MAN'S FIRST STEPS

TALES ABIUT SCIENTIFIC INSIGHTS

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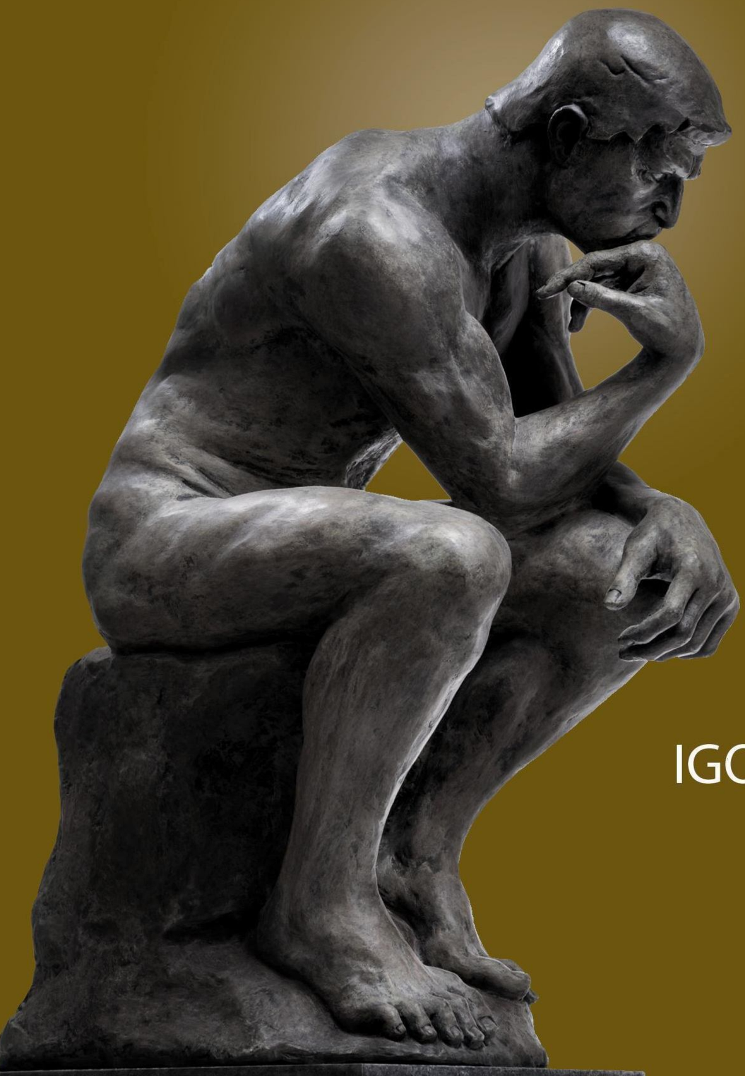

IGOR USHAKOV

Tales & Stories
about Mathematical & Scientific Insights

Igor Ushakov

Man's first steps

San Diego
2013

Cover design: Igor A. Ushakov.

Series

"Stories and Legends about Mathematical & Scientific Insights"

Book 1. **Man's first steps** takes us through the first use of scientific and mathematical thinking as man began to question the nature of his Universe and then takes us into the history of measurements of the physical quantities of temperature, length, time and mass.

Book 2. **In the beginning was the number …** You find here new facts about Roman and Arabic numbers and some interesting methods of calculations. You also find here interesting things about magic numbers.

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These books help teachers
make their classes more interesting
and help pupils to know even more
than their teachers!

Preface

The subject of mathematics is so serious that nobody should miss an opportunity to make it a little bit entertaining.

Blaise Pascal [1]**.**

What is this series of books about? For whom is it written? Why is this series written in this manner, not in another? Discussion about geometry, algebra and similar topics definitely hint that this is about mathematics. On the other hand, you cannot find within a proof of any statement or strong chronology of facts. Thus, these books are not tutorial. This is just a collection of interesting and sometimes exciting stories and legends about human discoveries in one or another way connected to mathematics…

These book are open for everybody who likes to enrich their intelligence with the stories of genius insights and great mistakes (mistakes also can be great!), and with biographies of creators of mathematical thinking and mathematical approaches in the study of the World.

Who are the readers of the proposed books? We believe that there is no special audience in the sense of education or age. The books could be interesting to schoolteachers and university professors (not necessarily mathematicians!) who would like to make their lectures more vivid and intriguing. At the same time, students of different educational levels – from middle school up to university – as well as their parents may find here many interesting facts and ideas. We can imagine that the book could be interesting even for state leaders whose educational level is enough to read something beyond speeches prepared for them by their advisors.

Summarizing, we have the courage to say: These books are destined for everybody!

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[1] **Blaise Pascal** (1623 –1662) was a French mathematician, physicist, inventor, writer and philosopher.

Trust us: we tried to write the book clearly! Actually, it is non-mathematical book around mathematics.

This book is not intended to convert you to a "mathematical religion". Indeed, there is no need to do this: imagine how boring life would be if everybody were a mathematician? Mathematics is the world of ideas, however any idea needs to be realized: integrals cannot appease your hunger, differential equations cannot fill gas tank of your car....

However, to be honest, we pursued the objective: we tried to convince you, the reader, that without mathematics *homo erectus* would never transform into *homo sapiens.*

Now, let us travel into the very interesting place: Terra Mathematica. We'll try to make this your trip interesting and exciting.

What in particular is particular book about?

Here you, Reader, find many interesting facts about Man's first steps takes us through the first use of scientific and mathematical thinking as man began to question the nature of his Universe. Then the book takes us into the history of measurements of the cosmic distances to the Moon and to the Sun and different the physical quantities of temperature, length, time and mass.

At the end you will be introduces with biographies of some genius in the area of knowledge that is subject of this book.

Igor Ushakov

San Diego
2012

Contents

1. MAN FIRST LOOKS AT THE WORLD

Even the longest journey starts with the first step.

Lao Tsu.[2]

1.1. The world through the eyes of the Ancients

Even from a small hill, one can see the entire World.

Unknown author

We can be certain that since time immemorial man took note of the natural world around him. Perhaps it was only that he had no choice but to study climate, plants, and animals to survive; but, as he distanced himself from other animals, it became more than that. From archeological records, we find that early man noted the daily and yearly movements of heavenly bodies including details of the phases of our Moon, seasonal changes, and length of daylight and so on. At some point, these observations became the focus of the first scientific developments. That transition occurred when civilization had progressed far enough that specialization was possible. There were now farmers, soldiers, masons, etc. and our major scientific characters, about which we write.

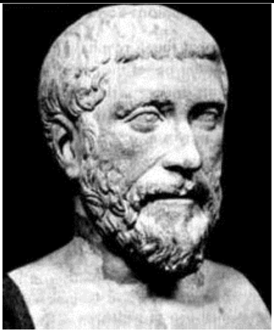
Our knowledge about the early scientists and their discoveries comes from various sources, which include Sumerian cuneiform tables, ancient Egyptian papyruses, fichus leaves with Mayan hieroglyphs and

[2] **Lao Tsu** (VI BC) was a legendary Chinese philosopher, whose name means literally "old philosopher". His teaching has been presented in "*Tao Te Ching*" ("*The Way and Its Power*"), which is a collection of aphorisms and wise thoughts. The central idea of his teaching was the idea of "tao" – "way of life".

ancient Chinese bamboo panels. From these we have learned about the astonishing successes of those gone forever civilizations in prediction of lunar eclipses and other phenomena of nature and such novel ideas as the calendar.

Although the first observations were very simple, such as just noting that there is a regular cycle to the moon, these elementary observations already were sufficient to stimulate an astounding natural curiosity about the cause of these events. There must have been a practical need for some study, perhaps to recognize tidal flows so that they might sail more quickly and safely, but it seems that there were a few men who had curiosity for its own sake; these were the scientists. From a modern perspective, we recognize the tremendous importance of scientists to the well being of man, but at the dawn of scientific study, science must have been one of those momentous leaps that propelled man beyond jungle animal status.

The most noteworthy figure of ancient science is Pythagoras. He, with his pupils, developed the idea of the spherical nature of the surrounding world; specifically, they held that the Earth is a sphere, located at the center of a system with the sun the moon and stars moving around the Earth, each in its own orbit.



Pythagoras of Samos
(580 - 500 BC)

One of the greatest scientists of all time. Physicists, mathematicians, astronomers, biologists, philosophers and some other scientists name Pythagoras as the founder of their sciences. He founded a philosophical and religious school in Croton, a city in southern Italy. This school attracted many followers, who called themselves Pythagoreans. Many famous mathematicians, historians and politicians graduated from Pythagoras' school, which continued for about a century after the death of the great teacher.

For more details see Chapter "Pantheon".

At the end of the 6th century BC Pythagoras created a brotherhood, called Pythagoreans, which persisted for several generations after his death. This school produced a number of outstanding scientists and public servants.

Several decades after Pythagoras, Anaxagoras pushed the thinking further by drawing upon his own observations of the celestial bodies to establish a new theory of the Universe. He gave a scientific account for rainbows, meteors and the Sun, which he described as a "mass of blazing metal, larger than the Peloponnesus" (that was certainly a good guess); the heavenly bodies were, in his theory, masses of stone torn from the earth and ignited by rapid rotation. This brought him into conflict with the people who believed in multiple gods.

Anaxagoras of Clazomenae
(500-428 BC)

Greek philosopher. Being from a noble family, he wished to devote himself entirely to science. He gave up his property to his relatives, and moved to Athens, where he rapidly became the center of Greek culture and established his own school. Some authorities assert that even Socrates was among his disciples.

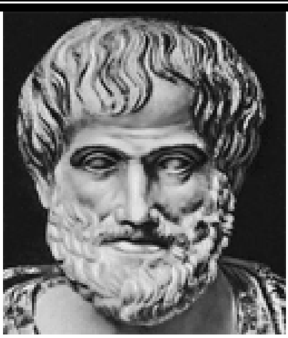
Due to his ideas of the nature of the Universe, Anaxagoras was arrested on a charge of contradicting the established religious dogmas, and it required the influence of his pupil Pericles – Athens' strategist and ruler – to secure his release. However, he was forced to leave Athens, and he went to Lampsacus where he died within 5 years.

There is a legend that once Anaxagoras was asked what the point of being born was. He replied: "*The investigation of sun, moon and heaven*".

With uncanny sense, Anaxagoras also guessed that the Moon reflected light from the Sun and did not itself produce light. He used this concept to explain eclipses as the shadows of the Earth.

The most indisputable authority who laid a foundation of the mathematical model of the Universe – what we now call Cosmology –

was the great Greek philosopher Aristotle, a disciple of both Socrates[3] and Plato[4].



Aristotle
(384–322 BC)

One of the greatest philosophers of all times. He spent 20 years in the Plato's Academy. After Plato's death, he left the Academy and became a tutor to Alexander the Great. In 335 BC he returned to Athens and established there his own school – Lyceum. At the sudden death of Alexander in 323 BC, the new government was anti-Alexander and Aristotle was charged with impiety, a trumped up accusation.

To escape prosecution Aristotle fled to Chalcis in Euboea where he died of a stomach illness in that same year.

Aristotle's works on mathematics, astronomy, physics, logics, philosophy, biology, ethics, sociology, history, poetry, and other sciences have played a large role in development of human civilization. They have been translated into all major languages.

Aristotle believed that the Universe is a sphere and that stars are attached to that sphere. Saturn is attached to another sphere, Jupiter to the third one and so on. All these spheres are involved in some common motion, and in the center of the Universe is the immovable Earth.

In earlier times everything was reduced to observation, collection and analysis of data, but it was the appearance of the spherical model of

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3 **Socrates** (470 – 399 BC.), ancient philosopher, father of philosophic dialectics, great teacher. He was sentenced to death for "introducing new gods and depravity of youth with new ideas". When in an appointed hour a slave brought him a cup with poisoned liquid, Socrates said farewell to his friends and stoically drank the poison.

4 **Plato of Athens** (427 – 347 BC.), Socrates' disciple. After his tutor had been executed, for 20 years he traveled within Greece and Egypt, until finally he founded in Athens the *Academy,* where he taught until his last days. Plato's Academy became a leading philosophical school for a thousand years. His works written in the form of dialogues, where one of the interlocutors was Socrates, dramatically influenced modern philosophy. His works have been translated into all major languages.

the Universe, which made it possible to begin understanding the physics of motion of heavenly bodies. Development of this model led to the invention of a convenient coordinate system to describe the location of the heavenly bodies. This coordinate system required three angles: the angle between the North Star (Polaris) and the horizon, the angle between the object of interest and the horizon, and the angle between the object of interest and the North Star. The importance of the development of a coordinate system for further development of astronomy and geography cannot be overstated.

1.2. The radius of the Earth

Though the Earth is not so round,
nevertheless, it has a radius!
Unknown author

The early scientists, having theorized that the Earth is a sphere, certainly felt compelled to measure the radius of the Earth, but with only the rudimentary observations that could be made from the surface of the Earth that task required cleverness. The very first calculation of the radius of the Earth is said to belong to a 15-year old intern, Eratosthenes, of the Library at Alexandria. It is quite possible that he was inspired and assisted by Aristarchus who was the most prominent scientist of the Library at that time.

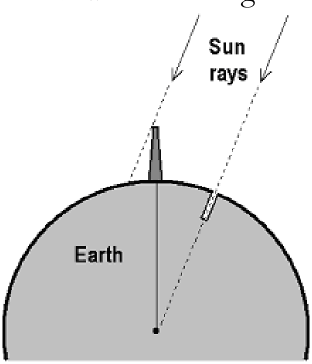
Eratosthenes of Cyrene
(276-194 BC.)

Famous ancient scientist. He headed the largest scientific center of the time –Alexandrian Museum (Asylum of Muses) with its famous Library. He founded geography and philology, and made important contributions to mathematics, philosophy, and music theory.

For more details see Chapter "Pantheon".

The very modest information of the Earth stimulated this young scientist's imagination to invent the first method of measuring the radius of the Earth. This experiment has become one of the ten most recognized experiments in the history of science and is known as "*Eratosthenes' Experiment.*" Legend and some documented facts tell that Eratosthenes, an inquisitive boy, found in a manuscript that there was very old and deep water well in the city of Syene (now Aswan). That well was remarkable because its bottom was lit by the rays of the sun only once a year, namely on the day of summer solstice. In the same Library, young Eratosthenes found written the distance between Alexandria and Syene. Because that area in the Nile valley was investigated in detail by different professional surveyors, the distance was known precisely enough to be useful to Eratosthenes; it was 5000 stadia[5], which is approximately 560 miles. Fortuitously, the way from Alexandria to Syene crosses a flat desert surface in a straight line running almost exactly from the North to the South.

So, on June 22, exactly at noon, Eratosthenes measured the shadow of the highest building of Alexandria, the famous Alexandria Lighthouse that is known as one of the Seven Wonders of the World. He found that the angle between the sun and the zenith was equal to z=7° 15' to the North or about 1/50 of the full circle. From here Eratosthenes computed that the earth radius for that meridian was equal to 5000 * 50 = 250 000 stadia. Understanding all approximations of his calculations, he added extra 2000 stadia just so that the value could be divided by 360 without leaving a remainder.



Eratosthenes had no way of knowing that in spite of all his measurement inaccuracies (e.g. errors in his equipment for measuring angles, approximate time measurement with a sundial, his arbitrary adding 2000 stadiums, etc.), it would not be until the 19th century before a more precise measurement would be made!

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[5] Stadion (pl. stadia) – ancient unit of distance with a widespread use throughout antiquity from as low as 171 yards up to 230 yards. The stadium at Olympus measures 210 yards. By the way, the word "stadium" directly relates to this unit of distance. At the Eratosthenes' time a stadion was equal 175 yards.

Of course, he was lucky that Syene is located almost exactly on the Tropic of Cancer[6] and both cities lie on the same meridian, but such luck is common (perhaps necessary) in discovery.

1.3. The radius of the Moon and the distance to the Moon

If ever asked: What's more useful, the sun or the moon, respond: The moon. For the sun only shines during daytime, when it's light anyway, whereas the moon shines at night.

Nasreddin Hodja[7]

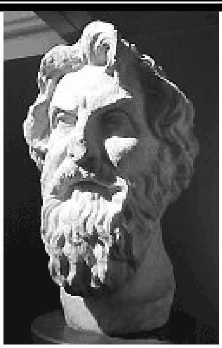
It is quite possible that the then 60 years old Aristarchus participated in Eratosthenes' experiment as might be expected from the head of the entire Alexandrian scientific school. Aristarchus' only extant treatise is "*On the Sizes and Distances of the Sun and Moon,*" so his ideas have come to us mostly in citations by other ancient scientists. It was Aristarchus who developed the revolutionary (and for his time, amazing) theory that the center of the Universe is the Sun, and that it is the Earth, Moon and other planets (or "moving stars"), which rotate around the Sun. Furthermore, he stated that the orbits of all of the planets and the Moon lie in the same plane. Such bold genius opened the way for geometry to play an important part in further calculations. And, by the way, did you notice that those discoveries were made only several years after Aristotle presented his model of the Universe!

When Eratosthenes calculated the radius of the Earth, Aristarchus discovered how to use it to find the radius of the Moon. He waited for a lunar eclipse and compared the size of the shadow of the Earth on the moon with the size if the moon! Of course, Aristarchus understood that he could not get precise measurements, though he was

[6] On the North Tropic (Tropic of Cancer – 23.5 ° of the North latitude), the Sun at noon on the day of the summer solstice (June 21-22) is exactly overhead at its zenith.

[7] **Nasreddin Hodja** was a Seljuk Turkish Dervish, sometimes believed to have lived around 13th century and considered a wise man, remembered for his funny stories and anecdotes.

interested mostly in a qualitative picture of the Universe rather than in quantitative preciseness.



Aristarchus of Samos

(320 - 250 BC.)

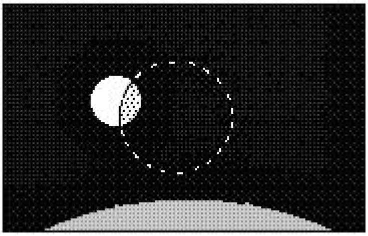
Philosopher, astronomer and mathematician of the Alexandrian school, and pupil of Euclid. His greatest accomplishment is the creation of the heliocentric system of the Universe. He believed that stars are immobile and located very far from the Earth, and the Earth rotates around its axis and revolves around the sun. Sometimes astronomers call him the Copernicus of ancient times.

For more details see Chapter "Pantheon".

During a partial lunar eclipse, the shadow of the Earth falls on the Moon in manner as depicted in the drawing below.

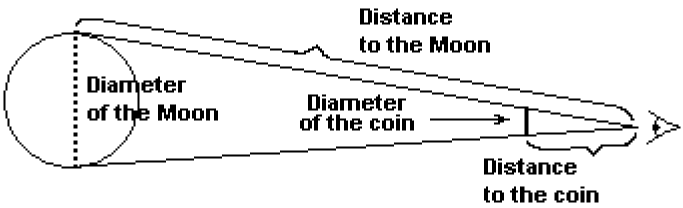
Observing a partial lunar eclipse, Aristarchus could draw a picture like one above and conclude that the radius of the Earth is approximately as large as 2.5 times that of the Moon[8]. By then Eratosthenes had computed the radius of the Earth, so getting the radius of the Moon was just a multiplication away. Yet another problem had been solved.

But, what is the distance to the Moon? By then Pythagoras already had developed concepts in plane geometry, and the theorem of similar triangles could be applied to a simple measurement to get an estimate of the distance to the Moon from the Earth.



It was enough to block the view of the moon with a coin by moving the coin along the direction to the moon until the edge of the coin coincided with the contour of the moon, then to measure the distance from the eye to the coin and the radius of the coin.

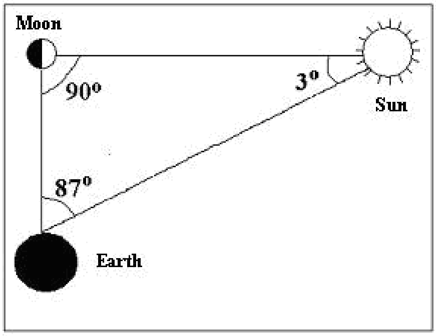
[8] The actual value is 3.67.



Then using similarity of triangles "eye-coin" and "eye-Moon" with three known values gives the distance from the observer to the moon[9]. Of course, Aristarchus used not a coin but a larger disk fixed to gain greater accuracy in the measurement.

1.4. The radius of the Sun and the distance to the Sun

> However, from another side, the Sun is more useful than the Moon: it not only shines but heats as well. Besides the Moon shines only on moonlit nights!
>
> ***Nasreddin Hodja.***



Let's now follow Aristarchus and his disciples to see how they measured the distance to the Sun and its radius. Aristarchus realized that the Earth and the Moon have orbits around the Sun that lie in the same plane[10]. After that realization, he applied simple math to the problem as

[9] Curiously, we don't know what value Aristarchus determined for the distance to the Moon; only his method is known to us. The actual average distance to the Moon is 240 thousand miles, about 10 times the circumference of the Earth.

[10] Strictly speaking, this is not correct. The Lunar orbit plane has an angle about 5^0 to the Ecliptic (the Earth orbit plane). However, for Aristarchus' methodology that error is not substantial.

follows: When we observe exactly a half of the moon disk (on the 7^{th} and 21^{st} days of a lunar month), it means that the "eye-moon-sun" angle must be a right angle.

If you observe the Moon in daylight (in the dawn or in the sunset), you can see at the same time the Sun in the sky. In this huge right triangle, you know the distance to the Moon, so if you can measure the angle "moon-eye-sun" you can find the distance to the Sun!

Aristarchus estimated this angle as 87°, so the ratio of the distance "Earth-Moon" to "Earth-Sun" was (in modern notations) equal to the sine 3°. Aristarchus did not know trigonometry, so he was forced to find an approximation of the value of interest. And he found a good one! His bounds for sine 3° were: 1/18 > sine 3° > 1/20, which he got by sequential consideration of polygons with increasing numbers of sides. By the way, it was the first attempt in mathematics to determine bounds of an unknown value when you have no means to compute a precise value. On the basis of his calculations, Aristarchus found that the Sun is 18-20 times farther from Earth than the Moon. The mistake in the calculation of the angle "Moon–Earth–Sun" was really serious[11], and it led to the wrong value of the distance between the Earth and the Sun: the actual distance to the Sun is as large as 400 distances to the Moon. However, notice that Aristarchus' measurement errors are not critical in this case – Aristarchus showed a principal technique for making measurements of cosmic distances. An accurate distance from the Earth to the Sun had no practical meaning at the time. The most important impact of Aristarchus discoveries was that he destroyed the dogmatic notions about the structure of the Universe.

To calculate the solar radius one can use the same "coin" technique that was used to get the radius of the Moon. But Aristarchus noticed that the moon almost precisely covers the sun during a solar eclipse. So, he used the Moon as his coin in this case. By this method, Aristarchus calculated the solar radius to be 6.75 greater than that of the Moon. The actual diameter of the Sun diameter is 109 times as large as that of the Earth. This error, of course, is the result of the error in his measurement of the distance to Sun. If he had been able to use the actual

[11] It is important to notice that the error in measuring small quantities can give large percentage errors, particularly when large and small quantities are involved. Aristarchus made a mistake of less than 2^0: actual angle is 89° 50'.

value, he would have produced a value of approximately 135 (20 times 6.75).

Did Aristarchus make errors in his measurements? Yes, he did. However, he had the correct ideas: he showed that the world of heavenly bodies could be studied and understood with the help of measurements and calculations. And this is his great scientific approach.

Besides, the fact that the sun is much larger than the Earth was the most important philosophical and scientific fact for those times, much more important than accurate knowledge of sizes and distances. Frankly, for most purposes, who cares about real size of the sun? Is it 100 or 1000 times larger than the Earth? Most of us know only that the Sun is "much-much" larger than the Earth.

So now you know that Aristarchus and his scientific school gave astronomy the first geometrical model of the solar system; and you also know how it was done.

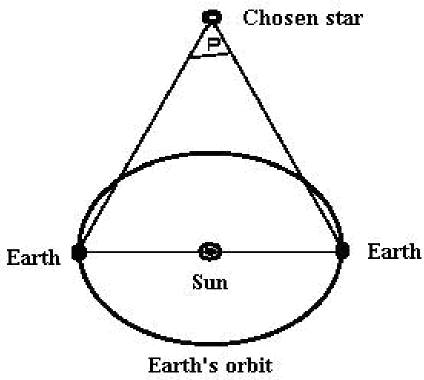
1.5. The distance to the stars

In his model of the universe, Aristarchus assumed that the stars could be at various distances from the Earth, which was an entirely new concept that departed from the contemporary belief that stars were just bright points pinned to a sphere in the sky. Aristarchus emphasized that due to the inaccuracy of his tools, in his experiments he tried to find distances only to the nearest stars.

For measuring distances to the stars, he had developed the method of annual parallax. Schematically, this method can be explained in the following way. We measure the angle between directions to the North Star and a chosen star. Exactly in half a year we repeat the measurement. The difference between the measured angles is called an annual parallax.

The idea of the method is in the fact that two points of observation and the chosen star form an isosceles triangle. The parallax is angle P (see the figure) that lies against the base of the triangle that equals to double distance between the Earth and the sun. So, anyone can calculate easily the distance between the Earth and the chosen star.

Unfortunately, Aristarchus did not possess tools that could measure angles with needed accuracy. Maximum accuracy was only ¼ of a degree. Such limitations could discourage anybody but not Aristarchus! He understood the roots of the problem and noted that the parallax is definitely non-zero but certainly less than 15 angle minutes, so he decided to estimate the lower bound of the distance to the nearest stars[12].



Indeed, if the parallax to the chosen star were 15′, the distance to it is about 100 million miles (one billion stadia), i.e. not fewer than 20 distances from the Earth to the Sun. All those discoveries made a picture clear: The Moon is smaller than the Earth and moves around the Earth; the Earth is substantially smaller than the Sun and moves around the Sun. And all those conclusions were based on measurements and mathematical calculations played against a theoretical model of the Universe.

