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НАЦІОНАЛЬНИЙ ТЕХНІЧНИЙ УНІВЕРСИТЕТ
«ХАРКІВСЬКИЙ ПОЛІТЕХНІЧНИЙ ІНСТИТУТ»

С. С. Ткаченко, М. В. Гутник, В. А. Садковська

HISTORY OF SCIENCE AND TECHNOLOGY

Навчальний посібник для студентів 1-4 курсів денної форми навчання

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Навчальний посібник «Історія науки і техніки» призначено для студентів-бакалаврів, які вивчають дисципліну англійською мовою. Матеріал для кожної із тем висвітлює певний історичний період розвитку історії науки і техніки від стародавніх часів до сьогодення. Остання тема присвячена вивченню історії НТУ «Харківський політехнічний інститут».

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The tutorial The History of Science and Technology is intended for undergraduate students who study this academic subject in English. The material for each of the themes covers a specific historical period in the history of science and technology from ancient times to the present. The last theme is devoted to the study of the history of NTU “Kharkiv Polytechnic Institute”.

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Content

Introduction

The Course of History and Technology is a special historical discipline researching the process of evolution of scientific ideas, forms of organization of science, activity of scientific schools and individual scientists with the purpose of reconstruction of the whole picture of history of science, identification of conceptual basis and regularities of its development.

History of Science was of particular interest in the XIX century. In 1892 the first Department of History of Science was founded in France. This course is the synthesis of humanitarian and natural knowledge aimed at forming holistic view of historical changes occurred in science and technology in the context of human civilization development.

The objective of the course is studying the main stages, processes and events in the History of Science and Technology since the ancient times till nowadays in the context of the main tendencies of human and world development. The task of the course is obtaining the holistic view of the development of science and technology as historical and cultural phenomenon by the students as a result of perceiving educational material.

The history of science and technology is an integral science, which consists of social, humanitarian and natural sciences.

Science is the study of the nature and behavior of natural things and the knowledge that we obtain about them. Science is a sphere of researching activity, which is directed to the producing of a new knowledge about nature and society.

Scientist is a person who studies or masters special knowledge in science. A scientist tries to understand how our world or other things work.

Technology is a basis of knowledge devoted to creating tools, processing actions and the extracting of materials. The term “Technology” is wide, and everyone has their way of understanding its meaning. We use technology to accomplish various tasks in our daily lives; briefly we can describe technology as products and processes used to simplify our daily lives. We use technology to extend our abilities, making people the most crucial part of any technological system.

Science and a technology are organically connected with each other. Science influences the technological development; a technology stimulates the scientific development.

The periodization of the history of science

The modern science appeared only in the XVII century, as a result of the scientific revolution in the natural science.

1. Pre-scientific period (till XVII century):
   a) The Ancient world;
   b) The Middle ages;
   c) The New times.
2. Scientific period (XVII cent. – nowadays):
   a) XVII century;
   b) At the turn of the XIX and XX centuries;
   c) The beginning of the XX century;
   d) From the middle of the XX century till nowadays.

Scientific revolution is a collection of new scientific discoveries, which promoted to the formation of new conceptions about human and nature.

Technical revolution is technical discoveries that led to fundamental changes in mass production.

The using of tools became an important element of historical development. That is why ancient history is divided by the dominant using of tools.

a) Stone Age
b) Bronze Age
c) Iron Age

In the history of the technology development two ways can be identified – evolutionary (gradual accumulation and change of tools or devices) and revolutionary dealt with drastic changes in mechanisms, use of new sources of energy and stage change of society.

THEME 1. SOURCES OF EUROPEAN CULTURE

The history of science and technology is characterized not only by the discoveries, but also by the names of their founders. Destiny of both the inventors and their creations is often tragic. In the modern world there are features of all previous epochs. Whatever discoveries are made today, they are based on the foundation created by many generations – from ancient times till today.

The Egyptian and Babylonian civilizations were among the most ancient in the history of mankind. Rudiments of knowledge created by them in the ancient times became the basis of our ancestors' notions about the world around. The culture of the western civilization both material and spiritual would be impossible, if it did not rely on this knowledge. Knowledge accumulated in Ancient Egypt and Ancient Babylon was borrowed by Persia, and passed to the Greek-Roman civilization. Then it was transferred to the European culture.

Egypt. Rudiments of applied mathematics, astronomy, medicine were known to the ancient Egyptians. In IV BC solar (gnomon) and a water-clock (clepsydra) were invented. Mathematical papyruses of the Egyptians contained collections of tasks with answers. Arithmetic and geometrical progressions, proportions, symbolical designations of fractions were used in calculations. In the epoch of the Middle kingdom (before XIV century BC) the equations with two unknowns and stereometry elements were known. The Egyptians had a decimal system of calculation. They were able to calculate the area of a triangle, a trapeze and a circle, accepting number π=3.14.

Copyists spent the most part of their time calculating the areas of the cultivated lands, quantity of products or defining the number and qualification of the personnel, etc. It was especially important to transfer the cost of certain items to the other items (money was not known in Egypt and barter was used), to calculate a salary and taxes. It demanded the knowledge of such operations, as squaring the number and square rooting. In Egypt the geometry took a special place. There was the knowledge in the field of planimetry and stereometry. The accuracy in building the pyramids, palaces and sculptural monuments is the evidence of that.

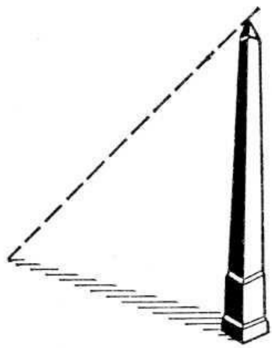

Fig. – Gnomon[1]

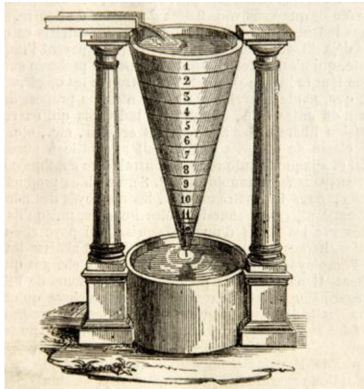

Fig. – Clepsydra

In the base of a calendar which we use today is the Egyptian calendar. The real duration of a year – 365 days – is difficult to establish. Long and careful supervision over the Sun and the stars is necessary for this purpose. Such observations were carried out by the priests in Egypt about 2700 BC and led to drawing up a solar calendar. It is assumed that the first calendar was introduced by the Egyptian priest Imhotep (2650 BC). The calendar appeared so perfect that it is used today with some changes. Such calendar met the requirements of agriculture. The division of a day into 24 hours became the contribution to astronomy. Egyptians created a sky map, grouped stars and constellations.

Knowledge in medicine is considered to be the most important contribution of the ancient Egyptians to science. Historical documents testify that their reputation in the field of medicine and pharmacology was very high. Ancient Egyptian doctors dealt with diagnostics. The doctor was simultaneously both a priest and a magician that is a characteristic feature for the whole East where there was no clear boundary between medicine and religion. But in Ancient Egypt for the first time in the world history,

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[1] *This one and all the following illustrations are taken from the open sources*

there a real medicine existed in modern understanding of this word. The European medicine is based on the Egyptian medicine.

The widespread custom of embalming promoted the development of a human body anatomy and surgery. From the sources we receive the notion of surgical experience of the Egyptians. They had some idea about heart and brain function, treating teeth. The Egyptians had the set of surgical tools in the epoch of the Ancient kingdom (in the end of IV–III BC). Success of the ancient Egyptians in mummification couldn't be reached without corresponding knowledge in physics, chemistry, medicine, surgery. Mummification skills were forgotten after the conquest of Egypt by Alexander the Great in 332 BC.

In Ancient Egypt geographical knowledge was accumulated throughout many centuries. In the Middle Ages they promoted the geographical discoveries connected, first of all, with the search of the ways to India from the European continent. The Egyptians didn't know that the Earth had the form of a sphere.

The invention of writing was the large achievement of the ancient Egyptian culture. To write on the stones The Egyptians used special signs – hieroglyphs to write on the stones, and the simplified cursive writing to write on the papyrus.

Thus, the Egyptians had enough knowledge of the world around. But this knowledge had the applied character. They did not rise to the level of generalization and conclusions. The priests were the basic social stratum storing scientific knowledge in Egypt. They were the teachers in the schools of Memphis and Thebes – the largest centers of concentrating the scientific thought in Egypt. Learning process at these schools was reduced to passive mastering the well-known recipes and rules by the pupils.

Babylon. The ancient states in Western Asia arose in the river valleys of the Tiger and the Euphrates. This territory gave the world some ancient civilizations, including Sumer, Babylon and Assyria.

The Sumerians reached the prosperity of their civilization in the IV BC. They were skillful astronomers, mathematicians, and they developed special written language – a cuneiform writing.

The Babylon civilization in Mesopotamia arose about 1900 BC and existed for more than 1300 years. In the Babylon society the religion played as important role as in Egypt. Here all the branches of cultural life were under its strong influence.

Fig. – Tower of Babel

The Mesopotamic civilization represented a special type of an agricultural civilization of the Middle East. The knowledge level of the people living here was high enough. It confused with religious-mythological ideas in consciousness of those who owned it.

The Ancient Babylonian period of IV–III BC was the period of science in the fields that were not connected with the practical use. This can be explained by an educational system in Babylon. The Babylon school of «e-duba» trained boys and girls.

A cuneiform writing, despite of complexity, literacy was widespread among all the levels of population. The copyist mastered a cuneiform writing well within the professional requirements. He could write the economic sheet or the legal document of the standard form.

Fig. – Sumerian writing and Cuneiform

The inhabitants of Mesopotamia worshipped the Moon and used the lunar and solar calendars. The Sumer priests regularly made observations during many years. In Ur there was a ziggurat devoted to the Moon. The stargazing register was found there. The Chaldean priests had been making records in it for 360 years. Guided by this register they established that a year had 365 days, 6 hours, 15 minutes, 41 sec. Within I BC the Babylonians reached appreciable progress in observing the celestial bodies movement. The data accumulated for many centuries were carefully recorded on the clay tables. They gave the chance to astrologists to predict the beginning of one or another celestial phenomenon.

Fig. – Ziggurat of Ur

The observations of the Babylonians, carried out throughout many generations, were recorded and on their basis some calculations were developed. So they developed sexagesimal numeral system – 360 degrees in a circle, 60 minutes in an hour, 60 seconds in a minute which we use till now for measuring angles and time. Calendar calculations were carried out by means of mathematical tables.

The Babylonians knew four rules of arithmetic, simple fractions; they were able to square and cube numbers, and also to take a root. Except planimetric problems, they solved also stereometric problems connected with defining the volumes of various spatial bodies.

The Babylonian mathematicians, more than one thousand years before Pythagoras, had been able to solve quadratic equations, knew "the theorem of Pythagoras". The number π was accepted equal to three. Plotting the plans of the fields, districts, and separate constructions was practiced. The scale in drawings was not used.

Fig. – Sumerian Star Chart

The historical chronicles of II BC represented the description of the events or the lists of the dated formulas. The Babylonian philologists, mathematicians, doctors, chemists, lawyers, architects already had some theoretical views. But they were not fixed in writing. We found only the lists, dictionaries, directories, problems. It is significant that all that was copied in the E-duba from century to century remained without any changes. The contents were learned by heart that limited the opportunities of developing the Babylonian science.

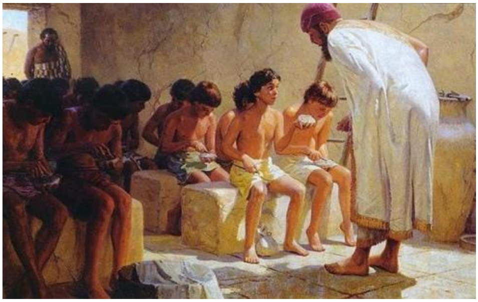

Fig. – E-duba school

The Babylonian world map is an attempt of generalizing the geographical knowledge. The Earth on it is represented in the form of a plane crossed by the rivers Tiger and Euphrates. The plane is surrounded by the World Ocean from different directions and according to the opinion of the author it floats on the ocean's surface.

Astronomical knowledge of the Babylonians was extensive enough. They allocated five planets in the sky from among stars, calculated their orbits. Observing the lunar phases the Babylonians worked out a calendar which had in its structure a year, months, days (12 hours in a day and 30 minutes in an hour).

Together with the birth of the basic concepts in the field of various sciences, astrology and mysticism were developed in Babylon.

QUESTIONS

1. *Characterize the development of scientific knowledge in ancient Babylon and Egypt.*
2. *Describe the system of education in ancient Babylon.*
3. *What was the Babylonian and Egyptian calendar based on?*
4. *What level of mathematical knowledge did ancient civilizations have?*
5. *Analyze the level of geographical knowledge in ancient Babylon and Egypt.*
6. *Estimate the contribution of ancient Egyptian medicine to modern science.*
7. *What system of writing was used in Babylon and Egypt?*
8. *Explain the causes of alchemy appearance in ancient Egypt.*
9. *Describe the system of education in ancient Egypt.*

10. Prepare the report on astronomy achievements of ancient civilizations.

THEME 2. ANCIENT SCIENCE AND TECHNOLOGY

The birth of ancient culture is considered to be in the VI century BC. The geographical position of Greece, as well as the colonization of the Mediterranean by Greeks identified its important mission. Greece began the transition from individual science to science, which developed and took forms recognized by us nowadays. Scientific advances in Greece were significantly different from science in Egypt and Babylon. Greek scholars tended to master the knowledge purely for the sake of knowledge. They did not try to use them practically. At the early stage of development these features of science played a positive role and stimulated the development of scientific thinking in the next period.

History of ancient science is considered to consist of three stages.

Ionian period. (VI century BC) is the period of the birth of Greek science. The influence of the science of ancient civilizations on Greece was obvious. The ancient science originated in the cities of Middle Asia, its center was Miletus. Natural philosophers tried to find answers to the questions on the world structure and its creation and manifestation of Nature. During this period, the science was enriched by the works of Thales of Miletus, Pythagoras and Heraclitus.

Thales of Miletus (624–546 BC). The stories about the scholars of Greece are thought to start with mention of seven Greek sages, the name of Thales is mentioned more often. Thales of Miletus was the first in the history of ancient Greek philosophy to abandon their traditional religious beliefs about the world.

During his studies Thales visited Egypt and Phoenicia, where he collected the remains of ancient knowledge. After his travels, he returned to his homeland in Miletus, where he founded a philosophical school. Thales was the first who described the solstice and equinox, the annual movement of the Sun among the stars. He created the devices which predicted total eclipse of the Sun by the Moon, on 28 May 585 BC by using a method known in ancient Babylon. The fact that the total solar eclipse was predicted by an ordinary man had a great psychological impact on the Greeks. For this he received this recognition of his contemporaries. Thales was one of the first geometers. The theorem named after him is widely known. The method of determining the height of various items by its shade also belongs to him. The theorems were proved in mathematics by Thales for the first time. He also tried to formulate the basic laws of the universe, assuming that the fundamental principle of the world was water.

Pythagoras (570–490 BC) was one of the founders of scientific schools in Greece. He brought mankind the belief in the power of human brain, the belief that the key to the mysteries of the universe was mathematics. When Pythagoras was 40 years old he founded a school on an island near Crotone Italy. In it he taught the disciples medicine, the principles of political activities, astronomy, mathematics, music, and ethics. In his school the idea of the spherical shape of the earth was formulated. Here it was suggested for the first time that the motion of celestial bodies was subjected to certain mathematical relationships. Pythagoras and his followers laid the foundations of number theory by their work.

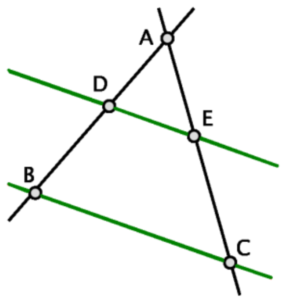

Fig. – Thales theorem,

$$\frac{AD}{DB} = \frac{AE}{EC}$$

In School of Pythagoras, geometry was first studied systematically as an independent science and theoretical teaching about the properties of abstract geometric shapes, rather than as a collection of problems for land measuring. The most important merit of Pythagoras is a systematic introduction of proof in mathematics, primarily in geometry. Only since that time mathematics begins to exist as a science. Much attention of Pythagoras was drawn to the proportions, progression and similar figures. The above-mentioned information is only a small part of achievements which characterize Pythagoras as a great scientist.

Athenian period. (V–IV centuries BC). After the Greco-Persian wars among the Greek states Athens had special position. This period was the peak of Greek science achievements. Athenian period coincided with the scientific activities of Archytas Tarentsky, Aristotle, Socrates, and Plato.

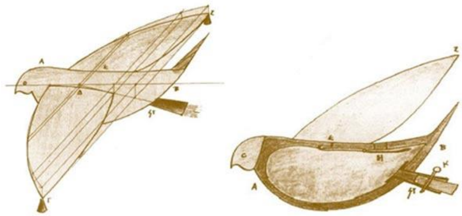

Fig. – The steam-powered pigeon of Archytas, 425 BC

Creativity of **Aristotle** (384–322 BC) continued during the development of Hellenic culture. For three years Aristotle was the tutor of the Macedonian King Philip's son Alexander. We can assume that mentoring of Aristotle largely increased the level of culture of the future outstanding personality.

Aristotle's writings deal with all branches of knowledge of his time: logic, zoology, embryology, psychology, botany, geography, etc. His idea of the classification of sciences today is the basis for logic. The spectrum of interests of Aristotle is so vast that it is impossible to characterize all of its sections. It is usually characterized as the most encyclopedic piece of antiquity, and the era of Alexander is believed to be the era of Aristotle.

Alexandrian period (III–II centuries BC). Association of independent city-states contributed to the possibilities of Greek science to strengthen ties with the more ancient sources of Culture of the East to India itself. During this period there was an intensive process of «internationalization» of science. In the Library of Alexandria, such famous scientists as Ctesibius, Archimedes and Hipparchus worked.

Without studying the works of ancient scholars any person cannot work in the respective industries. In addition to it Greek alphabet was the ancestor of the writing of many Slavic peoples, so we can feel the closeness to the achievements of the scientists of the Ancient World much more. After the fall of Rome in 476, the center of scientific progress of Greece and Rome moved to the east of the Euphrates.

The basis of scientific systems of the Universe was considered to be founded on two tenets by scientists in Greece. They are, firstly, the evidence of the immobility of the Earth, secondary, the uniform circular motion around the Sun, the Moon and the planets.

An attempt to refute the motion of the Sun around the Earth at the beginning of the IV century BC was done by **Eudoxus** (408–355 BC). He was the first of the astronomers who tried to create a theory of planetary motion on mathematical basis. But there was another point of view, which was vigorously supported by Heraclitus (540–480 BC). He argued that the Earth rotated and was located in the center of the universe.

The Moon and the Sun revolved around it. But the world didn't revolve around the Earth and the Sun. This system was borrowed by Tycho Brahe. **Aristarchus of Samos** (310–230 BC) was the first who created the heliocentric view of the universe, but it was not recognized. This system was known for the Arabs and revived later by Copernicus.

Fig. – Pharos Lighthouse

The scientific activity of **Euclid** (III century BC) took place in Alexandria, where he created a mathematical school. His work «Principia» was the most perfect example of a mathematical theory for 2000 years. It contains taking into account planimetry, stereometry, a number of issues in number theory, algebra, the method for determining areas and volumes. Euclid's «Elements» are the result of the achievements of Greek mathematics in the V-IV centuries BC. Each book begins with the definition of concepts (point, line, plane, shape, etc.) that are

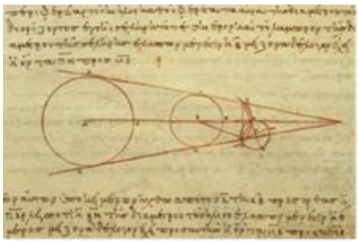

Fig. – Calculations on the relative sizes of the Earth, Sun and Moon according to Aristarchus of Samos used in it, and then on the basis of five axioms and postulates he constructs the entire system of geometry.

After the brilliant victories Alexander the Great decided to build in the Nile delta his new capital Alexandria. After Alexander's death, one of his generals, Ptolemy I continued the construction. He instructed Demetrius of Phalerum to create in Alexandria scientific and cultural center, wherever researches in the field of mathematics, mechanics, astronomy, chemistry, medicine, tools and machines were conducted as well as the development of sculpturing and painting. So it was erected "sanctuary of Muses" – Mouseion. There people from all over the known world worked.

The achievements of **Ctesibius** (285–222 BC), a mechanic of Alexandrian period, are very significant. Ctesibius started as a barber, but after learning at Mouseion he achieved great advances in mechanics, automation and mechanical engineering. The invention of a series of hydraulic and pneumatic devices belongs to Ctesibius. He worked on improving clepsydra (water clock) accuracy.

Each student is familiar with the school aphorisms of **Archimedes** (287-212 BC): "Eureka!" and "Give me a fulcrum and I will move the world". In history, he is known as a mechanic, a mathematician, an astronomer, a physicist and an engineer. Archimedes is one of the greatest figures of Greek mathematics and mechanics.

Archimedes checks and creates a theory of the five mechanisms: lever, wedge, block, endless screw and winch. They were used in almost all types of machine technology of the time, in particular in blocks and winches, gears, irrigation and military vehicles. Archimedes like Euclid studied math but, moreover, he was a distinguished engineer and inventor. He created machines for irrigation, water lifting screw, levers and blocks for lifting heavy loads.

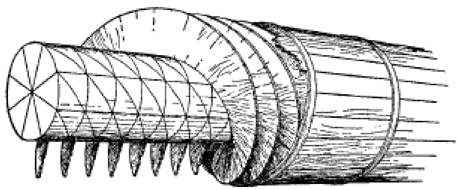

Fig. – Water-screw by Archimedes

During the Second Punic War, Archimedes' catapult deterred the enemy from Syracuse. The legends are walking around him. Among them it is that as Archimedes using mirrors burnt the enemy fleet.

As a mathematician he made important calculations in the field of geometry and coined the use of infinitesimals, by means of them Newton revolutionized science. In physics the Greek scholar gave a definition of center of gravity, and showed how it could be found for different shapes. In hydrostatics he formulated the law of the pushing force (Archimedes). Archimedes is known to be also an astronomer. He constructed a celestial globe, became the prototype of the modern planetarium. It is believed that under the influence of this device Antikythera mechanism was designed.

Works of Archimedes are great achievement of the Ancient World. As a scientist, he was far ahead of its time.

Roman period (I century BC – V century AD). At the end of the III century BC the process of forming the mighty Roman Empire took place, which existed about 500 years. In the II-I century BC recession of ancient science was realized. The most famous scientists in this period were Pliny the Elder, Hero of Alexandria, and Claudius Ptolemy, Seneca, Marcus Varro and Marcus Vitruvius Pollio.

