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THE CHARACTERISTIC FEATURES OF THE DEVELOPMENT OF SCIENCE AND TECHNOLOGY IN EUROPE IN THE 18-19TH CENTURIES

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The foundations of classical science were laid in the seventeenth century, and by the beginning of the eighteenth century science had obtained new problems to solve, with its further development impelled both by virture of the logic of its own development and by the social and economic reasons determining the practical usefulness of science.

The whole of the eighteenth century was marked by the assimilation of the Newtonian heritage. One should mention her first of all Euler's activities whose research ensured the fulfilment of the major part of the task.

As contrary to the seventeenth century, when scientific thought developed against the background of deep religiosity, the eighteenth century was characterized by profound scepticism towards religion and sometimes even by an evident antireligious orientation of thinking. French thinkers —Voltair and the Encyclopedists in the first place — were the most prominent figures in the process of emancipation of science and society.

The development of science in the nineteenth century was a much more complicated process which was characterized by the emergence of essentially new ideas and conceptions. The avalancheous accumulation of scientific knowledge nearly immediately resulted in an unprecedented growth of technology innovations, and the nineteenth century went into history as a century of steam and electricity. It was in that period that the mechanistic idea of the world became the predominant world outlook, though in the last quarter of the century the creation of classical electrodynamics brought science beyond the limits of mechanics.

Physical and mathematical sciences still preserved their leadership in the nineteenth century; however the greatest achievement of the century was the further development of chemistry and biology, and the creation of the evolutionary theory and the discovery of the Periodical Law should be mentioned here first of all.

The development of capitalism in European countries determined the rising tide of industrial revolution, which began in England and the Netherlands and later involved France and other countries. The establishment of state institutions for the purpose of promoting science became a typical phenomenon. Finally, K. Marx's works opened a new era in philosophy and economics.

1

The brilliant surmises and outstanding discoveries of the seventeenth century, best of all reflected in the scientific work of Kepler and Gallileo, Descartes and Huygens, were supplemented, reformulated, and systematized by the two titans —Newton and Leibniz. For the first time a scientific picture of the world was created, which enabled to obtain information, concerning the structure of the universe on the basis of a small number of initial postulates, with the scope of this information being apparently unlimited. One of the remarkable features of the new science was the possibility to receive quite unobvious and nontrivial results —through the assumptions, correctness of which nobody doubted already. The mechanism for solving such problems was provided by new mathematics with its differential and integral calculus; and it was rather difficult in complicated conditions of its development in that century to draw a boundary-line between the problems, dictated by the needs of other sciences, and those determined by its own needs.

The very fact of the emergence of new science was in a sense paradoxical, because it appeared as a response to the century-old resultless scientific debate concerning fundamental problems of the universe, and the whole work of the numerous scientific communities, which appeared in the seventeenth century in town republics and at the courts of enlightened sovereigns, was aimed at the study and the explanation of particular problems. Nevertheless, a universal system of knowledge was produced as a result, which claimed to explain both celestial and terrestrial phenomena.

One should not forget that the demand for exact knowledge of particular phenomena was determined by quite definite historic and social conditions, i.e. by the transition of the major European countries to capitalism, by prosperity of handicraft production and manufacturing and also by the unprecedented growth of international commerce, its rate increasing even more after the great geographical discovereies of the fifteenth-sixteenth centuries.

The remarkable inventions of the seventeenth century embodied practical achievements of science, moreover, they signified the epoch, when science, having yet no plan of research, extended its scope, increasing the number of experiments with just invented equipment. Such was the case of Galileo's telescope, Huygens' clock and Leeuwenhoek's microscope.

By the end of the seventeenth century capitalism had the most strong positions in the Netherlands and England. Despite absolutist traditions in England in 1679 Charles II had to ratify Habeas Corpus Act, and 10 years later, after the second revolution, the English bourgeoisie obtained even greater privileges. No less than broad rights, energetic employers needed new ideas concerning technology and methods of production, which could be provided only by science. At that time France also followed the way of its northern neighbour, undergoing severe trials; however, royal power was yet strong here, and into the 18th century France entered yet in all its magnificence of feudal and religious absolutism. In scattered feudal princedoms of Germany and Italy capitalism just began to awake.

