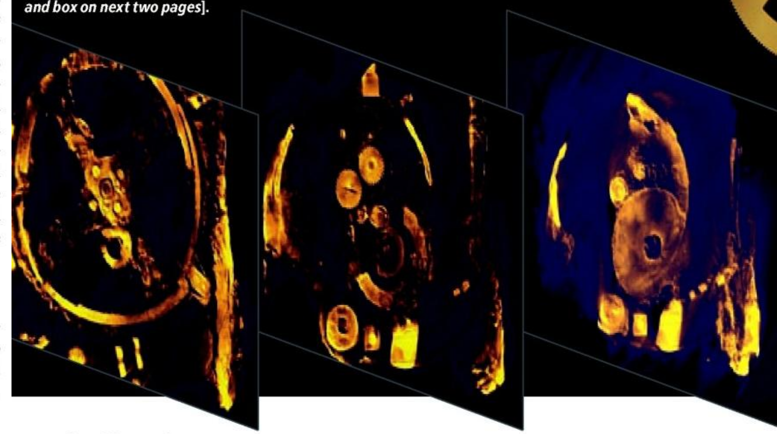
[THE AUTHOR]

Tony Freeth's academic background is in mathematics and mathematical logic (in which he holds a Ph.D.). His award-winning career as a filmmaker culminated in a series of documentaries about increasing crop yields in sub-Saharan Africa, featuring the late Nobel Peace Prize Laureate Norman Borlaug. Since 2000 Freeth has returned to an academic focus with research on the Antikythera mechanism. He is managing director of the film and television production company Images First, and he is now developing a film on the mechanism.

[THE RECONSTRUCTION]

Anatomy of a Relic

Computed tomography—a 3-D mapping obtained from multiple x-ray shots—enabled the author and his colleagues to get inside views of the Antikythera mechanism's remnants. For example, a CT scan can be used to virtually slice up an object (*below, slices of main fragment*). The information helped the team see how the surviving gears connected and estimate their tooth counts, which determined what calculations they performed. The team could then reconstruct most of the device [*see model at right and box on next two pages*].



gan to discover inscriptions that had been invisible to human eyes for more than 2,000 years. One translated as "... spiral subdivisions 235...," confirming that the upper back dial was a spiral describing the Metonic calendar.

Babylon System

Back at home in London, I began to examine the CT scans as well. Certain fragments were clearly all part of a spiral dial in the lower back. An estimate of the total number of divisions in the dial's four-turn spiral suggested 220 to 225.

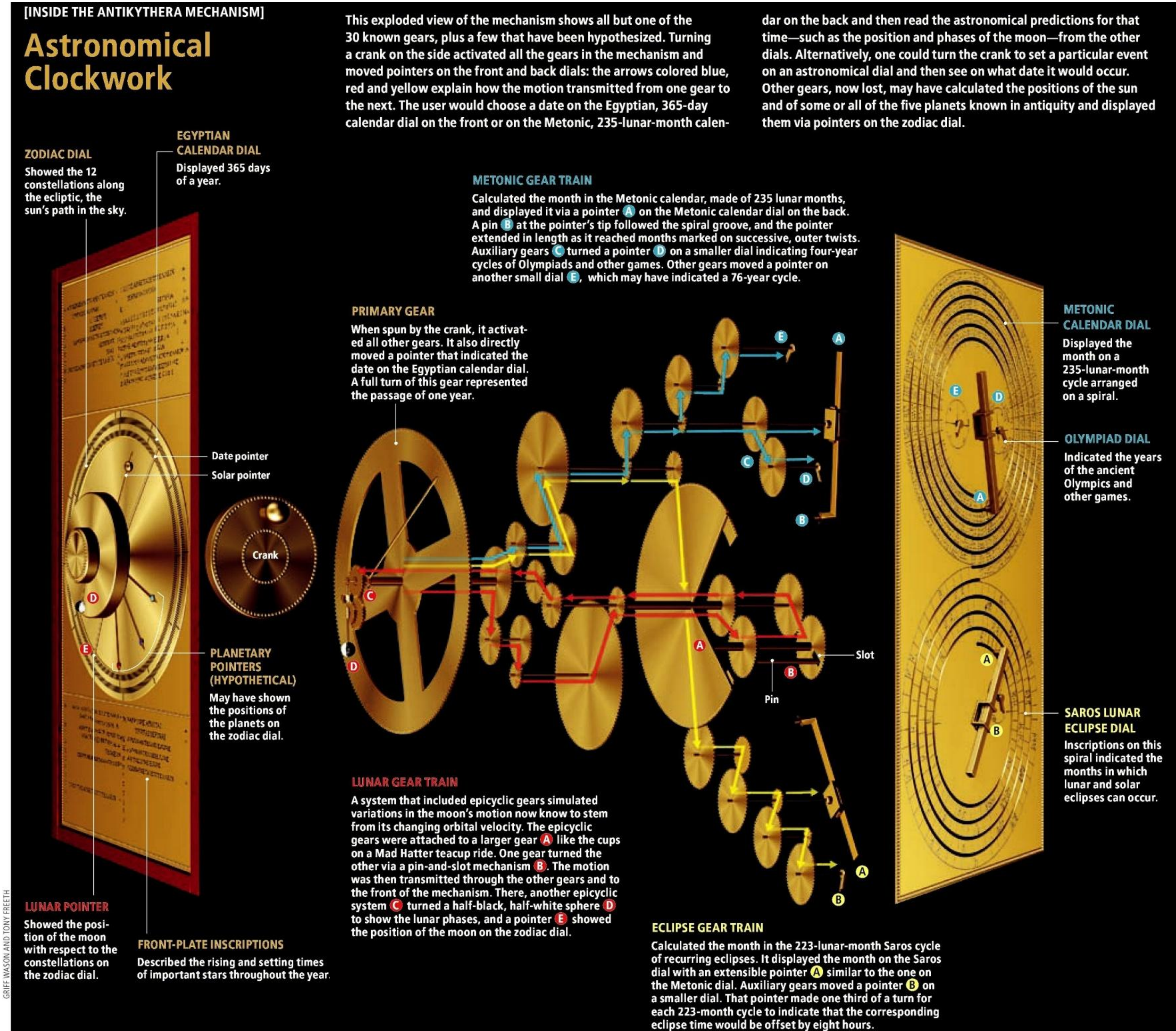
The prime number 223 was the obvious contender. The ancient Babylonians had discovered that if a lunar eclipse is observed—something that can happen only during a full moon—usually a similar lunar eclipse will take place 223 full moons later. Similarly, if the Babylonians saw a solar eclipse—which can take place only during a new moon—they could predict that 223 new moons later there would be a similar one (although they could not always see it: solar eclipses are visible only from specific locations, and ancient astronomers could not predict them reliably). Eclipses repeat this way because every 223 lunar months the sun, Earth and the moon return to approximately the same alignment with respect to one another, a periodicity known as the Saros cycle.

Between the scale divisions were blocks of symbols, nearly all containing Σ (*sigma*) or *H* (*eta*), or both. I soon realized that Σ stands for Σεληνη (*selene*), Greek for "moon," indicating a lunar eclipse; *H* stands for Ηλιοσ (*helios*), Greek for "sun," indicating a solar eclipse. The Babylonians also knew that within the 223-month period, eclipses can take place only in particular months, arranged in a predictable pattern and separated by gaps of five or six months; the distribution of symbols around the dial exactly matched that pattern.

I now needed to follow the trail of clues into the heart of the mechanism to discover where this new insight would lead. The first step was to find a gear with 223 teeth to drive this new Saros dial. Karakalos had estimated that a large gear visible at the back of the main fragment had 222 teeth. But Wright had revised this estimate to 223, and Edmunds confirmed this. With plausible tooth counts for other gears and with the addition of a small, hypothetical gear, this 223-tooth gear could perform the required calculation.

But a huge problem still remained unsolved and proved to be the hardest part of the gearing to crack. In addition to calculating the Saros cy-

GRIFF WASON AND TONY FREETH



cle, the large 223-tooth gear also carried the epicyclic system noticed by Price: a sandwich of two small gears attached to the larger gear in teacup-ride fashion. Each epicyclic gear also connected to another small gear. Confusingly, all four small gears appeared to have the same tooth count—50—which seemed nonsensical because the output would then be the same as the input.

After months of frustration, I remembered that Wright had observed that one of the two epicyclic gears has a pin on its face that engages with a slot on the other. His key idea was that the two gears turned on slightly different axes, separated by about a millimeter. As a consequence, the angle turned by one gear alternated between being slightly wider and being slightly narrower than the angle turned by the other gear. Thus, if one gear turned at a constant rate, the other gear's rate kept varying between slightly faster and slightly slower.

Ask for the Moon

Although Wright rejected his own observation, I realized that the varying rotation rate is precisely what is needed to calculate the moon's motion according to the most advanced astronomical theory of the second century B.C., the one often attributed to Hipparchos of Rhodes. Before Kepler (A.D. 1605), no one understood that orbits are elliptical and that the moon accelerates toward the perigee—its closest point to Earth—and slows down toward the apogee, the opposite point. But the ancients did know that the moon's motion against the zodiac appears to periodically slow down and speed up. In Hipparchos's model, the moon moved at a constant rate around a circle whose center itself moved around a circle at a constant rate—a fairly good approximation of the moon's apparent motion. These circles on circles, themselves called epicycles, dominated astronomical thinking for the next 1,800 years.

There was one further complication: the apogee and perigee are not fixed, because the ellipse of the moon's orbit rotates by a full turn about every nine years. The time it takes for the body to get back to the perigee is thus a bit longer than the time it takes it to come back to the same point in the zodiac. The difference was just 0.112579655 turns a year. With the input gear having 27 teeth, the rotation of the large gear was slightly too big; with 26 teeth, it was slightly too small. The right result seemed to be about halfway in between. So I tried the impossible idea that the input gear had $26\frac{1}{2}$ teeth. I pressed the key on my calculator, and it gave 0.112579655—exactly the right answer. It could not be a coincidence to nine places of decimals! But gears cannot have fractional numbers of teeth.

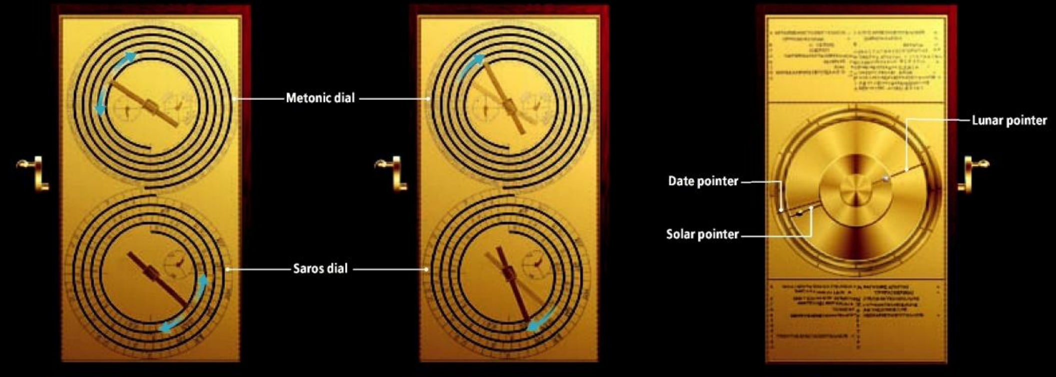
Then I realized that $26\frac{1}{2} \times 2 = 53$. In fact, Wright had estimated a crucial gear to have 53 teeth, and I now saw that that count made everything work out. The designer had mounted the pin and slot epicyclically to subtly slow down the period of its variation while keeping the basic rotation the same, a conception of pure genius. Thanks to Edmunds, we also realized that the epicyclic gearing system, which is in the back of the mechanism, moved a shaft that turned inside another, hollow shaft through the rest of the mechanism and to the front, so that the lunar motion could be represented on the zodiac dial and on the lunar phase display. All gear counts were now explained, with the exception of one small gear that remains a mystery to this day.

Further research has caused us to make some modifications to our model. One was about a small subsidiary dial that is positioned in the back, inside the Metonic dial, and is divided into four quadrants. The first clue came when I read the word "*NEMEA*" under one of the quadrants. Alexander Jones, a New York University historian, explained that it refers to the Nemean Games, one of the major athletic events in ancient Greece. Eventually we found, engraved round the four sectors of the dial, most of "*ISTHMIA*," for games at Corinth, "*PYTHIA*," for games at Delphi, "*NAA*," for minor games at Dodona, and "*OLYMPIA*," for the most important games of the Greek world, the Olympics. All games took place every two or four years. Previously we had considered the mechanism to be

[A USER'S MANUAL]

How to Predict an Eclipse

Operating the Antikythera mechanism may have required only a small amount of practice and astronomical knowledge. After an initial calibration by an expert, the mechanism could provide fairly accurate predictions of events several decades in the past or future. The inscriptions on the Saros dial, coming at intervals of five or six months, corresponded to months when Earth, the sun and the moon come to a near alignment (and so represented potential solar and lunar eclipses) in a 223-lunar-month cycle. Once the month of an eclipse was known, the actual day could be calculated on the front dials using the fact that solar eclipses always happen during new moons and lunar eclipses during full moons.



RESET DATE
Begin by turning the crank to set the current month and year on the Metonic calendar. The lower pointer will turn to the corresponding month on the Saros (*eclipse*) dial.

FIND ECLIPSE MONTH
Turn the crank to move time forward until the pointer on the Saros dial points to an eclipse inscription. The inscription will indicate month and time of the day (but not the day) of an eclipse and whether it will be solar or lunar.

CALCULATE DAY
Adjust the crank until the lunar and solar pointers are aligned (*for a solar eclipse*) or at 180 degrees (*for a lunar eclipse*). The Egyptian calendar pointer will move correspondingly and indicate the day of the eclipse.

DATA BY X-TEK SYSTEMS, SOFTWARE BY VOLUME GRAPHICS, © 2005 ANTIKYTHERA MECHANISM RESEARCH PROJECT

GRIFF WASON AND TONY FREETH

purely an instrument of mathematical astronomy, but the Olympiad dial—as we named it—gave it an entirely unexpected social function.

Twenty-nine of the 30 surviving gears calculate cycles of the sun and the moon. But our studies of the inscriptions at the front of the mechanism have also yielded a trove of information on the risings and settings of significant stars and of the planets. Moreover, on the "primary" gearwheel at the front of the mechanism remnants of bearings stand witness to a lost epicyclic system that could well have modeled the back-and-forth motions of the planets along the ecliptic (as well as the anomalies in the sun's own motion). All these clues strongly support the inclusion of the sun and of at least some of the five planets known in ancient times—Mercury, Venus, Mars, Jupiter and Saturn.

Wright built a model of the mechanism with epicyclic systems for all five planets. But his ingenious layout does not agree with all the evidence. With its 40 extra gears, it may also be too complex to match the brilliant simplicity of the rest of the mechanism. The ultimate answer may still lie 50 meters down on the ocean floor.

Eureka?

The question of where the mechanism came from and who created it is still open. Most of the cargo in the wrecked ship came from the eastern Greek world, from places such as Pergamon, Kos and Rhodes. It was a natural guess that Hipparchos or another Rhodian astronomer built the mechanism. But text hidden between the 235 monthly scale divisions of the Metonic calendar contradicts this view. Some of the month names were used only in specific locations in the ancient Greek world and suggest a Corinthian origin. If the mechanism was from Corinth itself, it was almost certainly made before Corinth was completely devastated by the Romans in 146 B.C. Perhaps more likely is that it was made to be used in one of the Corinthian colonies in northwestern Greece or Sicily.

Sicily suggests a remarkable possibility. The island's city of Syracuse was home to Archimedes, the greatest scientist of antiquity. In the first century B.C. Roman statesman Cicero tells how in 212 Archimedes was killed at the siege of Syracuse and how the victorious Roman general, Marcellus, took away with him only one piece of plunder—an astronomical instrument made by Archimedes. Was that the Antikythera mechanism? We believe not, because it appears to have been made many decades after Archimedes died. But it could have been constructed in a tradition of instrument making that originated with the eureka man himself.

Many questions about the Antikythera mechanism remain unanswered—perhaps the greatest being why this powerful technology seems to have been so little exploited in its own era and in succeeding centuries.

In *Scientific American*, Price wrote:

> *It is a bit frightening to know that just before the fall of their great civilization the ancient Greeks had come so close to our age, not only in their thought, but also in their scientific technology.*

Our discoveries have shown that the Antikythera mechanism was even closer to our world than Price had conceived. ■

➡ MORE TO EXPLORE

An Ancient Greek Computer. Derek J. de Solla Price in *Scientific American*, Vol. 200, No. 6, pages 60–67; June 1959.

Gears from the Greeks: The Antikythera Mechanism—A Calendar Computer from ca. 80 B.C. Derek de Solla Price in *Transactions of the American Philosophical Society*, New Series, Vol. 64, No. 7, pages 1–70; 1974.

Decoding the Ancient Greek Astronomical Calculator Known as the Antikythera Mechanism. Tony Freeth et al. in *Nature*, Vol. 444, pages 587–591; November 30, 2006.

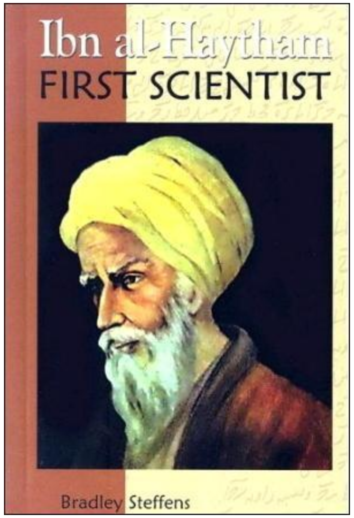
Calendars with Olympiad Display and Eclipse Prediction on the Antikythera Mechanism. Tony Freeth, Alexander Jones, John M. Steele and Yanis Bitsakis in *Nature*, Vol. 454, pages 614–617; July 31, 2008.

The Antikythera Mechanism Research Project: **www.antikythera-mechanism.gr**

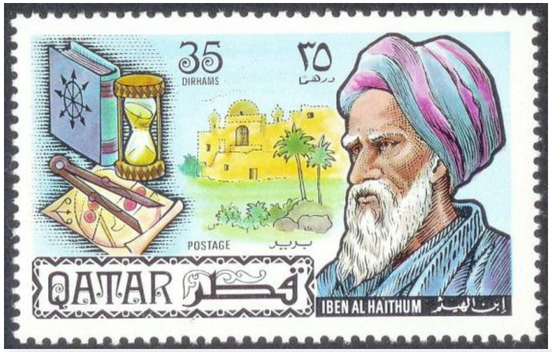
Historical Perspectives

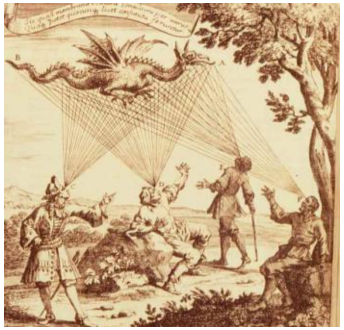
Abu Ali al-Hasan ibn al-Haytham (965-1039)

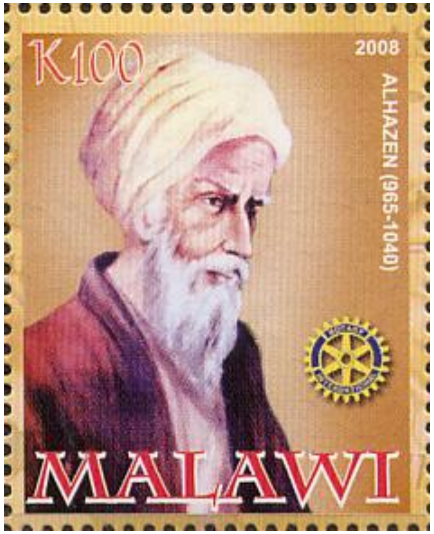
- AKA Alhazen or “The Physicist”
- Greatest scientist of the middle ages
- Contributed to mathematics, physics, optics, astronomy, anatomy, medicine, engineering, philosophy, psychology
- Pioneered the scientific method, modern optics and experimental physics
- Polymath: authored over 200 treatises, including influential “Book of Optics”
- Influenced Leonardo da Vinci, Bacon, Descartes, Kepler, Galileio and Newton

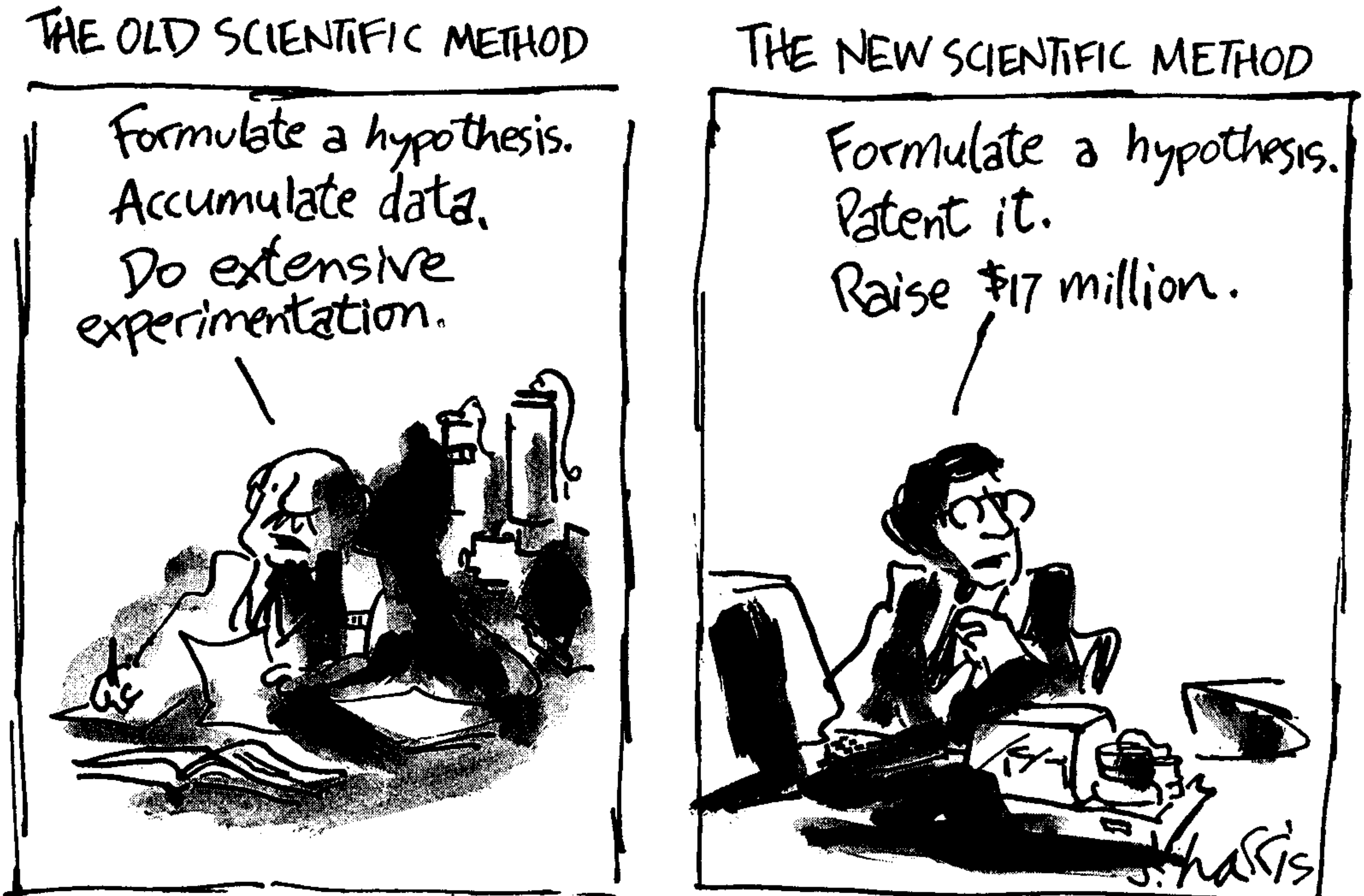



ALHAZEN FILII
ALHAYZEN OPTICAE
LIBER PRIMVS








THE OLD SCIENTIFIC METHOD
Formulate a hypothesis. Accumulate data. Do extensive experimentation.
THE NEW SCIENTIFIC METHOD
Formulate a hypothesis. Patent it. Raise $17 million.
S. harris

Historical Perspectives

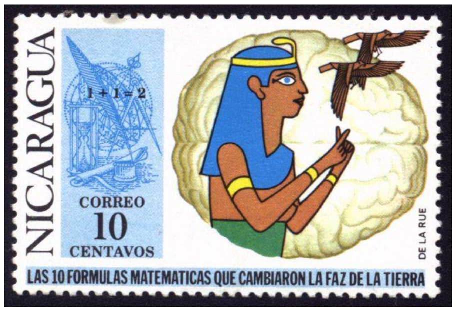
Leonardo of Pisa (1170–1250)

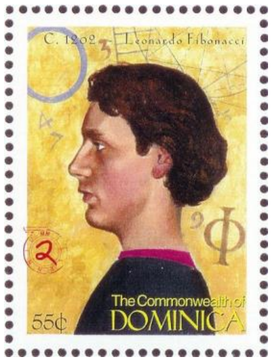
- Better known as “Fibonacci”
- Considered the most talented mathematician of the middle ages
- Published (1202) “Liber Abaci” – “The Book of Calculation”
- Introduced Hindu-Arabic positional number system in Europe
- Popularized Fibonacci sequence