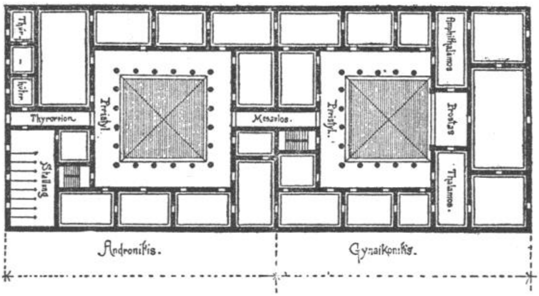

Fig. – Roman house plan by Vitruvius

The inhabitants of Pompeii liked to rest near the fountain, situated among the majestic and magnificent palaces. However, the pools dried up in summer. **Pliny the Elder** (99–23 BC) proposed an automatic feed water regulator. He created the first window sensor with a sensitive element of an alloy of copper and silver. Changes in temperature changed the shape of the plate. It was nothing like the first prototype of conditioner. In addition, Pliny the Elder wrote «Natural History» – an encyclopedia of natural and artificial objects and phenomena.

At the time when the ancient scientists created brilliant arrangements, governors carried out their plans. Roman legions under the command of Julius Caesar invaded the country and helped the Egyptian

Cleopatra to take on the throne. Her cruelty manifested in everything. Engineering activity was stopped, the level of education decreased, the number of scientists reduced too. The birthplace of the great discoveries and inventions plunged into darkness.

Fig. – Aeolipile by Hero from Alexandria

In the II–I centuries BC in Mouseion a brilliant engineer and inventor **Hero of Alexandria** (10–70 AD) studied manuscripts. He worked in the fields of mechanics, hydraulics, pneumatics, surveying, and automation. Hero set the principles for the mechanisms that were driven by the energy of falling weights, water jets and steam. Much attention was paid by the inventor to the description of machines and processes for their use. In the control devices and machines he used gears and worm gears. The manufactured selling machines for «holy water», the ancient «taximeter», the first automatic theatre, as well as machines Alexandria Lighthouse.

Claudius Ptolemy (100–178 AD) could not be compared with equal scientists in astronomy of that time. In his main work «Almagest», Ptolemy presented the collection of astronomical knowledge of ancient Greece and Babylon.

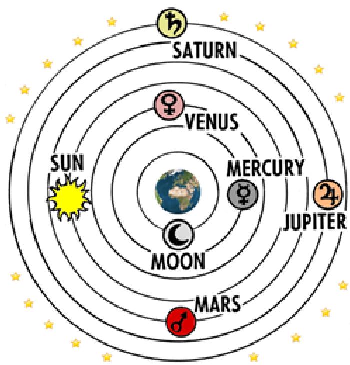

Fig. – Ptolemy's universe

He formulated the geocentric model of the world, which was adopted in the western and the Arabian world before the creation of the heliocentric system of Nicolaus Copernicus. The works of Ptolemy greatly influenced the development of astronomy, geography and optics; a table of sinus was completed by him.

Fundamental changes in the Greek mathematical tradition were carried out by an outstanding mathematician **Diophantus** of Alexandria (200–284 AD). He was the first scientist, who worked out algebra. He transferred achievements of the Babylonians in this area to the Greek science. The scientists used more than the Babylonian number of unknowns and the unknown letters stood for, coined the abbreviated word for the individual symbols and actions.

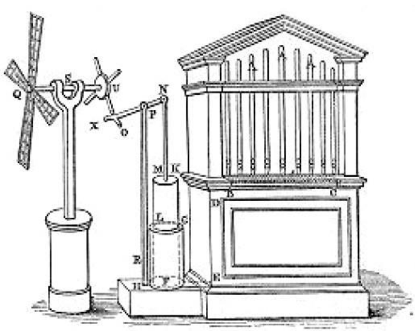

Fig. – Wind power organ by Hero from Alexandria

QUESTIONS

1. *Report about the technical achievements of Antique world.*
2. *Characterize four stages of the development of Antique science.*
3. *Estimate the contribution of Thales of Miletus to the world science.*
4. *Analyze the development of mathematics during the period from Pythagoras to Euclid.*
5. *Estimate the significance of Archimedes to the world science.*
6. *Characterize the scientific activity of Aristotle.*
7. *Prepare the report on automatic devices and mechanisms of Ctesibius and Hero of Alexandria. Where were they used?*
8. *Analyze the relationship of Pliny the Elder scientific activity with modern technical achievements.*
9. *Characterize the level of astronomy knowledge in Antique world. Prepare the report on geocentric system of the world according to Ptolemy.*
10. *Estimate the great technical achievements of Roman Empire.*

THEME 3. THE MIDDLE AGES

The Middle Ages cover the period from 476 AD to the end of the XV century. Many features and assertions of classical science were laid down at this time. The middle Ages left us monuments of art, scientific discoveries and inventions that led to the further progress of mankind, made a great contribution to the treasury of world culture and progress.

It is believed that the main achievement of the Middle Ages is that a complex civilization, which was not based on the labor of slaves, was created for the first time in history. Technological revolution was connected with the mastering the forces of nature, the power of animals, the energy of wind and water. If today we can speak about this period as «dark», it is only because scientists were working at night, hiding from the persecution of the church.

After the collapse of the Roman Empire and the conquest of the territory by the barbarians, the deep decline of culture and the complete destruction of science and art of the ancients began. The rulers of the new «barbarian» states started giving land to their faithful people, who were called «feud» that used obsolete technology. In the early stages of the development of such a system a feudal lord was satisfied with what his farm produced for domestic use. The stimulus for the development of agricultural technology in these conditions did not really exist. As to technology, lack of any major scientific and technological achievements determined the level of development of the productive forces of that period.

Since the XII century machinery, which was invented in the ancient world, began to «revive». It was at this time, Western Europe, partly based on the achievements of ancient Greece, was trying to wrest from Nature its secrets. An outstanding Franciscan monk **Roger Bacon** (1214–1294) published his scientific work, which described the manufacture of gunpowder, the invention of glasses and binoculars, a diving suit, a scooter, a boat plane. He like Leonardo da Vinci can be considered to be a theorist. He did not check them by experience, although he was a supporter of experimentation himself. But the problems were put forward, and it inspired the inventive minds of people.

During the time more and more trades were developed and, consequently, the means of production were improved, too. In the period of feudalism the production of iron increased greatly. A characteristic feature of Western European medieval society was its ability to borrow and improve the technical innovations that were created in other countries. The ancients did not often take new products from other states. Machinery of Ancient Egypt before the conquest of its territory by the Greeks remained at the level of the Bronze period. However, medieval Europe collected inventions of all countries, especially from China. Almost a half of the most important inventions and discoveries that constituted the base of the modern world belongs to China.

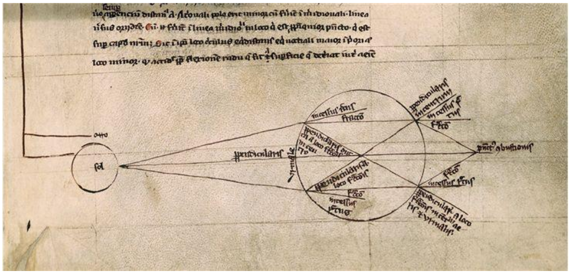

Fig. – Picture of optic from Roger Bacon's "De Multiplicatone Specierum", XIII A.D.

One of the technological development characteristics in Western Europe was that science influenced by the church virtually had no impact on technological development. Its technical achievements became possible only because of the use and development of inventions and discoveries of other countries. The Europe borrowed such important inventions like a clamp for the horses, a clock, a compass, steering of the ship, gunpowder, paper, printing and others – they came from the East. All these facts enabled the Europeans to make much progress in their development. The whole foundation for our modern civilization was created on this basis. We emphasize that during the main part of the time the medieval Europe was not the most progressive part of the world in scientific and technological development. Byzantium continued to keep technical sophistication of the ancient civilization.

From the very beginning of their rule Arab states passed ahead of the European countries. Almost until the end of the middle Ages the most advanced country in the technical sense was China. But at the end, the Islamic countries and China were in decline. By the fifteenth century, the Islamic world declined economically and was destroyed by internal wars. The Islamic religion ceased to be liberal and became orthodoxy. India became a battlefield between the Moslem invaders and Hindu. Native population of China kept its old culture. But the state system prevented for 400 years to make a necessary step to combining technology and theory. The medieval Europe made this decisive step. It did not only borrow the best ideas and inventions from other countries, but also complemented them with own ones, developed and united them.

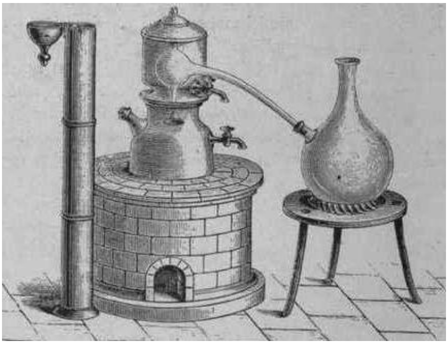

Fig. – Distillation apparatus

Using the power of water and wind. In ancient times, as it has been already noted, the slaves carried heavy work on their shoulders. However, in the VI–VII centuries the use of the water wheel was already widespread. At the beginning of the XI century there were 5,624 watermills in England. They also appeared in Belgium, on the Adriatic coast, in other areas.

At first, with the help of water wheel only corn was milled. Then it was used for a variety of needs. With the help of the cams on the shaft of the wheel the hammer raised and beat the cloth in water. By the same principle blacksmith hammers and bellows were equipped. In

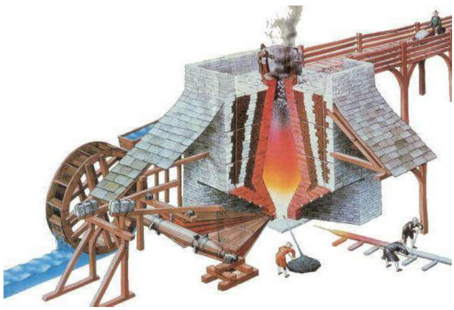

Fig. – Blast furnace

the XIII century paper mills were constructed, in the XIV century the use of mine equipment with water wheel was started. During 300–400 years, the water wheel evolved into a universal engine for various industries, which facilitated the work. As a result of its use the great changes took place in mining. People learned to use the deep mines. The devices for supplying air to a depth of mining and pumping water to the surface were invented.

Fig. – Example of a mill

At the end of the XII century in the Europe they began to use the energy of wind. In the Moslem countries the windmills were already found in the VII century. The usage of wind energy in different processes, except making flour, proved to be difficult. But since 1400 wind turbines became the basis of water-lifting works to drainage of wetlands in the Netherlands.
With the time, wind energy was used as a drive in a variety of mechanisms.

Before the invention of steam engine, wind and water, working cattle were the only driving forces.

Advances in vehicles. Starting from the IV millennium BC until the very end of the Middle Ages steering ships differed little from the rowing oars. In VIII century in China and in the XIII century in Europe steering device of modern design appeared.

The Epoch of Great Geographical Discoveries is one of the most critical in the history of mankind. The Europeans came into contact with distant, previously unknown to them people, they discovered a lot of land earlier unknown continents and oceans appeared on the maps. An important role was played by outstanding technical achievements of the middle Ages in naval business. To organize long expeditions, navigators had to build high-speed, safe, reliable and spacious ships. The Spanish caravels became this type of ships. They started to install a steering wheel at a certain depth under the water to hide it from the action of waves. This made it possible, along with other novelties, to provide the ships with good seaworthiness and the ability to sail against the wind.

In the days of **Christopher Columbus** (1451–1506) they began to establish direct sales, which made it possible to reach high speeds, while sailing. At the beginning of the III century China invented a compass. In Europe compass on the ships appeared only at the end of the XII century.

Fig. – Caravel with two settee sail rigs and a headsail

But it greatly differed from the Chinese one and could not be his backup. The invention of the way of accurate determining the position of the ship in the sea became very important for progressive changes in navigation.

New types of transport paved the way for the «transport revolution», the era of great flourishing of business. The Europeans began to import raw materials and finished products from all over the world. At first they were luxury goods, and soon the essential commodities.

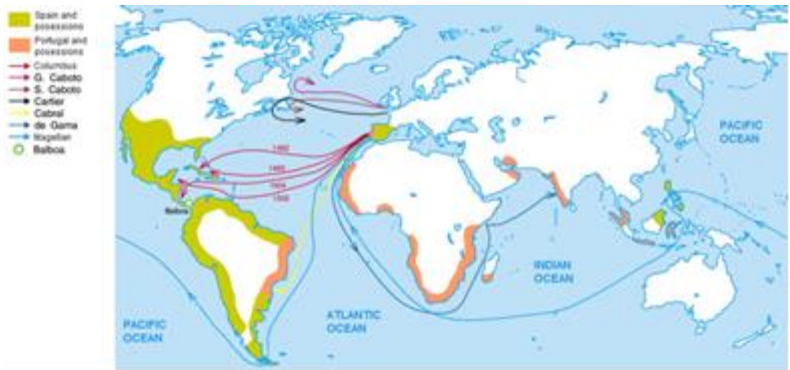

Fig. – Great Geographical Discoveries

This, in its turn, gave a strong impetus to the development of industry, at the same time, to the development of more powerful machines. The transport revolution created a privileged position of Europe on the oceans and the seas. The Geographical discoveries were in their nature the military aggression that contributed to the realization of the colonization policy in non-European lands.

Education and publishing. Printing was one of the most important achievements of the Middle Ages. One of the determining factors that stimulated the discovery of printing was the development of education.

Education in schools of medieval Europe was conducted in Latin. And only in the XIV century schools with teaching in national languages appeared. In the Middle Ages there was no clear separation of school into primary, secondary and higher. Religious in content, education was verbal rhetoric. The basics of mathematics and natural sciences were taught abruptly and descriptively. The acquaintance with the culture of the East made a positive impact on the outlook of the Europeans.

In 1088 one of the first European universities was founded in Italian city of Bologna. During the XII century universities were founded in some other cities. Oxford, Cambridge, Paris. In the fifteenth century in Europe, there were almost 60 universities. The biggest of these was the university in Paris. In schools and universities, students received broad knowledge of philosophy, mathematics, medicine, chemistry, astronomy. These institutions accelerated the formation of high intellectuals in Western Europe. They influenced the progressive development of the society.

Fig. – University of Bologna

The printed book became the first example in the history of mass media, which allowed transferring knowledge and experience from generation to generation.

The invention of paper by Chinese **Cai-Lun** (48–121) in 105, spread quickly throughout the countries of Islam: Baghdad (793), the Egypt (900) and Morocco (1100). Due to the Crusades the art of paper production, which was kept in secret, became known in Europe in the XII century.

The birthplace of printing is the area of the Rhine River in Europe. The Initial center of the invention is considered to be Holland, where in the late 1430's the first printed editions was published. Mainly they were the cheapest popular sheets, books for schools and religious posters. The name of the first book-printer remained unknown for us.

15–20 years later in the German city of Mainz the brilliant success in publishing was achieved and the modern development of this branch was begun. **Johann Gutenberg** (c.1400–1468) founded the first printing press and made several discoveries in printing. To improve his ideas, he worked for many years with great energy. He created different models several times, each time he postponed the work and then started again from the beginning. From 15 to 20 people worked in his workshop. The first printed book of the Bible (2 volumes) was completed in 1455 and 180 copies were made. In each book there were 1,282 pages and 42 tapes on each page.

Fig. – The Bible, printed by Gutenberg

To pay debts Gutenberg had to give his companion Johann Fust, who financed his production, printing equipment and the type for the Bibles. His companion opened his own printing house “Fust and Schaeffer together” with Peter Schaffer.

Gutenberg's printing house can be described by three theses. ***First:*** he invented forms of metal letters. Letters can be collected in a word and are arranged in a frame. Each word is disassembled into individual letters. ***Second:*** the text, which was placed in frames, was covered with special paint. ***Third:*** made up from letters and located in the frame text was inserted in the press, and typed off the paint on the paper. Printing spread rapidly across countries and continents. During the period of 40–50 years a printed book became common to the civilized world. With the era of printing the growth of human consciousness started. Before Gutenberg invented printings in Europe there were several thousand manuscripts. In 50 years after his death millions of books were published.

Fig. – The Apostle, printed by I. Fedorov

In Moscow state printing appeared in the XVI century during the reign of Ivan the Terrible. The first printed book, printed in Moscow in 1564 was called "The Apostle". It was printed by **Ivan Fedorov** (1510–1583) and his assistant **Peter Mstislavets**. Repressions of the church forced Fedorov to move to Lviv in Ukraine. At the same time, printing houses of Asia and America began their work on the publishing printed production.

The book contains all wisdom of mankind. It remains one of the main means of transmitting information from generation to generation. The fate of books in the future is that it will remain in the human civilization forever.

QUESTIONS

1. *Characterize the development of technology in the Middle Ages.*
2. *How was energy of wind and water used in the Middle Ages?*
3. *Prepare the report on Roger Bacon's scientific activity.*
4. *Analyze the development of military technology during this period.*
5. *Estimate the contribution of India and China to the world science.*
6. *Estimate the contribution of the Arabian countries to the world science.*
7. *Characterize the achievements in the field of transportation devices in the Middle Ages.*
8. *What was the influence of the Great Geographical Discoveries on the development of engineering?*
9. *Prepare the report on the foundation of the first universities in Europe.*
10. *Explain the social consequences of the discovery of printing.*

THEME 4. SCIENTIFIC REVOLUTION OF THE XVII CENTURY

Since this period, science began to take place ahead of technology. The period of gradual development was changed by the explosion of scientific creativity.

Scientific revolution of the XVII century is the final stage of the scientific revolution. It was started by Polish thinker Nicholas Copernicus. Since his work overcoming stagnation began the fight against the teaching of Aristotle and the doctrines of the Vatican. The Guidelines for this process started by Copernicus' works were continued by Kepler, Galileo, Descartes and Newton.

The ideologist of the new science was the Englishman **Francis Bacon** (1561–1626). The inductive method of research proclaimed him played a significant role in the further progress of science. Bacon opened a new epoch in science. He strongly opposed the dogmatic heredity of Aristotle. In his book "The New Organon" Bacon said that science must be based on investigation, which was the criterion of science. According to this opinion he was in agreement with his compatriot from the XIII century Roger Bacon.

Medicine. The priority of introducing new drugs, including chemicals into practice belongs to the doctor in Germany **Paracelsus** (1493–1541). The founder of human anatomy was **Andreas Vesalius** (1514–1564). He first introduced in practice of medical research the procedure of autopsy of a human body. The work "On the structure of the human body" with a detailed description of all human organs and systems belongs to him. The results of thirty years of anatomical research were described in the book by William Harvey (1578–1657) "Anatomical study of the motion of the heart and blood in animals". He discovered and described the small and large ring of blood circulation. William Harvey was the founder of modern physiology and embryology.

Fig. – Anatomy Notebook: Skinless Man Muscles by A. Vesalius

Amateur scientist **Antony van Leeuwenhoek** (1632–1723) invented the microscope, which allowed him to make many important discoveries. Most of them were made in 1674, when he first researched and proved the existence of microbes. Leeuwenhoek discovered a whole new world in a drop of water.

Physics. Englishman **William Gilbert** (1544–1603) is a pioneer in the science of electricity. He discovered that the magnet had two poles. He concluded that the Earth was a giant magnet.

Among the prominent scientists and thinkers of the XVII century **Evangelista Torricelli** (1608–1647) can be mentioned. His research is dealt with pneumatics and mechanics. His discovery of atmospheric pressure enriched science. Torricelli measured the pressure of the atmosphere by the height a mercury column. His famous experiment to detect the atmospheric pressure accelerated the progress of science and technology. The discovered fact of vacuum was the beginning that "emptiness" became an object of research. This led to its practical use, particularly in the air pump. The most outstanding result of Torricelli in mechanics was the discovery of the law of liquid motion in the vessels. This discovery gave him the glory of the founder of hydraulics.

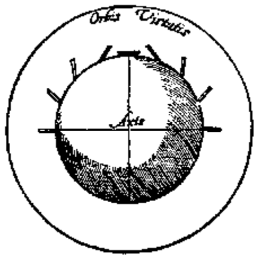

Fig. – Gilbert's terrella, a model of the magnetic Earth

Blaise Pascal (1623–1662) formed one of the fundamental theorems of projective geometry (Pascal's theorem). He also was interested in integration, calculation of infinitesimal values. In 1645 he invented the calculation machine to perform the four arithmetic operations. Repeating the experiments of Torricelli, Pascal proved that with the aid of a barometer you can do measuring heights. He proved the existence of a link between indicators of the barometer and the change in weather. Pascal discovered the law: the pressure exerted on the liquid is transferred in all directions perpendicularly and uniformly. Demonstrating the elasticity of air he proved that it had weight.

Otto von Guericke (1602–1686) became famous after the invention of the pump and conducting experiments to determine the air pressure, he experimentally proved its elasticity, defined its density and sound conductivity. He built one of the first electrostatic machines in the form of a ball that could rotate around an iron rod about an axis.

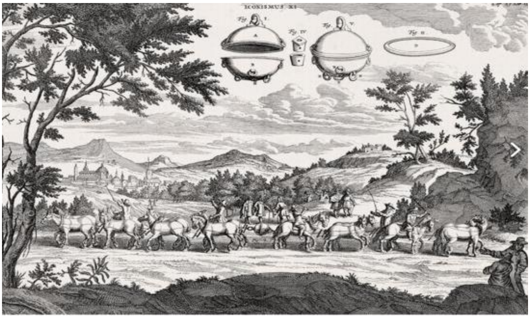
Fig. – Guericke's Magdeburg hemispheres experiment

In 1654 he made "The experiment with the Magdeburg hemispheres". In the experiment used "two copper hemispheres about 14 inches (35.5 cm) in diameter, hollow inside and pressed together". After downloading the sphere of air, 16 horses on 8 each side (here were no more horses) could not break the hemisphere. When the cavity between the hemispheres let air – the hemisphere collapsed without any external force. In 1663 he invented one of the first electrostatic generator that produced electricity by friction - a ball of sulfur that rubbed by hands.

Robert Boyle (1627–1691) began the development of chemistry as an independent branch of science. He is one of the pioneers of modern experimental scientific method. He is best known for Boyle's law, which describes the inversely proportional relationship between the absolute pressure and volume of a gas, if the temperature is kept constant within a closed system

The name of **Edmond Mariotte** (1620–1684) associated with the introduction of experimental physics in France. He was a co-author of Boyle's law. He showed an increase in the volume of water during freezing and discovered a blind spot in the eye, examined colors, studied optics and astronomy.

Denis Papin (1647–1714) made a great contribution to the development of pneumatic devices, initiating the stage in progress when science began to serve the technology and determine its rapid development.