These measurements took about three years to perform, and yet the process seems so simple! Alas, many of us are smart only *post factum (after the fact)*. Can you imagine how much knowledge, creativity and imagination was required to get all these brilliant results?

As you can see, Aristarchus for his great discoveries had only extremely simple tools and the theorem about isosceles triangles. That *could have been* done by almost anybody but it was Aristarchus *who did it.* And he did it because his main tool was his brain!

It's easy to see why Aristarchus is called the Copernicus of the ancient world. He was ahead of his time by nearly two millennia.

[12] Only by the 19th century did astronomers get tools capable of measuring angles with accuracy of less than a second. Then they could find distances to the nearest stars. Distances to the very far stars could be measured only in the last years with the help of the *Hubble* orbital space telescope of NASA.

1.6. Geographical coordinates

Flying in the balloon in the dark, Sherlock Holmes and Dr. Watson were lost. Watson saw a man on the ground and shouted to him: "Where are we?" –The man thought a while and shouted back: "You are in the basket of the balloon!" – "He is a mathematician…" – said Holmes. – "Why?!" – "His answer is as much correct as useless…" – commented Holmes.

Anecdote

It is interesting that scientists first studied the heavens before turning their attention to the very Earth beneath their feet. The spherical model of the sky led to the concept of coordinates of heavenly bodies in reference to the horizon and The North Star. And then a question arose: how does one determine coordinates on the Earth itself?

Eratosthenes, the founder of geography as a science, introduced the concepts of latitude and longitude of a point on the surface of the Earth. Later Hipparchus suggested some tools, tables and methods on how to use these concepts to establish a system of Earth coordinates; he put parallels and meridians on the globe and showed how to calculate geographic coordinates based on the location of stars in the sky.

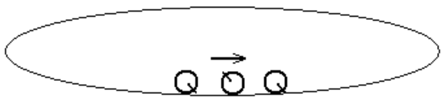
Hipparchus of Nicaea

(190 – 126)

One of the greatest ancient astronomers built the observatory on the island of Rhodes. Hipparchus is probably best known for having been the first to measure the precession of the Earth. It helped him make a precise catalogue of stars, which contained about 800 items. He measured the duration of a year with a preciseness of minutes.

He developed methods to determine coordinates on the Earth's surface and compiled the first geographical "handbook". Hipparchus also is known as the father of trigonometry.

Before going forward, though, to determine coordinates of object in the sky as well as points on the Earth, one needs a tool for measuring angles; this tool is called a *goniometer*. In ancient Greece, as we mentioned above, people could measure angles with an accuracy of ¼ of a degree.

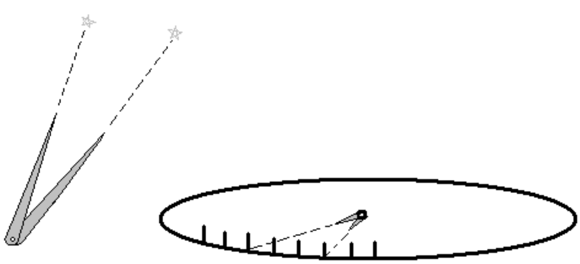


They did it in the following way. Let us take a wooden disk with diameter, say, 10" and place on it a spoke. Then we draw on the ground a circle with a diameter of 360". We carefully roll the wooden disk – just as a wheel – around the circumference of the circle we drew on the ground, making exactly 36 rotations, each rotation leaving a mark of the spoke on the circumference.

In result, one has a large circle on the ground with angles of 10 º made by two radii connected to two neighboring marks made by the wooden circle. Let us now improve the experiment: We use two perpendicular full diameter spokes through the wooden disk, so we can get four marks on the circle for each roll of the disk.

In addition, let us make the ratio of diameters of the disk and of the circle on the ground equal to 360. In this case, the angle between two neighbor marks on the circle is ¼º. Of course, to figure out what to do and then to do it with the desired accuracy needed a good mind and skilled hands, and fortunately the Greeks proved that they had both!

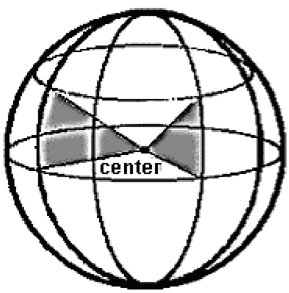
With such a marked circle, it is a simple task to measure any angle with the help of a pair of dividers: Direct one divider leg to the North star and the other one, say, to Sirius, secure both legs with some screw, put the apex of the divider at the center of the marked circle, count how many marks lay between the legs, and you now have the coordinates to Sirius.



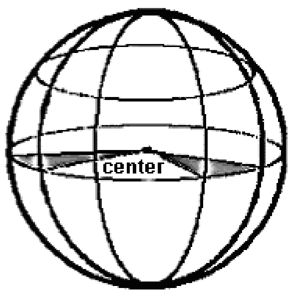
Several goniometrical tools were developed, but they all are variations of methods of construction of the divider legs, fasteners, and reference (marked) circles. The astrolabe, quadrant, sextant as well as any other relatives are examples of such goniometrical tools.

Eratosthenes proposed imaginary lines running from north to south and lines running from east to the west as a coordinate system on the Earth. He called the first lines meridians and the second lines parallels.

Hipparchus suggested to number parallels depending on the distance from the Equator. Let us imagine two rays from the center of the Earth: one to the Equator and another to the chosen parallel. The angle between them is called the latitude.



Latitude determination



Longitude determination

Unlike parallels, numbering (assigning a value to) meridians is a relative matter because there are no such fundamental natural milestones like the poles and the Equator. Eratosthenes defined the starting meridian to pass through the city of Syene. (From 1884 the "zero/prime-meridian" was defined as passing through Greenwich, England – a small town where the famous Royal Observatory was then located. When Greenwich was absorbed by Greater London, the observatory was moved from there, but the prime meridian remained unmoved.) Longitude is an angle between two radii at the Equator: one radius drawn to the prime meridian, and the other to the location being measured.

Hipparchus made measurements of latitude by two methods; one used the stars and the other the sun. The first method is based on the fact that the Earth's axis of rotation, when extended in an imaginary line above the northern hemisphere, points directly to Polaris, the North Star.

Therefore Polaris sits above the North Pole[13]. An observer, standing on the Equator, sees the North Star right at the horizon. Moving from the Equator to the North, an observer sees the North Star at higher and higher elevations. The angle between the horizon and the North Star is the measure of latitude.

The second method deals with observations of the sun at some specific moments of time. It is well known that on the day of vernal equinox, at noon the sun is at its zenith, i.e. at latitude 0° (at the Equator) the angle to the sun is 90° from the horizon. When you move northward, the position of the sun in the sky becomes lower and lower, and at last at the North Pole the sun is at the horizon. So, to know the latitude of any place of interest, one simply has to measure the angle between the sun and the local vertical (plumb line) on the day of vernal equinox. Similar analysis can be applied at the summer solstice.

As soon as the latitude is known by one of those methods, the position of the sun at noon for all days of the year at that latitude can be entered into a table– this is a method for compiling navigation tables.

Before Hipparchus – since the time of Eratosthenes –only one method of longitude determination was known. This method was based on measuring the distance between two points in the direction "West – East". Knowing the position of the parallel (i.e. actually the length of the parallel), it was an easy arithmetic task to calculate the difference of longitudes of those two points. This method was used in Eratosthenes' time as well, though distances – often based on travelers' impressions rather than on measurements – were known only approximately.

Hipparchus suggested a new method: compare local time at two chosen points. Indeed, if it is known that the Earth makes its full rotation cycle of 360^0 in 24 hours, then knowing the difference of time at the chosen point with the time at the prime meridian; it is easy to calculate the longitude of that point. His arguments were close to the following: local time is well measured in all cities in the civilized Mediterranean, so the problem is to mark the same moment in time at all locations and to note

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13 Strictly speaking, today the Earth's axis "misses" the North Star (by about 42') and due to the precession – the changing the angle of the axis inclination – this difference will decrease by 17" per a year until 2100, and then the angle will grow again. To be even more precise, the North Star is not a star at all – it is a mini constellation of three stars, which are very close to each other. This is the reason why the brightness of the North Star varies with four days interval.

the difference in readings. Such synchronization could be done easily at the moment of an eclipse of the Moon, an event that can be seen simultaneously by all participants (locations) of the experiment. Hipparchus was able to forecast eclipses of the Moon, had good communication with colleagues, and the authority to see through the execution of such an experiment. Using these measurements, he compiled maps of unprecedented accuracy.

Having completed the construction of the Earth's coordinate system, Hipparchus extended the method to the sky: he considered the sky sphere to be an imaginary continuation of the Earth sphere. Then taking the center of the Earth as a center of that larger sphere, one can construct imaginary parallels and meridians in the sky hemisphere. This method proved to be more convenient than the older method of determining a star's position above the horizon and its angle to the North Star.

1.7. The beginning of the Modern Model of the Universe

Ptolemy was the last scientist of the ancient (first) period of the formal development of astronomy.

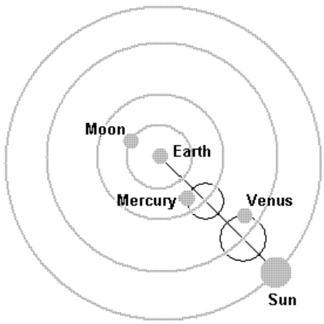
Claudius Ptolemy
(87–165)

Famous ancient Greek mathematician, astronomer, geographer and physicist – one of the greatest figures in the history of science. He lived in Alexandria. Whether he was related to the Egyptian Ptolemaic kings, who ruled 200 years before, is unknown. His 13-volume work "*Almagest*" ("*The Great Book*") was the only textbook and handbook on astronomy for about 15 centuries, and his "*Geography*" was not corrected until first around the World voyages.

For more details see Chapter "Pantheon".

The heliocentric model of the Universe put forth by Aristarchus was not well received by the "scholars" of the time, but it was Ptolemy who firmly "established" the geocentric model of the Universe giving the final deathblow to the genius of Aristarchus and his heliocentric model. Ptolemy's model would reign for 15 centuries until debunked by Copernicus.

According to Ptolemy, each planet moved uniformly in a circular orbit called an *epicycle*, and the center of epicycle, in turn, moved around the Earth in a circular orbit called *deferent*.



With carefully chosen deferent and epicycles, Ptolemy's model could predict planet positions with acceptable accuracy.

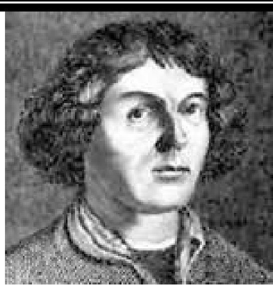
Ptolemy not only was a brilliant scientist, but he also was an historian, a role in which he contributed greatly to the history of science. His effort in this area was critical because few works of great scientists and writers of ancient Greece survived the struggle of Christianity with the "heresy of ancient gods". Almost everything we know about Pythagoras, Plato, Aristotle, Aristarchus, Archimedes, Eratosthenes, and Hipparchus and many others has come to us indirectly from other works. Sadly, the originals of the works have been irretrievably lost, but, as fate would have it, Ptolemy's works survived this egregious period because they had been translated, mostly into Arabic, and were preserved outside the grasp of the purges. These works were retranslated into Greek and authenticated against the few known Greek fragments of his works to survive the purges. Ptolemy not only wrote about his own scientific results, but he also gave a systematic generalization of previous results and supplied his text with biographies of the ancient scientists. By the way, literally everything we know about Hipparchus came to us from Ptolemy.

Being the most authoritative scientist of his time, Ptolemy played a most negative role in astronomy when he "closed" the heliocentric model of the Universe. He derided that theory: "If the Earth were revolving, as Aristarchus suggested, then birds and clouds – everything that is not attached firmly to the Earth – would be moving to the West".

Ptolemy was wrong but his authority was so great that everybody kept silent for centuries.

During the Renaissance, the level of inquisitiveness of the populace grew and some risk takers began to question some of the medieval dogmas, such as the medieval Christian teaching that the Earth is a huge disk surrounded by the World Ocean behind which there is a terra inhabited by one-legged people and human-wolves… and so on.

At that time, a young Polish priest – Nicolas Copernicus, having studied astronomy and mathematics in the best universities of Italy, thought that Ptolemy's geocentric model of the Universe was severely in error.



Nicolas Copernicus
(1473 – 1543)

Polish astronomer, mathematician, philosopher, physician, lawyer, theologian and public man. In his main work "*On the Revolution of Celestial Spheres*", he rejected Ptolemy's geocentric model of Universe and revive the heliocentric model. The religious and political Inquisition severely punished Copernicus' followers, burning some of them at the stake.

For more details see Chapter "Pantheon".

He found that the number of modifications and modernizations of Ptolemy's model which had been made to improve computational accuracy actually did not make calculations more accurate and that the methodology became more and more clumsy. Copernicus wrote to Pope in Rome: "On long reflection about the uncertainty of celestial spheres moving, I was confused that, despite the fact that we have made scrupulous and detailed measurements of the Universe, philosophers cannot choose a single theory of the Universe, which has been created for us by God who represents the highest order." And then Copernicus repeated the scientific deed by Aristarchus: he put the Sun in the center of the Universe and developed a full mathematical theory of the motion of the planets.

Around 1514 he distributed a little hand-written brochure among his friends who knew about his authorship even though no name was on the title page. This book, usually called "*The Little Commentary*", set out Copernicus's theory of the Universe with the Sun at the center. "*The Little Commentary*" was a fascinating document, containing seven axioms, on which Copernicus based his theory. Those axioms were:

1. There is no one center in the Universe.
2. The Earth's center is not the center of the Universe.
3. The center of the Universe is near the Sun.
4. The distance from the Earth to the Sun is imperceptible compared with the distance to the stars.
5. The rotation of the Earth accounts for the apparent daily rotation of the stars.
6. The Earth revolving round it causes the apparent annual cycle of movements of the Sun.
7. The motion of the Earth, from which one observes the planets, causes the apparent retrograde motion of the planets.

Subsequently Copernicus presented his ideas in his famous book "*On the Revolution of Celestial Spheres*". That book was met with a strange reaction from the scientific community. From one side, his mathematical approach had been accepted, and on its basis the so-called "*Prussian Tables*" were developed and widely used by astronomers and travelers. From another side, Copernicus' ideas that the Earth was revolving around its axis and that the Earth itself was rotating around the Sun were looked as crackpot ideas of Slavic priest. However, it is clear that without those revolutionary ideas, Copernicus' mathematical methods had no sense at all!

The greatest astronomical authority of the time, Tycho Brahe, stated that the Copernican statement about the Earth's rotation around its axis was nonsense.

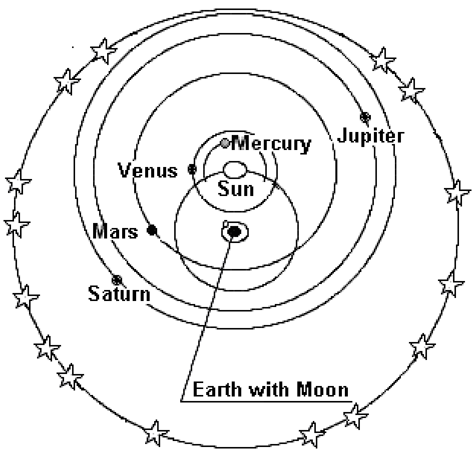
His argument was the following: if the Earth does rotate from the west to the east, then if one fires from the same place two cannons, one to the west and another to the east, then the cannon-ball fired to the west should fly farther. Because he did not observe such a phenomenon, he concluded that the Earth is immovable, and consequently, Copernicus was wrong.

Tycho Brahe
(1546 – 1601)

Dutch astronomer. Getting from the king a small island near Copenhagen, he built there a unique observatory where a number of outstanding worked with him. Using astronomical tools of his own construction, he achieved remarkable accuracy of measurements. Although he rejected the heliocentric model of the Universe, nevertheless, he found many discrepancies in Ptolemy's model of the Universe.

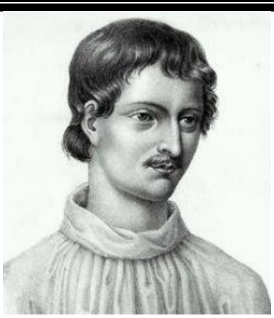
More details see in Chapter "Pantheon".

Brahe was the first astronomer to find a comet and to observe that its path crossed the orbit of Venus; even though Brahe rejected Copernicus's theory, he was forced by this observation to conclude that Ptolemy's vision of the Universe, based on the Procrustean bed of Aristotle's model of "crystal spheres" was not correct. Brahe wrote: "In my opinion, spheres should be excluded from the sky… the motion of comets clearly proves that the sky is not a solid body, consisting of different real spheres, as it was thought, but the sky is rather free and fluid, open from all directions".



Tycho Brahe introduced the concept of an orbit and suggested that that orbit is oval rather than circular. Thus, according to Brahe, the Universe was as follows:

At the same time, another famous scientist, Giordano Bruno, while unconditionally accepting Copernicus' ideas, came to the very same conclusion, that there were no spheres in the sky and the sky was infinite and non-solid.



Giordano Bruno
(1548-1600)

Great Italian philosopher of the Renaissance. Being a priest, he was forced to run to Switzerland from the Catholic Church. However, he was arrested by the Inquisition and spent 8 years in prison. For his support of Copernicus' ideas, he was condemned to death. His last words to the judges were: "You are scared condemning me to the death more than I accepting your death sentence!"

For more details see Chapter "Pantheon".

Bruno went even further than Copernicus: he did not limit the Universe to the Solar system; he wrote that the Sun is not the center of the Universe but an ordinary star and that there were other planetary systems around other stars, giving rise to the possibility of life not only on the Earth.

Johannes Kepler
(1571-1630)

Great German astronomer, optician, and mathematician. He was forced to flee his country because of his free thinking. He became an assistant to Tycho Brahe. By analyzing data collected by Brahe, he formulated "Kepler's laws" of planetary motion. He compiled an astronomical handbook which replaced Ptolemy's "Almagest," which was used for a millennium.

For more details see Chapter "Pantheon".

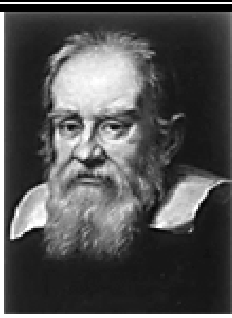
Johannes Kepler, already a professor of mathematics at 30 years of age, had access to the record of long term detailed observations of the planet Mars made by his mentor, Tycho Brahe. By analyzing those data, he concluded that Copernicus was right in his heliocentric theory, but instead of putting the Sun at the center of a circle, he put it at one of the foci in the elliptic orbit postulated by Brahe. The mathematics of the time was insufficient, though, to permit Kepler to make the calculations to support his proposed physical concepts, so, in 1619 he wrote his most famous and defining work, "*Harmonices mundi libri*" ("*Harmony of the World*"), which made him an immortal part of the "golden foundation" of science. In this work he presents laws governing the motion of the planets:

- The First Law: The orbit of any planet is an ellipse and the Sun is at one of the foci of that ellipse.
- The Second Law: A planet moves in such a way that its radius vector during equal time intervals "covers" equal areas. (The Law of Squares).
- The Third Law: The ratio of the square of the period of a planet's rotation around the Sun to the cube of the average distance of the planet to the Sun is the same constant for all planets. (The Law of Harmony).

Kepler's laws were based on the study of the huge volume of solid, detailed astronomical observations that had been compiled over many years. Of course, it is no surprise to anyone to learn that the Vatican forbade Kepler's book. On the basis of Brahe's observations and his own Laws, Kepler compiled a handbook of planetary motion – his famous "*Rudolf's Tables*", which were used for practical needs over the next two centuries.

A real revolution in astronomy began with the invention of the telescope by Galileo. Actually, a tube with lenses was known to Dutch sailors years before Galileo, however, he was the first to use it for astronomical observations and later significantly improved it. Galileo's telescope, directed to the sky, allowed him to make many, fantastic for that time, discoveries. His astronomical experiments were obvious and understandable by everybody. Galileo showed that there were the same physical laws everywhere – on the Earth and in the sky.

The Vatican, being afraid of the destructive (to their power) influence of the new scientific developments on Christian believers, immediately banned scientific works by Copernicus, Bruno, Brahe, Kepler and Galileo. However, take note that even the Inquisition was not able to stop the flow of scientific discoveries.



Galileo Galilei

(1564-1642)

Great Italian astronomer, physicist, mathematician and engineer, one of the founders of modern natural science. He designed and constructed a telescope, which opened new horizons in the oldest science – astronomy. He was called to the Inquisition court and was forced to reject his work and to make religious penance in his "delusions". It was said that upon exiting the court he pronounced a famous phrase, which is now a proverb in all-European languages: "*Eppur si muove!*" ("*And yet it does move!*").

For more details see Chapter "Pantheon".

It was the genius physicist and mathematician, Isaac Newton, who developed the very first mathematical model of the Universe. Prior work developed theory, but there was no fundamental mathematical unifying framework to permit further discovery.

Isaac Newton integrated the many separate astronomical observations into an elegant model based upon the laws of gravity, concepts that he originated. Newton's Law declared that there is a force (called gravity) of attraction between two bodies and that this force is proportional to the product of their masses and inversely proportional to the square of the distance between them. By this law, everybody has its own gravitational field that exists everywhere, weakening as the distance from the body increases.

Isaac Newton

(1643-1727)

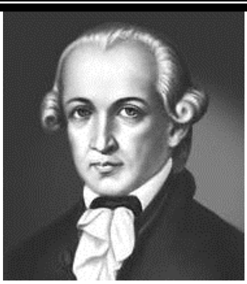
Great English physicist, mechanist, astronomer and mathematician, one of the greatest scientists of all times and all peoples, who put the foundation of modern natural sciences, classical physics and mathematics.

It is said that he brought into science as much as Euclid and Archimedes together.

For more details see Chapter "Pantheon".

So, is the Sun moving around the Earth or is the Earth moving around the Sun? Where is the center of the Universe? Nowhere – answered Newton. There is no center. Any planet, any comet, any asteroid or star – all of them are moving under the influence of the gravitational fields they all generate. Furthermore, the planets moving under the influence of gravitational fields move in orbits described by Brahe and in accordance to Kepler's Laws.

Of course, a curious person might ask: how could such a complex system come about? Perhaps the Universe was created in six days in the mysterious way told to us in the Bible. In the middle of 18th century German philosopher Immanuel Kant was absorbed by the idea of finding an alternative to the Biblical version of the creation of Life and the Universe by God. Kant was the first who suggested a theory that the Solar system came from a nebula. His theoretical musing preceded the future work of future astronomers in this area.



Immanuel Kant
(1724 - 1804)

German philosopher. He lived a majority of his life in poverty; however, he gained recognition as a genius and became a rich man before his death.

He was a famous critic of religion ("In the sphere of intelligence, there cannot be any proofs of God's existence"). As a result, almost all his hypotheses and ideas were rejected as wrong. Nevertheless, he is recognized as a father of classical philosophy and dialectics, and his "mistakes" generated an impetuous flow of new directions in philosophy and logic.

Kant accepted Newton's idea concerning the infinity of cosmic space and suggested that the Universe has no beginning and no end in time and space. From these hypotheses he concluded that chains of random events of arbitrary length might occur, so the appearance of any celestial system and any form of life is possible.

Independently from Kant[14], French mathematician Pierre Laplace developed a conceptual picture of the Solar system in which the Solar system is born from a nebula. His arguments were strong and scientific in comparison with Kant's ones.

Pierre Simon Laplace
(1749-1827)

Great French mathematician, physicist and astronomer. He is founder of the probability theory, mathematical physics and celestial mechanics. He made a fundamental input into differential equations, algebra, acoustics, thermodynamics, and geodesy. During the Great French Revolution he was Chair of Government Commission, during Napoleon he was the Chancellor, after Bourbons restoration – peer of France.

For more details see Chapter "Pantheon".

According to Laplace, a giant nebula rotated around its kernel – an "embryo" of the Sun. The kernel attracted particles of the nebula and a spindle-shaped cloud began to compress. The particles at the equator of the spindle had the maximum speed, and their centrifugal force balanced the inward pull of gravity to the kernel. That balance of forces led to the formation of gas rings – the precursors for future planets as particles continued to aggregate.

The Kant-Laplace hypothesis explained the fact that orbits of all planets lay almost in the same plane, the ecliptic plane.

Stepping forward to 1930, we find that the recently discovered Pluto is a small planet at the outer extent of the Solar system. How can we reconcile Pluto's orbit that is inclined about 17^0 to the ecliptic plane with the Kant-Laplace theory of the origin of the Solar system.

[14] Kant and Laplace were contemporaries but never met. Laplace was only 6 years old when Kant published his hypothesis though the publisher was bankrupted and the book was never distributed. The book was republished in 1791, and in 1796 Laplace published his theory. Maybe due to the language barrier, maybe because of stormy revolutionary events in France, however, Kant's book apparently never reached Laplace (at least, he never mentioned Kant's hypothesis).

Astronomers who accept the Kant-Laplace theory believe that Pluto does not belong to the family of planets of the Solar system that formed from the initial nebula. They speculate that it was a "free traveling body", which was captured by the Sun's gravity.

In 2005 NASA[15] announced the discovery in the Solar system of a new object, which was given the clumsy name – 2003UB313 (2003 stands for the year of discovery, when astronomers of the Palomar Observatory in California factually "caught" that object). Is it the 10th planet of the Solar system? It depends on the specific definition of "planet." Are all celestial objects moving around the Sun are planets? The question arose because the new object's orbit inclination is 44^0, so it is almost definitely "a stranger" having been caught by the Sun's gravity. This new object (2003UB313) has a diameter of approximately 1600 miles (slightly less than that of the Moon), a maximum distance from the Sun of approximately 10 million miles, and a minimum of approximately 2 million miles. This object's "year" equals to 560 our Earth years (remember the ratio formula of period to distance discovered by Kepler).

