SOVIET PHYSICS USPEKHI VOLUME 8, NUMBER 4 JANUARY-FEBRUARY 1966

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EINSTEIN'S PHILOSOPHICAL VIEWS AND THEIR RELATION TO HIS PHYSICAL OPINIONS

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Usp. Fiz. Nauk 86, 537-584 (July, 1965)

1. INTRODUCTION

TEN years have elapsed since Einstein's death, and his personality, his views, his contribution to science, and his interpretation of the evolution of physics still remain and will for long remain the object of reflection and argument among physicists and philosophers, scientists and writers, friends and opponents.

His amazing classical works on the theory of relativity, quantum physics, and statistical physics were published almost simultaneously during his youth at the beginning of our century.

Six decades have elapsed since then. Much in physics has been fully defined and can now be weighed with the balance of history. But even now it is amazing that Einstein's initial ideas, which were published in years of a re-estimate of the values accumulated in physics, were so deep, encompassed the main theoretical problems of physics, have shown vitality in their value in the study of nature and served as a basis for the blossoming of new technology even in our days.

Looking now at Einstein's scientific path, we see a picture on a very large scale. The motion of his mind was as powerful as a mountain stream, which has broken through an obstruction, and which floods as a result of the accumulated excess of water the valley together with the lowlands, until soon a definite channel is produced, through which all its energy flows in the direction of the infinitely remote sea, never deviating from its path.

But not only Einstein's direct results attract attention. Also surprising are his fate, in which was manifest the completeness and purposefulness of his nature, and in which at the same time many dramatic collisions are focused. One of them was due to the discrepancy of Einstein's views and the views of most physicists concerning the further paths of the development of physics and the ways of gaining knowledge about nature. We are not speaking here of disparities with views of those scientists who did not understand the need of moving forward from the classical notions and did not adopt Einstein's new ideas, developed in relativity theory; the disagreement and even clash with the conservative is natural and there is nothing unusual about it. But we are speaking here of disagreement with those physicists, who recognized the need for a sharp turning away from the old metaphysical notions, who recognized Einstein as a leader of modern theoretical physics, as one who provided a powerful stimulus to its broad development, including quantum ideas and quantum statistics. For the dramatic nature and the scale of this collision to be clear, we shall discuss below Einstein's significance to physicists during the acute and critical period of the departure from classical methods of study, and then attempt to analyze the principles which led to this collision.

2. EINSTEIN'S CONTRIBUTION TO MODERN PHYSICS

Einstein entered on the stage of scientific activity at the very beginning of the twentieth century, during a remarkable and critical period of physics. In the history of physics this period is characterized not only by the famous discoveries of the electron, radioactivity, development of the kinetic theory of gases, of spectral methods, etc., but also by the powerful uplift of theoretical thinking. Among the physical theories, besides thermodynamics, a tremendous importance was acquired by Maxwell's theory of the electromagnetic field.

Not so very long before that time, Maxwell's theory, which was far from intuitively clear, was greeted by many physicists with skepticism. However, at the beginning of the twentieth century this theory, which was seemingly extremely abstract and obtuse, already demonstrated its deep connection with the real world and with engineering. Its real cognitive value was expressed in the confirmation of the existence of the electromagnetic waves predicted by it (H. Hertz, 1887) and the rapid development of radio engineering on this basis (A. Popov, 1895), in a unification of all the electromagnetic radiation into a phenomenon of a single nature, including light, and in the discovery of the connection between the electromagnetic and optical properties of matter. During Einstein's student years, Maxwell's theory only started to be included in the curricula of European universities.

But during the same period essential difficulties were also observed in the theory. They were connected with the need of applying electrodynamics to moving charged bodies. This problem occupied the outstanding physicists of that time—Lorentz, Poincaré, Abraham, Langevin and others. This problem occupied also the young Einstein.

The difficulties arose in connection with the fact that Maxwell's theory described the interaction of a conductor and a magnet in such a way, that two cases of interactions could be distinguished: in the first one the conductor is at rest and the magnet moves, in the second one the situation is reversed. In the case when the magnet moves, the picture is as follows: when the magnet moves, the force lines of the electric field produced by this motion are cut by the conductor and induce current in it. On the other hand, when the magnet is at rest and the conductor moves, from the point of view of Maxwell's theory, no electric field is produced but an electromotive force is produced in the conductor, and this gives rise to exactly the same effect. Thus, Maxwell's theory regarded these two cases as different, although they do not differ in their manifestations.

This circumstance, noted by Einstein, was characterized by him as an asymmetry of the theory relative to the two cases. By the same token, the theory admitted implicitly of the presence in nature of a single unique reference frame, with respect to which one can establish what is at rest and what moves. The asymmetry of the form of the theory was not equivalent to the phenomenon itself. In fact, it is known that in order to excite a current in a conductor the important factor is only the displacement of the magnet and the conductor relative to each other.

This meant that the electrodynamic theory should also be formulated in such a way that its equations be valid for arbitrary reference frames, for which the equations of mechanics are also valid.

At the same time, it was necessary to take into account also the experimentally established fact that the rate of transmission of an electromagnetic signal (the speed of light) is independent of the motion of its source.

It is precisely these theoretical problems which were considered by Einstein in his remarkable paper "On the Electrodynamics of Moving Bodies" (1905), in which the fundamentals of relativity theory were developed. The theory has lead to the formulation of conditions of the invariance of the electrodynamic laws in inertial systems. These conditions consist in fact that the physical quantities, which hitherto were considered invariant (distance, time, mass, magnetic and electric intensities, etc.) actually are relative: on going to a new inertial system they are transformed in accordance with a definite law, which depends on the relative velocity of motion of the system.

The physical and fundamental significance of relativity theory is tremendous. Perhaps no other theory has resulted in the past in so many new generalizing ideas. We shall mention here only the most important of these.

The theory made untenable the metaphysical notion that there exists an absolute system of reference, absolute space and time. The idea of a world medium such as the ether, which is the specific carrier of electromagnetic processes and whose physical properties nineteenth-century physicists attempted in vain to define, collapsed. The treatment of many properties of bodies as being absolute, independent of the state of their motion, proved to be unfounded. A connection was established between mass and energy.

Relativity theory laid the groundwork for the notion of a space-time continuum, the physical properties (metric) of which are determined by the masses present in it. In developing these ideas, Einstein created a generalized theory of gravitation, showing that gravitational fields are naturally included in the continuum via a change in its metric. Einstein's theory of gravitation has led to the prediction of new physical phenomena, which will be discussed in detail below.

Having been founded as an abstract theory, which should resolve theoretical difficulties, arising in the electrodynamics of moving bodies, relativity theory has by now entered into the practice of atomic research. Without allowance for its conclusions it is impossible to construct modern accelerators for elementary particles, and it is impossible to calculate nuclear reactions. But this is not all.

Relativity theory has left a deep imprint on all other physical theories, present and future: in the limiting region of high velocities, these theories must satisfy its formal requirements. Therefore, along with ordinary quantum mechanics, there arises a relativistic quantum mechanics, along with classical cosmology we have relativistic cosmology, etc.

Relativity theory has exerted a tremendous influence on the very thinking processes of physicists. It has demonstrated the basic role played by generalization and generalizing sciences. Together with this theory, there appeared in physics many new innovations which have boldly broken away from fossilized views on physical concepts, always requiring a generalized approach to physical phenomena. But Einstein's contribution to physics was not limited to the creation of relativity theory and the generalized theory of gravitation, together with all the innovating ideas involved in them. His merits are tremendous also in other fields of physics, in which it was necessary to blaze the first paths. We must discuss here the most important of these not only because they are generally less known, but in view of the special negative position which Einstein displayed later with respect to those trends in physics, to the development of which he himself provided a powerful impetus.

We must point here first of all to the transformation which occurred in Einstein's views on the nature of light.

It is known that Planck, after analyzing the conditions under which the so called black-body radiation should be in the equilibrium state, established (in 1900) a connection between the energy ϵ and the frequency ν of light: $\epsilon = h\nu$, where $h = 2\pi\hbar$ is Planck's constant equal to 6 63 × 10^{-27} erg-sec. The presence of such a connection amazed physicists, since it was unusual within the aspect of classical physics, according to which the energy of a wave is connected with its amplitude and not with its frequency

But during the first years this connection was still not treated in depth According to the evidence of Max Born, it was regarded as a unique hypothesis, convenient only for the given case Experimenters showed no interest in it, assuming it to be a "tool of theoreticians," useful only to tie together the loose ends in a patently theoretical question concerning the distribution of energy in the radiation spectrum of an absolutely black body. The theoreticians were disturbed by this strange connection between energy and frequency together with it, there appeared the idea of quantization of energy, but nobody knew how to understand this The theoreticians did not go beyond imagining a mechanism, by means of which an oscillator can emit and absorb only definite batches of energy. Special difficulties were encountered in finding an absorption mechanism, since everyone still started from the notion that the energy is incident on the oscillator continuously apparently, it must accumulate in some manner before it can be absorbed None of the physicists including Planck himself, suspected that the discovery of a generalized formula for the radiation from an absolutely black body can lead to revolutionary ideas, which will uncover for the physicists entirely new horizons

The decisive step was taken by Einstein He was the first to recognize the fundamental significance of the quantum ideas and started to consider many difficulties which were of interest at that time, in classical physics in light of quantum notions *

One such difficulty was the phenomenon of the photoelectric current (the photoeffect) The photoeffect had been discovered already by Heinrich Hertz, Hallwachs, and other physicists in the 80's of the last century, and was then thoroughly investigated by A G Stoletov As is well known, this effect consists in the fact that light rays incident on a metallic plate knock out from it a stream of electrons which produces a current in a closed circuit Stoletov found a law relating the photocurrent and the light producing it It turned out that the photocurrent depends not on the brightness of the exciting light, as expected in accordance with the laws of classical physics, but on the color of the incident light, in other words, on the frequency of the radiation incident on the plate This could not be explained by means of the laws of classical physics The photoeffect contradicted these laws For almost two decades it remained a puzzling phenomenon

Einstein reviewed this phenomenon in the light of quantum notions and found that it can be explained simply and in noncontradictory fashion if it is assumed that the light flux itself is a stream of quanta (photons) which carry energy proportional to the frequency, $\epsilon = h\nu$, in accordance with Planck's energy quantum It is then clear that the energy transmitted by the quantum of light to the free electron of the plate will depend not on the brightness of the light but precisely on its frequency The relation previously obtained by Planck acquired in Einstein's papers a clear meaning the interaction between light and matter, during the course of which the matter absorbs or emits a quantum of energy, is determined by the quantum structure of the light itself, by the fact that the light flux itself consists of a stream of light quanta In this explanation there is no need for inventing for the atom a special mechanism which regulates the emission and absorption of light energy by the quanta the light energy itself is intermittent

In the same paper—"Concerning One Heuristic Point of View Touching upon the Occurrence and Transformation of Light" (1905)—Einstein used quantum ideas to explain the rules for the Stokes shift in luminescence, and also photo-ionization of a gas; he showed that in all similar phenomena there occurs a transformation of kinetic energy of the electron into a light quantum or vice versa Furthermore, in all the processes where electrons and light interact, the transmitted radiation energy is proportional to the frequency and to the Planck constant h This could already be readily verified experimentally

Following the quantum explanation of the photoeffect, of luminescence phenomena, and of the ionization of gas, Einstein considered one more puzzle which could not be solved within the framework of classical physics. We refer here to the specific heat of solids at low temperatures According to classical physics, each degree of freedom of a complicated physical system receives the same share of the energy present in the system Knowing the number of degrees of freedom of a physical system, one could calculate the specific heat of any substance, it should not have depended on the temperature of the substance (the Dulong and Petit law) The law of equipartition of energy among the degrees of freedom was confirmed by experiments for the not too low temperatures attainable at that time, this proved that the calculations of classical physics had a certain validity One might think that this law uncovers a simple and clear mechanism for the distribution of energy within a physical system, and is therefore most stable However, even by that time it was already clear that at temperatures approaching absolute zero, the specific heat becomes smaller than calculated theoretically; this deviation becomes quite sharp for crystalline solids, especially diamond Classical physics could not explain this fact And

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*Einstein had furthermore his own grounds, which will be discussed later, for doing this again, in order to explain this regularity, Einstein applied to the interatomic and molecular bonds the idea that they have a quantum nature. These investigations were subsequently successfully continued and refined by Debye, Born, Karman and others.