Astronomy. **Nicolas Copernicus** (1473–1543). The beginning of the period of the universe old system destruction, which was based on physics of Aristotle and kinematics of Ptolemaic celestial bodies, could be considered 1543, the year of edition of Polish philosopher and scientist Nicholas Copernicus' book "On the rotation of celestial spheres". Copernicus' calculations led him to important independent decisions in the field of plane and spherical trigonometry and, eventually, developed a concept of the heliocentric universe. The scientist did not live up to that time when his essay "The rotations of celestial spheres" spread throughout the world. He was already dying when friends brought him the first copy of the book, printed in one of the print houses of Nuremberg. But with the publication of a book of Polish scientist heliocentric world system was not immediately recognized. For its approval the tests of Kepler and Galileo were required, the introduction of a new school in education, upbringing since childhood, in the spirit of incomprehensible representations for empirical knowledge.

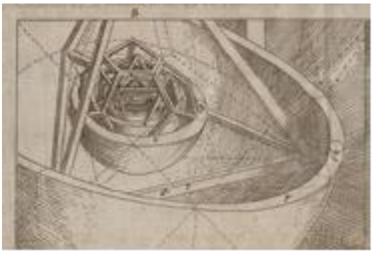

Fig. – Image of Platonic solid model of the Solar System from "Mysterium cosmographicum"

The Catholic Church did not immediately estimate the revolutionary view of the scientific work of Copernicus. In the 1616 book "The rotations of celestial spheres" was included in the Index of prohibited books by Vatican. It was abolished only in 1828.

Johannes Kepler (1571–1630) – a prominent astronomer and mathematician. The scientist was interested in three things: the number, size and motion of celestial bodies. The philosophers of ancient Greece believed that the world must move only on the right circles. After considerations

Kepler concluded, “Why was it necessary to submit all motions of the planets in the plane, if the orbits are three-dimension?” Because of these reflections he presented his conclusion as follows, “Earth's orbit was the measure of all things”. In 1596 scientist presented his entire arguments in a small book titled “Cosmographical mystery”.

Kepler’s work brought him glory. The famous Danish astronomer and observer **Tycho Brahe**, who was skeptical to the scheme of Kepler, but paid attention to the independent thinking of the young scientist, his knowledge of astronomy, art and perseverance in the calculations. And he expressed his desire to meet with him. In 1600, Kepler came to Tycho Brahe in Prague.

Generalizing the observations of Brahe, Kepler obtained the data, which showed that the planets moved irregularly. This fact forced Kepler's conclusion that the planets moved in elliptical orbits.

The need to improve the means of astronomical calculations, tabulations of the planets motions based on the Copernican system brought Kepler to the theory and practice of logarithms. Inspired by the work of

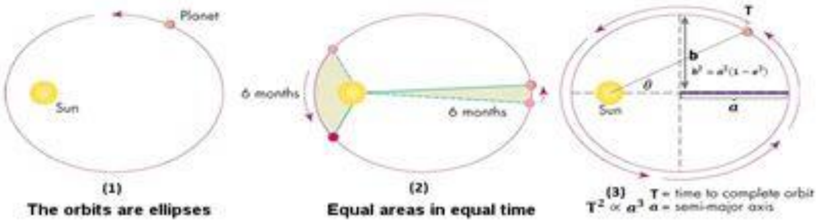

Fig. – Kepler's Laws of Planetary motion

J. Napier, Kepler independently developed a theory of logarithms on a purely arithmetical basis and with the help of accurate logarithmic tables. They were published in 1624 and Kepler was the first who applied a logarithmic calculation in astronomy.

Estimating the value of the work of Kepler, scientists named it “the legislator of the sky” because it was he who discovered the laws by which the motion of celestial bodies in the solar system can be explained.

Since **Galileo Galilei** (1564–1642) physics originates as a science. Galileo put forward the basic principle of relativity, that the laws of physics are the same in any system that is moving at a constant speed in a straight line, regardless of its particular speed or direction. Hence, there is no absolute motion or absolute rest. This principle provided the basic framework for Newton's laws of motion and it is central to Einstein's special theory of relativity.

Before to Galileo's science conventional point of view was that, according to which the rate of motion of the body was greater than a large force acts on it. This position was clearly articulated by Aristotle, and at first view, no doubt. Series of experiments made by Galileo proved the error of this assertion. He conducted experiments by throwing different bodies with sloping Leaning Tower of Pisa. So he checked accordance with the teachings of Aristotle that the heavy fall faster than light. Galileo was introduced a new principle: if the body was not carried out any external influence, it was either at rest or moved rectilinearly with constant velocity.

In 1608, Galileo learned about the invention of the telescope in Holland. He personally designed and built the first telescope – the telescope – an optical system with convex and concave lenses, directed it to heaven, began systematic astronomical observations. By his invention Galileo found that on the Moon as on Earth, there were "mountains" and "seas". Watching as sunspots moved through the solar surface, he found: «The sun rotates on its axis». Basing on observations, Galileo concluded that the rotation axis was characteristic of all the heavenly bodies. He discovered that the Milky Way was not a «Nebula», and star clusters.

Thanks to his efforts, the heliocentric system of the universe, before the little-known, in the first half of XVII century, took universal recognition. Galileo set up production of telescopes, created microscopes.

The views of **Rene Descartes** (1596–1650) converged with the views of Galileo by the structure of the universe. In 1669 a number of Descartes' work was included in the Vatican "Index of prohibited books".

The mechanics of Descartes was built on a mathematical description of the picture of the world. He formulated the laws that can explain the interaction between the particles of matter - the law of inertia and the law of conservation of momentum. Negative numbers have got a real interpretation of Descartes as directed coordinates. He introduced the now common to use variables (x, y, z ,...) and letter coefficients (a, b, c, ...), and written formulas in Descartes are not very different from today.

Of great importance for the formulation of general theory of the algebra it was a record of the equation by which one of its parts was zero. The discovery of analytic geometry by Descartes was not only important for mathematics and natural sciences in general for a wide range of expertise dealing with exact quantities.

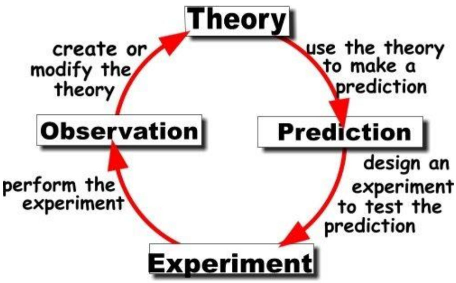

Fig. – Scientific method by Descartes

The rationalism of Descartes began a new era in science, culture. Nature became a kind of thinking. Human brain explains the totality of facts and laws of motion of interacting bodies.

Gottfried Leibniz (1646–1716). As a representative of the seventeenth-century tradition of rationalism, Leibniz's most prominent accomplishment was conceiving the ideas of differential and integral calculus, independently of Isaac Newton's contemporaneous developments. Leibniz's best known contribution to metaphysics is his theory of monads, as exposited in Monadology. He proposes his theory that the universe is made of an infinite number of simple substances known as monads.

He introduced several notations used to this day, for instance the integral sign $\int$, representing an elongated S, from the Latin word summa, and the d used for differentials, from the Latin word differentia.

Isaac Newton (1643–1727) is a genius in the history of science. Newton, giving explanations to their achievement, wrote that he saw further than his predecessors because they stood on their shoulders. Newton left a heritage in optics, astronomy and mathematics. But most importantly – a foundation of mechanics, the discovery of the law of universal gravitation, and developed on this basis the theory of motion of celestial bodies. He created the corpuscular theory of light, opened the spectral composition of sunlight. Any of these achievements is enough to have his name ended up in an encyclopedia. Newton invented and built a reflecting telescope.

Newton developed a framework of differential and integral calculus. In 1684, he began to write the main work of his life – "Mathematical Principles of Natural Philosophy". This work became the basis of classical Newtonian mechanics. It relies on observation, experiment and mathematical calculation. This is radically different from the old scholastic science, which saw the top of the evidence in reference to the authority.

In this work, a scholar summarized the results obtained by his predecessors and himself, created a rapid system of mechanical knowledge, which covered all known earthly and celestial phenomena. It defines basic concepts of mechanics (space, time, mass, density, quantity of motion, strength, etc.) and formulates the three laws of mechanics: the inertia, the proportionality of momentum to the applied force, the equality of action and reaction.

Fig. – Experiment by Newton with prism of glass

The scientific revolution is over. Final factor was also the establishment of Newtonian mechanics, the new world which was destined to have a significant impact on the development of science in the next two and a half centuries. The scientific revolution created the preconditions, which resulted in the XVIII century. The beginning of the industrial revolution prepared the ground for the newest revolution in natural science at the turn of the XIX–XX century.

QUESTIONS

1. *What is the significance of Francis Bacon's ideology for scientific revolution of the XVII century?*
2. *Prepare the report on heliocentric world system of Copernicus.*

3. Estimate the contribution of Kepler's works to astronomy and mathematics.
4. What is the importance of Galilei's personality for natural sciences?
5. What field of science did Torricelli work in? Describe his most famous physical experiments.
6. Report shortly on the founders of electricity as a science Gilbert and Otto von Guericke.
7. Characterize the level of medical knowledge in the European countries in the XVI - XVII centuries.
8. Analyze the scientific activity of Pascal and Leibnitz in mathematics.
9. Explain the ideas of Descartes in philosophy dealt with the structure of the Universe.
10. Prepare the report on Newton's activity in the field of physics, mathematics and alchemy.

THEME 5. THE INDUSTRIAL REVOLUTION

The history of Western civilization is connected with revolutions in the industry. These are periods in history when a society is undergoing rapid technological changes that change social and economic life. However, the history of mankind has only one Industrial Revolution, when for a century we saw a transition from an agrarian, handicraft economy to a predominantly urban, and the machine civilization. The birthplace of the Industrial Revolution in the late XVIII – early XIX centuries is considered to be Great Britain.

The Industrial Revolution is characterized by advances in the application of the steam engine and the introduction of machine production. Despite of the local character, the industrial revolution still expanded economic space of Western Europe. Some of them were provided with low-cost material and labor resources, so countries remained the main source of economic growth. The impact for this revolution in Europe became science, which led to radical changes in social and economic life of the planet. One result of the industrial revolution was the separation of countries into the colonies and metropolis.

The basis of progress in agricultural production was improving crop rotation, the use of seed breeding, cultivation of more productive species, improvement of tools. The agrarian revolution led to a significant increase in the efficiency of agricultural production. Peasants were left without land and this factor contributed to high productivity of agricultural production. Most of them were a reserve labor force for industry. A huge number of products contributed to the growth of the population that became characteristic feature of Western Europe. Thus, the population of England increased from 5.8 million in 1700 to 18 million in 1850, the mortality rate decreased. The fertility rate in the early XIX century reached 37 %. This influenced the dynamics of the industrial revolution.

Stimulating factors of industrial development. An integral part of the industrial revolution is a revolution in communication: railway, sea and river transport, the introduction of telephone and telegraph; the use of energy, as well as innovations in mining, metallurgy. The emergence of printing marked the information revolution – a revolution in science and education. The production development contributed greatly to the improvement of scientific experiment equipment. In the XVI–XVII centuries microscopes and telescopes were invented. With their appearance, the opportunity to discover an invisible world to micro- and macrocosm was realized. There were such familiar nowadays devices, such as a thermometer, a mercury barometer.

Already in the XVI century social practice according to the demand put forward strict requirements for science. If, before this period, the development and technology was based on empirical knowledge, now science-based knowledge acquired crucial significance, generalizing experience and creating a theory. The progress of production, as we mentioned, enriched science with experiences and science, in its turn, worked to improve machinery, technology and production organization.

Stages of the Industrial Revolution. The industrial revolution has passed through three stages. **Its first stage** is characterized by the invention and spreading of machines in the textile industry. This created unlimited possibilities for expansion and technical improvement of production.

The invention of a heat engine marks **the second phase** of the Industrial Revolution. The steam engine, which has become the engine of modern industry, met the needs of the factory system. It has stimulated the introduction of working machines in all sectors, primarily in engineering.

The third stage of the Industrial Revolution is associated with the creation of machines in mechanical engineering. The first was the use of machines in production led to a large number of enterprises, establishment of industrial centers and clusters in these populations.

The Industrial Revolution in all countries was held at the same time and gradually.

Great Britain. In 1760-s the industrial revolution began in Britain, it was earlier than in other countries. The English bourgeois revolution (1640–1660) paved the way for the development of capitalist relations. Industrial revolution is spurred financial capital. Manufactories in the UK reached a significant peak. The British manufactures, their achievements surpassed the Dutch ones. But at a certain stage of the manufacture development different contradictions between its narrow technical base and the most production needs appeared. This was manifested most noticeably in the textile industry.

«Small» Industrial Revolution in Western Europe was connected with the improvement of the loom. Knitting machine, which was invented in 1579 by clergyman **William Lee**, in comparison with the loom, was much more difficult because of the greater complexity of operations. Already in the first model of the knitting machine, most operations were automated as compared to other tools in this field. In the 1770–1780s mechanical spinning devices "Jenny" were widespread. It was designed by **James Hargreaves**. By the early 1787 in British industry more than 20 thousand of these machines were used. The further development of the mechanical spinning involves the use of mule-machines. Their inventor was **Samuel Crompton in 1770s**. After these machines were recognized and widespread, cotton yarn was made only by a factory method.

Mechanization of individual industries resulted in the need to increase labor productivity. In 1785, a patented design of the mechanical loom by **Edmund Cartwright** was registered. And in 1801 the UK began to operate the first mechanical weaving mill, which had 200 machines. Distribution of machine technology caused the decline of handicraft production and the ruin of the mass of small producers.

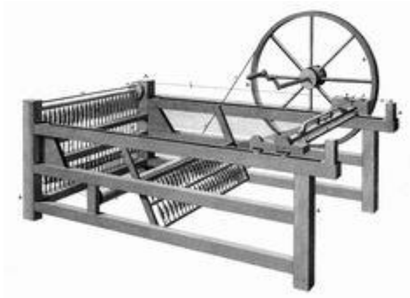

Fig. – Spinning "Jenny"

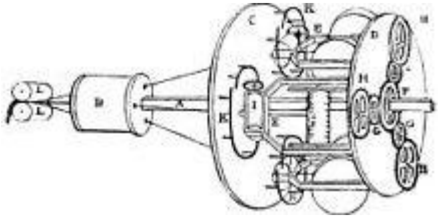

Fig. – Ropemaking machine by E. Cartwright

The development of equipment caused the need for new and better engines. In late 1790s textile industry in England used the patented in 1784 steam engine by **James Watt**. By 1810 there were about five thousand steam engines.

In the first quarter of the XIX century steamship and the steam railway began to operate.

USA. The progress of rapid development of heavy industry after the British was the USA, France, Germany and other countries. The general economic conditions for the rapid development of capitalist production in the United States were created after the victory in the War for Independence (1775–1783). The use technical experience of British industry contributed to the intensive technical re-equipment industry. The massive use of steam engines and accelerated development of engineering in the north-eastern states of America were held in 1850–1860. The most common steam unit was a machine by the inventor Corliss.

In the last third of the XIX century the USA made a great progress in the economy. They turned from agricultural country into a mighty industrial power. In 1880s America surpassed Britain in indicators of smelting iron and steel. Coal mining, firmly ranked the first place in the world. Machine tools, textile and food industries, rapidly developed with acceleration railways were built. Since 1890s new sectors of American industry: chemical, electrical, rubber, oil and others were growing rapidly.

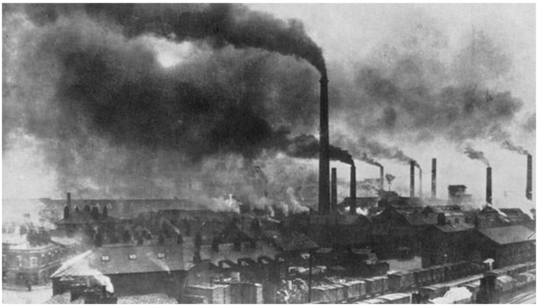

Fig. – Smoke pollution produced by Industrial revolution factories

In the United States the producers successfully linked scientific, technical and social progress. They began to put pressure on the market of European countries due to low cost and short terms of manufacturing production, the introduction of scientific labor organization and the achievements of scientific and technological progress. Rather high paying of industrial workers became one of the factors that stimulated the brilliant development of mechanical industry in America. The need for machines and mechanical work, which replaced the human muscle power in this country came indicator of American culture. In its turn, strong and vigorous competition between different types of unfolded states and cities, railways and trade companies, uniform companies took place.

Fig. – Children working in a factory

Considerable attention of the owners of USA engineering in the second half of XIX century was paid to the displacement of manual labor, particularly in the foundry, forging, lathe production, wood processing, as well as in the pipeline industry.

European countries began to buy machines that manufactured in the USA, and even entire industries. Among them, sewing machines, live ammunition, the production of rifles and revolvers, pump system Black and Worthington, steam engines of Corliss, boilers Bobcox and Wilcox, various machines, machines for shoes, American Turbine, various agricultural.

The important role in achieving such success in the U.S. industry, as already it was noted, assigned to competition between north and south of the country. This competition was conducted with great energy and even cruelty. It turned the peaceful industry to the total cruel war.

Russian Empire. In this region, the industrial revolution began with a large gap from the Western countries (with the first half of the XIX century, late of England and America for approximately 40 years).

The condition of chemical industry in Russia at the end of the first half of the XIX century in some industries may be characterized by the following figures. On its territory there were 111 chemical plants, employing 3,300 workers. Production of chromium compounds in Russia appeared earlier than in Germany and Austria. It produced potassium, potassium dichromate, and various chemical products (the factory in St. Petersburg, Warsaw, Kozielsk and other cities). Mining industry developed intensively. Metallurgy popularity enjoyed. However, for the successful implementation of the industrial revolution it was necessary to have employees, a wide market for industrial products and investments great capital in the industry. These conditions appeared only after the abolition of serfdom in 1861.

In the pre-reform period of Russia only in cotton and paper, sugar-bulk industry products were manufactured in factory-type plants. At the rest of the leading sectors were the transition from manual labor to machine over, were made mostly in the late 1870s – early 1880s. In 1879, the textile industry with the help of machines produced 54.8%, 96.3% of all paper products. At the metal-working enterprises machine produced 86.3 % of all products in the sugar beet industry – 85.1 %.

Technical modernization of transport network in Russia completed post-reform period. During the 1860–1870s on its territory more than 20 thousand kilometers of railway tracks were built. It is the basis of the modern rail network in Russia.

One characteristic feature of the industrial revolution in Russia was that it had underdeveloped individual industries, in particular machine tools.

Consequently, this revolution in the industry occurred with a lag of Western Europe and the USA, although the material and technical conditions of the industrial revolution in Russia were no less favorable than in Western countries.

Achievements in science

Chemistry. The theory of phlogiston. **Phlogiston**, symbol ϕ, from Greek, meaning "to enflame" or "fire of earth" was a hypothetical substance supposed to be common to all combustible bodies and metals, which escaped during combustion or calcinations, but could be transferred to one body to another, and restored to the metallic calices by heating with substances rich in phlogiston (charcoal, oil, etc.); metal.

Henry Cavendish (1731-1810). He identified (1766) the carbon-dioxide gas and hydrogen in the pure state, taking the last as phlogiston, established the main composition of the air as the mixture of nitrogen and oxygen. He got nitrogen oxides, through the combustion of hydrogen Cavendish received (1784) the water.

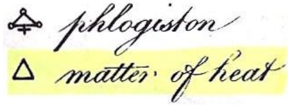

Fig. – Symbol of phlogiston

Mikhail Lomonosov (1711–1765). Very deep and original idea was expressed by him in the dissertation "The Thought about the Cause of Heat and Cold" (1744), in which he connected the temperature of body with the "internal movement of own matter", i.e. the movement of small particles (molecules) of which, in his belief, consisted any object. In the dissertation «The Attempt of the Theory of Elastic Force of Air» (1749), he predicted some of the principles of the kinetic theory of gases. Lomonosov introduced the term "physical chemistry".

Carl Wilhelm Scheele (1742–1786). In the work "Chemical Treatise about Air and Fire" Scheele described the obtaining and properties of "fire air" and said that the atmosphere contained of two "types of air", "fire" – oxygen and "phlogiston air' – nitrogen. On the day of his own wedding, he decided to make an experiment. He tasted the resulting substance and died because it was hydrocyanic acid. In spite of the fact that firstly in the history the oxygen was discovered, the priority of oxygen discovery belongs to **Joseph Priestley** (1774). Scheele and Priestly could not clearly explain their discoveries.

Antoine Lavoisier (1743–1794). Lavoisier's most important contribution to science – a refutation of the theory of phlogiston that prevailed many decades and creation of the theory of combustion, based on experimental data.

Ents Jacob Berzelius (1779–1848). Swedish chemist Berzelius discovered cerium, selenium, thorium, first received in a free state: silicon, titanium, tantalum and zirconium. In 1806, he coined the term “organic chemistry”. He determined the atomic weight of the known chemical elements at that time and brought them to abbreviated letters, developed the idea of the atom and the electric affinity, suggesting the concept of the first chemical reaction - electrochemical theory.

Dmitry Ivanovich Mendeleev (1834–1907). He was the author of works on chemistry, chemical engineering, physics, metrology, meteorology, economics, and other industries. In 1861, Mendeleev wrote the first textbook in the Russian Empire in organic chemistry. While working on a textbook on the basics of chemistry he decided to present the known elements in a table. He had long sought legitimacy and finally all the elements arranged in order of increasing atomic mass. The first version of the periodic law of chemical elements was presented in 1869. The scientist predicted the existence of undiscovered elements at that time. In 1894 he suggested that the atoms could be represented as resembling a small solar system moved continuously.

Electricity. Actually in Ancient times people knew that there was a shock fish, the magnet attracted the iron and people were afraid of lightning. **William Gilbert** (1540–1603, England) was interested in the healing properties of magnets. He made more than 600 experiments, found that the greatest strength of each bar magnet centered on its poles – North and South.

Otto von Guericke in 1672 in his book “About So-Called Experiments with Empty Space”, which was dedicated to the pneumatics, one of chapters he devoted to electricity.

Stephen Gray (1666–1736). In 1729 he discovered the electrical phenomenon, found that electricity can be transmitted from one body to another by a metal wire or spinning thread, but cannot be transferred by a silk thread. He was the first person who divided all bodies on conductors and non-conductors of electricity. He confirmed the existence of the phenomenon of electrostatic induction and showed that electric charge was spread on the body surface.

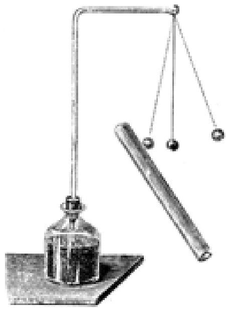

Fig. – Experiment by du Fay, electric pendulum

Charles du Fay (1698–1739), France. In 1733 he discovered the existence of two kinds of electricity: Glass: rock crystal, pearls, glass. Pitch: silk, paper, amber, wool, hair. The equal charges of electricity are pushed off, the opposite ones are attracted. In 1735 he putted forward the hypothesis that the lightning had electrical origin.

