History of Physics

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Review Article

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History of Physics

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ABSTRACT
Physics is an exact science and studies the quantitative regularities of natural phenomena at both the macroscopic and microscopic levels. The term "physics" first appears in the works of Aristotle in antiquity. In the early days, the terms "physics" and "philosophy" (natural) were used as synonyms, as both were intended to explain the laws of the universe. However, as a result of the scientific revolution, physics began to take shape as a separate field of science in the 16th century. A [1-50] reference was used in writing the review article.

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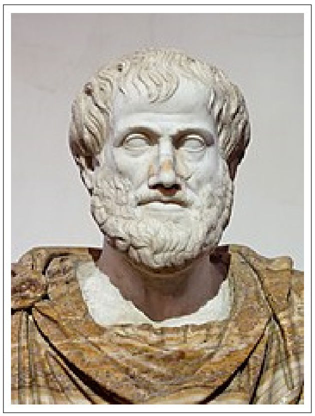
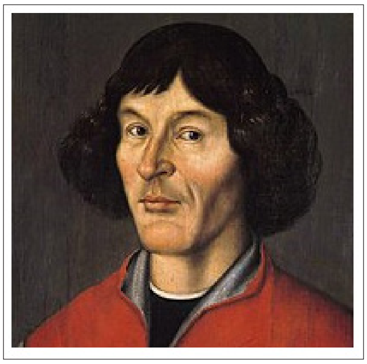
Famous physicists



Aristotle (384–322 BCE)

The ancient Greek mathematician Archimedes, famous for his ideas regarding fluid mechanics and buoyancy

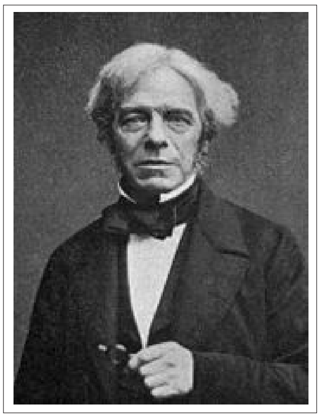


The Polish astronomer Nicolaus Copernicus (1473–1543) is remembered for his development of a heliocentric model of the Solar System

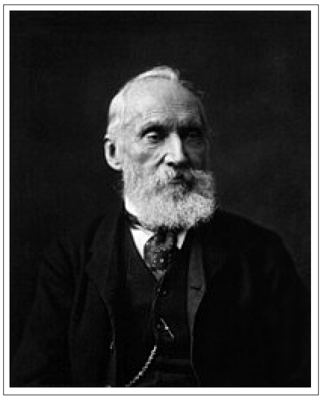
Christiaan Huygens (1629–1695)

Gottfried Leibniz (1646–1716)

Daniel Bernoulli (1700–1782)

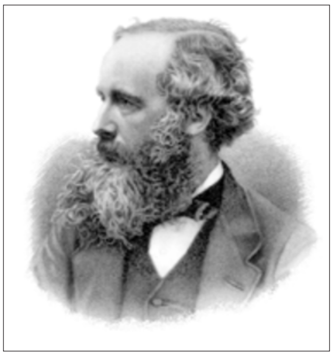


Michael Faraday (1791–1867)



William Thomson (Lord Kelvin) (1824–1907)

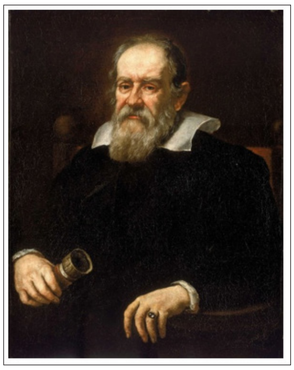
Ibn al-Haytham (965 - 1040), optics



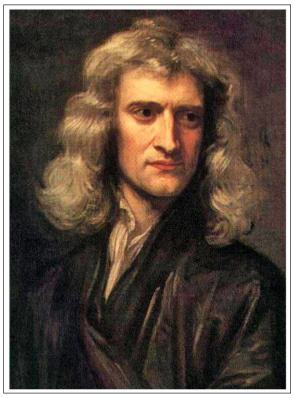
James Clerk Maxwell (1831–1879)

Ludwig Boltzmann (1844-1906)

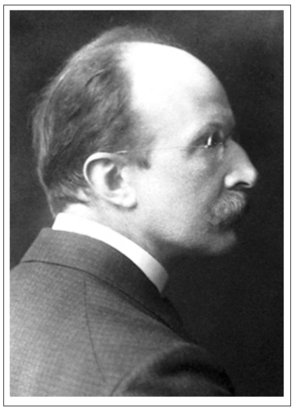
Marie Skłodowska-Curie (1867–1934)



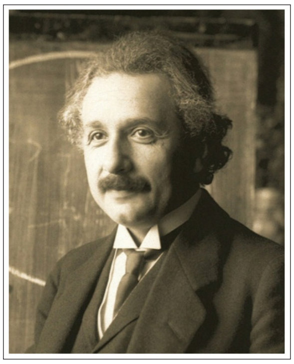
Galileo Galilei gave a modern assessment of the relationship between mathematics, theoretical physics and experimental physics



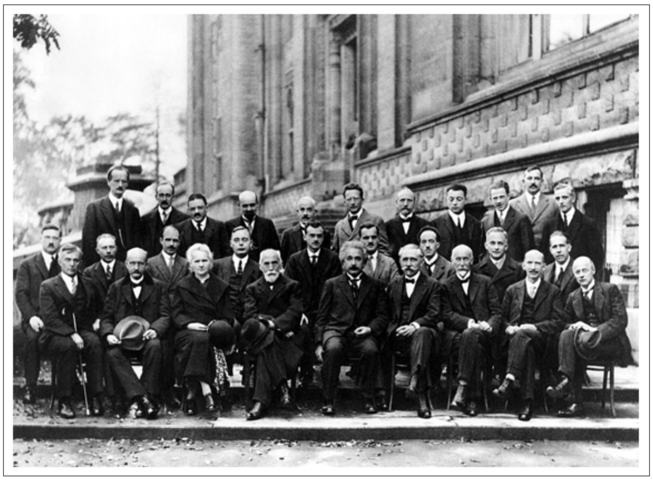
Isaac Newton (1643-1727). His laws of motion and the law of universal gravitation laid the foundations of classical physics