We see that Einstein broadened exceedingly the application of quantum ideas, demonstrating their decisive role in atomic physics. By the same token, he provided a powerful stimulus for numerous investigations by physicists in this direction. It became clear that all the difficulties known to physicists, and all the newly discovered phenomena must be analyzed in the light of these new ideas. The new ideas became the general line of development of physics.

It must be emphasized that one feature is characteristic of Einstein's research during these years: the deep connection between new theoretical ideas and experiment. He applied clearly abstract methods and hypotheses to practical problems which disturbed physicists, and immediately clarified them; furthermore, he developed his theoretical reasoning to such a stage, that it could be easily verified experimentally. Therefore, following Einstein's researches, a large number of experimental papers were published on a great variety of problems on atomic physics. These papers invariably confirmed his conclusions. They showed that the quantum hypothesis, which prior to Einstein was regarded only as a convenient device for calculations in the theory of black-body radiation, is in fact a discovery of a new aspect of physical processes and that it is now necessary to look at all of atomic physics only from the point of view of the quantum hypothesis.

The direct application by physicists of quantum ideas to the atomic structure started later, at the beginning of the second decade, after the famous experimental investigations of Rutherford, who discovered the nuclear structure of the atom, and on their basis. Closely participating in these investigations was also Nils Bohr, who worked at that time (1912) in Rutherford's group in Manchester. It is he who must be credited with creating the first model of the quantized atom.

During that time, Einstein was completely absorbed in the development of the theory of gravitation and did not participate in investigations of atomic structure. But who can deny that the strong impetus which aroused Nils Bohr was also the influence of Einstein's ideas who had convincingly shown the decisive role of the quantum relations in all of atomic physics? Bohr himself, in his "Recollections of Rutherford. . ." (1961) wrote about the history of his own work: "This discovery (of the quantum of action—S.S.), especially in the papers of Einstein, found very promising applications in the theory of specific heat and photochemical reactions. Therefore, perfectly independently of the new experimental data concerning the structure of the atom, there was a widespread conviction that the quantum notions can have a decisive significance for the entire problem of the atomic structure of matter.*" This conviction was precisely the result of the influence of Einstein's papers. The great popularity of this conviction is evidenced also by the fact, mentioned by Bohr, that attempts to apply quantum ideas to the spectra of the atom were undertaken at that time by many physicists (A. Haas, J. Nicholson, N. Bjerrum, and others).

Of course, it cannot be stated that complete unanimity was immediately reached by all physicists. There were also skeptics, among them prominent physicists, such as Nernst, Rubens, Warburg, and even Planck.

But physics developed unceasingly, and the progress of quantum ideas could no longer be stopped, especially after their successful application to the explanation of the structure of atoms. And after the discovery of the Compton effect (1923) which demonstrated that photons have momentum, the photon hypothesis of light was also ultimately confirmed.

Einstein, however, initiated not only the broad "quantum thinking," but showed also the tremendous possibilities of statistical methods in physics.

Somewhat later than Gibbs, but apparently independently of him, Einstein developed the general methods of statistical mechanics and, what is particularly important, in a form which made it possible to apply them directly to the analysis of Brownian motion—the random motion of minute particles, suspended in a liquid and visible in a microscope. At the start of the twentieth century, a large number of various hypotheses were advanced concerning the causes of the motion of Brownian particles. One of the hypotheses consisted in the statement that this cause is the thermal motion of unobservable molecules of liquid, which push the suspended particles from all sides; the resultant of all the momenta acquired by the particle is not equal to zero, but varies continuously and randomly as a result of the continuous random variation of the individual momenta. The problem consisted of finding the connection between the observable quantities with unobservable ones and by the same token explain the cause of the process. Einstein showed the statistical character of this connection; in this manner he calculated the dimension of the liquid molecules, their number in a gram molecule and other parameters. Einstein's calculations were later confirmed. By the same token he raised the kinetic theory of matter from the level of a possible hypothesis to the level of a physical theory that is amenable to confirmation.

The deductions of these statistical papers by Einstein were also of appreciable methodological significance. "I believe"—states correctly Max

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*Here and throughout, unless otherwise stated, the emphasis is by the author of this article.

Born in the article 'Einstein's Statistical Theories (1949)'—" that these researches by Einstein have convinced physicists, more than any other work, of the reality of atoms and molecules, of the correctness of the theory of heat, and of the fundamental role played by probability in the laws of nature." It is not superfluous to mention that this was a time (1902—1906) when some physicists denied the reality of atoms simply because they are not directly observable, and cannot make themselves felt. Recalling these works in his autobiography (1948), Einstein himself states: "My major aim in this was to find facts, which would guarantee as much as possible the existence of atoms of definite finite size." Actually, he was justified in concluding: "The agreement of these considerations (concerning the determination of the parameters of the atom—S.S.) with experience, together with Planck's determination of the true molecular size from the law of radiation (for high temperatures) convinced the sceptics, who were quite numerous at that time (Ostwald, Mach) of the reality of atoms."

We must also emphasize the other aspect of the problem: these investigations of Einstein's demonstrated the heuristic role of statistical laws in physics. It was observed for the first time that statistical laws reflect a new type of real connections in nature.

It was natural, as the quantum ideas continued to develop in atomic physics, to include quantum connections among the statistical ones. The way to this approach was uncovered by the fundamental relation of Boltzmann, which connects a thermodynamic quantity—the entropy S of a closed system—with the probability W of its state: $S = k \ln W$, whence $W = \exp(S/k)$. Boltzmann derived this relation for systems which obey the laws of classical mechanics. But the statistical laws have the advantage that they have a tremendous generality, and do not depend on the nature of the investigated objects. Einstein applied them to the analysis of the structure of radiation of an absolutely black body. He used Boltzmann's relation to determine the probability of random concentration of total energy E in a definite part of the volume αV, calculating the entropy S from Wien's radiation law ($h\nu \gg kT$). This probability is equal to $W = \alpha^{E/h\nu}$

It is precisely this result of purely statistical methods that led Einstein to the idea that radiation behaves as if it consisted of an aggregate of $N = E/h\nu$ independent quanta of energy of magnitude $h\nu$. This deduction was so convincing for Einstein, that he immediately started to look for a direct confirmation of this deduction in the known physical processes. He thus arrived to a consideration, from a new point of view, of the photoeffect, which was already described above, the puzzle of which was finally solved.

Einstein expanded the use of statistical methods also further. In an article "On the Quantum Theory of Radiation" (1917) he presented a derivation of the laws of black body radiation (Planck's formula), based on the picture of radiation as a purely statistical process. It turned out that Planck's formula can be obtained by this method and by assuming a new type of radiation, occurring under the influence of an electromagnetic field surrounding the radiator ("stimulated emission"). For decades stimulated emission existed only as a "theoretical fact." Only at the beginning of the fifties was a method proposed, for the amplification of light and of radio waves, based on the use of stimulated emission, and nowadays it serves as a basis for the construction of quantum generators and quantum amplifiers. Einstein's statistical derivation of Planck's formula and his theoretical discovery of stimulated emission not only corresponded to the spirit of quantum physics, but confirmed even more the heuristic value of statistical methods and their objective meaning.

Finally, in the early twenties, Einstein developed and generalized the ideas of the Indian physicist Bose, who applied statistical methods to photons as particles, and considered the distribution of states in an ensemble of identical particles. This method yielded Planck's radiation law directly. Thus, quantum statistics led to a deeper understanding of the subject of this statistics: physical meaning is attached not to the counting of individual objects, but to the statistics of their states. This specific quantum statistics, called Bose-Einstein statistics (to distinguish it from quantum statistics of a different type—that of Fermi-Dirac), turned out to be applicable to a special class of quantum particles (photons, alpha particles, atomic nuclei with even number of nucleons).

Einstein has thus contributed to the foundation and extensive introduction of statistical methods in physics.

Naturally, during that time Einstein was engaged in the problem of bringing together the two perfectly stable pictures formed after the discovery of photons: one was expressed in terms of a continuous electromagnetic field with its dynamic laws, and the other in terms of a flux of photons with their statistical laws. In this respect he advanced the very important idea that the photon density in a light beam should coincide with the energy density of the electromagnetic waves in it. Noting this fact in his Nobel speech, Max Born, who founded the statistical treatment of the wave function, stated that, he, Born, in 1927 only developed this idea of Einstein's as applied to the Schrödinger wave function.

Thus, at this turning point of the development of physics, when physics turned to a deeper generalization of the electromagnetic and gravitational fields, and also to the study of atomic processes, Einstein showed the penetrating insight of a researcher, unparalleled boldness of thinking, and the ability to overcome established dogmas. It is no wonder that the leading physicists recognized Einstein to be their "flag-bearer and leader" (Born).

3. DEPARTURE FROM THE IDEAS OF QUANTUM THEORY

With the appearance of the papers of Rutherford and Bohr, the focal point of scientific interest in physics shifted to the investigation of quantum properties of atomic systems. Einstein, on the other hand, after providing the strong impetus which laid the groundwork for the ideas of atomic physics (the quantum structure of light, quantization of atomic processes, statistical methods in atomic physics) again concentrated his creative energy on problems connected with further generalization of the ideas of relativity and the theory of gravitation.

Meanwhile at the end of the first quarter of the twentieth century, problems of generalization already arose in atomic physics. The discovery at that time of laws governing atomic phenomena and radiation (the photoeffect, the Compton effect, explanation of atomic spectra, determination of the excitation potential of atoms, etc.) had disclosed the quantum properties of light and of the energy states of the atoms. However, the abundant experimental material was not generalized in a single theory. In the light of classical notions, it was extremely contradictory. The quantum properties of fields and micro-objects appeared only as one of the aspects of reality. Experiment had shown that another aspect of reality constitutes wave properties. The work of de Broglie, which was later confirmed by the experiments of Davisson and Germer, and also of Thomson, has shown that the wave properties are characteristic not only of the electromagnetic field, but also of matter (of a stream of real particles). Although both types of properties (corpuscular and wave) are mutually contradictory in the classical sense and exclude each other, neither could be neglected in the description of quantum phenomena. This unusual situation highly complicated their understanding and treatment. Furthermore, physicists (Bohr, Sommerfeld, and others) were busily engaged in the development of the methods of quantization of atomic orbits; but these methods were based on certain classical representations and were in the way of searches for solutions which applied to a case, something which was patently unsatisfactory.

It was necessary to develop a theory which would include in organic fashion the description of the possible quantum transitions of systems from one state to another, unifying in a single generalized theory the wave and corpuscular concepts. Physicists were never faced with such complicated problems before.

Einstein did not participate in this work. He devoted himself completely to the problem of constructing a unified field theory, in which he thought to unify electromagnetic and gravitational fields. This departure of Einstein from the urgent problems of atomic physics caused tremendous bitterness and regret on the part of physicists.

Quantum theory was developed in the middle twenties by the works of Bohr, Heisenberg, Born, Jordan, Dirac, Schrödinger, Fermi, Pauli, and other physicists.