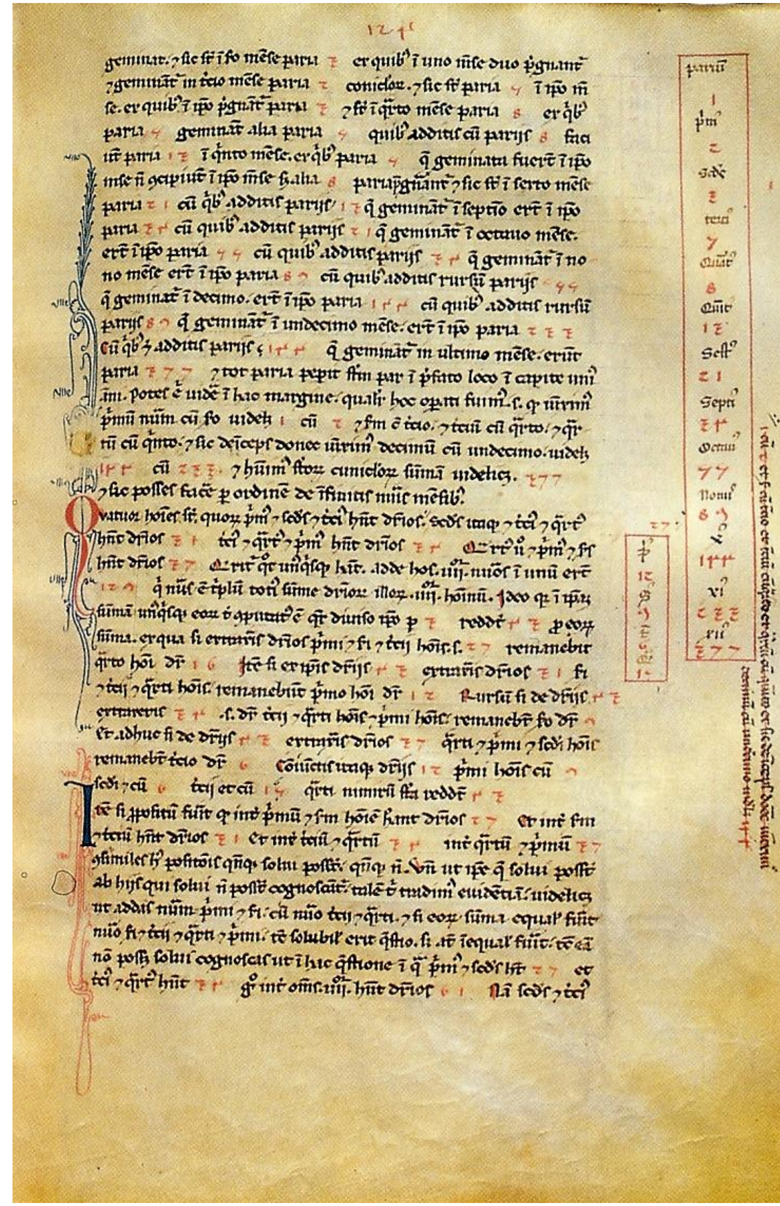
1 1 2 3 5 8 13 21 34 55 89

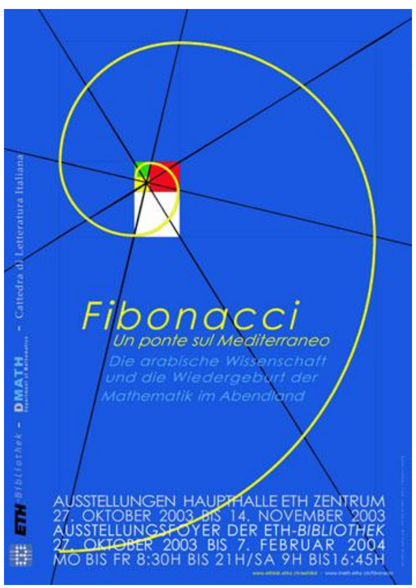
	0	1	2	3	4	5	6	7	8	9
European	0	1	2	3	4	5	6	7	8	9
Arabic-Indic	٠	١	٢	٣	٤	٥	٦	٧	٨	٩
Eastern Arabic-Indic (Persian and Urdu)	۰	۱	۲	۳	۴	۵	۶	۷	۸	۹
Devanagari (Hindi)	०	१	२	३	४	५	६	७	८	९
Tamil		௧	௨	௩	௪	௫	௬	௭	௮	௯

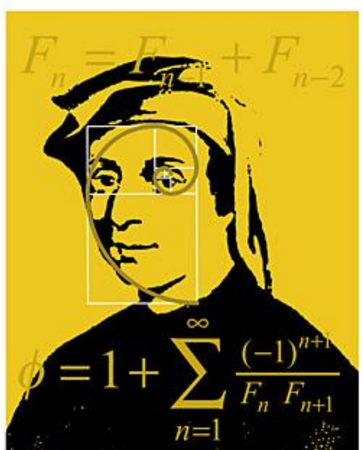
$\overline{\mathrm{V}}\mathrm{MDCLXVI} = 6666$











Leonardo Pisano Fibonacci

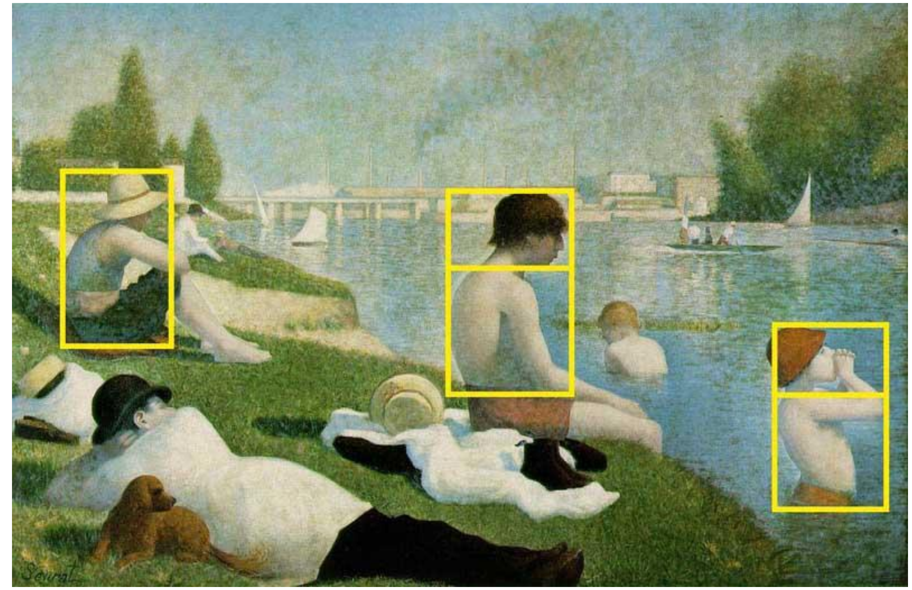
1170 - 1250

THE FIBONACCI ASSOCIATION

The Fibonacci Quarterly

Official Publication of The Fibonacci Association

THE FIBONACCI ASSOCIATION

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13
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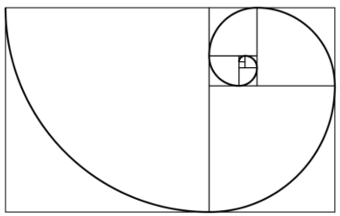
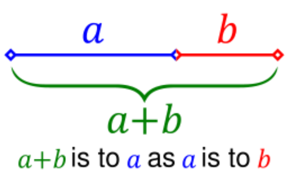
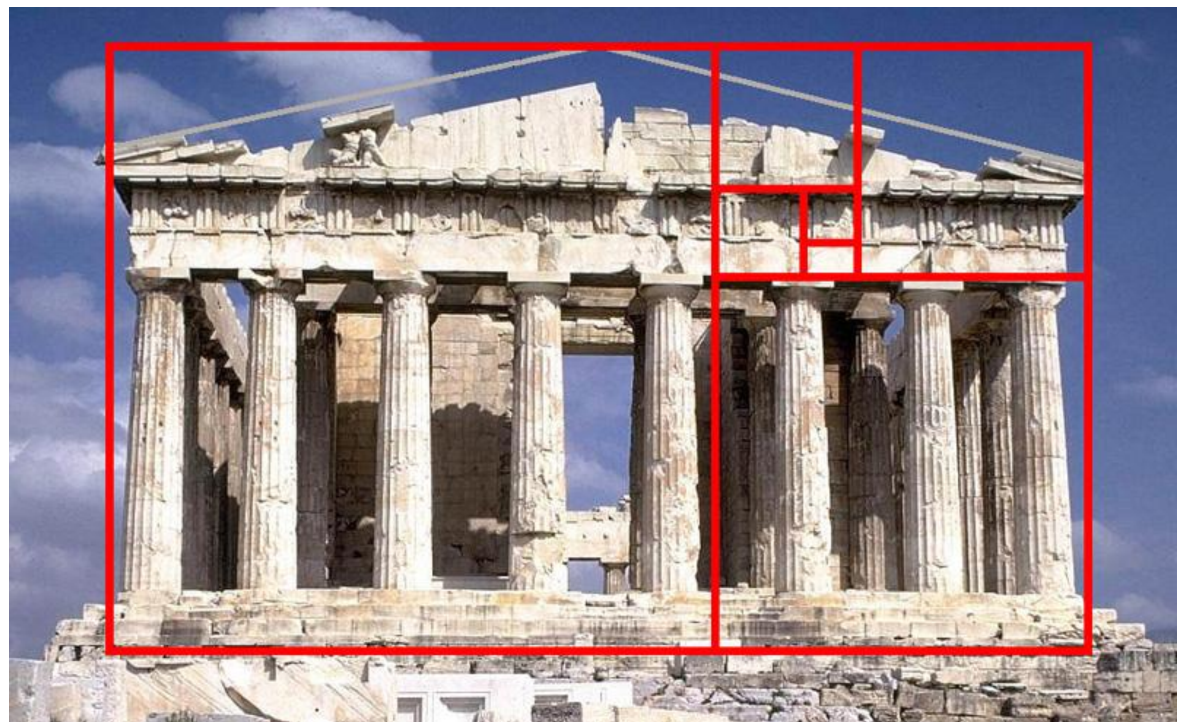
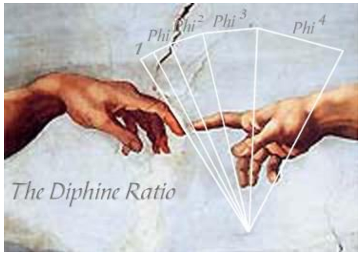
34
55



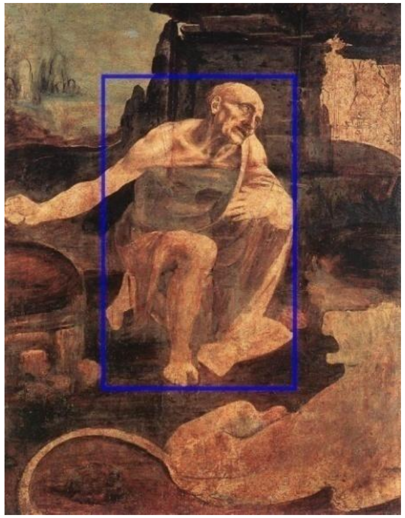

a
b
a+b
a+b is to a as a is to b





Phi
Phi 2
Phi 3
Phi 4
The Diphine Ratio

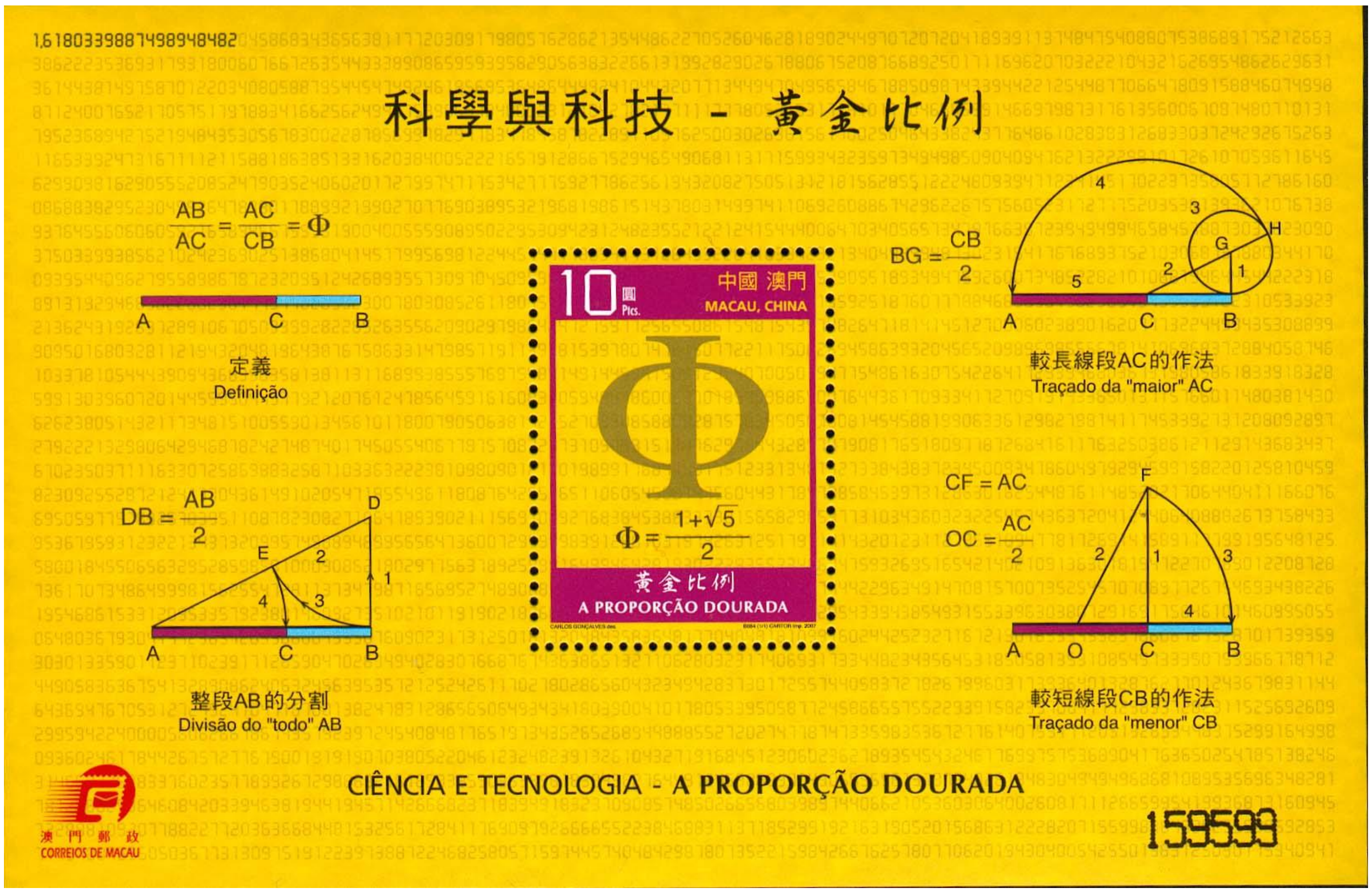
HELVETIA
80
1837-1987
sia
STEPHAN BUNDI
1987
COURVOISIER



Australia
35c
CHRISTMAS 1972
CHRIST THE LIGHT OF THE WORLD
LANCE STIRLING
RBA

日本郵便
NIPPON
60

1.5 圓 Ptcs.
Φ
中國 澳門
MACAU, CHINA
黄金比例 • 費波納奇數列
A PROPORÇÃO DOURADA • SEQUÊNCIA DE FIBONACCI
2.0 圓 Ptcs.
黄金比例 • 向日葵螺線
A PROPORÇÃO DOURADA • ESPIRAL DO GIRASSOL
3.5 圓 Ptcs.
黄金比例 • 鸚鵡螺
A PROPORÇÃO DOURADA • NAUTILUS
2.5 圓 Ptcs.
黄金比例 • 彭羅斯鑲嵌
A PROPORÇÃO DOURADA • LADRILHOS DE PENROSE



1,6180339887498948482
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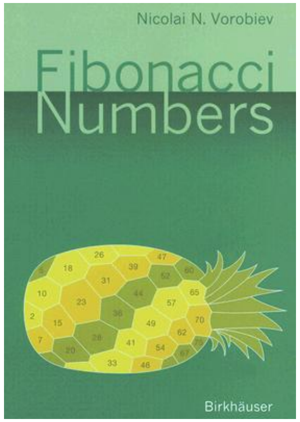
AB/AC = AC/CB = Φ
A C B
定義
Definição
DB = AB/2
D E A C B
整段AB的分割
Divisão do "todo" AB
10 圓 Ptcs.
中國 澳門
MACAU, CHINA
Φ
Φ = (1+√5)/2
黃金比例
A PROPORÇÃO DOURADA
BG = CB/2
H G A C B
較長線段AC的作法
Traçado da "maior" AC
CF = AC
OC = AC/2
F A O C B
較短線段CB的作法
Traçado da "menor" CB
CIÊNCIA E TECNOLOGIA - A PROPORÇÃO DOURADA
澳門郵政
CORREIOS DE MACAU
159599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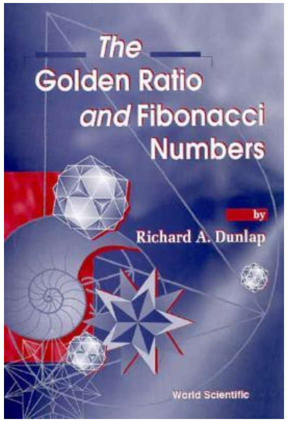
Birkhäuser

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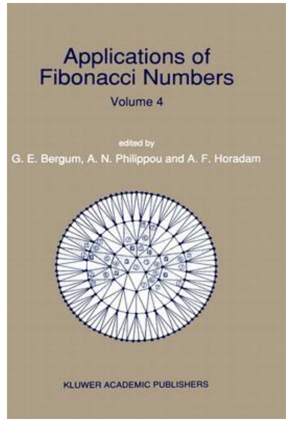
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Volume 4
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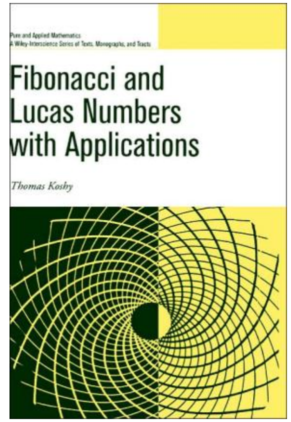
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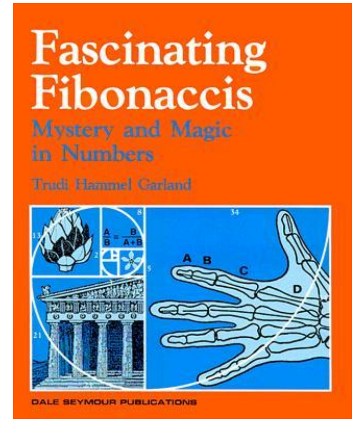
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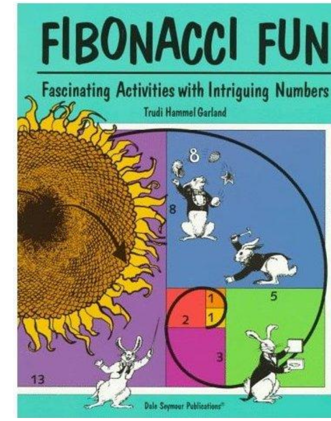
Mystery and Magic in Numbers
Trudi Hammel Garland
DALE SEYMOUR PUBLICATIONS

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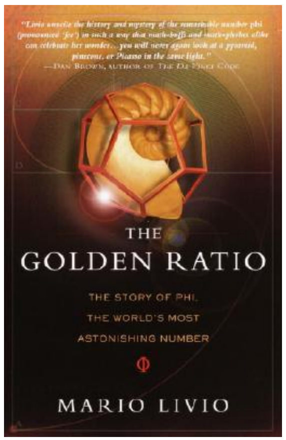
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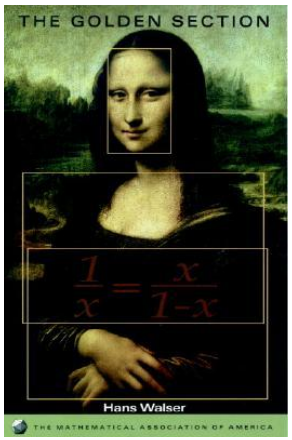
THE STORY OF PHI, THE WORLD'S MOST ASTONISHING NUMBER
Φ
MARIO LIVIO

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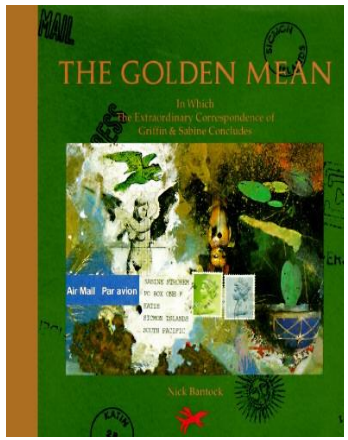
$\frac{1}{x} = \frac{x}{1-x}$
Hans Walser
THE MATHEMATICAL ASSOCIATION OF AMERICA

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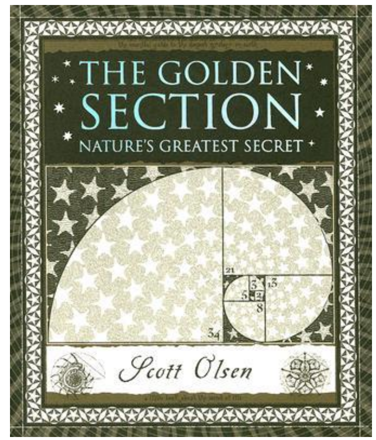
In Which The Extraordinary Correspondence of Griffin & Sabine Concludes
Air Mail Par avion
Nick Bantock

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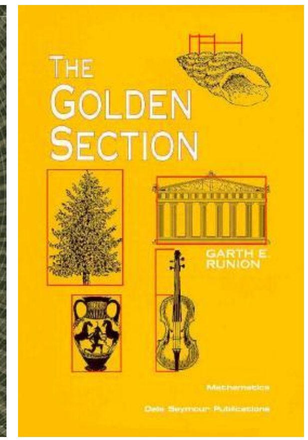
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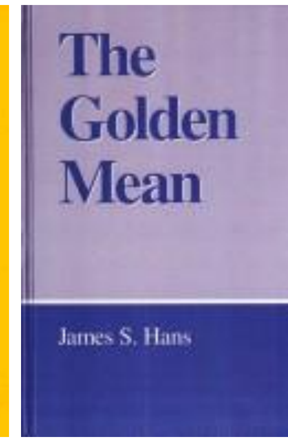
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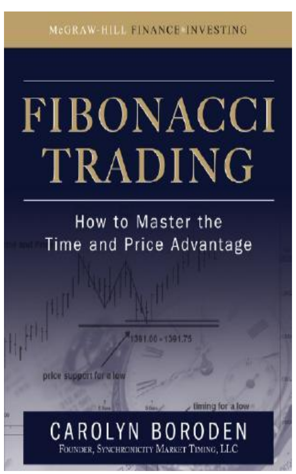
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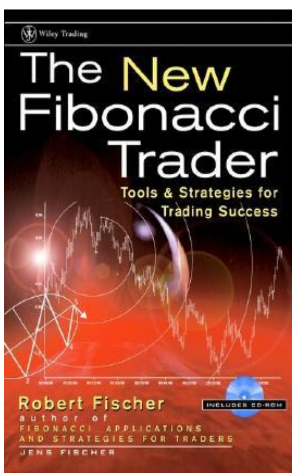
CAROLYN BORODEN