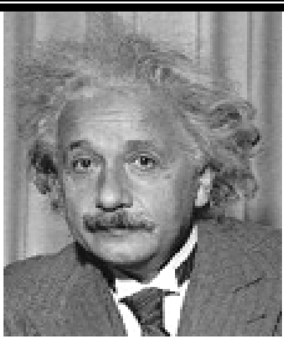
NASA hurried to make this announcement before getting more detailed and more reliable information, as it would customarily do, because computer hackers had broken into the Palomar Observatory computer system, and NASA feared that the hackers would publish the sensational news themselves and hence take credit for the discovery. Even with this rush to publish, NASA already had made the discovery more than 2 years prior to the announcement.

Developments in physics proceeded rapidly along classical lines after the Renaissance, but by the late 19th century limits to Newtonian (classical) physics were noted as the Gravity Law broke down and could not explain, for example, the interactions of atoms and other particles. Thus a new branch of physics, electrodynamics, the next major step after Newton's discoveries, was born. In 1905 the young German physicist and mathematician Albert Einstein presented a new theory governing the interaction of celestial and Earthy bodies, atoms and electrons, electrical and magnetic fields and so on, and so on…

As laid out in Newton's theory, we live in a 3-dimensional Euclidean space in which light moves in a straight line and each body instantaneously exerts a force – by its gravity – on all other bodies of the

[15] NASA – National Aeronautics and Space Agency (USA).

Universe. Newton, himself, understood that assuming an infinite speed of propagation for gravity was a weakness place in his theory; however without this assumption his gravitational theory had no sense.



Albert Einstein
(1879 – 1955)

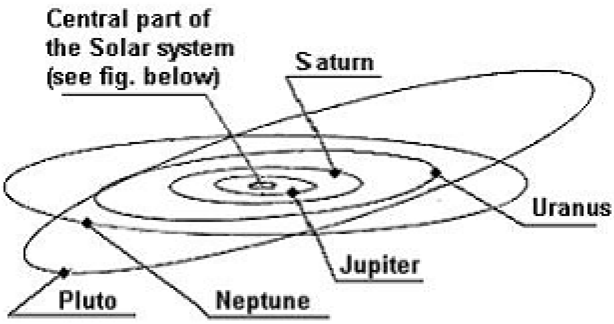
Physicist and mathematician, creator of the theory of relativity, one of founders of quantum mechanics and statistical physics. He spent several years working as a teacher and clerk at the Patent Bureau. He used his free time to work on science, and he developed the mathematical methods of his theory of relativity, published papers on statistical physics, theory of radiation, etc. He was awarded the Nobel Prize for his work in physics.

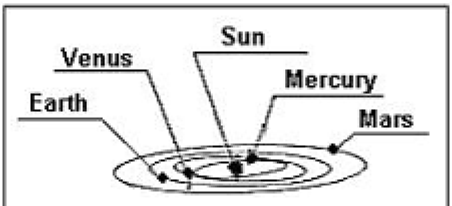
For more details see Chapter "Pantheon".

In Einstein's theory, we live in 4-dimensional world in which the fourth dimension is time. Gravity of a particular body has no instantaneous global influence on other bodies; it "works" in some zone that grows in extent at the speed of light. And gravity does not "attract" anything: it only distorts the space within its neighborhood. The intensity of that distortion depends on the body mass and the distance. Thus, the ray of light that moves by the shortest path but in a gravitationally distorted space does not travel this in a straight line in a Euclidean sense.

It might seem that Newton's beautifully conceived theory was destroyed and by an enigmatic, hardly understandable and unimaginable theory, which, nevertheless, however, has been confirmed by real experiments and mathematical proofs. However, Einstein did not reject Newton's approach, nor did he blame him for its shortcomings, as Copernicus and Galileo blamed Aristotle. Simply, Newton's laws are particular cases of Einstein's theory when speeds are much less than the light speed.

With relativistic physics applied to the Solar system we can calculate the position of the Sun, all nine (or is it 10?) planets, all the 65 moons in the Solar system, hundreds of comets and asteroids for any moment of time with the accuracy needed for any astronautic voyage and successful landing at any point.





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2. CALENDARS

2.1. Why do we say "calendar?"

When we talk about time in term of days, we are forced into the concept of calendars. From where did the word "calendar" come? In ancient Rome a New Year was declared to start on the day of the first new Moon in March. The first days of each new year were called *calendae*[16]. These were special days when all citizens had to pay their debts and interests. Because of that, the debt book was called a *calendarium*. Now you see that from calendarium it is but a step to our common notion of a calendar!

[16] It is said that the Supreme Roman Priest loudly announced the beginning of each month. In Latin the verb "announce" or "proclaim" is *calare*, so the day when that announcement occurred was called *calendae*.

Of course, a calendar existed long before those ancient Rome traditions. And in modern times, a calendar is just a method to count large time intervals based on astronomic cycles: the Earth rotation around its axes, the Moon moving around the Earth, and the Earth moving around the Sun.

2.2. The year and the Sun, the month and the Moon, the day and the Earth…

Nothing is new under the Moon …
King Solomon [17].

The simplest calendar item to define and measure is the solar year, the time it takes the Earth to move around the Sun one complete cycle. More exactly, it is period of time between adjacent summer solstices[18]. People as far back as has been recorded recognized the existence of the yearly cycle. They also noted that the phases of the Moon changed in a regular period of time. They began to use period of time between two sequential new Moons (or full Moons) as a unit of time, giving to it a special name, which is in one or another form connected with the word "moon." For instance, in English "*months*" is phonetically close to "*moons*", and in Slavic languages the month is called "*mesiats*" which means *new moon*.

Another easily measured unit of time is the day – one rotation of the Earth around its axis. However, 365 days is not equal exactly to the time it takes the Earth to move around the Sun in one complete orbit by. The Exact length of a year is 365.242199... days[19]. And a Moon cycle also

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[17] **Solomon, King of Israel (965-928 BC.)**, son of King David. Made a number of administrative reforms in his state, centralized religion and completed the construction of the First Jewish Temple in Jerusalem. According to the Bible, he was very wise man (though in the Bible there was given only one allegoric example of his wisdom). By legend, Solomon was the author of some of the most poetic texts in the Bible.

[18] More exactly, this year is called "tropical" because on tropic of Capricorn (on magnitude 23.5 °) the Sun exactly at noon on the day of summer solstice (21-22 of June) crosses the zenith. A year is measured by the neighbor measurement of these moments of time. Of course, the same measurement can be done in the Southern Hemisphere in the point located on tropic of Cancer but on day of winter solstice (21-22 of December).

[19] Factually, the situation is even more complicated. Period of the Earth moving around its axes is not constant due to different factors (secular tidal friction, seasonal atmospheric circulations, and additional unexplained jump-like fluctuations).

is not an integer number of days: months are equal to 29.53059... days[20]. And though there are approximately 12 moons in a solar year, the solar year is longer than the "moon year" by 11 days.

However, ancient people though not as knowledgeable as we are today, were doubtlessly no less smart than we are! They used many tricks to make their calendars work. For example, they invented a solar year that does not depend on the cycle of the Moon and a moon year that ignores the visual moving of the Sun, and moreover, they designed the so-called solar-moon year that reconciles both of them!

The number of days in a year (365) cannot be divided without leaving a remainder (independently on 12 or 13 months we take). Ancient people introduced additional days at the end of a year, or added days to some months, or even introduced a special shorter month.

In the 5th century BC an astronomer, Meton,[21] made a brilliant discovery: every 235-moon months (or 6940 days) the new moon year coincides with a vernal equinox. That 19-year period (especially frequently used for calculations of religious holidays) was called a Metonian.

To correct for the non-integer number of days in a solar year, in the 2nd century A.C., Claudius Ptolemy suggested the addition every four years of one day, celebrated as a holiday to honor the gods. It was a clever solution: people were glad to have an extra holiday!

2.3. Days of week

Babylonian priests knew seven heavenly bodies – seven habitants of the sky: The Sun, the Moon, Mars, Mercury, Jupiter, Venus and Saturn. Each of them was said to be the ruler of its corresponding day, and the collection of days made up a week, an entity that repeats itself forever. The order and names of the days of the week was established by edict by

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20 Moon, or synodal month is a period between two days of new moon. Its duration is varying due to a non-circular orbit of the Moon. Therefore it is said about average duration of synodal month.

21 **Meton of Athens** (460 BC – unknown), ancient Greek astronomer and mathematician, who corrected the ancient Greek calendar. He built on the central square of Athens a gnomon – the first prototype of a sundial.

Emperor Constantine,[22] and these names have been carried into our current calendar. For instance, in English, Saturday is literally "Day of Saturn" and Sunday is "Day if the Sun". And it is the same in many other European languages – French, German and others. Imagine the names of the days of the week have a four millenniums history!

Italian "Sabato" and Spanish "Sabado" also came from Babylonian; in Babylonian "Sabbath" means literally to rest or relax. The reason name came about is because that day of the week ruled by Saturn was considered to be the unhappiest day of the week. People believed that anything done on Saturday would come to no good. Therefore people tried not to work on this day, instead choosing to go to the temples. Priests particularly were fond of this holiday because, as one can imagine, their cut of the increased sacrifices to the gods was significant. The word "Sabbath" then came to the ancient Jews and this day became the day of rest named sacred by the Bible.

Looking further into the names of the week, we can see that in many languages the days of the week are named after a heavenly body or by the number of the day in the week.

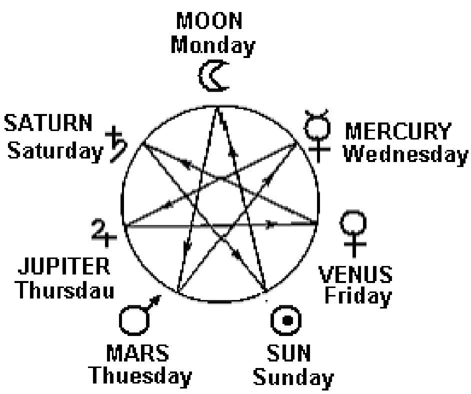
Latin name	**English**	**French**	**Italian**	**Spanish**		**Symbol**
Dies Lunae – day of the Moon	Monday	Lundi	Lunedi	Lunes		☾
Dies Martis – day of Mars	Tuesday	Mardi	Martedi	Martes		♂
Dies Mercuri – day of Mercury	Wednesday	Mercredi	Mercoledi	Miercoles		☿
Dies Jovis – day of Jupiter	Thursday	Jeudi	Giovedi	Jueves		♃

[22] **Constantine I, or Great** (285-337), Roman Emperor. He had built so-called "Second Rome", moving the capital of the Empire to the Byzantine city of Constantinople (now Istanbul). Factually, this step predetermined the fall of the Roman Empire. He made Christianity the main religion of the Empire. He gathered in the city of Nycea (now Izvic in Turkey) Ecumenical Council of 318 bishops, who then chose four canonic Gospels from the more than 30 that circulated at that time.

Dies Veneris – day of Venus	Friday	Vendredi	Venerdi	Viernes		♀
Dies Saturni – day of Saturn	Saturday	Samedi	Sabato	Sabado		♄
Dies Soils – day of the Sun	Sunday	Dimanche	Domenica	Domingo		☉

The view that the planets as well as other objects in the sky were somehow related to the gods fed the notion of supernatural forces; coupled with the periodicity and numbering used to describe these objects, this notion of the supernatural those generated a host of superstitions: "black magic", astrology, fortune telling, etc.

This is an astrological explanation of the weekdays' relations.



We cannot take bravery to interpret this graph! First of all, we are afraid of tribunal of the Saint Inquisition…

However, you could come to any neighbor chiromancer.

Nevertheless, the seven-pointed star is beautiful!

There are other hypotheses to explain how the 7-day week came to be. The most popular one concerns the fact that there are four Moon phases during the 28-day Moon month: in 7 days after new moon it becomes a half moon (half is lit, half is dark), then in 7 days we see the full moon, which is followed in 7 days by another half moon, and then back in 7 days to the new moon. Certainly, it is a good explanation for the origin of the week, but there is no consensus among historians of the correct origins of the week. Perhaps there were so many plausible origins of the week that the concept of a week always had support and therefore has endured to today.

Notice, though, that not all calendars consisted of 7-day weeks. Ancient Mayas used a 13- and 20-day week. In Lithuania before Christianity there was 9-day week. The calendar of the Great French Revolution divided a month into 3 decades. In the former Soviet Union in 1929-31, there were experiments with 5 and later 6-day weeks.

2.4. Sumerian calendar

The oldest recorded calendars come to us from the Ancient Sumerians[23]. Sumerian city-states apparently each had their own calendar. Some of these still are a puzzle to us. The best-known and best-deciphered one is the 3rd millennium BC calendar of the city of Nippur. This calendar is known as Nippur's cult calendar.

Ancient Sumerian astronomy was based purely on direct observations. Sumerians believed in the divinity of the sky and the main heavenly bodies and recorded the behavior of the gods of Sun ("Utu"), of Moon ("Nanna"), Venus (Inanna) and others. They knew that the Morning Star and the Evening Star is the same planet – Venus. All we know about Ancient Babylonian astronomical observations has came to us from clay tablets written in *cuneiform*, which typically were made well after the actual observations, during the reign of King Hammurabi[24].

The Babylonians and Assyrians adopted the calendar of the Sumerian sacred city of Nippur in the 18th century BC. The new calendar had 12 months: *Nisanu, Ayaru, Simanu, Du'uzu, Abu, Ululu, Tashritu, Arakhsamna, Kislimu, Tebetu, Shabatu,* and *Adaru*. Each month began with a new moon and contained 29 or 30 days alternatively. A year consisted of 4 seasons of 3 months each, thus the year had 12 months totaling 354 days. The lunar year began in the spring, on Nisanu 1.

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[23] Ancient Sumerian civilization included city-states built by the people came from the North to Sumeria in 5th-4th centuries BC. Ancient Sumeria was located in the southern part of Modern Iraq, between the rivers Tigris and Euphrates.

[24] **Hammurabi** (1792-1750 BC), king of Ancient Sumeria. He created a powerful empire. He ordered the carving on a basalt pillar a Code of Laws ("*Code of Hammurabi*"), which became a source/inspiration for legal systems to follow.

Of course, the main problem of the lunisolar calendar is in the fact that the solar year (365 days) is longer than 12 lunar months (354 days). This problem was addressed by the use of an intercalated month. For those purposes, in the 21st century BC, a special intercalated month *Iti Dirig* was introduced. The intercalation was operated haphazardly, according to real or imagined needs, and each Sumerian city inserted months at will. Later, under the Persian kings (380 BC), the Babylonian calendar became almost perfectly related to a lunisolar cycle: after 19 solar years, or 235 lunar months with intercalations in the years 3, 6, 8, 11, 14, 17, and 19, the first day of the new year on both solar and lunar calendars coincided. Within that cycle the New Year's Day (Nisanu 1) moved from year to year around the spring equinox within a period of 27 days.

To make a New Year day a strong astronomical sense once each 3-4 years, they introduced a special 13th month until in 19 years solar and lunar calendars coincides again in the beginning of the year. It shows that the Ancient Babylonians discovered the Metonian cycle long before Meton had discovered it!

The Babylonian day was divided into 12 equal "hours", making their hours equal to two of ours. The Babylonian hour was divided into 30 parts, each part equal to four of our minutes.

Later Babylonians developed from Nippur's calendar a system of Zodiac signs. They observed that each new month some specific constellation appeared over the horizon, and, therefore, they associated each constellation with a corresponding form of activity: sowing, weeding, reaping, etc. Thus, they were the first to create 12 Zodiacal signs with defined spheres of influence.

2.5. Egyptian calendar

Ancient Egyptian priests had introduced a lunar calendar sometime in the 3rd millennium BC for the purpose of planning religious rituals. However, the practical needs of an agrarian society needed the more season-stable solar calendar that was introduced sometime between the 18th and 16th centuries BC.

Multi-year observations allowed Egyptian priests to associate the periodicity of the yearly Nile floods with the appearance of the bright "*Nile Star*" (*Sotis*) in the early dawn – it was Sirius rising (becoming visible) after a 70-day period of being invisible. Egyptians had three seasons that were defined by the conditions of the Nile: flood, sowing and harvesting. The first season was called *akhet* ("*flood*" in ancient Egyptian), which, of course, coincided with the Nile flood. This season lasted from July to October. The next season was called *peret* ("*ground drying*") and also lasted four months. Floodwaters receded in this period and the season began with sowing and finished with harvesting. In March dry and hot winds from the Saharan desert blew until the middle of April, and that season was called "temu" ("absence of water").

Thus, each season lasted four months, each month consisting of 30 days. Each month was broken down into three decades, each of which was broken into two pentads (5-day period of time). Because their year added up only to 360 days, every year produced an error of 5 days.

Enumeration of years began anew with the start of the reign of each pharaoh[25]; months were numbered within a season; days were numbered within a decade. A typical date sounded something like: the fifth day of the second decade of the fourth month of the season of akhet (Nile's flood) of the 26th year of the reign of Ramses the Third. Doubtlessly, the Egyptian calendar was not as good as the ancient Sumerian one. It was inevitable that later on five days were added to the year; those days were not included in any month but were placed at the end of each year and, of course, celebrated as birthdays of the gods. Ancient Egyptians did not introduce a leap year, but in their papyruses one can find mention that every four years the rising of Sirius moved one day.

Thus, in ancient Egypt, a calendar was determined by the natural yearly periodic epochs of the Nile, and it is no surprise that the ancient Greek historian Herodotus[26] wrote: "Egypt is a gift of Nile".

In the 3rd century BC, Egyptian Pharaoh tried to accept Greek calendar, which was more progressive, but old tradition prevailed and people continue to use old calendar. Is it better? When Egypt became part of the Roman Empire, the old Egyptian calendar gave way to the

[25] Actually, for the "zero-point" the Egyptians used the rising of Sirius in the year just before a new Pharaoh went to the Throne, so they could keep "continuity of time".

[26] **Herodotus** (480 - 425 BC), ancient Greek historian, is considered to be the father of this discipline. He was a great traveler; he visited Asia Minor, Babylon, Phoenicia, Egypt, Cyrena, the Balkan Peninsula, and the Black Sea. He wrote a description of Greek-Persian wars, the history of Egypt, and others.

Roman calendar for all but religious purposes. The priests continued to use the archaic ancient Egyptian calendar for several more centuries.

2.6. Greek calendar

Ancient Greeks completely accepted the Sumerian idea of a calendar, specifically that there were 12 months with alternating 29 and 30 days. In the beginning of the 5th century BC Athens changed to the usage of a solar-lunar calendar that they modified as follows: first, they inserted an additional month every 3 years. However, this was not enough of a correction, so they began to change the number of days in a month, first by changing 3 months from 29 to 30 days each 8 year period; then additional months were added to 3rd, 5th and 8th year. This still was not enough, so every 16 years they added 3 extra days.

Although the principle of a calendar was the same throughout all of Greece, the year began differently in different places, in Athens on the day of summer solstice, in Delos on the day of winter solstice**,** in Beotia – in October, and so on. Also, months in different places had different names.

All calendar reforms were made sporadically and chaotically. We can see reflection of this in ancient Greek literature. People continued use the "natural calendar." For example, "Harvest begins when the Pleiades are rising", "When Arcturus goes above the horizon – gather grapes next day", etc. The configuration of constellations and their names were carved in stones for everyone to see, and simple astronomical knowledge became a part of any education.

In 3rd century BC, the head of the Museum[27] of Alexandria, mathematician Eratosthenes, and historian Timey[28] proposed to take as a milestone origin for all Greek calendars the year of the Olympic Games. That proposal was accepted, so from that time on a year was marked by the number of Olympic Games that had passed before. That calendar existed until Olympic Games were forbidden by Rome.

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27 The word "*museum*" came from Greek expression "*Muses' asylum.*" The Museum at Alexandria included the most famous library and scientific center of the time.

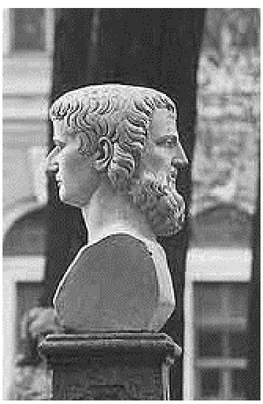
28 **Timey** (356 - 260 BC), ancient Greek historian. Author of 40-volume "*History*" of Italy and North Africa of ancient times.

2.7. Julian calendar

Accurate information about the appearance of the Roman calendar does not exist. As some Italian historians assume, even before Romulus[29], Romans had a solar-lunar calendar, which included 10 months and contained only 304 days. The remaining days were not divided into months; the Romans just waited until spring to start the new counting of days and months of a new year!

Because the year began from the day of the spring equinox, the first month was March called so in honor of Mars, the God of War. The next month was April, from the Latin *aperire* ("to *open*"), because that is the time of year that leaf-buds open. The third month was named for the goddess of fertility, Maya, Mercury's mother. The fourth month was named in honor of Juno, Jupiter's wife and goddess of the family, maternity and the patron of women.

The next months of the year were named by their ordinal number. Some ordinal names persist today: September (i.e. seventh), October (i.e. eighth), November (i.e. ninth) and December (i.e. tenth).



In the 7th century BC two months were added; January (in honor of the two-face god Janus who looks simultaneously with one face to predict the future and with another to remember the past) and February (from Latin "februarius"- "purification"; in the middle of this month there was a ritual of purification dedicated to Februus, the god of Underground Kingdom[30]). It is interesting to note that initially January followed February, but two centuries later the order was been changed so that February followed January.

In the 2nd century BC, Romans decided

[29] **Romulus** (735-716 BC), legendary Rome founder. By legend, twins – Romulus and Remus – descendants of Trojan hero Eney, were thrown into the river because a new king was afraid that they would pretend for kingdom. They were saved by she-wolf and afterwards fostered by shepherds. They founded a new city-state on the bank of Tiber River. During constructing the city they had a quarrel, and Romulus killed Remus. Then Romulus completed building the city, named it by his own name, and became the first Roman King.

[30] Februus later was renamed to Pluto.

make the origin of time the year Rome was built; this was a difficult task: there were many opinions about when Rome was built. The Roman historian Varro[31] convinced his compatriots that Rome had been founded in 753 BC, and that became the first "calendar epoch".

Within a month, Romans had three milestones to mark the days: Calendae (the new moon and the beginning of the month), Idus (13th or 15th day of the month depending on the length of the month) and Monae (the first quarter of the Moon). Days were referred to by their closeness to the nearest of those events. For example, a day might be the 4th day before the Ides of May.

[31] **Marcus Terrentius Varro** (116–27 BC), ancient Roman encyclopedic-scientist. He was twice sentenced to death for his political activity but was forgiven for his brilliant scientific approaches. He wrote more than 600 books on logic, law, geography, and history and was the author of a 15-volume collection of biographies of outstanding ancient Greeks and Romans.

It is not simple dealing with gods to understand who is Greek and who is Roman. However, they are the same mythological personages with different IDs! When they moved from ancient Greek mythology to ancient Roman mythology, they just changed their name, that's all! The only one who kept his original name was Apollo!

Duty	**Greece**	**Rome**
Chief god, father and king of all gods	Zeus	Jupiter
Goddess of Earth, Chief god's wife, Chief Olympic goddess	Hera	Juno
Goddess of Wisdom, Knowledge and Just Wars, protégé of Science and Arts	Athena	Minerva
God of Light and protégé of muses	Apollo	Apollo
Goddess of Love and Beauty	Aphrodite	Venus
God of Trade	Hermes	Mercury
God of Time, later turned into god of Agriculture	Chronus	Saturn
God of War (any, not only just!)	Ares	Mars

To make the solar and lunar years correspond correctly to each other, since the 4th century BC, Romans inserted an extra month with 22 or 23 days.

The Roman calendar was ruled by pontific[32]. Because the length of the extra month influenced the date set aside for the payment of debts, its length "conveniently" varied for purposes of profit. The situation with a Roman calendar was messy, a fact noted by Voltaire[33] who wrote: "Roman strategists always won; however nobody knew on what day it was happened".

[32] Pontific – a member of the Council of supreme priests in ancient Rome. The Council compiled calendar, register the main historical events, determined the Code of civil rules and laws. The chair of the Council was called The Great Pontific.

[33] **Voltaire** (1694 - 1778), real name **Marie Francois Arouet**, French philosopher, writer and historian. For his epigrams, he was imprisoned in Bastille and then expatriated to England. The French Parliament ordered his books to be burned in a fire in the main square of Paris. Later he returned to France and was chosen a member of Paris Academy of Sciences. He propagated ideas of enlightened monarchy and republic. He is considered as one of the cleverest men of all times.

The Roman calendar differed from the solar calendar by 70 days, which created messy problems. The first Roman emperor, Gaius Julius Caesar,[34] in 46 BC decided to reform the calendar. Caesar could do it because he not only was an emperor but he also claimed to be The Great Pontific as well. (From that time, all Roman emperors kept the title of Great Pontific until Vatican took in hand all religious power). This new calendar was the result of a project, done in Alexandria, which took the best ideas from the Egyptian and Greek calendars. Later, this new Roman calendar was named Julian in honor of Caesar.

Julius Caesar completely rejected the lunar calendar – the new calendar was solely solar. He moved the beginning of the year to January 1st when new consuls took their duties. A year consisted of 12 months with 30 and 31 days alternating each other with February as an exception: it had 29 days and one day added each forth year (leap-year). Thus the calendar change in 46 BC, in which two extra months were inserted in the calendar, created a transition year that, at 445 days, was the longest year in Roman history. Not surprisingly it was called "a year of great confusion." The Roman Senate, taking into account his service for the country, decided to rename month *quintiles*, when Julius Caesar was born, into July (Julius).