Just like the theory of relativity in its day generalized experimental facts in electrodynamics and led to a new broad picture of the world, uncovering hitherto unknown properties of the space-time continuum, quantum mechanics now also developed many new ideas.

Quantum mechanics discovered specific properties of a quantum object, which distinguish it radically from a classical rigid body. It turned out that in a quantum object wave and corpuscular properties are inseparably bound; the object is not invariable, and depending on the physical conditions it is transformed, approaching alternately more closely the image of a wave and the image of a particle; its characteristics are expressed in the "uncertainty relations" of certain pairwise conjugate quantities which characterize the quantum object (for example, the momentum and coordinates). Quantum mechanics has advanced the statistical concept of the "state of microparticles"; it showed that statistical laws in the microworld can no longer be regarded as devices for calculation, as a measure of our lack of knowledge about the dynamic behavior of individual processes; they represent a new form of relations in an object: classical determinism, according to which events always develop uniquely and which excludes randomness is only a limiting and abstract case.*

What was Einstein's attitude as a scientist who was exceedingly sensitive to logical integrity and to logical perfection of physical theory to these new ideas?

Einstein rejected the path followed by the majority of the physicists who developed quantum theory.

He rejected paths to whose development, as shown above, he himself contributed greatly by establishing the quantum concepts in all fields of atomic physics, and by showing that quantum problems must be solved by statistical methods. This was clearly manifest in his public discussions, in personal conversations, in correspondence with others who continued to develop the methods of quantum physics, and finally in a stubborn tendency on the part of Einstein for many years to construct physics on a different basis. It is known from all these materials

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*In this article we have no opportunity or need for discussing the treatment of these problems by individual physicists and schools.

that Einstein regarded the statistical interpreation of quantum mechanics as a temporary substitute for the knowledge of individual, uniquely defined processes which he regarded as the only true knowledge. He also regarded as foreign to the spirit of physics the dual, corpuscular-wave character of the properties of fields and objects of atomic physics; he apparently regarded the combining of such properties in a single object as impossible. But the essence of quantum mechanics consists precisely in the fact that it reflects the dual character of the micro-objects and fields and their statistical laws. To deny them would mean to deny all of quantum mechanics.

Why did Einstein, this fearless innovator in science, criticize sharply this course which quantum physics followed?

Of course, our answer to this question can be more or less substantiated only by an analysis of his creative efforts. In connection with a clarification of his criticism, it is instructive to consider Einstein's own reproach to Mach because the latter refused to admit the existence of atoms and molecules.

It is known that Mach regarded science as a system for ordering our sensual perceptions, as an economic and mnemonic way of writing down the "facts of sensation," and not as a reflection of the external world. It is precisely such a treatment of the subject of cognition that lead him to deny the existence of atoms and molecules which, were after all not encountered directly by the sensations. Yet the entire development of science has led to the conclusion that the role of cognition increases by abstraction, resulting from man's reprocessing of sensations. We recall that Einstein himself was led to the establishment of many characteristics of directly unobservable atoms and molecules precisely by abstract statistical methods. Naturally, he understood perfectly the reasons for Mach's negative position and could not accept them. In his "Creative Autobiography" he wrote: "the prejudices of these scientists (Ostwald and Mach—S. S.) against atomic theory can be undoubtedly attributed to their positivistic philosophical views. This is an interesting example of how philosophical prejudices hinder a correct interpretation of facts even by scientists with bold thinking and subtle intuition."

Einstein's explanation is correct. Unfortunately, however, it is applicable to his own negative position with respect to quantum mechanics. This was already noted by Max Born, one of the founders of quantum theory, a close friend of Einstein. In his article "Recollections of Einstein," citing Einstein's above explanation, Born noted: "It seems to me that in quantum mechanics this was confirmed by himself."

And, indeed, Einstein's position in physics can be understood only in the light of his general philosophical concepts, in the light of how he understood the unity of the laws of nature and the ways of its cognition, how he understood the connections existing in nature, and also the object of physical research. It is precisely this fact that the philosophy influences the program and method of physical investigations which is the main reason for our interest in a scientist's philosophical views.

However, the question of Einstein's philosophical views is not so simple.

4. WHAT WAS EINSTEIN'S GUIDING PHILOSOPHY?

How can we answer the question of what philosophy guided Einstein? Was he in his philosophic views a materialist, an idealist, or a positivist?

We cannot answer this question unambiguously: in his papers we can find sufficient statements favoring any of these trends.

It is known, for example, that Einstein placed a high value on Mach's critical work with respect to the a priori ideas of Kant, or Newton's introduction of the concepts of absolute space, time, motion into the practice of classical physics, and the general "metaphysical" concepts which do not correspond to anything in experiment, as understood by Mach. Einstein stated many times that Mach's concept enabled him to review critically the initial premises of classical physics.

Einstein also repeatedly defined theory as a system that orders our sensual perceptions, and not as a reflection of objective laws of the external world. These formulations are not accidental in the case of Einstein, and are encountered in his papers written during his entire lifetime. Thus, in lectures on the principles of relativity theory, delivered at Princeton in 1921, he stated that "the concept and systems of concepts are valuable for us only inasmuch as they facilitate our conception of the complexes of our experiences." In 1936, in an article "Physics and Reality" Einstein wrote: "In contrast with psychology, physics interprets (directly) only sensory perceptions and the 'comprehension' of their connections." And further: "The first step in the establishment of a 'real outer world' consists, in my opinion, in the formation of the concept of physical object and of physical objects of different types. From the whole variety of sensory perceptions we separate mentally and arbitrarily the constantly repeating complexes of sensations (partially in coincidence with the sensations that can be interpreted as signs of the sensory experience of other persons), and we set them in correspondence with the concept of a physical object." In the book "The Evolution of Physics" it is stated: "with the aid of physical theories we attempt to find our way through the labyrinth of observed facts, to order and comprehend the world of our physical sensations."

Finally, we find in his autobiography: ". . . all our thinking is of the same type: it represents a free game with concepts. The basis of this game lies in the possibility, attainable with its aid, of visualizing physical sensations. The concept of 'truth' is still altogether not applicable to such a formation; this concept can, in my opinion, be introduced only when we are faced with a conditional agreement with respect to the elements and rules of the game." And further: "the system of concepts is a human creation, just like the rules of syntax, and defines its structure. . . All concepts, even those closest to sensations and experiences, are from the logical point of view arbitrary premises, just as the concept of causality, which was primarily discussed here."

Such are Einstein's statements, in which the influence of positivistic philosophy is undoubtedly seen. However, we also know other facts. We recall that Ostwald's and Mach's positivistic views were called by Einstein philosophical prejudices which hindered them in finding a correct interpretation of facts that led to the admission of atoms and molecules. Furthermore, his disagreement with the ideas of quantum mechanics, in particular with the introduction by it of statistical laws along with dynamic laws, was motivated by Einstein by the fact that the transition from a description of the things themselves to a description of probabilities of the appearance of things is a transition to positivism. Criticizing the arguments in favor of quantum mechanics, he wrote in his "Reply to Criticisms" (1949): "What I dislike in this kind of argumentation is the basic positivistic atitude, which from my point of view is untenable and which seems to me to come to the same thing as Berkeley's principle, esse est percipi (to exist is to be perceived)." Einstein believes that the defense of the statistical treatment of quantum mechanics is the defense of positivistic views. Even in his friendly correspondence Einstein comes out against positivism. In the late Forties, when speaking of a desirable meeting with Born, he wrote him: "Although you will never agree with my point of view, it could entertain you. I would also get pleasure in tearing down your positivistic philosophical views."

Incidently, Max Born did not agree with such an accusation. Commenting on this letter, Max Born told Selig, Einstein's editor and biographer: "These lines concern my views on the main problems in physics. I, like Nils Bohr and Werner Heisenberg, defend the statistical quantum mechanics, whereas Einstein's viewpoint is that of classical determinism. On the other hand, I am altogether no follower of positivism." We see that the outstanding physicist of our time, Max Born, does not want to be listed among the positivists, and he actually did much to debunk positivism among foreign scientists.*

However, let us return to Einstein. This is, of course, serious proof against calling Einstein a positivist, for he rejected the entire trend in physics, the tremendous practical significance of which he always admitted without stipulation, rejecting it only because he considered its basis positivistic. It is another matter, whether Einstein is correct in interpreting quantum physics as being essentially positivistic; here it is important to emphasize that in rejecting it he was guided by antipositivistic motives.

An extremely interesting understanding of the cognition process was expressed by Einstein in the article "Maxwell's Influence on the Evolution of Ideas of Physical Reality," written at Maxwell's centennial in 1931. He starts this article with the following statement: "The belief in an external world independent of the perceiving subject, is the foundation of all science. But since sense perceptions inform us only indirectly of this external world, or physical reality, it is only by speculation that it can become comprehensible to us. From this it follows that our conceptions of physical reality can never be definitive. We must always be ready to alter them, to alter, that is, the axiomatic basis of physics, in order to take account of the facts of perception with the greatest possible logical completeness. A glance at the development of physics shows this axiomatic basis has in fact suffered profound modifications in the course of time." This statement is close in its spirit to materialism, and it is difficult to understand how Einstein combines such contradictory points of view.

However, he not only combines them, but perceives perfectly what misunderstanding this combination can cause. But he attributes this misunderstanding to the philosophers, who are too stringent in their concepts, which represent, to be sure, a unified but nevertheless abstract scheme. The natural scientist, however, cannot be fitted into any particular scheme. His position, according to Einstein is more complicated because he must take into account the results of his investigations and assume points of view which are not compatible in a single system. In his "Reply to Criticisms" he writes that the philosopher, once having thought up some system will be, ". . . inclined to interpret the thought-content of science in the sense of his system and to reject whatever does not fit into his system. The scientist, however, cannot afford to carry his striving for epistemological systematic that far. He accepts gratefully the epistemological conceptual analysis; but the external conditions, which are set for him by the facts of experience, do not permit him, to let himself be too much restricted in the construction of his conceptual world by the adherence to an epistemological system. He therefore must appear to the systematic epistemologist as a type of unscrupulous opportunist; he appears as realist (that is, a materialist-S. S.), insofar as he seeks to describe a world independent of the acts of

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*See S. Suvorov, Max Born and His Philosophical Views in the book called Max Born, Physics in the Life of my Generation (Russian translation), IL, 1963, also S. Suvorov, The Problem of "Physical Reality" in the Copenhagen School, UFN 62 (2), 141 (1957).

perception; as idealist—insofar as he looks upon the concepts and theories as the free inventions of the human spirit (not logically derivable from what is empirically given); as a positivist—insofar as he considers his concepts and theories justified only to the extent to which they furnish a logical representation of relations among sensory experiences. He may even appear as a Platonist or Pythagorean, insofar as he considers the viewpoints of logical simplicity as an indispensable and effective tool of his research."*

Einstein has emphasized on various occasions the impossibility for the natural scientists to adhere to any single philosophical system. Answering Margenau's statement that "Einstein's position. . . contains features of rationalism, and also of extreme empiricism," Einstein writes in his "Reply to Criticisms": "This remark is entirely correct. From whence comes this fluctuation? A logical conceptual system is physics insofar as its concepts and assertions are necessarily brought in relationship with the world of experiences. Whoever desires to set up such a system will find a dangerous obstacle in arbitrary choice (embarras de richesse). This is why he seeks to connect his concepts as directly and necessarily as possible with the world of experience. In this case his attitude is empirical. This path is often fruitful, but is always open to doubt, because the specific concept and the individual assertion can, after all, assert something confronted by the empirically given only in connection with the entire system. He then recognizes that there exists no logical path from the empirically given to that conceptual world. His attitude becomes then nearly rationalistic, because he recognizes the logical independence of the system. The danger in this attitude lies in the fact that in the search for the system one can lose every contact with the world of experience. A wavering between these extremes appears to me unavoidable."