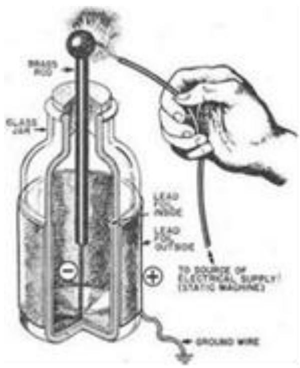

Fig. – Leyden jar

Peter Musschenbroek (1692–1761) from city of Leiden, the Netherlands. Together with his apprentice Kyuneus he created the world's first capacitor. In a glass flask he electrified water from the machine of Guericke. He touched there by hand and was struck by electric shock. There are several legends that current performance was tested on themselves by monks and later Musketeers (up 180 people joined hands and formed a line– the last putted his hand in the jar and all of them were shocked, it was like stroke of the sword). Later "Leyden jar" was combined to a battery to increase the total capacity.

From Europe "Leyden jar" came to America. Probably at the fair, where with the help of the Leyden jar chickens were being killing, candles were being lightening **Benjamin Franklin** (1706–1790) saw it. He was the 15th of 17 children of the poor craftspeople. The family did not have money for education of their children. Franklin tried to learn by himself. In the field of electricity he introduced generally accepted symbols of charges + and –, battery, capacitor, winding, conductor. Confirmed, that lightning is an electrical discharge. He flew a «kite by Franklin» during a thunderstorm (**Georg Richmann** made such experiments in Russia – the scientist was killed by the lightning). Franklin was the first who said, that electricity could be transferred (before 150 years to Tomson's invention). He created the lightning rod.

Luigi Galvani (1737–1798), founder of electrophysiology. In 1771 he began experiments with the animal electricity. Muscles of dead toad reacted when two different metals touched it. He expressed his opinion about animal electricity, which was similar to Leiden jar, which was storing the electric charge. The theory was denied by **Alexander Volta** (1745–1827). The source of electricity was the contact of two electrified metals, which were used by Galvani. "Iron plate – muscular tissue – copper hook" it is an electric circuit, muscles of a toad as an electrolyte. In 1775 Volta created the electrophorus machine to strengthening of the electricity. In 1800 he created "Voltaic pile" – the source of direct current based on chemical processes. A simple and reliable source of electric current that did not need to be recharged like the Leyden jar, his invention quickly led to a new wave of electrical experiments. Within six weeks of Volta's announcement, English scientists **William Nicholson** and **Anthony Carlisle** used a voltaic pile to decompose water into hydrogen and oxygen, thus discovering electrolysis (how an electric current leads to a chemical reaction) and creating the field of electrochemistry.

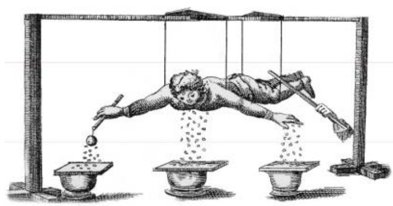

Fig. – Experiment with electricity and human body

Michael Faraday (1791–1867) London. He was born in the family of blacksmith, finished only primary school, engaged in self-education. Listening to lectures by **Humphry Davy** he decided to be a chemist. He discovered liquid benzene, chlorine, hydrogen sulfide, carbon dioxide, nitrogen dioxin. After meeting with Ampere and Gay-Lussac he decided to become a physicist. In 1831 he discovered the phenomenon of electromagnetic induction. Now you can receive electricity by mechanical means, and reverse – to provide motion of machines with electric current. Discovery by Faraday determined the fate of all heavy industry.

Also he enriched ABC of electricity – introduced concepts: mobility, cathode, anode, ions, electrolysis, and electrolyte. He invented voltmeter, discovered the phenomenon of paramagnetism and diamagnetism. Experimentally he proved the law of conservation of electric charge.

James Clerk Maxwell (1831–1879). He was born in a wealthy Scottish family. He graduated from Edinburgh University and Cambridge. Faraday was interested lines of force, by writing them in the form of mathematical formulas (used integrals). He introduced the function of vector-potential of “bias”. In 1873 he published two-volume work “A Treatise on Electricity and Magnetism” which contained the basic equations of the electromagnetic field, known today as Maxwell's equations. Scientists believe he is the author of the principle of color photography. He prepared for publication manuscripts of works by Henry Cavendish, a lot of attention was paid to popularize a science.

Heinrich Rudolf Hertz (1857–1894). Germany. He experimentally confirmed Maxwell's electromagnetic theory of light. Hertz proved the existence of electromagnetic waves. In 1885–1888s he conducted a series of experiments with the transmission of electricity. Details studied reflection, interference, diffraction, polarization of electromagnetic waves. He proved that light was a kind of electromagnetic waves. The results were taken as the basis for the development of wireless telegraphy and radio.

Biology. **Jean-Batiste Lamarck** (1744–1829). Lamarck was the first biologist who tried to establish a clear and comprehensive theory of the evolution of the living world, known today as one of the historical evolution of concepts, the so-called “Lamarckism”. In 1802, he coined the term “biology” (along with German scientist G. R. Treviranus). The author of the first scientific data on the flora of France (three-volume work was published in 1778). The important work of Lamarck was the book “The Philosophy of Zoology” published in 1809.

Charles Darwin (1809–1882) – British scientist who created the theory of evolution and offered in conjunction with Wallace principles of natural selection. At the end of 1831 he began a five-year voyage around the world aboard the “The Beagle”. This trip was an important event in the life of Darwin, a real school for him. He intensively worked as a geologist, zoologist, botanist, and gathered a vast and very valuable scientific data, which played a crucial role in the development of evolutionary ideas. In 1859 a brilliant work of Charles Darwin's “The Origin of Species by Means of Natural Selection or the Preservation selected races in the struggle for life” was published.

Metallurgy. **Pavel Petrovich Anosov** (1796(9)–1851). He began a systematic study of the effect of various chemical elements on steel. Scientific principles laid metallography, the first time used a microscope to study the structure of the steel.

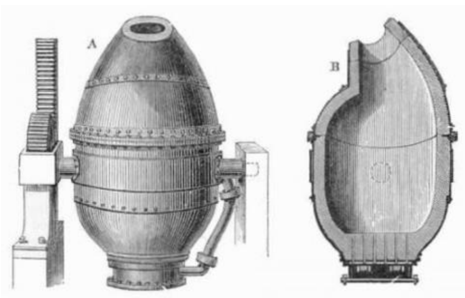

Fig. – H. Bessemer's converter

Henry Bessemer (1813–1898). He had patents for more than a hundred inventions, but his most important invention was the development of the process of steel obtaining without additional heating in 1856, blowing air through molten pig iron in pear-shaped reservoir (now known as Bessemer's converter). In industrial scale a steel proved low quality and for long time scientist was involved into finding solutions to remove contaminants: sulfur and phosphorus.

Fig. – Mushet's Special Steel

The Englishman **Robert Forester Myushet** (1811–1891) helped him to solve this problem. In 1857 R. Myushet was the first who made the long strips of steel instead of cast-iron, thus creating a basis for the development of rail transport in the world in the late 19th century. He invented actually tool steel and the first air-hardening steel, "R. Mushet's Special Steel" (RMS) in 1868. He proposed Bessemer to add some percent manganese and a problem was solved.

A new method for producing Cast steel flame hearth regenerative furnace offered a French metallurgist – **Pierre Martin** (1825-1915). As the reducing agent he used oxygen. Together with Bessemer's and open-hearth method was known method proposed in 1878 by **Sidney Gilchrist Thomas** (1850-1885) with his cousin **Percy (Carlyle) Gilchrist** (1851-1935), the so-called "Tomas's method" for manufacturing low-phosphorous steel.

Development of basics of mathematical analysis.

Augustin-Louis Cauchy (1789–1857). France. He was a mathematician, engineer, and physicist who made pioneering contributions to several branches of mathematics, including mathematical analysis and continuum mechanics. He was one of the first to state and rigorously prove theorems of calculus, rejecting the heuristic principle of the generality of algebra of earlier authors. He almost singlehandedly founded complex analysis and the study of permutation groups in abstract algebra. Cauchy is most famous for his single-handed development of complex function theory. The first pivotal theorem proved by Cauchy, now known as Cauchy's integral theorem (1825) and later he proposed a formula – Cauchy's integral formula (1831).

Carl Frederic Gauss (1777–1855). German mathematician is generally regarded as one of the greatest mathematicians of all time for his contributions to number theory, geometry, probability theory, geodesy, planetary astronomy, the theory of functions, and potential theory (including electromagnetism). Gauss's first significant discovery, in 1792, was that a regular polygon of 17 sides could be constructed by ruler and compass alone. Its significance lies not in the result but in the proof, which rested on a profound analysis of the factorization of polynomial equations and opened the door to later ideas of Galois Theory. His doctoral thesis of 1797 gave a proof of the fundamental theorem of algebra: every polynomial equation with real or complex coefficients has as many roots (solutions) as its degree (the highest power of the variable).

Jean Baptiste Fourier (1768–1830). France. He proved a theorem of the number of actual roots of equalization of algebra in the set borders (Theorem of Fourier, 1796). In the monograph of 1822 the “Analytical Theory of Heat” it was shown out equalization of heat-conducting in a solid and development of methods of his integration at different maximum terms. Fourier invented the formula of presentation of function by means of integral that plays an important role in modern mathematics. In 1823, regardless of Ersted, he opened a thermo-electric effect, showed that it was a characteristic of superposition, and created a thermo-electric element.

Creation of geometry of Non-Euclidean by **Nikolay Ivanovich Lobachevsky** (1792–1856). Russia. “Copernicus of Geometry”. From 1835 to 1838 Lobachevsky published “Imaginary Geometry”, “New Foundations of Geometry with the Complete Theory of Parallels”, and “Application of Geometry to Certain Integrals”. Realizing that Euclidean geometry has a valuable alternative, he produced the large impression on the scientific world and gave an impulse to other innovative ideas in mathematics and physics.

Mihajlo Vasilyovich Ostrogradsky (1801–1862). Ukraine. He was the author of 40 works on mathematical analysis (infinitely-small, integration of rational functions), mathematical physics (differential equalizations of distribution of heat are in liquid solids), theoretical mechanics (principle of the possible moving, ation principles of mechanics, theory of w, theory of resiliency, distribution of es on the surface of liquid and others like), written with mainly French. He verted integral over the volume into the gral over the surface, named after him mula of Ostrogradskiy 1828, published in 1831).

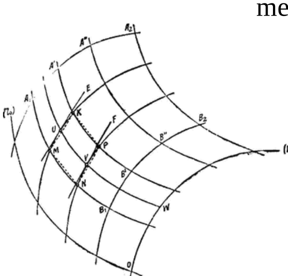

Fig. – Geometric network by P. Chebyshev

Pafnuty Lvovich Chebyshev (1821–1894). Chebyshev is known for his work in the fields of probability, statistics, mechanics, and number theory.

Chebyshev is also known for the Chebyshev polynomials and the Chebyshev bias – the difference between the number of primes that are congruent to 3 (modulo 4) and 1 (modulo 4).

Consequences of technological revolution. The transition from manufacture to large-scale machine industry fundamentally changed not only the technical base of production countries, but the sphere of public relations. The adoption of the large-scale machine industry in the leading industries of all countries that had passed this way, created preconditions for the further development of productive forces. The industry became the main branch of production. The Industrial Revolution had a tremendous social impact. It made drastic changes in the structure of production and national wealth, the emergence of a qualitatively new type of economic relations. For 100 years an industrial civilization of the world was formed.

QUESTIONS

1. *Characterize shortly three stages of the industrial revolution.*
2. *Name the stimulating factors of industrial development in the XVIII - XIX centuries.*
3. *Analyze the development of chemistry as a science in the XVI - XVIII centuries.*
4. *Characterize scientific (not only electrical) activity of Benjamin Franklin.*
5. *How was Galvani's theory of animal electricity refuted?*
6. *Consider the special features of the industrial revolution in the Russian Empire.*
7. *Tell about the history of modern metallurgy formation in the beginning of the XIX century.*
8. *Describe the research in mathematics of Cauchy, Gauss, Fourier.*
9. *Give examples of non-Euclidean calculations.*
10. *What are the results of technological revolution in the XVIII – XIX centuries?*

THEME 6. THE NEWEST REVOLUTION IN NATURAL SCIENCE IN THE LATE OF THE XIX – AT THE BEGINNING OF THE XX CENTURY

The newest revolution in natural science at the turn of the 19th and 20th century was created by the whole history of philosophy, physics, and chemistry.

In 1870s–1890s the research on cathode rays started up. It was found that cathode rays were negative electric charges, therefore, they were discrete, and not the wave formations. This discovery was the beginning of electronics.

On the boundaries of physics and chemistry many remarkable discoveries were made in the field of electrochemistry in 1880s that laid the foundation of physical chemistry. In 1885–1887 **Svante Arrhenius** (1859–1927) developed a theory of electrolytic dissociation. The central concept of this theory was the concept of ion – a charged fragment of a molecule of solute that carried a discrete charge – positive (for cation) or negative (for anion). Although the idea of complexity and divisibility of an atom had already arisen, but there wasn't any direct experimental evidence supporting these ideas before the end of the 19century.

However, **D. Mendeleev**, who in the early 1870s tended to think that atoms were divisible and composed of "ultimates", then by the end of 1880s under the influence of invariably negative results, he came to conclusion that chemical elements, or «simple bodies», were extreme face of our knowledge about the matter. These elements didn't decompose and didn't transform from one to another. Correspondingly, atoms must be indivisible, not only mechanically, and in the real sense of chemistry.

Although it was established that the valence of the elements had a discrete character and varied in oxygen (negative element) and hydrogen (positive elements), nevertheless a direct link between electrical and chemical properties of the material hadn't been discovered, and the periodic law of Mendeleev was treated as a purely chemical. In this case, the chemistry of the elements linked only with their mass.

Despite of the great progress of electromagnetism theory, the physical picture of the world generally remained mechanical until the end of the 19th century. Meanwhile, these advances in knowledge of electrical phenomena at the end of the 19th century prepared the collapse of the old mechanical picture of the world and the creation of a new electromagnetic one that it was possible due to outbreak of the newest revolution in natural science. First it all physics was involved by this revolution, especially the area of electromagnetic phenomena knowledge, which than enabled to penetrate into the sphere of microcosm.

Three great physical discoveries were made one after the other: the first, in 1895 when **Wilhelm Conrad Roentgen** discovered rays (another theory it was made by **Ivan Pului**), called *X*-rays; the second, when the phenomenon of radioactivity was discovered by **Antoine Henri Becquerel** in 1896 and the third was in 1897 when **J. Thompson** found the electron. All three discoveries were connected with electricity and magnetism: it was a new type of electromagnetic waves or radiation of charged particles.

Fig. – Photo of a stillborn baby made by I. Pului's lamp

The discovery supported opening of a new chemical element – radium that was made by **Marie Sklodowska-Curie** (1867–1934) and **Pierre Curie** (1859–1906) in 1898. It played particularly important role. Radium had much stronger radioactive properties, rather than uranium. **A. Becquerel** was the first who discovered the radiation of uranium.

In 1902–1903s **Ernest Rutherford** (1871–1937) and **Frederick Soddy** (1877–1956), created the first theory of radioactivity as the spontaneous decay of atoms and the transformation of one elements into another, in this case, transformation of radium to the radium emanation (radon), and helium. Since the discovery of radium and the creation of the theory of radioactive decay a new branch of physics nuclear physics originates.

The creation of the theory of quanta by **Max Planck** in 1900 helped the penetration of discrete ideas into physics greater degree. Studying the thermal emission of so-called blackbody, Planck discovered that it couldn't be described by classical formulas of the radiation, but for this process a special discrete constant value - the quantum of action must be introduced into the appropriate formula.

Five years later in 1905 **Albert Einstein** (1879–1955) introduced a concept of light quantum, or photon (an atom of light). As a result, it was revealed deeply contradictory nature of light. On the one hand, the wave (continuous), as classical optics established, on the other hand – a discrete (dashed), as quantum physics opened it.

In November 1915 Einstein completed the general theory of relativity. Einstein also launched the new science of cosmology. His equations predicted that the universe is dynamic – expanding or contracting.

From Maxwell's theory, confirmed and proved experimentally by **Hertz**, it followed that there were electromagnetic waves of great length. In the late 1880s **Olexander Stepanovich Popov** (1859–1906) began to study them, and in 1895 he invented the radio, which became one of the first and very important practical applications the newest revolution in science.

In 1896–1897 **Guglielmo Marconi** (1874–1937) invented wireless telegraphy; he continued its further development and promotion it into a service. In 1900 he took out his famous patent No. 7777 for "tuned or syntonic telegraphy" and, on an historic day in December 1901, determined to prove that wireless waves were not affected by the curvature of the Earth, he used his system for transmitting the first wireless signals across the Atlantic between Poldhu, Cornwall, and St. John's, Newfoundland, a distance of 2100 miles.

Important discoveries and inventions were made by **Nikola Tesla** (1856–1943). Among them there were alternating current, high-frequency engineering, multi-phase electrical machinery (including an induction motor), radio (patented in 1891, before Popov and Marconi), a theory of resonances, and transmission of electricity wirelessly and many others.

Earlier matter and light were treated as incapable to mutual transformation and conversion, and only much later; nuclear physics proved the existence of such transformations. The foundation for these nuclear reactions was a fundamental law of physics, discovered by Einstein in 1905, and stating that, in general, for anybody total energy was equal to its mass multiplied by the speed of light squared. This law, Einstein deduced theoretically as a consequence of the theory of relativity created by him. After that Einstein's law became the basic one for nuclear physics.

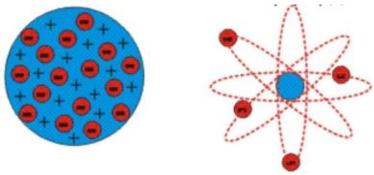

Fig. – The model of atom by Thomson "Raisin cake model" vs by Rutherford "Planetary model"

At the end of the 19th century a close relationship of physics and chemistry was manifested. **J. Thomson** created a static atomic model where fixed electrons were embedded in a positive electrical charge spread all over the entire volume of an atom. At the same time an attempt was made to arrange the electrons in concentric rings, corresponding to a definite period of the Mendeleev's periodic table of elements. Along with the static model of the atom a dynamic model was proposed, proving from the thought of moving electrons inside an atom.

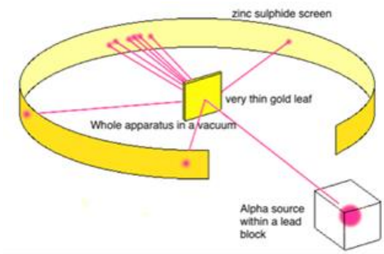

Fig. – E. Rutherford's experiment

In 1911, a new great discovery was made in physics: as a result of the atoms bombing by alpha particles, **E. Rutherford** discovered an atomic nucleus that carried all the positive charge in an atom and almost the entire mass of an atom. It became clear that atomic model should have a planetary character, remembering a miniature solar system: its nucleus was in the center of an atom and around it, like planets around a star, electrons speed with great spinning.

Before 1911 science knew only two "building bricks". That was an electron, which was opened in 1897, and a photon, the concept of which was defined in 1905. But there was no way to get electrically neutral formations, so as a particle carrying a positive charge failed. Now such a particle was found: a proton that was a nucleus of an atom of hydrogen. All three elementary particles were photons, electron, and proton formed a set of particles that was already enough to build, nearly any physical formations, in particular, a model of the atom.

In 1913 **Niels Bohr** (1885–1962) created an atomic model. His model of an atom in its original form was still very imperfect. First of all, there was no accurate picture of the structure of electron orbits. Therefore, the orbits were necessarily circular, arranged in concentric circles, in the general center of which a nuclear atom was.

Even in the first static models of atoms, J. Thomson, disposed electron layers that in such a way to explain the periodicity of the elements in Mendeleev's classification. Bohr likewise conceded that at each quantized level a number of electrons that didn't exceed their limit for that level of significance could be arranged. Only later Pauli gave a theoretical justification of that limit.

The improved model of an atom created by Bohr was a culmination of the first phase of the newest revolution in natural science, which was connected to generation of an electromagnetic picture of the world. However, this model brought together as in prism all the difficulties and contradictions that had arisen on the way of development of this revolution and exacerbated by the end of its first phase, and more insistently demanding permission and overcome.

Meanwhile the active research in nuclear physics was going on. It was directed to the methods of artificially induced nuclear reactions, i.e. transmutation of elements. The main center of these studies was still the Rutherford Laboratory. In 1919 he succeeded bombarding atoms of stable element (nitrogen) with alpha particles, and to call its artificial transformation into atoms of another stable element (oxygen). It was a real revolution in nuclear physics.

In 1922 **Niels Bohr** divided all the properties of elements into two distinctly different classes. To one of them he referred most ordinary of their properties, including all chemicals. Another class was, according to Bohr, radioactivity, that depended entirely on a nucleus.

Later, when the electromagnetic picture collapsed under the impact of new discoveries, it appeared that chemistry of an atom partly depended on the mass of a nucleus, and not only on its electric charge, and that Bohr was wrong in his sharp division of the properties of elements into two unrelated classes.

Electromagnetic picture of the world that was emerged in the field of scientific ideology and worldview on the basis of physics and natural science, was organically combined with the aspiration to the most complete and widespread use of electricity in real life: in industrial production (electrometallurgy), in agriculture, in transport (electric trains), in communication (telephone, radio), in urban life and in everyday life (electric lighting), in medicine and other fields of human activity. In all these areas, the science of electricity, directly and indirectly contributed to the practical application of electricity for human needs.

QUESTIONS

1. Characterize the main stages of the development of scientific knowledge in the field of electricity on the boundary of the XIX – XX century. What is the scientific contribution of Faraday and Maxwell to this process?

2. Prepare report on scientific activity of Benjamin Franklin in the field of electricity.

3. Name the most important inventions of Thomas Edison's company.

4. What are the historical causes of the discovery of atomic nucleus?

5. Analyze the main theories of atomic models on the boundary of the XIX - XX century.

6. Characterize Mendeleev's scientific activity in the field of chemistry.

7. What role did the experiments of Becquerel and the Curies play in the history of physics?

8. Compare the experiments and discovery of X-rays made by Pului and Roentgen.

9. Analyze the activity of Cavendish Laboratory on the boundary of the XIX – XX century and scientific research of Thomson, Rutherford.

10. Why is the theory of relativity of Albert Einstein considered to be a triumphant conclusion of classical ideas arid the beginning of new trends in physics?

THEME 7. SCIENTIFIC AND TECHNICAL DEVELOPMENT IN THE FIRST HALF OF THE 20TH CENTURY

The 20th century was the era of electronics. Radio, tape recorder, television, CD player – appeared in 1904, when the British engineer John Fleming invented the first electronic tube, a diode tube.

In this brief volume of material it is difficult to give characteristic to all aspects of scientific and technical progress, so we emphasize our attention to what we observe every day.