However, scientists of that time were not that disintegrated as it might seem at first sight, if we take into account the absence of modern communication means, transport, and scientific journals (with few exceptions like, *Leibniz Acta Eruditorum* and the *Proceedings of the London Royal Society*). On the contrary, they were closely connected, discoveries became known quite soon, and an intensive correspondence between scientists, direct or through intermediaries, such as for example the well-known Mersenne, played the role of scientific journals. This characteristic feature, inherent in the international science community, remained in the 18th century as well.

Thus, by the beginning of the 18th century science had obtained new problems to solve, with its further development impelled both by virtue of the logic of its own development and by the social and economic reasons, determining the practical usefulness of science.

2

In his work "Mathematical Principles of Natural Philosophy" Newton laid the foundation of the modern science, having shown how from a limited number of axioms and laws (the law of inertia, the law of proportionality between force and acceleration, the law of equality of action and reaction and the law of universal gravitation) a harmonious system could be built, explaining such different phenomena as for example, the movement of planets, tides, the collision, or the outflow of a jet from an opening. Nevertheless, much was incomplete in the system, required a more precise definition and updating the mathematical apparatus. Newton's book was far from being a guide to practical use of numerous physical problems, besides, there remained many philosophical and methodological problems to solve, which in particular, served as a ground for the well-known polemics between the Newtonians and Leibniz.

The most prominent contribution to the solution of these problems in mechanics was made by Euler, and according to Trusdell, it will be no exaggeration to call the period of assimilation of Newton's heritage the Age of Euler.

"Mechanics, as it is taught today to engineers and mathematicians is largely his creation. He took up every aspect of it and every important special problem then under study. Everything he touched he transformed, clarified, refounded and enriched. His work on any given subject always subsumed and rendered obsolete all previous studies of it."

However, Euler was not the only scientist to receive fundamental results. At least the Bernoulli family, and also D'Alembert, Clairaut, and Lagrange should be mentioned on this connection. It is interesting to note that Euler was Johann Bernoulli's pupil and was closely connected with his sons —Daniel, Johann and Jacob. On Daniel's recommendation Euler was invited to the Petersburg Academy of Sciences, and 30 years later it was Euler who recommended Lagrange for the post of the President of the Prussian Academy in Berlin. These facts indicate the close ties between the leading scientists of the 18th century and the influence of personal contacts on their work and life.

The establishment of variational principles —first by Maupertuis and later by D'Alembert and Lagrange —was an important and essentially new achievement in mechanics. These principles had a considerable influence on the whole further development of science.

The fate of physical and mathematical sciences in England, Newton's homeland, was not very fortunate. While continental Europe developed infinitesimal methods with unprecedented success, following the way shown by Leibniz, English scientists still adhered to fluxion symbolics, resultive, evidently, only when used by true genuises. But for the research of Brook Taylor and Machaurin, one could say that the whole eighteenth century turned to be a period of stagnation in English mathematics and mechanics.

While in the field of fundamental research English science didn't succeed, in the fields connected with experimental work and technology English researchers acheived prominent success.

Bradley, the Oxford professor, discovered the phenomenon of aberration of light which enabled to prove the fact of the Earth's revolution round the Sun, and this was one of the greatest achievements of astronomy of the 18th century. William Herschel, another English astronomer, won the world fame by his consumate mastery of reflection telescopes. He constructed the largest telescopes of that time, which allowed to discover the planet of Uranus, the satellites of Saturn and Uranus, to make up catalogues of nebulae and star-clusters. Finally, Dollond managed to design achromatic lenses, which had been considered impossible since the times of Newton. These discoveries placed England into the leading position in the world in the sphere of optic equipment production, which it preserved untill up to the nineteenth century.

The 18th century saw a great range of experimental research into electricity, which by the second half of the century took shape of a separate branch of science. Started by the Englishmen, experiments on electrization by friction later spread throughout Europe, came into a kind of fashion—experiments with static electricity attracted great attention in society salòns, were very popular here. This is a rather typical example of scientific results intruding into everyday sphere, though sufficiently rare for science of the past.

Experiments on electricity, (though having given many outstanding discoveries —Leyden jar, electrostatic induction, lightning conductor and others) didn't however, yet allow to speak of electricity as a branch of science, until Coulomb established the law of interaction between charges. This law was discovered with the help of torsion balance, which later enabled Cavendish to define the gravitational constant in the Newtonian law of gravitation.