To honor the next Roman Emperor, the Senate made another modification to the calendar. You probably already guessed that it was for Emperor Augustus,[35] who was born on the 19th of *sextilis,* the sixth month! So, August got a gift; that month was renamed to August, and because July had 31 days, the Senate decided that it was not proper to give August only 30 days, i.e. one fewer days than they gifted to Julius Caesar. Thus one more month came to possess 31 days. (Even numbers in ancient Rome were believed to be unlucky, so there was yet another reason for 31 days!) Of course, February was robbed again to give that day to August!

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[34]**Gaius Julius Caesar** (102-44 BC.) – great Roman conqueror, statesman and writer. His ruling ended the Roman Republic. He was killed by conspirators among his friends. The name "Caesar" was turned into a title of Roman Emperors and later became a common noun: in Germany we can find "keiser", in Russia "kesar' (and even "tsar").

[35] **Caesar Augustus** (63 BC –14 AD), Roman Emperor, known earlier in his life as Gaius Octavius. His great-uncle was Rome's greatest conqueror, Julius Caesar. Octavius became Gaius Julius Caesar Octavianus after Caesar adopted Octavian as his son and heir before his assassination on the Ides of March.

Then it was also decided that an extra day on a leap year was added to February that became 29 days long. By Julius Caesar wish this extra day was inserted between 23 and 24 of February, i.e. six days before March Calendae.

As mentioned before, the time origin of the Julian calendar was the founding of Rome; nevertheless some Emperors (or their flattering chronologists) changed the beginning of the calendar to the day of his crowning. In 525 Emperor Dionysus[36] for purposes of determining the date of the Easter holiday introduced a new epoch, the birth of Jesus Christ. He determined Jesus' birth date based on some historical notes.

2.8. Gregorian calendar

By the end of the 16th century, the Christian church, which had accepted the Julian calendar as the standard, found that the vernal equinox already long ago did not coincide with March 21st. Moreover, every 128 years the vernal equinox came yet one day earlier. It meant that Julian calendar with its year consisting of 365.25 days was still not enough accurate.

The actual solar year is a bit shorter than that; it is 365.242199 days. This difference, 11 minutes and 14 seconds per year, is not significant within the time span of, say, a single generation, but in a little more than a hundred years, that difference accumulates to a full day of error.

By the 16th century AC the difference between the actual and the then official calendar already was approximately 10 days. In 1582 Pope Gregory XIII introduced a new calendar reform; he declared that everybody should consider every leap year as non-leap-year if the number of the year was divisible by 400 without a remainder. Thus, for instance, the years 1600, 2000 and so on are not leap-years, but 1700, 1800, 1900, and 2100 and so on are leap-years. This formula is more accurate than the others; however, the next correction for a day has to be done in 3300 years.

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36 **Dionysus the Little** (died about 550), monk and Pope archivist, outstanding mathematician, Scythian by origin. He developed the method of calculating Easter Day. He did not leave an explanation of his methodology, and even today nobody understands why the Easter by Dionysus method always coincides with a new moon!

Introduction of Gregorian calendar led to the same situation as it was with Julius Caesar; people had to "set a clock". By Papal decree the calendar made a 10-day jump in the year 1582, so the next date after October 4th that year was October 15th! All European countries except Russia due to its Orthodox Christian church accepted that new calendar: the calendar there was corrected only after the Bolshevik Revolution of 1917.

2.9. Will the calendar continue to evolve?

Today there are 5 different calendars in use. An overwhelming number of countries and International Organizations use the Gregorian calendar. Russian and Armenian churches keep Julian calendar. Saudi Arabia, Iran, Arab Emirates and some other countries of Persian Gulf officially use the Islamic calendar. Israel uses the Jewish calendar. Japan, China, Korea and Vietnam use the Oriental calendar, as they have done for about 3-4 millenniums.

The Islamic calendar is purely lunar. Each of 12 months starts at the Crescent (usually, it is the third day after new moon) when a new moon is clearly visible. Each month has exactly four seven-day weeks. The day of rest is Friday. The Islamic calendar begins from the year when Prophet Mohammed transmigrated from Mecca to Medina (year 622 on the Gregorian calendar). Because this calendar has no ties to a solar period, the months float freely within a solar year, coinciding again with a solar year after the 19-year Metonian cycle.

The Judaic calendar is solar-lunar. Years are counted from the Day of Creation (by the Bible) in 3761 BC.

Before the destruction of the Temple in Jerusalem in 70 AD by the Roman army, all events of the Judaic calendar were determined by specially designated Temple who used direct astronomical observations. A month usually began when a priest on duty observed from the mountain the first Moon's crescent; however, sometimes the beginning of the month could be delayed voluntarily, for instance, to wait until "the first barley sheaf has harvested". A new year was postponed in such a way that it never coincided with Sunday, Wednesday or Friday. There were many such rules and exclusions, so priests were always very busy!

The modern version of Judaic calendar was developed in the middle of the 4th century AC for the purpose of synchronizing religious holidays for Jewish communities dispersed in different countries.

The main cycle of the Judaic calendar is Metonian, i.e. 19-year length. In this cycle, there are 12 years by 12 months, and 7 years by 13 months. Depending on the year number there might be additional 1 or 2 days. It adjusts for solar and lunar systems.

The Judaic week has 7 days and begins on Sunday; Saturday is a Holiday. The beginning of the day in Israel is at18:00 hours in Jerusalem time (the time when the Sun goes below the horizon). The Jewish Lunar New Year ("*Erev Rosh ha-Shanah*") is celebrated in the fall, on the first day of the month *Tishre* (the end of September); however the numbering of months starts from the spring month, Nissan.

The names of the months and the calendar principles are reminiscent of the Babylonian calendar. Eventually, Jewish people accepted this calendar after capture of Judean cities by Babylonians.

Month Number	**Babylonian Month Name**	**Hebrew Month Name**
1	Nisanu	Nissan
2	Ayaru	Iyar
3	Simanu	Sivan
4	Du'uzu	Tammuz
5	Abu	Av
6	Ululu	Elul
7	Tashritu	Tishrei
8	Arach-Samna	Cheshvan
9	Kislimu	Kislev
10	Shabatu	Shevat
11	Tebetu	Tevet
12	Adaru	Adar

In the Oriental calendar, years have names based on two independent cycles, the 12-year Jupiter cycle and a10-year cycle of elements, which are coded by colors. Because both cycles have different lengths, combinations of animal and color whimsically alternate. Here you have a table, which includes complete cycles of elements and colors. Notice that after 60 years a "megacycle" repeats itself.

Year	Animal	Element	Color
2006	Dog	Fire	Red
2007	Pig	Fire	Red
2008	Rat (Mouse)	Earth	Brown
2009	Bull (Cow)	Earth	Brown
2010	Tiger	Metal	White
2011	Cat (Hare, Rabbit)	Metal	White
2012	Dragon	Water	Black
2013	Snake	Water	Black
2014	Horse	Wood	Green
2015	Goat	Wood	Green
2016	Monkey	Fire	Red
2017	Cock	Fire	Red
2018	Dog	Earth	Brown
2019	Pig	Earth	Brown
(and so on)	(and so on)	(and so on)	(and so on)

The Oriental calendar is similar to the Judaic calendar in number of months and days in a year and in the year-by-year changes. The main difference is in the numbering of the months and the rules for adding extra days.

However, Oriental calendars in different countries of South-East Asia differ from each other, having a different time origin, different rules of inserting additional days, different New Year day, etc.

All calendars presented so far are religious. Of course, that leads to the question: are there non-religious calendars? The answer is positive. More exactly, there were such calendars, and probably there will be future ones.

The most well known among such calendars is the calendar of the Great French Revolution, which is based on the solar Egyptian calendar, 12 months, 30 days each plus 5 additional days at the end of the year. Weekdays were eliminated; instead the month was divided into 3 decades (nine working days and one holiday each). The calendar was introduced in 1793 and lasted only about 12 years, though some months' names solidly entered history and literature (Brumer – month of fog, Termidor – month of hot weather).

What may be in the future? Has the calendar evolved to completion? It seems even necessary because modern globalization due to frequent traveling and developed telecommunications. Furthermore, even the Gregorian calendar, which is the *de facto* standard of the International Community, has a number of deficiencies. For work planning it is not convenient that the number of working days is different for different months. The main unit of everybody's life – a week – is "in conflict" with a month and a quarter. Imagine how convenient it would be if a year always began with the same day of week.

However, starting with the middle of 19^{th} century, there were a number of attempts of unification and regularization of the calendar. In 1923 the League of Nations created a Committee for World calendar reform. The Committee outlasted the League of Nations and became a Committee under the United Nations. So far, there has been no progress because there are too many obstacles in the way of this committee: national traditions, religious preconceptions, resistance to change, etc.

There are various projects to produce the "best calendar". The calendar system invented in 1888 by French astronomer Gustave Armeline has the most number of supporters. In his proposal, each year consists of 4 quarters, three months each. The first month of a quarter has 31 days, the two remaining have 30 days each. The first day of a quarter (as well as a year) is Sunday. Each quarter ends on Saturday and has exactly 13 weeks. To these 364 days a nameless (not a day name in current use) day is added after December 30. In a leap year an extra day also is added after June 30.

It is interesting to note that Armeline's calendar brings to mind a calendar found relatively recently by archeologists in the so-called "The Dead Sea Scrolls". This manuscript of Qumran Sect that lived there about 2000 years ago has been found in 1947. The story of founding the manuscript is very exciting. A shepherd-boy, trying to find his lost goat threw a stone into a hole in the mountain and listen a sound of broken clay jar. He crawled into the hole and found there a number of sealed jars, in which there were rolled manuscripts. Half a century of research proved that the Scrolls are original. By the Bible found in one of the jar, it was found that those scrolls were sealed about 68 AC.

Armeline's calendar several times was presented to the General Assembly of the UN and was supported by many states. However, the project was blocked by those states where clerical influence is too powerful. For instance, Christians consider the floating day at the end of the year to be an obstacle for the calculation of Easter; Christians divide the entire yearly cycle into 7-day links from Easter to Easter[37]. If one inserts an extra day between Saturday and Sunday the chain of 7-day links will be broken! Similar reasons exist in other religious.

3. UNITS OF MEASUREMENT

Measure what is measurable, and make measurable what is not so.

Galileo

3.1. Origins of the Metric system

During the Great French Revolution (1789-1793), Jacobins not only beheaded "the enemies of the people" but, occasionally, also did some very useful things. For example, they introduced a comprehensive system of measurement. On May 8 of 1790, the National Assembly of France gave to Academy of sciences the commission to create a system of measurements and weights "for all times and for all nations." For this purpose, the Office (Bureau) of longitudes was established. And we note that Laplace[38] was appointed to a chair of that governmental body.

The Bureau created the so-called *metric system*. The metric system is used in almost all countries, with the significant exceptions of the USA, Canada and England, which use the English system. There have been steps in these countries to discard the English system in favor of the metric system, but progress is slow. Not only is there the personal human

[37] The problem here is in the following: by the Bible Jesus Christ has been crucified on Friday and resurrected on Sunday, which coincided with the first new moon after the spring equinox. The formula Dionysus for Easter calculation is based on the non-interrupted sequence of 7-day links from that same day! By the way, Christians typically used the formula that was developed by the great German mathematician Karl Gauss in 1800.

[38] **Pierre-Simon Laplace** (1749-1827), great French mathematician, physicist and astronomer. Founder of probability theory and celestial mechanics.

adjustment required thinking in metric, but also there is an enormous cost to transition machinery to components built to metric standards.

Is one of these measurement systems better than the other? The metric system is more logical than the English system. The regularity and decimal basis (which is universal in the world) for the units in the metric system make scaling and naming sensible rather than arbitrary. For example, consider that there are 12 inches to a foot, while there are 10 millimeters to a centimeter. Furthermore, all scientific work is based on the metric system, with rigorous, precise fundamental definitions of metric quantities.

French scientists arranged an order in all measurement units, tying all of them in a single logical and understandable structure. The greatest advantage of the metric system is that it provides a common "language" for science, technology and International trade.

We will not consider all existing units of measurement of various physical values, though will make an attempt to touch the most common and interesting, in our opinion.

3.2. Units of Length

People began to measure distances many millennia ago… In ancient Egypt there were special "walkers" with a "standard step" who measured distances between cities; travelers measured their paths by activity or by eye, for instance, "ten days by camel riding" or "a month of sailing". Similarly in trade, one could measure fabric at a bazaar by some ad hoc means. What was used in this case? Usually elbows were used, rolling the fabric on a hand; the measuring tool was always "at hand!" This was not accurate, of course, but who cares at the bazaar?

Naturally, in trade various units of length measurement were used, which forced the establishment of equivalence relations between long and short distances. Tradition played the main role: in one case ten small units were added to get the larger one; in another case 12 units were added to make a dozen of smaller units. For years and years people tried to standardize the measures of length, and each country developed its own ("the best") units, ever increasing the measurement mess.

Even in modern times the now largely contained measurement system disparities have led to serious consequences. A notable example occurred during World War II, when the French army joined the USA and UK to fight in North Africa against the Nazis; American and British industries used inches while the French used centimeters, so ammunition and spare parts were incompatible.

A similar situation occurred when Soviet aviation manufacturers attempted thoughtlessly to copy Boeing's "Superfortress" B-29, one of which was forced to land at the Russian Far East just at the beginning of the Cold War.

In Europe in Medieval centuries there were two main measurement systems – "continental" and British. It is well known fact that GB is separated from continental Europe not only by the English Channel (Eng.) or La Manche (Fr.) but also by a real ocean of their own immovable traditions.

The United States, having deep roots with England, beginning with the first emigration wave at 1620, naturally adopted many attributes of British culture and technology.

Let us begin with British length units. It is said that they are a mixture of ancient Roman heritage (league, mile, yard, foot, inch) and units adopted from the Normans (furlong, chain, rod, link, palm).

As in all traditional measuring systems everywhere, short distance units are based on typical parts of the human body. The *inch* equals the width of a thumb. By the way, in many languages, there is a word for "thumb" that means a distance that is close to an "inch". The *foot* equals 12 inches and is approximately the length of a human foot. The *yard* (3 feet) was the name of a 3-foot measuring stick. Another ("natural") definition of yard is the distance from the tip of the nose to the end of the middle finger of the outstretched arm. The fathom (6 feet) is equal to the total span from one fingertip on one hand to one fingertip on the other hand of widely stretched arms.

Historically, there are many other similar "natural units": the *digit* (the width of a finger, 0.75 inch), the *nail* (length of the last two joints of the middle finger, or 3 digits or 2.25 inches), the *palm* (width of the palm, or 3 inches), the *hand* (4 inches), the *shaftment* (width of the hand and outstretched thumb, or 2 palms, or 6 inches), the *span* (width of the outstretched hand, from the tip of the thumb to the tip of the little finger, or 3 palms, or 9 inches), and the *cubit* (length of the forearm, 18 inches).

Before the Norman conquest of 1066, short distances in England are believed to have been measured in several ways. The inch ("*ynce*") was defined to be the length of 3 barleycorns, which is very close to its modern length. The shaftment was frequently used, but it was roughly 6.5 inches long. Several foot units were in use, including a foot equal to 12 inches, a foot equal to 2 shaftments (13 inches), and the "natural foot" (about 9.8 inches). The fathom was also used, but it did not have a definite relationship to the other units.

Normans brought the Roman traditional 12-inch foot, and during the reign of Henry I (1100-1135) it became the official definition for a foot. A 12-inch foot was inscribed on the base of a column of St. Paul's Church in London, and it was said about measurements "by the foot of St. Paul's" (*de pedibus Sancti Pauli*). Henry I also introduced the *yard* as a 3-foot length.

All land in England was traditionally measured by the *gyrd* or *rod*, an Old Saxon unit equal to 20 "natural feet". During the Norman period, the length of the rod was fixed at 5.5 yards (16.5 feet). In the Saxon measuring system, 40 rods make a *furlong* (*fuhrlang*), the length of the traditional furrow (the trench in the earth made by the plow on Saxon farms). These ancient Saxon units – the rod and the furlong – have come down to us today unchanged. The *chain*, a more recent invention, equals 4 rods or 1/10 furlong in order to fit nicely with the Saxon units.

Longer distances in England are traditionally measured in miles. The mile is a Roman unit, defined in ancient times as the length of 1000 double steps of a Roman soldier, defined as having a length of 5 Roman feet. Accuracy requirements of long distances measurement back then seemed not to be of concern. What difference did it make whether the next village was 10 or 12 miles away?

The important fact was that a mile should equal 8 furlongs. Because the Romans had set their mile equal to 8 *stadia*, the furlong was an English unit roughly equivalent to the Roman *stadium*. (Actually, the furlong is 660 English feet and the stadium is only 625 due to the slightly shorter Roman feet, so there is no exact correspondence).

Queen Elizabeth I, who in the 16th century issued a special bill concerning length units, attempted to unify length measures.

For convenience of visual comparison of various British length units, we give the following table:

Name	Relation to other units	Equivalent Metric Measure
Sea league	3 see miles	5559.6 m
Sea mile	10 cabletows	1853.2 m
Cabeltow	608 feet	185.32 m
Earth ligue	3 earth miles	4828.0 m
Earth mile	1760 yards = 8 furlongs	1609.3 m
Furlong	220 yards =10 chains	201.2 m
Yard	3 feet	91.44 cm
Foot	12 inches	30.48 cm
Inch		25.4 mm
Chain	4 rods	20.1 m
Rod	25 links	5.03 m
Link		20.1 cm

Even as recently as 100 years ago all those units were used widely in the United States and the United Kingdom, however, now only the mile, yard, foot and inch are in active use.

We see that to understand the old English system of length units is not a simple task. However, in continental Europe the situation was even worse! In the middle of 18th century, for example, a popular unit of length was the *palm*. In Holland it was equal to 10 cm, in Portugal – 22 cm, in Spain – 20 cm, and in England –10.16 cm. Not better was the order in large units. Besides, there was a huge difference between British and "continental" units. For instance, the French league was equal to 4445 m.

The modern Metric System is clear and simple for those accustomed to a decimal counting system: kilometer = 1000 meters (*m*), meter = 100 centimeters (*cm*), centimeter = 10 millimeters (*mm*), millimeter = 1000 micrometers, or microns (*µm*), micron = 1000 nanometers (*nm*), nanometer = 1000 picometers (pm).

In our everyday life we don't use such units like nanometer (10^{-9} m) or picometer (10^{-12} m) because we don't typically need to measure the diameters of atoms (0.05- 0.6 nm) or their kernels (0.1 pm). Such units are used by opticians, atomic physicists, molecular chemists, who as far back as in the middle of 19th century already had introduced the *angstrom* (= 10^{-10} m), named after Anders Jonas Angstrom[39].

[39] **Anders Jonas Angstrom** (1814-1874), Swedish physicist.

In the metric system, the fundamental unit of length is the meter. Although it is close by its value to the historically traditional length of human steps, the origin of the meter is tied to a measure of the Earth's circumference (~40,000 km). The kilometer equals 1/40,000 of the length of the Earth's meridian. As the matter of fact, the meridian was regarded as the fundamental length and the meter as a derived secondary measurement.

The French Bureau on longitudes, headed by Laplace, defined the meter as 1/1,000,000 part of the Earth's meridian from the North Pole to the Equator. And the name "*meter*" came from the Greek word *metron* (measure).

Of course, one meridian is quite different from another; for example, one may go through highest Himalayan Mountains while another goes over flat surface (desert, ocean). Surprise! French scientists chose the meridian going through Paris as the reference! Of course, it does not mean that someone had to make the journey from the North Pole to the Equator through Paris to calculate the meter. In 1799 in France there had been made a standard – a platinum-iridium rod with two engraved marks exactly 1 meter apart at the specified environmental temperature of melting ice ($+4^0$C). A master-copy of the standard is kept in Paris at the Bureau of longitude, and copies were sent to other states for their measurement Bureaus.

With technological improvements in measurement techniques, measurement accuracy increased, and soon it was found that the Laplacian meter is a little bit shorter than it should be for the Paris meridian. In addition, the platinum-iridium fusion began to change its properties (including length) due to a re-crystallization effect.

Fortunately, by that time scientists were able to measure the wavelength of light. And it was found that the wavelength of light radiated by atoms is much more stable than the length of a metallic rod. The most convenient material to use in a standard was the inert gas krypton. When subjected to an electrical voltage causing a flow of electrons, krypton radiates orange light waves. In 1960, the length of 1,650,763.73 wavelengths of this orange light was accepted as the standard meter. The original platinum-iridium rod became a museum exhibit.

A further important step in physics was the accurate measurement of one of the most important "World constants" – the speed of the light in vacuum. That value was measured even with higher accuracy:

299,792,458 m/sec. Thus, in 1983 a new definition of the meter has been accepted: it is the length of the path that a ray of light makes in a vacuum for 1/299,792,458 part of the second.

Of course, such a physical value is impossible to feel, touch or imagine (like a part of the Earth's meridian), however it is much more convenient when one needs an accurate and reproducible value of the meter.

And if you have the meter, then you have all the other lengths, such as the kilometer and centimeter.

So, is the meter a better measurement than, say, the yard? No. In principle, a value of length unit might be any; the only necessary condition for utility is that this unit has to be the same for everybody!

Meter and kilometer are very convenient on the Earth. But is this true for astronomers with the huge numbers, octillions and decillions of kilometers? To avoid such a situation, astronomers introduced their own units for measuring "astronomical distances."

The first astronomical unit for distance measurement to appear was the *astronomical unit* (*AU*), equal to 149,597,870 km. This unit approximately is equal to the average distance between the Earth and the Sun. This unit is mostly used for measurements of distances within the Solar system. To imagine the size of this unit, imagine that the Solar system is shrunk to the size of your living room, and then AU would be equal roughly to 1 cm.

Another astronomical unit of distance is the *light year* (LY) – the distance light travels in a vacuum in one year[40]. This unit is equal to 9.46×10^{12} meters. This unit is used for measurement distances between stars. For smaller distances *light minute* and *light second* might be used.

There is also *parsec* – the distance an object would have to be from Earth for its heliocentric parallax to be 1 second of arc. This unit is equal to 3.26 light years. Just to give you a possibility to "touch" such a value, we can tell you that the distance from the Earth to the nearest star – Proxima Centaurus is 4.22 LY or 1.3 parsec. The distance to the nearest Galaxies of the Milky Way is measured in millions of LYs.

[40] The year is defined as 365.25 days or 86,400 seconds.

3.3. Units of Volume and Weight

The first written mention of units of volume one is found in the "Code of Hammurabi" (18^{th} century BC); these are the *ka* and the *gur*. One gur is equal to 5 ka (or as the Sumerians wrote then "ka-ka-ka-ka-ka").

In the ancient world, units of measurement initially had subdivisions of 12, because 1/2 and 1/3 appear very naturally, and 1/4 is half of 1/2, and 1/6 is half of 1/3, and, finally, 1/12 is half of 1/6.

One exception, and the earliest known decimal system of weights and measures, is the Harappan system. The Harappan civilization flourished in the Punjab between 2500 BC and 1700 BC. The Harappans appear to have adopted a uniform system of weights and measures. An analysis of the weights discovered in excavations suggests that they had two different series, both decimal in nature, with each decimal number multiplied and divided by two. The main series has ratios of 0.05, 0.1, 0.2, 0.5, 1, 2, 5, 10, 20, 50, 100, 200, and 500. Indeed, it is a convenient set of units. In many countries coins have the same set: 1, 2, 5, 10, 20, 50, and 100. Any needed value can be arranged with few coins: 1, 2, 3=2+1, 4=2+2, 5, 6=5+1, and so on. Of course, larger numbers typically require more coins. For example, 99 = 50+20+20+5+2+2 is a price likely to be found only in a modern supermarket and not in ancient bazaar, where it would be just 100!

For measurements of volume, the earliest people used standard measuring earthenware pottery. For instance, in the ancient city of Heraclea Pontica on the coast of Asia special amphorae for measuring liquids and grains were found. Those Heraclean amphorae were used as units of volume within all Greek territories in the Mediterranean. They were of various forms and different sizes, from 2 to 26 liters. Archeologists believe that those amphorae were calculated with the help of Heron's[41] formulae, used for calculating the area of a triangle from its perimeter.

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[41] **Heron**, or **Hero** (approx. 1st century), Greek mathematician, physicist and inventor. In his manuscripts, he described a fire pump, a water organ, a mechanical puppet theater, an automat for selling "sacred water" and other sophisticated tools. He described methods of calculating forces for levers, windlasses, screws and pulley blocks. He gave rules for the solution of quadratic equations and methods for approximating square and cube roots.

Ancient Greeks had many varieties of containers which differed from each other by their intended use: the *hydria* (from Greek *hydron* = water), a large egg-shaped amphora with high and narrow neck, was a container for water; the *kyathos,* a metallic or ceramic bell-shaped cup with a long handle, was a container for wine; the *kylix* (Greek for "bowl") was a flat cup for drinking; the *scythes* was a cup for drinking wine; the *phial* (Greek for "*cup*") was a metallic or ceramic container for wine.

Hydria

Kiathos

There also were large measures. For instance, *pithos* was a large (up to 2 meters height) ceramic egg-shaped container for storing grain, water, wine, etc. Usually they were dug into the ground.

In Medieval centuries, in Europe liquids (especially wine) were usually measured by Old Dutch measures. The largest one was the *okshoofd* (in English – "*hogshead*"); it was a barrel of 232 liters (61.3 gallons). The okshoofd was equal to 6 *ankers* (in English – "anchors"). Another barrel, called the *aam* contained 4 ankers (or 155 liters). An anker could be split up in 16 *stoops,* a stoop being equal to two *mingle*, or *mengel*, which was the name of a can containing 1.2 liters. The smallest amount was the *pint* (0.568 liter), which was equal to the English[42] pint.

Later the most popular measure for large-scale volumes became the English barrel. Since the middle of 19^{th} century, the barrel has been used to measure crude oil output. Barrels in different countries were slightly different, until the International standard established the barrel to be equal to 42 gallons (or 159 liters) of crude oil.

However, chaotic inconsistency continues with the barrel as a measure of volume. The American barrel is approximately 119 liters; the

[42] American pint equals 0,473 liter, i.e. close to half a liter.