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Tools & Strategies for Trading Success
Robert Fischer
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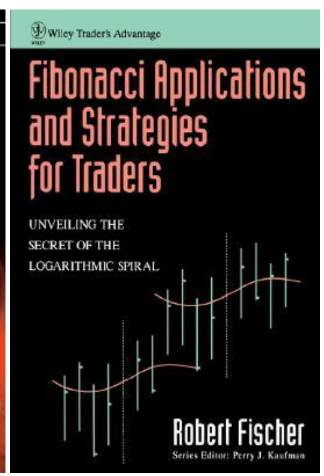
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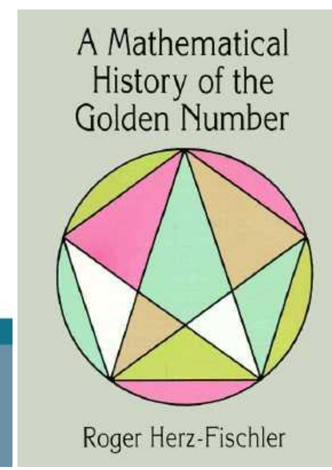
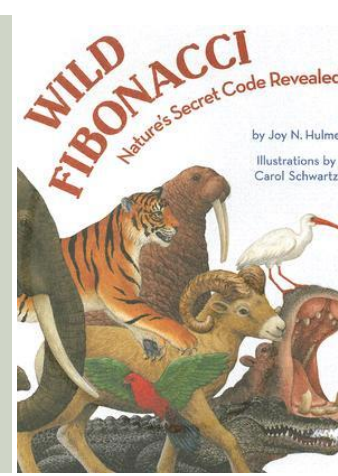
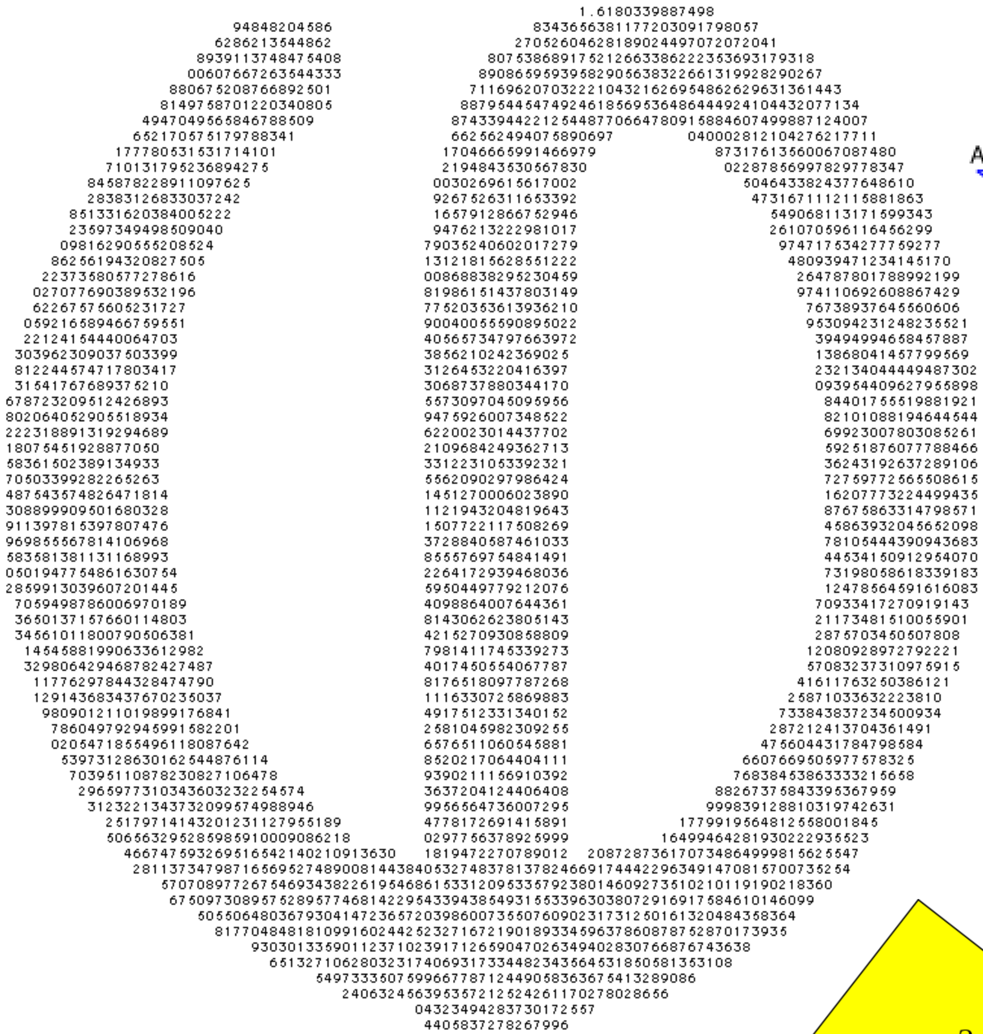
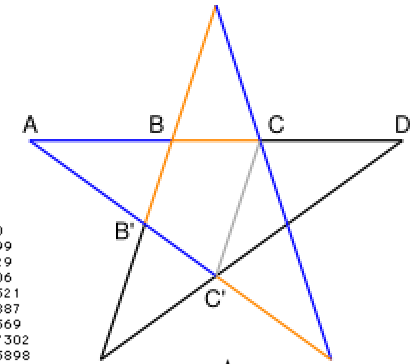
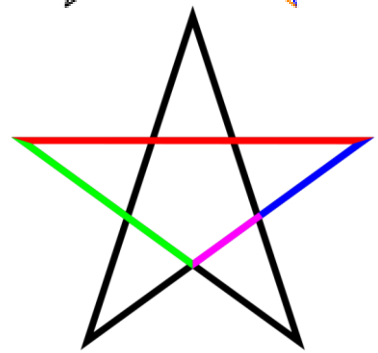
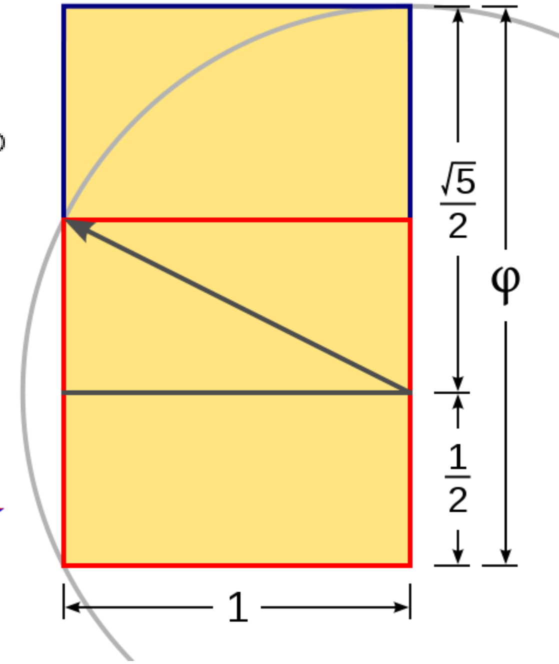
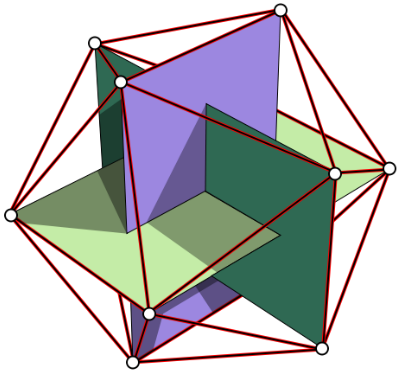
Constance BROWN

A Mathematical History of the Golden Number
Roger Herz-Fischler

WILD FIBONACCI
Nature's Secret Code Revealed
by Joy N. Hulme
Illustrations by Carol Schwartz

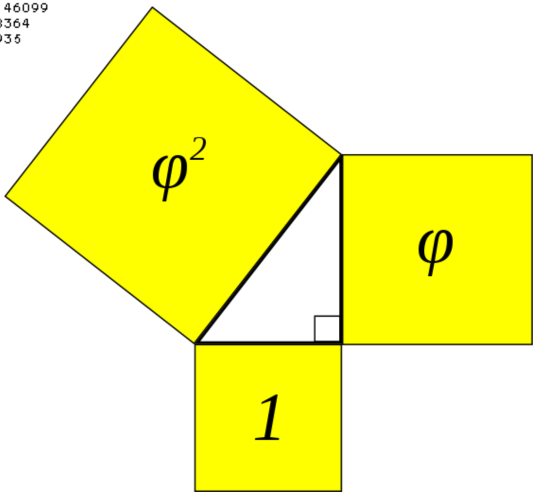

1.6180339887498

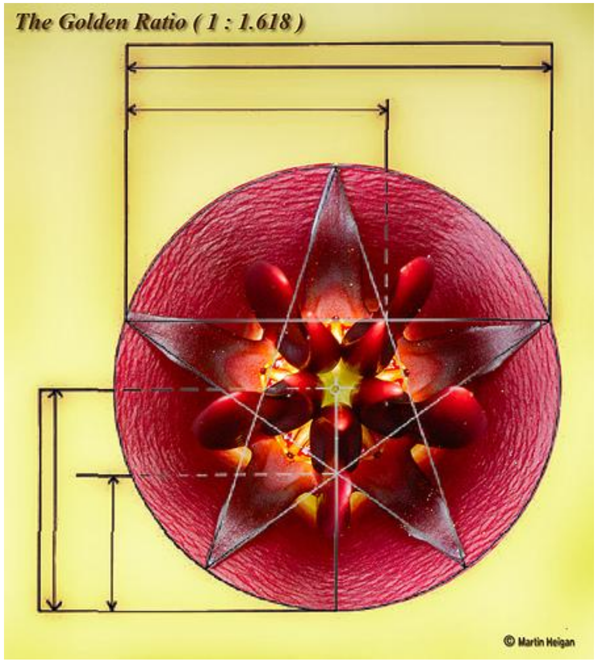

A
B
C
D
B'
C'




$\frac{\sqrt{5}}{2}$
φ
$\frac{1}{2}$
1




φ^2
φ
1


The Golden Ratio (1 : 1.618)
© Martin Heigan


Fibonacci


235813
0 FIBONACCI 1 1
.618033
GOLDEN


1.6180339887498948482
30917980576286213544
86227052604628189024
38908659593958290563


$\phi = \frac{1}{\phi - 1}$
$\phi(\phi - 1) = 1$
$\phi^2 - \phi - 1 = 0$
$\phi = \frac{1+\sqrt{5}}{2}$
$\phi = 1.618033989...$


1
1
2
3
5
8
13
21


WANT MY NUMBER?
1.6180339887498948482...

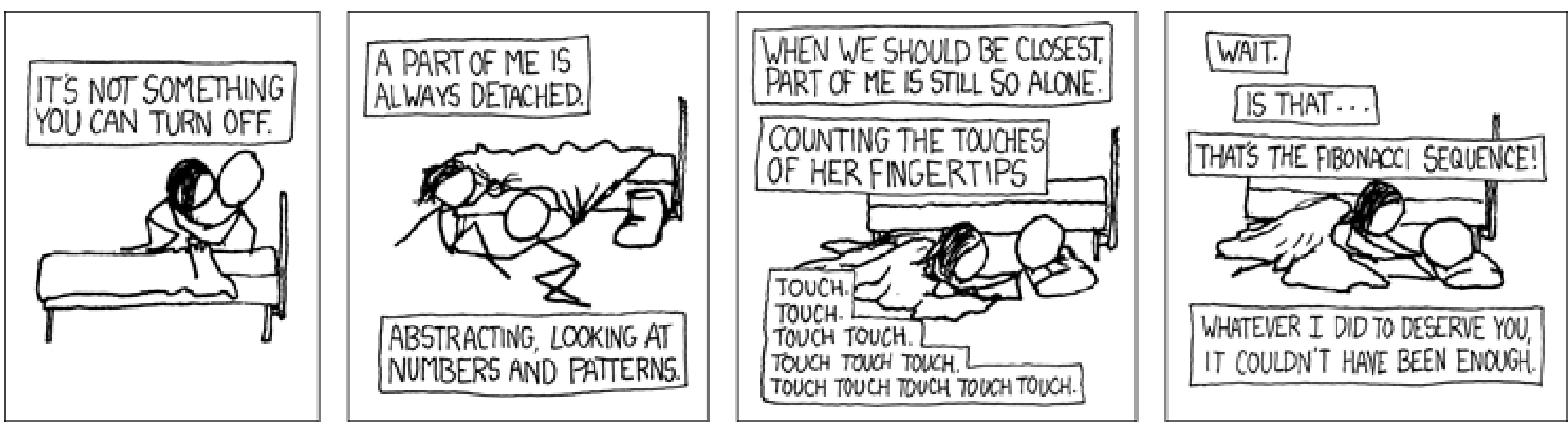

$\phi = \sqrt{1+\sqrt{1+\sqrt{1+\sqrt{1+}}}}$


(defun fib (n)
(if (< n 2)
n
(+ (fib (- n 2)) (fib (- n 1)))))


...1,2,3,5,8...
Fibonacci!


MADE IN THE USA

"This must be Fibonacci's."

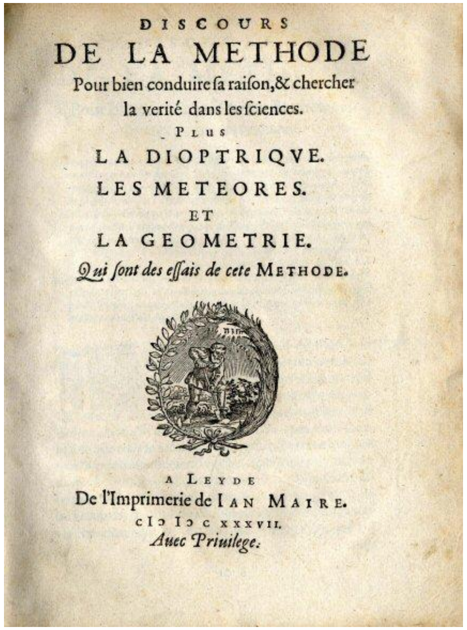


Historical Perspectives

René Descartes (1596-1650)

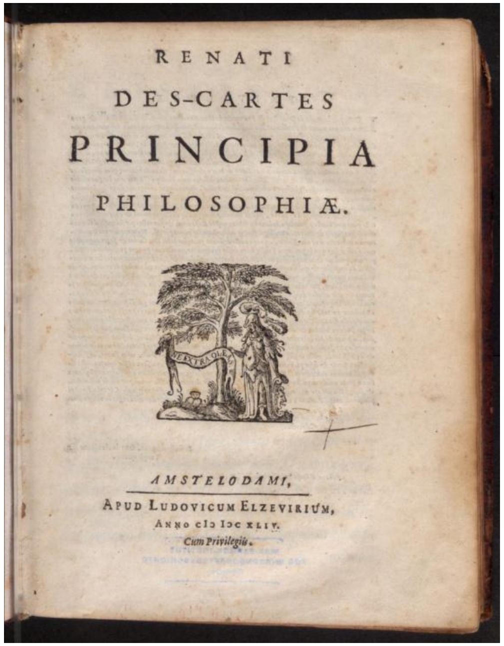
- Father of modern philosophy
- Invented Cartesian coordinates, analytic geometry, heuristics
- Characterized paradoxes & falacies
- Discovered momentum conservation
- Authored "Principia Philosophiae"
- Pioneered methodological skepticism "Cogito ergo sum" - "Je pense, donc je suis "
- "Discours de la Méthode" (1637) - one of the most influential works in modern science
- Pioneered the scientific method & revolution

"For it is not enough to have a good mind: one must use it well." - Descartes

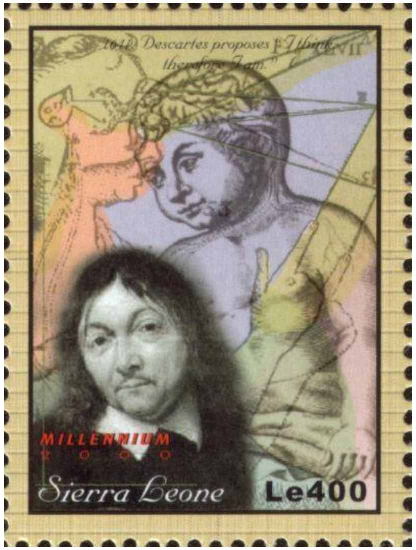


DISCOURS
DE LA METHODE
Pour bien conduire sa raison, & chercher
la verité dans les sciences.
Plus
LA DIOPTRIQVE.
LES METEORES.
ET
LA GEOMETRIE.
Qui sont des essais de cete METHODE.

A LEYDE
De l'Imprimerie de IAN MAIRE.
cIↃ IↃ c XXXVII.
Auec Priuilege.


RENATI
DES-CARTES
PRINCIPIA
PHILOSOPHIÆ.

AMSTELODAMI,
Apud Ludovicum Elzevirium,
Anno CIƆ IƆC XLIV.
Cum Privilegio.



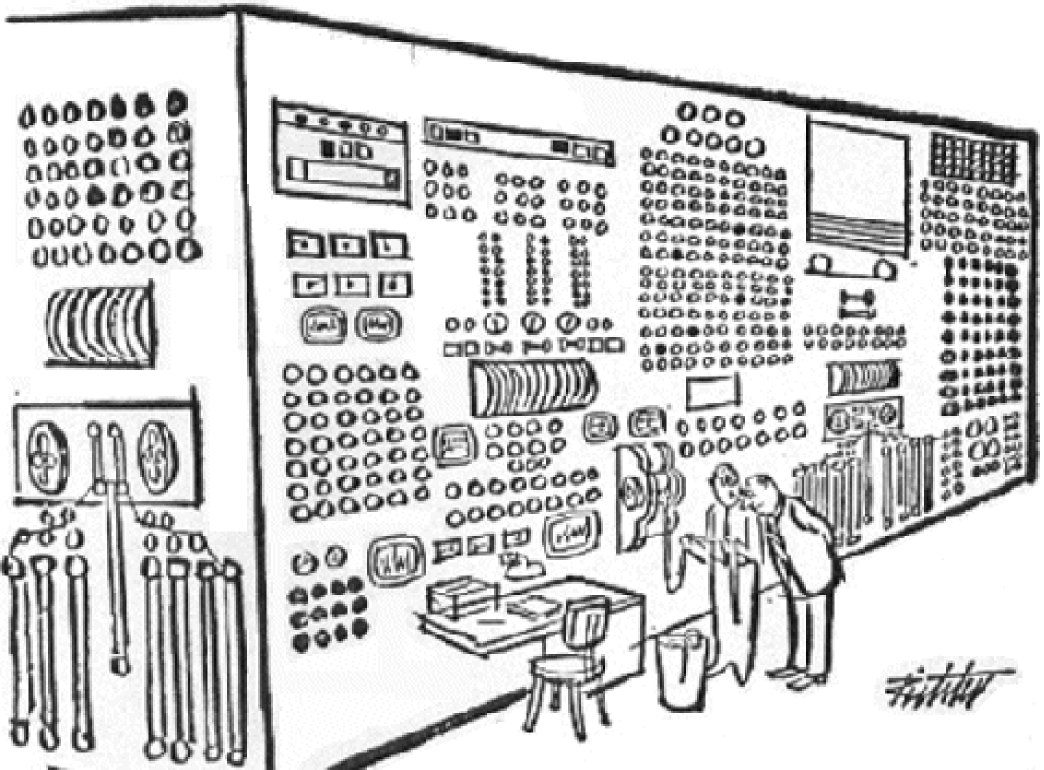

I am a think tank, therefore I am.
S. Harris


COGITO
ERGO
OBAMA

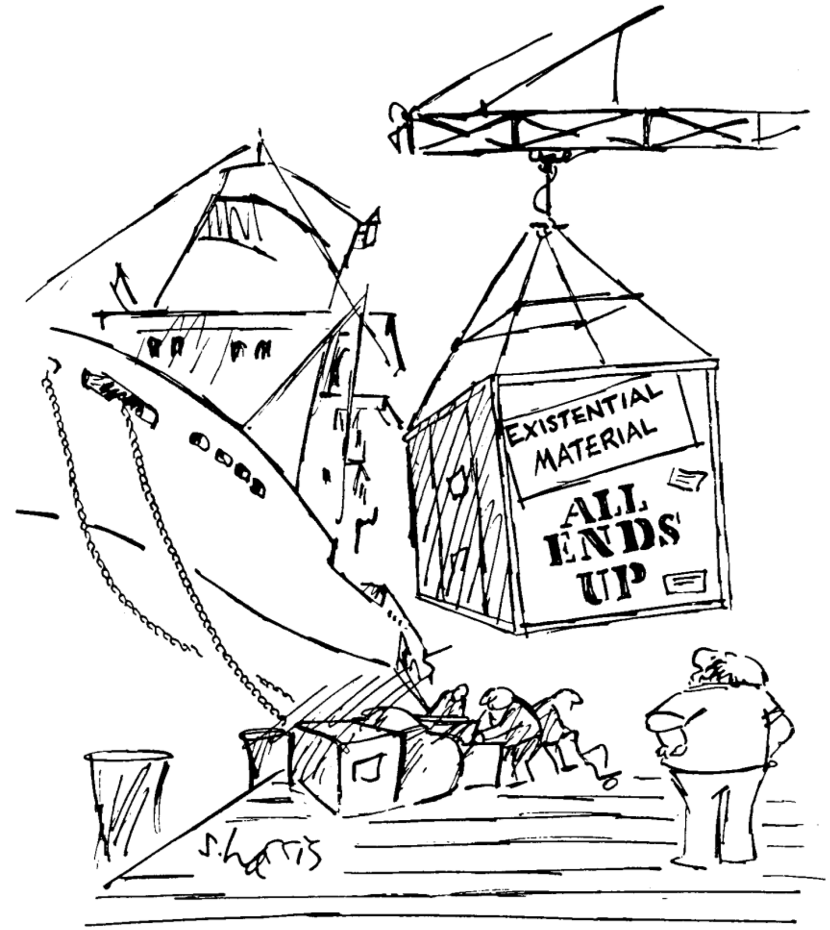

I think therefore I am.
I am therefore I think... Ii think...
I think, and therefore (yawn) -
therefore I am.
I am, therefore I
(YAWN) think.
I think....
ZZZZzzzz
ZZzzzzz.
POP!
DJL

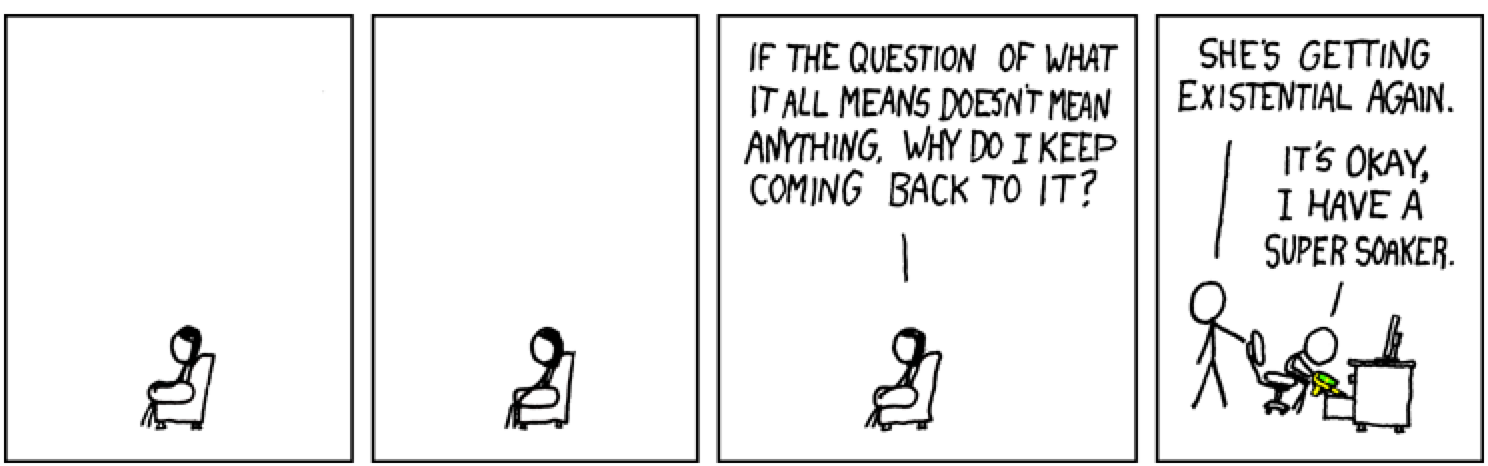

So, If Rene Descartes never blogged... Did he really exist?
Pirillo & Fitz
© BLAUGH.COM · FITZ & PIRILLO · SAVE 10% AT GODADDY BY USING THE COUPON CODE "BLAUGH"


RUE
RENE DESCARTES



" I'll be damned. It says, 'Cogito, ergo sum.' "





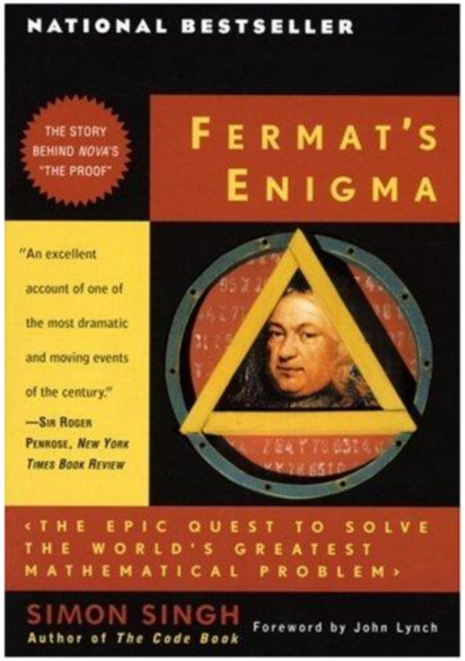
René Descartes 1596 - 1650

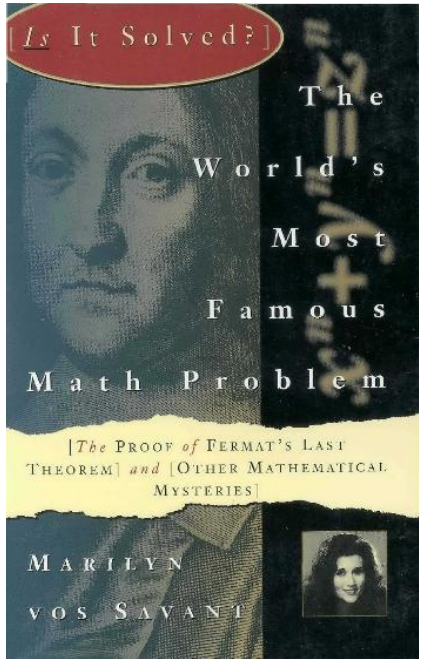
RENÉ DESCARTES EXPLAINS THE COORDINATE SYSTEM WHICH TIES TOGETHER ALGEBRA AND GEOMETRY