Experiments aimed at the study of thermal phenomena and initially related to the research into the expansion of substances, led to the creation of the steam-engine, which could be used in industry as a mechanical drive. Newton and Watt's works produced a revolution in the industrial production of developed European countries, and first of all in England. However, the relationship between science and technology in this particular case was indirect, technology innovations were brought to life rather by an expanding industrial production. This conformity with the law is well illustrated by the fact that Newcomen was a smith, Watt was a mechnical engineer, who produced various machines ranging from musical organs to cranes, and Josiah Wedgwood, the inventor of the first pyrometer (Darwin's grandfather, by the way) was a chinaware manufacturer. K. Marx wrote: "The creation of driving machins necessiated a revolution in the steam-engine". Note, that the invention of such machines for textile industry in England of the eighteenth century was the first stage of the industrial revolution, which inevitably should have led to the establishment of machine industry. This process can be observed already in the nineteenth century.

Academies of sciences, which appeared in the seventeenth and in the early 18th century in major European countries, sought to attract scientists' attention to works being important from their point of view. Thus, the Paris Academy announced a competition for the best work on the nature of heat, with the first prize awarded to Euler, who gave a correct explanation of this phenomenon. Nevertheless, in the second half of the century the "material" theory of heat prevailed nearly everywhere, being closely connected with the phlogiston theory, which was particularly popular in Germany. There was an opposition to this theory in France, where Laboisier, the father of modern chemistry, started his research from its negation, and also in Russia, where Lomonosov came out against it.

Science of the 18th century was characterized by a continual idea of matter. Atomistic conceptions, according to which physical phenomena were determined exclusively by the shape and movement of matter particles, were set aside. Therefore so widely spread at that time were the ideas about all kinds of "fluids" as if responsible for electrical, magnetic, thermal and other phenomena.

The process of mastering and further development of Newtonian ideas proved to be a complicated and contradictory one. Extremes seemed indispensable here, and, as L. Rosenfeld noted, "all the deeply significant hesitations of the creator's thought, arising from his intimate insight into difficulties of the subject, had been ironed out by less subtle epigons." The total prevalence of the corpuscular theory of light, negation of the existence of meteorites and an extermely critical attitude towards any hypothesis connected with attempts to penetrate into the essence of primary problems (e.g. the nature of gravitation) were examples of such ironing.

Finally, one should note a great influence, which science had on philosophy and social and political ideas of the eighteenth century. As contrary to the seventeenth century, when scientific conceptions developed against the background of deep religiousness, the eighteenth century was characterized by profound scepticism towards religion, and sometimes even by an evident antireligious orientation of thinking. Voltaire and encyclopedists were the most prominent figures in the process of emancipation of science and society. It is often difficult to draw a line of distinction between "scientists" and "philosophers", or "scientists" and "authors" in the Age of Enlightenment. The spirit of science penetrated so deeply amidst educated people, that it often became a guiding principle of their activity. Thus, Voltaire was possibly the most ardent advocate of Newtonian mechanics on the Continent. Golbach tried to transfer physical concepts into the sphere of social life, and Fridrich Schiller, the poet, was the first to translate Adam Smith's works into German.

3

While in the eighteenth century the development of science can be characterized as a period of assimilating of the Newtonian heritage, it is more difficult to give such a simple definition to science of the nineteenth century. The progress of science was a pre-complicated process, characterized, on the one hand, by the revision of doctrines, vailing in the eighteenth century and often by turning back to the ideas of the seventeenth century (the wave theory in optics may serve as an example here) and on the other hand, by the appearance of essentially new ideas and conceptions simultaneously with the emergence of new branches of science.

Such an avalanche-like accumulation of scientific knowledge nearly immediately resulted in an unprecedented growth of technology innovations, and the nineteenth century went into history as a century of steam and electricity.

It is interesting to note that though a mechanistic picture of the world had been given preference already in the previous century, it was only in the second half of the nineteenth century that it turned into the predominant—in the full sense of the word—world outlook. However, it was in that period (i.e. in the last quarter of the century), when the absolute majority of scientists made no doubt about the firmness of the mechanistic idea of the world, that Maxwell, Hertz, and Lorentz' works struck a crushing blow to the idea. The significance of these works was not yet fully realized by their contemporaries, but it was evident for them, that the era of mechanistic concepts came to its end, and that classical electrodynamics helped science to go beyond the limits of mechanics.

In the 19th century physical and mathematical sciences preserved their leading position, but besides that, the further development of chemistry and biology became one of the greatest achievements of the century.

The main events of the end of the eighteenth century and of the early 19th century can be in brief characterized as follows—this is a period, when the industrial revolution in England was in its full swing, and another type of revolution—social and political was going on in France. Both these events had a determinant influence on the further development of science and technology.