Max Planck (1858–1947), founder of quantum mechanics



Albert Einstein (1879—1955). His work on the photoelectric effect and the theory of relativity revolutionized 20th-century physics



The 1927 Solvey Conference with the participation of prominent physicists such as Albert Einstein, Werner Heisenberg, Max Planck, Hendrik Lawrence, Niels Bohr, Maria Curie, Erwin Schrödinger and Paul Dirac

General Information

Physics was formed mainly as an experimental science: its laws are based on facts obtained experimentally. These laws are based on certain quantitative relations and are expressed in mathematical language. Physics is divided into two sections - experimental physics and theoretical physics. In experimental physics, special conditions are created for the observation and experimental study of physical phenomena. The methods and equipment used to conduct experiments can vary widely, depending on the specific field of physics, from simple devices (such as the Cavendish experiment) to giant mega-projects such as the Large Hadron Collider. Theoretical physics, on the other hand, seeks to explain real events in nature by creating mathematical models of physical objects and systems, and predicts the possibility of new effects and phenomena unknown to science. Of course, the achievements and development of modern physics is the product of the mutual exchange of the two approaches mentioned above. Thus, experimental physics provides theoretical physics with both experimental facts and confirms experimentally whether the theoretical propositions are true. Also, at the beginning of the 21st century, the whole set of physical knowledge, depending on the size of the objects studied, was applied to microphysics (in the order of $10–^{18}–10–^{8}$ m), macrophysics ($10–^{8}–10^{20}$ m) and mega physics (section $10^{20}–10^{26}$ m). has been; microphysics studies elementary particles and the atomic nucleus, as well as atoms and molecules, macrophysics studies the physical objects that make up animate and inanimate nature, and mega physics studies cosmic objects. In order to systematize the diversity of the world's objects of study and forms of motion, physics is divided into several interrelated sections at one level or another. This separation is not monolithic and can be based on different criteria. According to the objects of research, physics is divided into elementary particle physics, nuclear physics, atomic and molecular physics, gas and liquid physics, solid state physics, and plasma physics. According to the forms of motion of matter, there are divisions such as mechanical motion, thermal processes, electromagnetic phenomena, gravity, weak, and strong interactions. From a macroscopic point of view, physics includes mechanics (classical mechanics, relativistic mechanics, mechanics of solids - including hydrodynamics, acoustics, and solid state mechanics), thermodynamics, optics (physical optics, crystal optics, and nonlinear optics), electrodynamics, electrodynamics, and electrodynamics. Electro Hydrodynamics). From a microscopic point of view, physics includes atomic physics, statistical physics (statistical mechanics, statistical field theory, physical kinetics), quantum physics (quantum mechanics, quantum field theory, quantum electrodynamics, quantum chromo dynamics, theoretical physics of wires, theoretical physics, theory). Can be divided into sections.

In physics, the teaching of dances and waves is often referred to as a special section. This is due to the fact that many of the various phenomena that occur in nature can be explained by regularities inherent in dance processes and studied by general methods. In this section, mechanical, acoustic, electrical, optical oscillations and waves are considered from a single position. Sometimes applied physics is also distinguished as one of the branches of physics. Despite all the diversity of the physical world, modern physics is based on several fundamental theories. These theories, which are the quintessence of knowledge about the nature of physical processes and events, allow us to explain the different forms of movement of matter in nature.

Formation of Physics

From ancient times the physical phenomena of the environment have attracted people's attention. Attempts to understand and explain the causes of these events have played an embryonic role in the development of physics. During the Greco-Roman period (6th-2nd centuries BC), the first ideas about the atomic structure of matter were formed (Democritus, Epicurus, Lucretius); the geocentric system of the world was created (Ptolemy); the simplest laws of statics (ling's rule) were defined, the laws of linear propagation of light, as well as the laws of return were discovered; the initial regularities of hydrostatics (Archimedes' law) were discovered; elements of the manifestations of electrical and magnetic phenomena began to take shape. BC Achievements up to the 4th century were summarized by Aristotle. In addition to individual correct propositions, Aristotle's physics had some flaws; he did not reflect in his work the progressive ideas of some of his predecessors, such as the atomic hypothesis. Although Aristotle emphasized the importance of experience, he preferred abstract ideas as the main criterion for the accuracy and validity of knowledge. In the later stages of history, the process of development and dissemination of ancient knowledge stopped, and over a long period of time this knowledge was lost and reached the point of extinction (Europe's "Dark Ages", 5th-15th centuries). It was only in the middle Ages, as a result of the efforts of Eastern thinkers, that Aristotle's works were translated into Arabic and reborn in the scientific and philosophical environment of the East. These scholars not only gave a detailed explanation of the scientific and philosophical views of antiquity, but also enriched them with new ideas. Thus, in the Middle Ages, Ibn al-Haytham (Latin name Alhazen; 965, Basra - 1039, Cairo) is considered the creator of a scientific method based on experiment and mathematical explanation. In his 7-volume Book on Optics, written by Ibn al-Haytham from 1011 to 1021, he described his experiments to prove his theory of vision and showed that the eye only perceives other objects. Until then, Euclid-Ptolemy's teaching was that the eye itself radiates light. Ibn al-Haytham studied the laws of light propagation in his experiments using an observation camera. Later, research on optics was further developed by the founder of the Istanbul Observatory, Tagi al-Din (1526, Damascus - 1585, Istanbul). In general, during the 8th and 15th centuries, Nasreddin Tusi, Al-Kindi (Alkindus), Al-Farabi (Alpharabius), Ibn Rushd (Avverroes), Ibn Sina (Avisenna), Abu Rayhan al-Biruni, Omar -Khazini, Ibn-Bajja (Avempace), Jabir-ibn-Khayyam and other scientists - philosophers contributed to the development of optics, laws of mechanical motion (statics, dynamics, kinematics), mechanisms, hydrostatics and astronomy. Some of the negative aspects of Aristotle's teaching, canonized by the church in Europe, hindered the development of science until the Middle Ages. It was only in the 15th and 16th centuries that science was able to break free from Aristotle's scholastic teachings. In the middle of the 16th century, Copernicus advanced the heliocentric system of the world, freeing the natural sciences from theological influences. The needs of the manufacturing industries, as well as the development of crafts, shipbuilding and artillery, stimulated experimental research. However, in the 15th and 16th centuries, experimental research was largely episodic. It was not until the 17th century that the experimental method began to be systematically applied to physics, and this led to the emergence of the first fundamental theory, classical Newtonian mechanics.