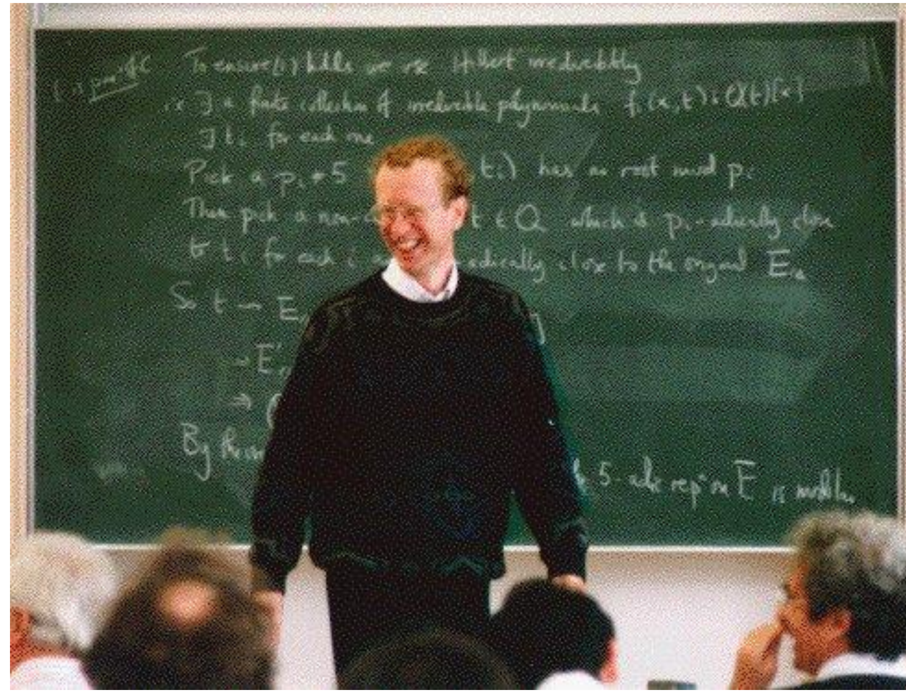
Historical Perspectives

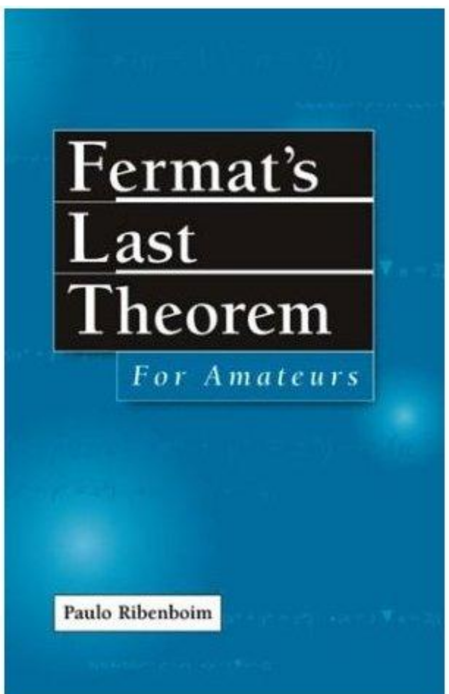
Pierre de Fermat (1601-1665)

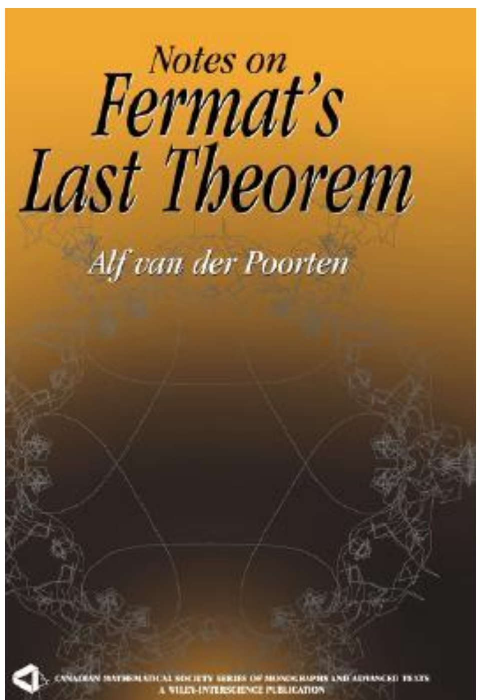
- Father of modern number theory
- Lawyer, Parlement of Toulouse
- Laid groundwork for calculus
- Contributions to optics, probability, and analytic geometry
- Fermat numbers, primes, perfect #'s
- Descartes' Law of refraction
- Reponsible for many open problems
- "Fermat's Last Theorem" (1637-1995)
- Recognized "principle of least action" and "principle of least time" in physics
- Influenced Newton and Leibniz

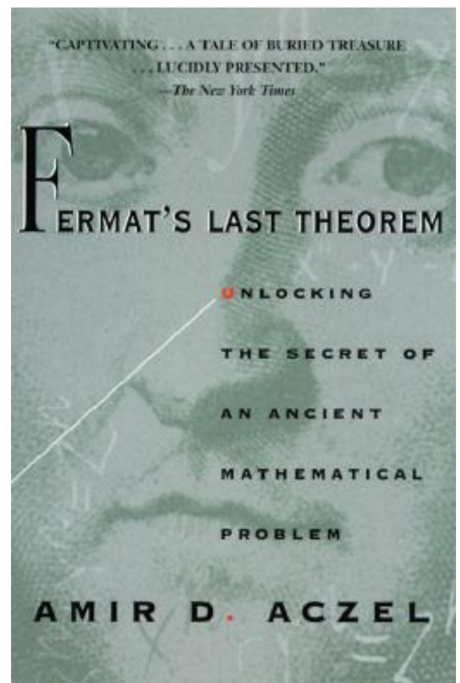

NATIONAL BESTSELLER
THE STORY BEHIND NOVA'S "THE PROOF"
FERMAT'S ENIGMA
"An excellent account of one of the most dramatic and moving events of the century."
—Sir Roger Penrose, New York Times Book Review
‹THE EPIC QUEST TO SOLVE THE WORLD'S GREATEST MATHEMATICAL PROBLEM›
SIMON SINGH
Author of The Code Book
Foreword by John Lynch

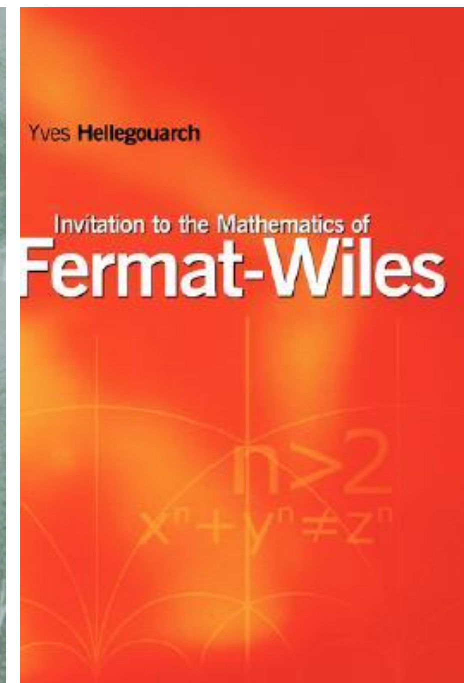

[Is It Solved?]
The World's Most Famous Math Problem
[The Proof of Fermat's Last Theorem] and [Other Mathematical Mysteries]
MARILYN VOS SAVANT




Fermat's Last Theorem
For Amateurs
Paulo Ribenboim

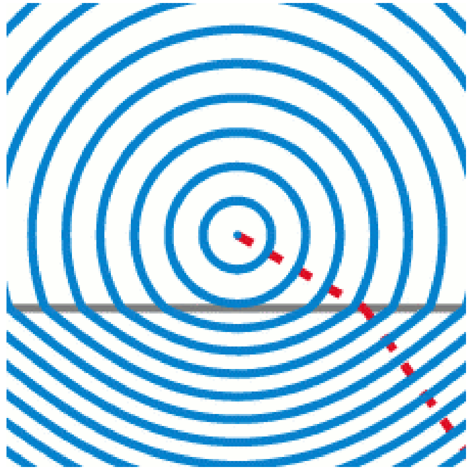

Notes on Fermat's Last Theorem
Alf van der Poorten
CANADIAN MATHEMATICAL SOCIETY SERIES OF MONOGRAPHS AND ADVANCED TEXTS
A WILEY-INTERSCIENCE PUBLICATION

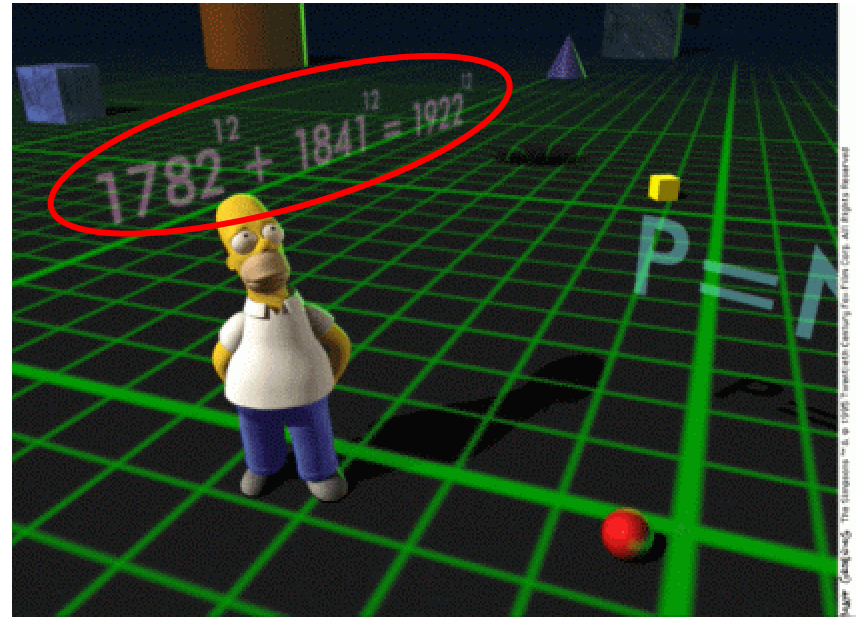

"CAPTIVATING . . . A TALE OF BURIED TREASURE . . . LUCIDLY PRESENTED."
—The New York Times
FERMAT'S LAST THEOREM
UNLOCKING THE SECRET OF AN ANCIENT MATHEMATICAL PROBLEM
AMIR D. ACZEL

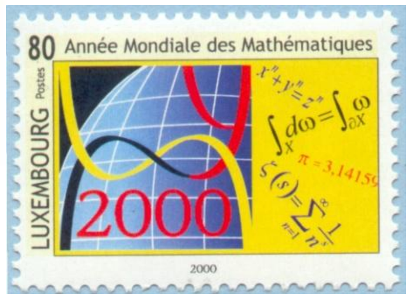

Yves Hellegouarch
Invitation to the Mathematics of
Fermat-Wiles
n>2
xⁿ+yⁿ≠zⁿ

Pierre de Fermat

1601 - 1665





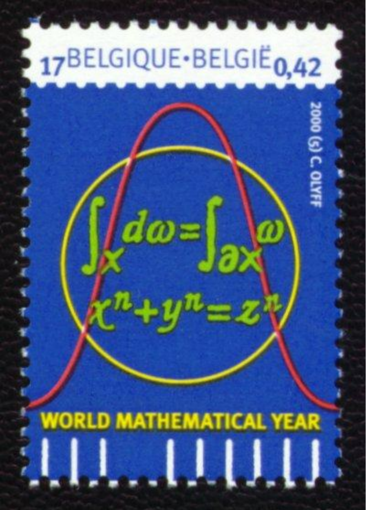


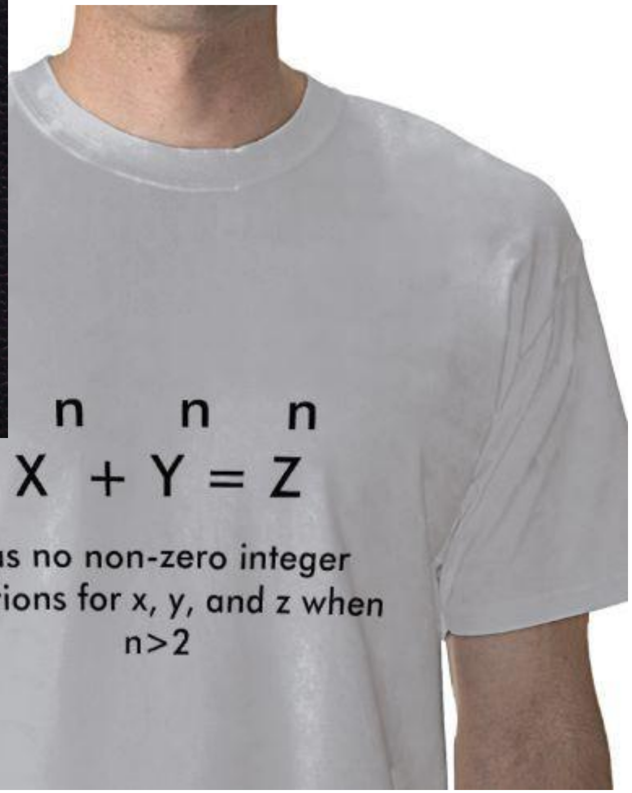
Université Paul Sabatier

TOULOUSE III

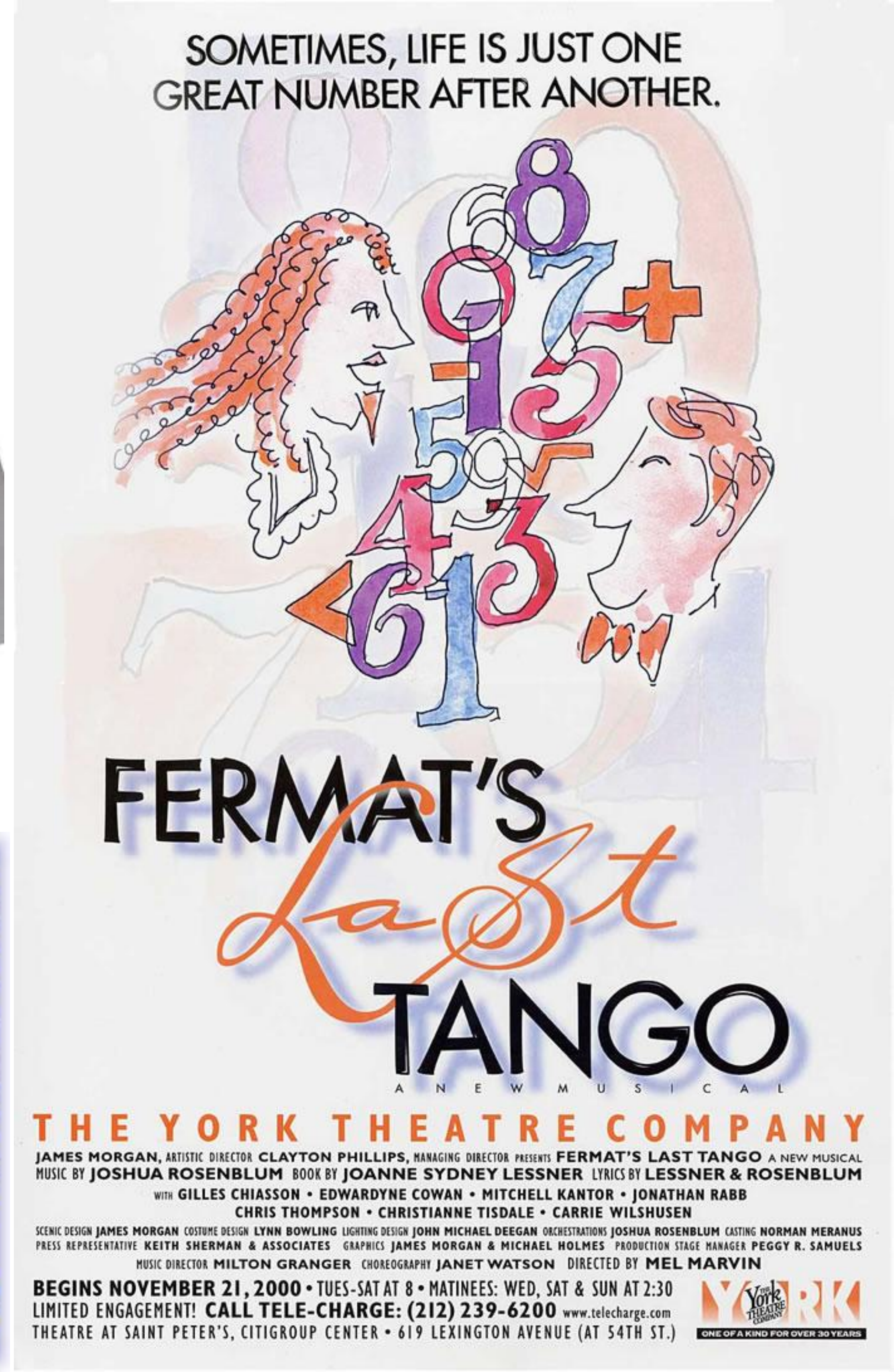
INSTITUT de MATHEMATIQUES de TOULOUSE

Fermat Prize for Mathematics Research


17 BELGIQUE·BELGIË 0,42
2000 (c) C. OLYFF
$\int_X d\omega = \int_{\partial X} \omega$
$x^n + y^n = z^n$
WORLD MATHEMATICAL YEAR


$X^n + Y^n = Z^n$
has no non-zero integer
solutions for x, y, and z when
n>2


FERMAT
39 km
97 / 10 / 08
D=254mm f/D=10
© António J. Cidadão
Moon "LIGHT"
7
B/W QuickCam
a.cidadao@mail.telepac.pt


SOMETIMES, LIFE IS JUST ONE
GREAT NUMBER AFTER ANOTHER.
FERMAT'S
LaSt
TANGO
A NEW MUSICAL
THE YORK THEATRE COMPANY
JAMES MORGAN, ARTISTIC DIRECTOR CLAYTON PHILLIPS, MANAGING DIRECTOR PRESENTS FERMAT'S LAST TANGO A NEW MUSICAL
MUSIC BY JOSHUA ROSENBLUM BOOK BY JOANNE SYDNEY LESSNER LYRICS BY LESSNER & ROSENBLUM
WITH GILLES CHIASSON • EDWARDYNE COWAN • MITCHELL KANTOR • JONATHAN RABB
CHRIS THOMPSON • CHRISTIANNE TISDALE • CARRIE WILSHUSEN
SCENIC DESIGN JAMES MORGAN COSTUME DESIGN LYNN BOWLING LIGHTING DESIGN JOHN MICHAEL DEEGAN ORCHESTRATIONS JOSHUA ROSENBLUM CASTING NORMAN MERANUS
PRESS REPRESENTATIVE KEITH SHERMAN & ASSOCIATES GRAPHICS JAMES MORGAN & MICHAEL HOLMES PRODUCTION STAGE MANAGER PEGGY R. SAMUELS
MUSIC DIRECTOR MILTON GRANGER CHOREOGRAPHY JANET WATSON DIRECTED BY MEL MARVIN
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Music **by Joshua Rosenblum**
Book by **Joanne Sydney Lessner**
Lyrics by **Lessner and Rosenblum**

FERMAT'S Last TANGO

A NEW MUSICAL

THE YORK THEATRE COMPANY

A Musical Fantasy inspired by Andrew Wiles and his encounters with Fermat's Last Theorem

"Rollicking! Whimsical! Catchy & Clever!" - The New York Times

FERMAT'S LAST TANGO

Followed by an Interview with Andrew Wiles

A CMI production

VHS

In 1993 Andrew Wiles stunned the world when he announced a solution to "Fermat's Last Theorem," the famous unsolved mathematics problem set forth by Pierre de Fermat in 1637. In the musical *Fermat's Last Tango*, the fictional character Daniel Keane earns overnight acclaim when he presents his findings. However, fanfare soon gives way to doubt when the reincarnated Fermat discovers a hole in Keane's proof. The singular pursuit by Keane to correct this flaw results in a love triangle involving himself, his wife, and mathematics—the story of which is brought to life by Fermat and his immortal friends from the "AfterMath," namely: Pythagoras, Euclid, Newton, and Gauss. The musical is both a cheerful romp through history and a personal confrontation with destiny. It provides a testament to the extraordinary excitement of mathematics and its unparalleled beauty.

The Composer Joshua Rosenblum enjoyed mathematics while studying music at Yale along with the author, his wife Joanne Sydney Lessner. They both take an active role in the New York music community. This recording was captured by David Stern and his Emmy Award-winning crew during a performance at the York Theatre Company in New York City.

STARRING

Carl Friedrich Gauss / Reporter	GILLES CHIASSON
Anna Keane	EDWARDYNE COWAN
Pythagoras / Reporter	MITCHELL KANTOR
Pierre de Fermat	JONATHAN RABB
Daniel Keane	CHRIS THOMPSON
Euclid / Reporter	CHRISTIANNE TISDALE
Sir Isaac Newton / Reporter	CARRIE WILSHUSEN

Approximate Running Time:
100 minutes
Color/Not Rated/VHS/NTSC
Produced by The Clay Mathematics Institute, Cambridge, MA
Arthur Jaffe, *Producer*
David Stern, *Director*

Illustrated Guide Enclosed

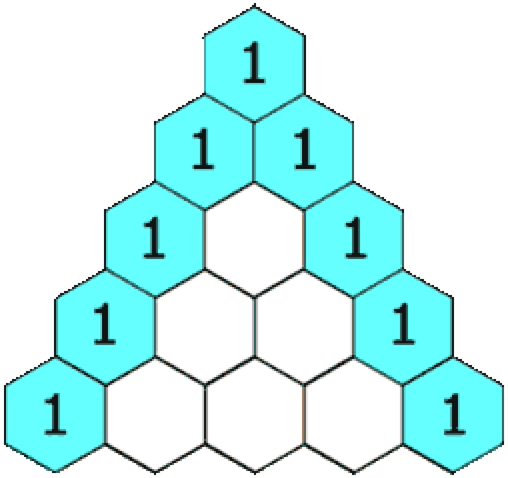
The Clay Mathematics Institute
1770 Massachusetts Avenue #331
Cambridge, MA 02140
Email: fermat@claymath.org
Website: www.claymath.org

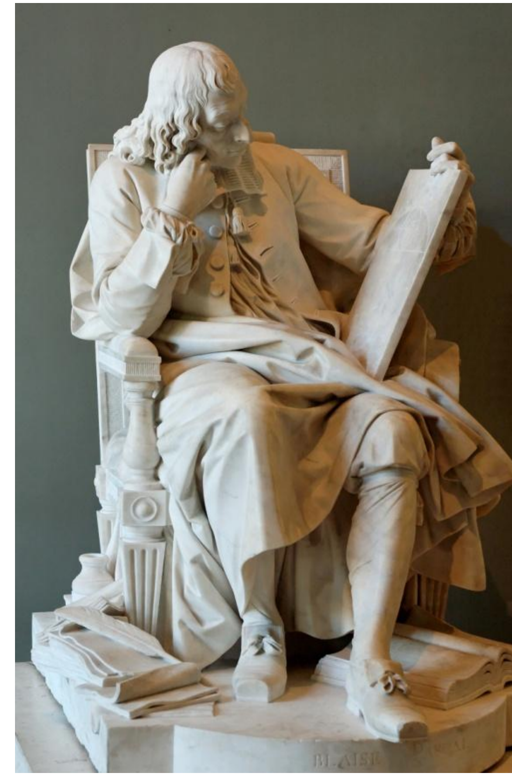
FERMAT'S Last TANGO

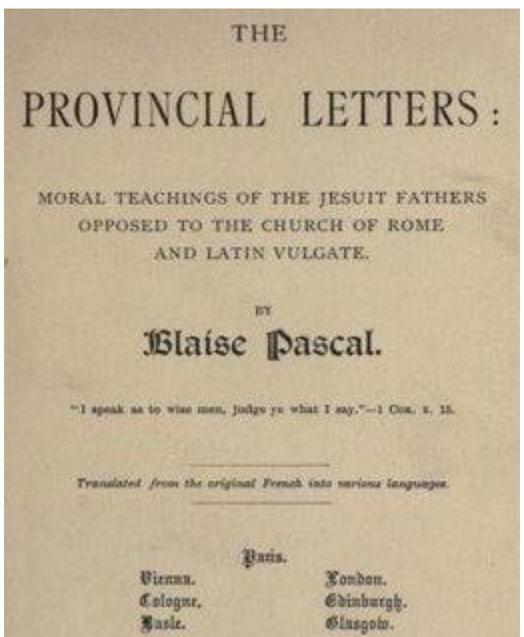
Historical Perspectives

Blaise Pascal (1623-1662)

- Mathematician, physicist, philosopher
- Studied fluids, pressure, vacuum
- Helped pioneer projective geometry, probability, and the scientific method
- Influenced modern economics
- "Pascal's triangle", "Pascal's law"
- Invented hydraulic press and syringe
- Constructed a mechanical calculator
- Used humor, wit, and satire in writings
- Influenced Voltaire and Rousseau
- Inagurated the world's first bus line
- SI unit of pressure - "pascal"







THE

PROVINCIAL LETTERS:

MORAL TEACHINGS OF THE JESUIT FATHERS
OPPOSED TO THE CHURCH OF ROME
AND LATIN VULGATE.