The evolution of the automotive industry. This technical device was developed from the self-propelled toy for the Chinese emperor, created by scientist F. Ferbist circa 1672, the steam engine car – the invention by the Frenchman **Nikolas Cugnot** in 1769, Daimler-Benz internal combustion engine from 1880s.

Fig. – N. Cognot steam engine car

Despite the rapid development of this type of transportation, in some countries absurd laws were adopted. In the middle of the XIX century Britain was the leader in the development of emerging road transportation. However, owners of railways and equestrian crews thought that the car is a threat to their existence. They united in the fight against a potential competitor. In 1861, they were allowed to pass a law restricting the speed of «highway locomotives» up to 10 miles/h (out of the city and up to 5 miles/h in the city. Also, for the car driving, there should have been not less than two people. But it seemed to them that it was not enough and in 1865 the «Red Flag Act» was adopted. The law restricted the speed of cars within the city to 2 miles/h. In addition, the law obliged to have minimum of three people in the crew: a driver, a stoker, and a man with a red flag. Signal with a flag, went ahead of the car at a distance of 55 meters and informed the passers-by of the approaching danger, waving the red flag. The «Red Flag Act» actually destroyed the emerging automotive industry in the UK – and the designers of the cars from France and Germany broke ahead.

For example, **Leon Serpollet** (1858–1907), the inventor from France even achieved the speed of steam engine car in 120 miles/h; unfortunately, the efficiency remained only 3%. Instead, cars with an internal combustion engine were created. Thus in Germany in 1883, K. Benz developed a two-cylinder engine. His countryman – G. Daimler developed the first car with four cylinders in 1889.

Fig. – Mercedes-Benz Model S

Starting from the inventions by **K. Benz** and **G. Daimler** the cars with internal combustion engine were developed in the world. In particular, this was due to the powerful sponsorship of the fervent racing driver **E. Elinnek**, who, in honor of his daughter, gave the name "Mercedes-Benz". So, a new era in automotive history began in 1901 when Daimler Motoren produced its first Mercedes, which already had a form of a modern car. This beautiful, elegant and reliable car had a frame that was made of pressed steel sections, a bronze radiator, a gearbox and a four-cylinder engine of 35 horsepower that provided the ability to reach speed up to 70 km/h. With advent of first Mercedes car childhood was over and the rapid development of automotive industry began.

It was a revolution in the life of towns and villages. Those who had been in Paris and Berlin could see a large number of cars in the streets. In Paris, even there were automobile cabs – carriages, this name was given to the first taxi.

The history of the modern automobile industry began in 1903 when in Detroit in America a new enterprise of Ford Motor Company was opened. Its founder was forty years old **Henry Ford**, a former chief engineer of Edison Electric Company, who made a car available for everybody.

By the start of 20th century, the demand for cars started growing but the cars were still expensive, because these cars were manufactured and assembled with hands. In 1908 Henry Ford introduced the legendary Ford

Model T which was the beginning of an era, where even middle class could own a car. For the first time, Ford’s Model T introduced the concept of Assembly line in the automobile sector. The concept of mass production-high volume low variety” - was brought into focus and this was made immortal by the words said by Henry Ford in his Autobiography where he says, “Any customer can have a car painted any color that he wants so long as it is black.”

The era after the First World War was known as the vintage era (1919–1930). The First World War was a milestone, as closed body cars were put into production in the 1920s and the technology of automatic transmission was first conceptualized in this era.

In 1892 German engineer **Rudolf Diesel** obtained a patent for an internal-combustion engine that was capable to run on heavy grades of fuel. The problem was so difficult that it took five years of work for the inventor and help of Augsburg engineering plant and Krupp plant. In 1897 the first working design engine was ready for testing, that it successfully carried out. The new engine was named after its creator – Diesel.

The history of tanks. In 1903, a French artillery captain named Leon Levavasseur proposed the Levavasseur project, a canon, moved by a caterpillar system and fully armored for protection. Powered by an 80 hp petrol engine “the Levavasseur machine would have had a crew of three, storage for ammunition, and a cross-country ability”.

Vasily Mendeleev, an engineer in a shipyard, worked privately on a design of a super-heavy tank from 1911 to 1915. It was a heavily armoured 170 ton tracked vehicle armed with one 120 mm naval gun. However, the cost was almost as much as a submarine and it was never built.

The Vezdekhod was a small cross-country vehicle designed by aero-engineer **Oleksandr Porokhovschikov** that ran on a single wide rubber track propelled by a 10 hp engine. Two small wheels either side were provided for steering but while the vehicles could cross ground well its steering was ineffectual. In post-revolution Russia, the Vezdekhod was portrayed in propaganda as the first tank.

From late 1914 a small number of middle-ranking British Army officers tried to persuade the War Office and the Government to consider the creation of armored vehicles. Amongst their suggestions was the use of caterpillar tractors, but although the Army used many such vehicles for towing heavy guns, it could not be persuaded that they could be adapted as armored vehicles. The consequence was that early tank development in Great Britain was carried out by the Royal Navy.

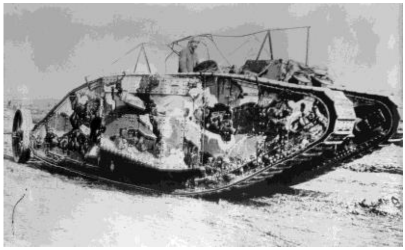

Fig. – British Mark I tank

The first offensive using tanks took place on 15 September 1916, during the Battle of the Somme. Forty-nine tanks of the Mark I type were committed, of which 32 were mechanically fit to take part in the advance and achieved some small, local successes.

The evolution of aeronautics. In 1852 the first airship took the air. It was created by **Henri Giffard** providing it with a small steam engine and steering control. The airship flew 27 km but could not overcome the wind. In 1900 a German engineer, **Ferdinand von Zeppelin** (1838–1917) built an airship on a rigid construction and took a flight. It was designed of aluminum that included huge bags filled with explosive hydrogen. During the First World War airships bombed London at night. After the war a luxury airship «Graf Zeppelin» and «Hindenburg» transported thousands of passengers across the Atlantic Ocean. Famous "Graf Zeppelin" had five engines and was capable of making 128 km/h. In 1937 "Hindenburg" exploded in New York, while berthing to the mast, and fell down to the ground. By the 1940s airships had given the way to airplanes.

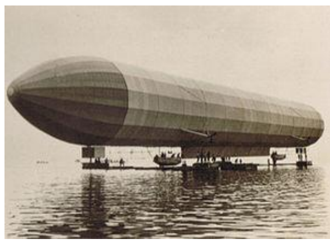

Fig. – LZ2, 1905

The problem of control flight on the vehicle with a machine-engine practically was decided by American designers, brothers Wilbur and Orville **Wright**. After several attempts on December 17, 1903 Wilber on a plane with a gasoline engine producing 12 horsepower made the first in the history of mankind sustained controlled flight at a distance of 260 meters. It lasted 59 seconds with a speed of 50 km/h.

1909 was the year of international competition of pilots, universal triumph of airplanes. Outstanding French aviator Bleriot on an airplane Bleriot-II with a 35 horsepower motor made a flight across the English Channel. Thus it was proved that water under the plain wasn't a hazard for flights. It took him 37 minutes to make 35-mile flight. Bleriot struggled with the wind, the engine overheating and made a crash landing.

At the same time **Farman** created his aircraft Farman 3 – reliable, steady, and manageable. It became a main training machine of that time and one of the first airplanes that began to produce commercially. Thousands of pilots from many countries passed a curriculum on it.

Igor Sikorsky (1889–1972) was a Ukrainian-American aviation pioneer in both helicopters and fixed-wing aircraft. His first success came with the S-2, the second aircraft of his design and construction. His S-6-A received the highest award at the 1912 Moscow Aviation Exhibition.

In 1913 I. Sikorsky created "Russky Vityaz" – first four-engine aircraft. Later this year he designed the "Ilya Muromets" airliner and it became the first four-engine bomber. After immigrating to the United States in 1919, Sikorsky founded the Sikorsky Aircraft Corporation.

Fig. – Heavy bomber "Ilya Muromets"

In 1925, in Kyiv the protocols of the successful flying tests of the new passenger airplane K-1 were signed (designed by Kostantin Kalinin). It was recognized to be accepted in civil aviation as the one, which fully meets all the requirements to the passenger machines. There were in the design of K-1 several new technical ideas, which later became classic: the plane fuselage first time in the USSR was made from the steel tubes, the wings were adjusted with wire's bracings, the passenger cabin and the front part of the fuselage were covered by light and sturdy, corrosion resistant material – aluminum. With its full load – three passengers and a pilot – the plane reached the speed up to 160 km/hour with a maximum flight altitude – 3 thousand meters.

1920s and 1930s was "golden age of aviation" in America. This was a romantic time when flying was still somewhat new, and pilots were considered heroes. Each ace-high pilot tried to master The North and The South Atlantic. First three decades of the 20th century were the era of seaplanes. During this period people didn't believe in the reliability of aircraft engines, preferring to cross water areas on floating aircraft.

Over time the speed of aircraft was increasing. The world was filled with airplanes. Specialists equipped with technology and theoretical transactions, created more sophisticated aircraft designs. During the Second World War rockets and jet engines appeared. Aircraft equipped with such engines and with the speed of about 880mph lost control and began to vibrate so they sometimes destroyed. Many pilots died trying to overcome this barrier. In 1947 **Chuck Yeager**, on the plane "Bell", managed to break the sound barrier.

Television. It is considered that television invention, as well as the radio is one of the most remarkable inventions of the XX century.

In 1884 German student **Paul Nipkov** (1860–1940) patented a scanning disk used in transformation of an image into electrical impulses. In the Nipkov's device there were compounds of so-called mechanical television. Although the problem of the sweep signal was successfully solved, neither Nipkov nor his followers were capable to transmit images.

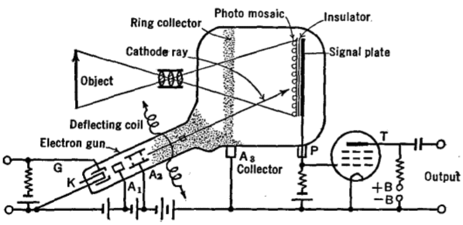

Fig. – The iconoscope

Further improve of television development contributed to the discovering of the photoelectric effect. In 1923 the first practical transmission of stationary images were carried out from Washington to Philadelphia.

Two years later – images of moving figures.

The first substantially operating television system was established by the British engineer **J. D. Byrd**. Basing on the principle of scanning with the use of Nipkov's disk, he demonstrated to audience a transmitting of an image and restoration of it on the screen in 1926. Thus for the first time in the world a television image was rendered to the size of a postage stamp. With the beginning 1929 the British Broadcasting Corporation (BBC) used this system for regular experimental broadcasting. The system was based on a mechanical deployment. The same studio existed in Moscow and Leningrad. Tens of thousands people had televisions at home. Mechanical television didn't obtain a wide circulation. At last electronic television began to be used widely.

The most primitive and imperfect form electronic television appeared with **B. L. Rosing's** discovery, a professor of physics from St. Petersburg. On July 25, 1907 he proceed with an application to grant him patented rights on the invention the way of electrical transmission of images over a distance. Soon he received patents for an electronic television in England (1908), Germany (1909) and Russia (1910). On May 9, 1911 Rosing's friends and colleagues attended an amazing experiment: on the small screen of an electron ray tube four parallel lines of light appeared.

In 1923 **V. K. Zworykin**, one of the students of Rosing, who helped him in inventing the first television, patented completely electronic television system with transmitting and receiving CRT in the USA where he emigrated from Russia in 1917. In 1933 he announced about successful completion of the operative television tube – iconoscope.

The first black and white TVs in the USA are sold as a set of "Do It Yourself" that buyers made. TV screen size did not exceed 10 inches height and 5 inches wide.

In early 1935 in Leningrad (St. Petersburg) the creation was completed and the demonstration of the current TV screen measuring 8 cm by 11 cm took place. It was watched by 15 people at the same time.

In 1927 the British Broadcasting Corporation (BBC) was founded. Pictures of Herbert Hoover, U.S. Secretary of Commerce were transmitted 200 miles from Washington D.C. to New York, in the world's first televised speech and first long-distance television transmission. In 1936 the BBC started the world's first television broadcast.

QUESTIONS

1. *What are the special features of scientific and technological progress in the first half of the XX century?*
2. *Characterize the main stages of automobile industry development in the second half of the XIX and the first half of the XX century.*
3. *Why did steam-engine cars cease to exist? What prompted the developers to use new fuels?*
4. *What machines became the prototypes of the first tanks?*
5. *What are the most important stages of aviation development in the second half of the XIX century and in the first half of the XX century?*
6. *What happened to the Ukrainian pioneers of aviation – Sikorsky and Kalinin?*
7. *Why are not airships used in our time?*
8. *What was the role of radio and television in the first half of the XX century? Tell about the history of their invention.*
9. *Analyze the development of military engineering in the first half of the XX century.*

THEME 8. SCIENTIFIC AND TECHNOLOGICAL REVOLUTION

Under the influence of science and technology from the second half of the XX century in developed industrialized countries qualitative changes had occurred in the productive force based on the transformation of science into a leading component of material production. Science and technology changed characteristics of social production conditions, the nature and content of work, the structure of the productive force. They provided the rapid growth in working efficiency – the main factor that affects all spheres of society: culture, living conditions, psychology of people, and their relationship with nature.

With new knowledge, space-flight became possible; lasers were designed and used, transistors, computers, nuclear power appeared. Using of nuclear energy has largely affected the psychology of people, confirmed the enormous potential of science and its practical use.

Development of discoveries in the first half of the 20th century led the humanity to the true scientific and technological revolution. 90% of all inventions and discoveries were made during the period of the STR. For example High-speed trains, cars, planes, mobile telephone, TV, Internet and other were created in the period of STR.

STR in the world began in the middle of XX century. It “gave birth” to new scientific revolutions like genetic, biological, information, laser, and psychological revolutions.

The main components of scientific and technological development are:
— Development of science, organization and conduct of fundamental and applied research, experimental design and technological work;
— Creation, commercialization and distribution of advanced production technologies and their corresponding equipment, facilities and controls;
— Training and retraining of personnel with technological knowledge and skills;
— Introduction of advanced production technologies in the production and release on their basis of competitive high-tech products;
— Formation and development of technological infrastructure;
— Development of applied technological science.

Periodization (symbolic, example for Ukraine)

1. From the middle of 1940s to the late 1960s. Mechanization of production. Nuclear weapons. New construction materials. A space flight.
2. 1970th – middle of 1980s. Automatization of production, intensive development of information technology. Using of intellectual capacity of other countries.
3. The end of 1980th – nowadays. Information Revolution. Biotechnology, medicaments, using of laser technology.

At the present stage of development, it becomes evident that since the beginning of the industrial revolution, science and technology have brought not only a positive but also a serious negative contribution to the social and economic process. Strengthening the ecological crisis and increasing the instability of social development contributed wars and testing all kinds of weapons in conjunction with man-made disasters. Negative fallouts of the STR, such as new safety issues, unemployment, pollution, and health risks result in psychological - replacement of the real world.

Development of nuclear energy. After discovering the secrets of the atom the experimental work on splitting of the atom began. Artificial splitting of the atom was made in 1919 by **Rutherford** at Cambridge at the Cavendish Laboratory.

In 1928 in our city the Kharkov Institute for Physics and Technology (UPTI) was created. In1932 first in the Soviet Union, **Anton Walter**, **George Latyshev**, **Olexander Leypunskyy** and **Cyril Sinelnykov** split nucleus of Llithium. In the future, UPTI's scientists got liquid hydrogen and liquid helium, built the first radar and equipment designed for industrial vacuum industry. In 1935–1937 scientists of UPTI was repressed, five were executed.

Enrico Fermi (1901–1954). Italy. In 1934, a theory of beta decay, the essence of which is that in addition to the electron in beta decay and neutrinos produced too. (Nobel Prize in Physics, 1938). In 1939 he immigrated to America. During his work at Columbia University, he introduced the term "chain reaction ". In 1944 he started working in the Los Alamos National Laboratory in New Mexico. He was one of the leaders of the Manhattan project. This Project was a research and development undertaking during World War II that produced the first nuclear weapons. It was led by the United States with the support of the United Kingdom and Canada. From 1942 to 1946, the project was under the direction of Major General Leslie Groves of the U.S. Army Corps of Engineers. Nuclear physicist **Robert Oppenheimer** was the director of the Los Alamos Laboratory that designed the actual bombs.

Fig. – Bikini Atoll, July 1, 1946

The first nuclear device ever detonated was an implosion-type bomb at the Trinity test, conducted at New Mexico's Alamogordo Bombing and Gunnery Range on 16 July 1945. “Little Boy” and “Fat Man” bombs were used a month later in the atomic bombings of Hiroshima and Nagasaki, respectively. In the immediate postwar years, the Manhattan Project conducted weapons testing at Bikini Atoll as part of Operation Crossroads, developed new weapons, promoted the development of the network of national laboratories, supported medical research into radiology and laid the foundations for the nuclear navy. It maintained control over American atomic weapons research and production until the formation of the United States Atomic Energy Commission in January 1947.

Igor Vasilyevich Kurchatov (1903–1960) USSR. He is widely known as the director of the Soviet atomic bomb project. Under his guidance the first Europe cyclotron (1939) was built, he opened a spontaneous nuclear split of uranium (1940), developed a method of demagnetizing ships to protect them from German mines (1941). Together with C. Sinelnikov he started working on the first proton accelerator at the Kharkov Institute for Physics and Technology in 1933.

He created Europe's first nuclear reactor (1946). On 29 August 1949, Kurchatov's team successfully detonated its initial test device First Lightning (a plutonium implosion bomb) at the Semipalatinsk Test Site.

In 1953, the Soviet Union detonated its first thermonuclear device, codename Joe 4. Under his guidance the first in the world nuclear power plant NPP (1954 in Obninsk city) was built.

In 1957, the International Atomic Energy Agency (IAEA) was created. This organization established to promote cooperation in the peaceful uses of atomic energy. It is located in Vienna. The most important activity of the IAEA is to ensure non-proliferation of nuclear weapons.

The development of genetics.

Between 1856 and 1863, **Gregor Johann Mendel** cultivated and tested some 5,000 pea plants. From these experiments, he induced two generalizations which later became known as Mendel's Principles of Heredity or Mendelian inheritance.

In 1908 **Thomas Hunt Morgan** (1866–1945) American zoologist and geneticist, famous for his experimental research with the fruit fly (Drosophila) by which he established the chromosome theory of heredity. He showed that genes are linked in a series on chromosomes and are responsible for identifiable, hereditary traits. Morgan’s work played a key role in establishing the field of genetics. He received the Nobel Prize for

Physiology or Medicine in 1933. The chromosome theory of heredity confirmed principles proposed by G. Mendel.

Genetic, as independent scientific discipline, began to develop in Ukraine actually from 20th of the XX century. To the most prominent achievements should to be putted works by **Mykola Vavilov** (1887–1943). He proposed the law of homological lines in the inherited changeability. This law played an enormous role in the study of evolution and systematization of cultural plants, opened new ways for the selection of the cultivated crops. M. Vavilov also developed the theory of origin of selection of the cultivated crops. He collected unique collection of plants, providing a basis for further selection work. As a result of study of kinds and sorts of the plants, gathered in the countries of Europe, Asia, Africa, North, Central and South America, scientist determined the centers of origin and variety of cultivated plants.

In 1929, by the Vavilov initiative the All-Union Academy of Agricultural Sciences named after Lenin (VASKhNIL; AAASL) was created. It was the highest scientific, research, coordinative and methodical institution of Water, Forestry and Agriculture of the USSR.

Another scientist who predicted in 1928 the matrix mechanism of reproduction of genes and protein biosynthesis was **Mykola Koltsov** (1872-1940). In 1953, this idea was finally confirmed in works of American **James Watson** and British **Francis Crick**, who created the famous "double helix" – a model of DNA and processes of replication. For this discovery, in 1962, the scientists were awarded by the Nobel Prize.

In the 1930s, genetic studies in the Soviet Union receive worldwide recognition. However, in 1940 V. Vavilov was arrested. Many scientists were repressed. With the support of J. Stalin, in August 1948 at the session of Agricultural Sciences Genetics the genetics was announces as pseudoscience. There was announced a ban (prohibition) of genetic research.

In 1956 **Arthur Kornberg** (1918-2007) discovered the first enzyme capable to synthesizing of DNA in vitro. In 1961, S. Brenner, F. Jacob and M. Meselson discovered messenger RNA. In 1962, **John Gerdon** (born 1933) made the first cloning of an animal organism (a frog). In 1972, **Paul Berg** (born 1926) received the first artificial DNA. Thus the foundations of genetic engineering were laid.

In 1984, **Alec Jeffreys** (born 1950) created genomic fingerprinting method in which DNA is used to identify a person. Jeffreys's DNA method was first put to use in 1985 when he was asked to help in a disputed immigration case to confirm the identity of a British boy whose family was originally from Ghana. The case was resolved when the DNA results proved that the boy was closely related to the other members of the family, and Jeffreys saw the relief in the mother's face when she heard the results.

In 1990, the International Organization for the study of the human genome was created. **Ian Wilmut** (born 1944) is best known as the leader of the research group that in 1996 first cloned a mammal from an adult somatic cell, a Finnish Dorset lamb named Dolly.

Now in genetics there is close cooperation of scientists from different countries. Special attention is paid to the development of genotypes possessing high antioxidant characteristics, high content of vitamins and carbohydrates as well as of low content of allergens, leptins, natural toxins, minimal accumulation of pesticides, heavy metals, radionuclides etc.

Aviation**.** **Sergei Pavlovich Koroljov** (1907-1966). Koroljov was born in Zhytomyr, the capital of Volhynian Governorate of the Russian Empire now located in Ukraine. He studied at the Kyiv Polytechnic Institute, and then the Bauman Moscow State Technical University. Koroljov studied specialized aviation topics until 1929, while living with his family in the typically crowded conditions of Moscow. Koroljov enjoyed opportunities to fly gliders and powered aircraft during this part of his education. He designed a glider in 1928, and flew it in a competition the next year. His advisor was the famous **Andrei Tupolev**. In 1930 he became interested in the possibilities of liquid-fueled rocket engines to propel airplanes while working as a lead engineer on the Tupolev TB-3 heavy bomber.

August 27, 1957 under the head of Koroljov the Ultra Long intercontinental multistage ballistic missile was launched. Humanity applauds on October 4 1957 the first artificial satellite launched into the Earth's orbit.

Apogee of scientist activity – April 12, 1961 –was the first space flight aboard the ship “East” by **Yuri Gagarin**.

USA: July 20, 1969 Flying “Apollo 11” to the Moon. Apollo 11 astronauts: **Neil Armstrong**, **Buzz Aldrin** and **Michael Collins.**

The development of information technology. Abacus – also called a counting frame used in ancient world. In the middle of the 17th century traditionally was - calculations by pen on paper or using special tokens, which replaced the memorizing of numbers.