Formation of Physics as a Science

The development of physics as a science in the modern sense is associated with the works of G. Galilei (first half of the 17th century). Galileo showed that the effect of a given body on a given body determines its acceleration, not its speed, as is accepted in Aristotle's mechanics. The initial expression of the law of inertia, the discovery of the principle of relativity in mechanics, the experimental proof that the acceleration of the independence of objects does not depend on their mass and density, and the confirmation of Copernicus' theory are associated with Galileo's name. He also made many astronomical discoveries (mountains on the surface of the moon, Jupiter's satellites, etc.) by creating a telescope with high magnification. The first thermometer, developed by Galileo, paved the way for the quantitative study of thermal phenomena. During this period, advances were also made in the study of the properties of gases. Thus, Galileo's student E. Torricelli confirmed the existence of atmospheric pressure and created the first barometer. R. Boyle and E. Marriott correctly studied the elastic compression properties of gases and correctly expressed the first gas law named after them. W. Snellius and R. Descartes discovered the law of refraction of light. It was during this period that the microscope was created. A new step in the study of magnetic phenomena was taken by U. Gilbert. He proved that the Earth resembles a large magnet, and for the first time explained the significant difference between electrical and magnetic phenomena. The greatest achievement of the 17th century was the emergence of classical mechanics. Developing the ideas of Galileo, H. Huygens and other predecessors, I. Newton systematically expressed all the basic laws of mechanics in his work "Mathematical Foundations of Natural Philosophy" (1687). For the first time in the creation of classical mechanics, the idea of scientific theory, which is still used today, was applied. The greatest achievement of Newtonian mechanics was the creation of a universal law of gravitation that explained the motion of celestial bodies. With the help of this law, it has been possible to calculate the motion of the planets and comets of the Moon and the solar system with great accuracy, and to explain the phenomena of swells and contractions in the oceans. Newton's law was based on the concept of long-term effects. According to this concept, the interactions between objects (particles) in space propagate instantly. Newton also articulated classical concepts such as the absolute space in which all matter is located and the absolute time flowing with a single decision, regardless of its properties or the properties of motion. Until the theory of relativity emerged, these notions of space and time remained unchanged. It was during this period that Huygens and G. Leibniz discovered the law of conservation of momentum; Huygens, the founder of the theory of physical dancing, created the first dancer (kaffir) watch. The scientific review of the principle of operation and construction of stringed musical instruments began after M. Mersenn discovered the regularities of the oscillation frequency of a stretched wire; Mersenn also experimentally determined the speed of sound in the air for the first time, and Newton theoretically obtained the formula for the speed of sound. Beginning in the second half of the 17th century, the installation of new telescopes and optical devices led to the rapid development of geometric optics, as well as physical optics. The physicist Grimaldi discovered the diffraction of light, and Newton conducted fundamental research on the dispersion of light, thus laying the foundations for optical spectroscopy. In 1676, O. Romer first measured the speed of light. At about the same time, two different theories about the physical nature of light — corpuscular and wave theory — began to develop. According to Newton's corpuscular theory, light is a stream of particles emanating from a source and propagating in all directions. According to Huygens, light is a wave of waves propagating in the air, in a hypothetical environment that fills all space and penetrates all objects. In the 18th century, the development of classical mechanics, especially celestial mechanics, became even more widespread. The mathematical explanation of a small anomaly in the motion of the planet Uranus made it possible to predict the existence of a new planet, Neptune (discovered in 1846). Such achievements increased the belief in the correctness of Newtonian mechanics, and thus the diversity and diversity of all events in the world. Such a description of the world has long influenced the development of physics. The scientific and complete explanation of a physical phenomenon was measured by its degree of conformity to mechanical laws. One of the factors driving the development of mechanics was the ever-increasing demand for production. Thus, L. Euler et al. they worked out the dynamics of an absolutely rigid body. Along with the development of the mechanics of particles and solids, the mechanics of liquids and gases were also developed. Already in the first half of the 18th century, as a result of the efforts of D. Bernoulli, J. Lagrange, L. Euler and others, the foundations of the hydrodynamics of an ideal fluid - a non-compressible fluid with no viscosity and thermal conductivity - were laid. In Lagrange's Analytical Mechanics (1788), the equations of mechanics were expressed in such a general way that they could be easily applied to non-mechanical processes, such as electromagnetic processes. In other fields of physics, the process of collecting experimental data and finding simple experimental laws was also developing. Dufe discovered the existence of two types of electric charges and showed that objects with charges of the same name repel each other, and objects with charges of different names attract each other. B. Franklin discovered the law of conservation of electric charge, H. Cavendish and S. Coulomb discovered the basic law of electrostatics (Coulomb's law), which determines the force of interaction between electric charges at rest. Franklin, G. Richman, and M. Lomonosov, who studied electrical phenomena in the atmosphere, proved that lightning and thunder were of an electrical nature. In the field of optics, P. Buger and I. Lambert laid the foundations of photometry; infrared (U. Herschel, U. Wollaston) and ultraviolet rays (I. Ritter, Wollaston) were discovered. Significant progress has also been made in the study of thermal events; after the discovery of the latent melting temperature by C. Black and the experimental proof of heat retention in calorimetric experiments, the concepts of temperature and heat quantity began to be differentiated. The concept of heat capacity was introduced into science; the study of heat transfer and thermal radiation phenomena has begun. It should be noted that during this period, misconceptions about the nature of heat were created - a calorie theory that perceived heat as an indestructible, weightless special liquid (caloric) that could flow from heated objects to cold objects. The theory of molecular-kinetic heat, proposed by Newton, R. Hooke, Boyle, Bernoulli, and others, who took heat as the result of the internal motion of the particles that make up matter.