The creation of the steam-engine in England resulted in the appearance of the first locomotives early in the century (Stephenson 1814), but in the 1810's it was a novelty yet. A German traveller pointed out that there was even no special word for a locomotive at that time, it was called simply "wagon". However, the industrial engine manufacturing began already in the 1820's, and in the end of the 1820's the first railway service between Manchester and Liverpool was established.

The Great French Revolution gave rise to an extraordinary creative activity, with science, both applied and fundamental, being the subject of special attention of the revolutionary government. The question was to reorganize completely the system of education and science institutions in France. On the instructions of the ad-hoc committee, proposed by Robespierre, Condorcet submitted a plan of reforms, which was fulfilled later. According to this plan the Ecole Polytechnique was established with a view of training civil and military engineers. The Ecole Polytechnique played later an extremely important role in the development of science. Suffice it to say that such outstanding scientists as Malus, Biot, Fresnel, Arago, Gay-Lussac, and others graduated from this college. Also, Ecole Normale was established to train teachers for higher education institutions. Finally, the elite Academy was replaced by the Institute with three equalized divisions—physical and mathematical, social and political, and literary. This reform was a consequence of the increased prestige of physical and mathematical sciences, and from the end of the eighteenth century exact sciences finally occupied their proper positions in French universities, where earlier the humanities prevailed.

Early in the nineteenth century France occupied a predominant position in mathematical sciences. The analytical trend in mechanics, with Euler rightfully referred to as its founder, was continued by Lagrange, who achieved outstanding results in construction of the theory, characterized by an exhaustive mathematical accuracy and a possibility of its wide usage in practical applications. Laplace, one of the most prominent mathematicians of the end of the 18th century and of the early nineteenth century, systemized all the previous research into celestial mechanics (including his own research, with the fundamental theory of solar system stability to be mentioned in particular). Although this work, the five volumes of which were published during a quarter of a century, was entitled "Celestial mechanics", its content went far beyond the scope of the title—it dealt with such phenomena as capillarity, barometrical levelling, the laws of liquids equilibrium etc. In a popularized essay of his fundamental work Laplace stated his famous cosmogonical hypothesis, which hasn't lost its significance till now-a-days. Finally, Laplace can be considered the founder of the mathematical theory of probability.

Both, Lagrange and Laplace— in particular, were rather unscrupulous in political aspect, they didn't worry much about the political and social system. Lagrange, equally prospered in the time of the Republic, being its ardent adherent at the beginning, and under Napoleon, when he became the Minister of Home Affairs, and under Louis XVIII, who made him a marquis and a peer. Unscrupulousness is, possibly, an exaggerated word here, and one should speak of a kind of political "exterrioriality" which science exercised at that time. This is proved by the fact that when Davy together with his assistant (young Faraday) went on tour through European countries, while England and France being at war then, Napoleon gave the scientists a special permit, allowing them to visit France and the conquered countries without any hindrance.

The progress, which French scientists made in the field of physical and mathematical sciences, greatly influenced the development of chemistry, where research of pure physical nature began to play a determinant role. Such were the works aimed at the determination of various gas and vapour characteristics (density, expansion factors, thermal capacity etc.). The results achieved by Gay-Lussac as well as by Dulong and Petit for the first time related physical properties of gaseous substances to chemical ones. However, the greatest achievements in the development of science in that direction belonged to Dalton, an Englishman, who was the founder of chemical atomistics. It was he, who established that chemical compounds consisted of a definite number of chemical units, or atoms of different weights, which in their turn, correspond to equivalent weights, determined by means of chemical analysis. Thus, Dalton placed chemistry on a stable foundation of quantitative measurements, which determined the further progress in this branch of science. Davy, another outstanding English chemist, made his chief discovery also at the junction of physics and chemistry—he discovered the decomposition of alkali by electrical current. Nevertheless, early in the nineteenth century France seemed to preserve its superiority in chemistry, with French chemists having achieved an essential progress in the applied sphere. In France chlorine was widely used for cloth blaching—the discovery made by Berthollet already in the eighteenth century, the manufacture of beet sugar came to be organized. Many achievements in the field of applied chemistry were promoted by the lack of English colonial goods in France, the access to which was terminated as a result of the Continental Blockade.