British is nearly 160 liters; and the Dutch anker (Dutch for "barrel") equals 155 liters.

England and later the United States chose as the principal measure of liquids the *gallon,* which is divided into 4 *quarts*, and the quart is divided into 2 *pints*, and the pint is divided into 2 *cups*, and the cup is divided into 16 *tablespoons*, and the table spoon is divided into 3 *teaspoons*. Thus, one gets a fantastically good measurement system … for a kitchen! But even for these purposes, the variable scale of division is not so convenient.

However, the worst thing in this system is that the modern English gallon equals 4.546 liters while the American one equals 3.785 liters. So the expected harmony between English and American units falls apart. Furthermore, there also is a "*liquid ounce*;" there are 20 ounces in an English pint, while there are only 16 such ounces in the American pint!

Looking at all this "order", it is easy to see what a great job Laplace and his Bureau of Longitude did! Here is what the Bureau of Longitudes: First they tied units of weight to units of length; the *liter* was chosen to be the main unit of liquid volume, and it was defined as the volume of one cubic decimeter (a cube with sides equal 10 cm). Other units differ by decimal orders. The most popular units are *deciliter* = 10 liters (main unit in wine production), *kiloliter*, or *cubic meter* = 1000 liters, *milliliter* = 1/1000 of liter[43]. So, you see? It is very logical and simple to remember and understand, and no spoons, cups, bowls and other kitchen attributes are needed!

Now let us look at units of weight. Again the "*Code of Hammurabi*" gives us the first mention of the *shekel* and *mina*, two main units of weight that had some broad usage.

From the earliest times, the grain was the smallest weight unit used in the apothecary and jewelry. The early unit was a grain of wheat or barleycorn used to weigh the precious metals silver and gold.

In ancient Greece, the main unit of weight was the *drachma,* which varied in value from 4.5 to 6 grams, with no standard value being defined. Smaller weights were the *diobol* (1/3 drachma), the *obolo* (1/6 drachma) and the *khalkoi* (1/8 obolo). Ancient Greek units of weight partially

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[43] Prefixes deca- (=10), gecto- (=1000), kilo- (=1000), mega- (=1,000,000), deci- (1/10), centi- (1/100), milli- (1/1000), micro- (1/1,000,000) are use for all units in the metric system.

coincided with monetary ones. It is clear because in earlier times people paid for goods by some weights of precious metals.

Larger units were developed that were used as both units of mass and of monetary currency. The *mina* was equal to 100 drachmas and the *talent* was equal to 60 minas. The Talent was from 27 to 36 kg. (The word "talent" applied to a gifted person has Greek roots; it means having a significant weight!)

The Roman talent consisted of 100 *Libra* (pound), which were smaller in magnitude than the mina.

The Hebrew weight units mentioned in the Bible were the *gerah*, which is a Hebrew word, meaning a grain or kernel; it was equal to 12 grains (778 mg); *shekel* = 20 gerah, *bekah*= 1/2 shekel ("bekah" means "a half"); *ma'neh* = 50 shekels; *kikkar* = 3000 shekels.

So, each major group of people had their own units of weight, which is natural outcome for countries separated geographically and culturally. The only reason for having common units of weight was trade, but for exchange of goods it was not so critical.

As time went on, until the modern era, there was no progress in arriving at a consistent and logically ordered system of weights. Some systems were reasonably organized and more or less logical, however, units changed from country to country. To make matters worse, even within the same country the weight system in use might vary from region to region.

Consider the British system of weights. The basic unit of weight in the British system was the grain - originally based on the weight of a grain of barley (though money was based on the grain of wheat: three grains of barley weigh the same as four grains of wheat!).

There were three systems: avoirdupois, troy and apothecaries.

The *avoirdupois* system of weights is based on the pound and the ounce. The name of the system is derived from the Old French term *aveir de peis* meaning literally "*goods of weight*".

This system is used now in the USA for everyday purposes. It was also used in the United Kingdom and other countries until the introduction of the Metric System. It is considered more modern than the alternative troy or apothecary systems. In the avoirdupois system, all units are multiples or fractions of the pound. In 1959 the pound was defined to be approximately 0.454 kilograms. These are these units: *Ounce* (*oz.*) = 16 *drams* (or *drachms*); *pound* (*lb.*) = 16 oz.; *quarter* (*qtr.*) = 25 lb.; *hundredweight* (*cwt.*) = 4 quarters; *ton* (or *tonne*) = 20 *hundredweight*

People in the British Isles, when they began to use this system, included the *stone*, which was defined as 14 lbs.

The *troy* weight system name comes from the city of Troyes in France, an important trading city in the Middle Ages. The story of that has its roots back to the time of William the Conqueror.

A troy ounce, the only unit of the system currently used in the pricing of precious metals, such as gold and silver. It has 480 grains, i.e. heavier than an avoirdupois ounce (437.5 grains). One troy ounce is about 31.1g, i.e. about 10% more than the avoirdupois ounce. In the troy weight system, there are 12 ounces in a pound, rather than 16 in the avoirdupois system. From 1878 forward, the troy pound was superseded in common use by the avoirdupois pound; the troy ounce was used and continues to be in use today only for weighing precious metals, especially gold.

The *apothecaries* system is an obsolete system formerly used by apothecaries (i.e. pharmacists and chemists) in English-speaking countries. The system was closely related to the troy system of weight, having identically sized pounds and ounces, but the two systems differed in how the ounce was subdivided. (Similar systems had been in use in other European countries).

Now let's see what the Laplace Commission created for a system of weights. They associated weight units to volume units! A cubic decimeter (liter) of water was taken as the main unit of weight. It was called the *kilogram*. However, it is known that water has different densities at different. Water is at its maximum density at the temperature of melting ice, i.e. at $+4^0$C. So, this temperature was chosen for the weight standard.

Accurately measuring a liter of water proved to be very difficult. Instead, in 1889 an English goldsmith was hired to make a platinum-iridium cylinder that would be used to define the kilogram. The master copy – a cylinder about the size of a plum – is kept in Paris, and 80 copies of the reference kilogram have been created and distributed to signatories of the metric treaty. Having kilogram, it is easy to get all increasing and decreasing weight units: *ton* (*t*) =1000 kg; *gram* (*g*) = 1/1000 kg; *milligram* = 1/1000 g.

3.4. Measuring Time

No man can cross the same river twice, because neither the man nor the river is the same.

Heraclit of Ephesos[44].

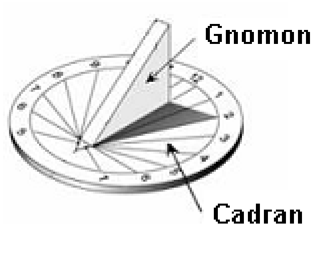
Time… What is it? How can it be measured? Each historic epoch produced own particular answers to these questions.

Plato talked about the cyclic nature of time; by this he meant that everything repeats in the World, much like going around in a circle. Aristotle defined time as something that helps measure speed.

The simplest tool for time measuring, the sundial, was invented in Sumeria about 3.5 millennia ago, and was used for many centuries. A small vertical *gnomon*[45] was attached on the flat dial face with engraved marks of hours. The shadow of gnomon served as an arrow showing time.

By the way, do you know why the arms on our watches move "clockwise?" It is because the Sun's shadow moves on the face of the sundial in that direction.

However, a sundial works only on sunny days, and therefore during the dark times, a different device, the *clepsydra*[46] (Greek for water watch) was either by Babylonians or Egyptians. (By the way, ancient Chinese also had analogous watches). It was a simple ceramic or bronze container filled with water. A tiny hole in the bottom of the container let water escape a drop at a time. Time was read by the marks on the inner part of the wall.



Remark: The fact that clock arms move clockwise shows that our civilization came from the Northern Hemisphere. If a sundial were invented by somebody in the Southern Hemisphere, we would have the

44 **Heraclit of Ephesos** (6th century BC), Greek philosopher, one of the founders of materialism and dialectics. Influenced Socrates, Plato, Aristotle and others. Being disillusioned in human beings, he left society and accept a life of hermit.

45 *Gnomon* in Greek means "*pointer*".

46 *Klepsydra* (or *Clepsydra*) in Greek means literally "*who steals water*".

inverse direction of watch arm motion!

The hourglass, which by its idea is very close to water-watches, uses sand instead of water. The first hourglasses appeared relatively recently – not more than a millennium ago, when glass-blowing reached a sufficiently developed level. Those tools could be used for small time intervals.

There also were "fire-watches," candles with uniformly distributed marks. When the candle has burned down to the mark, it meant that fixed time interval has passed. There even were "fire alarm-clocks," a candle with a needle stuck into it with a metallic weight hanging by the needle; at the appropriate moment, when the candle had burned to expose the needle, the weight dropped into a copper basin and by its sound awoke the sleeper.

A gigantic step was taken when in the 13th century mechanical watches were invented. A weight on the chain was a reliable and simple source of needed energy; it forced a system of geared wheels to turn, where one of the wheels had an hour-arm attached. Accuracy of such clocks was low, so there was no need for a minute-arm. Many countries fought for the claim to have been the first to invent the mechanical clock, however there is no convincing evidence for supporting any specific claim.

In 1657 Christian Huygens[47] had a patent for using a pendulum to stabilize the time keeping of mechanical clocks. The discovery of pendulum properties belongs to Galileo; however, it was Huygens who developed the mathematical theory of the motion of a pendulum. The pendulum increased the accuracy of new clocks by tenfold.

In two decades, Huygens invented the escapement mechanism, which kept a clock wheel from moving backwards. Then he substituted a spring for the weight on the chain, which opened a new era of "portable" mechanical chronometers.

[47] **Christian Huygens** (1629 - 1695), Dutch physicist, mathematician and engineer. Founder of the wave theory of light and theoretical mechanics. He invented an ocular for telescopes, a pendulum clock and a planetarium. He discovered Titan's satellite and Saturn's ring. He was the first foreign member of London Royal Society and the Paris Academy of sciences.

At the end of 19th century, properties of quartz resonators[48] were discovered, and already in 1937 unique quartz watches appeared with an accuracy of about 2 milliseconds per a day. These watches were installed in the Greenwich observatory.

In the second half of 20th century, with the arrival of the electronic era, quartz resonators firmly occupied a place in billions of watches, computers, telephones, TV sets and other everyday equipment all over the World.

The next level of watch accuracy came from atomic physics. Quantum Theory teaches that every atom can be in only one of several stable states; for instance, the Cesium atom has only two states, relaxed or excited. Transition from one state to another is a very stable process. After the discovery of atomic watches, physicists of different countries created several types of atomic clocks, each successive one more accurate than the previous one.

After the ammiac maser[49] was discovered, atomic watches became smaller and smaller. So, soon we might see atomic wristwatches!

In 1967 the World accepted time standard was based on the frequency of oscillation of the cesium atom; one second is the time of 9,192,631,770 oscillations during resonance.

Now let us return to the French Bureau on Longitude: they define a second as 1/86400 of average Solar day.

The three main units of physical measurements – length, weight (mass) and time – are basic to all of the World systems.

[48] If an electric signal is applied to the edges of quartz crystal, then it begins to oscillate. The frequency of those oscillations depends on size and form of the crystal, and the oscillation stability depends on the stability of the environment and the electrical stimulus.

[49] Maser is a generator of super high frequency radiation from a group of ammonia molecules. This discovery was made by Soviet scientists Nikolai Basov (1922-2001) and Alexander Prokhorov (1916-2002) and independently by American physicist Charles Townes (born 1915). In 1964 they got Nobel Prize for this discovery.

3.5. Force, power and work

In the 18th century, advancements in physics and technology led to the formalization of the concepts of force, power and work. These quantities are difficult to define, except operationally, when a specific process is described for measuring them. We note that length, mass, and time are fundamental quantities, while, say, volume is a derived quantity, measurable in units of length. Force, the key concept of the three (force, power, and work), has a rigorous definition that is based on operational methods of measuring force quantities. Force also is a derived quantity; units of force are expressed as combinations of length, mass, and time. Loosely, force is the capability to influence a body to change its speed, or direction, or shape or any combination of these three. Force is a *vector* quantity, meaning that it has a magnitude (value) and direction.

The force that must be applied to accelerate 1 kilogram by 1 m/sec^2 is called a *newton* in honor of the great English scientist, Isaac Newton. To get a feel for a newton of force, you can hold a 100-gram weight in the palm of your strong arm; your muscles feel the influence of a force equal approximately to 1 newton. This is the force you need to exert to keep that mass from falling due to the force of gravity, which would otherwise accelerate the mass in your hand by ~0.8 m/sec^2.

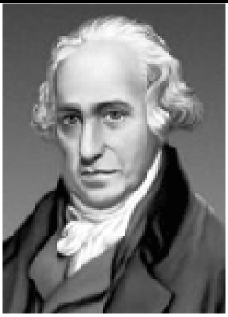
Notice that in science and technology one usually considers mass rather than weight. So, the same platinum-iridium standard of weight is considered as the standard of mass. However, again there is a place for special notice; weight is a force due to gravity and it is different at different points of the Earth! Due to that fact, the Laplace Commission calibrated the standard at the latitude of 45^0. The mass of the standard does not change; the standard has the same mass on the Moon, at the Pole or even in Paris. However, the weight of this standard is different at different points if you measure it by a spring balance.

How is work measured? The formal definition of work has nothing to do with a final result, but rather it is about the measurement of some conceptual physical process that involves a force causing a change in the state of an object.

Using an operational definition, if one applies the force of 1 Newton to a material point, and this point is moved the distance of 1 meter, it is said that *work* of 1 *joule* was done. The unit is named in honor of the English physicist Joule[50].

A Joule is a very small value. We all are more used to another unit – *kilowatt-hour*. One such unit consists of 3.6 million joules! So, you were hardly sweating making a work in one Joule☺.

What is power? In a sense, it is intensity of work; it is defined as work divided by the time the work was being done. Doing a work of one joule in one second is called a *watt*. This unit is called in honor English inventor James Watt.



James Watt
(1736-1819)

Genius Scottish inventor with no formal education. At age 19 his father sent him to London to learn how to make tools for mathematical and astronomical studies.

Once he was asked to repair a broken steam pump which gave him the impetus to invent a general purpose steam engine with a centrifugal regulator, the governor. This engine gave birth to the industrial revolution.

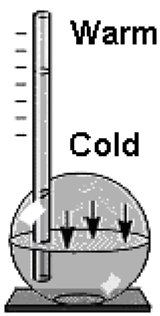
Let us not forget about one more unit of power – *horsepower*. This unit is used in England and Russia (especially for automobiles characterization) and is equal to approximately 746 watts.

50 **James Prescott Joule** (1818 - 1889), famous English physicist. He never attended school, though his home tutor was Dalton (who discovered color-blindness called Daltonism), well known mathematic and physicist. Joules published hundreds of first-class papers. He was 23 when he discovered a physical law named after him (the quantity of heat produced by a conductor is proportional to its resistance and the square of the intensity of flow). At age 25 he gave an experimental proof of the law of energy conservation. It is interesting that science for Joule was just a hobby: he was a full time employee at his father brewery business. He continued to work at the brewery even when he became a member of the London Royal Society.

A professor asked a student:
- What is the horsepower?
- That is the force of the horse with height of 1 meter and weight of 1 kilogram…
- My dear friend! Where can you find such a horse?! – asked the angry Professor.
- It is not so simple, Professor. That horse is hidden in Paris at the Bureau of Longitude…

3.6. Temperature measurement

The very first tool for measuring temperature, thermoscope, was invented by the great scientist, Galileo in around 1600. The tool was based on the fact that air expands as its temperature rises. Galileo took a chemical flask, turned it upside down and put its neck into a pot of water. The water moved up and down depending on the volume of the air inside the flask. Of course, the tool was not precise, because not only temperature but also atmospheric pressure affected the measurement.



However, Galileo himself considered his invention mostly as a tool to rebut Aristotle's teaching that cold and heat are different properties mixed within a substance.

Torricelli[51], who was a pupil of Galileo, suggested fixing the volume of gas. It was a rather sophisticated tool for the comparison of temperatures. (At that time there was no idea of quantitative measurement of the temperature, and thus scales had not yet been invented.)

Followers of Galileo and Torricelli invented the use of a spirit instead of a gas, thus excluding the influence of atmospheric pressure. At the same time the idea of a temperature scale appeared, with two

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[51] **Evangelista Torricelli** (1608-1647), known Italian mathematician and physicist. He developed Galileo's idea, staying with him until his teacher's death. After that he was invited to be a professor of University of Florence. He proved a possibility to get vacuum (the so-called "Torricelli's emptiness").

fundamental temperatures being mentioned, that of boiling water and of melting ice.

Amonton[52] suggested using mercury as the liquid because it was inert and more precise.

Fahrenheit[53] began to make modern thermometers with is introduction of a temperature scale. Trying to avoid negative temperatures, he chose as the zero-point the temperature of melting of a mixture of snow, salt and ammonia, the lowest temperature gotten at the time in a laboratory. Fahrenheit scale has two registration points: 32° F – the temperature of ice melting, and 212° F – the temperature of water boiling. This temperature scale is still in use in the United States, though in all other countries for many years only the Celsius scale has been used.

To convert temperature in Fahrenheit (*F*) into temperature in Celsius (*C*):

$$\mathrm{C} = \frac{5}{9} \cdot (F - 32)\,.$$

Reomur[54] believed that alcohol is more convenient for thermometers than mercury. He also did not like the Fahrenheit scale, which had no fundamental physical logic. He introduced a scale where 1^0 meant increasing alcohol volume by 0.0012 of the initial volume. The zero-point in his thermometer was the temperature of melting ice. Then the boiling point of water was automatically equal to 80^0. Reomur's scale was short-lived, but alcohol thermometers are still used for atmospheric measurements because they freeze at a lower temperature do mercury thermometers.

52 **Guillaume Amontons** (1663-1703), French physicist, developed the theory of friction, constructed a hygrometer, improved an air thermometer. First came to the idea of "absolute zero" (in temperature) and made its first evaluation (-293,8 in Celsius scale).

53 **Daniel Gabriel Fahrenheit** (1686-1736), German physicist and inventor who had been working in Holland. Being a glass-blower, he made the first practically used thermometers. He discovered the dependence of liquid boiling temperature on atmospheric pressure and salinity.

54 **Rene Antoine Reomur** (1683-1757), French zoologist and physicist, member of Paris Academy of Sciences.

The winner in the battle between thermometer scales is the Celsius[55] scale, which is accepted everywhere (but not commonly used in the USA). In this scale 0° corresponds to the melting temperature of ice and 100° corresponds to the boiling temperature of water. However, we note that Celsius himself defined the temperature of boiling water as 0^0, and the temperature of melting ice as 100^0. It was Linney[56] who turned the Celsius original scale upside down; 0^0 became the temperature of melting ice and 100^0 the temperature of boiling water.

[55] **Anders Celsius** (1701-1744), Swedish astronomer, physicist and geophysicist. He was the first to measure the brightness of stars. He established that the northern lights depend on the fluctuation of the Earth's magnetic field. He was a member of the team that measured the length of the Earth's meridian. A year before his death, he suggested his famous 100^0 scale for thermometer.

[56] **Karl Linney** (1707 -1778), Swedish naturalist, created the system of classification of the Earth flora and fauna. In 1735 he published his "*System of Nature*", which had been published 12 times during his life and, by the way, the volume of the book increased from 14 pages of the first edition to 3 volumes of the 12th edition!

PANTHEON

Eratosthenes of Cyrene
(275 - 194 BC)

Ancient Greek scientist, Head of the famous Library in Alexandria, Egypt. He was a founder of mathematical geography. He is famous for his works on the theory of numbers, philology, philosophy and music.

Eratosthenes is believed to be one of the most versatile scientists of the ancient World. His approaches in astronomy, geography, and mathematics were successfully supplemented by works in philosophy, philology, poetry, and music. For all those talents he was nicknamed "*Pentathlon*", i.e. a sportsman who participated simultaneously in competition in several sportive contests. Another his nickname was "*Beta*" ("*The Second*") that means that he was considered the second after his best older friend Archimedes (who was "*Alpha*").

Eratosthenes was born in Africa, in the city of Cyrene. He was educated in Alexandria and Athens. When he was only 15 years old, working with Aristarchus in Alexandria, he made his world-famous measurement of the radius of the Earth.

At 30, he was invited to head the famous Library of Alexandria and to be a tutor of the heir of the king. He held this positions entire life.

No Eratosthenes works come to us; however, many of his contemporaries quoted his works. For example, Archimedes's in his writing, "*Method,*" highlighted some important scientific results by Eratosthenes.

Eratosthenes made a huge contribution in geometry and theory of numbers. His well-known method of constructing a sequence of a numbers to identify prime numbers is named the Sieve of Eratosthenes.

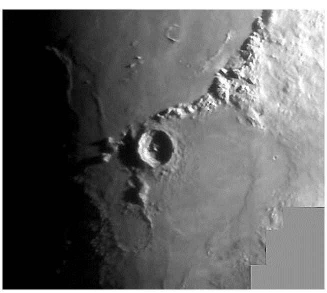
Geographers consider him as a founder of their science; although the work did not survive, we know he wrote a three-volume book "*Geography*" in which he introduced the term "geography". He measured the size of the Earth, introduced concepts of meridians and parallels and gave a methodology for the calculation of geographic coordinates. He is considered to be the "Father of cartography".

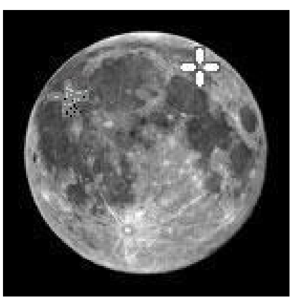
Philology is yet another discipline named and identified by Eratosthenes. He introduced the word "*philology*", which means "*philos*" ("*love*") + "*logos*" ("*word*"). By the way, philosophy means "*philos*" ("*love*") + "*sophia*" ("*wisdom*").

Eratosthenes is counted as a founder of scientific chronology. In his tractate "*Chronography*" he, using scientific methods, determined accurately enough when the Trojan War occurred and compiled a list of winners of Olympic Games.

Blindness in his last years of life depressed Eratosthenes so much that he starved himself to death in about 192 to 194 BC; he was 80 or so years old at the time of his death.

The name of this great Greek astronomer bears one of the largest craters on the surface of the Moon.





Eratosthenes Crater. Location of the crater.

Aristarchus of Samos
(320 – 250 BC)

Ancient Greek philosopher, astronomer and mathematician. First in history to suggest a heliocentric system of the Universe. He is called Copernicus of the ancient time.

Aristarchus was born on the Island of Samos. His first tutor was one of Aristotle's pupil, Strato,[57] whose nickname was "Physicist." Aristarchus intended to enter the Athenian Lyceum, but instead he fled from Athens to Egypt upon his conviction of blasphemy for having suggested that the Earth moves around the Sun and not vice-versa. In Alexandria, Aristarchus became one of Euclid's students and devoted his entire scientific life to the Alexandrian School of philosophy and the Library of Alexandria. Despite this turn of events, Aristarchus continued to claim to be one of Aristotle's followers.

Information about his personal life is very poor and of his personal writings only the small manuscript, "*About the sizes of the Sun and the Moon and distances to them,*" survived to our times. We learned of

[57] **Strato of Lampsacus (340-268 BC.)** –philosopher, physicist, third mentor of Aristotle's Lyceum.

Aristarchus' scientific discoveries only from narrations by Archimedes[58] and Plutarch[59]. For instance, Archimedes in his book "*The Sand Reckoner*" wrote, "Astronomers believe that the Universe is a sphere with its center coincident with the center of the Earth and with its radius equal to the distance from the Earth to the Sun. However, Aristarchus in his "*Assumptions*" rejects that description of the Universe and has concluded that the Universe is much larger than that. He suggested that the Sun and immobile stars[60] do not change their location in space".

Besides changing the center of the Universe from the Earth to the Sun and assuming that stars are located far away from the Sun, Aristarchus also explained that day alternated with night due to the rotation of the Earth around its axis. At Aristarchus' time the scientific community considered a hypothesis that rejects the geocentric model of the Universe as too extravagant and even unnatural. Even Archimedes, who admired the quality of Aristarchus' thoughts, left the Earth in its traditional place, the center of the Universe. Aristarchus' contemporaries rejected his heliocentric model of the Universe, and the truth had to wait for almost one and a half millennia for Copernicus.

Aristarchus was able to use his model of the Universe to develop simple yet elegant methods for calculating the sizes of heavenly bodies and the distances between them.

In the honor of Aristarchus' scientific exploits, his name is given to a crater on the Moon, which is one of the main basic coordinates on the surface map of the Moon. So, now the name of this great Greek is mentioned whenever scientists observe the surface of the Moon.

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58 **Archimedes** (287 - 212 BC), ancient Greek mathematician, founder of theory of leverage and hydrostatics. He developed methods of measurement of surfaces and volumes of different figures and bodies and so anticipated many ideas of differential and integral calculus. Many technical and military inventions belonged to him.

59 **Mestrius Plutarch (c 45 - c 120)** – ancient Greek writer and historian. His main work is "*Comparative biographies*" with 50 biographies of most famous Greeks and Roman.

60 Ancient astronomers called planets as mobile stars, or moving stars.

Claudius Ptolemy
(87– 165)

Outstanding ancient Greek mathematician, astronomer, geographer and physicist – one of the greatest figures in the history of science.

Ptolemy influenced modern science, probably, more than any other ancient scientists. In his fundamental works he summarized approaches of ancient mathematics, physics, astronomy and geography. The geocentric model of the Universe, which was developed in detail, is known in history as Ptolemy's System of the Universe.

We know little about his personal life; there are no legends or historical anecdotes about him, even though his works have come to us almost in full. His main work is the 13 volume "*Almagest*", which were translated from Greek into Arabic languages in the 7th - 10th centuries, then from Arabic into Sanskrit and into Latin in the 12th century, and, finally, from Latin into English, French, German and Russian. Up to the beginning of 17th century "*Almagest*" was the main textbook on astronomy. This work by Ptolemy shares with Euclid's "*Elements*" the distinction of being in practical use by scientists for the longest duration of time.