Classical Physics

The rivalry between the corpuscular and wave theories of light finally culminated in the victory of wave theory in the early 19th century. One of the main reasons for this was the convincing explanation of the phenomena of diffraction and interference of light by T. Jung and O.J. Fresnel, as well as the wave theory of polarization. Corpuscular theory could not explain these events. Fresnel, who imagined light as transverse waves propagating in an elastic medium (ether), proposed the law that determines the intensity of refracted and returning streams of light as light waves pass from one medium to another, as well as the double refraction of light. The discovery of electric current by L. Galvani and A. Volta was of great importance for the development of physics. The emergence of strong direct current sources - galvanic batteries - has led to the study of various effects of electric current. The chemical effects of electric current have been studied by H. Devi and M. Faraday. The discovery of the effect of an electric current on a magnetic needle (H.K. Ersted, 1820) proved that there is a close connection between electrical and magnetic phenomena, and on this basis A. Ampere said that all magnetic phenomena are charged particles that move a moving particle. As a result of these studies, Ampere determined the value of the interaction force between electric wires experimentally (Ampere's law). In 1831, Faraday discovered the phenomenon of electromagnetic induction. Attempts to explain this phenomenon with a long-term concept have failed. To explain such phenomena, Faraday (before the discovery of the phenomenon of electromagnetic induction) puts forward a new hypothesis: the electromagnetic interaction takes place through an intermediate agent - the electromagnetic field (the concept of proximity). This hypothesis led to the formation of a new science about the properties and regularities of a special type of matter - the electromagnetic field. In the early 19th century, Dalton introduced the idea of atoms, the smallest indivisible part of matter, to science (1803). The foundations of solid state physics were laid in the first quarter of the 19th century. In the 17th and 18th and early 19th centuries, data were collected on the macroscopic properties of solids (metals, technical materials, minerals, etc.) and on external influences (mechanical forces, heat, electric and magnetic fields, light, etc.). empirical laws concerning Thus, the study of the elastic properties of solids is based on Huck's law (1660), the study of their thermal properties is based on Dulong-Pti's law for heat capacity (1819), and the study of the electrical conductivity of metals is based on Ohm's law (1826). During this period, a general theory of the elastic properties of solids was developed (L.M.A. Navye 1819–26, O.L. Cauchy, 1830), as well as a scientific idea of the basic magnetic properties of solids. It should be noted that in the explanation of most of the results obtained in this field, solids were considered as a solid medium (although most scientists of that time knew that crystals have an internal microscopic structure). The discovery of the law of conservation of energy, which encompasses all the phenomena that occur in nature, was of great importance not only for physics, but also for the natural sciences in general. In the middle of the 19th century, the amount of heat and the equivalence of work were proved experimentally and it was shown that heat is a type of energy and that no hypothetical substance - calories - is needed to explain it. It was during this period that YR Mayer, C. Cole and G. Helmholtz discovered the law of conservation and conversion of energy independently of each other. The law of conservation of energy, called the first law of thermodynamics, became the basic law of the theory of thermal phenomena (thermodynamics). Even before the discovery of this law, S. Carnot in his book "Thoughts on the driving force of fire and the machines that can develop this force" (1824) introduced another fundamental law of thermal theory - the second law of thermodynamics. R. Clausius (1850) and W. Thomson (1851) correctly stated this law in their works. This law, arising from the generalization of experimental facts proving the irreversibility of thermal processes occurring in nature, also determines the direction of possible energy processes. J.L. Gay-Lussac's research played an important role in the formation of thermodynamics as a doctrine. Based on these studies, B. Clapeyron obtained the equation of state for an ideal gas, and later D. Mendeleev generalized this law. Along with the development of thermodynamics, the molecular-kinetic theory of thermal phenomena was developing, and soon a new type of probabilistic law, the statistical law, was discovered between physical quantities. In the early stages of the development of kinetic theory, a simple medium for gas - Coul, Clausius, etc. average values of different physical quantities: velocity of molecules, one sec. the number of their collisions during the period, the number of free runs, and so on. They managed to calculate. A formula was obtained that expressed the dependence of the gas pressure on the number of molecules in a single volume and the average kinetic energy of their forward motion. Such an approach to thermal phenomena has made it possible to characterize the physical nature of the concept of temperature as a measure of the average kinetic energy of gas molecules. The second stage in the development of molecular-kinetic theory began with the work of C.K. Maxwell. In 1859, he was the first to introduce the concept of probability into physics, discovering the law of distribution of molecules by speed (see Maxwell's distribution). After that, the possibilities of molecular-kinetic theory expanded and led to the emergence of statistical mechanics. L. Boltsman developed the kinetic theory of gases and gave a statistical explanation of the laws of thermodynamics. Boltsman contributed to the solution of a major problem - the fact that macroscopic processes do not return in nature when the motion of individual molecules rotates with time. According to Boltzmann, the thermodynamic equilibrium state of the system is max. that is, the irreversibility of the process is due to the system becoming more probable. Boltsman also proved the theorem of equal distribution of the average kinetic energy of the molecules that make up a gas according to the degrees of independence. The method of calculating the distribution function for any system in thermodynamic equilibrium was proposed by C. Gibbs (1902), and thus the process of formation of classical statistical mechanics was completed. After A. Einstein and M. Smoluxowski correctly explained the Brownian motion observed experimentally by J. B. Perren on the basis of molecular kinetic theory, statistical mechanics was universally accepted in the 20th century. In the second half of the 19th century, Maxwell's long-term study of electromagnetic phenomena was completed. Thus, in his Treatise on Electricity and Magnetism (1873), he used the equations of the electromagnetic field (named after him) to explain the facts up to that time from a single point of view, and even to predict the possibility of new events. Maxwell described the phenomenon of electromagnetic induction as the process of creating a vortex electric field by means of a changing magnetic field. He also predicted the possibility of the opposite effect - the creation of a magnetic field by means of an alternating electric field. The most important result of Maxwell's theory is that the speed of propagation of an electromagnetic interaction is finite (equal to the speed of propagation of light). H. Hertz's experimental observation of electromagnetic waves (1886–1889) confirmed Maxwell's theory. According to his theory, light is electromagnetic in nature. Thus, optics became a subject of electrodynamics. One of the results of Maxwell's theory was that the light flux had a pressure. At the end of the 19th century, PN Lebedev observed this in practice and measured the pressure of light, while AS Popov and G. Marconi were the first to transmit electromagnetic waves wirelessly. During this period, G. Kirchhoff and P. Bunzen laid the foundations of spectral analysis (1859). The theory of elastic oscillations and waves in acoustics (Helmholts, C.U. Reley, etc.) was developed. The mechanics of wet environments continued to develop. The technique of obtaining low temperatures was developed. All gases except helium were obtained in liquid form; at the beginning of the 20th century, H. Kamerling-Onnes (1908) was able to liquefy helium.