BY

Blaise Pascal.

"I speak as to wise men, judge ye what I say."—1 Cor. x. 15.

Translated from the original French into various languages.

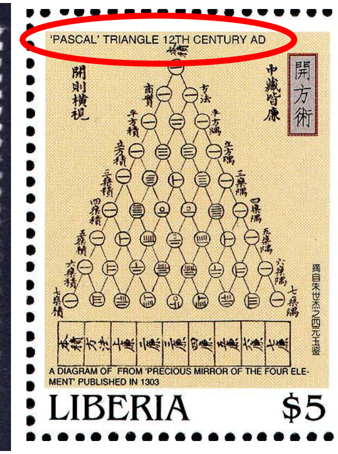
Paris.

Vienna. London.
Cologne. Edinburgh.
Basle. Glasgow.

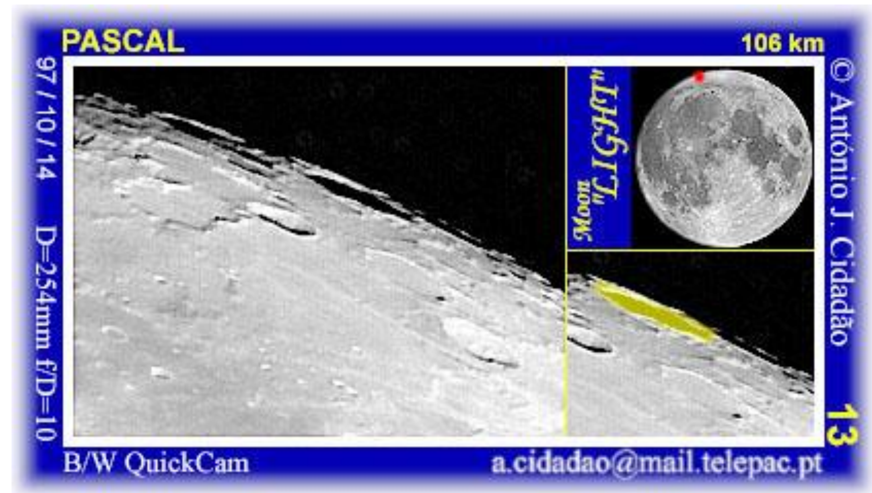

0,50
PASCAL
1623-1662
PENSÉES
REPUBLIQUE FRANÇAISE
POSTES


BLAISE PASCAL
1623-MONACO-1973
0,50

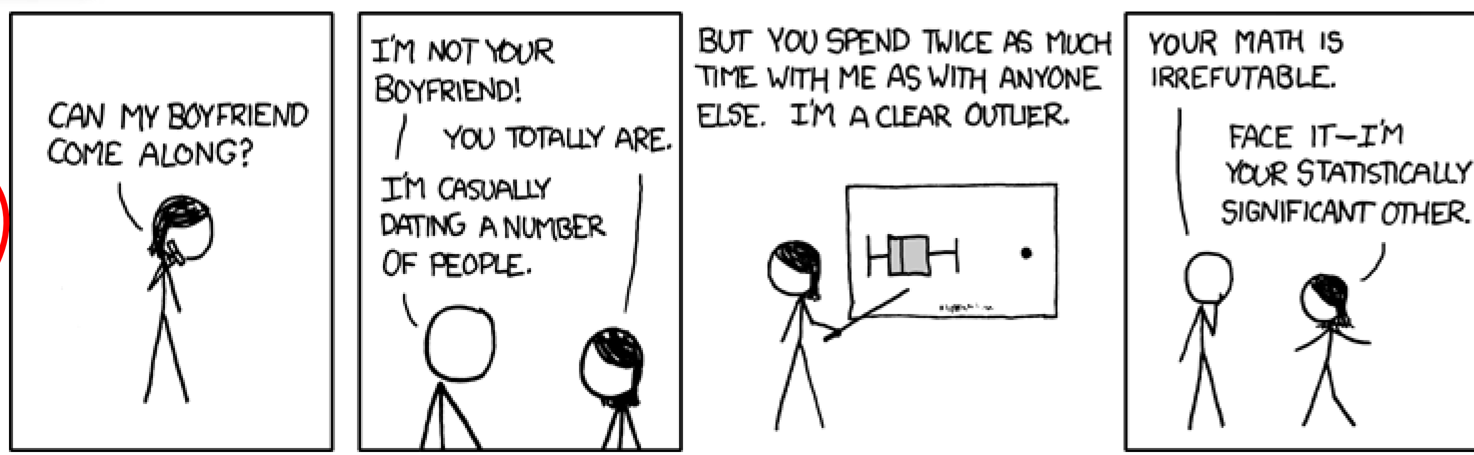

1623
PASCAL
1662
POSTES
1f20+2f80
FRANCE


'PASCAL' TRIANGLE 12TH CENTURY AD
A DIAGRAM OF FROM 'PRECIOUS MIRROR OF THE FOUR ELEMENT' PUBLISHED IN 1303
LIBERIA
$5

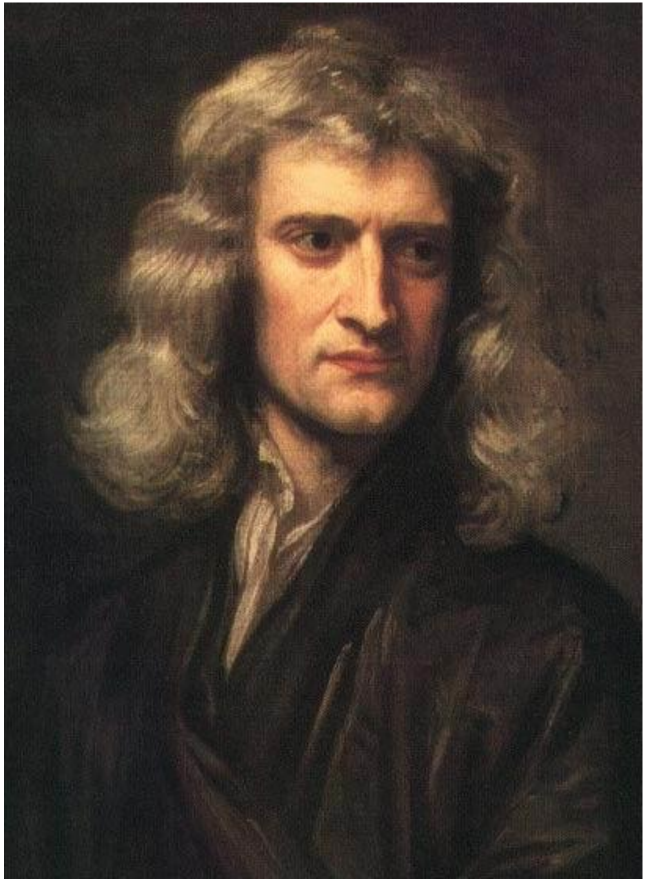

The heart has its reasons which reason cannot know
Blaise Pascal


PASCAL
106 km
97 / 10 / 14
D=254mm f/D=10
Moon "LIGHT"
© António J. Cidadão
13
B/W QuickCam
a.cidadao@mail.telepac.pt


2008
Db 10000
Inventor of mechanical calculator
Blaise Pascal (1623-1662)
S. TOMÉ E PRÍNCIPE

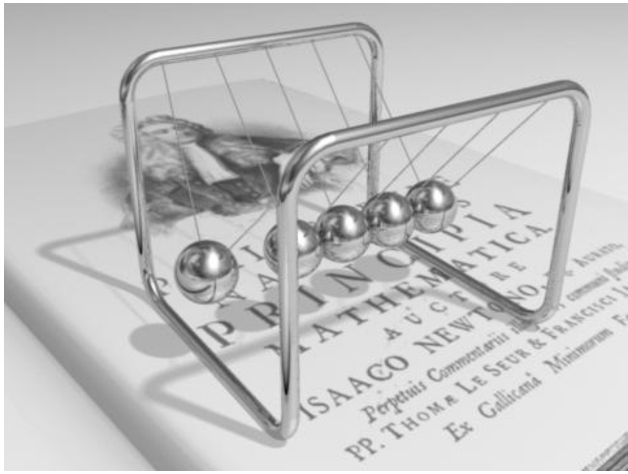

CAN MY BOYFRIEND COME ALONG?
I'M NOT YOUR BOYFRIEND!
YOU TOTALLY ARE.
I'M CASUALLY DATING A NUMBER OF PEOPLE.
BUT YOU SPEND TWICE AS MUCH TIME WITH ME AS WITH ANYONE ELSE. I'M A CLEAR OUTLIER.
YOUR MATH IS IRREFUTABLE.
FACE IT—I'M YOUR STATISTICALLY SIGNIFICANT OTHER.

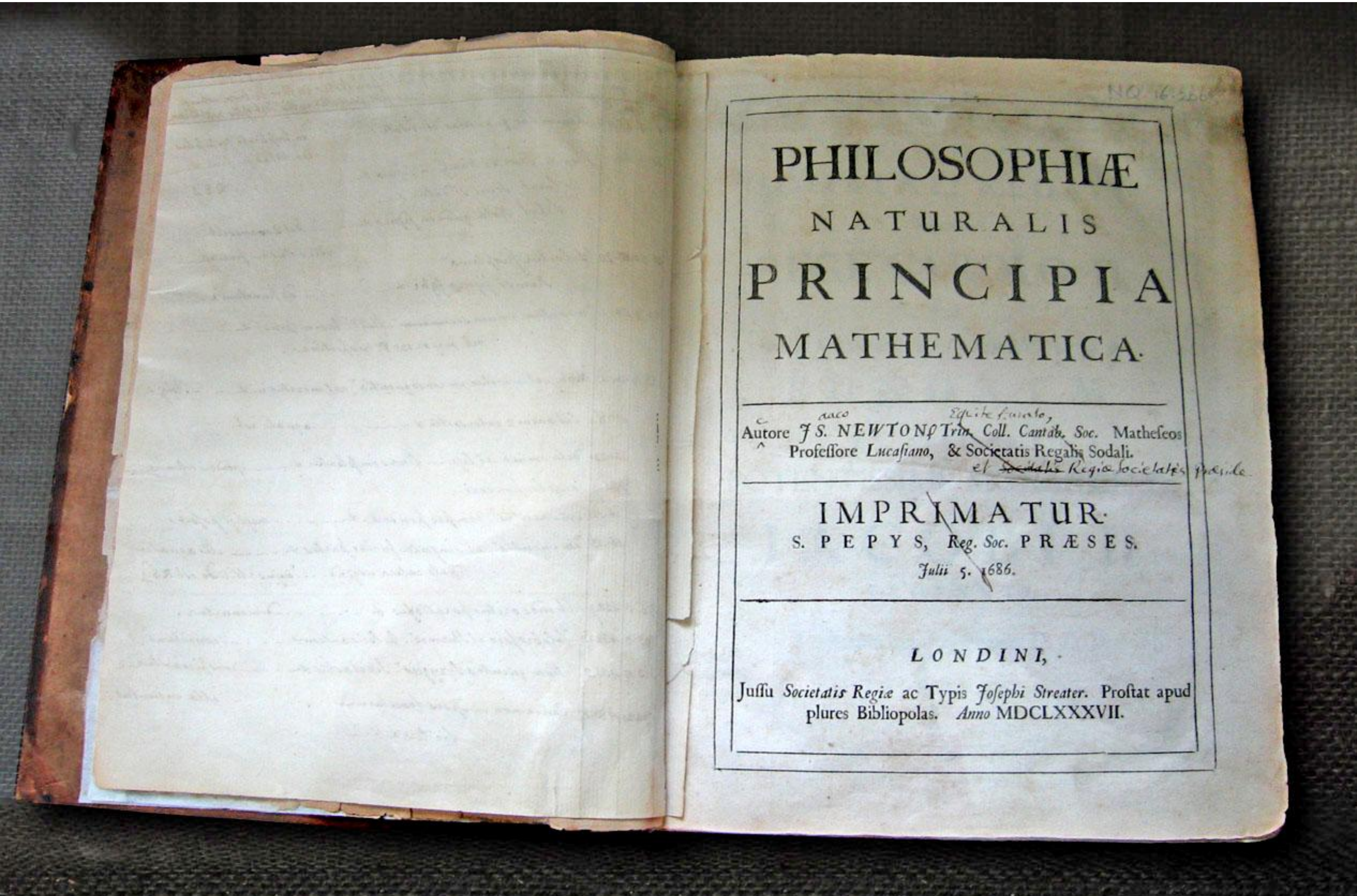
Historical Perspectives



Sir Isaac Newton (1643-1727)

- Mathematician, physicist, astronomer, philosopher, alchemist, theologian
- One of history's most influential people
- "Principia Mathematica" (1687)
- Invented calculus, theory of gravitation
- Founded "Newtonian mechanics"
- Discovered laws of motion, inertia
- "Newtonian fluid", "Newtonian Universe"
- Advanced the Scientific Revolution
- Developed practical reflecting telescope, theory of color, "Newton's method"
- SI unit of force: newton





PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA.

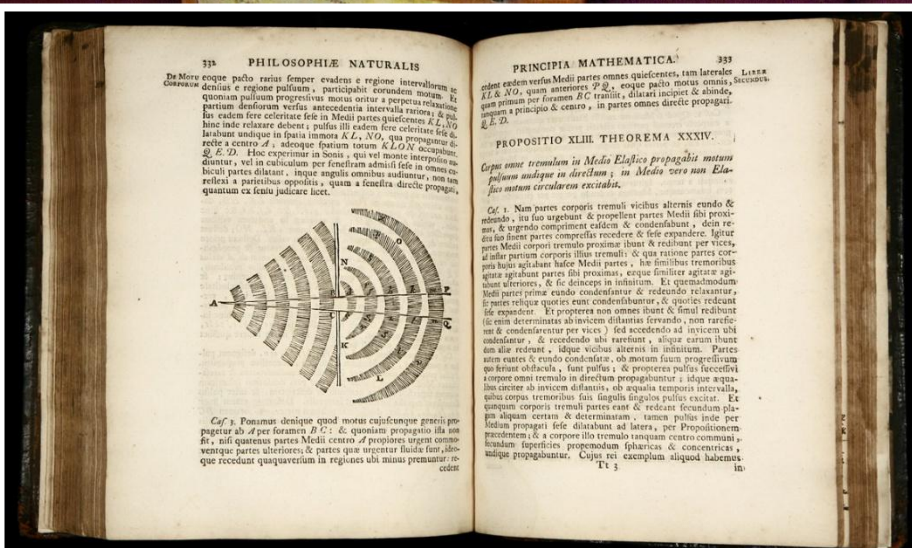
Autore J S. NEWTON, Trin. Coll. Cantab. Soc. Matheseos Professore *Lucasiano*, & Societatis Regalis Sodali.

Equite Aurato,
et ~~Societatis~~ Regiæ Societatis præside

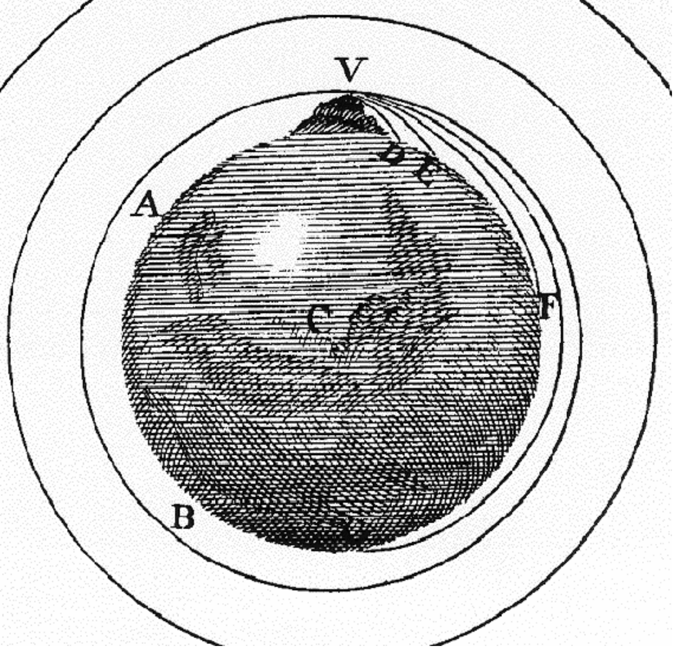
IMPRIMATUR.
S. PEPYS, *Reg. Soc.* PRÆSES.
Julii 5. 1686.

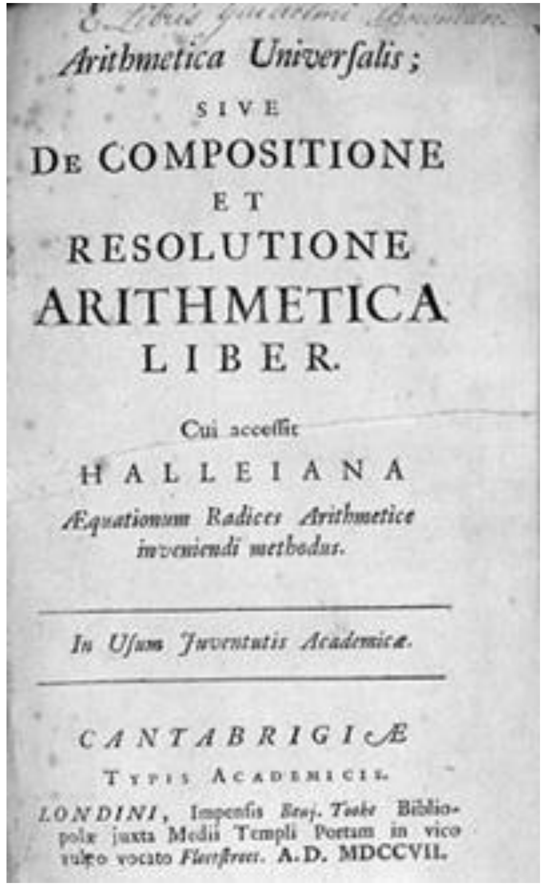
LONDINI,

Jussu *Societatis Regiæ* ac Typis *Josephi Streater*. Prostat apud plures Bibliopolas. *Anno* MDCLXXXVII.


332 PHILOSOPHIÆ NATURALIS
PRINCIPIA MATHEMATICA. 333
PROPOSITIO XLIII. THEOREMA XXXIV.


NEWTON





Arithmetica Universalis;

SIVE

DE COMPOSITIONE

ET

RESOLUTIONE

ARITHMETICA

LIBER.

Cui accessit

HALLEIANA

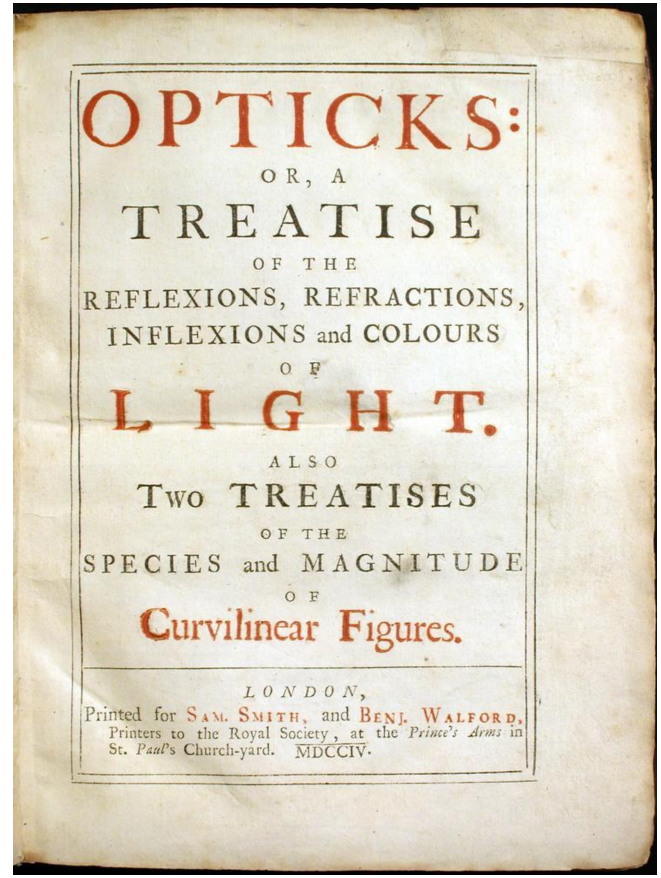
Æquationum Radices Arithmetice inveniendi methodus.

In Usum Juventutis Academicæ.

CANTABRIGIÆ

Typis Academicis.

LONDINI, Impensis Benj. Tooke Bibliopolæ juxta Medii Templi Portam in vico vulgo vocato Fleetstreet. A.D. MDCCVII.



OPTICKS:

OR, A

TREATISE

OF THE

REFLEXIONS, REFRACTIONS, INFLEXIONS and COLOURS

OF

LIGHT.

ALSO

Two TREATISES

OF THE

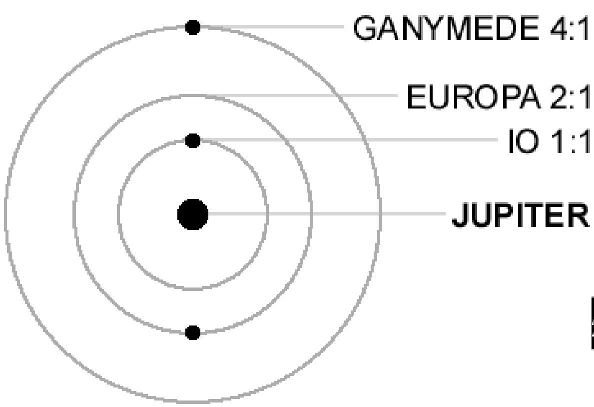
SPECIES and MAGNITUDE

OF

Curvilinear Figures.

LONDON,

Printed for SAM. SMITH, and BENJ. WALFORD, Printers to the Royal Society, at the Prince's Arms in St. Paul's Church-yard. MDCCIV.