Of course, we cannot agree with the fact that the natural scientist must appear in the eyes of a philosopher an "unscrupulous opportunist" and be in perpetual unavoidable fluctuation between philosophical "extremes." If philosophy exists as a science, and not as a preconceived scheme, then such categories as an objective external world, sensations as information about this world, concepts and theories as the generalization of information constituting the image of objective reality must be generalized in this science in a noncontradictory manner. We are convinced that such a philosophy exists. Einstein's philosophy, however, is indeed not such, and the fact that it is not such was regarded by him not as a shortcoming but as an advantage. Einstein is correct in stating that the philosophy of such a natural scientist, that is, Einstein's own philosophy, will be regarded by some philosophers (scholastic philosophers) as positivistic, and by others as realistic (materialistic), and some will damn what others praise. In particular, this can be seen in some articles of the collection devoted to Einstein's seventieth birthday, in which various authors attempt to analyze Einstein's philosophical views. For example, Philipp Frank, a physicist and philosopher occupying the chair of theoretical physics at the Prague German University, the head of the "Vienna circle" of neopositivists, lists Einstein among the active practitioners of "logical positivism." A. Bridgman—a physicist and philosopher, the principal ideologist of operationalism—believes that in founding the special theory of relativity, Einstein proved himself an operationalist. Among Soviet scientists also most extreme estimates have been expressed of Einstein's philosophical views. We have seen, that the reason for these extreme views were due to Einstein himself, who incidently was little concerned about them.

It would be more correct, however, to regard Einstein's views in their entire complexity and to attempt to understand where this complexity came from. And here too, he himself gave a good answer of how to deal with self-estimates of a scientist. In his interesting Spencer Lecture "On the Method of Theoretical Physics" (1933) he said: "If you wish to learn from the theoretical physicist anything about the methods which he uses, I would give you the following piece of advice: Do not listen to his words, examine his achievements. For to the discoverer in that field, the constructions of his imagination appear so necessary and so natural that he is apt to treat them not as the creations of his thoughts but as given realities. And he wants others to regard them in the same way."

To study the actions of the scientists, that is the correct answer. The professional activity imposes a deep imprint on the entire way of thinking of the scientist, and of any creative person in general. He sees through this window of professional activity the world, its external aspect, its laws, the method of its perception. What a scientist achieves in science, how he views the way towards this achievement—in this lies the key to his frequently complicated contradictory world outlook. Here, in our opinion, lies the key to the understanding of the views of Einstein himself, the contradictory nature of which from the point of view of an integral philosophy he himself understood.

But in this case we must answer the following question: What was most important in Einstein's professional activity?

One could hardly doubt that for all his remarkable ideas in the field of quantum and statistical physics, the main aspects of Einstein's activity were (and remained for him) always the development of the theory of relativity and his, Einstein's system of

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*The emphasis is Einstein's.

generalization and expansion of the sphere of application of this theory The electromagnetic and gravitational fields, which became real to physicists only during his youth, and the space-time continuum, as a unified theoretical basis for all physics—this was the circle of closely related problems which from his early years to the end of his life swayed Einstein, and in the development of which was his soul and his reason

Work on these problems and the method of their solution indeed exerted a decisive influence on Einstein's views We should consequently attempt to consider the question of what philosophical ideas could be arrived at, and apparently were arrived at, by Einstein through his development of the theory of relativity and his contemplation of its results

5. METHODOLOGICAL DEDUCTIONS FROM THE DEVELOPMENT OF THE THEORY OF RELATIVITY

Rejection of positivism and operationalism During the beginning of the century, Einstein was faced with the necessity of presenting a more highly perfected "symmetrical" formulation of Maxwell's electromagnetic theory This was required by the physical facts

However, the construction of symmetrical electrodynamics led to major consequences, which went beyond the confines of the solution of the particular problem which was directly posed A change took place not only in the form of the electrodynamic theory, but also in the concepts of space, time, length, duration, etc , with the notions of the connection between physical categories completely changed in general All that was wanted was to adapt field theory to facts, to correct this theory somewhat, but the result was the downfall of the concepts of Newtonian physics, which were introduced as a priori, beyond any experiment, and the deduction that physical quantities depend in definite fashion on the state of motion of a body with respect to the reference frame in which this motion is expressed

Experimentally such relations were not yet established During that time relatively large velocities, which could produce experimentally measurable effects, were possessed only by electrons in cathode rays ($v = 0\ 1c$) By studying the deflection of cathode rays in a magnetic field, Kaufmann observed the fact that the mass of a fast electron changes, however, the law governing the change in mass was not determined from these experiments The question of the possible shrinking of the length of a moving body (in the direction of the motion) already arose in connection with the Lorentz coordinate transformation

All this stimulated physicists to think about the causes of the changes in the parameters of the body as it moves In accordance with the method of thinking of those days, these were sought directly in the physical interaction between the moving body and the field A search was made for a mechanism for the interaction between the body and the field, capable of leading to such a change We know, for example, of the hypothesis of the shrinking of the lengths of bodies (in the direction of motion) advanced by Fitzgerald and supported by Lorentz; attempts were made to explain the change in mass on the basis of the hypothesis of its electromagnetic nature (M Abraham, G Herglotz, P Herz, A Sommerfeld, and others) An important fact is that having once started on this path, the physicists sought a *different* mechanism for the change in each parameter

Einstein encountered these problems when formulating the theory of relativity He first attempted to motivate the dependence of physical categories on the speed of motion on a purely logical basis, with the aid of a Gedanken experiment the magnitude of the parameters of the body is a result of measurements, it depends on the *measurement procedure*, and the measurement procedure is different for a body moving and for a body which is at rest with respect to the observer

Bridgman was right in stating that Einstein's approach to the determination of the physical concepts was at that time operational, more accurately, it was precisely this explanation that the change of the physical quantities is due to the measurement procedure that initiated an entire new trend in philosophy —operationalism, which was subsequently developed by Bridgman According to operationalism, any physical concept can be introduced in science only if it can be set in correspondence with a definite measurement operation, by which the meaning of the concept is indeed determined It might appear that the history of physics fits fully into this operational methodology Newton sinned against physics in that he introduced in it absolute concepts, which cannot be set in correspondence with any measurement operation (this, incidently, Newton himself admitted), Einstein discovered the non-experimental concepts of Newtonian physics and showed that, in accordance with the measurement procedure, the concepts which are set into correspondence with it change A theory can be constructed only on the basis of such operationally defined concepts by relating them into laws

This operational approach in explaining the change of physical quantities, and in the definition of con cepts, is rather common in physics even now, many books devoted, in particular, to theory, not excluding Einstein's books, begin their exposition with a consideration of the measurement procedure, which seemingly defines the meaning of the concepts *

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*A criticism of operationalism is found in an article written by the author "Operationalism," Great Soviet Encyclopedia, Second Edition.

But, although Einstein contributed to the development of operationalism, he himself did not follow it in his further researches and thereby incurred Bridgman's criticism. His article "Einstein's Theory and the Operational Point of View" in the collection mentioned above, Bridgman starts with this reproach: "This exposition will endeavor to show that Einstein did not carry over into his general relativity theory the lessons and insights which he himself has taught us in his special theory." This is indeed the case.

Why did Einstein move away from operational methodology?

Because relativity theory gave no grounds for it, just as it gave no grounds for positivism, and for the principle of observability, for which attempts were made later to find a justification by referring to Einstein's method of constructing this theory. To the contrary, relativity theory reflects an entirely different approach to the method of determining the content of concepts and the structure of theories. Speculating about the end results of relativity theory, Einstein apparently recognized this, as can be seen also from the method of his defense of the premises of relativity theory, and from the subsequent means of research he used, and from his statements which, to be sure, he made later. What is this approach and how was it arrived at by Einstein?

It is known that many deductions of relativity were subjected to severe criticism because of their unusual nature. They were indeed unusual. Such, for example, was the deduction that the length of the same rule is different in different inertially moving systems; that this change is mutual, so that the length of a rule at rest in a system S and equal in it to unity will be foreshortened in an inertially moving system S′ in exactly the same way as the length of a rule, which resting in a system S′ and equal in it to unity will be foreshortened in the system S, and in the same ratio, was greeted with disbelief. It is sufficient to formulate these concepts, for purposes of clarity and concreteness, with the aid of the term "observers sitting in the systems S and S′," and a description of what they "observe" becomes highly subjectivistic in form. This was indeed the case, and at the time this gave rise to tremendous opposition on the part of physicists and philosophers.

They criticized the unusual conclusion that, in a traveling system processes should occur more slowly than in a system which remains stationary during that time, in view of which, for example, an astronaut traveling to a remote star and returning to earth, turns out to be "younger" than his contemporaries on earth. The new law of addition of velocities, the change in the mass "due only to motion," etc. were in contradiction with everyday experience and intuitive notions.

All the analogous deductions of relativity theory turned out to be paradoxical from the point of view of direct perceptions or common experience. Numerous attempts to relate the behavior indicated in this theory for each physical category directly with the change of the structure of the moving body did not lead to positive results. These attempts were later abandoned.

All this offers evidence of the difficulties with which the development of the new concepts was connected. It is not an accident that relativity theory had for many long decades not a few opponents.

However, the deductions of the theory were being confirmed. Physicists, and first among them Einstein, became more and more convinced that the *correctness of the new ideas concerning the nature* and changes in physical categories can be confirmed only by referring to the fact that they are the logical results of relativistic theory (as a "relativistic effect"), which physicists were forced to create in seeking to reach directly a different goal—the generalization of the principle of relativity and the fact that the velocity of light is independent of the motion of its source. If the theory is correct, then there is no need for thinking up an individual mechanism for the explanation of each of its consequences. In particular, the justification of changes in the corresponding physical categories, which we are observing by referring them to a moving system, is already included in the justification of the theory itself, and furthermore this justification is immediately valid for all physical categories.

Thus, the creation of relativity theory led Einstein to the discovery of the unity of physical concepts, their connection with the theory as a whole. This connection of the concepts was equivalent to the representation of the connection of the physical categories in the object itself. For example, the change of length or duration in an inertially moving system is explained by the fact that they exist not in themselves, but are connected in some sort of a unity in terms of an invariant interval. In the course of time Einstein adhered to this point of view more and more. There are grounds for assuming that a tremendous influence was exerted in this respect on the physicists, and on Einstein in particular, by the works of the outstanding mathematician Hermann Minkowski. In 1908 he published a paper "Principles of the Theory of Electromagnetic Processes in Moving Bodies," in which space and time were generalized in a unified four-dimensional "world" with pseudo-Euclidean geometry. The idea of unity of space and time was developed by Minkowski in a well known popular paper "Space and Time" (1908) before the Society of German Natural Scientists and Physicians, which he began with the famous aphorism: "From now on space in itself and time in itself should be reduced to the role of shadows, and only some form of connection of both should as before retain independent significance."

In physics, the problem of the connection of the concepts and theory in such a radical form arose for the first time. Newton introduced certain concepts—absolute space, time, motion, mass, and others—even prior to the theory, as external definitions, or as a condition for formulating laws. For Mach (positivism) all concepts were symbols for distinguishing features of some complex of sensations, had a mnemonic-subservient purpose, and were introduced ahead of the theory. For Bridgman (operationalism), the concepts have to be defined first of all in terms of a direct measurement operation, and only after this turns out to be possible can they be used in the theory.