Relativist and Quantum Physics

Nuclear and Elementary Particle Physics

The discovery of the electron in 1897 by C. Thomson marked a new era in the development of physics. It turned out that atoms are not elementary particles, but complex systems with electrons inside. The study of electrical discharges in gases played an important role in this discovery. In the late 19th and early 20th centuries, Lawrence laid the foundations of electronic theory. Albert Einstein (1879—1955). His work on the photoelectric effect and the theory of relativity revolutionized 20th-century physics. At the beginning of the 20th century, it became clear that in order to explain electrodynamics, it was necessary to radically change the notions of space and time that underlie Newton's classical mechanics. In 1905, A. Einstein created a new doctrine of space and time - a special theory of relativity. The works of Lawrence and H. Poincaré played an important role in the development of this theory. According to Galileo's principle of relativity, mechanical events occur in the same way in all inertial computational systems. It was considered that electromagnetic phenomena should also follow this principle, and therefore the form of Maxwell's equations should not change (remain invariant) as it passes from one inertial system to another. However, research has shown that electromagnetic phenomena do not conform to Galileo's principle of relativity. Although the formulas for the transformation of coordinates and time to keep Maxwell's equations invariant were found by Lorentz, he was unable to correctly interpret these transformations. Einstein clarified this issue with the help of his special theory of relativity. The discovery of the special theory of relativity showed the limitations of the mechanical model of the world, and proved that attempts to explain electromagnetic processes by mechanical processes occurring in the air, which is a hypothetical environment, proved futile. Thus, it became clear to science that the electromagnetic field is a special type of matter and does not obey the laws of mechanics. In 1916, Einstein approached the concepts of space, time and gravity from a single point of view, creating a physical theory that unites them in the form of unity - the general theory of relativity. At the turn of the twentieth century, with the emergence and development of quantum theory, the foundations were laid for great change in the field of physics. As far back as the late 19th century, it became clear that classical statistical physics, which assumed an equal distribution of energy according to degrees of freedom, could not explain the experimental facts about the spectrum of thermal radiation. According to the existing theory, an object had to radiate electromagnetic waves at any temperature and thus had to cool to absolute zero temperature, i.e. the heat balance between matter and radiation was impossible. But daily experience showed the opposite. M. Planck found a way out in 1900. He showed that if we accept that the electromagnetic energy emitted by atoms (according to classical electrodynamics) is not continuous, but irradiated in the form of separate portions - quanta, we can explain the experimental facts. The energy of each quantum is directly proportional to the frequency of the radiation; later called Planck's constant in honor of Planck, this ratio is called the quantum of influence (h = 6,626 • 10–34C • sec). In 1905, Einstein extended Planck's hypothesis to show that electromagnetic energy is not only irradiated in portions, it is also absorbed in portions, and thus it behaves like a particle (later called a photon). Einstein also explained the phenomenon of the photoelectric effect, which cannot be explained by classical electrodynamics, on the basis of this hypothesis. Thus, the corpuscular theory of light has already been developed to a qualitatively new level. The dualism in the nature of light allows it to be interpreted, on the one hand, as a stream of particles (corpuscles) and, on the other hand, as a wave (interference, diffraction). Based on the "quantization" of electromagnetic radiation, in 1913, N. Bor concluded that the energy of intra-atomic processes must also change by leaps and bounds. This result of the tube made it possible to explain Rutherford's atomic model. Thus, in 1911, E. Rutherford created a planetary model of the atom by experimentally studying the scattering of alpha particles from matter. According to this model, electrons revolve around the nucleus, and planets revolve around the Sun. However, according to Maxwell's electrodynamics, such an atom cannot be stable, because electrons moving in elliptical orbits must constantly emit electromagnetic radiation, lose energy, and fall on the nucleus in about 10 to 8 seconds. It was not possible to explain the stability of atoms and their linear, discrete spectra within the framework of classical laws. Bor showed the way out of this difficult situation. According to his postulate, atoms are in special stationary states, in which case the electrons do not radiate energy. Radiation occurs only when moving from one stationary state to another. The study of the collision of atoms with electrons accelerated in an electric field by C. Frank and H. Hertz (1913–14) proved that the energy spectrum of atoms is discrete. For hydrogen, the simplest atom, boron developed a quantitative theory consistent with the experiments of the radiation spectrum. During this period, a modern view of solid state physics began to take shape as a condensed system consisting of a large number of particles (~ 1022 cm – 3). Until 1925, solid state physics developed in two directions: the physics of the crystal lattice and the electron physics of crystals (mainly metals). Later, these directions merged on the basis of quantum theory. Crystals - The idea of a multitude of atoms arranged in space in order and balanced by the forces of interaction was already fully formed in the early 20th century. At the end of the 19th century, ES Fyodorov laid the foundations of theoretical crystallography with his work in the field of structure and symmetry of crystals; he proved the possibility of 230 symmetry groups for crystals in 1890–91 — regular types of atoms in a crystal lattice (Fyodorov groups). In 1907, according to Einstein's crystal model, which was accepted as a set of quantum harmonic oscillators of the same frequency, the decrease in the heat capacity of solids, which contradicted Dulong-Pti's law but was observed in practice, led to a decrease in temperature? In 1912, M. Laue and his colleagues discovered the diffraction of X-rays in crystals and conclusively confirmed that crystals have a regular atomic structure. On the basis of this discovery, a methodology for the experimental determination of the regularities of the arrangement of atoms in crystals and the distance between atoms was developed, and the method was developed by U.L. Bregg, U.H. Bregg (1913) and G. Wolf (1913). In 1907–14, a dynamic theory of the crystal lattice based on quantum imagery was developed. The more complete dynamic theory, which presents the crystal lattice as a set of interconnected quantum oscillators of different frequencies, was further developed by P. Debay (1912), M. Born, T. Karman (1913) and E. Schrödinger (1914). After the discovery of the electron, the electronic theory of metals began to develop. In this theory, the electrons inside the metal were considered to be ordinary dilute molecular gas-like free electrons that filled the crystal lattice and were subject to classical Boltzmann statistics. With the help of electron theory, it became possible to explain Ohm's and Wiedemann-French laws (P. Drude) and the basis for the theory of dispersion of light in crystals. However, many facts could not be explained with the help of classical electronic theory. Thus, the temperature dependence of the specific resistance of metals, as well as the fact that the share of electron gas in the heat capacity of metals is insignificant, remained unexplained. It was only after the application of quantum mechanics to these issues that these dark points were clarified. In the 1920s, the movement of microparticles, as well as many physical phenomena occurring in macroscopic objects, consistently, logically explained, and developed into a modern theory (theory). The basis of quantum theory was the idea of quantization by Planck-Einstein-Bohr, as well as the hypothesis put forward by L. de Broglie (1924) - corpuscular dualism is not only about electromagnetic radiation (photons), but also about the hypothesis of matter in general. According to this hypothesis, all microparticles (electrons, protons, atoms, etc.) have not only corpuscular properties but also wave properties: each particle has a specific wavelength λ (λ = h / p), where h is the plan frequency (ν = E / h, E is the energy of the particle) corresponds to the wave. De Broglie waves describe free particles. Experimental observations of electron diffraction in 1927 proved that they had a wave nature. Later, diffraction was observed in other microparticles (including molecules) (see Diffraction of Particles). 