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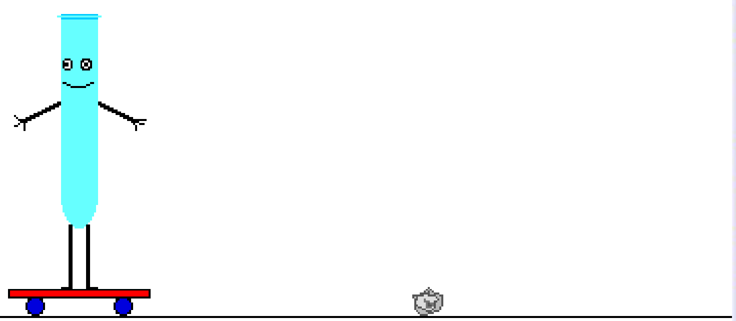

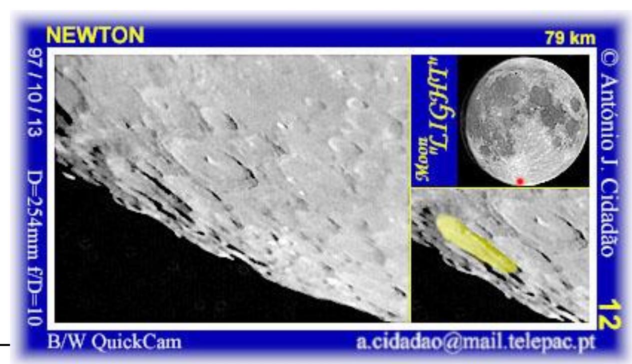

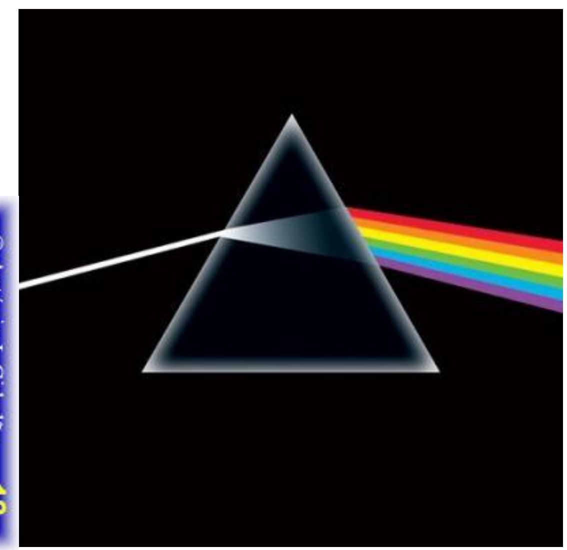

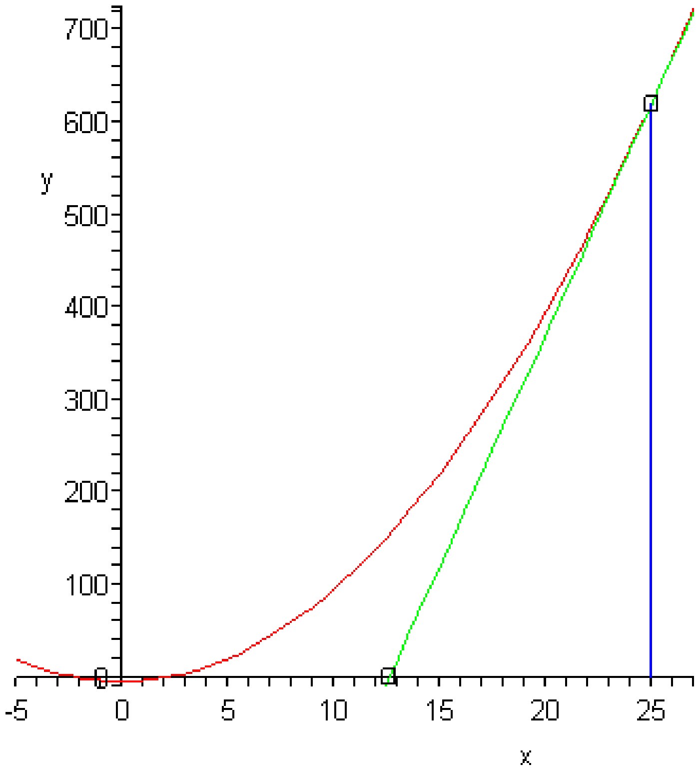

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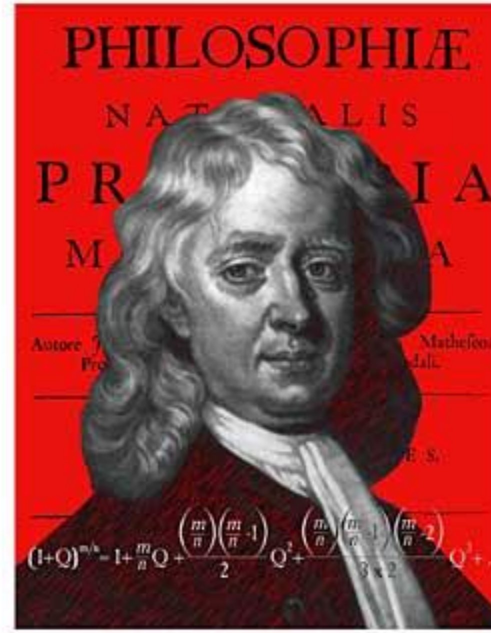
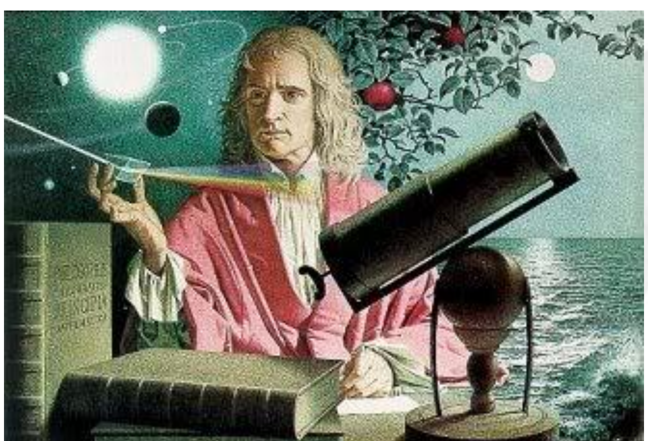
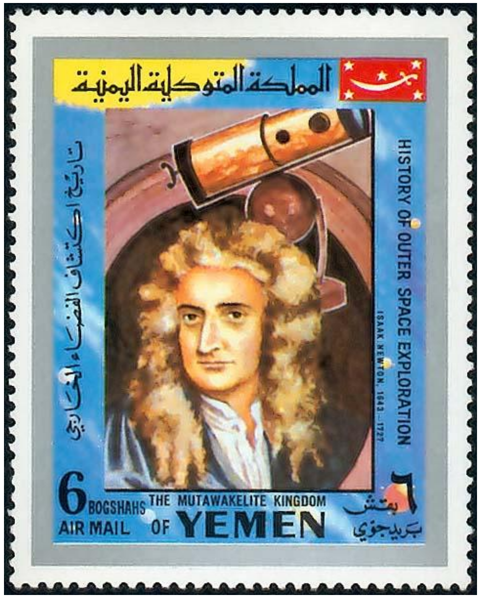
JOHANNES KEPLER'S UPHILL BATTLE
...SO, YOU SEE, THE ORBIT OF A PLANET IS ELLIPTICAL.
WHAT'S AN ORBIT?
WHAT'S A PLANET?
WHAT'S 'ELLIPTICAL'?
S. harris



Sir Isaac Newton 1642 [1643 New Style Calendar] - 1727



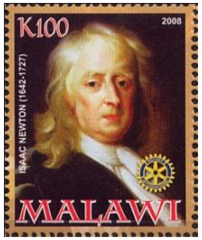
ONE POUND
£1
Sir Isaac Newton
1642 · 1727



المملكة المتوكلية اليمنية
HISTORY OF OUTER SPACE EXPLORATION
6 BOGSHAHS
AIR MAIL
THE MUTAWAKELITE KINGDOM
OF YEMEN

REDONDA
20¢
SIR ISAAC NEWTON
CRANE COURT, HOME OF THE ROYAL SOCIETY

REPUBLIQUE DU NIGER
100F
LUNA 16 — Sept. 1970
PREMIERS PRELEVEMENTS
AUTOMATIQUES SUR LA LUNE
POSTE AERIENNE
~~150~~
1970
PRECURSEUR DE L'ESPACE - ISAAC NEWTON - 1642 - 1727



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REPUBLIQUE POPULAIRE DU CONGO
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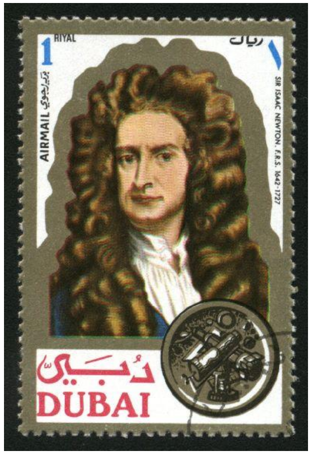
ISAAC NEWTON 1642.1727



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ИСАК НЮТОН
1643
1727
F=k mM/r²
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IZAAK NEWTON
1642-1727
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ISAAC NEWTON 1643-1727
$\Delta(mv)=F\Delta t$
DEUTSCHE BUNDESPOST 100
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NEWTON 1642-1727
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M.LALAU
P.MUNIER
1642-1727 ISAAC NEWTON
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A. TITONEL
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Исаак НЬЮТОН 1643 1727
1687
„Математические начала натуральной философии" вершина творчества И.Ньютона. Впервые была создана единая система земной и небесной механики, которая легла в основу классической физики.
REPUBLIQUE POPULAIRE DU BENIN
150F
POSTE AERIENNE
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250e ANNIVERSAIRE DE LA MORT D'ISAAC NEWTON ·1642 ·1727
QUILLIVIC
Isaac Newton 1643-1727
3Ft MAGYAR POSTA
PRINCIPIA MATHEMATICA
L'Histoire de L'Espace
SIR ISAAC NEWTON (1642-1727) inventa le télescope à réflexion utilisant une lentille et un miroir paraboloïque
BURUNDI 1500 F
18P
PHILOSOPHIÆ NATURALIS PRINCIPIA MATHEMATICA
Sir ISAAC NEWTON (1642-1727)
22P
MOTION OF BODIES IN ELLIPSES
Sir ISAAC NEWTON (1642-1727)
31P
OPTICKS OR A TREATISE OF THE REFLEXIONS REFRACTIONS INFLEXIONS and COLOURS OF LIGHT
Sir ISAAC NEWTON (1642-1727)
34P
THE SYSTEM OF THE WORLD
Sir ISAAC NEWTON (1642-1727)
1987

1666. Sir Isaac Newton formulates law of gravitation
50¢
Grenada
MILLENNIUM
2000
REPUBLIQUE TOGOLAISE
La comète de Halley
Edmond HALLEY 1656-1742
Isaac NEWTON 1642-1727
1000F
Poste Aérienne 1986
POSTES LAO 1984
SIR ISAAC NEWTON
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МОНГОЛ ШУУДАН мөнгө
1977
Isaac Newton
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CORREOS
(1642 - 1727)
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HALLEY ET NEWTON
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HALLEY'S COMET
1985 - OFFICIAL - 1986
HALLEY ET NEWTON OBSERVANT LA COMETE
POSTES
300f
REPUBLIQUE CENTRAFRICAINE
IMPRESSOR S.A. (SWITZERLAND) • W.SPINNER • 1985
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USA EXPLORER VII
13.10.1959
DISCOVERIES OF UNIVERSE
ISAAC NEWTON
1642 - 1727
ENGLAND
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YEMEN ARAB REPUBLIC
AIR MAIL
الجمهورية العربية اليمنية
بريد جوي
1668: Newton builds first reflecting telescope
MILLENNIUM
2000
Grenada
50¢
RÉPUBLIQUE DE GUINÉE
300 F
POSTES
Sir Isaac Newton
1642-1727
Sonde
Voyager
PUVILLAND
NEVIS
30¢
MILLENNIUM
1704: Isaac Newton publishes Opticks, in which he describes nature of light and his invention of the reflecting telescope.
LESOTHO
5s
REFLECTING TELESCOPE
Sir Isaac Newton
1642-1727
MONGOLIA
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UGANDA
35/
OPTICKS
SIR ISAAC NEWTON
1642-1727
THEORY OF COLOR AND LIGHT
GREAT SCIENTIFIC ACHIEVEMENTS
5 К
Почта СССР 1987
Исаак НЬЮТОН
1643
1727
1687
„Математические начала натуральной философии" вершина творчества И.Ньютона. Впервые была создана единая система земной и небесной механики, которая легла в основу классической физики
300-летие опубликования И.Ньютоном „Математических начал натуральной философии"
GHANA
C200
HALLEY'S COMET 1985-6
REPUBLIQUE DU CONGO
POSTES 2000
150F
ISAAC NEWTON (1642-1727)
GRENADA
50¢
NEWTON
Law of Gravity
CORREO DEL PARAGUAY
LUNA
TIERRA
ORBITAS ELIPTICAS
GRAVITACION UNIVERSAL
OPTICA
ISAAC NEWTON
25 DICIEMBRE 1642
CALCULO INFINITESIMAL Y DIFERENCIAL
BINOMIO
TANGENTES
₲ 0.10
DE LA RUE DE COLOMBIA
MOSDÓSSY
CORREO DEL PARAGUAY
LUNA
TIERRA
ORBITAS ELIPTICAS
GRAVITACION UNIVERSAL
OPTICA
ISAAC NEWTON
25 DICIEMBRE 1642
CALCULO INFINITESIMAL Y DIFERENCIAL
BINOMIO
TANGENTES
₲ 0.30
DE LA RUE DE COLOMBIA
MOSDÓSSY


1993
Newton, Sir Isaac
1642 - 1727
조선우표
D P R KOREA
50전
10전
20전
70전
30전
$(a+b)^n = \sum_{k=0}^{n} C_n^k a^{n-k} b^k$
$F = f \frac{Mm}{r^2}$
OPTICKS
PHILOSOPHIAE
PRINCIPIA
ST. VINCENT
AND THE GRENADINES
1668 - SIR ISAAC NEWTON
90¢
EXPLOITATION DES RESSOURCES DE L'ESPACE
SIR ISAAC NEWTON — SATELLITE TDF 1
REPUBLIQUE DU TCHAD
1500F
1642. Birth of Isaac Newton.
MILLENNIUM
Sierra Leone
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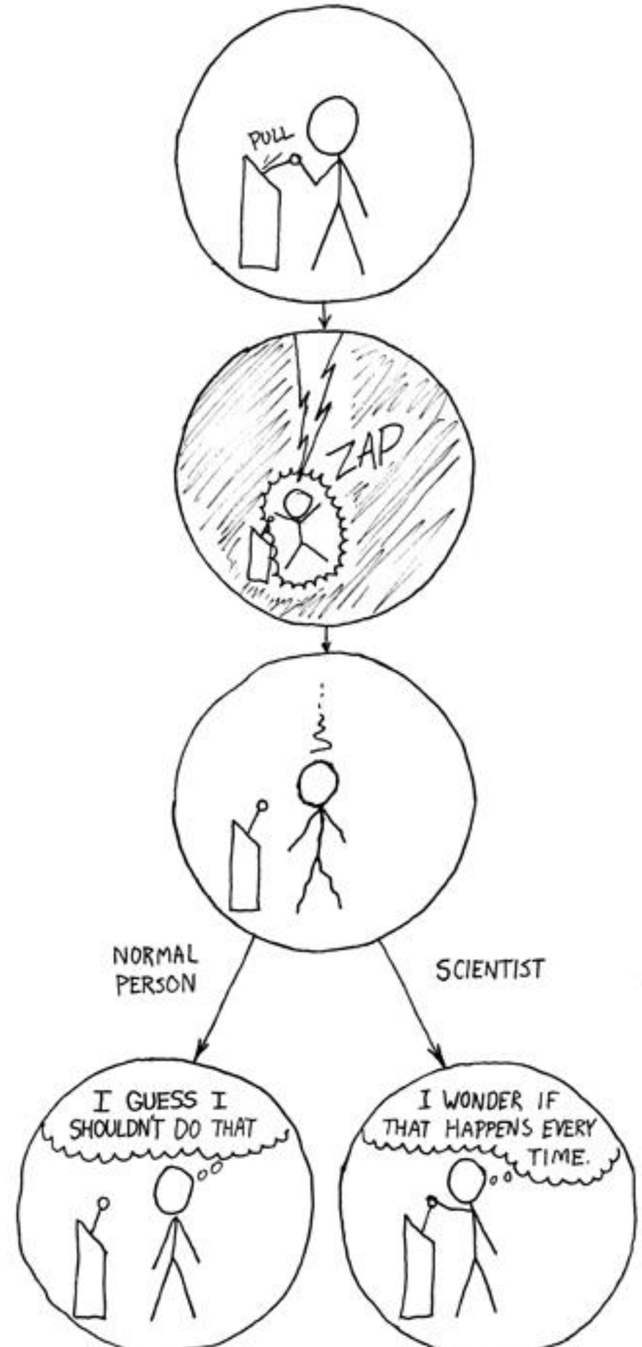
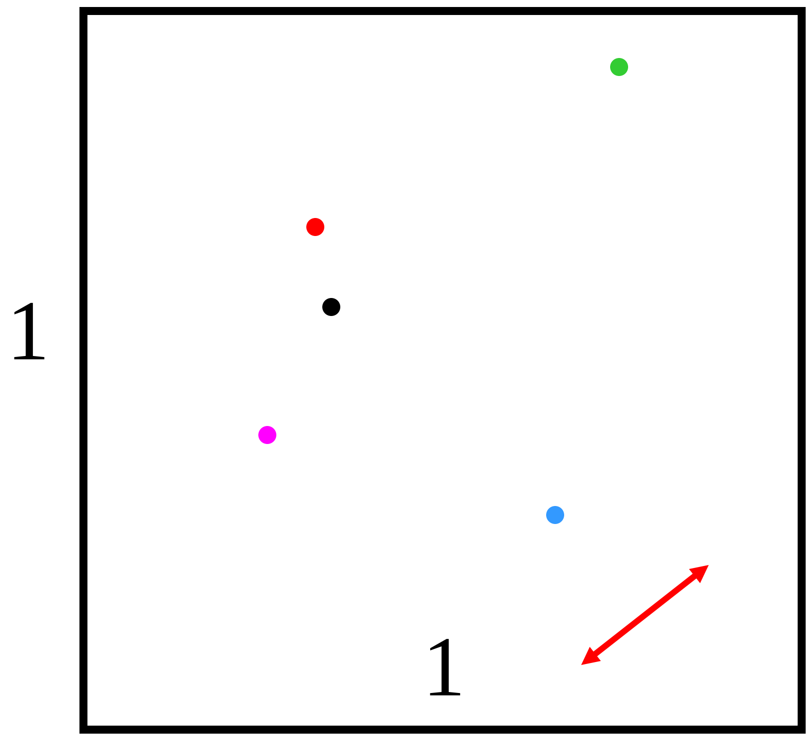
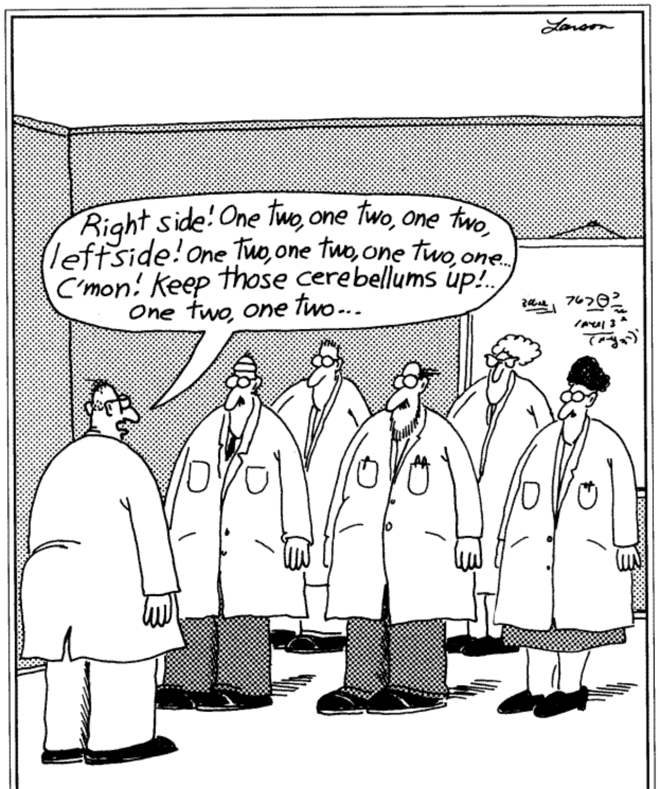
Postes 1999
150F
1600 ~ Sir Isaac Newton,
1642-1727
République du Tchad
ISAAC NEWTON,
MATHEMATICIAN
& ASTRONOMER
$2\frac{1}{2}$P
ASCENSION
2006
SIR ISAAK NEWTON (1642-1727)
REPUBLIQUE DE DJIBOUTI
300F
Isaac Newton (1642-1726)
Telescopio de Newton 1688
CORREOS 1994
C$1.50
NICARAGUA
ISAAC NEWTON .1643.1727
400F
REPUBLIQUE DU MALI


THE UNKNOWN SCIENTIST
(WHO DID SOME VERY IMPORTANT GROUNDWORK)


PULL
ZAP
NORMAL PERSON
SCIENTIST
I GUESS I SHOULDN'T DO THAT
I WONDER IF THAT HAPPENS EVERY TIME.

Problem: Given any five points in/on the unit square, is there always a pair with distance $\leq \frac{1}{\sqrt{2}}$?

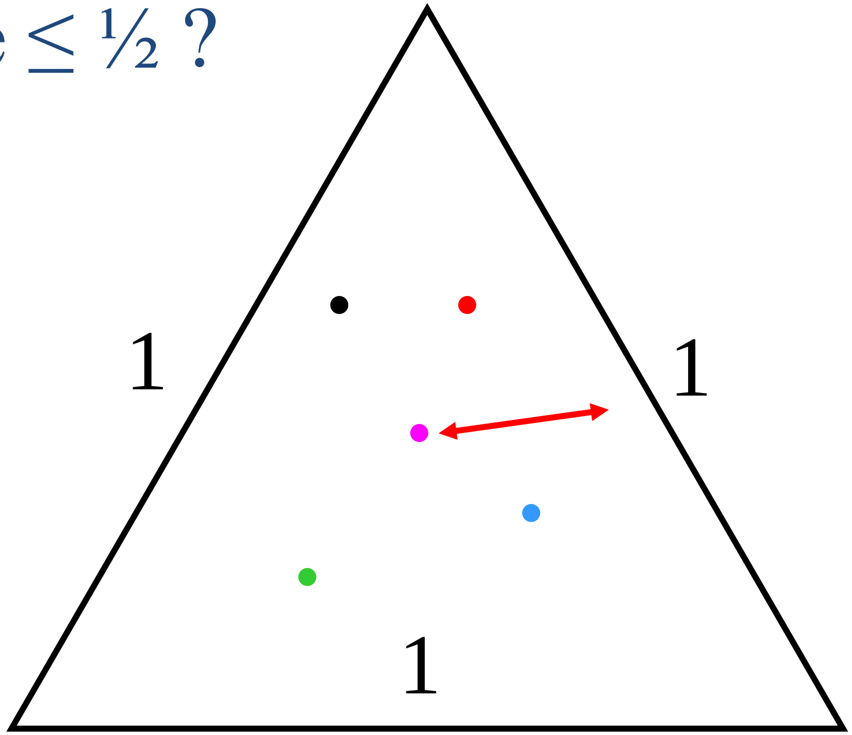


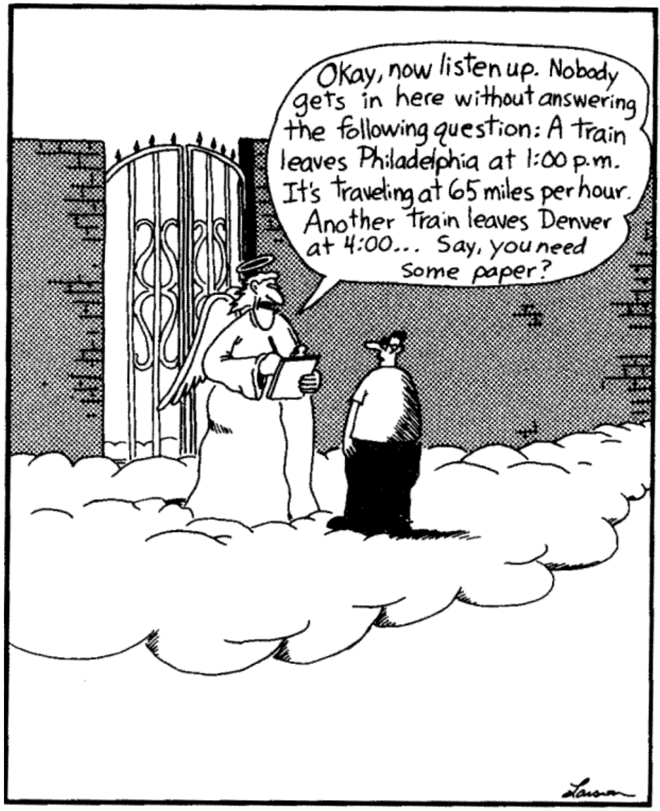


Brain aerobics

- What approaches fail?
- What techniques work and why?
- Lessons and generalizations

Problem: Given any five points in/on the unit equilateral triangle, is there always a pair with distance $\leq \frac{1}{2}$?





Math phobic's nightmare

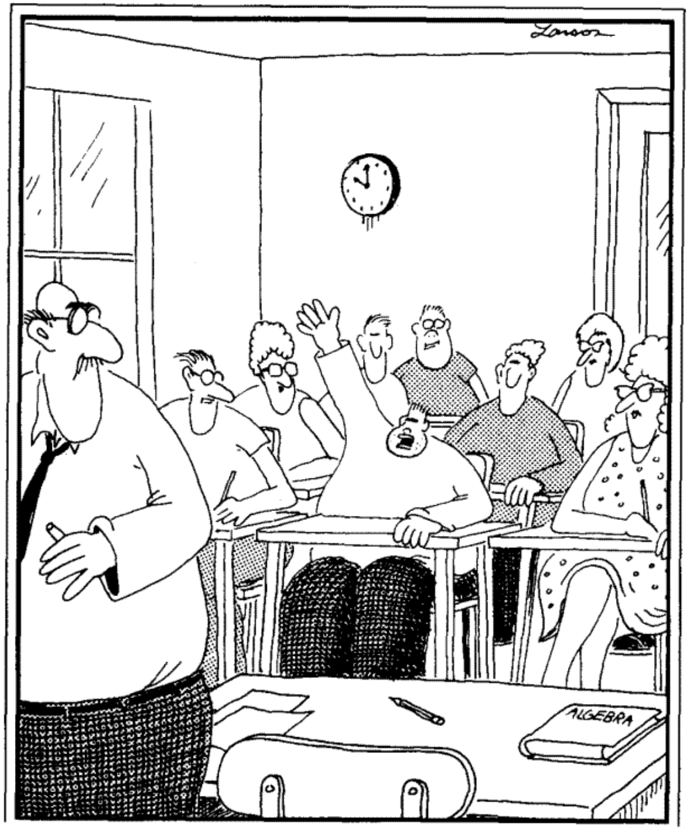
- What approaches fail?
- What techniques work and why?
- Lessons and generalizations

Problem: Solve the following equation for X:

$$X^{X^{X^{X^{\cdot^{\cdot^{\cdot}}}}}} = 2$$

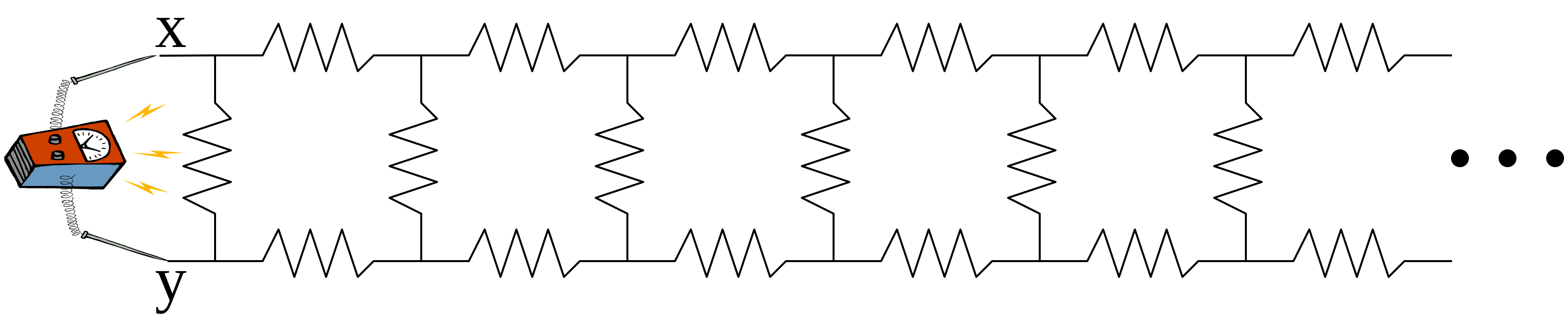
where the stack of exponentiated x’s extends forever.