The first title of his great book was "*Mathematical Compilation,*" but that was changed to "*The Greatest Compilation*" (in Greek "*Megiste Syntaxis*"). The Arabic translation of the latter title came out as "*Al-kitabu-al-migisti*". The translator into Latin understood "*Al-migisti*" to be a name and transliterated the title instead of actually translating the meaning to the original.

Ptolemy gathered in "*Almagest*" all ancient approaches in astronomy and arranged them into a solid logical system. Our knowledge about the works of others came from that book; in particular, Hipparchus' discoveries are known only from Ptolemy's book.

"Almagest" contains a detailed model of the Universe with the Earth in the center of it, a catalogue of stars (coordinates and brightness of 1028 stars), a theory of the Solar motion, a calculation of the duration of a year, a theory of the Lunar motion, a theory of parallax, and rules for measuring the distance between the Moon and the Sun. The most important contribution of "*Almagest*" is the precise methods (for that time) of measuring planetary motion.

In addition to the "*Almagest,*" Ptolemy wrote an 8-volume book, "*Geography,*" and a 5-volume book, "*Optics,*" both of which also played a significant role in the development of corresponding sciences.

In "*Geography*" Ptolemy presented methods of cartography: how to find longitude and latitude on the Earth, how to transfer spherical images onto a plain, etc. He also listed more than 8000 names and coordinates of cities, islands, mountains, river mouths, etc. The theoretical aspects of cartography he presented are satisfactory even for today's elementary textbook. That book has played in geography the same role as "*Almagest*" in astronomy – it became a major textbook and handbook for centuries.

We know that "*Optics*" was a 5-volume book, but only three volumes have survived to today. Like many other ancient documents which have survived to today, these volumes survived only because they had been translated into Arabic from Latin. Here Ptolemy described the theory of reflection and refraction of light and an attempt of application of laws of the light propagation for evaluation how atmosphere influenced on astronomical observations. That book is the most comprehensive book on optics among all ancient books.

He wrote also a book on astrology "*Tetrabiblos*", where he gave descriptions of how the position of heavenly bodies influenced human fates. For many centuries it was the most influential book in use by fortunetellers.

Nicolas Copernicus
(1473–1543)

Great Polish astronomer, mathematician, philosopher, physician, lawmaker and theologian.

Copernicus put the Sun in the center of the Universe. The Inquisition pursued him and his followers and exacted severe punishments, including burning them at the stake.

Nicolas Copernicus is the Latin version of the famous astronomer's name; the original form of his name was Mikolaj Kopernik, but he chose to go by his Latin name in his later years.

Copernicus was born to a Polish merchant in a small fishing town at the mouth of the River Vistula. When his father died, 10 years old Nicolas began to live with his uncle, a Bishop of a tiny Polish province of Varmia in West Prussia.

He entered the Jagellon University in Krakow. Copernicus later wrote that his studies at the University were a vital factor in everything that he went on to achieve. There he studied Latin, mathematics, astronomy, geography and philosophy.

When he returned home, his uncle was determined that Copernicus should have a career in the Church. So, to get the necessary qualifications, Copernicus decided to go to Italy. First, he entered the University of Bologna to take a degree in canon law. There he studied Greek, mathematics and astronomy in addition to his official course of canon law.

After that he continued his education at the famous medical school of the University of Padua where he studied both medicine and astronomy. After this, he obtained his doctorate in canon law at the University of Ferrara. Then he returned to his native land.

Around 1514 he distributed a little book "*Commentariolus*" ("*Little Commentary*"), not printed but hand written, to a few of his friends who knew that he was the author even though no author is named on the title page. This book set out Copernicus's theory of the Universe with the Sun at its center. This manuscript by Copernicus was believed to have been lost until two copies were found in the 19th century.

Shortly thereafter he began writing his major work "*De revolutionibus*." Using data and concepts from Ptolemy's "*Amalgest*", Copernicus had found that only a heliocentric model of the Universe was consistent with the data. He began to create a new theory, which would be a complete and accurate methodology for solving various astronomical problems; it would be like a new "*Amalgest*". It was an important practical problem of the time because Ptolemy's methods produced inaccuracies, which had increased with time so much that some planet positions, as predicted, were in error by 30 days.

Rumors about Copernicus' ideas spread among Copernicus' friends and colleagues. The Bishop of Padua asked him to present his results publicly, but Copernicus only joked that Pythagoreans did not release their scientific results prematurely.

At that time, the Vatican decided to improve the calendar, which was known to be out of phase with the seasons, and the Pope appealed to experts for advice. One of these experts was Copernicus. Though many experts went to Rome, Copernicus chose to respond by letter. He did not wish to contribute more to the calendar because he felt that the motions of the heavenly bodies were still not understood correctly.

It was a period of frequent wars in the region, but in spite of war, Copernicus returned to his home and became a canon for the Cathedral in Frauenburg. He continued his research work whenever his duties permitted. Soon Frauenburg came under siege but Copernicus continued making his observations even at this desperate time. By the autumn of 1520 Copernicus organized the city defense against attacking forces.

When peace came at last to the city, Copernicus continued his observations and his work on the details of his heliocentric theory. His life's work under the title "*De revolutionibus orbium coelestium*" ("*Motion of heavenly spheres*") was published in Nuremberg just at the very end of his life. In fact, Copernicus's masterpiece might never have been published without the efforts of a young professor of mathematics and astronomy, Georg Joachim Lauchen (whose nickname was Rhaticus), who had been working with Copernicus during Copernicus' last years of life. A theologian who presented a heliocentric system only as a convenient model for astronomical calculations had written the preface to the book. Such an "umbrella" helped to publish the book.

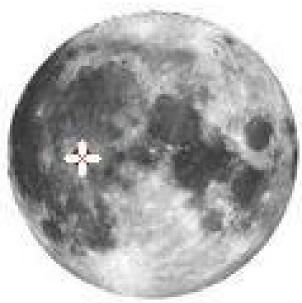
Copernicus is said to have received for the first time a copy of the printed book, consisting of about 200 pages written in Latin while on his deathbed. He died of a cerebral hemorrhage.

For some period of time Copernicus' book was freely distributed among scientists. The revolutionary nature of it has been understood only after Galileo's discoveries and Copernicus' heliocentric system was proved by observations.

In 1616 by the decree of the Inquisition, Copernicus' book was included in the "*Index of Forbidden Books*." After this, his book was abandoned for many years, and Copernicus' teaching was considered to be heresy.

Today one of the largest craters on the Moon's surface is named after Copernicus.

Copernicus crater on the Moon.



Crater's location.

Tycho Brahe
(1546–1601)

Outstanding Dutch astronomer.

He rejected Aristotle's concept of heavenly spheres, suggesting his ideas of elliptical orbits of the planets.

Tycho Brahe was born a gentleman by birth. His parents wanted him to be a diplomat and at age 13 sent him to the University of Copenhagen. However, their son chose mathematics and astronomy. At 17 he continued his education at the Leipzig University, and afterwards took courses at the universities of Wittenberg, Basel and Augsburg.

> Tycho Brahe was one of the most scandalously famous duelists of the time. At one of the duels, he lost a piece of his nose. A skillful surgeon could cover the wound with a silver plate (it is seen on his portrait). After that event, Tycho had a nickname "Nose".

In 1572 a "super" new star appeared in the night sky; it was the brightest object during about 16 months. By Aristotle's theory, the sphere of immovable stars is unchangeable, and all new stars and comets were considered just as flashes in the atmosphere. However, Brahe on the basis of his observations came to the conclusion that the new star is much farther than the Moon. Additional observations were needed.

Dutch King Frederick II, who was a generous patron of science, gifted Brahe an island where he had an observatory and living quarters built. By legendary account, he gave Brahe a barrel of gold for astronomical researches, as well as a substantial yearly pension.

Tycho Brahe built a real castle on the island and called it *Uraniborg* ("*Heaven Castle*"). Within the castle there were several observatories with movable roofs, libraries and laboratories. That scientific center began to attract talented people from all of Europe, and, to accommodate the greater number of scientists, Brahe built another castle – *Stjerenborg* ("*Star Castle*") and equipped it with a unique observatory well (to observe stars even in day time) and a workshop for producing the astronomic tools.

Tycho Brahe was, probably, the first who understood that precise tools, systematic observations and their scrupulous recording were the necessity for both practical and theoretical astronomy. With the help of his precise astronomic tools, he rejected the theory of heavenly spheres and introduced the concept of elliptic orbits for planets. In addition, he compiled a star catalogue with a precise description of about 8000 stars.

With 20 years of Brahe's observatory work completed, Denmark had become a leading European scientific center, and Brahe himself became the most authoritative figure in astronomy of the time.

Beyond his scientific genius, Brahe was well known for his arrogance and unbearable character that only his friends (including the king) could bear. Thus, after King Frederick's death, Brahe was out of favor and was forced to run from Denmark. He was accepted by Czech (today the Czech Republic); however there was no possibility to create a new observatory because he died within three years. Although his observatory was demolished, Brahe left the world with a talented pupil, Johannes Kepler, who became his scientific heir.

Giordano Filippo Bruno
(1548-1600)

Great Italian philosopher of the Renaissance, poet, and Dominican Monk.

He was the first to present the concept of multiple worlds within the Universe. He was burned at the stake by the Inquisition.

Filippo Bruno was born in the tiny town of Nola near Naples, Italy. Later in life, he assumed the nickname "*Il Nolano,*" meaning the fellow from Nola. When he was 11 years old, his parents sent him to a monastery school in Naples, where he studied literature, logics and dialectics. Four years later, he entered the Order of St. Dominic, giving up his worldly name of Filippo and taking that of Giordano. He made his novitiate in Naples and continued to study there. At age of 24 he was ordained priest.

He attracted attention by his outspoken criticism of accepted theological doctrines, which in four years of activity led to a formal accusation of heresy. From that point on, his life was reduced to wandering from one country to another, seeking but failing to find peace anywhere. In 1579 he went to Geneva, where he seems to have adopted the Calvinist faith, though soon on account of his disrespectful attitude towards the heads of that Church, he was obliged to leave the city. He moved to France.

In France he published some his satiric literature works. In 1583 he moved to England, and even enjoyed the favor of Queen Elizabeth.

Bruno intended to be a professor at Oxford but was refused, so he wrote a pamphlet about Oxford professors, saying that they knew more about beer than about Greek. Then he returned to London, where he published several works, the major of which was "*De l'Infinito, Universo e Mondi*" ("*On Infinity, the Universe and Worlds*"). In that book he developed further the Copernican heliocentric system. In particular Bruno claimed:

- The Earth is only approximately spherical, actually being flattened at the Poles.
- The Sun rotates around its axis.
- Immovable stars are heavenly bodies similar to the Sun.
- Around stars there are planets that revolve around them; nobody can see them because they are too distant from Earth.
- Those other planetary worlds might be in habited.
- Comets are a special kind of planet and they also move revolve the Sun.
- The Universe's worlds and even entire star systems are in the process of constant change, and they have the beginning and the end.
- "Eternal is only the inner power inherent to each atom".

Thus, Bruno presented a set of genius guesses in cosmology, which were very much ahead of his time. When the Church argued that it was impossible that there were a number of other worlds if God is single, Bruno had the temerity to answer that the basis of Christian religion is wrong.

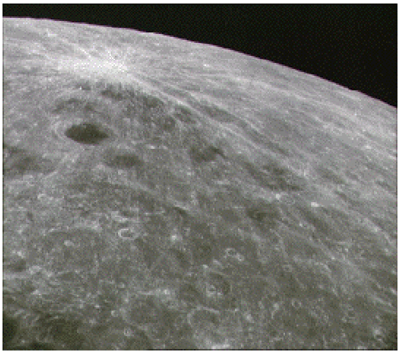
He was forced to leave England and in 1585 returned to France, attempting to reconcile with the Catholic Church. Refusing to accept the conditions imposed for reconciliation, Bruno moved to Germany. After some time spent in literary activity in Frankfurt, he went to Italy. A sponsor who invited him in 1591 to Venice denounced him to the Roman Inquisition. Bruno was arrested, and for six years was kept in the prison. In the spring of 1599, his trial was begun before a commission of the Roman Inquisition, and he was finally condemned to death, and on 17 February 1600 he was burned at the stake in the Campo dei Fiori in Rome.

By witnesses' testimony, when judges announced their verdict, Bruno said, "It seems that you are scared to read your verdict because I am listening to it." At the last moment he was asked to reject his ideas so that his life would be spared, but he answered, "I die a martyr voluntarily…"

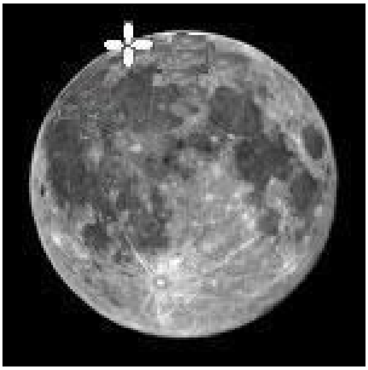
Giordano Bruno mostly is well known for his martyrdom. However, he was not only a martyr who preferred to die rather than recant his ideas but was a great philosopher who influenced future generations, who helped transform medieval philosophy into modern philosophy. His vision of the Universe was unique and almost unbelievable for his time.

By the way, he is the only one who is still on the Catholic Church list of "heretics."

In 1178 five people observed "fire, hot coals, and sparks" bursting forth from the Moon! Some scientists have suggested that the heavenly spectacle witnessed by that people was the impact that created the lunar crater Giordano Bruno, though some recent analysis casts doubt on this theory. Nevertheless, the crater (visible in the picture below as the bright white spot) named after the great astronomer.



Bruno Crater on the Moon.



Crater's location.

Johannes Kepler
(1571–1630)

Famous German astronomer, optician and mathematician. On the basis of huge astronomical records made by Tycho Brahe, he developed the laws of planetary motion.

Johannes Kepler is remembered chiefly for discovering the three laws of planetary motion. He was also a prominent optician who did important work in this area. In mathematics he is known for his discovery of two new regular polyhedrons, for giving the first mathematical treatment of the closest packing of equal spheres (leading to an explanation of the shape of the cells of a honeycomb), for giving the first proof of how logarithms work, and for devising a method of finding the volumes of solids of revolution, a precursor to the development of calculus. His input into astronomy cannot be overestimated; he calculated the so-called "*Rudolphine Tables*," which were most exact astronomical tables hitherto known, whose continued accuracy did much to establish the truth of heliocentric astronomy.

Kepler was born in the small town of Weil in Swabia, a wine region in southwest Germany not far from France. When he was 5 years old, his family moved to nearby Leonberg. His father was a mercenary soldier and his mother was the daughter of an innkeeper. Johannes was their first child. Soon after their move to a new place, his father left home and was killed in the war in the Netherlands. As a child, Kepler lived with his mother in his grandfather's inn, helping in the inn as a waiter.

His early education came from a local school and then a seminary. Being born two months prematurely, Kepler was sickly from birth, and contracted smallpox when was very young. His vision was severely defective, and he had various other illnesses fairly constantly throughout his life. He took twice as long as normal children to get through elementary Latin. He did a little better when he got to the higher school.

Kepler enrolled at the University of Tuebingen, a bastion of Protestant orthodoxy, which gave grants and scholarships for the poor, so he was able to get education. At the University, he studied mainly theology and philosophy, but also mathematics and astronomy. He also studied Greek and Hebrew for reading the scriptures in their original languages. All subjects were taught in Latin. At the end of his first year Kepler got the best academic grades for everything … except mathematics! However, very soon Kepler's exceptional intellectual abilities became apparent. He greatly admired his astronomy professor, who publicly taught the Ptolemaic scheme, but privately believed Copernicus. Kepler himself defended Copernicus' scheme in a public debate, which cost him a great price; after graduation, he was not offered a faculty position at Tuebingen and instead in 1594 he was sent as a professor of astronomy to Graz, Styria (now part of Austria). By the way, making astrological predictions was one of his duties there.

In 1596 Kepler had developed his first cosmological model based on Copernicus' vision of the Universe. Instead of the seven planets in standard geocentric astronomy, the Copernican system had only six, the Moon having become a body of a kind previously unknown to astronomy. Later, after Galileo had discovered in 1610 Jupiter's moons, Kepler coined the name "satellite" for such heavenly objects. In geocentric astronomy there was no way of using observations to find the relative sizes of planetary orbits. In the Copernican system, the fact that the annual component of each planetary motion was a reflection of the annual motion of the Earth allowed one to use observations to calculate the size of each planet's path, and it turned out that there were huge spaces between the planets.

In 1596 Kepler's wrote his "*Mysterium cosmographicum*" ("*Mystery of the Cosmos*"). He saw his cosmological theory as providing evidence for the Copernican theory. For instance, the Copernican theory can explain why Venus and Mercury are never seen very far from the Sun (they lie between the Earth and the Sun) whereas in the geocentric theory there is no explanation of this fact. Kepler lists nine analogous questions in the first chapter of the book.

He sent a copy of the book to one of the foremost astronomers of the time, Tycho Brahe and Galileo Galilei. Both scientific giants responded the author, fingering some mistakes but accepted the book as a whole.

In 1598, the young Archduke closed down the Lutheran school in Graz, where Kepler lectured. The new ruler had decided to cleanse the Austrian provinces of the Lutheran heresy. Kepler was allowed to stay for a while, but the next year he was given the choice either to embrace Catholicism or be expelled from Austria. He tried to go back to Protestant Tuebingen, but they didn't want him, because he was known as a "Copernican."

Tycho Brahe invited Kepler to come and work with him. At the time, Brahe escaping from Denmark had been living in Prague, which was the capital of the Holy Roman Empire. He served as Imperial Mathematician at Emperor Rudolph the Second's court. On January 1, 1600, Kepler accepted Brahe's invitation and left Graz for Prague.

When Kepler began working with Tycho Brahe, he realized that there would be problems with the use of Brahe's huge data set of observations. Brahe was very secretive with his model of the Universe, in which he has the Sun going around the Earth though all the other planets go around the Sun. It was some kind of funny compromise between Ptolemy's and Copernicus' systems.

Kepler was happy that Brahe invited him to work on the orbit of Mars, which was one of the least circular orbits, and thus presented a good test of Kepler's models. Kepler who was a virtuous master of calculations believed that it would be a job for a couple weeks. As it happened, he spent over 8 years of hard work, but the result was splendid. He found that calculations gave huge discrepancies with reality. Knowing the scrupulous quality of Brahe's observations, Kepler believed that the problem was not in erroneous data records but that it was due to wrong theoretical foundations. It forced him to create a new theory of planetary motion.

Johannes Kepler was the first philosopher who assumed that the Sun radiated some force that is the reason of planets' motion, because the Sun is the center of the planetary system.

Though Kepler supported Copernicus' model of the Universe that was against Christian Church dogmas, he was a deeply religious man; all his writings – from scientific papers to letters to his friends – contain numerous references to God, and he saw his work as a fulfillment of his Christian duty to understand the works of God. Kepler was convinced that God had made the Universe according to a mathematical plan. (As one can see, the viewpoint was close to ones of Plato and Pythagoras.)

In 1601, Tycho Brahe died in agony of a bladder infection, and Kepler succeeded him as Imperial Mathematician. He was promised a substantial salary, though he got it only once during 10 years of service. To support himself financially, he compiled horoscopes and calendars while he performed astronomical research.

Kepler's main task as Imperial Mathematician was to complete astronomical tables, the work, which Tycho Brahe had begun several years before, naming them "*Rudolphine Tables*" in honor of the emperor-patron. Calculating tables always involved enormous volume of arithmetic calculations, so Kepler was very glad when in 1616 he came across a book on logarithms. He calculated his astronomical tables with the use of eight-figure logarithms, which were published with the "*Rudolphine Tables*". However, he not only used the logarithms for his calculation, he gave a deep theoretical explanation of the nature of logarithm.

Kepler's dream was to write his second book "*Harmonices mundi libri*" ("*The Harmony of the World*"), which he had planned since 1599. This book was published in1619 and presented more elaborate mathematical models than in the previous one. Besides, this book contained Kepler's Third Law, that for any two planets the ratio of the squares of their periods will be the same as the ratio of the cubes of the mean radii of their orbits.

While Kepler was working on his "*Harmony of the World*", his mother, Katharina Kepler, was charged with witchcraft. She collected herbs and made potions, which she believed had magical powers. By the way, she was raised by an aunt who was burned at the stake as a witch, and Kepler's mother narrowly escaped a similar fate herself. Kepler did everything possible to save her; he hired several lawyers to defend his seventy-year-old mother. At last, his mother was released, partially as a result of technical objections; the correct legal procedure was not followed in the use of torture. However, even in that situation Kepler had strength to continue his work; in the coach, on his way to Württemberg to defend his mother, he read a work on music theory by Vincenzo Galilei (Galileo's father), to which there are numerous references in "*The Harmony of the World*".

After Brahe's death, Kepler made the best possible usage of Brahe's huge number of astronomical records. Based on this data, Kepler concluded that the orbit of Mars was an ellipse with the Sun in one of its foci (a result which when extended to all the planets is now called "Kepler's First Law"), and that a line joining the planet to the Sun swept out equal areas in equal times as the planet moved in its orbit ("Kepler's Second Law"). All those discoveries Kepler published in 1609 in his book "*Astronomia Nova*" ("*New Astronomy*"), which became the major scientific event of that time.

During those years, Kepler also paid attention to optics. He discovered that light intensity is inversely proportional to the square of the distance to the light source – this formula remains central in photometry.

Being fascinated by Galileo's use of the telescope in discovering the moons of Jupiter in 1610, Kepler in 1611 wrote a study on the properties of lenses, in which he presented a new design of telescope, using two convex lenses. This design was so successful that it had completely replaced Galileo's telescope and was called Keplerian telescope. Today we use Keplerian telescope, though call it simply the "astronomical telescope," forgetting about its creator.

After those many successful years in Prague, an avalanche of bad events befell Kepler: First, his two small sons died; then his wife died. In addition, a new Emperor came to rule and, being a Catholic, showed his negative attitude toward Kepler who was a Protestant. Thus, Kepler and his remaining children moved to Linz (Austria). In 1613 he married again; this time by necessity because he needed someone to look after his children. However, misfortune continued to follow after him; he lost two of his daughters.

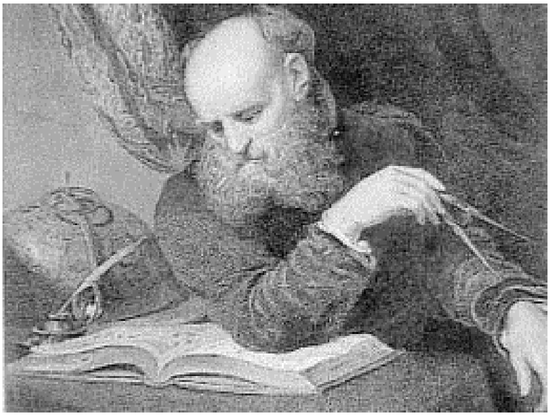
During this same period, Johannes Kepler was laboring on his greatest work, "*Epitome Astronomiae Copernicanae*" ("*Epitome of Copernican Astronomy*"), which was finally published in 1621. This publication tied together all of his previous work. This book, the first astronomy textbook based on the Copernican model, became the primary astronomical text for many years to follow.

In 1627 Kepler, after more than 20 years of hard work, had completed the "*Rudolphine Tables*." With those tables accurate predictions of eclipses of the Sun and Moon as well as the motion of planets could be made from 5509 BC up to 2000 AC. In the book, there were also catalogs of 1005 stars and coordinates of the largest cities of the World.

"*Rudolphine Tables*" replaced Ptolemy's "*Amalgest*" being at the time already obsolete.

Kepler died in Regensburg, after a short illness. He was staying in the city on his way to collect some money owed to him in connection with the "*Rudolphine Tables*". He was buried in the local church, but this was destroyed in the course of the Thirty Years' War and nothing remains of the tomb.

Galileo Galilei
(1564-1642)



Great Italian astronomer, physicist, mathematician and engineer. One of the founders of modern natural science.

Galileo was born in Pisa to a family of the minor nobility with limited financial means. His father was a teacher of music and a fine lute player, who composed music, which is played sometimes even now. His father was a well-educated man who wrote about music theory, read Aristotle and wrote polemic papers. However, all those activities were his hobbies that, because he needed to feed seven children, gave way to his job as retailer.

Galileo lived in Pisa and went to school until age 11, when his family moved to Florence. There he continued his education in a Benedictine monastery. He studied the so-called "seven arts," grammar, logic, rhetoric, arithmetic, geometry, music and astronomy. The Benedictine Order combined the life of the hermit with the strict life of the monk. Young Galileo found this life attractive and intended to join the Order, but his father had decided that he, as the eldest son, should become a medical doctor. Using the excuse that his son suffered bad vision, his father took him away from the monastery, and for the next two years he taught Galileo music, literature and fine art.

In 1581 Galileo enrolled for a medical degree at the University of Pisa. Galileo never seems to have taken medical studies seriously, attending courses on his real interests, which were in mathematics, practical mechanics and natural philosophy. At this time he got to know works by Aristotle, Euclid and Archimedes.

During this time he wrote his first work, on finding the center of mass of various bodies. The first reader of that work was his father who approved of his son's interest in mathematics and stopped insisting on a medical career.

After graduation Galileo began teaching mathematics in Florence and then in 1589 he became chair of mathematics at the University of Pisa. In 1591 Galileo's father died, and because Galileo was the eldest son, he had to provide financial support for the family. He was appointed professor of mathematics at the University of Padua (the University of the Republic of Venice) at a salary substantially higher than he had received at Pisa. His duties were mainly to teach Euclid's geometry and astronomy to medical students, who would need to know some astronomy in order to make use of astrology in their medical practice.

During his 18 years at this University, Galileo made most of his discoveries.