However, the real development of physical theory has shown that the content of the physical concepts cannot be defined outside the theory, ahead of the theory. In this respect neither Newton, nor Mach, nor Bridgman, were correct. The concepts should be advanced as an organic part of the theory, which as a whole corresponds to the really conceived facts, and only through this unity do those categories which the theory employs correspond to the facts; this was the conclusion towards which Einstein tended more and more.

There is no doubt that this idea already swayed Einstein when he proceeded to develop the theory of gravitation which he regarded as a further generalization of the principle of relativity, as a second stage of the development of relativity theory.

6. PROBLEM OF THE REFORM OF CLASSICAL PHYSICS FROM THE POINT OF VIEW OF ITS UNITY

Einstein's gravitational theory. It is impossible to ignore the differences in the problems which were raised by Einstein during the first and second stages of the development of physical theory. In the first stage he was faced directly with a concrete physical problem—to bring Maxwell's equations into correspondence with the symmetry requirement of the electromagnetic processes and with the fact that the velocity of light is independent of the motion of its source. As a result, Einstein observed that a rationally constructed theory uncovers interrelations between concepts, such as were not suspected outside the generalizing theory, unsuspected just because the approach to the development of science was too empirical.

Now, after obtaining fruitful results, Einstein began to regard all of classical physics with different eyes, the eyes of a critic. He saw that the point lies not only in the fact that Newton included in physics extra-experimental concepts of absolute space, time, long-range forces, etc.; the origin of these quantities disturbed Newton himself. The point is that also all other concepts of classical physics were too weakly "fitted" within a unified theory, since they originated independently of one another from different types of experiments. In the already mentioned lecture "On the Method of Theoretical Physics" Einstein said: "Newton, the first founder of the first working system of theoretical physics, was still convinced that the main concepts and laws of his system come from experiment. His words hypotheses non fingo (I do not make hypotheses) can be understood in this sense. Indeed, the concepts of time and space which arose at that time created no problems. The concepts of mass, inertia, and force and the associated laws appear to be taken directly from experiment. Once this base was assumed, then the expression for the force of gravitation also appeared to be derived from experiment and there were grounds for expecting the same with respect to other forces."

It is clear for Einstein that with such an understanding of the method of formation of concepts and laws—from separated experiments—there should unavoidably arise in physics concepts, which although different in origin, different in their connection with experiment, are yet equivalent in nature. Thus, "the special theory of relativity" uncovered the equivalence of mass and energy. It is obvious that the accumulation of such concepts, which later turn out to be equivalent, is not an advantage of the method, as a result of which they arose; a theory constructed on the basis of such concepts cannot be perfect.

Einstein now saw his most important task in the reform of classical physics, in introducing order in it, in removing from it the concepts which were formulated without connection to the theory, and also all the superfluous equivalent concepts which are as necessary in the theory as a fifth wheel in an automobile.

The result of these methodological purposes of Einstein was the generalized theory of gravitation, which he developed and which he interpreted as the "general theory of relativity."

Thus, the appearance of this theory was not imposed on him by the contradiction between existing theory and any new experiment. Einstein himself took it to be a result of the requirement of "internal perfection" of the theory, the logical order of the general picture of the universe. It is precisely this difference between the causes of the appearance of the "special" and "general" theory of relativity which led to the situation described by Max Born in his lecture "Physics and Relativity" (1955) in the following words: "Special relativity was in the final analysis not the discovery of a single person. Einstein's work was the last and decisive element in the foundation laid by Lorentz, Poincaré, and others, on which the building then constructed by Minkowski could be supported." Problems connected with the electrodynamics of moving systems occupied many physicists, including Einstein, who contributed the "decisive element" to the theory. And the "internal perfection" of classical theory interested only Einstein. Therefore Born notes that "in contrast to special relativity theory, this was the work of a single person."

The principal idea of Einstein's new theory consisted in representing the space-time continuum, to the idea of which relativity theory led, as the unified essence of the external physical world.

What does physics gain from this?

In classical physics all laws are separated, they connect physical categories, notions concerning which arise in different experiments. In the new physics of the continuum all the physical laws should be represented as properties of this continuum, as its metric. This indeed makes it possible to improve the "conceptual foundation" of physics, remove from it the superfluous concepts, and represent it as a unified system.

From this new point of view Einstein considered Newton's law of gravitation. In place of the laws of gravitation he started to operate with gravitational fields; this was already done in classical physics, but there it was more of a "formal device." The gravitational fields were included by Einstein in a space-time continuum as its "curvature." The metric of the continuum ceased to be Euclidean (more accurately pseudo-Euclidean), and became a "Riemannian metric." By the same token, Newton's long-range forces, which were always regarded as the weak spot of Newtonian physics, were eliminated from physics. The "curvature" of the continuum was regarded as the consequence of the corresponding "distribution of moving masses" in it. Leaning on the idea of Riemannian geometry, Einstein introduced a measure of the curvature of space-time (in covariant form) in the form of a certain "curvature tensor." For the "distribution of moving masses" in this continuum he found a certain specific measure—"the energy-momentum tensor." The most important results of all these investigations of Einstein is the establishment of a relation between the energy-momentum tensor (the distribution of the moving masses) and the space-time curvature tensor (the metric of the continuum). The equation obtained plays here a role analogous to the role of Newton's equation of motion of masses in ordinary Euclidean space.

The concepts with which Einstein operates in this theory are very abstract. But the scheme of interaction is here quite simple. The "distribution of moving masses" in the continuum defines its "curvature." The curvature of the continuum defines in it "geodetic lines"—the "lines of shortest distances." The curvature and the geodetic lines of the continuum are *its essential properties, they determine the processes* which occur in it. Thus, masses which do not produce a large field move in the continuum only along geodetic lines.

In Euclidean space geodetic lines are straight. According to Newtonian mechanics, inertial motion takes place along *these lines*. But an examination of all other motions requires in Newtonian mechanics the introduction of new physical categories—forces, the definition of the law of their action, the problem of transmitting action of forces over a distance, etc. Furthermore, Newton's gravitational theory does not fully explain all the processes connected with the interaction of masses. Thus, for example, stating the presence of rotation of the perihelion of planets close to the sun (Mercury), it does not lead to an exact value of this rotation. Newton's theory reflects reality only for weak fields and small velocities of masses.

The fact that Einstein's theory does not call for the introduction of gravitational forces and that the interaction of masses is taken into account in terms of the character of the curvature of the space-time continuum, that is, in terms of its general property, uncovers new possibilities for the theory. In fact, the general properties of the continuum, once found, determine the character of arbitrary physical processes which occur in it. For example, it follows from this that along the geodetic lines of the continuum there should move not only masses but also light rays; if the geodetic lines of the continuum are curved, the propagation of light will not be along straight lines. This should be observed in regions of *the continuum, in which the curvature of the lines* is sufficiently large, for example when the rays pass near the sun, where the field of gravitation is large compared with the field near the earth. Einstein calculated, that a ray of light from a star, passing near the sun, should deviate from a linear path by 1.75 seconds of arc. This deduction of Einstein's theory was confirmed during the time of the total solar eclipse of 29 May 1919, when two British expeditions—one on the west shore of Africa and the other in the northern part of Brazil—obtained photographs of stars visible near the eclipsed solar disc.

Einstein's theory predicted also a red shift of the line spectrum of radiation passing in the gravitational field of stars; this shift is particularly noticeable when the radiation passes near stars of large mass, where, consequently, the gravitational field is large. The theory also calculated the exact rotation of the trajectory of Mercury.

In general, Einstein's gravitational theory is more accurate than Newton's theory, in that it represents processes in the vicinity of strong fields in the presence of rapidly moving masses.

Thus, in spite of the tremendous abstractness, foreign to the thinking of many physicists of that time, Einstein's theory turned out to be fruitful and advanced our knowledge of nature. It is precisely in this juxtaposition of abstractness and fruitfulness that the source of Einstein's world fame as a scientist lies. After confirmation of the predictions of the generalized theory of gravitation one spoke of Einstein as a scientist who by the force of his own thinking alone uncovered previously unknown secrets of nature.

But simultaneously, the success of the theory convinced Einstein of his theoretical-cognitive views. The development of relativity theory and gravitational theory convinced Einstein of the tremendous importance of the theory when taken as a whole.

There is no doubt that he was convinced of it during the course of his investigations, that is, already in the first and second decades of our century. Later, in his "Reply to Criticisms" Einstein returned twice to an explanation of his position with respect to this question. To Reichenbach's criticism he gave his answer in the form of a dialogue between Reichenbach and some non-positivist (!), and has the following question: "Why are individual concepts encountered in the theory of need of some separate justification, if they are necessary only within the framework of the logical structure of the theory and the theory is confirmed only in its entirety?"

To Bridgman's accusation of departing from operationalism, Einstein defines his own position even more accurately: "In order for a logical system to be regarded as physical theory, there is no need to require that all its statements be capable of interpretation independently and that they be independently verifiable in the operational sense"; actually this was never fulfilled in any known theory, and cannot be fulfilled at all. In order to be able to regard any theory as physical it is necessary only that it include in general the empirically verifiable statements" (emphasis by Einstein).

Thus, the reform of classical (Newtonian) theory of gravitation, carried out by Einstein from the point of view of tying in the physical concepts in a unified theory (generalized theory of gravitation), has led to positive results and confirmed the role of theory as an entirety. Clarifying later the line actually realized by him, Einstein already emphasized in explicit form this significance of theory.

7. ESTIMATE OF THE DIFFERENTIAL LAW AS THE ONLY FORM OF CAUSALITY

Einstein's continuum with its Riemannian metric were a more generalized image of objective reality than Newton's notions, according to which masses which are separated by a distance acted on one another with long-range forces inversely proportional to their mutual distance. Einstein's generalization was a successful attempt to remove from Newton's theory some of its weak aspects, for example, the notion of forces acting at a distance, of independence of the metric and the laws of motion, and others.

But at the same time, Einstein regarded himself not as one who overthrows classical physics, but also a reformer who perfects its foundations.

In Newton's theory he also saw such essential aspects which, in Einstein's opinion, should remain inseparable from any future theory, no matter what general form the latter may assume. He saw Newton's genius in the fact that this founder of classical physics was able to express in his laws of motion in quantative fashion the connection between each state of motion of the body at a given instant with its states in the past in a neighboring point of space and in the future in another neighboring point. Space, time, and motion in Newton's physics appeared as continuous realities, and the connections between states were expressed in the form of differential equations. Newton's greatest achievement was his discovery of the method of differential calculus, which uniquely defines the interconnection between states of a body and its motion. In Newton's differential equations of motion Einstein saw the "satisfaction of the needs of modern physicists" for a causal connection. Of course, the credit for the discovery of the mathematical form of the causal connection he gave entirely to Newton.

In an article "Newton's Mechanics and Its Influence on the Development of Theoretical Physics" (1927) Einstein wrote: "Actual results of a kind to support the belief in the existence of a complete chain of physical causation hardly existed before Newton." Kepler's laws, he explained further, gave the answer to the question of how the planets move, but they did not satisfy the need for showing a causal dependence; these laws appeared as three logically independent rules, "lacking any internal connection." Only Newton, by inventing differential calculus, gave the necessary form of the law of causal interrelation. "The differential law"—Einstein writes—"is the only form which completely satisfies the modern physicist's requirement for causality. The clear conception of the differential law is one of Newton's greatest intellectual achievements." The dispute whether Newton or Leibniz was the first to discover differential calculus is immaterial, what is important is that for Newton the discovery of differential calculus was a necessity, because according to Einstein, it was the equivalent form of the causal relation. A full causal conception was obtained after the introduction, along with the equations of motion, of a force acting on the mass and determined by the positions of all the other masses.