1929 Solvey Conference with the participation of prominent physicists such as Albert Einstein, Werner Heisenberg, Max Planck, Hendrik Lawrence, Niels Bohr, Maria Curie, Erwin Schrödinger and Paul Dirac. In 1925, W. Heisenberg and M. Born established matrix mechanics that explained quantum phenomena with the help of a special mathematical apparatus. In 1926, Schrödinger, who tried to explain the discrete energy spectrum of the atom by wave equations, obtained the basic equation of quantum mechanics. In 1925, C.Y. Ulenbeck and S.A. Gaudsmith discovered by spectroscopic experiments that an electron had a specific moment of motion - a spin (as well as a specific spin magnetic moment associated with it). The size of the spin is usually expressed in units ħ = h / 2π; with this unit the spin of the electron is equal to 1/2. V. Pauli obtained the equation of motion of a non-relativistic electron, taking into account the interaction of the magnetic field with the magnetic field in the external electromagnetic field and the spin magnetic moment. He also formulated the principle (Pauli's principle) that only one electron can be located in a quantum state (1925). Pauli's principle was of great importance in the construction of the quantum theory of systems consisting of many particles. Thus, with his help, it was possible to explain the laws of electron filling of electron shells and layers in multi-electron atoms, and thus Mendeleev's theory of the periodic table of elements. In 1928, P.A.M. Dirac received the quantum relativistic equation of electron motion. It follows from this equation that the electron has a spin. On the basis of this equation, in 1931, Dirac announced the existence of a positron (the first antiparticle), and in 1932, K.D. was discovered experimentally over the years). Along with quantum mechanics, quantum statistics also developed. In 1924, the Indian physicist S. Boze applied the principles of quantum statistics to a photon with spin 1 to express Planck's formula for the energy spectrum of equilibrium radiation. In 1926, Dirac and the Italian physicist E. Fermi showed that a different statistical distribution law - Fermi-Dirac statistics - should be applied to electrons and other particles with 1/2 spin. Quantum statistics played a very important role in the development of solid state physics. In 1929, I.E. Tamm proposed to look at the thermal motion of crystal atoms as a collection of quasi-particles - phonons. Such an approach explained the decrease in the heat capacity of metals with decreasing temperature at low temperatures according to the law ~ T3, and also showed that the main reason for the electrical resistance of metals is the scattering of electrons from phonons. In 1928, the German physicist A. Sommerfeld used the Fermi-Dirac distribution function to explain the transfer processes in metals. This step gave impetus to the development of quantum theory of kinetic phenomena (electrical and thermal conductivity, galvanomagnetic, thermoelectric, etc. effects) on solids. According to Pauli's principle, even at absolute zero, the total energy of the electrons inside such a metal is different from zero that is, in the unexcited state, all energy levels start at zero and reaches a certain maximum value of the electron (Fermi). Using this model, Sommerfeld explained the small contribution of electrons to the heat capacity of metals: when heated, only excited electrons near the Fermi level contribute to the heat capacity. In 1928–34, F. Blox, H.A. Bethe, and L. Brilluen developed a theory of the zonal energy structure of crystals, and with the help of this theory the electrical properties of dielectrics and metals were easily explained. In 1928, YI Frankel and Heisenberg showed that ferromagnetism occurs on the basis of the interaction of quantum exchange; in 1932–33, the French physicist L. Neel and, independently, L.D. Landau predicted the existence of antiferromagnetism. Kamerlinq-Onnes tərəfindən ifratkeçiriciliyin (1911) və P.L.Kapitsa tərəfindən maye heliumda ifrataxıcılığın (1938) kəşfi kvant statistikasında yeni metodların inkişafına təkan verdi: Landau tərəfindən ifrataxıcılığın fenomenoloji nəzəriyyəsi (1941), daha sonra isə Landau və V.L.Ginzburq tərəfindən ifratkeçiriciliyin (1950) fenomenoloji nəzəriyyəsi was created. The application of new, powerful computational methods to the statistical quantum theory of multiparticle systems in the 1950s by J. Bardin, L. Cooper, J. Schriffer (USA) and NN Bogolyubov (USSR). In the second quarter of the 20th century, significant progress was made in the study of the structure of the atomic nucleus and in the development of elementary particle physics. Before Rutherford's discovery of the atomic nucleus, radioactivity was discovered in the late 19th century (A. Beckerel, P. and M. Curie, France), and isotopes were discovered in the early 20th century. In 1919, Rutherford was able to convert stable nitrogen nuclei into oxygen nuclei by bombarding them with α-particles. The discovery of the neutron by J. Chadwick in 1932 led to the creation of the modern proton-neutron model of the nucleus (D.D. Ivanenko, Heisenberg). In 1934, French physicists I. and F. Jolio-Curie discovered the phenomenon of artificial radioactivity. The discovery of charged particle accelerators has made it possible to study various nuclear reactions. Nuclear fission was discovered. In 1939–45, for the first time, a chain reaction of 235U nuclei resulted in the release of nuclear energy and the creation of the atomic bomb. Along with the development of nuclear physics, the rapid development of elementary particle physics began in the 1930s. Thus, muons, pi-mesons, K-mesons, and the first hyperons were discovered. As the power of charged particle accelerators increased, so did the discovery of new elementary particles, their properties, and the study of their interaction properties. Along with many new particles, extremely unstable particles with an average lifespan of 10–22–10–24 seconds — resonances — have been discovered and the existence of two types of neutrinos has been experimentally confirmed. The interchangeability of elementary particles showed that they were not necessarily elementary and that they had a complex internal structure. A coherent, logical explanation of the elementary particles and the mechanisms of their interaction is the work of a quantum field theory that has not yet reached the level of maturity. In 1917, Einstein, who put forward the quantum theory of the process of radiation, showed the possibility of a mechanism of forced radiation. Intensive research in the field of generation and amplification of electromagnetic waves by quantum systems in the 1950s NG Basov, AM Prokhorov and independently Ch. Towns (these three scientists were awarded the Nobel Prize in 1964). led to the development of the laser, a quantum generator operating in the visible light range. The creation of modern accelerators and the improvement of methods for observing elementary particles led to the emergence of high-energy physics. The development of high-energy physics increased confidence in the validity of the hypothesis that hadrons were composed of quarks and that strong interactions were carried by gluons, and that experiments with weak interactions W ± (1982) and Z^{o} (1983) were discovered in practice.