Arguing against Aristotle's astronomy and natural philosophy, Galileo in 1604 used parallax arguments to prove that the New Star (now known as "*Kepler's supernova*") could not be close to the Earth.

By artful experiments he proved that the Earth rotated around its axis, refuting Ptolemy's arguments that "if the Earth were rolling, then birds and clouds should be moved to the West."

To reject Aristotle's statement that the speed of a falling body is proportional to its weight, Galileo performed an elegant experiment. Proving the constant acceleration of freely falling bodies, he dropped simultaneously from the famous Tower of Pisa two balls similar in size, one wooden and the other metallic.

Later he discovered the Law of Inertia, namely that a body at rest tends to remain at rest unless acted upon by an outside force.

From some merchants, he heard that Dutch skippers use a tube with magnifying glasses to enlarge an image of far objects. Using his own technical skills as a mathematician and as a craftsman, Galileo began to make a series of telescopes whose optical performance was much better than that of the Dutch instrument. His first telescope was made from available lenses and gave a magnification of about four times. To improve on this Galileo learned how to grind and polish his own lenses and made an instrument with a magnification of around thirty times. Galileo immediately saw the commercial and military applications of his telescope (which he called a *perspicillum*) for ships at sea.

By the end of 1609 Galileo had turned his telescope on the night sky and began to make remarkable discoveries. In about two months, he made more discoveries that changed the world than anyone has ever made before or since.

Aristotle's heavenly spheres collapsed like house of cards… Mountains and craters were found on the Moon… The Milky Way appeared to consist of myriads of stars… Four "moons" orbiting around Jupiter were discovered… (He named the Jupiter moons "the Medici stars" in honor of Cosimo de Medici, who was the Grand Duke of Tuscany.) He observed Venus' phases, which proved that the planet was moving around the Sun…And the Sun … had spots on its surface! And all that was not a product of philosophical thinking and mathematical calculations; it was visible to anyone with a telescope.

Galileo's telescope among medieval educated people was effectively an explosion. Copernicus' ideas, which were mostly considered as the fantasies of a Slavic priest, now had the force of empirical observation behind.

In 1610 Galileo returned to the University of Florence in the position of "first mathematician." He was called to the Vatican, and nearly all-influential scientific societies invited him to lecture… He was in the zenith of his glory.

The astronomical discoveries he made with his telescopes were described in a short book called the "*Siderius Nuncius*" ("*Starry Messenger*"). The printing of 550 books was enormous by the standards of the day.

Only a month after his book was published, Galileo became Chief Mathematician at the University of Pisa and "Mathematician and Philosopher" to the Grand Duke of Tuscany.

Despite his private support for Copernicus' ideas, Galileo tried to avoid controversy by not making public statements on the issue. However, he was drawn into the controversy through his former student Castelli who actually supported him. Galileo wrote a letter to Castelli arguing that the Bible had to be interpreted in the light of what science had shown to be true. "May I assume that the same God who gifted us with our intellect and feelings kept in his mind that we will never use it?" – wrote he. A copy of the letter ended up in the hands of the Inquisition in Rome.

In 1616 the Pope ordered the Sacred Congregation of the Index to render the decision on the Copernican theory that, "Copernicus' teachings are false and contradict the Pythagorean teaching about the immobile Sun …" The cardinals of the Inquisition condemned the teachings of Copernicus, and Galileo was forbidden to hold heretical Copernican views.

But soon Maffeo Barberini, who was an admirer of Galileo, was elected as Pope, taking the name Urban VIII. This happened just as Galileo's book "*Il saggiatore*" ("*The Assayer*") was about to be published in 1623, and Galileo was quick to dedicate this work to the new Pope. Urban VIII invited Galileo to papal audiences on six occasions and led Galileo to believe that the Catholic Church would not make an issue of the Copernican theory.

Galileo began to write his most famous work– "*Dialogo sopra i due massimi sistemi del mondo Ptolemaico e Copernicano*" ("*Dialogues about two main Worlds systems – Ptolemy's and Copernicus'* "). It takes the form of a dialogue between supporter of the Copernican system, and an Aristotelian philosopher. Writing the book took him six years to complete. In the preface to the book, Galileo was forced to write that the Copernicus' theory was taken only as hypothesis.

After Galileo had completed work on the "Discourses," it was smuggled out of Italy, and was published in Holland. It was his most rigorous mathematical work, which treated problems on impetus, moments, and centers of gravity.

Shortly after the publication of "*Dialogue*", the Inquisition banned its sale and ordered Galileo to appear in Rome before them. Illness prevented him from traveling to Rome until 1633. Galileo's accusation at the trial was that he had breached the conditions laid down by the Inquisition in 1616. In June 1663, almost in the same place where Giordano Bruno had heard his verdict, 70-year old Galileo, on his knees, read the text of renunciation of his teaching. Found guilty, Galileo was condemned to lifelong imprisonment, but the sentence was carried out somewhat sympathetically and it amounted to house arrest rather than a prison sentence.

The legend says that Galileo had uttered "*Epur si muove*" ("*And yet it does move!*"), as he rose from his knees after renouncing the motion of the earth.

Under home arrest, he wrote "*Discorsi e Dimostrazioni Matemariche intorno a due nuove scienze*" ("*Discourses and mathematical demonstrations concerning the two new sciences*") and in an underhanded way sent the manuscript to Holland where it was published in 1638. It was published in a year in which Galileo had become blind, and he could only touch the cover of the book.

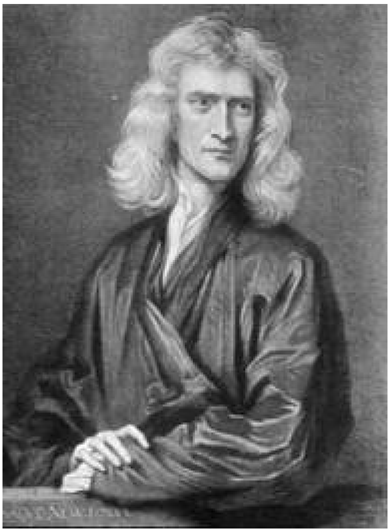
His will indicated that he wished to be buried beside his father in the family tomb in the Basilica of Santa Croce but his relatives feared, quite rightly, that this would provoke opposition from the Church. He was buried in a modest Florence cemetery in the presence only of his son and daughter-in-law, two pupils, and two Inquisition guards who followed him up to the end of his life. This grave was kept hidden until his body was moved by the civil authorities against the wishes of many in the Church to a fine tomb in the church in 1737.

Only on 31 October 1992, 350 years after Galileo's death, Pope John Paul II gave an address on behalf of the Catholic Church, in which he admitted that errors had been made by the theological advisors in the case of Galileo. He declared Galileo's case closed, but he did not admit that the Church was wrong to convict Galileo on a charge of heresy because of his belief that the Earth rotates round the sun.

Galileo's aphorisms

- I do not feel obliged to believe that the same God who endowed us with sense, reason, and intellect intended us to forgo their use.
- I have never met a man so ignorant that I couldn't learn something from him.
- All truths are easy to understand once they are discovered; the point is to discover them.
- Doubt is the father of invention.
- You cannot teach a man anything; you can only help him find it within himself.
- The Universe cannot be read until we have learned the language and become familiar with the characters in which it is written. The laws of Nature are written in the language of mathematics ...
- In questions of science, the authority of a thousand is not worth the humble reasoning of a single individual.
- It is very pious to say and prudent to affirm that the holy Bible can never speak untruth – whenever its true meaning is understood. But I believe nobody will deny that it is often very abstruse, and may say things, which are quite different from what its bare words signify.

Isaac Newton
(1643 - 1727)



…The science of classical mechanics was completed by the genius of Newton.

Niels Bohr[61]

Great British physicist, theoretical mechanic, astronomer and mathematician, one of the giants in science of all times and all people.

Isaac Newton was born on Christmas Day 1642 in the manor house of Woolsthorpe, near Grantham in Lincolnshire.

Isaac Newton came from a family of farmers. His father had died shortly before his son was born. The family was quite a wealthy, though Isaac's father was completely uneducated and could not even sign his own name.

Isaac's mother remarried, when Isaac was two years old. The young child was then left in the care of his grandmother. Treated as an orphan, Isaac did not have a happy childhood. His mother returned after 12 years with three more children.

Isaac began attending the Free Grammar School in Grantham. His first school reports described him as "idle" and "inattentive." His mother

[61] **Niels Henrik David Bohr** (1885 - 1962) was Dutch physicist, one of the creators of modern physics.

soon took him as the elder child to help her manage her estate, though Isaac showed no talent for that.

His uncle decided that Isaac should prepare for entering a university and Isaac was allowed to return to the same school to complete his school education. He lodged with the headmaster of the school, and probably then showed some academic promise, because the school headmaster persuaded Isaac's mother to let him enter university.

In 1661, Newton entered Trinity College, Cambridge, as one of the older students. Despite his mother's relatively good financial situation, he entered as a sizar, i.e. as a student receiving an allowance toward college expenses in exchange for serving other students.

Going to Cambridge for a law degree, Newton was exposed to philosophy, mechanics, astronomy, and optics. He kept a diary entitled "*Quaestiones Quaedam Philosophicae*" ("*Certain Philosophical Questions*"), from which one can make a fascinating account of how Newton's ideas were already forming around 1664. By the way, the epigraph of his diary was re-phrasing of Aristotle's aphorism, "Plato is my friend, Aristotle is my friend, but my best friend is truth" that portrayed him as a free thinker from the very early stage of his life.

Though there was some evidence that Newton was not specifically good in learning, nevertheless he received his bachelor's degree in 1665. In the summer of 1665, the University was closed because of the plague, and Newton had to return to Lincolnshire. During that ensuing two-year period Newton made remarkable advances in mathematics, optics, physics, and astronomy. He singled out those two years as "the prime of my age for invention."

When the University of Cambridge reopened after the plague in 1667, Newton put himself forward as a candidate for a fellowship. In October he was elected to a minor fellowship at Trinity College, and in a year after being awarded his Master's Degree, he was elected to a major fellowship.

His tutor at the college, Professor Barrow, sent to a publisher in London Newton's text "*De Analysi*" to make Newton's mathematical achievements known to the scientific world. When Barrow resigned in 1669, he recommended 27-year old Newton as an appointee for his position. By the University code, a professor had to take holy orders or leave the position. By the University's council request, the King by edict permitted the making of an exception for Newton. Such an action was almost impossible at that time.

Newton's first work in his new position was on optics. During those two years during plague, which he spent home, he came to the idea that white light is not a simple entity, being convinced of that by the chromatic aberration in a telescope lens. He passed a beam of sunlight through a glass prism and discovered the formation of the spectrum of colors.

Based upon this observation, Newton believed that telescopes using refracting lenses would always suffer chromatic aberration. It led him to the idea of constructing a reflecting telescope. This new construction of telescope opened for him the door to the Royal Society; in 1672, after the presentation of his report "New Theory of Light and Colors" Newton was elected a fellow of the Society. Notice that within 11 years he became President of the Society and was re-elected every year up to his death.

In the same year (1672) he published his first scientific paper on light and color in the "*Transactions of the Royal Society*". However, Newton's "*Opticks*" ("*Optics*"), dealing with the theory of light and color, appeared only in 1704. The book was largely written by 1692; however, its publication was delayed by Newton himself because Newton was extremely sensitive to criticism. By the way, in this book Newton expressed his view on the substance of nature, where, in a veiled form, he wrote about atoms and molecules, which are separated from each other by space, and in turn consisted of smaller particles also separated by space.

The book established itself, from about 1715, as a model of the interweaving of theory with quantitative experimentation.

Huygens objected to Newton's statements that light consists of the motion of small particles rather than waves, motivating their criticism by the fact that there were no theoretical proofs. Nevertheless, perhaps because of Newton's high scientific reputation, his corpuscular theory dominated until in the 19th century the wave theory was revived and shadowed Newton's theory.

Newton laid the foundations for differential and integral calculus. He called his discovery the "method of fluxions" ("*fluxion*" in Latin means "*flow*"), which was based on his essential insight that integration and differentiation are inverse procedures. Not only did Newton discover that these problems were inverse to each other, but he discovered general methods of solving problems of curvature using his "method of fluxions" and "inverse method of fluxions," methods that correspond to differential and integral calculus. Some notes on the subject related to as early as 1666. There are letters to friends and colleagues with some details and descriptions of the method.

In 1671 Newton wrote in Latin "*De Methodis Serierum et Fluxionum,*" but this work did not appear in print until an English translation in 1736.

More than 10 years later, Leibniz had independently discovered the same mathematical idea and named it as we call it now – differential and integral calculus. He invented convenient notations, proved some important results, though his approach appeared definitely than Newton's.

Newton's greatest achievements were in physics and celestial mechanics. The theory of universal gravitation was a real crown of those achievements. According to the well-known legend, Newton discovered the law of gravity by seeing an apple fall in his orchard at some time around 1665. He guessed that the same force governed the apple's fall, as did the motion of the Moon.

In 1687 Newton published the "*Philosophiae naturalis principia mathematica*" ("*Mathematical Principles of Natural Philosophy*"), or "*Principia*" as it is always known. This book is recognized as the greatest scientific book ever written. Newton analyzed the motion of bodies in resistive and non-resistive media under the action of centripetal forces. The results were applied to orbiting bodies, pendulums, and free-fall near the Earth. He further demonstrated that the planets were attracted toward the Sun by a force varying as the inverse square of the distance and, moreover, all heavenly bodies mutually attract one another.

Newton's work explained a wide range of phenomena that previously had been considered as unrelated: the eccentricity of the orbits of comets, the tides and their variations, the precession of the Earth's axis, and the motion of the Moon as it is perturbed by the gravity of the Sun.

He formulated three axioms, which later became known as the Newton's First, Second and Third Laws:

- First Law (Law of Inertia): A material point keeps its state of rest or uniform motion until acted upon by external forces.

- Second Law (Major Law of Dynamics): The acceleration of a body is proportional to the applied force, inverse proportional to its mass, and directed in accordance with the force direction.
- Third Law: When two bodies interact, two forces are applied to both bodies: they are equal in strength and opposite in direction.

This outstanding work proved the international Newton's leadership in science.

> Newton once was asked how long he took to formulate his famous physical laws. The great scientists replied that his laws are extremely simple and need almost no time. However, he had to spend almost his entire life to discover them.

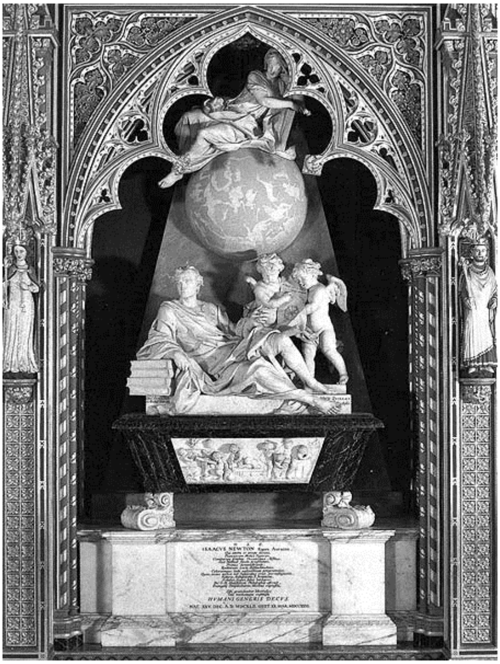
In 1693, Newton was suffering a nervous breakdown and retired from research. In 1696, Newton left Cambridge and took up a prestigious and highly paid government position as Warden of the Royal Mint in London. In 1699 he became Master of the Mint, and that made him a very rich man.

In 1703 he was elected President of the Royal Society and was re-elected each year until his death. Queen Anne knighted him in Cambridge in 1705, and, thus, he became the first scientist honored for his work.

Newton made incredible contributions in algebra (Newton's binomial) and analytical geometry; he created the concept of interpolation. However, his highest mathematical achievements were his creation of differential-integral calculus and fundamental discoveries in infinite sets. Unfortunately, Newton officially published his works almost always with a great delay, though he already would have sent his ideas to colleagues. He published his work on calculus after Leibniz[62], though he developed the method more than 10 years earlier.

[62] **Gottfried Willhelm Leibniz** (1646-1716), German philosopher, scientist, diplomat and statesman. Made a big input in mathematics (one of the creators of calculus) and physics (a prototype of principle of conservation of energy). He is also known as geologist, biologist, historian, linguist and author of some significant inventions. He was the first scientist (the second was Newton) who became the member of two major European academies – London Royal Society and Paris Academy of Sciences. He was a founder of Prussian Academy of Sciences in Berlin and compiled the project of Russian Academy of Sciences in St, Petersburg.

His last decades were passed in revising his major works, polishing his studies of ancient history, and defending himself against critics, as well as carrying out his official duties. Newton was modest, diffident, and a man of simple tastes. Criticism or opposition angered him; he was harsh towards enemies but generous to friends. In government, and at the Royal Society, he proved to be an able administrator. He never married and lived modestly, but was buried with great pomp in Westminster Abbey.



By his scientific methodology, Newton was a materialist; however he was deep Christian believer and an outstanding theologian. He created his version of Christianity with a unique God (he rejected the idea of a Trinity) and with Jesus Christ as a talented religious teacher though not God's son. Though he accepted the Bible as the Holy Book, he believed in Apocalypses, and he even tried to calculate the time of the creation and destruction of the Universe.

The Latin inscription on Newton's tomb proclaims: "Mortals! Rejoice at so great an ornament to the human race!"

Alexander Pope's[63] wrote in his dedication to Newton:

> Nature and Nature's laws lay hid in night;
> God said: "Let Newton be!" And all was light.

It is no exaggeration to identify Newton as the most important contributor to modern science and its development.

Newton's aphorisms

- It is the weight, not numbers of experiments that is to be regarded.
- Tact is the art of making a point without making an enemy.
- We build too many walls and not enough bridges.
- No great discovery was ever made without a bold guess
- If I have ever made any valuable discoveries, it has been owing more to patient attention, than to any other talent.
- I can calculate the motion of heavenly bodies, but not the madness of people.
- A man may imagine things that are false, but he can only understand things that are true, for if the things were false, the apprehension of them is not understanding.
- To me there has never been a higher source of earthly honor or distinction than that connected with advances in science.
- To myself I am only a child playing on the beach, while vast oceans of truth lie undiscovered before me.
- If I have seen farther than others, it is because I was standing on the shoulders of giants.
- If I have done the public any service, it is due to my patient thought.
- Errors are not in the art but in the artificers.

[63] **Alexander Pope** (1688 – 1744), one of the greatest English poets of the XVIII century.

Pierre-Simon Laplace
(1749-1827)

Great French mathematician, physicist and astronomer.

Founder of Calculus, Probability Theory, Mathematical Physics and Celestial Mechanics.

Pierre-Simon Laplace was born in Beaumont-en-Auge in Normandy. His father, Pierre Laplace, was in the cider trade; his mother, Marie-Anne Sochon, came from a farming family.

Between the ages of 7 and 16Laplace attended a Benedictine priory school. His father expected him to make a career in the Church, so at 16 Laplace entered Caen University to study theology. However, during his two years at the University, he showed his mathematical talents and his love of the subject. Once he knew that mathematics was to be his subject, Laplace left Caen without taking his degree, and went to Paris.

He presented the famous mathematician d'Alembert[64] with a letter of introduction from one of his teacher. Although Laplace was only 19 years old, when he arrived in Paris, he impressed d'Alembert, who began

[64] **Jean Le Rond d'Alembert** (1717 – 1783), French mathematician, mechanical physicist, physicist and philosopher, member of Paris Academy of Sciences. He was also one of the editors of the famous French "Encyclopédie." D'Alembert's method for the wave equation is named after him. He proved the fundamental theorem of algebra (Gauss- d'Alembert Theorem), stating that every complex polynomial of degree n has exactly n roots. D'Alembert was the illegitimate son of an artillery officer. His mother left the newly born child on the steps of the church of St. Jean Le Rond. Taken to a children's home, he was baptized Jean Le Rond, named after the church, on which steps he had been found. When his father returned to Paris, he made contact with his young son and arranged for him to be cared. His father died when Jean was only 8 but left enough money to give his son security. The boy enrolled in college in the name of Jean-Baptiste Daremberg but soon changed his name to Jean d'Alembert.

to teach him. Laplace's paper on the principles of mechanics excited D'Alembert's interest, and he recommended his student for a teaching position at the military school – École Militaire.

He began producing a steady stream of remarkable mathematical papers, the first presented to the Paris Academy of Sciences in 1770. This first paper, read to the Society but not published, was on maxima and minima of curves where he improved on methods given by Lagrange. His next paper on difference equations followed in half year afterwards, and he read it at the Academy.

The year 1771, being only 22 years old, Laplace made his first attempt to gain election to the Academy of Sciences but Vandermonde[65] was preferred.

He was elected to the Academy two years later for his model of the planets motion, which corresponds to the Newton's gravity law

Even Laplace's early works were major contributions to difference equations and differential equations with its applications to mathematical astronomy and to the theory of probability, two major topics of his entire life. His work on mathematical astronomy included a work on the inclination of planetary orbits, which was the first step towards his later masterpiece on the stability of the Solar system.

In the 1780s Laplace produced results of such depth and strength that it had made him one of the most important and influential scientists in the world. However, one of the obstacles holding back his recognition was his character; he had poor relationships with his colleagues, including his patron d'Alembert. They did not accept Laplace's public behavior; he was not modest about his abilities and achievements.

Applying quantitative methods to a comparison of living and nonliving systems, Laplace and Lavoisier[66] in 1780, with the aid of an ice calorimeter that they had invented, showed that respiration is a form of combustion. Although Laplace soon returned to his study of mathematical astronomy, this work with Lavoisier marked the beginning of a third important area of research for Laplace, namely, his work in

[65] **Alexandre-Theophile Vandermonde** (1735-1796), French mathematician, the founder of the theory of determinants. Known for his works on the theory of music.

[66] **Antoine Laurent Lavoisier** (1743–1794), French chemist, economist, and public servant. He is most noted for his discovery of the role oxygen plays in combustion.

physics particularly on the theory of heat which he continued to work on up to the end of his career.

In 1784 Laplace was appointed as examiner at the Royal Artillery Corps, and it happened that next year he examined 16-year old Napoleon Bonaparte.

In 1785 Laplace was promoted to a senior position in the Academy of Sciences.

In 1790, Laplace became a member of the Commission on weights and measures at of the Academy of Sciences. This committee worked on standardization of the metric system on a decimal base. When the Reign of Terror began in 1793, the Academy along with the other scientific societies went underground. The Commission was the only one allowed continuing but just before 1793 Laplace together with his wife and two children left Paris. He did not return to Paris until after July 1794. Laplace managed to avoid the fate of some of his colleagues during the Revolution, such as Lavoisier who was guillotined in May 1794. Nevertheless, he had some difficult times. He was involved in compiling the new calendar for the Revolution. Laplace knew well that the officially proposed scheme was wrong because the length of the administrative year did not fit with the astronomical data. However, he had to avoid overruling political dogma with scientific facts.

In 1795 the Academy of Sciences was reopened with the new name: the National Institute of Sciences and Arts. Also in 1795 the Bureau des Longitudes was founded and Laplace was among its founding members as the mathematician. Moreover, Laplace went on to lead the Bureau and the Paris Observatory.

Laplace presented his famous nebular hypothesis in 1796 in "*Exposition du systeme du monde*" ("*Explanation of the World System*").

There is a story that when Laplace presented this book to Napoleon, Napoleon, who was fond of asking embarrassing questions, remarked, "Messier Laplace, how have you written this book on the system of the universe, and have never even mentioned its Creator?" Laplace answered straightforwardly: "*Je n'avais pas besoin de cette hypothèse-là*" ("*I had no need of that hypothesis*"). Napoleon, greatly amused, replied "*Ah, but actually that is a fine hypothesis. It explains so many unexplainable things!*"

According to this hypothesis the Solar system has been evolved from a globular cloud of incandescent gas rotating around an axis through its center of mass. With time, that cloud cooled and rings broke off from its outer edge. These rings, in turn, finally condensed into the planets, while the Sun represented the central core. In this view, one should expect that the more distant planets are the older ones.

The book contains some extraordinary interesting thought for the time. In his book Laplace wrote, in particular: "... the small probability of collision of the Earth and a comet can become very great in adding over a long sequence of centuries. It is easy to picture the effects of this impact on the Earth. The axis and the motion of rotation are affected, the seas abandon their old position, and a large part of men and animals drown in a universal deluge or are destroyed by the violent tremors imparted to the terrestrial globe". These words likely have been said in modern times…

"*Exposition du systeme du monde*" was written as a non-mathematical introduction to Laplace's most important work "*Mécanique Céleste*" ("*Celestial Mechanics*"), which volume No.1 appeared three years later (in total there were 5 volumes). Laplace had already discovered the invariability of planetary mean motions. In 1786 he had proved that the eccentricities and inclinations of planetary orbits to each other always remain small, constant, and self-correcting. These and many others of his earlier results formed the basis for his great work. The five volumes of the "*Mécanique Céléste*" made him "*the Newton of France*".

Napoleon promoted Laplace first to a member and then Chancellor of the Senate. Then Laplace was appointed Minister of the Interior, because Napoleon always respected scientists,[67] and in addition he singled out his former mathematical professor. However, in fewer than two months Laplace was dismissed for administrative failure! The problem was that due to his scientific methodology, he began to scrutinize minor problems instead of solving large ones.

In 1805 he received the Legion of Honor Medal…However, in his memoirs written during his exile on St. Helena, Napoleon mockingly said that he removed Laplace from the office of Minister of the Interior, which he held in 1799, after only six weeks " ... because he brought the spirit of the infinitesimally small into the government.