Finally, it should be noted, that early in the nineteenth century the main achievements in natural sciences belonged also to French scientists. Exact sciences, which were so brilliantly developed in France and which determined then, as it was already mentioned, not only special, but also broad social and public views couldn't but have an inspiring influence on biological sciences. By the beginning of the nineteenth century a scientist still remained to a considerable extent an encyclopedist, the sphere of his interests was not limited as a rule by his direct profession. Thus, Lavoisier was awarded the Golden medal of the Paris Academy of Sciences for his work on a better street lighting, and later he took part in making up a geological map of France. At the same time Laplace, the mathematician, was interested in thermochemistry, Lamarck published a meteorological annual, and Dulong was a physician by profession. It is very likely therefore, that general methodological aims and success of exact sciences implicitly contributed to the progress in natural sciences as a whole. First of all one should point out here the evolutionary doctrine, created by Lamarck, according to which the whole variety of the animal and vegetable world appeared as a result of changes in species under the influence of various environmental conditions. Cuvier, another great French naturalist, was a violent opponent to the evolutionary theory, but a vast amount of the facts, found in his studies—Cuvier was one of the founders of modern comparative anatomy, palaeontology, and taxonomy—promoted further strengthening of the evolutionary theory.

4

Science of the nineteenth century was characterized by much broader objectives than previously, resulting from the increased dynamism of science, an unprecedented variety of forms of scientific activity and a powerful growth in technology. The industrial revolution reached its third stage—the stage of machine production, with the progress in technology acquiring a avalanche-like nature with the expansion and the intensification of the capitalist production.

The development of many branches of science entered a new stage, and frequently even a new epoch, and this epoch is often related to the appearance of a new branch of science, or a new orientation. The development of mathematics appears very typical in this connection. Outstanding achievements of the French mathematical school showed the power of new method, and in the first decades of the new century even England abandoned its conservative approach, the fluxion symbolics was replaced by the generally accepted Leibniz symbolics, and the talented English mathematicians, such as Green, got plunged in the study of French authors. Herschel the son and Babbage founded in Cambridge the "Analytical society" with the aim to promote the propaganda of French scientists' ideas. However, the beginning of the century coincided with the date of real significance for mathematics, i.e. with the beginning of Gauss' research. It was apparently Gauss who brought back to the German mathematical thought its past authority and importance. He was the founder of a brilliant mathematical school, which influenced the whole development of science. He has performed outstanding services both to pure and applied mathematics, and especially in the development of algebra, the theory of numbers and the perturbation theory. Felix Kleiane, the prominent mathematician and historian, wrote, "already the contemporaries realized the whole greatness of his genius, of which the inscription made on Gauss' medal in 1855 indicates in a brief and expressive form: "the king of mathematicians". Gauss' works marked the beginning of a new approach to the development of certain fields of mathematics, in fact attaching to each the characteristics of an independent branch of science. This was promoted, on the one hand, by the personal features of his character—his mathematical genius and the rule "not to consider anything done if there is something to be done yet", and, on the other hand, by the ideological situation, which existed in mathematics in the beginning of the century, when by virtue of the logic of its development it was ready to suggest essentially new problems. It is interesting to note that Gauss was a typical representative of the eighteenth century, his characteristic feature being the versatility of his scientific interests. Many of Gauss' researches were closely connected with practical goals, he was an astronomer, a geodesist, a physicist. Together with Weber he carried out a cycle of absolute measurements of electrical and magnetic units, performed systematic measurements of the magnetic field of the Earth, designed the first telegraph. As a rule Gauss didn't hasten to publish his works. Only after his death it was found out that he had anticipated many results obtained by Bessel, Hamilton, Abel, Jacobi and Cauchy, which they in fact rediscovered.

At the same time another great mathematician, Cauchy, worked in France, to whom modern science owes the main results in the field of analysis bases. The work of the two titans gave rise to the broad development of mathematics both in terms of further creations of new orientations and in terms of deep elaboration of classical problems.

Problems, connected with the grounds of mathematics, acquired particular significance in the nineteenth century, and in the first half of the century works on the grounds of geometry led to the result, quite unexpected but rather fruitful for all the exact sciences. This was the non-Euclidian geometry, created by Lobachevsky. In the middle of the century the scope of non-Euclidian systems was considerably widened by Riemann. There exists an opinion, that non-Euclidian geometry was allegedly known already to Gauss. Nevertheless, the creation of a new kind of geometry was one of the greatest fundamental achievements of science in the nineteenth century, the significance of which could be fully appreciated only in our century after the appearance of Einstein's theory of relativity.