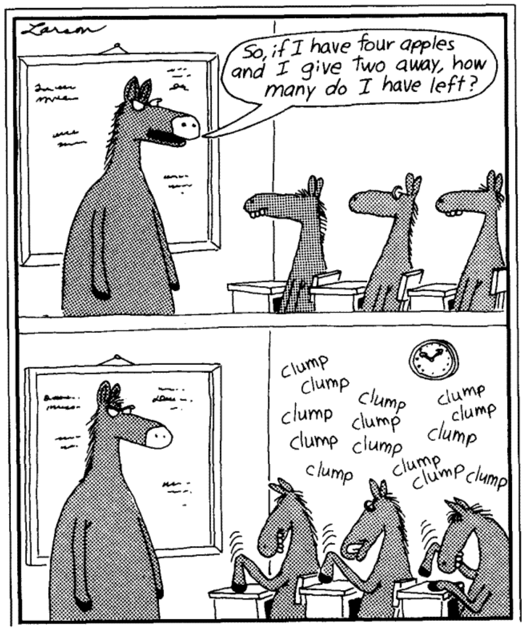
- What approaches fail?
- What techniques work and why?
- Lessons and generalizations



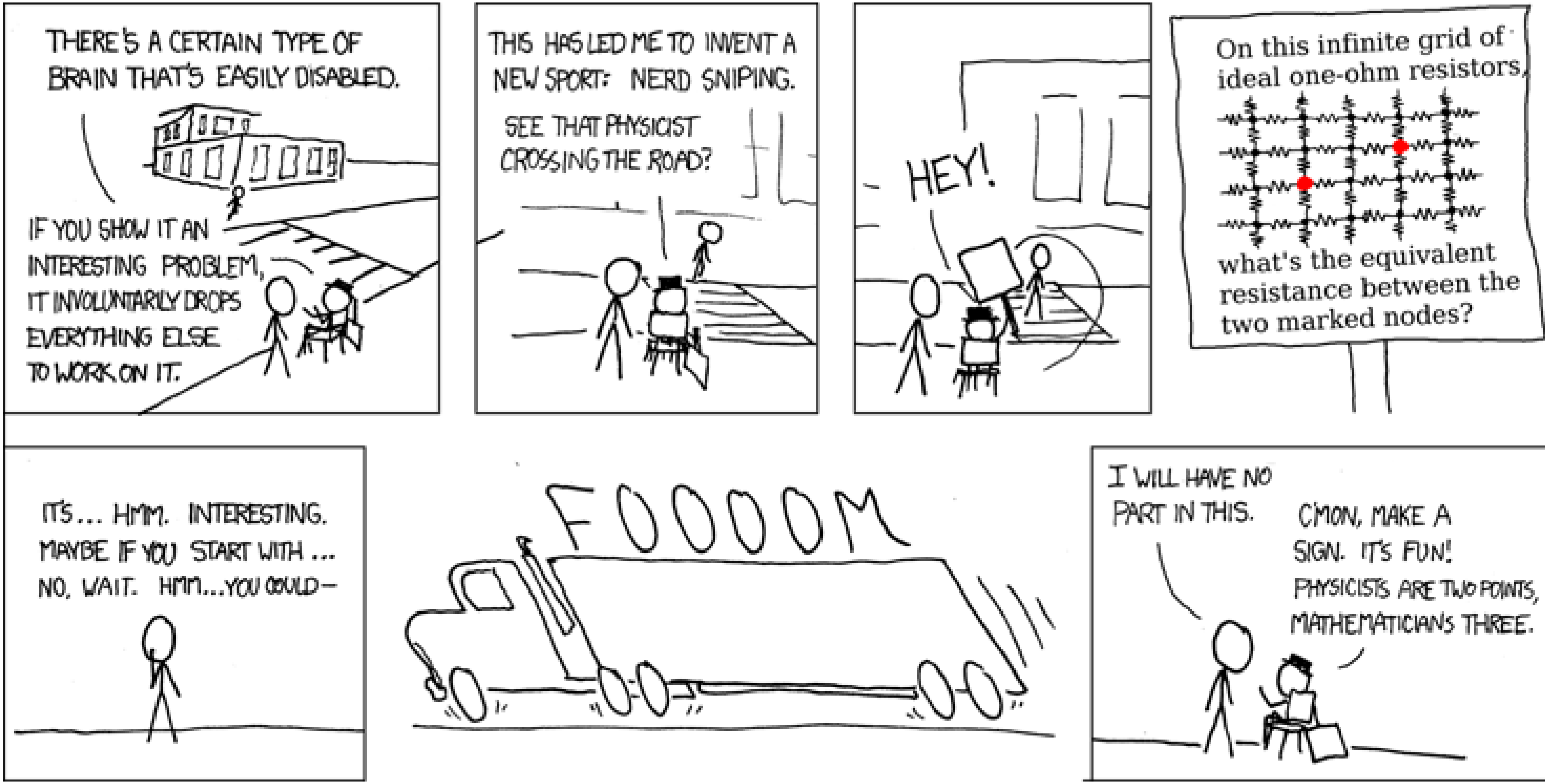
“Mr. Osborne, may I be excused? My brain is full.”

Problem: For the given infinite ladder of resistors of resistance R each, what is the resistance measured between points x and y?





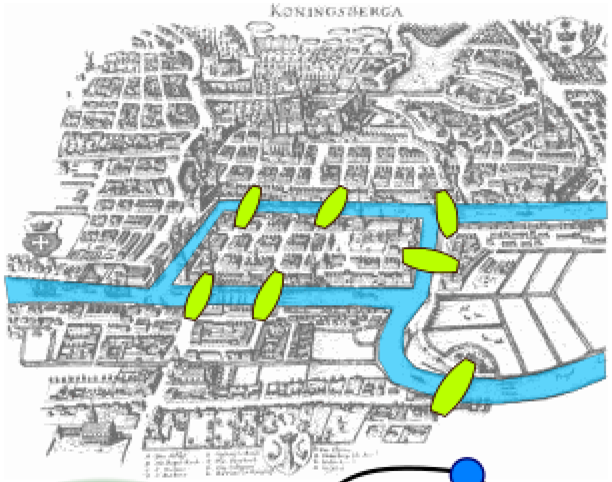
- What approaches fail?
- What techniques work and why?
- Lessons and generalizations

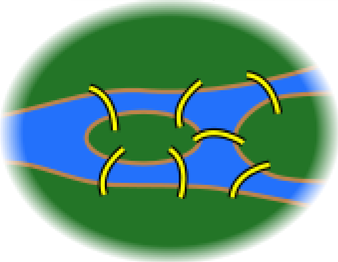

THERE'S A CERTAIN TYPE OF BRAIN THAT'S EASILY DISABLED.
IF YOU SHOW IT AN INTERESTING PROBLEM, IT INVOLUNTARILY DROPS EVERYTHING ELSE TO WORK ON IT.
THIS HAS LED ME TO INVENT A NEW SPORT: NERD SNIPING.
SEE THAT PHYSICIST CROSSING THE ROAD?
HEY!
On this infinite grid of ideal one-ohm resistors, what's the equivalent resistance between the two marked nodes?
IT'S... HMM. INTERESTING. MAYBE IF YOU START WITH ... NO, WAIT. HMM...YOU COULD—
FOOOOM
I WILL HAVE NO PART IN THIS.
C'MON, MAKE A SIGN. IT'S FUN! PHYSICISTS ARE TWO POINTS, MATHEMATICIANS THREE.

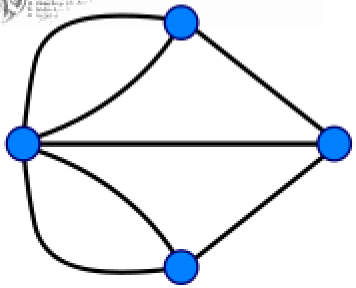
Historical Perspectives

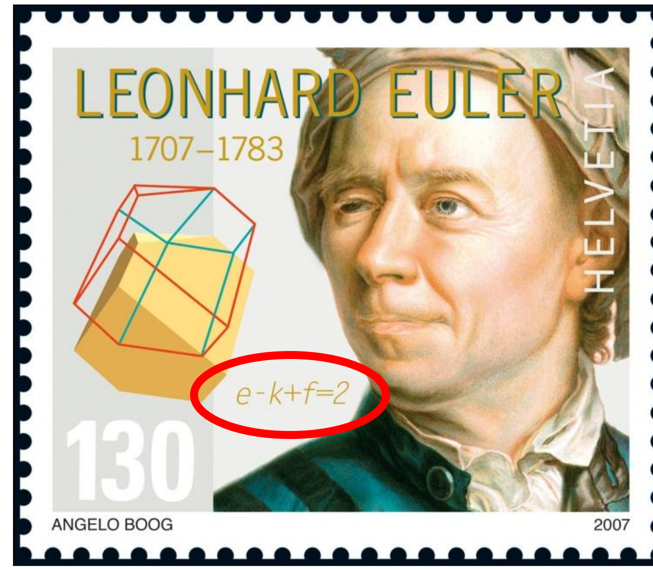
Leonhard Euler (1707–1783)

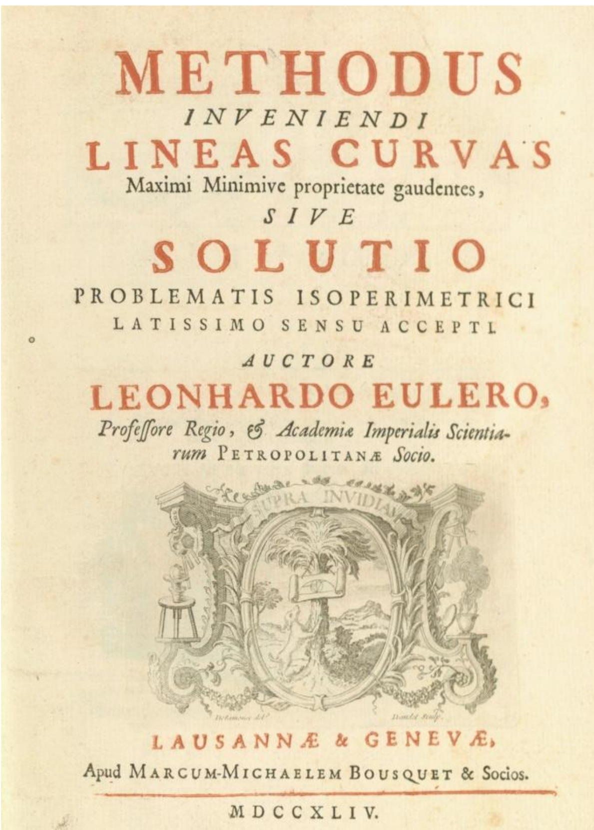
- Invented graph theory
- "Bridges of Königsberg", Prussia
- Eulerian tour
- Euler's formula: V + F = E + 2
- Euler's number: e
- Euler's identity: $e^{i\pi} + 1 = 0$
- Major contributions to analysis, algebra, calculus, number theory, topology, optics, fluid dynamics, mechanics, astronomy, education





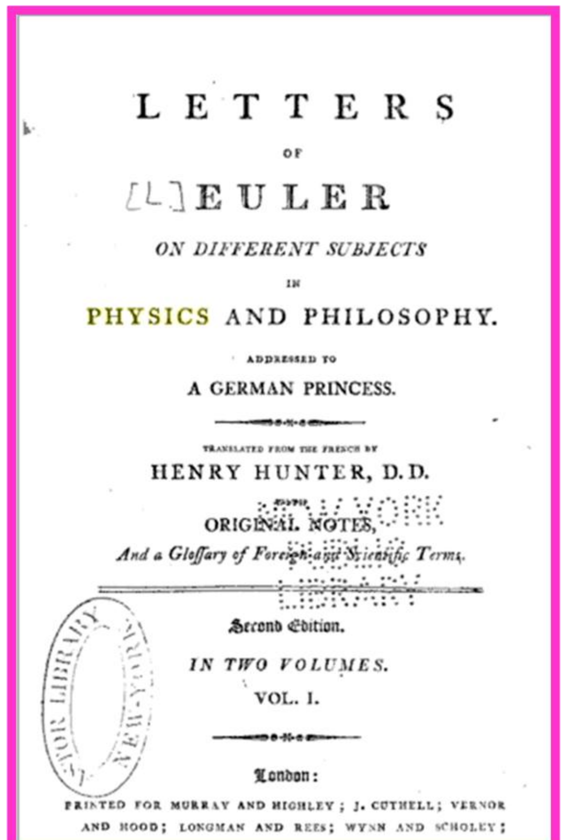





METHODUS
INVENIENDI
LINEAS CURVAS
Maximi Minimive proprietate gaudentes,
SIVE
SOLUTIO
PROBLEMATIS ISOPERIMETRICI
LATISSIMO SENSU ACCEPTI
AUCTORE
LEONHARDO EULERO,
Professore Regio, & Academiæ Imperialis Scientiarum PETROPOLITANÆ *Socio.*

SUPRA INVIDIAM

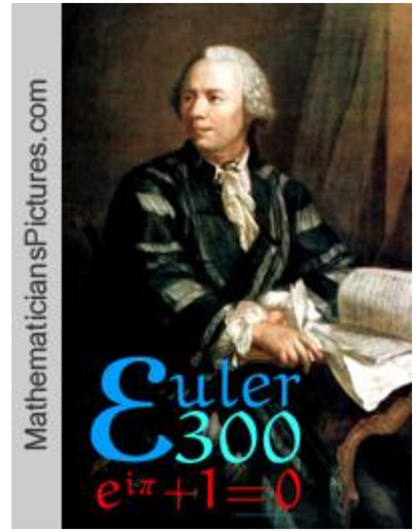
LAUSANNÆ & GENEVÆ,
Apud MARCUM-MICHAELEM BOUSQUET & Socios.
MDCCXLIV.

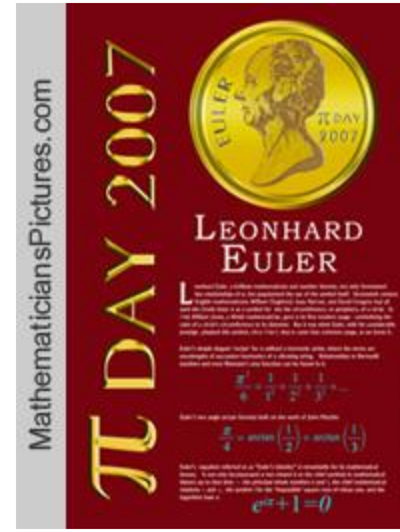

LETTERS
OF
[L] EULER
ON DIFFERENT SUBJECTS
IN
PHYSICS AND PHILOSOPHY.
ADDRESSED TO
A GERMAN PRINCESS.

TRANSLATED FROM THE FRENCH BY
HENRY HUNTER, D.D.
WITH
ORIGINAL NOTES,
And a Glossary of Foreign and Scientific Terms.

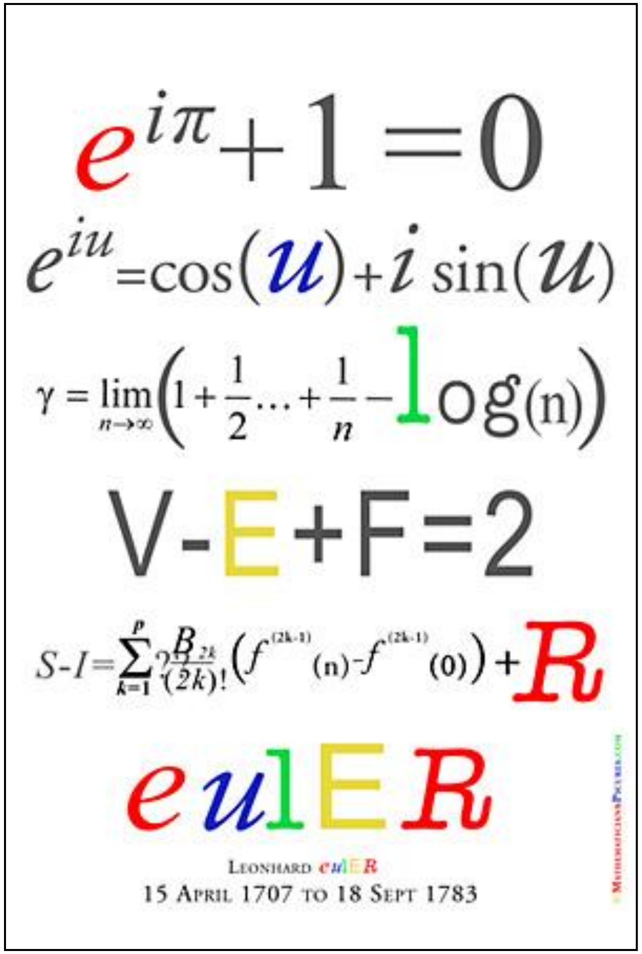
Second Edition.
IN TWO VOLUMES.
VOL. I.

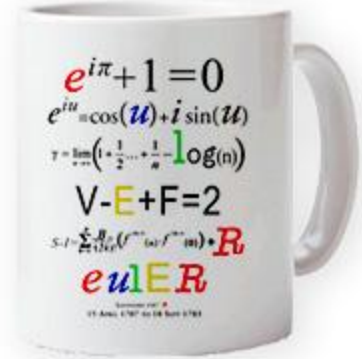
London:
PRINTED FOR MURRAY AND HIGHLEY; J. CUTHELL; VERNOR AND HOOD; LONGMAN AND REES; WYNN AND SCHOLEY;

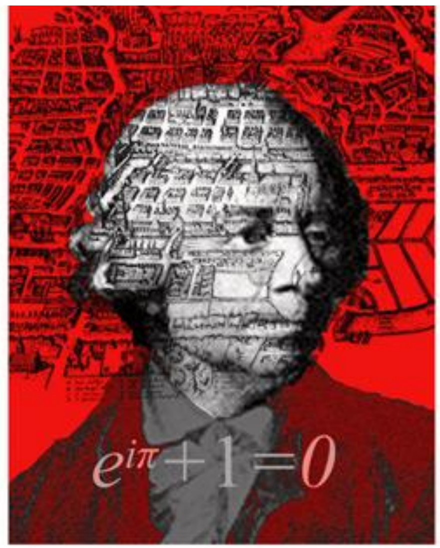

MathematiciansPictures.com
Euler
300
$e^{i\pi}+1=0$


MathematiciansPictures.com
π DAY 2007
EULER
π DAY 2007
LEONHARD
EULER
$e^{i\pi}+1=0$


MathematiciansPictures.com
Euler
300
$e^{i\pi}+1=0$
© MATHEMATICIANSPICTURES.COM

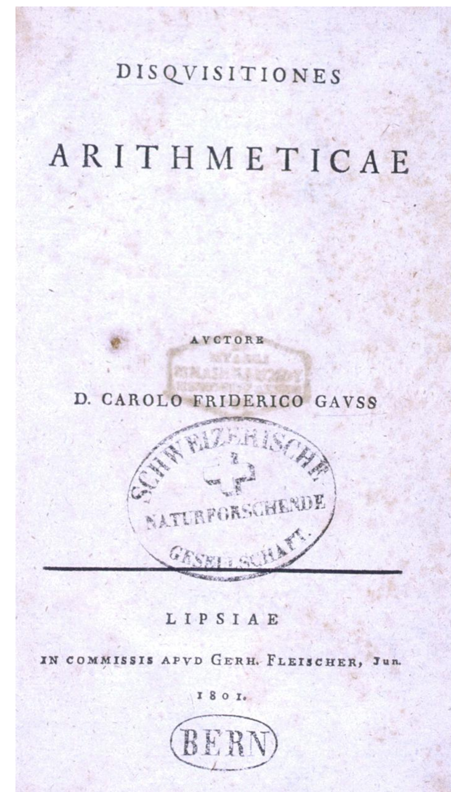






Leonhard Euler
1707 - 1783

Historical Perspectives



DISQVISITIONES

ARITHMETICAE

AVCTORE

D. CAROLO FRIDERICO GAVSS

SCHWEIZERISCHE NATURFORSCHENDE GESELLSCHAFT

LIPSIAE

IN COMMISSIS APVD GERH. FLEISCHER, Iun.

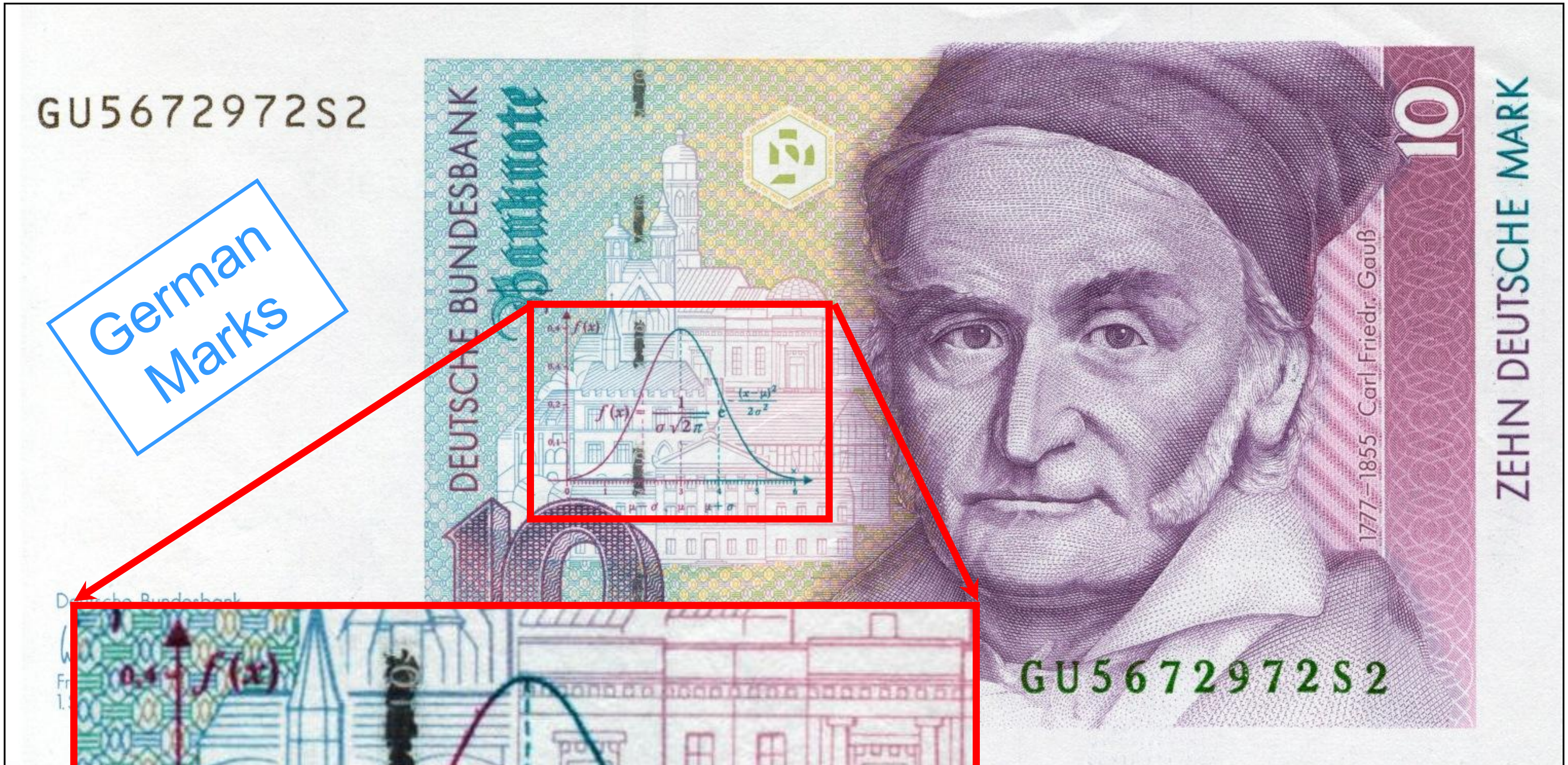
1801.