In 1622 **William Otred** – created a slide rule. In 1645 **Blaise Pascal** (1623–1662) created a machine to help his fathers, work – “Pascaline”.

Fig. – The Pascaline

In 1670 Gottfried Wilhelm **Leibniz** made more complex summary-multiplied machine (prototype of adding machine).

1833 **Charles Babbage** – announced the idea to combine the mechanisms that carry out arithmetic calculation with mechanisms of data record. These mechanisms will be had a “memory” and if we need to return to the first results we can do it. But he couldn’t create this mechanism – it was only an idea. The idea remained on paper.

For a computing machine to be a practical general-purpose computer there must be some convenient read-write mechanism, punched tape, for example. With knowledge of Alan Turing's theoretical 'universal computing machine' John von Neumann defined an architecture which uses the same memory both to store programs and data: virtually all contemporary computers use this architecture (or some variant). While it is theoretically possible to implement a full computer entirely mechanically (as Babbage's design showed), electronics made possible the speed and later the miniaturization that characterize modern computers.

Working in isolation in Germany, **Konrad Zuse** (1910–1995) started construction in 1936 of his first Z-series calculators featuring memory and (initially limited) programmability. Zuse's purely mechanical, but already binary Z1, finished in 1938, never worked reliably due to problems with the precision of parts.

Fig. – Z1 by Konrad Zuse

Zuse's later machine, the Z3, was finished in 1941. It was based on telephone relays and did work satisfactorily. The Z3 thus became the first functional program-controlled, all-purpose, digital computer. In many ways it was quite similar to modern machines, pioneering numerous advances, such as floating point numbers.

In 1939, **John Vincent Atanasoff** and **Clifford E. Berry** of Iowa State University developed the Atanasoff–Berry Computer (ABC), The Atanasoff-Berry Computer was the world's first electronic digital computer. The design used over 300 vacuum tubes and employed capacitors fixed in a mechanically rotating drum for memory.

The US-built ENIAC was the first electronic general-purpose computer. It combined, for the first time, the high speed of electronics with the ability to be programmed for many complex problems. It could add or subtract 5000 times a second, a thousand times faster than any other machine. It also had modules to multiply, divide, and square root. High speed memory was limited to 20 words (about 80 bytes). Built under the direction of **John Mauchly** and **J. Presper Eckert** at the University of Pennsylvania, ENIAC's development and construction lasted from 1943 to full operation at the end of 1945. The machine was huge, weighing 30 tons, and contained over 18,000 vacuum tubes. One of the major engineering feats was to minimize tube burnout, which was a common problem at that time. The machine was in almost constant use for the next ten years.

First-generation machines. In this generation of equipment, temporary or working storage was provided by acoustic delay lines, which used the propagation time of sound through a medium such as liquid mercury (or through a wire) to briefly store data. A series of acoustic pulses is sent along a tube; after a time, as the pulse reached the end of the tube, the circuitry detected whether the pulse represented a 1 or 0 and caused the oscillator to re-send the pulse. Others used Williams tubes, which use the ability of a small cathode-ray tube (CRT) to store and retrieve data as charged areas on the phosphor screen. By 1954, magnetic core memory was rapidly displacing most other forms of temporary storage, and dominated the field through the mid-1970s.

The first universal programmable computer in the Soviet Union was created by a team of scientists under direction of **Sergei Oleksiyovich Lebedev** from Kyiv Institute of Electrotechnology, Soviet Union (now Ukraine). The computer MESM (Small Electronic Calculating Machine) became operational in 1950. It had about 6,000 vacuum tubes and consumed 25 kW of power. It could perform approximately 3,000 operations per second.

Second generation: transistors. The bipolar transistor was invented in 1947. From 1955 onwards transistors replaced vacuum tubes in computer designs, giving rise to the «second generation» of computers.

A second generation computer, the IBM 1401, captured about one third of the world market. IBM installed more than ten thousand 1401s between 1960 and 1964.

Post-1960: third generation and beyond. During the 1960s there was considerable overlap between second and third generation technologies. IBM implemented its IBM Solid Logic Technology modules in hybrid circuits for the IBM System/360 in 1964.

The first mass-market home computers MOS Technology KIM-1 and Altair 8800, were sold as kits for do-it-yourselfers, as was the Apple I, soon afterward. The first Apple computer with graphic and sound capabilities came out well after the Commodore PET. Computing has evolved with microcomputer architectures, with features added from their larger brethren, now dominant in most market segments.

Fourth generation. The basis of the fourth generation was the invention of the microprocessor by a team at Intel.

Unlike third generation minicomputers, which were essentially scaled down versions of mainframe computers, the fourth generation's origins are fundamentally different. Microprocessor-based computers were originally very limited in their computational ability and speed, and were in no way an attempt to downsize the minicomputer. They were addressing an entirely different market.

Although processing power and storage capacities have grown beyond all recognition since the 1970s, the underlying technology of large-scale integration (LSI) or very-large-scale integration (VLSI) microchips has remained basically the same, so it is widely regarded that most of today's computers still belong to the fourth generation.

Steve Wozniak, a regular visitor to Homebrew Computer Club meetings, designed the single-board Apple I computer and first demonstrated it there. With specifications in hand and an order for 100 machines at $500.00 US Dollars each from the Byte Shop, Wozniak and his friend Steve Jobs founded Apple Computer.

About 200 of the machines were sold before the company announced the Apple II as a complete computer. It had color graphics, a full QWERTY keyboard, and internal slots for expansion, which were mounted in a high quality streamlined plastic case. The monitor and I/O devices were sold separately. The original Apple II operating system was only the built-in BASIC interpreter contained in ROM. Apple DOS was added to support the diskette drive; the last version was «Apple DOS 3.3».

In spite of slow initial sales, the Apple II's lifetime was about eight years longer than other machines, and so accumulated the highest total sales. By 1985 2.1 million had sold and more than 4 million Apple IIs were shipped by the end of its production in 1993.

IBM responded to the success of the Apple II with the IBM PC, released in August, 1981. Like the Apple II, it was based on an open, card-based architecture, which allowed third parties to develop for it. It used the Intel 8088 CPU running at 4.77 MHz, containing 29,000 transistors. The first model used an audio cassette for external storage, though there was an expensive floppy disk option.

The IBM PC typically came with PC-DOS, an operating system based upon Gary Kildall's CP/M-80 operating system. IBM turned to Bill Gates, who was already providing the ROM BASIC interpreter for the PC. Gates offered to provide 86-DOS, developed by Tim Paterson of Seattle Computer Products. IBM rebranded it as PC-DOS, while Microsoft sold variations and upgrades as MS-DOS.

Internet. In 1982 the Internet Protocol Suite (TCP/IP) was standardized and the concept of a world-wide network of fully interconnected TCP/IP networks called the Internet was introduced. Access to the ARPANET was expanded in 1981 when the National Science Foundation (NSF) developed the Computer Science Network (CSNET) and again in 1986 when NSFNET provided access to supercomputer sites in the

United States from research and education organizations. The ARPANET was decommissioned in 1990. Commercial internet service providers (ISPs) began to emerge in the late 1980s and 1990s and the Internet was commercialized in 1995 when NSFNET was decommissioned, removing the last restrictions on the use of the Internet to carry commercial traffic.

Since the mid-1990s the Internet has had a drastic impact on culture and commerce, including the rise of near instant communication by electronic mail, text based discussion forums, and the World Wide Web.

QUESTIONS

1. *Describe the scientific and technology revolution features.*
2. *What stage of STR is going now?*
3. *Analyze the reasons of atomic weapon creation. Report on the activity of Manhattan project headed by Robert Oppenheimer.*
4. *The development of genetics.*
5. *What are the causes of the first computing machines appearance in the first half of the XX century?*
6. *Characterize the scientific activity of Alan Turing, John von Neumann, Claude Shannon as the base for creation of modern computers structure.*
7. *Report on the first electronic computing machine in the USSR "MESM" designed by Sergey Lebedev.*
8. *What are the main stages of the development of local nets and the global net «Internet»?*
9. *Estimate the contribution of "IBM" and "Apple" to the development of computer technology.*
10. *What are the results of modern society computerization?*

THEME 9. HISTORY OF THE NATIONAL TECHNICAL UNIVERSITY "KHARKIV POLYTECHNIC INSTITUTE"

The history of Kharkiv Polytechnic Institute has become an integral part of scientific, technical, intellectual and cultural history of Ukraine since its founding.

NTU «KhPI» played an important role in the creation and development of the leading technical universities of Kharkiv and Ukraine, which founders were graduates of the university. Among them are the best modern universities: National Aerospace University named after M. Ye. Zhukovsky "Kharkiv Aviation Institute", Kharkiv National University of Radioelectronics, Kharkiv National University of Construction and Architecture, Volodymyr Dahl East Ukrainian National University, also Kropivnickiy, Sumy and Kremenchug technical universities that were branches of Kharkiv Polytechnic Institute for a long time. The creation of Kharkiv Practical Technological Institute was due to the pressing needs of economic development of Ukraine.

Fig. – Main classroom building (GAK)

In April 1885, the tsar government approved of a provision, according to which Kharkiv Practical Technological Institute started functioning. The grand opening took place on September 15, 1885. A prominent scientist in the field of mechanics and material strength, talented organizer of higher technical education in Russia and Ukraine **Viktor Lvovich Kyrpychov** (1845–1913) was appointed the first Director of the Institute (1885–1898).

V. L. Kyrpychov involved professors of Kharkiv University to work at KhPTI. Thus, in 1886–1888, **M. M. Beketov** delivered a course in chemistry at the institute (1827–1911) – the founder of physical chemistry, the founder of Kharkiv School of physical chemists. During 1887–1894, **O. M. Lyapunov**, an outstanding scientist, future Academician, worked at the institute (1857–1918) – the author of the modern theory of stability of mechanical systems motion, defined by a finite number of parameters. In addition, during the first decade since the creation of the institute, such prominent scientists as V. A. Steklov, O. M. Beketov, K. O. Andryeyev, M. A. Tyhomandrytskyi and others had been working at the institute. In addition to the teachers of fundamental theoretical subjects, it was necessary to find professionals on specific subjects. For this V. L. Kyrpychov began to involve engineers, first of all graduates of the St. Petersburg Technological Institute.

125 students were admitted: 85 students to the mechanical department and 40 to the chemical one. In general, the number of students was not supposed to exceed 500 people. According to the staffing approved in April 1885, the Institute could take ten professors, seven associate professors, teacher of religion (professor of God's law), a mechanic for the mechanical workshops, a laboratory assistant for chemical workshops and a librarian.

At the time of foundation, the institute had the main, physical and chemical buildings, workshops and residential building. In the main building (currently the main classroom building), there were lecture halls, rooms for drawing, library, museum and conference room. The chemical building accommodated laboratories for quantitative and qualitative analysis, organic chemistry, offices, classrooms and two lecture halls. The physical building has a physics laboratory and a mechanical workshop, which was actually a small mechanical factory, where students had the opportunity to have practical classes and covered basic methods of mechanical treatment technology for metal and wood. The chemical building had small plants (gas, soda, soap-boiling, butter-making and distilling), workshops of leather processing. In 1885–1886, physical and chemical laboratories were created.

In 1897, the admission of students for the first year of education doubles. Instead of 125 people, 250 students were admitted annually.

One of the brightest figures among teacher-researchers was Professor **K. O. Zworykin** (1861–1928), who worked at KhTI in 1888–1898. For his fundamental work «The work and effort required to separate metal chips» in 1896, he was awarded the prize of the Russian Technical Society. In 1902–1908, Professor **M. D. Pylchykov** (1857–1908) worked at the institute he made experiments in various fields of physics, meteorology, geophysics, electricity, radiotechnology.

Most scientific heritage was left by **P. M. Mukhachev** (1861–1935), the founder of the scientific school for national locomotive construction, who worked at the Institute in 1887–1935. During 1887–1904, student of D. I. Mendeleyev Professor **V. O. Gemilian** (1851–1914) made research of synthesis of organic compounds according to a method based on benzyl hydrol condensation in the presence of dehydrating substances with a number of aromatic compounds at the institute. Professor **O. P. Lidov** (1853–1919) carried out a large number of experimental studies on solubility analysis, formation and technology of organic substances.

An outstanding scientist in hydrodynamics **G. F. Proskura** began his scientific activity at the institute at the beginning of the XX century. In the beginning of his scientific and engineering activity, he studied hydraulic turbines, devoted considerable attention to the calculation of hydraulic machines motion. He continued experiments made by **V. I. Albitsky**.

In 1898, the university received the name of Kharkiv Technological Institute. The same year, after KhTI had passed the stage of formation, V. L. Kyrpychov became the first Director of the newly created Kyiv Polytechnic Institute.

The beginning of the First World War in 1914 changed the established mechanism of functioning of KhTI. Mobilizations started and the staff and students fell under it. There were significant financial and economic difficulties. Military hospital was set up in the drawing building. Additional problems appeared, because KhTI had placed in its premises Novo-Alexandria Institute of Agriculture and Forestry evacuated from Poland.

Because a lot of men were mobilized to the war, rector **I. P. Osypov** together with South-Russian Society of Technologist proposed to open in Kharkiv women's higher educational institutions, which graduates would replace men. In the autumn of 1916, Kharkiv Women Polytechnic Institute was created and I. P. Osypov was chosen as a Director. The deputy director – **V. Kh. Gerburt-Geybovich**. The studying process was carried out on the base of KhTI.

The political crisis that swept across the former Russian Empire in 1917–1921, significantly changed the life of the institution. In 1917, the limits of political, gender and national and religious nature for the applicants were abolished.

The structure of the Institute, especially the formation of student groups and Faculty staff, training programmes were subject to the following two main objectives: the post-war reconstruction of the country and creation of conditions for its further scientific and technical modernization. As a result, a Civil Engineering Faculty was established; one of its founders was an outstanding architect, Academician of architecture **O. M. Beketov**. In 1921, the Faculty of Electrical Engineering was headed by Professor **P. P. Kopnjaev.**

Despite the difficulties of those years, KhTI was gradually restoring its scientific and educational potential. In the early 1920s aircraft was developing rapidly, and the Institute decided to open aviation department at the mechanical Faculty.

In December 1929, the institution was renamed into Kharkiv Polytechnic Institute (KhPI). In the spring of 1930 it was reorganized. On the basis of the mechanical department, the Mechanical Machine Engineering Institute (KhMMEI) formed. The Faculty of Chemistry served as the basis of the Institute of Chemical Technology (KhChTI). On the basis of the Electrical Engineering Faculty the Electro-technical Institute (KhETI) was formed. The KhPI Building Faculty and the Faculty of Architecture of Kharkiv Building Institute became the basis for the Civil Engineering Institute, and one of its specialties at the Mechanics Faculty was the Institute of Aircraft and Aviation Engine Building. KhMMEI, KhChTI and KhETI remained on the campus territory of the former Institute of Technology, distributing among them its educational funds. KhETI had a new building, namely the Electrical Engineering Building, which was finished in 1930.

At the time of the Polytechnic Institute reorganization it taught about 1500 students, 52 professors and 151 lecturers worked here. Evening and correspondence departments did not exist at the time. Each new university had about 250–300 students (without the Workers Faculty).

The war of 1941–1945 drastically changed the destiny of every student, lecturer and professor. The names of 197 students and lecturers, whose lives were taken by the war, are engraved at the university memorial of Fame.

In mid-September 1941, the Germans invaded the territory of Kharkiv region. On September 20, evacuation started in Kharkiv. Institutes also were preparing for it. People and valuable assets were subject to evacuation. In mid-October, overcoming enormous difficulties, educational institutions managed to leave for the east together with Kharkiv enterprises in the last echelons. German troops occupied Kharkiv on October 24, 1941.

Occupation of the city lasted for 21 months. Lecturers and employees of the institutes that for various reasons remained in the occupied city had to adapt to new conditions. The scientific and production equipment and devices were exported by the Nazis in Germany. Occupation authorities raised the question of restoring the Polytechnic Institute. Formally five faculties restarted their work: Chemical, Technological, Electrical Engineering, Construction and Mechanics. However, none of them resumed full activity at an appropriate level.

The restoration of work at KhMMEI and KhChTI in Krasnoufimsk and Chyrchyk, where the institutions were evacuated in autumn 1941, was not easy. KhETI was not evacuated as an independent organization, so its teaching staff and students found themselves in different cities of the Urals, the Volga region, Siberia and Central Asia. The Institute temporarily stopped functioning. Even in the most difficult war years (1942–1943) 30 and 45 engineers for the industry graduated from KhMMEI, and 150 engineers, chemists, engineers graduated from KhChTI. The institutes prepared 883 specialists for the period of war.

At the beginning of 1946 the institutes first began to admit foreigners from other socialist countries (Bulgaria and North Korea). From 1949 the rebuilding of the «Giant» campus began.

In 1949–1950, the revival of KhPI took place. This process was based on the association of institutes it included until 1930, namely Machine Engineering, Chemical Engineering and Faculty of Electrical

Engineering, as well as Institute of Engineers in Cement Industry. Associate Professor **M. F. Semko** was appointed as the Rector.

By January 1950, KhPI had been completely restored and become one of the largest universities of the country. The Institute operated 57 departments training engineers in 32 specialties.

Fig. – Department of pre-university training of foreign citizens. Vesnina street, 5

KhPI trained dozens of students from the socialist countries. By 1960, the institute had prepared engineers in 27 specialties. For Bulgaria – 65, Hungary – 40, Romania –38, Poland – 34, China – 17, Korea – 15, Czechoslovakia – 14, Albania – 7, Mongolia – 4.

The pre-entrance course for foreign citizens was founded in KhPI in 1973 on the initiative of vice-rector for international contacts A. V. Boyko.

In 1978–1990, KhPI was headed by Professor **M. F. Kyrkach**. Being a talented organizer, he ensured a transformation of the Polytechnic Institute in a leading engineering higher educational institution in Ukraine. His name is related to the creation of new institutions of higher education on the basis of Kremenchug and Sumy branches of KhPI, training engineers in new modern specialties, organization of new departments and faculties in the institute. The scientist made a significant contribution to the development of the material assets of the Institute, in the construction of new academic buildings and student dormitories. During the period of STP, the Institute is expanding its ties with academic institutions around the world. 24 departments of KhPI

Fig – International students, circa 1970s effectively cooperated with Miskolc University of Heavy Industry, Poznan Polytechnic University, Magdeburg Otto von Guericke Higher Technical School, Hanoi Polytechnic Institute, Machine Engineering Energy Plant of the national “Shkoda” company (Czechoslovakia).

In 1990–1999, KhPI was headed by Professor **Yu. T. Kostenko**. He managed to preserve the accumulated potential of the Institute and to adapt to new market realities. The Scientific-Research and Design Institute «Molniya» was established at KhPI in 1990.

In April 1994 KhPI was provide with the status of the State Polytechnic University (KhSPU) and in September 2000 it acquired the status of the national university (“National Technical University “Kharkiv Polytechnic Institute”). From February 2010, NTU “KhPI” has had the status of a self-governing (autonomous) national research university.

In 1999–2015, the Rector of the institute was Professor **L. L. Tovazhnyanskyy.** The huge experience of scientific and pedagogical work allowed him to successfully implement ways to improve the educational process in accordance with the requirements of the Bologna Process and for further development of the potential of scientific schools of the university. He made a significant contribution to the development of scientific school of heat and mass transfer and integration of technological processes.

In 1996, the Center for Foreign Citizens Training (CFC) was established to organize and coordinate all work related to foreign students at the university. Since 2004, training of foreign students in separate specialties is implemented in English. For example at Department of oil, gas and gas-condensate production; at the Department of Software Engineering and Management Information Technologies; at the Department of Labor and Environment Protection; and at five departments of Institute of Education and Science in Power Engineering, Electronics and Electromechanics

In 2009, because of the expansion of the tasks and directions of work, a faculty of International Education was formed, which included CFC, preparatory department and departments of pre-university training of foreign citizens. Now it is headed by D. A. Kudii and coordinates by G. S. Khrypunov as a Vice-rector for Scientific-and-Pedagogical Work (International Relations).

In 2015 Professor **Ye. I. Sokol** was elected as the Rector. On February 1, 2018, a new structure of the university began to operate. Today, there are 5 new institutes and 4 faculties within NTU "KPI", two of which have been reorganized (there were 17 faculties). They train engineers for educational programs of 42 specialties on full-time and corresponded courses.

QUESTIONS

1. *Who was at the forefront of the organization of higher technical education in Ukraine?*
2. *What are the main universities created on the basis of KhPI branches?*
3. *Name the main structural transformations of NTU "KhPI".*
4. *Describe the activities of the first directors.*
5. *Activities of the German Polytechnic on the basis of KhPI.*
6. *Post-war reconstruction.*
7. *Organization of recreation for students and teachers.*
8. *The main achievements of University in the XXI century.*
9. *Scientific schools of NTU "KhPI".*
10. *Development of international cooperation.*

ANNEX

BIOGRAPHIES OF FAMOUS SCIENTISTS AND INVENTORS

Thales of Miletus
(624 BC – 546 BC)

Thales of Miletus was a pre-Socratic Greek philosopher from Miletus in Asia Minor, and one of the Seven Sages of Greece. Many, most notably Aristotle, regard him as the first philosopher in the Greek tradition. According to Bertrand Russell, «Western philosophy begins with Thales». Thales attempted to explain natural phenomena without reference to mythology and was tremendously influential in this respect. Almost all of the other pre-Socratic philosophers follow him in attempting to provide an explanation of ultimate substance, change, and the existence of the world—without reference to mythology. Those philosophers were also influential, and eventually Thales' rejection of mythological explanations became an essential idea for the scientific revolution. He was also the first to define general principles and set forth hypotheses, and as a result has been dubbed the «Father of Science», though it is argued that Democritus is actually more deserving of this title.

In mathematics, Thales used geometry to solve problems such as calculating the height of pyramids and the distance of ships from the shore. He is credited with the first use of deductive reasoning applied to geometry, by deriving four corollaries to Thales' Theorem. As a result, he has been hailed as the first true mathematician and is the first known individual to whom a mathematical discovery has been attributed. Also, Thales was the first person known to have studied electricity.

Pythagoras
(570 – 495 BC)

Pythagoras of Samos was an Ionian Greek philosopher, mathematician, and founder of the religious movement called Pythagoreanism. Most of the information about Pythagoras was written down centuries after he lived, so very little reliable information is known about him. He was born on the island of Samos, and might have traveled widely in his youth, visiting Egypt and other places seeking knowledge. He had a teacher named Themistocles, who introduced him to the principles of ethics. Around 530 BC, he moved to Croton, a Greek colony in southern Italy, and there set up a religious sect. His followers pursued the religious rites and practices developed by Pythagoras, and studied his philosophical theories.