France could not but exert influence on neighbouring Germany, and after the Napoleon wars the trend towards the establishment in Germany of Ecole Polytechnique-like institutions became more and more apparent (note, that the Berlin University was founded in 1810). This plan, however, was destined to fail, mainly because of Gauss' refusal to take the management of such an institute. Nevertheless, a kind of a consolidating centre was organized in the field of mathematics, which united practically all the German mathematicians. This was a scientific journal, founded by Crelle, the popularizer and the organizer of science. The necessity to institutionalize the research was realized in England as well, and this process, which began with the foundation of the Analytical society for popularization of French mathematicians' ideas, resulted in the early 1920's in the establishment of Mechanics Institutes in various English cities—a kind of evening-schools for those, who wanted to broaden their knowledge in science and technology. This trend was significative for two reasons. Firstly, it indicated that a wide stratum of handicraftsmen existed in England, who were capable of making discoveries in technology and needed a corresponding educational basis; and, secondly, this process was most intensive in industrially developed cities (e.g. Glassgow, Manchester, Leeds etc.) which needed a wide influx of innovations and improvements. Science was gaining an ever-increasing prestige in public opinion, and finally, in 1830, the British Association for Advancement of Science was founded, which played an important role in the organization and the development of scientific research in the country.

Physics of the first quarter of the century was marked by two outstanding discoveries in its most significant fields, i.e. in optics and electromagnetism. Research, carried out by Young and by Fresnel, in particular, enabled to prove the wave nature of light and also the fact that these waves, or oscillations, were perpendicular to the direction of their propagation. Oersted's discovery was no less significant. He was the first to find out a non-Newtonian type interaction between physical objects, i.e. the fact that a force acting between the magnetic pole and a current element is not directed along the connecting line, but is perpendicular to it. The contemporaries gave different and not always adequate estimates of these two significant events, however, it was these studies that finally resulted in the downfall of mechanistic physics and in the creation of modern theories in physics. Moreover, as related to the contemporaries, these discoveries gave a powerful impetus to new research, undertaken for their explanation. Such prominent scientists as Cauchy, Poisson, Ampere and Arago can be found among the authors of the research in this direction.

5

From the second quarter of the nineteenth century the development of science has gained such a scope, that it is nearly impossible to give in a brief essay a comprehensive picture of science with its ramification and complex inner interactions. Thus, from a great number of facts only several lines will be picked out, i.e. those which appear to be the most typical for that epoch and which have had the greatest influence on civilization. These lines are: the mechanical theory of heat and thermodynamics, electrodynamics, progress in chemistry and the discovery of the Periodic Law, and, finally, Darwin's theory of evolution.

The establishment of the principle of conservation of energy as a universal Law of Nature was one of the most significant discoveries of science in the nineteenth century. This law was intuitively understood by many scientists of the past, but Sadi

Carnot was, apparently, the first to connect heat with work. (Proceeding from erroneous assumptions concerning the nature of heat, he, nevertheless, gave a correct definition of the mechanical equivalent of heat.) In this connection the great physicist and historian of science Max Lane wrote the following: "During the first decades after 1800 one could often encounter the idea of the existence of "a force" acting, subject to conditions, as a movement, chemical affinity, electricity, light, heat, magnetism etc., each of the forms being able to turn into the others. It was necessary to find a general measure of the force in order to transform this vague idea into a clear notion. Such a clear understanding was reached in the middle of the century owing to the works of R. Mayer and Joule, the latter, in addition, having given an exact definition of the mechanical equivalent of heat. Mayer and Joule followed different ways to the discovery of the principle of conservation of energy, proving its truth for various particular cases; however, Helmholtz soon generalized the results and gave to the law its universal character. After a short struggle for its acceptance, the principle of conservation of energy came to be considered as one of the most fundamental law of the universe. Henceforth the truth of all other assumptions and theories in science came to be verified—in the first place—by their correspondence to the new law.

The mechanical theory of heat gave rise to thermodynamics, quite a unique formation in the variety of sciences. With the development of science as a whole it became more and more divided into specific branches, each having its own structure, language and applications. But the more intensive the process of differentiation is, the more we realize the necessity of ideas and notions, which would be common for different branches of science. Thermodynamics turned out to be such a system of notions embracing practically all the sections of chemistry and physics and showing their internal unity. On the other hand, the statistical approach, resulting from the attempts to explain phenomena by means of thermodynamical notions, and the associated conception of entropy played an outstanding role in the development of new ideas, and of the quantum theory in particular.