Not only was relativity theory ("special") based on Newton's dynamic treatment of causality, but it refined it in one respect: it indicated that events M and N can be in a cause-and-effect relation to each other only if these events are separated by a time interval sufficient for the transfer of action from the place of the event M to the place of the event N, with a final velocity which does not exceed the speed of light. This refinement introduces a factor of action between the events M and N and emphasizes the connection between space and time in a single continuum. The causality formulation, refined by relativity theory, was used in it as a starting point for the analysis of a most important concept of theory—simultaneity.

It follows from the foregoing that the classical notion of causal connection enters organically into the very structure of relativity theory.

Einstein's theory of gravitation does not differ in this respect from his relativity theory. In both cases the physical processes are expressed as processes which occur in a continuum—a certain continuous space-time formation; only in relativity theory this continuum has a Euclidean (more accurately, pseudo-Euclidean) metric, whereas in gravitational theory it has a Riemannian metric. In both theories the equations of motion are differential equations which relate events close to each other in space and time. Einstein's continuums with different metrics are described by partial differential equations, which is characteristic of the description of processes occurring in a field. These continuums indeed constitute some continuous "field" image. Infinitesimally small continuous changes of the arguments in partial differential equations do not differ in principle at all, in Einstein's opinion, from infinitesimally small changes of the arguments in equations with ordinary derivatives. Therefore Einstein supposed that his gravitational theory will leave unchanged the classical notions of physical causality according to which events which are infinitesimally close to one another in space and in time are uniquely related. However, inasmuch as he regarded the continuum as the only reality, the classical form of the causal relation seemed to him universally general. The successful predictions of the generalized theory of gravitation must have reinforced this conviction.

8. RATIONAL WAYS OF CONSTRUCTING A PHYSICAL THEORY

Thus, Einstein's professional experience convinced him that concepts are organically connected with the theory, and receive their content and justification through the theory. And the theory reflects the world only as a whole.

This raises the question: How is theory itself constructed? Mach, who was for Einstein a stimulating example of a critic of the absolute categories of Newtonian physics answered this question simply. A concept is a purely psychic formation. The characteristic feature of a concept is the recollection of a permanent complex of sensations and the separation in it of the principal sensations from which the entire complex is recalled (abstracting, according to Mach). Scientific theories have as their purpose the "ordering" of the numerous perceptions which cannot be retained in the memory without such ordering. Even such a process as the falling of a body, contains many facts of perception, for each instantaneous moment of time corresponds to its own height of the falling body. In order to be able to visualize all these correspondences, it would be necessary to compile an infinite table. But such a table can never be exhaustive or retained in the memory. We are helped here by an ordering theory, which compresses the infinite table into a single formula $S = gt^2/2$, and gives a rule whereby the path S covered by the falling body can always be found for any given time. "

"But this rule, this formula, this 'law'—wrote Mach in his early paper 'The Principle of Conservation of Work'—has no more essential meaning than all the individual facts taken together. Its only significance lies in the convenience of its application. It has an economic value."

Thus, theory, according to Mach, includes none other than all the individual "facts of perception." It is only an economic notation which helps memory.

Einstein could not follow Mach on this question. He already saw in theory something more than a concise notation of "facts of perception": it gives a "picture of the world," of its connections, which cannot be seen directly in the facts of perception.

Nor is this picture given by a theory constructed on physical experiments. An example of such a theory was seen by Einstein to be Newton's gravitational theory. It gave much, but still Einstein had to reform it, inasmuch as it contained many concepts which were not necessary for a generalized perfect theory. Although such a theory has an "external justification," since it explains experiments, it is "internally imperfect."

The need for transforming the classical theory of gravitation and the successful experience in constructing a new reformed theory prompted him to arrive at the following deduction: direct experiment does not lead to a unique theory. Einstein had long ago reached this conclusion and was guided by it in his theoretical work, but he formulated it most succinctly in his "Creative Autobiography" in which he reviewed the path covered by him: "Gravitational theory taught me someting else, too: the gathering of empirical facts, no matter how extensive, cannot lead to such complicated equations (of the field of gravitation—S. S.). Experiment can verify the theory, but there is no path from experiment to the construction of theory."*

We see here also a direct reference to his professional experience, to his method of constructing the theory of gravitation (the significance of his professional experience was emphasized above), and the sharp negation of the path from experiment to the construction of a theory. What is contained in experiment, and the mutual relations between the experi-

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*See an analogous statement given in Sec. 4, page 586.

mental data, are manifest only in the deductions of the theory; the deductions of the theory should indeed correspond to the experiments, or else the theory will turn out to be an empty scheme. Experiment comes into play here only as a measure of an estimate of the theory and only after the theory has been created.

But if there are no paths from experiment to the construction of the theory, what is the origin of the latter?

In the lecture "On the Method of Theoretical Physics" Einstein stated: "On the possibility alone of such a correspondence (of experiment and deductions of the theory—S. S.) rest the value and the justification of the whole system, and especially of its fundamental concepts and basic laws. But for this, these latter would simply be free inventions of the human mind which admit of no a priori justification either through the nature of the human mind or in any other way at all." The physicist seeks such fundamental concepts and laws which are not further logically reducible. "The most important purpose of the theory consists in having as few as possible of these irreducible elements," continues Einstein, "and having them as simple as possible, but such that they do not exclude an exact representation of what is contained in experiment."

We see here an expression of two important gnosiological ideas, which Einstein regarded as a deduction from his method of constructing the theory of gravitation. The first idea is that concepts and theories are free inventions of reason, the second is that the task of the theoretician is to find the further-irreducible simplest elements, fundamental concepts, which should serve as the basis of the theory.

The idea that concepts and theories are free inventions of reason is not an accidental statement by Einstein. This idea can be found in almost all of his papers in which methodological problems are discussed, starting with the article dating back to the period of the construction of his gravitational theory, continuing with the book "The Evolution of Physics," written for a large class of readers, and ending with his "Creative Autobiography."

There is no doubt that the idea that concepts and theories are free inventions of reason were set in correspondence by Einstein with Kant's idea of the a priori nature of knowledge, desiring to emphasize by means of this that concepts (for example, of time or space) are not given a priori by virtue of the nature of reason, but are produced because of its activity. This juxtaposition can be seen from the phrase given above. But there is likewise no doubt that he juxtaposed this idea with another idea, namely that concepts and theories are obligatory to the extent to which they are the necessary consequence of an analysis of experimental material or experience. It is not by accident therefore that Einstein's treatment of the method of constructing concepts and theories was objected to even by his friends, who disagreed with his treatment of the role of experiment. For example, Max Born said in his paper "Albert Einstein and Optical Quanta" (1955): "Einstein himself does not cease to emphasize that there is no unique logical path from the experimental facts to the theoretical systems of physics; the latter, in his opinion, are the offspring of free fantasy. Yet there is no doubt that the value of a theory is the greater, and our faith in it is the stronger, the smaller the freedom of choice in the theory and the larger its logical compulsion."

The success in the construction of the general theory of relativity was attributed by Einstein to a correct choice of the fundamental concepts on which it was based. But now he considers also the imperfection of Newton's physics to be a result of a poor choice of fundamental concepts. Newton and his followers only imagined that they employed the only possible concepts connected with experiment. In fact, however, the concepts of classical physics do not originate with experiment, and all this is the free creation of reason. Only usually this fact is not realized to the end, and this leads to an imperfect theory. In the already mentioned lecture "On the Method of Theoretical Physics," developing his idea that Newton and his followers considered the concepts and laws of classical physics as being directly connected with experiment, Einstein continued: ". . . the scientists of those times were for the most part convinced that the basic concepts and laws of physics were not in a logical sense free inventions of the human mind, but rather that they were derivable by abstraction, i.e. by a logical process." Einstein regards this idea as erroneous, although to be sure he realized that no other understanding was possible at that time. "It was the general theory of relativity which showed in a convincing manner the incorrectness of this view (again professional experience—S. S.). For this theory revealed that it was possible for us using basic principles very far removed from those of Newton to do justice to the entire range of the data of experience in a manner even more complete and satisfactory than was possible with Newton's principles."

A similar thought was advanced by Einstein also in his "Creative Autobiography": "The prejudice, which has remained to this very day, lies in the conviction that facts in themselves, without a free theoretical construction, can and should lead to a scientific cognition. Such a self-deception is possible only because it is not easy to realize that even those concepts which, owing to verification and prolonged use, appear directly related to the empirical material have in fact been freely chosen."

Thus, according to Einstein regardless of how Newton and his successors themselves understood the sources of the theory, they actually constructed it on a foundation of certain freely chosen concepts, which are therefore not binding; these were the concepts of absolute space, time, motion, the material point, gravitational and inertial mass, long-range forces, acceleration, inertia, energy, etc.

The deductions of the theory constructed on these concepts were actually confirmed by experiment. But the theory turned out to be imperfect. Some concepts in it were artificial, organically unconnected in the subsequently developed theory, and were only external conditions for the theory. Some of the other concepts turned out to be pairwise equivalent to each other.

Einstein considered his general theory of gravitation as an attempt to construct another system of fundamental concepts, tied into a unified theory. This theory covers the same experimental facts. But its foundation has been cleared, speaking in optical language, of "ghosts" and therefore the connections in it, which lead from the fundamental concepts to experiment, are different. This theory differs from the first in its "internal perfection"; the single criterion of "external justification" is insufficient, since there can be several, and possibly even a whole set of theories corresponding to this criterion, that is, covering one and the same aggregate of experimental facts.

Einstein speaks of these criteria many times, in particular, in his "Creative Autobiography," where he admits the "insufficient determinacy" of his statements with respect to the criterion of "internal perfection." It is clear, however, that searches for a criterion of the theory, corresponding to the requirement of "internal perfection" are primarily searches for the most perfect foundation of the theory, for initial categories and laws on which it is supported. It was noted already above how this most perfect foundation is to be understood: there should be a minimum of final irreducible elements, and they should be as simple as possible.

In his very last paper, devoted to the methods of theoretical physics—the second Appendix to the third edition of the "The Nature of the Theory Relativity" (1950)—Einstein wrote: "One theory differs from another principally in the choice of 'bricks' for the foundation, that is, the fundamental concepts which cannot be reduced to any others and on which the entire theory is built."

Einstein indicates further how the foundation of physics changes: "In classical theory (mechanics) these fundamental concepts were: the material point, interaction force between material points (potential energy), and an inertial system (the latter is made up of a Cartesian coordinate system and a time coordinate). As our knowledge of the electromagnetic field increased, there was added to the number of fundamental concepts, on par with the material point (matter) also the concept of a field, regarded as a second carrier of energy." Special relativity "presumes further that we can discard the concept of the material point and deal only with the field concept." General relativity "altogether discarded the concept of an inertial system."

The main trend in the evolution of physics is seen by Einstein to be precisely in the improved selection of "bricks" for the foundations of physics. This is the guiding theme of his book (written with Infeld) "The Evolution of Physics." "Before we learned about relativity theory," the authors write, "we could have tried to answer this question in the following way: matter has a mass, whereas field has none. Field represents energy, matter represents mass." Relativity theory, on the other hand, having established the equivalence of mass and energy, has shown that matter differs from the field only in its large concentration of energy. "But if this is the case, then the difference between matter and field is a quantitative rather than a qualitative one. There is no sense in regarding matter and field as two qualities quite different from each other." On the basis of a qualitative identification of matter and field, the authors tend to construct a "new philosophical basis" for natural science. They write: "We cannot build physics on the basis of the matter concept above. But the division into matter and field is, after the recognition of the equivalence of mass and energy, something artificial and not clearly defined. Could we not reject the concept of matter and build a pure field physics? What impresses our senses as matter is really a great concentration of energy into a comparatively small space. We could regard matter as the regions in space where the field is extremely strong. In this way a new philosophical background [of natural science] could be created. Its end purpose would be to explain all the events in nature by means of structural laws which are valid everywhere and at all times. From this point of view, a thrown stone is a varying field, in which the states of maximum field intensity move in space with the velocity of the stone. In our new physics there would be no room for field and matter, inasmuch as the only reality would be the field."