Physics in Modern Times (Development of Microphysics)

According to the modern level of knowledge, elementary or fundamental particles are called particles that do not consist of simpler particles. Numerous experiments have revealed 12 elemental fermions (leptons) and 4 massive vector bosons, notwithstanding the corresponding anti-particles. Elemental fermions - 6 species or fragrances, quarks are combined in 3 generations and form the "bricks" of the world. According to the confinement, quarks do not exist in the form of freely isolated particles; they combine in the form of hadrons (nucleons and mesons) through gluons. Thus, vector bosons "bricks" play the role of "glue" to each other, that is, bosons transmit fundamental interactions. Although there is a hypothesis of the existence of "protocquarks" or preons in nature, it has not yet been confirmed. For quarks, a one-dimensional wire theory model is usually adopted. At high energies, a new state of matter is formed - quark-gluon plasma. One of the main problems of microphysics that Einstein still wanted to solve was the creation of a single field theory that combines all four fundamental types of interactions known in the universe: gravity, electromagnetic, weak and strong interactions. The emergence of such a theory could be a fundamental breakthrough in all areas of science. At present, a well-tested theory of weak interactions and quantum chromodynamics describing the strong interaction quark-gluon hypothesis has been developed. In 1964, Peter Higgs proposed the idea of a new boson with a mass of 125 GeV. The combination of the quark-gluon hypothesis and the theory of strong interactions are called the standard model. The main component of this model is the Higgs boson, the existence of which was predicted by P. Higgs in 1964, with a mass of 125 GeV. The Higgs boson was experimentally observed in July 2012 at the Large Hadron Collider (CERN); the result was confirmed in March 2013. The fundamental role of this boson is that, according to modern ideas, the mechanism of the formation of the mass of elementary particles is a spontaneous violation of symmetry as a result of interaction with the Higgs boson. The most pressing issue in microphysics is the subsequent unification of all fundamental interactions and the transition from the standard model to the Great Consolidation, in which the existing particles - fermions and bosons - are described in a unified manner. Within this generalization, the baryon asymmetry of the universe, the small rest mass of the neutrino, the quantization of the electric charge, as well as the existence of a magnetic monopoly predicted by P. Dirac, can be explained. The most convincing evidence in favor of a large compound would be the discovery of a very rare event, the splitting of a proton (the lifespan of a proton is estimated at 1.6 · 1033 years) into positrons and -mesons. One of the important directions in microphysics is the supersymmetric expansion of the standard model, in which a boson is placed on it, which is supersymmetric for each fermion. New particles must have a very large mass, which makes them difficult to observe. However, in 2015, a new particle with a mass of 700 QeV split into 2 photons in the Large Hadron Collider, which may indicate the existence of a supersymmetric partner of the Higgs boson.