The appearance and the development of the scientific theory of heat served as a passport to the foundation of thermodynamics as an engineering discipline and contributed to the further progress in the sphere of heat-engine design, which formed the basis for progress in technology as a whole. The appearance of powerful steam-engines not only led to railway transport being practised on a large scale, but also totally changed the whole nature of industrial production. The opening of the first World Industrial Exhibition in London in 1851 was the triumph of technology. The location of the Exhibition emphasized the leading position of England as an industrial country, which, however, was substantiated by the fact that the international judges awarded to English firms the greatest number of prizes. Engineering industry rapidly developed in England from the first years of the second half of the century, London, Manchester, and Leeds still being its leading centres. It should be noted that in the middle of the century the first steam-hammer was constructed in England, which also contributed to progress in mechanical engineering.

However in the second half of the century England lost its obvious leadership in many branches of industry and had to withstand a severe competition on the part of other European countries, France and Germany in the first place. It was in Germany in the last quarter of the century that the event took place, which changed the nature of technological civilization. That was the creation of the internal-combustion engine by Otto and Diesel.

Besides steam-engines of the second half of the nineteenth century, technology acquired a new powerful source of energy, i.e. electricity. But let's return to the times of Oersted's discovery in order to make up a more complete idea of the process of electrical energy mastering.

Oersted's experiment, representing the first illustration of the non-Newtonian interaction, soon became the subject of intensive studies. This experiment was reproduced by Ampere, who created later the first theory in electrodynamics. Electricity and magnetism were reduced to the same principle in his works, which was an outstanding result by itself. The further merits in the development of the electromagnetic theory belong to Faraday. It should be first of all noted that Faraday's discovery of electromagnetic induction stipulated the possibility of conversion of mechanical energy into electrical one, and, consequently the creation of electrical generators and electric motors. Faraday's views concerning the nature of electricity to a certain extent came in conflict with Newton's ideas on the character of interactions occurring in Nature (rather with their canonized interpretation). Faraday believed that the presence of an electric charge or a magnet changed the surrounding medium, thus, he introduced for consideration a notion of field. Trying to present Faraday's ideas in a mathematical form, Maxwell came in the long run to the creation of classical electrodynamics. Though using various analogues in the process of theory construction, with the concept of medium as of elastic ether playing an important role in the genesis of his ideas, he never tried to prove the obtained data by means of mechanical schemes. As future showed, he was quite right in that, as the notion of field, being fundamental for his electrodynamics, could not be reduced to any mechanical analogue, and represented a completely new, unknown form of the matter. It follows from Maxwell's theory that a static electrical field doesn't cause any magnetic effect and vice versa. An alternative electrical field, however, generates a magnetic field immediately and, equally, changes in a magnetic field lead to the emergence of an electrical field. An electromagnetic disturbance spreads with the velocity of light, indicating the electromagnetic nature of light as well. The significance of this revolutionary achievement can be best of all defined by the following statement, made by the Nobel-prize winner R. Feynman in his famous course of lectures on physics. He wrote that in the history of mankind (if looked at, say, in some ten thousand years) the discovery of electrodynamics laws by Maxwell would certainly be the most significant event of the nineteenth century. The Civil War in America would seem a minor provincial incident against the background of this important scientific discovery.

Maxwell's contemporaries hardly grasped his theory, but after Hertz experimentally proved the existence of electromagnetic waves, it was universally accepted as one of the most fundamental parts of modern science.

The theory of electromagnetism, founded by Maxwell and developed by Hertz and Lorentz, provided technology with unprecedented potentialities. Thus, at the close of the nineteenth century the wireless telegraph appeared, and the era of radioelectronics began.

One of the characteristic features of the nineteenth century was the development of chemistry, the scientific foundations of which had been laid in the previous century, and which in the nineteenth century represented a quite developed sphere of knowledge with its specific theoretical apparatus and a wide experimental basis. There was an attempt to synthesize all the previous results, achieved in the first decades of the century by Berzelius, who tried to combine Gay-Lussac's notions with Dalton's ideas. Adjoining Davy's conceptions, Berzelius' electrochemical theory explained the existence of chemical compounds through electrical attraction of constituent atoms, however, it attributed to atoms a positive and a negative charge simultaneously and thus was incorrect in its very essence. Nevertheless, Berzelius' theory played an important role in the development of chemistry. An essential influence on the formation of theoretical ideas in chemistry was exerted by Prout's hypothesis claiming that various chemical elements represented different combinations of atoms of one and the same proto-element, i.e. stating the unity of matter. Thorgh not generally recognized the hypothesis was regularly reproduced in the ideas of various scientists ranging from Dumas to J. J. Thomson.