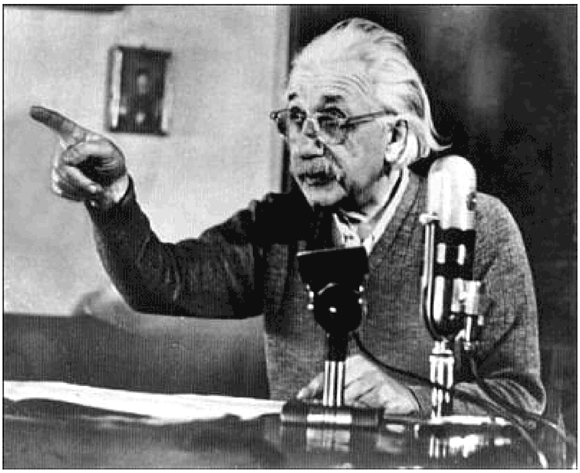
[67] It is the time to recall Napoleon's order that he gave during the Egyptian campaign; when the enemy attacked his army, "Donkeys and scientists in the center for safety!" He understood who was needed most!

The first edition of Laplace's "*Théorie Analytique des Probabilités*" ("*Analytical Theory of Probability*") was published in 1812. This first edition was dedicated to Napoleon-le-Grand. Later editions were published, naturally, with no dedication.

Laplace had a wide knowledge of all sciences and dominated all discussions in the Academy. Laplace attained World recognition; the Royal Society of London and the principal academies of Europe honored him with membership. His influence on the European scientific community was huge. It is interesting that Laplace, with his quite unique mathematical genius, viewed mathematics as nothing in itself but a tool to be called upon in the investigation of a scientific or practical inquiry.

On the morning of Monday, March 5 of 1827, Laplace died. Legend tells us that his last words were: "*What we know is not much. What we do not know is immense*". It seemed that no event could cause the cancellation of an Academy meeting but they did it on that day as a mark of respect for one of the greatest scientists of all time. In the epitaph of a French newspaper it was written, "Laplace was born to bring perfection, to exhaust all problems and to solve everything solvable. He even would have closed celestial mechanics if this science were not endless".

Albert Einstein
(1879-1955)



Great physicist, mathematician and public server, the father of Relativity Theory, one of the founders of the Quantum Mechanics.

Albert Einstein was born on March 14, 1879 in the German town Ulm, located on the bank of Danube at the foothills of the Alps. Six weeks later the family moved to Munich, and he began his schooling there at a gymnasium, where he studied mathematics. At the same time, influenced by his mother, he began to take violin lessons, which he continued until the age of thirteen. He remembered that time as boring exercises until he started to play Mozart. After that he could not leave a violin until his last days.

When Albert was five, his father showed him a compass, and the boy realized that something in "empty" space acted upon the needle. Later he described that childhood experience as one of the revelatories of his life.

It is said that at age 12, Albert took textbooks for the next grade. He found the book on geometry and was so involved in reading that read the book until had read it up to the end.

Music and geometry took a special place in Einstein's heart. He told that Mozart opened for him in music a new world as geometry did in science.

In 1894 Einstein's family moved to Milan but Einstein remained in Munich and next year he tried to enroll in the Swiss Federal Polytechnic School in Zurich where he intended to get a diploma of electrical engineer but he failed an examination.

In 1896 he entered the Polytechnic School to be trained as a teacher in physics and mathematics. In 1901 he gained his diploma and acquired Swiss citizenship. Upon graduation, Einstein could not find a teaching post, then his friend's father recommended him to the director of the Swiss Patent Office in Bern, and Einstein accepted a position of technical assistant there. He worked at the Office seven years.

While in the Bern patent office he completed an astonishing number of theoretical physics publications, written in his spare time and without any contact with colleagues or using literature. Einstein earned a doctorate from the University of Zurich in 1905 for a thesis "*On a new determination of molecular dimensions*".

In another paper he examined the phenomenon discovered by Max Planck, according to which electromagnetic energy seemed to be emitted from radiating objects in discrete quantities. His second paper, written also in 1905, proposed what is today called the special theory of relativity. The third of Einstein's papers of 1905 concerned statistical mechanics.

Most physicists agree that three of those papers (on Brownian motion, the photoelectric effect, and special relativity) deserved Nobel Prizes. Only the paper on the photoelectric effect would win one.

Later in 1905 Einstein showed how mass and energy were equivalent. His contribution is unifying parts of classical mechanics and Maxwell's electrodynamics.

In 1908 Einstein was appointed "*privatdozent*" at the University of Bern after submitting his thesis "*Consequences for the constitution of radiation following from the energy distribution law of black bodies*". The following year he became Professor Extraordinary at the University of Zurich.

In 1911 he was appointed Professor of Theoretical Physics at the Karl-Ferdinand University in Prague. This year was very significant for Einstein: he made predictions about how a ray of light from a distant star, passing near the Sun, would appear to be bent slightly, in the direction of the Sun. This prediction was highly significant because it gave a potential test for experimental confirmation of his theory.

Einstein returned to Germany in 1914, accepting an offer to take a research position in the Prussian Academy of Sciences and a chair at the University of Berlin. He was also offered the directorship of the Kaiser Wilhelm Institute of Physics in Berlin, which was to be established soon.

Late in 1915, Einstein submitted a perfect version of his general relativity theory. In fact, Hilbert submitted for publication, a week before Einstein completed his work, a paper that contains the correct field equations of general relativity.

When the British eclipse expeditions in 1919 confirmed Einstein's predictions that light from a star would be bent by the Sun, the popular press idolized him: "Revolution in science. New theory of the Universe. Newtonian ideas overthrown" ("The Times" headline on 7 November 1919).

In 1920 Einstein's lectures in Berlin were disrupted by anti-Semitic demonstrations. It was not still the time of governmentally supported anti-Semitism. Nevertheless, Einstein chose a long trip abroad. In 1921 he first time visited the United States and received the Barnard Medal. In the same year he received the Nobel Prize but not for relativity rather for his 1905 work on the photoelectric effect. Then he visited Japan, Paris (earlier in 1922), Palestine (1923), South America (1925).

Among further honors, which Einstein received, were the Copley Medal of the Royal Society in 1925 and the Gold Medal of the Royal Astronomical Society in 1926.

Indeed Einstein's life had been hectic and as the result in 1928 he had a physical collapse brought on through overwork.

By 1930 he made his second visit again to the United States, and in two years at his third visit to the USA he was offered a professorship at Princeton. The idea was that Einstein would spend seven months a year in Berlin, five months at Princeton. Einstein accepted and left Germany in December 1932 for the United States. The following month the Nazis came to power in Germany, and Einstein was never to return there.

After Adolf Hitler came to power in 1933, Einstein was accused by the National Socialist regime of creating "Jewish physics" in contrast with "Deutsche Physik." Einstein renounced his German citizenship and stayed in the United States, where he was granted permanent residency in 1935. He accepted a position at the newly founded Institute for Advanced Study in Princeton, New Jersey. In 1935 he received the

Franklin Medal of the Franklin Institute. He became an American citizen in 1940, though he still retained Swiss citizenship.

In 1939 Einstein sent a letter to President Franklin Delano Roosevelt urging the nuclear study for military purposes, under fears that the Nazi government would be first to develop atomic weapons. Roosevelt responded to this by setting up a committee for the investigation of using uranium as a weapon, which had grown up into the giant Manhattan Project.

Einstein was deeply shocked by the bombing of Hiroshima and Nagasaki. After the war, Einstein lobbied for nuclear disarmament and a world government: "I know not with what weapons World War III will be fought, but World War IV will be fought with sticks and stones".

By 1949 Einstein was unwell. Being in a hospital, he began to prepare for death by drawing up his will. One more major event was to take place in his life. After the death of the first president of Israel in 1952, the Israeli government decided to offer Einstein the post of second president, which he declined. At that time he participated in establishing the Hebrew University of Jerusalem.

In the beginning of 50s Einstein began to form a generalized theory of gravitation with the Universal Law of Gravitation.

In his final week of life, Einstein signed his last letter. It was a letter to Bertrand Russell in which he agreed that his name should go on a manifesto urging all nations to abandon nuclear weapons.

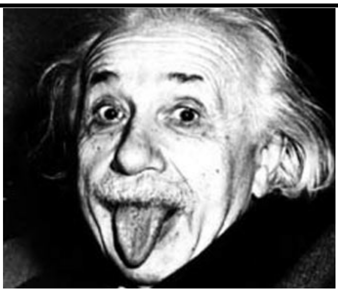
He died at a hospital in Princeton on April 18, 1955, leaving the Generalized Theory of Gravitation unfinished. Present at his deathbed was only a hospital nurse, who said that just before death Einstein mumbled several words in German, which she did not understand. He was cremated without ceremony on the same day he died, in accordance with his will. His ashes were scattered at an undisclosed location.

Einstein's Aphorisms

- All religions, arts and sciences are branches of the same tree.
- Any intelligent fool can make things bigger, more complex, and more violent. It takes a touch of genius – and a lot of courage – to move in the opposite direction.
- Anyone who has never made a mistake has never tried anything new.

- As far as the laws of mathematics refer to reality, they are not certain; and as far as they are certain, they do not refer to reality.
- Before God we are all equally wise and equally foolish.
- Do not worry about your difficulties in Mathematics. I can assure you mine are still greater.
- Education is what remains after one has forgotten everything he learned in school.
- Everything should be made as simple as possible, but not simpler.
- God is subtle but he is not malicious.
- Gravitation is not responsible for people falling in love.
- I am convinced that God does not play dice.
- I have no special talent. I am only passionately curious.
- I never think of the future – it comes soon enough.
- I want to know God's thoughts; the rest are details.
- If the facts don't fit the theory, change the facts.
- If you are out to describe the truth, leave elegance to the tailor.
- Imagination is more important than knowledge. Knowledge is limited. Imagination encircles the world.
- Information is not knowledge.
- Insanity: doing the same thing over and over again and expecting different results.
- Intellectuals solve problems, geniuses prevent them.
- Most of the fundamental ideas of science are essentially simple, and may, as a rule, be expressed in a language comprehensible to everyone.
- Most people say that is it is the intellect, which makes a great scientist. They are wrong: it is character.
- Never lose a holy curiosity.
- Only a life lived for others is a life worthwhile.
- Only two things are infinite, the universe and human stupidity, and I'm not sure about the former.
- Pure mathematics is, in its way, the poetry of logical ideas.
- Reading, after a certain age, diverts the mind too much from its creative pursuits. Any man who reads too much and uses his own brain too little falls into lazy habits of thinking.
- Reality is merely an illusion, albeit a very persistent one.

- Science is a wonderful thing if one does not have to earn one's living at it.
- Science without religion is lame, religion without science is blind.
- The difference between stupidity and genius is that genius has its limits.
- The eternal mystery of the world is its comprehensibility.
- The important thing is not to stop questioning. Curiosity has its own reason for existing.
- The most beautiful thing we can experience is the mysterious. It is the source of all true art and all science. He to whom this emotion is a stranger and can no longer pause to wonder and stand rapt in awe, is as good as dead: his eyes are closed.
- The most incomprehensible thing about the world is that it is at all comprehensible.
- The only real valuable thing is intuition.
- The only source of knowledge is experience.
- The only thing that interferes with my learning is my education.
- The problems that exist in the world today cannot be solved by the level of thinking that created them.
- The pursuit of truth and beauty is a sphere of activity in which we are permitted to remain children all our lives.
- The tragedy of life is what dies inside a man while he lives.
- The value of a man should be seen in what he gives and not in what he is able to receive.
- The whole of science is nothing more than a refinement of everyday thinking.
- The world is a dangerous place, not because of those who do evil, but because of those who look on and do nothing.
- There are only two ways to live your life. One is as though nothing is a miracle. The other is as though everything is a miracle.
- To raise new questions, new possibilities, to regard old problems from a new angle, require creative imagination and marks real advance in science.
- Try not to become a man of success but rather to become a man of value.
- You can never solve a problem on the level on which it was created.



Myths and stories about Einstein.

At an interview, Einstein was asked, "Do you have a special notebook for writing down your genius ideas?" Einstein responded, "You ask me if I keep a notebook to record my ideas? I've only ever had one... No need of a notebook."

• • •

Once at the public lecture Einstein was asked how he did his great discoveries. After a while he answered, "It is so simple. Assume that everybody knows that some statement in improvable. However some ignoramus does not know this. Just this person will have made a discovery!"

• • •

Einstein loved Chaplin's movies. Once he sent him a wireless, "Your last movie. I admire you. Everybody in the World understands it. Sure that you will be a great man. A.E." Chaplin sent the message back: "Your Relativity Theory is understood by nobody; nevertheless you are a great man. C.C."

• • •

In Odessa (Ukraine) people are awaiting Einstein's arrival for a lecture. A man asks his friend: "What is it – Relativity Theory?" –"Well… How to explain it to you? You see – one hair on the head is too few, however one hair in the soup is too many, do you agree?" – "Sure!" – "so, you see, everything in this World is relative…" – " And with this joke he came to visit Odessa?!"

• • •

Once Einstein was at the reception at the King of Belgium; after a lunch, there was a concerto where the Queen played violin. After the performance, Einstein come to the Queen and told her, "Your Majesty, you have played perfectly! I wonder why you need the profession of Queen?"

• • •

Once Einstein explained to his wife's friends the difference between telephone and radio, "You see, wire telegraph is a kind of a very, very long cat. You pull his tail in New York and his head is meowing in Los Angeles. Do you understand this? And radio operates exactly the same way: you send signals here, they receive them there. The only difference is that there is no cat".

SUMERIAN CIVILIZATION

(IV – II millennium BC)

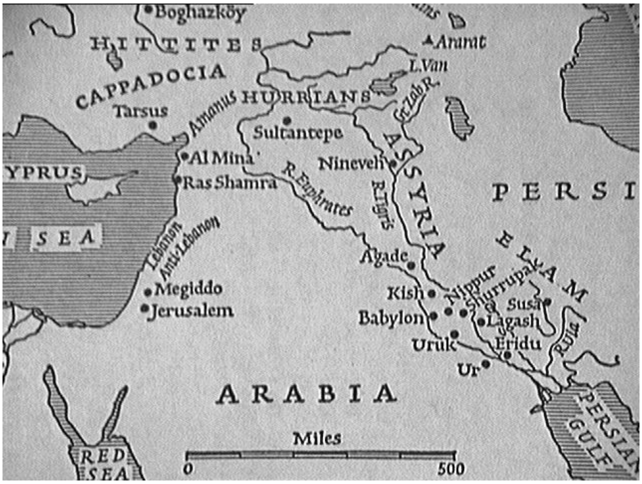
1 **Ancient "advertisement" for Sumerian Beer**

Among historians, there is a consensus that Sumeria was the cradle of human civilization. That relatively small number of people gave to the World more than any other group in the history of mankind.

Civilization has a number of definitions. Some historians say that a civilization is characterized by urban life, other characterize a civilization by existence of a system of writing, monumental architecture and an art. All these characteristics of civilization first appeared in Mesopotamia.

In ancient days, Mesopotamia (Greek for "between the rivers") was the name of the area between rivers Tigris and Euphrates. The Northern part of the area was Akkadia, which was inhabited by Semitic peoples. On the South to them was Sumeria, located just at the delta of the two-river system (now the very Southern part of Iraq).

When a new Semitic people called the Amorites conquered the area about 2000 BC, they founded a great new capital city of Babylon after which the area henceforth came to be known as Babylonia.



Around the 4th millennium BC, some people migrated from their homeland, located probably northeast of Mesopotamia, perhaps in the Caspian Sea area. The newcomers, who became known as Sumerians, spoke an agglutinative language unrelated apparently to any other known language. The name "*Shumer*" to those whom we call Sumerian was given by their neighbors, Akkadians, living next to them.

The Sumerians described themselves as "*the black-headed people*" (*sag-gi-ga*) and called their land *ki-en-gir* that means "*place of the civilized lords*".

The land where Sumerians had settled was mostly swamp, and the delta could only be made habitable by large-scale irrigation and flood control. Sumerians developed an excellent irrigation system, which allowed them to have a splendid agriculture. For the first time in human history, wheat farming and cattle rising were performed on a grand scale.

Sumerians brought to early human civilization various tools, gadgets and technological inventions. The greatest among them are the invention of the wheel: about 3500 BC wheeled vehicles appear in the form of ass-drawn war chariots. Wheels were made from a solid piece of wood.

Approximately at the same time the oldest known sailing boat was represented by a model found in a Sumerian grave. (Water transport down the Tigris and Euphrates was used for delivering stone, metals, and timber from Syria and Asia Minor.)

Another very important invention was the potter's wheel, first used in Sumeria soon after 3500 BC. Earlier, people made pots by molding clay by hand, but with the Sumerian invention symmetrical items could be produced in a much shorter time. A pivoted clay disk heavy enough to revolve of its own momentum, the potter's wheel was, actually, the first really mechanical device ever used by man.

Before 3000 BC the Sumerians had learned to make tools and weapons by melting copper with tin to make bronze, a much harder metal than copper alone.

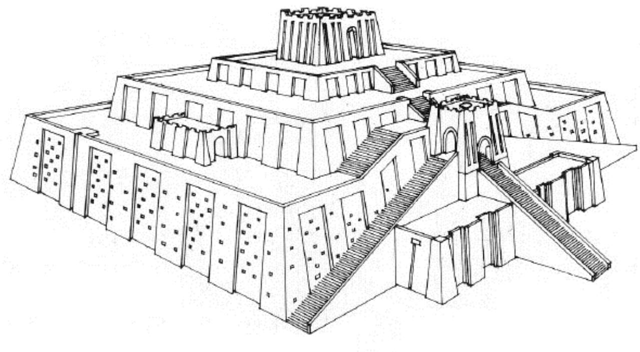
The list of Sumerian inventions is quite large; in addition to the wheel and potter's wheel they are, in particular: the plough, daggers, saws, burn bricks, architectural arc, leather, chisels, hammers, braces, bits, nails, pins, needles, rings, hoes, axes, knives, arrowheads, swords, glue, water skins, lance points, bags, harnesses, armor, quivers, scabbards, boots, sandals, harpoons, and beer brewing.

These inventions and innovations easily place the Sumerians among the most creative cultures in human pre-history and history.

In the earliest known period, Sumeria was divided into several independent city-states, the most widely known of them were Eridu, Kish, Lagash, Uruk, Ur, and Nippur. Large cities arose up to from 20,000 to 40,000 people. The city of Uruk probably had a population around 45,000 at the end of Sumerian era.

These early cities, which existed by 3500 BC, were called temple towns; in the center of each city there was a temple that housed the city's gods. Around each city were fields of grain, orchards of date palms, and land for herding. Besides planting and harvesting crops, some Sumerians hunted, fished, or raised domestic animals.

The temples were eventually built up on towers called *ziggurats* ("*holy mountains*"), which had ramps or staircases winding up around the exterior. It is astonishing that those ziggurats in architecture sense were very close to Maya's temples. Public buildings and marketplaces were built around these shrines.



Ziggurat in Ur (reconstruction)

Thus, at a time when most people were nomads and lived in small villages, the Sumerians built cities with 2- and 3-story houses, defense walls around cities, water storages, and high watchtowers…

The Sumerian language is unrelated to any other known languages. Sumerians invented picture-hieroglyphs that developed into cuneiform, which are known as the oldest written human language. The clay tablets on which they wrote were very durable when baked. Archaeologists have dug up many thousands of them – some dated earlier than 3000 BC. Fortunately, hundreds of thousands of clay tablets with Sumerian texts have survived through long time of wars and natural cataclysms. And unfortunately, a lot of priceless tables were lost for humanity during waves of looting in 2003 at the time of Iraq war…

Those texts include personal and business letters, receipts, laws, hymns and poems as well as mathematics, astronomy, and medicine scripts. Sumerian continued to be the language of religion, law and science in Mesopotamia and even in ancient Egypt and Greece long after Semitic speakers had become the ruling race.

Following the invention of cuneiform writing, a rich epic literature was created, of which the three most impressive survivals are the story of the creation, an epic of the flood which parallels in many details the Biblical story of Noah, and the Epic of Gilgamesh, two-thirds god and one-third man.

As all other pre-historic peoples, Sumerians idolized nature and the sky. The Sumerians worshipped An as the primary god, equivalent to the sky (the meaning of Sumerian word "an"). The goddess Inana was the deification of Venus. By the way, Sumerians already knew that the morning (eastern) and evening (western) star is the same star. The sun was called Utu and the moon was called Nanna. She was the Mother Goddess. Each Sumerian god, or "*dingir*," (the Sumerian name for god) was a patron of a particular city. The gods were said to have created human beings from clay for the purpose of serving them. (The myth is very close to the Bible version.) Sumerians believed that the universe consisted of a flat disk enclosed by a tin dome.

Sumerians had a developed religion, which significantly influenced Babylonian, Egyptian and Jewish religious concepts. Clay tables present us cuneiform texts with myths about the creation of the World, the Flood, Heaven and Hell, Golden Age – all those were written ahead of the Biblical scripts at least on a millennium!

About 150 chef-d'oeuvres of Sumerian literature have survived to our day: They are myths, religious hymns, collections of fables, people sayings, etc. Among them is the first poem, the "Epic of Gilgamesh". Latest discoveries give is a hint that Gilgamesh is a historical figure – the King of city-state Uruk, who was idolized after his death. Linguists also have found a collection of "Aesopian fables", which preceded the famous Greek[68] by about a millennium.

[68] By legend, Aesop was a Frakian slave on the Island of Samos. Having no possibilities to tell openly the truth to his masters, he transformed his thoughts into stories about animals. There is a legend that indeed Pythagoras was the author of those fables, who used them for teaching his pupils and at the judicial processes when he was asked to be an arbitrator.

Sumerians had professional physicians. There are clay tables with concrete recipes for the making of medicine and for treatment recommendations. They had professional teachers who taught botany, zoology, geography, and mathematics to the children of rich families; they used cuneiform texts with problems descriptions and mathematical tables. In solving arithmetic, geometrical and astronomical problems Sumerians were doubtlessly ahead of the ancient Babylonians, Assyrians, Egyptians and Jews. Only the ancient Greeks surpassed them. Though, it is worth mentioning that Hipparchus in the 2nd century BC studied Sumerian astronomical tables (the Sumerian language still remained a language of science after 2000 years after disappearance of Sumerian city-states!). Those tables were in use 15 more centuries!

Probably it was Sumerian religion that gave rise to their interest in the sky and heaven's bodies. Sumerian astronomy recognized and cataloged the brightest stars, outlined a rudimentary set of Zodiacal constellations, and noted the movements of the five visible planets (Mercury, Venus, Mars, Jupiter, and Saturn), as well as the Sun and Moon amongst the stars of the Zodiac.

Sumerians also developed a rudimentary system of astrological divination for use in foreseeing the future of city-states and battles, but not for predicting personal futures.

Both for religious and agricultural purposes, they studied the heavens, and they created a lunar calendar, based on the phases of the moon. A year consisted of 12 lunar months, a week of seven days, and a day of 24 hours. The month began at sunset, with the first visible (thinnest) crescent of the New Moon. To make up for the difference between this year and the year of the seasons, they inserted an extra month in the calendar about every four years.

They came up with the concept of dividing an hour into 60 minutes and a minute into 60 seconds.

In ancient Sumeria there were two seasons in a year - a summer season *Emesh* which began on the Vernal Equinox - and a winter season, *Enten*, which began on the Autumnal Equinox. New Year Day was an important holiday. This was celebrated around the Vernal Equinox, depending on the synchronization of the lunar and solar calendars.

The New Year and month would begin on the first New Moon, after the completion of the old lunar year.

The day began and ended at sunset and contained twelve "hours." It is important to note the similarity of the old Sumerian calendar and the Hebrew calendar, including the timing of the Hebrew Passover (around the same time as the Sumerian New Year), and the beginning of the Hebrew Sabbath (at sundown).

They invented mathematical tables and used quadratic equations. The Sumerians based their number system on 10, but they multiplied 10 by 6 to get the next unit. They multiplied 60 by 10, and then multiplied 600 by 6, and so on. (The number 60 has the advantage of being divisible by 2, 3, 4, 5, 6, 10, 12, 15, 20, and 30.) The Sumerians also divided the circle into 360 degrees. From these early people came the word dozen (a fifth of 60) and the division of the clock to measure hours, minutes, and seconds.

Much of this science was transmitted to the West by the Greeks and later by the Arabs.

From its beginnings to its final collapse under the Amorites around 2000 BC, the Sumerians developed a religion and a society, which influenced both their neighbors and their conquerors. In fact, traces and parallels of Sumerian myth can be found in the Bible.

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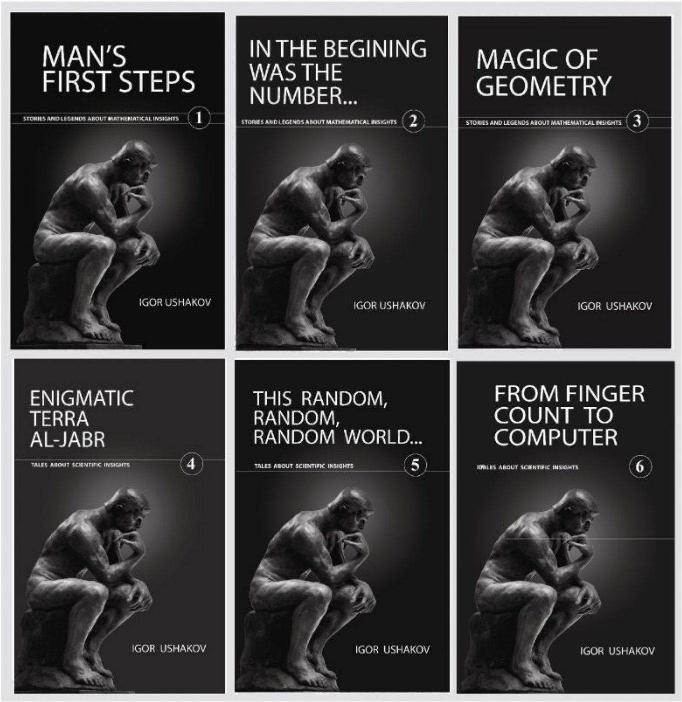

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