Thus, Einstein's main physical conception consists in the following. All the processes which occur in nature should be expressed in a unified field theory. This theory can be freely constructed by reason on the foundation of freely selected concepts. The theory should correspond to definite requirements: it must be internally perfect, relate events in a unique fashion, and lead to conclusions which do not contradict the experiment.

9. ELEMENTS OF RATIONALISM, POSITIVISM, AND KANTIANISM IN EINSTEIN'S GNOSIOLOGY

The understanding of the role of theory as a whole, in which each physical category plays a subservient role, is a major accomplishment in modern theoretical thought. Einstein's works, and incidentally not only his, have greatly contributed to the mastery of this truth.

We have seen, however, that Einstein rejected the path from experiment to the construction of theory. This path, which was prompted by Mach, could not satisfy Einstein. For all his high estimate of Mach's criticism of the a priori concepts of Newtonian physics, Einstein could not accept the thesis of positivism, namely that only the world of sensations exists, and that concepts are psychic formations and that theories are an economic notation for all these facts of perception. Einstein himself created theories, and not at all by following the path indicated by Mach; all of Einstein's professional experience expressed internal protest against Mach's simplification of the problem of the origin of concepts and theories. It led to deeper deductions. If the formation of the theory is not such a simplified operation with "facts of perceptions" and "complexes of perceptions" as indicated by Mach, but a logical process resulting in an integral logical system, the deductions of which coincides with new "complexes of sensations," then this indeed instills a "faith in the existence of an external world, independent of the perceiving subject," and in the fact that both the theory and the sensations express precisely this world.

However, the very thing that raised Einstein above positivism led him to rationalism. In fact, let us dwell on his explanation why fluctuations between empiricism and rationalism are unavoidable (see the quotation on p. 586). Here Einstein states something new in cognition: researchers reached the conclusion that "a separate concept and a single statement can express something comparable with empirical data in the final analysis only in connection with an integral system." But, "it is then conceded that there is no path from the experimental data to the world of concepts. Then the views of the researcher become more readily rationalistic."

Thus, Einstein himself admits that he arrived at rationalism precisely through the recognition of the role of theory as a complete entity. Was his deduction unavoidable? Not at all. This answer will be proved in the next section, and here we shall dwell on peculiarities in Einstein's rationalism.

We know that Einstein expressed sympathy for the outstanding rationalist of the seventeenth century, Spinoza. But it is possible that his method is closer to the rationalism of an older contemporary of Spinoza, namely Descartes.

Just as in our own time Einstein took as a model of the scientific method Euclid's geometrical method and mathematics in general (Einstein speaks of this in his lecture "On the Method of Theoretical Physics" and in his "Creative Autobiography"), so did Descartes in his time base himself on the geometrical method (as is well known, geometry was Descartes' profession and he initiated analytic methods in it). In his "Discourse on the Method of Rightly Conducting the Reason and Seeking Truth in the Sciences" (1637) Descartes wrote: "The long chains of simple and easy reasonings, by which geometers are accustomed to reach the conclusions of their most difficult demonstrations, had led me to imagine that all things, to the knowledge of which man is competent, are mutually connected in the same way, and that there is nothing so far removed from us as to be beyond our reach, or so hidden that we cannot discover it, provided only we abstain from accepting the false for the true, and always preserve in our thoughts the order necessary for the deduction of one truth from another."

In this rationalistic scheme of Descartes all things are interrelated as in geometry, and in the latter the logical consequences of his schemes coincide with experiment. Descartes (like Einstein in our time) sought for the initial premises of cognition, from which he could derive all knowledge. "I attempted to find the principles or primordial causes of everything that exists or can exist in the world. . . Therefore I investigated the first and most ordinary consequences which can be derived from these causes: and it seems to me that in this way I found the sky, the celestial bodies, the stars, and on them water, air, fire, minerals, and some other objects which are the simplest and most common, and therefore the most accessible to study."

As is well known Descartes regarded it as impossible to follow this logical thread in practice to "the most remote things," for although things do stand in some geometrical sequence relative to each other, this sequence becomes ambiguous at some point, and which of the alternate consequences is realized in nature cannot be decided by human reason. "Consequently, we can turn them (the various particular consequences—S. S.) in our favor only by going back from the consequences to the causes and carrying out a large number of different experiments."

Descartes believed in the rational structure of the world, but he admitted that it can be reflected in thinking only in principle, while in practice it is necessary to go back from the consequences to the causes. Einstein's position differs in that he did not compromise at all on this question. Einstein's rationalism differs from the classical also in another respect. In the classical rationalism (Descartes) all consequences are derived from initial principles, and are arranged in a consecutive chain, in which each link follows from the proceeding one and each of which can be compared with the real world.

Einstein on the other hand started from the fact that the physical theory represents a closed logical structure and therefore can be verified only in its entirety, in its final conclusions. Consequently, the theory does not develop into a successive chain of consequences, in which each link can be verified. To obtain final conclusions the investigator creates the theory purely logically. During the very process of creating the theory, reason follows its own laws: Einstein insistently emphasized that theory is a free invention of reason—he carried rationalism through to its limit.

What, however, do the words "verification of the deductions of theory" mean?

When discussing gnosiological problems, Einstein does not advance as a decisive criterion of cognition any active interaction between man and the external world, or the change of the external world on the basis of cognition. He compares the deductions of the theory with the world of sensations, being satisfied with a knowledge of the fact that the sensations relate somehow man with the external world. How a theory freely created by reason is related to the external world can be judged from the fact of how it explains or "orders" the world of perceptions, which is undoubtedly produced in us by the external world. A confirmation of the latter fact is seen by Einstein not in the intentional interaction with the external world, but in the fact that our sensations have a "super-personal" (or transpersonal) character. That is, the same sensations under identical circumstances will be felt not by one person but by many.

Thus, according to Einstein, the theory results not from experiment, but is freely invented by reason on the basis of a more or less perfect selection of concepts—"bricks of the foundation"—and, bypassing the external world, it is short circuited directly to the world of perceptions, with that "super-personal" that is encountered in it, and explains and "orders" the latter.

This short circuiting of the theory directly to the "world of perceptions" leaves a great deal of leeway in the construction of theories. Einstein reasoned as follows: once the theory as a whole must correspond to the perceived facts, then its parts can be arbitrary, free, but in the given theory essential, inventions of reason. He explains in this manner the fact, paradoxical at first glance, that although mathematics (geometry) deals with idealized objects (and is therefore always correct), it is nevertheless essential for the cognition of reality. This is explained in the following premise by Einstein, which he advanced in his paper "Geometry and Experience" at the gala session of the Prussian Academy of Sciences in 1921: "Geometry (G) predicts nothing about the relations of real things, but only geometry together with the support of physical laws (P) can do so. Using symbols, we may say that only the sum of (G) + (P) is subject to the whole of experience. Thus (G) may be chosen arbitrarily, and also parts of (P); both these laws are conventions. All that is necessary to avoid contradictions is to choose the remainder of (P) so that (G) and the whole of (P) are together in accord with experience."

This idea belongs to Poincaré, but Einstein admitted that "this view of Poincaré is perfectly correct."

In this idea, in contrast with the view expressed above on theory, a positivistic thesis is clearly realized: the theory is a system of ordering of the sensual perceptions, and there can be many such ordering systems. In order for this to become obvious, let us recall the reasoning of the positivist Reichenbach in his "Philosophic Foundations of Quantum Mechanics" (1946) in connection with his discussion of the question of whether observables exist in physics. This question, says Reichenbach, is analogous to the question: Does a tree exist if we stop looking at it? The answer, according to Reichenbach, can be arbitrary: we can propose that the tree vanishes, or that it doubles, triples, etc., but it is important to observe one rule: each proposition should correspond to such a construction of physical laws, which would justify in all cases the perception of a single shadow. These will be different but equivalent descriptions of the unobservable; in Reichenbach's gnosiology it represents a "class of equivalent descriptions." What actually occurs is immaterial to Reichenbach, for him reality is only the fact of the given sensation (a single shadow of the tree).

Einstein essentially adhered to the same concept of the possibility of many equivalent descriptions of sensory perceptions. However, unlike the positivists, Einstein admits that the sensory perceptions come from an external world, which, consequently, exists. But the external world itself remains to Einstein a puzzle. He finds this idea—the world as a puzzle—very valuable and indicates that it comes from Kant. In his "Reply to Criticisms" Einstein writes: "I did not grow up in the Kantian tradition but came to understand the truly valuable which is to be found in his doctrine, alongside of errors which today are quite obvious, only quite late. It is contained in the sentence: 'The real is not given to us, but put to us (aufgegeben) (by way of a riddle).' This obviously means: There is such a thing as a conceptional construction for the grasping of the inter-personal, the authority of which lies purely in its validation. This conceptual construction refers precisely to the 'real' (by definition), and every further question concerning the 'nature of the real' appears empty."

This concept was developed in more popular form in the book "The Evolution of Physics." The authors of this book write: "Physical concepts are free creations of the human mind and are not, however it may seem, uniquely determined by the external world. In our endeavor to understand reality we are somewhat like a man trying to understand the mechanism of a closed watch. He sees the face and the moving hands, even hears its ticking, but he has no way of opening the case. If he is ingenious he may form some picture of a mechanism, which could be responsible for all the things he observes, but he may never be quite sure his picture is the only one which could explain his observations. He will never be able to compare his picture with the real mechanism, and he cannot even imagine the possibility of the meaning of such a comparison. But he certainly believes that, as his knowledge increases, his picture of reality will become simpler and simpler and will explain a wider and wider range of his sensuous impressions. He may also believe in the existence of the ideal limit of knowledge and that it is approached by the human mind. He may call this ideal limit the objective truth."

We now have before us the complete picture of the world and the methods of its cognition as presented by Einstein. This picture indeed contains all philosophical trends—realism (more precisely, materialism) and positivism, rationalism and Kantianism, and undoubtedly elements of a number of other philosophic trends. Einstein saw in this an advantage for the philosophical views of the scientist, an expression of the necessity not to allow a "one-sided philosophical scheme," but a real many-sided process of cognition.

In this chapter we traced the beginnings of Einstein's gnosiology from his understanding of his own experience in constructing physical theories. In the following chapter we will consider the question of whether this gnosiology was confirmed when he used it as a guide in treating already existing physical theories, and also in constructing new ones.

10. EINSTEIN'S GNOSIOLOGY AND THE REAL PROCESS OF COGNITION: EXPERIMENT AND THEORY AS SEEN BY EINSTEIN

Thus, during the course of development of relativity theory and the generalized theory of gravitation, Einstein developed a certain methodological weapon, the theory of cognition by the natural scientist. Let us recall briefly its fundamentals.

There is no way from experiment to the construction of a theory. Concepts and theories do not have an experimental origin, but likewise they are not of a priori origin. They are the free invention of reason, justified only when the final deductions of the theory are compared with experiment. The natural scientist selects a minimum number of "building blocks for the foundation" and on this "conceptual foundation" he constructs the theory which is internally most perfect. The direct purpose of the theory is the ordering of our perceptions. If this is attained, then we can assume that the theory constructed by us corresponds to some degree to the external world, which is always closed to us, and that it corresponds to that extent to which the perceptions are the consequence of the processes occurring in this world.

This is Einstein's scheme of cognition.