From the second quarter of the nineteenth century organic chemistry began flourishing owing to the scientific work of Dumas, Wöhler, and Leibig, in particular. The process of differentiation in chemistry had already become apparent by that time; besides non-organic and organic chemistry there appeared such branches as thermochemistry, stereochemistry etc.

The second half of the ninteenth century was marked by a parallel growth in research into the structure and synthesis of organic compounds. The development of chemical industry at that time played a paramount role in stimulating scientific research. The modern organic-chemistry-based industry began, in fact, with Perkin's accidental discovery of movein when he tried to synthesize quinine in laboratory conditions. This discovery was followed by Graeby and Liebermann's works on dye-stuff from madder roots, which resulted in synthesis of alizarin. Henceforth industry and science became closely connected in the field of organic chemistry, which provided their successful development and rapid rate of growth. It is obviously difficult to find in science and technology so close a relationship, as can be observed in organic chemistry; the interval between a discovery and its implementation in industry is nowhere that short.

In the second half of the nineteenth century Russian science entered the international scene, with natural sciences and chemistry accounting for its most remarkable achievements. In the early 1860's continuing offorts of Wöhler, Colbert, and Berthelot efforts, Butlerov completed his classical studies in organic synthesis by obtaining sugar from dioximethylene affected by lime solution. At the same time he put forward his theory of chemical structure of substances. According to it, the structure of chemical compounds is determined not only by its constituent atoms, but also by the capability of these atoms to become connected with each other in a certain manner. This theory enabled to express the structure of organic molecules by means of formulae, and, moreover, to predict the structure of yet unknown compounds. However, it was the Periodic System, created by Mendeleyev, which became the most prominent achievement of Russian science of that time, the importance of which for science as a whole can hardly be overestimated. The Periodic System not only solved the problem, confronting chemists from the times of Dalton, by giving them the necessary basis for carrying out research in any field; as further studies of physicists showed already in the twentieth century, this discovery became an impressive justification of the unity of scientific knowledge.

Let's turn finally to the theory of evolution. It was Darwin who proved the fact of evolution and introduced into the theory the proposition, according to which random positive factors accumulated in an organism in the process of evolution, passing on from one generation to another, with the process of evolution itself being determined by the struggle of organisms for existence —"the survives the fittest". Darwin's theory, as stated in his work "On the Origin of Species by Means of Natural Selection", became a turning point in the history of biology, giving for the first time a scientific explanation for the infinite variety of organisms in Nature, and was enthusiastically received by Marx and Engels who considered the book to be a scientific justification of dialectical materialism.

Thus, to the end of the nineteenth century science arrived with unprecedented achievements. We could see, that by the end of the eighteenth century the process of mastering the Newtonian heritage had been in the main completed, and new fundamental theories began to appear, exceeding already the frame of the mechanistic picture of the world, which had served as an ideal of scientists during two centuries and a half.

The development of capitalism in Eupropean countries, having reached its last stage by the end of the nineteenth century, determined the rising tide of industrial revolution, which began in England and the Netherlands and later involved France and other countries. This revolution resulted in a rapid growth of technology, the demands of which in their turn served as a powerful impetus for scientific research. The advance and strengthening of capitalism caused a number of social revolutions and social reforms as well, which led to the expansion and consolidation of bourgeoisie power in all countries. This had a positive influence on the development of science and technology, in particular, as most governments soon realized the possibility of benefitting by scientific research and introduction of technological innovations into industry. Reforms in education and the establishment of state institutions with their activity aimed at financing and control of scientific research, was a characteristic for the nineteenth century form of interaction between science and society.

The achievements of science and progress in technology had a determinant influence on public opinion. Atheism and materialism became the distinctive feature of scientific view of the world. Finally, in the middle of the century Marx's studies revealed the economic laws of social development and at the same time created the materialist philosophy, which henceforth had an ever-increasing influence on mankind.

Although some of the scientists of the end of the nineteenth century believed that the edifice of science had been nearly constructed (such was, for example, Lord Kelvin's opinion), science and technology were, in fact, on the thershold of new discoveries and achievements—on the way of conversion of science into one of the main productive forces of the society.

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