Pythagoras made influential contributions to philosophy and religious teaching in the late 6th century BC. He is often revered as a great mathematician, mystic and scientist, but he is best known for the Pythagorean Theorem which bears his name. However, because legend and obfuscation cloud his work even more than with the other pre-Socratic philosophers, one can give account of his teachings to a little extent, and some have questioned whether he contributed much to mathematics and natural philosophy. Many of the accomplishments credited to Pythagoras may actually have been accomplishments of his colleagues and successors. Whether or not his disciples believed that everything was related to mathematics and that numbers were the ultimate reality is unknown. It was said that he was the first man to call himself a philosopher, or lover of wisdom, and Pythagorean ideas exercised a marked influence on Plato, and through him, all of Western philosophy.

Aristotle
(384 BC – 322 BC)

Aristotle was a Greek philosopher and polymath, a student of Plato and teacher of Alexander the Great. His writings cover many subjects, including physics, metaphysics, poetry, theater, music, logic, rhetoric, linguistics, politics, government, ethics, biology, and zoology. Together with Plato and Socrates (Plato's teacher), Aristotle is one of the most important founding figures in Western philosophy. Aristotle's writings were the first to create a comprehensive system of Western philosophy, encompassing morality and aesthetics, logic and science, politics and metaphysics.

Aristotle's views on the physical sciences profoundly shaped medieval scholarship, and their influence extended well into the Renaissance, although they were ultimately replaced by Newtonian physics. In the zoological sciences, some of his observations were confirmed to be accurate only in the XIX century. His works contain the earliest known formal study of logic, which was incorporated in the late XIX century into modern formal logic. In metaphysics, Aristotelianism had a profound influence on philosophical and theological thinking in the Islamic and Jewish traditions in the Middle Ages, and it continues to influence Christian theology, especially the scholastic tradition of the Catholic Church. All aspects of Aristotle's philosophy continue to be the object of active academic study today.

Archimedes

(287 BC – 212 BC)

Archimedes of Syracuse was a Greek mathematician, physicist, engineer, inventor, and astronomer. Although few details of his life are known, he is regarded as one of the leading scientists in classical antiquity. Among his advances in physics are the foundations of hydrostatics, statics and an explanation of the principle of the lever. He is credited with designing innovative machines, including siege engines and the screw pump that bears his name. Modern experiments have tested claims that Archimedes designed machines capable of lifting attacking ships out of the water and setting ships on fire using an array of mirrors.

Archimedes is generally considered to be the greatest mathematician of antiquity and one of the greatest of all time. He used the method of exhaustion to calculate the area under the arc of a parabola with the summation of an infinite series, and gave a remarkably accurate approximation of Pi. He also defined the spiral bearing his name, formulae for the volumes of surfaces of revolution and an ingenious system for expressing very large numbers.

Archimedes died during the Siege of Syracuse when he was killed by a Roman soldier despite orders that he should not be harmed. Cicero describes visiting the tomb of Archimedes, which was surmounted by a sphere inscribed within a cylinder. Archimedes had proven that the sphere has two thirds of the volume and surface area of the cylinder (including the bases of the latter), and regarded this as the greatest of his mathematical achievements.

Hero of Alexandria

(10 – 70 AD)

Hero (or Heron) of Alexandria was an ancient Greek mathematician and engineer who was active in his native city of Alexandria, Roman Egypt. He is considered the greatest experimenter of antiquity and his work is representative of the Hellenistic scientific tradition.

Hero published a well-recognized description of a steam-powered device called an aeolipile (hence sometimes called a “Hero engine”). Among his most famous inventions was a wind wheel, constituting the earliest instance of wind harnessing on land. He is said to have been a follower of the Atomists. Some of his ideas were derived from the works of Ctesibius.

Much of Hero's original writings and designs have been lost, but some of his works were preserved in Arab manuscripts.

Pliny the Elder

(23 AD – 79 AD)

Pliny the Elder was a Roman author, naturalist, and natural philosopher, as well as naval and army commander of the early Roman Empire, and personal friend of the emperor Vespasian. Spending most of his spare time studying, writing or investigating natural and geographic phenomena in the field, he wrote an encyclopedic work “Naturalis Historia” which became a model for all such works written subsequently.

Pliny is referring to the fact that Tacitus relied on his uncle's now missing work on the History of the German Wars. Pliny the Elder died on August 25, 79 AD, while attempting the rescue by ship of a friend and his family from the eruption of Mount Vesuvius that had just destroyed the cities of Pompeii and Herculaneum. The prevailing wind would not allow his ship to leave the shore. His companions attributed his collapse and death to toxic fumes; but they were unaffected by the fumes, suggesting natural causes.

Cai Lun

(48 – 121 AD)

Cai Lun courtesy name Jingzhong, was a Chinese eunuch, inventor, and politician of the Han dynasty. He is traditionally regarded as the inventor of paper and the papermaking process, in forms recognizable in modern times as paper (as opposed to papyrus). Although early forms of paper had existed in China since the 2nd century BC, he was responsible for the first significant improvement and standardization of papermaking by adding essential new materials into its composition.

Cai Lun committed suicide by poison. Cai was later revered in Chinese ancestor worship. Fei Zhu of the later Song Dynasty wrote that a temple in honor of Cai Lun had been erected in Chengdu.

Roger Bacon
(1214 – 1294)

Roger Bacon, also known as Doctor Mirabilis, was an English philosopher and Franciscan friar who placed considerable emphasis on the study of nature through empirical methods. He is sometimes credited, mainly starting in the XIX century, as one of the earliest European advocates of the modern scientific method inspired by the works of Aristotle and later pseudo-Aristotelian works, possibly of Arabic origins. However, more recent reevaluations emphasize that he was essentially a medieval thinker, with much of his «experimental» knowledge obtained from books, in the scholastic tradition. A survey of the reception of Bacon's work over centuries found that it often reflects the concerns and controversies central to the receivers.

Johannes Gutenberg
(1398 – 1468)

Johannes Gutenberg was a blacksmith, goldsmith, printer, and publisher who introduced the printing press. His usage of movable type printing started the Printing Revolution and is widely regarded as the most important event of the modern period. It played a key role in the development of the Renaissance, Reformation and the Scientific Revolution and laid the material basis for the modern knowledge-based economy and the spread of learning to the masses.

Gutenberg was the first European to use movable type printing, in around 1439. Among his many contributions to printing are: the invention of a process for mass-producing movable type; the use of oil-based ink; and the use of a wooden printing press similar to the agricultural screw presses of the period. His acclaim is due to the engineering of these elements into a practical system for the mass production of printed books that was economically viable for printers and readers alike.

The use of durable metallic movable type allowed rapid mass production of printed works. Gutenberg's printing technology spread rapidly throughout Europe, and quickly replaced most of the handwritten manuscript methods of book production throughout the world. Woodblock printing, rubricating, and engraving continued to be used to supplement Gutenberg's printing process.

His first major work using his printing methods was the Bible.

Leonardo da Vinci

(1452 – 1519)

Leonardo da Vinci was an Italian Renaissance polymath: painter, sculptor, architect, musician, scientist, mathematician, engineer, inventor, anatomist, geologist, cartographer, botanist and writer whose genius, perhaps more than that of any other figure, epitomized the Renaissance humanist ideal. Leonardo has often been described as the archetype of the Renaissance Man.

Leonardo is revered for his technological ingenuity. He conceptualized a helicopter, a tank, concentrated solar power, a calculator, the double hull, and he outlined a rudimentary theory of plate tectonics. Relatively few of his designs were constructed or were even feasible during his lifetime, but some of his smaller inventions, such as an automated bobbin winder and a machine for testing the tensile strength of wire, entered the world of manufacturing unheralded. He made important discoveries in anatomy, civil engineering, optics, and hydrodynamics, but he did not publish his findings and they had no direct influence on later science.

Nicolaus Copernicus

(1473 – 1543)

Nicolaus Copernicus was a Renaissance astronomer and the first person to formulate a comprehensive heliocentric cosmology which displaced the Earth from the center of the universe.

Copernicus' epochal book “De revolutionibus orbium coelestium” (“On the Revolutions of the Celestial Spheres”), published just before his death in 1543, is often regarded as the starting point of modern astronomy and the defining epiphany that began the scientific revolution. His heliocentric model, with the Sun at the center of the universe, demonstrated that the observed motions of celestial objects can be explained without putting Earth at rest in the center of the universe. His work stimulated further scientific investigations, becoming a landmark in the history of science that is often referred to as the Copernican Revolution.

Among the great polymaths of the Renaissance, Copernicus was a mathematician, astronomer, jurist with a doctorate in law, physician, polyglot, classics scholar, translator, artist, Catholic cleric, governor, diplomat and economist.

Francis Bacon
(1561 – 1626)

Francis Bacon was an English philosopher, statesman, scientist, lawyer, jurist, author and pioneer of the scientific method. He served both as Attorney General and Lord Chancellor of England. Although his political career ended in disgrace, he remained extremely influential through his works, especially as philosophical advocate and practitioner of the scientific method during the scientific revolution.

Bacon has been called the father of empiricism. His works established and popularized inductive methodologies for scientific inquiry, often called the Baconian method, or simply the scientific method. His demand for a planned procedure of investigating all things natural marked a new turn in the rhetorical and theoretical framework for science, much of which still surrounds conceptions of proper methodology today. His dedication probably led to his death, bringing him into a rare historical group of scientists who were killed by their own experiments.

Bacon was knighted in 1603, and created both the Baron Verulam in 1618, and the Viscount St Alban in 1621; as he died without heirs both peerages became extinct upon his death. He famously died of pneumonia contracted while studying the effects of freezing on the preservation of meat.

Tycho Brahe
(1546 – 1601)

T. Brahe was a Danish nobleman, astronomer, and writer known for his accurate and comprehensive astronomical observations. He was born in the then Danish peninsula of Scania. Tycho was well known in his lifetime as an astronomer, astrologer, and alchemist. He has been described as "the first competent mind in modern astronomy to feel ardently the passion for exact empirical facts." Most of his observations were more accurate than the best available observations at the time.

In Prague, Tycho worked closely with Johannes Kepler, his assistant. Kepler was a convinced Copernican, and considered Tycho's model to be mistaken, and derived from simple "inversion" of the Sun's and Earth's positions in the Copernican model. Together, they worked on a new star catalogue based on his own accurate positions – this catalogue became the Rudolphine Tables. Kepler had great respect for Tycho's methods and the accuracy of his observations and considered him to be the new Hipparchus, who would provide the foundation for a restoration of the science of astronomy.

He was mercury poisoned. The two main suspects were his assistant, Johannes Kepler, whose motives would be to gain access to Tycho's laboratory and chemicals, and his cousin, Erik Brahe, at the order of friend-turned-enemy Christian IV, because of rumors that Tycho had had an affair with Christian's mother.

Johannes Kepler

(1571 – 1630)

Johannes Kepler was a German mathematician, astronomer and astrologer. A key figure in the XVII century scientific revolution, he is best known for his eponymous laws of planetary motion, codified by later astronomers, based on his works Astronomia nova, Harmonices Mundi, and Epitome of Copernican Astronomy. These works also provided one of the foundations for Isaac Newton's theory of universal gravitation.

During his career, Kepler was a mathematics teacher at a seminary school in Graz, Austria, where he became an associate of Prince Hans Ulrich von Eggenberg.

Later he became an assistant to astronomer Tycho Brahe, and eventually the imperial mathematician to Emperor Rudolf II and his two successors Matthias and Ferdinand II. He was also a mathematics teacher in Linz, Austria, and an adviser to General Wallenstein. Additionally, he did fundamental work in the field of optics, invented an improved version of the refracting telescope (the Keplerian Telescope), and mentioned the telescopic discoveries of his contemporary Galileo Galilei.

Kepler lived in an era when there was no clear distinction between astronomy and astrology, but there was a strong division between astronomy (a branch of mathematics within the liberal arts) and physics (a branch of natural philosophy). Kepler also incorporated religious arguments and reasoning into his work, motivated by the religious conviction and belief that God had created the world according to an intelligible plan that is accessible through the natural light of reason.

Kepler described his new astronomy as “celestial physics”, as ‘an excursion into Aristotle's Metaphysics”, and as “a supplement to Aristotle's On the Heavens”, transforming the ancient tradition of physical cosmology by treating astronomy as part of a universal mathematical physics.

Galileo Galilei
(1564 – 1642)

Galileo Galilei was an Italian physicist, mathematician, astronomer, and philosopher who played a major role in the Scientific Revolution. His achievements include improvements to the telescope and consequent astronomical observations and support for Copernicanism. Galileo has been called the “father of modern observational astronomy”, the «father of modern physics”, the “father of science”, and “the Father of Modern Science”.

His contributions to observational astronomy include the telescopic confirmation of the phases of Venus, the discovery of the four largest satellites of Jupiter (named the Galilean moons in his honour), and the observation and analysis of sunspots. Galileo also worked in applied science and technology, inventing an improved military compass and other instruments.

Galileo's championing of heliocentric was controversial within his lifetime, when most subscribed to either geocentrism or the Tychonic system. He met with opposition from astronomers, who doubted heliocentric due to the absence of an observed stellar parallax. The matter was investigated by the Roman Inquisition in 1615, and they concluded that it could only be supported as a possibility, not as an established fact. Galileo later defended his views in Dialogue Concerning the Two Chief World Systems, which appeared to attack Pope Urban VIII and thus alienated him and the Jesuits, who had both supported Galileo up until this point. He was tried by the Inquisition, found «vehemently suspect of heresy», forced to recant, and spent the rest of his life under house arrest. It was while Galileo was under house arrest that he wrote one of his finest works, Two New Sciences. Here he summarized the work he had done some forty years earlier, on the two sciences now called kinematics and strength of materials.

Rene Descartes
(1596 – 1650)

René Descartes was a French philosopher, mathematician, and writer who spent most of his adult life in the Dutch Republic. He has been dubbed the “Father of Modern Philosophy”, and much subsequent Western philosophy is a response to his writings, which are studied closely to this day. In particular, his Meditations on First Philosophy continue to be a standard text at most university philosophy departments. Descartes' influence in mathematics is equally apparent; the Cartesian coordinate system – allowing algebraic equations to be expressed as geometric shapes, in a 2D coordinate system – was named after him. He is credited as the father of analytical geometry, the bridge between algebra and geometry, crucial to the discovery of infinitesimal calculus and analysis. Descartes was also one of the key figures in the Scientific Revolution.

Descartes was a major figure in XVII century continental rationalism, later advocated by Baruch Spinoza and Gottfried Leibniz, and opposed by the empiricist school of thought consisting of Hobbes, Locke, Berkeley, Jean-Jacques Rousseau, and Hume. Leibniz, Spinoza and Descartes were all well versed in mathematics as well as philosophy, and Descartes and Leibniz contributed greatly to science as well.

Blaise Pascal
(1623 – 1662)

Blaise Pascal was a French mathematician, physicist, inventor, writer and Catholic philosopher. He was a child prodigy who was educated by his father, a tax collector in Rouen. Pascal's earliest work was in the natural and applied sciences where he made important contributions to the study of fluids, and clarified the concepts of pressure and vacuum by generalizing the work of Evangelista Torricelli. Pascal also wrote in defense of the scientific method.

In 1642, while still a teenager, he started some pioneering work on calculating machines, and after three years of effort and 50 prototypes he invented the mechanical calculator. He built twenty of these machines (called the Pascaline) in the following ten years. Pascal was a mathematician of the first order. He helped create two major new areas of research. He wrote a significant treatise on the subject of projective geometry at the age of sixteen, and later corresponded with Pierre de Fermat on probability theory, strongly influencing the development of modern economics and social science. Following Galileo and Torricelli, in 1646 he refuted Aristotle's followers who insisted that nature abhors a vacuum. His results caused many disputes before being accepted.

Pascal had poor health especially after his eighteenth year and his death came just two months after his 39th birthday.

Gottfried Leibniz
(1646 – 1716)

Gottfried Wilhelm Leibniz was a German philosopher and mathematician. Leibniz occupies a prominent place in the history of mathematics and the history of philosophy. He developed the infinitesimal calculus independently of Isaac Newton, and Leibniz's mathematical notation has been widely used ever since it was published. He became one of the most prolific inventors in the field of mechanical calculators. While working on adding automatic multiplication and division to Pascal's calculator, he was the first to describe a pinwheel calculator in 1685 and invented the Leibniz wheel, used in the arithmometer, the first mass-produced mechanical calculator. He also refined the binary number system, which is at the foundation of virtually all digital computers. Leibniz made major contributions to physics and technology, and anticipated notions that surfaced much later in biology, medicine, geology, probability theory, psychology, linguistics, and information science. He wrote works on politics, law, ethics, theology, history, philosophy, and philology. Leibniz's contributions to this vast array of subjects were scattered in various learned journals, in tens of thousands of letters, and in unpublished manuscripts.

Isaac Newton

(1642 – 1727)

Sir Isaac Newton was an English physicist, mathematician, astronomer, natural philosopher, alchemist, and theologian.

His monograph “Philosophiæ Naturalis Principia Mathematica”, published in 1687, lays the foundations for most of classical mechanics. In this work, Newton described universal gravitation and the three laws of motion, which dominated the scientific view of the physical universe for the next three centuries. Newton showed that the motions of objects on Earth and of celestial bodies are governed by the same set of natural laws, by demonstrating the consistency between Kepler's laws of planetary motion and his theory of gravitation, thus removing the last doubts about heliocentric and advancing the Scientific Revolution. The Principia is generally considered to be one of the most important scientific books ever written.

Newton built the first practical reflecting telescope and developed a theory of color based on the observation that a prism decomposes white light into the many colors that form the visible spectrum. He also formulated an empirical law of cooling and studied the speed of sound.

In mathematics, Newton shares the credit with Gottfried Leibniz for the development of differential and integral calculus. He also demonstrated the generalized binomial theorem, developed Newton's method for approximating the roots of a function, and contributed to the study of power series.

Petro Mohyla

(1596 – 1647)

He was an influential Ruthenian Orthodox theologian and reformer, Metropolitan of Kyiv, Galych and All Rus'. founded at the Lavra a school for young monks (1632). The tutoring was conducted in Latin. The students studied theology, philosophy, rhetoric, and classical authors. At the same time, Mohyla significantly improved the print shop at the Lavra where Orthodox books were published not only in Old Slavic but in Latin as well and distributed to various places in eastern Europe. Later that year, Mohyla merged this school with the Kyiv Brotherhood school and created the Mohyla collegium which later became known as the Kyiv Mohyla Academy (National University of Kyiv-Mohyla Academy).

The students at the collegium had diverse backgrounds. They came from noble, clerical, gentry, Cossack and peasant families. The school offered a variety of disciplines: Ukrainian, Latin, Greek, and Polish languages; philosophy; mathematics, including geometry; astronomy; music; and history. Because of the high profile of the faculty, the collegium received the status of a higher educational establishment.

Mikhail Lomonosov

(1711 – 1765)

Mikhail Vasilyevich Lomonosov was a Russian polymath, scientist and writer, who made important contributions to literature, education, and science. Among his discoveries was the atmosphere of Venus. His spheres of science were natural science, chemistry, physics, mineralogy, history, art, philology, optical devices and others. Lomonosov was also a poet, who created the basis of the modern Russian literary language.

He regarded heat as a form of motion, suggested the wave theory of light, contributed to the formulation of the kinetic theory of gases, and stated the idea of conservation of matter.

Lomonosov was the first person to record the freezing of mercury. Believing that nature is subject to regular and continuous evolution, he demonstrated the organic origin of soil, peat, coal, petroleum and amber. In 1745, he published a catalogue of over 3,000 minerals, and in 1760, he explained the formation of icebergs.

Lomonosov was proud to restore the ancient art of mosaics. In 1763, he set up a glass factory that produced the first stained glass mosaics outside of Italy.

Ivan Ivanovich Polzunov
(1728 – 1766)

He created the first steam engine in Russia and the first two-cylinder engine in the world.

In the library of Barnaul plant he found works of Mikhail Lomonosov, that he studied by himself as well as the descriptions of contemporary steam machines by I. Shlatter. In 1763 he proposed an original 1.8 h.p. (1.2kW) steam machine. The design used two cylinders on the same shaft that allowed its operations completely independently from water power even on dry places or in mountains. This design was a great step forward from contemporary steam machines that used hydropower to return the pistons and so could not be used if the hydropower was not available.

In 1765 Polzunov designed a large 32 h.p. steam machine for air pumps for steel furnaces.

Leonhard Euler
(1707 – 1783)

Leonhard Euler was a pioneering Swiss, German and Russian mathematician and physicist. He made important discoveries in fields as diverse as infinitesimal calculus and graph theory. He also introduced much of the modern mathematical terminology and notation, particularly for mathematical analysis, such as the notion of a mathematical function. He is also renowned for his work in mechanics, fluid dynamics, optics, and astronomy.

Euler spent most of his adult life in St. Petersburg, Russia, and in Berlin, Prussia. He is considered to be the preeminent mathematician of the XVIII century, and one of the greatest of all time. He is also one of the most prolific mathematicians ever; his collected works fill 60–80 quarto volumes. A statement attributed to Pierre-Simon Laplace expresses Euler's influence on mathematics: “Read Euler, read Euler, he is the master of us all”.

Michael Faraday
(1791 – 1867)

Michael Faraday was an English chemist and physicist who contributed to the fields of electromagnetism and electrochemistry.

Although Faraday received little formal education and knew little of higher mathematics such as calculus, he was one of the most influential scientists in history; historians of science refer to him as having been the best experimentalist in the history of science. It was on account of his research regarding the magnetic field around a conductor carrying a DC electric current that Faraday established the basis for the concept of the electromagnetic field in physics, which was subsequently enlarged upon by James Clerk Maxwell. Faraday established that magnetism could affect rays of light and that there was an underlying relationship between the two phenomena. He similarly discovered the principle of electromagnetic induction, diamagnetism, and the laws of electrolysis. His inventions of electromagnetic rotary devices formed the foundation of electric motor technology, and it was largely due to his efforts that electricity became viable for use in technology.

As a chemist, Faraday discovered benzene, investigated the clathrate hydrate of chlorine, invented an early form of the Bunsen burner and the system of oxidation numbers, and popularized terminology such as anode, cathode, electrode, and ion. Faraday ultimately became the first and foremost Fullerian Professor of Chemistry at the Royal Institution of Great Britain, a life-time position.

James Clerk Maxwell

(1831 – 1879)

James Clerk Maxwell was a Scottish physicist and mathematician. His most prominent achievement was formulating classical electromagnetic theory. This united all previously unrelated observations, experiments and equations of electricity, magnetism and optics into a consistent theory. Maxwell's equations demonstrated that electricity, magnetism and light are all manifestations of the same phenomenon, namely the electromagnetic field. Subsequently, all other classic laws or equations of these disciplines became simplified cases of Maxwell's equations. Maxwell's achievements concerning electromagnetism have been called the “second great unification in physics” after the first one realized by Isaac Newton.

Maxwell demonstrated that electric and magnetic fields travel through space in the form of waves, and at the constant speed of light. In 1865 Maxwell published A Dynamical Theory of the Electromagnetic Field. It was with this that he first proposed that light was in fact undulations in the same medium that is the cause of electric and magnetic phenomena. His work in producing a unified model of electromagnetism is one of the greatest advances in physics.