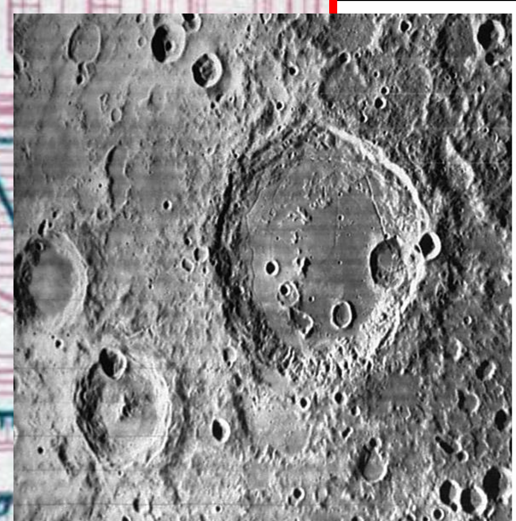
BERN

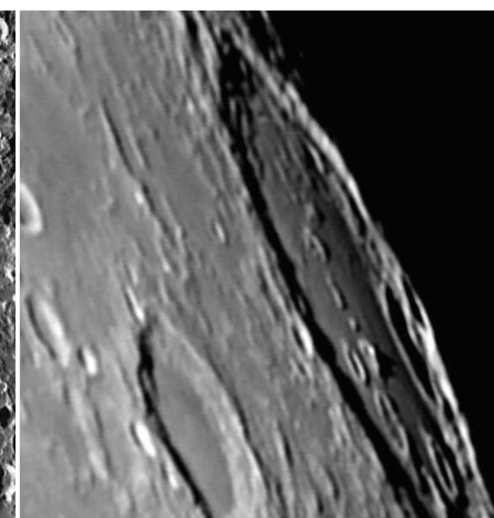
Carl Friedrich Gauss (1777–1855)

- “Prince of Mathematics”
- Founded modern number theory
- Authored “Disquisitiones Arithmeticae”
- Fundamental Theorem of Algebra
- Major contributions to astronomy, optics electromagnetism, statistics, geometry
- Gaussian distribution, Gaussian elimination Gaussian noise, Gaussian integers & primes Gauss’ Law, Gauss’ constant, “degaussing”
- SI unit of magnetic field strength: gauss
- Students: Dedekind, Riemann, Bessel

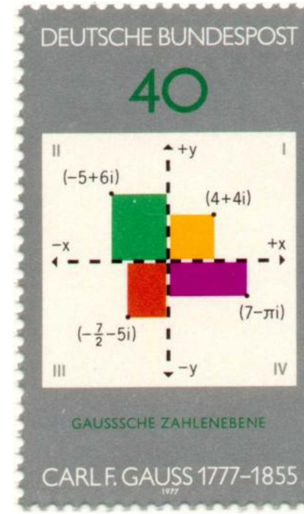
German
Marks

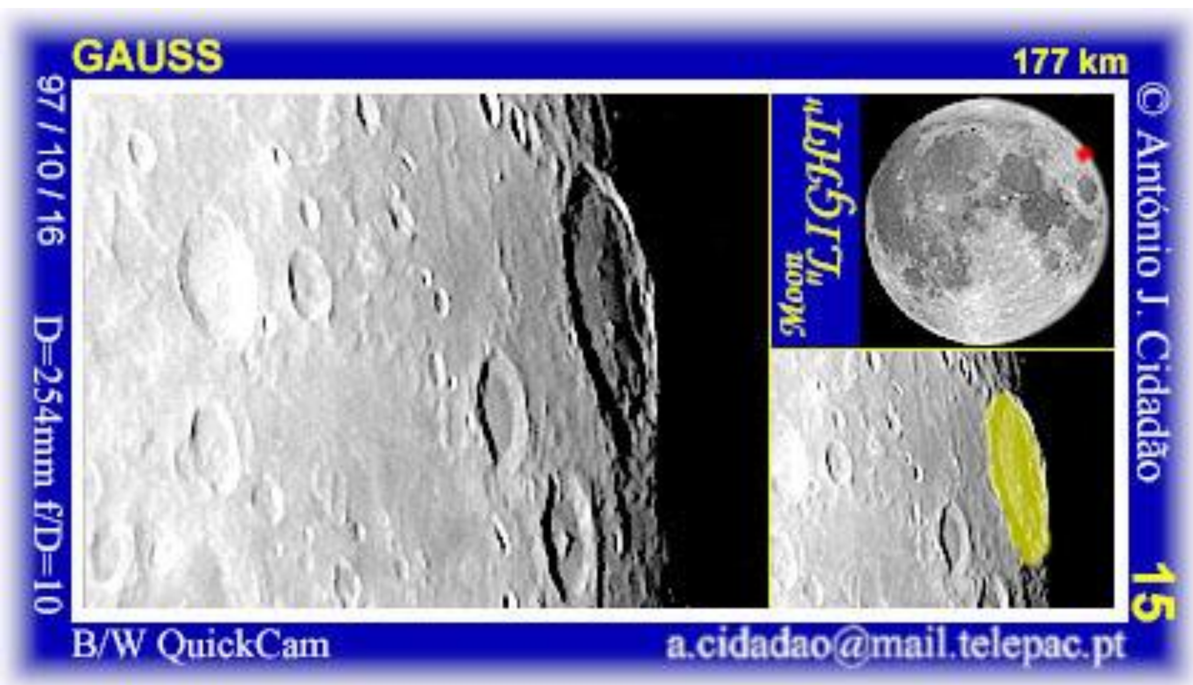







TERRES AUSTRALES ET ANTARCTIQUES FRANÇAISES
9,00
NAVIRE SCIENTIFIQUE
"GAUSS"
1901-1903
POSTE AERIENNE


DEUTSCHE BUNDESPOST
40
+y
+x
−x
−y
I
II
III
IV
(−5+6i)
(4+4i)
(7−πi)
$(-\frac{7}{2}-5i)$
GAUSSSCHE ZAHLENEBENE
CARL F. GAUSS 1777–1855


GAUSS
177 km
97 / 10 / 16
D=254mm f/D=10
Moon "LIGHT"
© António J. Cidadão
15
B/W QuickCam
a.cidadao@mail.telepac.pt


C.F.GAUSS ✱1777 †1855
DEUTSCHE
BUNDESPOST
10


NICARAGUA
CORREOS 1994
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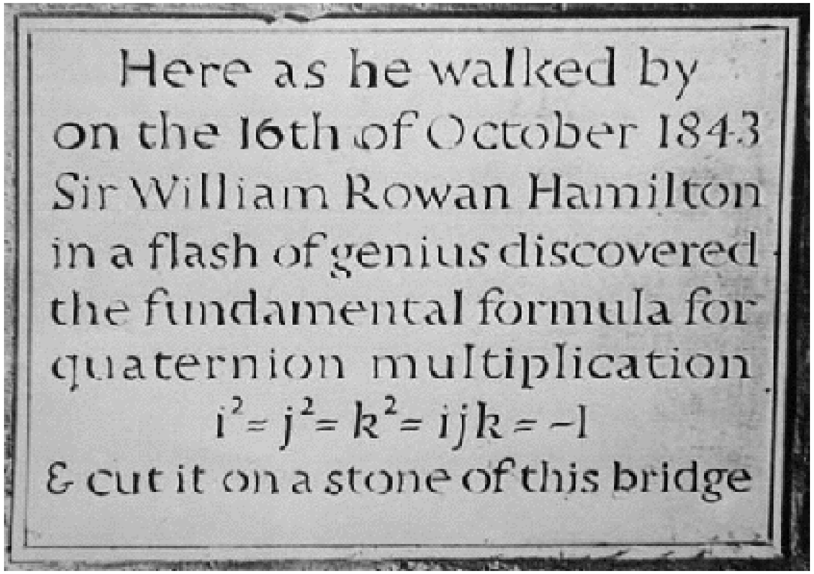
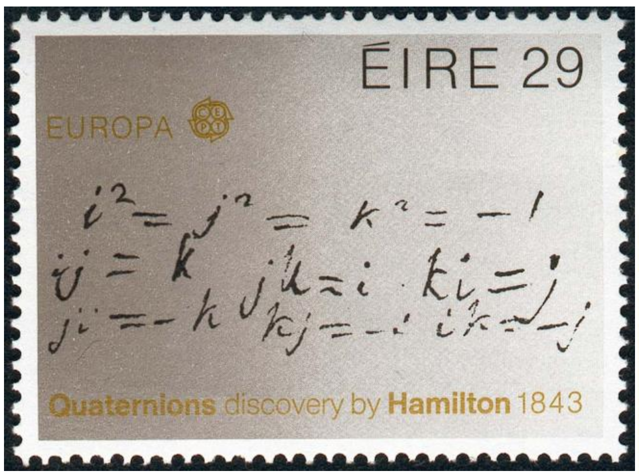
Gottinga
Karl Friedrich Gauss (1777-1855)

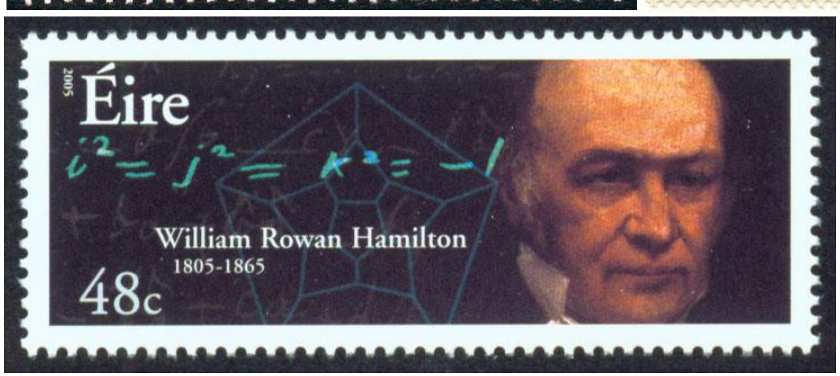
Historical Perspectives

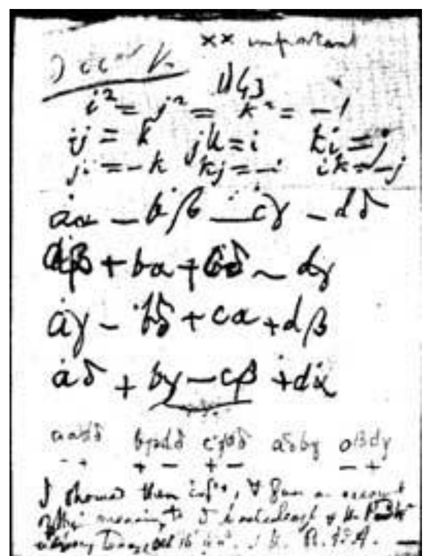
William R. Hamilton (1805-1865)

- Mathematician, physicist, and astronomer
- Contributed to algebra, mechanics, optics
- Formulated Hamiltonian mechanics
- Discovered quaternions, conical refraction, Hamilton function, Hamilton principle, Hamiltonian group
- Invented "Icosian Calculus", dot & cross products, Hamiltonian paths
- Influenced computer graphics, mechanics, electromagnetism, relativity, quantum theory, vector algebra

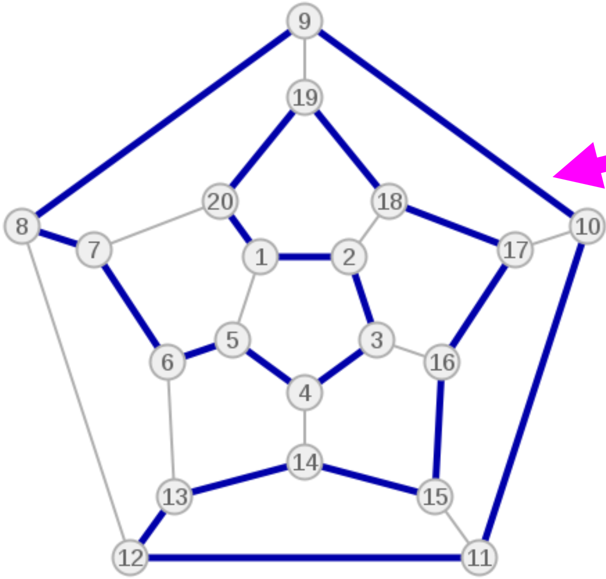


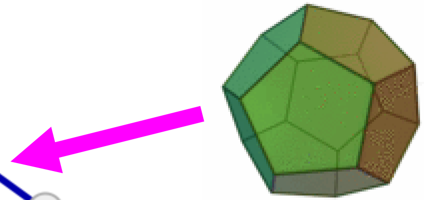


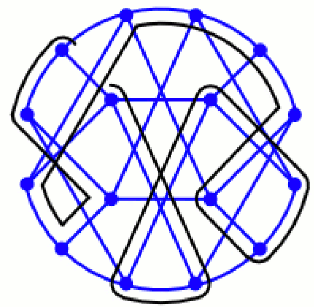


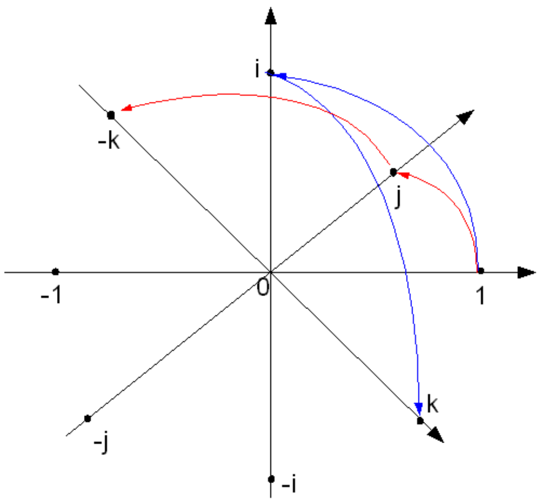


	1	−1	i	−i	j	−j	k	−k
1	1	−1	i	−i	j	−j	k	−k
−1	−1	1	−i	i	−j	j	−k	k
i	i	−i	−1	1	k	−k	−j	j
−i	−i	i	1	−1	−k	k	j	−j
j	j	−j	−k	k	−1	1	i	−i
−j	−j	j	k	−k	1	−1	−i	i
k	k	−k	j	−j	−i	i	−1	1
−k	−k	k	−j	j	i	−i	1	−1



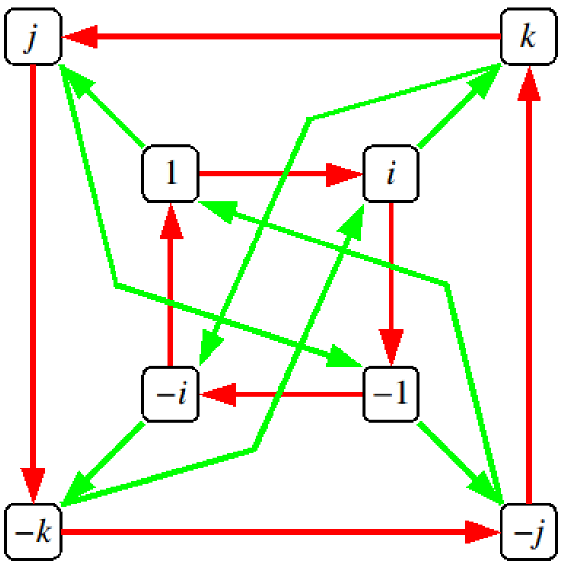






Graphical representation of quaternion units product as 90°-rotation in 4D-space

$ij = k$
$ji = -k$
$ij = -ji$



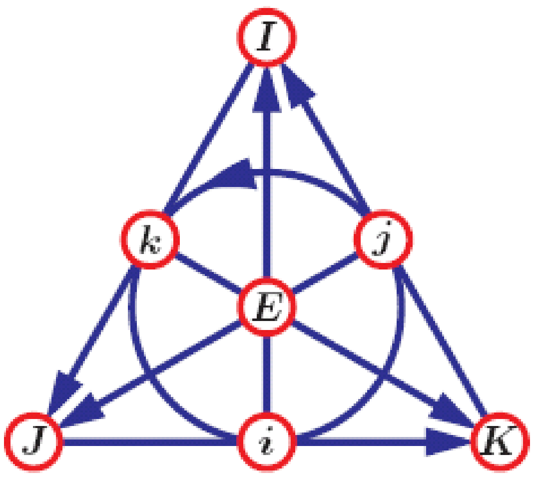
Non-commutative: $ij=k \quad ji=-k$

the
Hamilton Mathematics Institute
TCD

Octonions: Generalization of Quaternions

- Non-associative! (e.g., (ij)K=-E ≠ E=i(jK))
- Discovered by John Graves (1843), friend of Hamilton
- Useful in general relativity, quantum logic, string theory

×	i	j	k	E	I	J	K
i	−1	k	−j	I	−E	−K	J
j	−k	−1	i	J	K	−E	−I
k	j	−i	−1	K	−J	I	−E
E	−I	−J	−K	−1	i	j	k
I	E	−K	J	−i	−1	−k	j
J	K	E	−I	−j	k	−1	−i
K	−J	I	E	−k	−j	i	−1



Mnemonic diagram for unit octonions products

"The real numbers are the dependable breadwinner of the family, the complete ordered field we all rely on. The complex numbers are a slightly flashier but still respectable younger brother: not ordered, but algebraically complete. The quaternions, being noncommutative, are the eccentric cousin who is shunned at important family gatherings. But the octonions are the crazy old uncle nobody lets out of the attic: they are *nonassociative*."

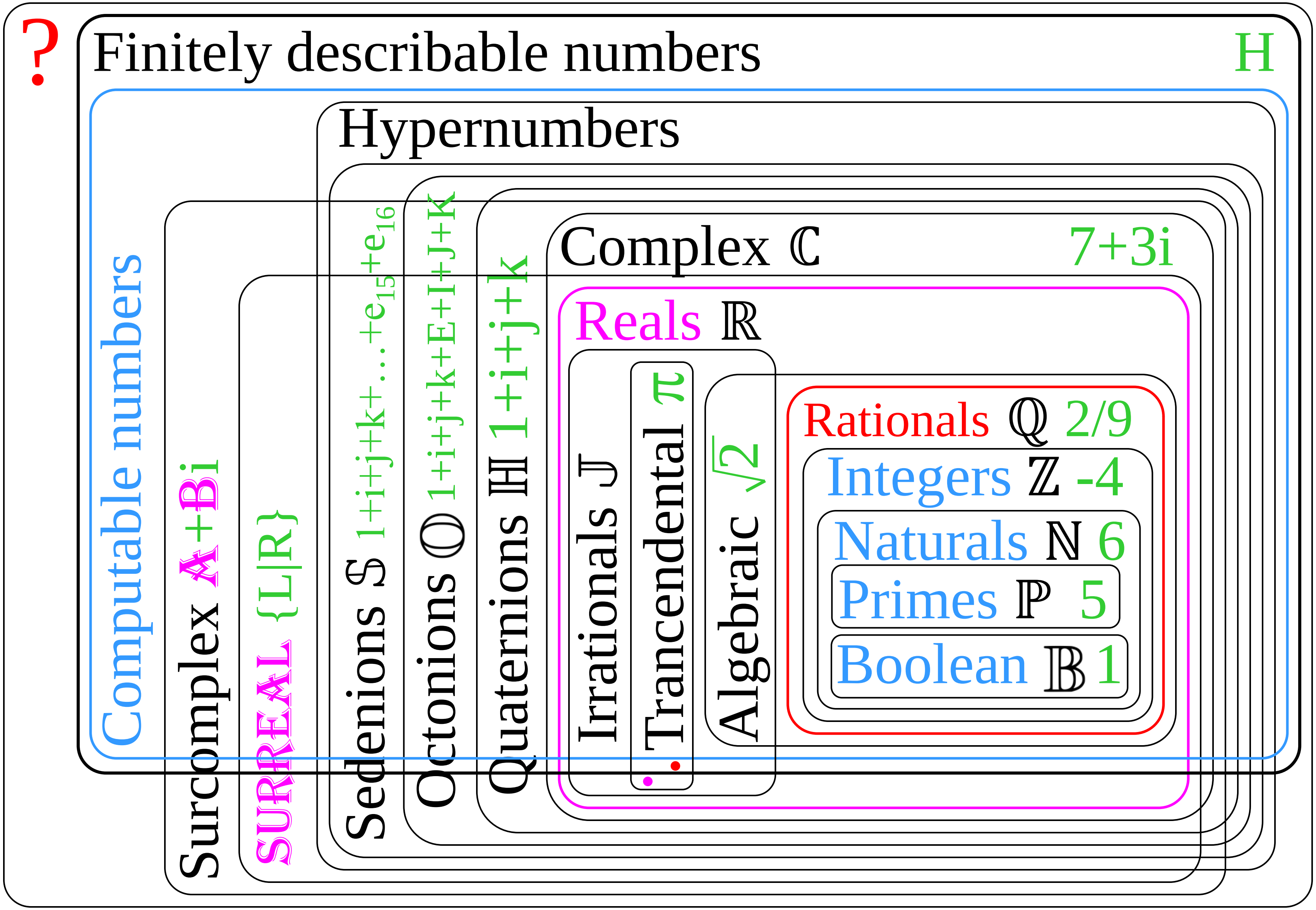
— John Baez (1961-), physicist
works on spin foams
and loop quantum gravity

Sedenions: Generalization of Octonions

- Non-alternative! (i.e., x(xy)=(xx)y doesn't hold)

×	1	e_1	e_2	e_3	e_4	e_5	e_6	e_7	e_8	e_9	e_{10}	e_{11}	e_{12}	e_{13}	e_{14}	e_{15}
1	1	e_1	e_2	e_3	e_4	e_5	e_6	e_7	e_8	e_9	e_{10}	e_{11}	e_{12}	e_{13}	e_{14}	e_{15}
e_1	e_1	-1	e_3	$-e_2$	e_5	$-e_4$	$-e_7$	e_6	e_9	$-e_8$	$-e_{11}$	e_{10}	$-e_{13}$	e_{12}	e_{15}	$-e_{14}$
e_2	e_2	$-e_3$	-1	e_1	e_6	e_7	$-e_4$	$-e_5$	e_{10}	e_{11}	$-e_8$	$-e_9$	$-e_{14}$	$-e_{15}$	e_{12}	e_{13}
e_3	e_3	e_2	$-e_1$	-1	e_7	$-e_6$	e_5	$-e_4$	e_{11}	$-e_{10}$	e_9	$-e_8$	$-e_{15}$	e_{14}	$-e_{13}$	e_{12}
e_4	e_4	$-e_5$	$-e_6$	$-e_7$	-1	e_1	e_2	e_3	e_{12}	e_{13}	e_{14}	e_{15}	$-e_8$	$-e_9$	$-e_{10}$	$-e_{11}$
e_5	e_5	e_4	$-e_7$	e_6	$-e_1$	-1	$-e_3$	e_2	e_{13}	$-e_{12}$	e_{15}	$-e_{14}$	e_9	$-e_8$	e_{11}	$-e_{10}$
e_6	e_6	e_7	e_4	$-e_5$	$-e_2$	e_3	-1	$-e_1$	e_{14}	$-e_{15}$	$-e_{12}$	e_{13}	e_{10}	$-e_{11}$	$-e_8$	e_9
e_7	e_7	$-e_6$	e_5	e_4	$-e_3$	$-e_2$	e_1	-1	e_{15}	e_{14}	$-e_{13}$	$-e_{12}$	e_{11}	e_{10}	$-e_9$	$-e_8$
e_8	e_8	$-e_9$	$-e_{10}$	$-e_{11}$	$-e_{12}$	$-e_{13}$	$-e_{14}$	$-e_{15}$	-1	e_1	e_2	e_3	e_4	e_5	e_6	e_7
e_9	e_9	e_8	$-e_{11}$	e_{10}	$-e_{13}$	e_{12}	e_{15}	$-e_{14}$	$-e_1$	-1	$-e_3$	e_2	$-e_5$	e_4	e_7	$-e_6$
e_{10}	e_{10}	e_{11}	e_8	$-e_9$	$-e_{14}$	$-e_{15}$	e_{12}	e_{13}	$-e_2$	e_3	-1	$-e_1$	$-e_6$	$-e_7$	e_4	e_5
e_{11}	e_{11}	$-e_{10}$	e_9	e_8	$-e_{15}$	e_{14}	$-e_{13}$	e_{12}	$-e_3$	$-e_2$	e_1	-1	$-e_7$	e_6	$-e_5$	e_4
e_{12}	e_{12}	e_{13}	e_{14}	e_{15}	e_8	$-e_9$	$-e_{10}$	$-e_{11}$	$-e_4$	e_5	e_6	e_7	-1	$-e_1$	$-e_2$	$-e_3$
e_{13}	e_{13}	$-e_{12}$	e_{15}	$-e_{14}$	e_9	e_8	e_{11}	$-e_{10}$	$-e_5$	$-e_4$	e_7	$-e_6$	e_1	-1	e_3	$-e_2$
e_{14}	e_{14}	$-e_{15}$	$-e_{12}$	e_{13}	e_{10}	$-e_{11}$	e_8	e_9	$-e_6$	$-e_7$	$-e_4$	e_5	e_2	$-e_3$	-1	e_1
e_{15}	e_{15}	e_{14}	$-e_{13}$	$-e_{12}$	e_{11}	e_{10}	$-e_9$	e_8	$-e_7$	e_6	$-e_5$	$-e_4$	e_3	e_2	$-e_1$	-1

Generalized Numbers



Theorem: some real numbers are not finitely describable!

Theorem: some finitely describable real numbers are not computable!