Development of Macrophysics

Macrophysics is currently the most intensive field of physics due to its large number of objects and the maximum number of practical applications. Atomic nuclear physics can be attributed to macrophysics, because in many respects, the nucleus of especially heavy and extreme chemical elements is similar to a liquid droplet. Artificial synthesis of heavy nuclei is one of the main problems of modern macrophysics; for 2016, elements with atomic numbers up to 118 were synthesized. Also, exotic nuclei of unusual (non-spherical) shape, hadron atoms (for example, an atom consisting of a proton and an antiproton), nuclei with a density greater than that of an ordinary nucleus ($\approx 3 \cdot 10^{17}$ kg / m3), and so on is studied. Controlled thermonuclear fusion (ITS) is a problem of great practical interest. Its solution can meet people's energy needs. For 2016, in 1950, I.Y. Tamm and A.D. The plasma temperature in the weave proposed by Sakharov is approx. $1.5 \cdot 10^7$ K and the research is being carried out within the framework of the International Experimental Thermonuclear Reactor ITER (International Thermonuclear Experimental Reactor, Kadarash, France; planned commissioning period - 2025) project. Another direction in the development of macrophysics is low-tempo physics. Macroscopic quantum phenomena such as superconductivity in liquid 4He (P.L. Kapitsa, 1938) and superconductivity in Hg (H. Kamerling-Onnes, 1911) have been studied. In 1986, high-temperature (T≈100 K) superconductivity was discovered (Y.Q. Bednorts, K.A. Müller). At present, the main issue is the purchase of superconductors with a crisis temperature of T≈ 300 K (room temperature). Its solution could revolutionize energy. Rev.1970s. A unique anisotropic magnetic superconducting liquid at temperatures of 300 μK and a superheat 3He with liquid crystalline properties have been discovered. The record low temperature range for 2016 is picoquelvin (10–12 K). In modern times, the interests of macrophysics have focused on the study of other different (practically unlimited) forms of matter (soft matter) from regular and irregular (both homogeneous and alloyed) solids (hard matter). Substances of this type include liquid crystals, polymers (including biopolymers), colloids and other dispersed systems, metallic hydrogen, graphene, graphene, fullerons and various heterostructures (J. Alfyorov, 2000; H. Alfyorov, H. Alfyorov). An example can be given. Such physical objects are used to create the systems needed to process and describe information, as well as the elements of integrated circuits. In the manufacture of nanoelectronic elements, materials with high electrical conductivity and mechanical properties - new allotropic modifications of carbon, such as fullerons exhibiting semiconducting properties (when they are alloyed, have superconducting properties) are studied. Of particular interest is graphene, a two-dimensional modification of carbon as a material that could stimulate the future development of nanoelectronics - a structure consisting of an atomic thickness layer with a hexagonal two-dimensional crystal lattice - because of its high thermal conductivity and high thermal conductivity. Obtaining Bose-Einstein condensate (BEC), one of the (new) aggregate states of matter - boson gas cooled to absolute zero temperature (T <10–^{6} K), storage in magnetic traps (H. Demelt, V. Pauli, Nobel Prize, 1989) and the study of their physical properties plays an important role in the modern development of macrophysics; In 2010, it was possible to observe the BEC of photons in a limited optical resonator. These achievements became possible after the development of methods for "capturing" and cooling atoms by laser beams (K. Cohen-Tannuci, Nobel Prize, 1997). Purposeful selection of different physical properties of layers in multilayer structures - for example, spintronics (sequence of magnetic and non-magnetic layers), Josephon electronics (sequence of normal and superconducting layers; see Josephon effect), molecular electronics (molecular electronics). It is possible to create a new type of electronic devices based on. A new type of associative memory device that can be used in quantum computers can be created from a two-dimensional Josephon network of contacts. Macroscopic quantum effects are manifested in all nanostructured functional electronic devices. In the future, it will be possible to reach quantum limits where only one electron, one spin, energy, magnetic flux, and so on. let a quantum “work”. Within these limits, the basic parameters of prospective computers will be 1THs many times higher than the corresponding parameters of current computers - processing speed (speed), information write frequency ~ 10^3 Tbit • cm – ^{2} - times, energy consumption.

Development of Mega Physics

The development of mega physics, although paradoxical at first glance, is closely connected with the problems of microphysics, above all with the cosmological problem - the problem of the creation and renaissance scenario of the universe. At present, the idea of the Big Bang with the next stage of inflation is widely accepted. In the earliest stages of evolution (less than $10^{–3}$ seconds), as well as in less than $10^{–35}$ seconds, the problem of the hypothetical state of the initial cosmological singularity remains unsolved. It is in these dimensions that mega physics merges with microphysics, so that the cosmological problem can be solved by the construction of quantum gravity. The cosmological hypothesis is very difficult to test experimentally (perhaps not at all) due to the excessive amount of energy required. For example, Planck's energy is 10^{19} GeV, while the largest modern accelerator (Large Hadron Collider) has a total of about $1.4 \cdot 10^4$ GeV. The most important problem of mega physics is the experimental verification of the existence of gravitational waves predicted by the general theory of relativity. At present, this hypothesis is fully confirmed with the help of the LIGO (Laser Interferometer Gravitational-Wave Observatory) device, released in 2002 in the United States. Many astrophysical objects - the nuclei of neutron stars and pulsars, extreme new stars, black holes, quasars and galaxies, and, in recent years, new exotic (unusual) objects with a thickness of 10–2 cm. It includes the study of the physical nature of cosmic wires, which are made up of strings stretched between the boundaries of the universe. The relatively recent problem of both mega- and microphysics, the dark matter responsible for the rapid expansion of the universe, and especially the dark energy hypothesis (since the late 1990s), is a serious problem.

The Role of Physics in the Modern World

The development of physics has radically changed not only the shape of the natural-scientific landscape of the world, but also the material and technical support of modern civilization. The close connection of physics with other branches of natural science led to the development of astronomy, geology, chemistry, biology, and so on. Penetrated other natural sciences with very deep roots. A number of frontier disciplines emerged: astrophysics, geophysics, chemical physics, biophysics, medical physics, molecular biology, and so on. Methods of physical research were crucial for all the natural sciences. Physics lays the foundation for the main directions of technology. Construction equipment, hydraulic engineering, electrical engineering and energy, radio engineering, lighting engineering, military equipment, electronics, computer technology have developed on the basis of physics. The development of technology, in turn, has a great impact on the perfection of experimental physics. Electrical engineering, radio engineering, etc. without the development of elementary particle accelerators, semiconductor devices, and so on. It would not be possible to create.

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