Maxwell is also known for presenting the first durable color photograph in 1861 and for his foundational work on the rigidity of rod-and-joint frameworks like those in many bridges.

Dmitriy Mendeleev

(1834 – 1907)

Dmitri Ivanovich Mendeleev was a Russian chemist and inventor. He is credited as being the creator of the first version of the periodic table of elements. Using the table, he predicted the properties of elements yet to be discovered.

Mendeleev made other important contributions to chemistry. Mendeleev was one of the founders, in 1869, of the Russian Chemical Society. He worked on the theory and practice of protectionist trade and on agriculture.

In an attempt at a chemical conception of the Ether, he put forward a hypothesis that there existed two inert chemical elements of lesser atomic weight than hydrogen. Of these two proposed elements, he thought the lighter to be an all-penetrating, all-pervasive gas, and the slightly heavier one to be a proposed element, coronium.

Mendeleev devoted much study and made important contributions to the determination of the nature of such indefinite compounds as solutions.

In another department of physical chemistry, he investigated the expansion of liquids with heat, and devised a formula similar to Gay-Lussac's law of the uniformity of the expansion of gases, while in 1861 he anticipated Thomas Andrews' conception of the critical temperature of gases by defining the absolute boiling-point of a substance as the temperature at which cohesion and heat of vaporization become equal to zero and the liquid changes to vapor, irrespective of the pressure and volume.

Mendeleev is given credit for the introduction of the metric system to the Russian Empire.

He invented pyrocollodion, a kind of smokeless powder based on nitrocellulose. This work had been commissioned by the Russian Navy, which however did not adopt its use. In 1892 Mendeleev organized its manufacture.

Ivan Pului

(1845 – 1918)

He was a Ukrainian physicist and inventor, who has been championed as an early developer of the use of X-rays for medical imaging.

His contributions were largely neglected until the end of the 20th century. Ivan Pului graduated with honors from Theological Faculty of the University of Vienna (1869), later also from the Department of Philosophy (1872). In 1876 Pului finished his doctorate on internal friction in gases at the University of Strasbourg under supervision of August Kundt. Pului taught at the Navy academy in Fiume (Rijeka, Croatia) (1874–1876), University of Vienna (1874–1884) and the German part of the Higher Technical School in Prague (1884–1916).

He served as the rector of the Higher Technical School in Prague (German part) in 1888–1889. Puluj also worked as a state adviser on electrical engineering for Bohemian and Moravian local governments. In addition he completed a translation of the Bible into the Ukrainian language.

Pului did heavy research into cathode rays, publishing several papers about those rays between 1880 and 1882. In 1881 as a result of experiments into what he called cold light Prof. Pului developed the Pului lamp.

While I. Pului's findings were essentially X-rays, he did not recognize them as such at first, although he demonstrated X-ray pictures of a hand and fingers obtained by using his tube/lamp to his students. He presented photographs that exhibited the skeleton of a stillborn child.

The quality of Pului's pictures was much better than that of Roentgen's.

Thomas Edison

(1847 – 1931)

Thomas Alva Edison was an American inventor and businessman. He developed many devices that greatly influenced life around the world, including the phonograph, the motion picture camera, and a long-lasting, practical electric light bulb. In addition, he created the world’s first industrial research laboratory. Dubbed «The Wizard of Menlo Park» by a newspaper reporter, he was one of the first inventors to apply the principles of mass production and large teamwork to the process of invention, and therefore is often credited with the creation of the first industrial research laboratory.

Edison is the fourth most prolific inventor in history, holding 1,093 US patents in his name, as well as many patents in the United Kingdom, France, and Germany. He is credited with numerous inventions that contributed to mass communication and, in particular, telecommunications. These included a stock ticker, a mechanical vote recorder and a battery for an electric car, electrical power, recorded music and motion pictures. His advanced work in these fields was an outgrowth of his early career as a telegraph operator. Edison originated the concept and implementation of electric-power generation and distribution to homes, businesses, and factories – a crucial development in the modern industrialized world. His first power station was on Manhattan Island, New York.

Antoine-Henri Becquerel
(1852 – 1908)

A. Becquerel was a French engineer, physicist, Nobel laureate, and the first person to discover evidence of radioactivity. He was the son of a professor of applied physics, Alexander Becquerel.

He began his studies in 1872 at Ecole Polytechnique just south of Paris. After a couple of years, he began working for the French government's Department of Roads and Bridges. In 1894, he was appointed chief engineer of the department. Becquerel received a Doctor of Science degree in 1888. He later became Professor of Applied Physics in the Department of Natural History at the Paris Museum, a post his father had held previously. In 1895, he was appointed Professor at Ecole Polytechnique.

In 1896, Becquerel discovered natural radioactivity.

Later in his life in 1900, Becquerel measured the properties of Beta Particles, and he realized that they had the same measurements as high speed electrons leaving the nucleus. In 1901 Becquerel made the discovery that radioactivity could be used for medicine.

The becquerel (Bq), is named after him.

Marie Skłodowska-Curie
(1867 – 1934)

Marie Skłodowska-Curie was a physicist and chemist famous for her pioneering research on radioactivity. She was the first person honored with two Nobel Prizes in physics and chemistry. She was the first female professor at the University of Paris, and in 1995 became the first woman to be entombed on her own merits in the Pantheon in Paris.

In 1891, aged 24, she followed her older sister Bronisława to study in Paris, where she earned her higher degrees and conducted her subsequent scientific work. She shared her 1903 Nobel Prize in Physics with her husband Pierre Curie and with the physicist Henri Becquerel. She was the sole winner of the 1911 Nobel Prize in Chemistry. Skłodowska-Curie was the first woman to win a Nobel Prize, the only woman to date to win in two fields, and the only person to win in multiple sciences.

Her achievements included a theory of radioactivity (a term that she coined), techniques for isolating radioactive isotopes, and the discovery of two elements, polonium and radium. Under her direction, the world's first studies were conducted into the treatment of neoplasm, using radioactive isotopes. She founded the Curie Institutes in Paris and Warsaw, which remain major centers of medical research today.

Curie died in 1934 of aplastic anemia brought on by her years of exposure to radiation.

Ernest Rutherford

(1871 – 1937)

Ernest Rutherford was a New Zealand-born British chemist and physicist who became known as the father of nuclear physics. In early work he discovered the concept of radioactive half-life, proved that radioactivity involved the transmutation of one chemical element to another, and also differentiated and named alpha and beta radiation, proving that the former was essentially helium ions. This work was done at McGill University in Canada. It is the basis for the Nobel Prize in Chemistry he was awarded in 1908 “for his investigations into the disintegration of the elements, and the chemistry of radioactive substances”.

Rutherford performed his most famous work after he had moved to the Victoria University of Manchester in the UK in 1907 and was already a Nobel laureate. In 1911, he theorized that atoms have their positive charge concentrated in a very small nucleus, and thereby pioneered the Rutherford model of the atom, through his discovery and interpretation of Rutherford scattering in his gold foil experiment. He is widely credited with first “splitting the atom” in 1917 in a nuclear reaction between nitrogen and alpha particles, in which he also discovered (and named) the proton.

Nikola Tesla

(1856 – 1943)

Nikola was a Serbian-American inventor, mechanical engineer, and electrical engineer. He was an important contributor to the birth of commercial electricity, and is best known for developing the modern alternating current (AC) electrical supply system. His many revolutionary developments in the field of electromagnetism in the late XIX and early XX centuries were based on the theories of electromagnetic technology discovered by Michael Faraday. Tesla's patents and theoretical work also formed the basis of wireless communication and the radio.

Born an ethnic Serb in the village of Smiljan, in the Croatian Military Frontier of the Austrian Empire, Tesla was a subject of the Austrian Empire by birth and later became an American citizen. Because of his 1894 demonstration of wireless communication through radio and as the eventual victor in the «War of Currents», he was widely respected as one of the greatest electrical engineers who worked in America. He pioneered modern electrical engineering and many of his discoveries were of groundbreaking importance. In the United States during this time, Tesla's fame rivaled that of any other inventor or scientist in history or popular culture. Tesla demonstrated wireless energy transfer to power electronic devices in 1891, and aspired to intercontinental wireless transmission of industrial power in his unfinished Wardenclyffe Tower project.

Volodymyr Vernadsky

(1863 – 1945)

Volodymyr Ivanovich Vernadsky was a Ukrainian and Soviet mineralogist and geochemist who is considered one of the founders of geochemistry, biogeochemistry, and of radiogeology. His ideas of noosphere were an important contribution to Russian cosmism. He also worked in Ukraine where he founded the National Academy of Science of Ukraine. He is most noted for his 1926 book

The Biosphere in which he inadvertently worked to popularize Eduard Seuss 1885 term biosphere, by hypothesizing that life is the geological force that shapes the earth. In 1943 he was awarded the Stalin Prize.

Wright brothers

Orville Wright (1871 – 1948), Wilbur Wright (1867 – 1912)

The Wright brothers were two Americans credited with inventing and building the world's first successful airplane and making the first controlled, powered and sustained heavier-than-air human flight, on December 17, 1903. In the two years afterward, the brothers developed their flying machine into the first practical fixed-wing aircraft. Although not the first to build and fly experimental aircraft, the Wright brothers were the first to invent aircraft controls that made fixed-wing powered flight possible.

They gained the mechanical skills essential for their success by working for years in their shop with printing presses, bicycles, motors, and other machinery. Their work with bicycles in particular influenced their belief that an unstable vehicle like a flying machine could be controlled and balanced with practice. From 1900 until their first powered flights in late 1903, they conducted extensive glider tests that also developed their skills as pilots. Their bicycle shop employee Charlie Taylor became an important part of the team, building their first aircraft engine in close collaboration with the brothers.

The Wright brothers' status as inventors of the airplane has been subject to counter-claims by various parties. Much controversy persists over the many competing claims of early aviators.

Simon S. Kuznets
(1901 – 1985)

S. Kuznets was an American economist and statistician who received the 1971 Nobel Memorial Prize in Economic Sciences "for his empirically founded interpretation of economic growth which has led to new and deepened insight into the economic and social structure and process of development."

He was born in Belarus. He studied at Kharkiv Institute of Commerce, later in Columbia University. After the War, he worked as an advisor for the governments of China, Japan, India, Korea, Taiwan, and Israel in the establishment of their national systems of economic information.

Kuznets is credited with revolutionizing econometrics, and this work is credited with fueling the so-called Keynesian revolution".

Alan Turing
(1912 – 1954)

Alan Turing was an English mathematician, logician, cryptanalyst, and computer scientist. He was highly influential in the development of computer science, providing a formalization of the concepts of «algorithm» and «computation» with the Turing machine, which played a significant role in the creation of the modern computer. Turing is widely considered to be the father of computer science and artificial intelligence.

During the Second World War, Turing worked for the Government Code and Cypher School at Bletchley Park, Britain's code breaking centre. For a time he was head of Hut 8, the section responsible for German naval cryptanalysis. He devised a number of techniques for breaking German ciphers, including the method of the bombe, an electromechanical machine that could find settings for the Enigma machine. After the war he worked at the National Physical Laboratory, where he created one of the first designs for a stored-program computer, the ACE.

In 1948 Turing joined Max Newman's Computing Laboratory at Manchester University, where he assisted in the development of the Manchester computers and became interested in mathematical biology.

Albert Einstein
(1879 – 1955)

Albert Einstein was a German-born theoretical physicist who developed the theory of general relativity, effecting a revolution in physics. For this achievement, Einstein is often regarded as the father of modern physics and one of the most prolific intellects in human history. He received the 1921 Nobel Prize in Physics The latter was pivotal in establishing quantum theory within physics.

Near the beginning of his career, Einstein thought that Newtonian mechanics was no longer enough to reconcile the laws of classical mechanics with the laws of the electromagnetic field. This led to the development of his special theory of relativity. He realized, however, that the principle of relativity could also be extended to gravitational fields, and with his subsequent theory of gravitation in 1916, he published a paper on the general theory of relativity. He continued to deal with problems of statistical mechanics and quantum theory, which led to his explanations of particle theory and the motion of molecules. He also investigated the thermal properties of light which laid the foundation of the photon theory of light. In 1917, Einstein applied the general theory of relativity to model the structure of the universe as a whole.

He settled in the U.S., becoming a citizen in 1940. On the eve of World War II, he helped alert President Franklin D. Roosevelt that Germany might be developing an atomic weapon, and recommended that the U.S. begin similar research; this eventually led to what would become the Manhattan Project. Einstein was in support of defending the Allied forces, but largely denounced using the new discovery of nuclear fission as a weapon. Later, together with Bertrand Russell, Einstein signed the Russell–Einstein Manifesto, which highlighted the danger of nuclear weapons. Einstein was affiliated with the Institute for Advanced Study in Princeton, New Jersey, until his death in 1955.

Einstein published more than 300 scientific papers along with over 150 non-scientific works. His great intelligence and originality have made the word «Einstein» synonymous with genius.

John von Neumann

(1903 – 1957)

John von Neumann was a Hungarian-American mathematician and polymath who made major contributions to a vast number of fields, including set theory, functional analysis, quantum mechanics, ergodic theory, geometry, fluid dynamics, economics, linear programming and game theory, computer science, numerical analysis, hydrodynamics, and statistics, as well as many other mathematical fields. He is generally regarded as one of the greatest mathematicians in modern history.

Von Neumann was a pioneer of the application of operator theory to quantum mechanics, in the development of functional analysis, a principal member of the Manhattan Project and the Institute for Advanced Study in Princeton (as one of the few originally appointed), and a key figure in the development of game theory and the concepts of cellular automata, the universal constructor, and the digital computer. Von Neumann's mathematical analysis of the structure of self-replication preceded the discovery of the structure of DNA.

Niels Bohr

(1885 – 1962)

Niels Bohr was a Danish physicist who made foundational contributions to understanding atomic structure and quantum mechanics, for which he received the Nobel Prize in Physics in 1922. Bohr mentored and collaborated with many of the top physicists of the century at his institute in Copenhagen. He was part of a team of physicists working on the Manhattan Project. Bohr married Margrethe Norlund in 1912, and one of their sons, Aage Bohr, grew up to be an important physicist who in 1975 also received the Nobel Prize. Bohr has been described as one of the most influential scientists of the 20th century.

Norbert Wiener

(1894 – 1964)

Norbert Wiener was an American mathematician and cybernetist.

A famous child prodigy, Wiener later became an early researcher in stochastic and noise processes, contributing work relevant to electronic engineering, electronic communication, and control systems.

Wiener is regarded as the originator of cybernetics, a formalization of the notion of feedback, with many implications for engineering, systems control, computer science, biology, philosophy, and the organization of society.

Sergiy Korolev
(1907 – 1966)

Sergiy Pavlovych Korolev was the lead Soviet rocket engineer and spacecraft designer in the Space Race between the United States and the Soviet Union during the 1950s and 1960s. He is considered by many as the father of practical astronautics.

Although Korolev was trained as an aircraft designer, his greatest strengths proved to be in design integration, organization and strategic planning. Arrested for alleged mismanagement of funds (he spent the money on yet unsuccessful experiments with rocket devices), he was imprisoned in 1938 for almost six years, including some months in a Kolyma labour camp. Following his release, he became a recognized rocket designer and a key figure in the development of the Soviet ICBM program. He was then appointed to lead the Soviet space program, made Member of Soviet Academy of Sciences, overseeing the early successes of the Sputnik and Vostok projects. By the time he died unexpectedly in 1966, his plans to compete with the United States to be the first nation to land a man on the Moon had begun to be implemented.

Before his death he was often referred to only as “Chief Designer”, because his name and his pivotal role in the Soviet space program had been held to be a state secret by the Politburo. Only many years later was he publicly acknowledged as the lead man behind Soviet success in space.

J. Robert Oppenheimer
(1904 – 1967)

Robert Oppenheimer was an American theoretical physicist and professor of physics at the University of California, Berkeley. Along with Enrico Fermi, he is often called the «father of the atomic bomb» for his role in the Manhattan Project, the World War II project that developed the first nuclear weapons. The first atomic bomb was detonated on July 16, 1945 in the Trinity test in New Mexico.

After the war he became a chief adviser to the newly created United States Atomic Energy Commission and used that position to lobby for international control of nuclear power to avert nuclear proliferation and an arms race with the Soviet Union. After provoking the ire of many politicians with his outspoken opinions during the Second Red Scare, he had his security clearance revoked in a much-publicized hearing in 1954, and was effectively stripped of his direct political influence; he continued to Theme, write and work in physics. A decade later President John F. Kennedy awarded (and Lyndon B. Johnson presented) him with the Enrico Fermi Award as a gesture of political rehabilitation.

Sergiy Lebedev
(1902 – 1974)

Sergiy Olexiovych Lebedev was a Soviet scientist in the fields of electrical engineering and computer science, and designer of the first Soviet computers.

During World War II, Lebedev worked in the field of control automation of complex systems. His group designed a weapon-aiming stabilization system for tanks and an automatic guidance system for airborne missiles. To perform these tasks Lebedev developed an analog computer system to solve ordinary differential equations.

From 1946 to 1951 he headed the Kiev Electrotechnical Institute of the Ukrainian Academy of Sciences, working on improving the stability of electrical systems. For this work he received the Stalin prize in 1950.

In 1948 Lebedev learned from foreign magazines that scientists in western countries were working on the design of electronic computers, although the details were secret. In the autumn of the same year he decided to focus the work of his laboratory on computer design. Lebedev's first computer, MESM, was completed by the end of 1951. In April 1953 the State commission accepted the MESM as operational, but it did not go into series production because of opposition from the Ministry of Machine and Instrument Building, which had developed its own weaker and less reliable machine.

Lebedev and his team developed several more computers, notably the BESM–6, which was in production for 17 years.

In 1952, Lebedev became a professor at the Moscow Institute of Physics and Technology. From 1953 until his death he was the director of what is now called the Institute of Precision Mechanics and Computer Engineering.

In 1996 the IEEE Computer Society recognized Sergiy Lebedev with a Computer Pioneer Award for his work in the field of computer design and his founding of the Soviet computer industry.

Wernher von Braun
(1912 – 1977)

Wernher von Braun was a German-born American rocket scientist, aerospace engineer, space architect, and one of the leading figures in the development of rocket technology in Nazi Germany during World War II and in the United States after that.

A former member of the Nazi party, commissioned Sturmbannführer of the paramilitary SS and decorated Nazi war hero, von Braun would later be regarded as the preeminent rocket engineer of the XX century in his role with the United States civilian space agency NASA. In his 1920s and early 1930s, von Braun was the central figure in Germany's rocket development program, responsible for the design and realization of the deadly V–2 combat rocket during World War II. After the war, he and some of his rocket team were taken to the U.S. as part of the then-secret Operation Paperclip. Von Braun worked on the US Army intermediate range ballistic missile (IRBM) program before his group was assimilated by NASA, under which he served as director of the newly formed Marshall Space Flight Center and as the chief architect of the Saturn V launch vehicle, the superbooster that propelled the Apollo spacecraft to the Moon. His crowning achievement was to lead the development of the Saturn V booster rocket that helped land the first men on the Moon in July 1969.

Victor Glushkov
(1923 – 1982)

Victor Glushkov was the founding father of information technology in the Soviet Union, and one of the founders of Cybernetics.

In 1956 he began working in computer science and worked in Kiev as a Director of the Computational Center of the Academy of Science of Ukraine.

He made contributions to the theory of automata. He and his followers successfully applied that theory to enhance construction of computers. His book on that topic «Synthesis of Digital Automata» became well known.

He greatly influenced many other fields of theoretical computer science (including the theory of programming and artificial intelligence) as well as its applications in USSR. He published nearly 800 printed works.

One of his great practical goals was the creation of a National Automatized System of Administration of Economy. That very ambitious and probably too early project started in 1962 and received great opposition from many communist leaders. He struggled for his ideas for years but the system won and the project stopped.

Steve Jobs

(1955 – 2011)

Steven Jobs was an American businessman and inventor widely recognized as a charismatic pioneer of the personal computer revolution. He was co-founder, chairman, and chief executive officer of Apple Inc. Jobs was co-founder and previously served as chief executive of Pixar Animation Studios; he became a member of the board of directors of The Walt Disney Company in 2006, following the acquisition of Pixar by Disney.

In the late 1970s, Apple co-founder Steve Wozniak engineered one of the first commercially successful lines of personal computers, the Apple II series.

In the early 1980s, Jobs was among the first to see the commercial potential of Xerox PARC's mouse-driven graphical user interface, which led to the creation of the Apple Lisa and, one year later, of Apple employee Jef Raskin's Macintosh.

Jobs was named Apple advisor in 1996, interim CEO in 1997, and CEO from 2000 until his resignation. He oversaw the development of the iMac, iTunes, iPod, iPhone, and iPad and the company's Apple Retail Stores.

Bill Gates

(Born in 1955)

William «Bill» Gates is an American business magnate, investor, philanthropist, and author. Gates is the former CEO and current chairman of Microsoft, the software company he founded with Paul Allen. He is consistently ranked among the world's wealthiest people and was the wealthiest overall from 1995 to 2009, excluding 2008, when he was ranked third. Gates is one of the best-known entrepreneurs of the personal computer revolution.

After reading the January 1975 issue of Popular Electronics that demonstrated the Altair 8800, Gates contacted Micro Instrumentation and Telemetry Systems (MITS), the creators of the new microcomputer, to inform them that he and others were working on a BASIC interpreter for the platform.

Microsoft launched its first retail version of Microsoft Windows on November 20, 1985, and in August, the company struck a deal with IBM to develop a separate operating system called OS/2. On August 24, 1995, Microsoft released Microsoft Windows 95, a new version of the company's flagship operating system which featured a completely new user interface; more than a million copies of Microsoft Windows 95 were sold in the first four days after its release.

Elon Musk

(Born in 1971)

Elon Reeve Musk is an engineer and technology entrepreneur. He holds South African, Canadian, and U.S. citizenship and is the founder, chief executive officer (CEO), and chief engineer/designer of SpaceX;

In December 2016, he was ranked 21st on the Forbes list of The World's Most Powerful People, and was ranked (co-)first on the Forbes list of the Most Innovative Leaders of 2019. He is the longest tenured CEO of any automotive manufacturer globally.

In May 2002, Musk founded SpaceX, an aerospace manufacturer and space transport services company, of which he is CEO and lead designer. He joined Tesla, Inc., an electric vehicle manufacturer, in 2004, the year after it was founded, and became its CEO and product architect. In 2006, he inspired the creation of SolarCity, a solar energy services company (now a subsidiary of Tesla). In July 2016, he co-founded Neuralink, a neurotechnology company focused on developing brain–computer interfaces. In December 2016, Musk founded The Boring Company, an infrastructure and Tunnel-Construction Company focused on tunnels specialized for electric vehicles.

His goals include reducing global warming through sustainable energy production and consumption, and reducing the risk of human extinction by establishing a human colony on Mars.

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