The main feature distinguishing Einstein's cognition method is the negation of a path from experiment to theory. It is the weakest point of his gnosiology.

Is it possible, however, that this negation is accidental, although repeated (see the quotations on pages 586 and 592), a stipulation on the part of a great physicist, criticism of which would be an unworthy act? Is it not known that Einstein based himself on experiment even during the time when he developed his generalizing theories, for example on the experimental fact of the equality of gravitational and inertial masses? Is it not true that Einstein (together with Infeld) showed in "The Evolution of Physics" how new notions and concepts arise under the influence of the discovery of new facts, and how in particular the field concept, which is the main concept in Einstein's physics, originated and was confirmed?

This is undoubtedly so. Nevertheless, Einstein's reference to experiment does not change in any way the outlined rationalistic scheme of his cognition, in which the essential factor is the choice of the "conceptual foundation" and the construction of a theory on its basis. In other words, Einstein's individual references to experiment do not denote that his conclusion that "there is no path from experiment to the construction of a theory" is a stipulation which is accidental in his case. This becomes clear if we consider the most general form of the connection between physical theory and experiment, and compare it with the role that experiment plays in Einstein's works.

Physical cognition begins with the establishment of certain experimental relations, which connect in a definite manner physical categories (concepts, quantities) with one another (with the essence of the categories in these relations always determined in light of existing theories). These experimental relations may appear (again in light of the existing theories) even to be contradictory. But inasmuch as they represent manifestations of the same type of objects, the problem unavoidably arises of finding the logical condition for the compatibility, and generalization of the experimental relations. Consequently, the essence of this type of generalization consists in considering the experimental facts jointly as a unified logically connected system, and finding the conditions for the compatibility of the results of the different experiments. In physics these conditions are formulated in the form of mathematical equations or inequalities. Of course, they are difficult and sometimes painful to find, the process lasting sometimes many years. The result of this process is the theory.

The relation between the aggregate of experimental facts and the theory is mutual. In other words, theory should be a generalization of experimentally established relations, such that under certain conditions there should be derived from it the same relations which have led to the formation of the theory. But this requirement is insufficient for a genuine theory. Theory does not merely summarize the experimental relations which have become known to the investigator, but (in complete contradiction to Mach) extends beyond their limits, revealing through them objective relations in nature. And if these objective relations are actually correctly revealed, then the theory unavoidably also leads to the discovery of such relations which exist in the nature of the objects, but have hitherto been unknown to the researcher. In this lies the heuristic value of the theory. It does not passively sum up the already known experience, but gives new knowledge, and broadens the possibility of experimentation. Theory is something more than the mere sum of individual experiments.

This is precisely why in Marxist philosophy theory is regarded with full justification as the image of objective reality.

This way of generalizing the crucial experiments is the most general and deepest path of formation of theory. In fact it is realized in all the fruitful physical theories, although this is not always recognized. This is precisely how quantum mechanics was created, a fact which we shall discuss later on, and also the ("special") theory of relativity. Such a generalization was indeed realized by Einstein himself, who at that time still did not develop his special conception of cognition and proceeded on a spontaneous path. It must not be forgotten that Einstein rejected Maxwell's classical theory, in which were already generalized the experimental facts in the field of electromagnetism, established by his predecessors. But Maxwell's theory turned out to be an incomplete generalization; it was necessary to take account also of such facts as symmetry (relativity) of electromagnetic interactions and the independence of the velocity of light from the motion of its source. This further generalization was carried out by Einstein and led to his theory of relativity.

Such a path of generalization is difficult but it is the only one possible, and always leads to fruitful results. We cannot enter here into a detailed examination of the theory understood in this manner and its relation with experiment, but we shall note two additional essential aspects.

Theory is based on a definite group of uniquely established experimental relations. The condition for the compatibility of these relations is also always unique. This means that theory comes forth as a unique image of the external world both as a whole and in its parts. It is possible to obtain different forms of the theory; upon further refinement they turn out to be equivalent, as was the case, for example, with respect to the matrix and wave forms of quantum mechanics. The generalization process, which has led to the "special" theory of relativity was so unique that this result was arrived at not only by Einstein, but also by other physicists, especially Lorentz and Poincaré. As witnessed by Max Born, Lorentz was forced, in spite of personal sympathies, to forego the mechanistic idea of the existence of a special carrier of electromagnetic processes, the ether; as is well known, he derived the essential transformation conditions which are essential for relativity theory, and which were named after him, and was forced to introduce "local time" in inertial systems, although he did not understand its meaning. Poincaré published only a few months after Einstein an article "On the Dynamics of the Electron" (1906) which contains essentially all the necessary elements of relativity theory. In a word, the experimental facts at the start of our century led inevitably to a unique theoretical generalization—relativity theory. Furthermore, theory, which is a formulation of the conditions of compatibility of experimental facts, is based by virtue of its nature only on established experimental relations and does not presuppose any preconceived notions concerning the properties of the object or definite types of constraints acting in the object. The latter can be obtained only as a result of finding conditions for the compatibility of the experiments, that is, as a result of development of a physical theory. This is a very important property of this method of formation of theories, since it denotes that this method does not impose any a priori concepts either regarding the object or on the constraints acting in it; in view of this, it is the necessary and most general method of discovering new properties in the object and new types of constraints, and furthermore its conclusions are realized with strong conviction, frequently contrary to the habits and psychological resistance of the researcher.

We now examine the role which Einstein assigned to experiment in the cognition scheme. This role is two-fold. Concerning one of its aspects, Einstein speaks clearly: the deductions of the theory must coincide with experiment, otherwise the theory is converted into an empty scheme. This position is undisputable. But his is an a posteriori, control function of the experiment. It selects the theories that are equivalent to the object from among all those created, contributing by the same token to the development of science as a whole, but it does not lead directly to the construction of the theory.

Experiment plays in Einstein's scheme also a second role. In Einstein's scheme of theory construction it is easy to note two stages: during the first he constructs a "conceptual foundation," and in the second he creates on this basis the theory. But where does he take the concepts for the "foundation"? Einstein states that concepts (like the theory) are the product of the free invention of reason. But of course, he does not invent them arbitrarily, and actually *selects them from among those which for some* reason have already been created in physics. We shall not investigate here this process of creation of concepts and their subsequent confirmation or rejection. Einstein (with Infeld) showed this process in "The Evolution of Physics." It is clear that experiment plays a decisive role in the creation of the physical concept (but not a direct one, not in the sense of positivism or operationalism). In Einstein's case it plays a role also in the selection of concepts for the "conceptual foundation" (equality of gravitational and inertial masses). But this is by no means the same role which is played by experiment when a search is made for the only possible condition of compatibility of experiments. Einstein is correct: the role which he assigns to experiment does not make it possible for him to find the way from experiment to the construction of the theory. The role merges completely with the concept of the theory as the product of the free invention of reason, with all the consequences derived from it, namely that the same facts can be described by different theories, and that one theory differs from another in different "conceptual foundations," which serve as the basis of the theory, and that in addition to the criterion of "external justification" of the theory there exists also the criterion of "internal perfection" etc.

The idea of multiplicity of theories, representing the same group of facts, but differing in the fact that they are constructed on different "conceptual foundations," is not confirmed by the real process of cognition. There are no grounds for assuming that the two theories of gravitation, Newton's and Einstein's, pertain to the same circle of facts, but "order" them differently, since the former has an imperfect "conceptual foundation," and the latter a perfect one. It becomes necessary to classify these theories in a different manner. The two theories do not stand alongside each other, as was many times emphasized by Einstein, but are in a definite relation to each other, the second covering a larger circle of facts than the first. Newton's gravitational theory is valid only for velocities which are small compared with the speed of light, and for potentials which are small compared with the square of the speed of light. Einstein's generalized theory of gravitation includes also regions of large velocities and potentials, and when the latter are small it assumes the form of Newton's theory. Both theories represent different degrees of deepening of the knowledge of nature. We cannot state, therefore, that the "conceptual foundation" and the theory itself were freely constructed by reason. Born's remark *on this subject (see page* 593) is correct.

Nor can we accept the idea that the world is and will always remain a puzzle to us. If the body of the world's mechanism is tightly sealed from us and will never be uncovered, then the requirements imposed *on the theory will no longer be so stringent, since* the "outward justification" of its final conclusions actually reduces in this case only to some degree of "ordering" of our perceptions. This concept deprives the theory of unique reliability, a fact many times admitted by Einstein himself (see his statement cited on pages 594 and 597).

However, man's real knowledge develops not at all in this manner: today there are no theories at all, but tomorrow there will be a theory covering the entire self-enclosed world, the "body of the mechanism" which we can never uncover. Man creates theories pertaining not to the world as a whole, but to separate groups of natural phenomena. He continuously interacts with nature, both before and after the creation of the theory. He creates a theory on the basis of the interaction and verifies his theoretical conclusions concerning it by interaction, by practice. As a result, man continuously broadens and deepens his relations with nature. This is indeed the process of learning about nature. This is the uncovering of the "body of the world mechanism." Only by ignoring this constant interaction with the external world can the researcher state that his theory is the product of the free invention of reason. The conclusions to which this ignoring have led Einstein himself in practice will be shown later, and for the time being we shall consider the result to which it leads in the theory of cognition itself.

In its logical aspect, a physical theory constitutes a certain relation between physical categories or concepts. By choosing the "building blocks for the foundation" Einstein proceeds to construct a theory, establishing a certain relation between the selected concepts. But what types of relations does he use? Only those types which are expressed by differential equations and for the field by partial differential equations. Consequently, Einstein's gnosiology starts from a predefined type of causal relations, ascribed to the external world: this is the unique continuous connection between events that are adjacent in time and in space. Einstein must lean on relations of this type, for he knows of no other relations and he has no way of drawing knowledge concerning them, since he does not consider the conditions for the compatibility of different experiments. By ignoring this method, which uncovers the real relations in nature, Einstein was forced to postulate in implicit form that the external world obeys relations of just this type.

It turns out that the a priorism, the validity of which Einstein correctly subjected to criticism when striving to rid classical physics of it, appears in Einstein's theory in a new form: now the a priori character is acquired not by individual physical categories, but by a definite type of regular relations which are characteristic of classical physics.

But whence does it follow that the world must obey precisely this type of relation, which is known to the researcher during the period when he develops the theory, or which is for some reason closest to his spirit? And what if the external world does in fact follow laws of a different type? How are we to obtain information concerning this fact? Does not the cognition method adopted here serve as an obstacle to cognition?

This is indeed the case. This is a contradiction, but it is unavoidable for rationalism, both classical and modern. All the same, classical rationalism was in its time a progressive movement, since it came out against dogmas which stated that truth is found only in church books, and advanced the idea that man's creative reason is capable of reading it in nature's own book. In our times the religious dogmas have been overcome and the rationalistic philosophy only hinders cognition: it is incapable of discovering relations of a new type in nature. And if Einstein did discover them during a certain stage, then, as stated above, he discovered them because he actually made use of a non-rationalistic method of cognition.

Thus, Einstein recognized experiment, but underestimated its gnosiological value, its essential role in the construction of theory. He used experiment in such a way that he admitted the possibility of multiple theories describing one and the same set of facts, and excluded the possibility of cognition of objective relations and properties of a new type.

In the sections that follow we shall examine Einstein's method in action.

11. EINSTEIN'S METHOD IN ACTION. GENERAL THEORY OF RELATIVITY OR GENERALIZED THEORY OF GRAVITATION?

As was already stated above, the "special" theory of relativity was the result of a generalization of experimental facts. But Einstein interpreted the causes of its appearance in his own way. In light of the general conception he developed, he started to consider it as a result of the elimination from physics of the exclusiveness of one "absolute" reference frame. Furthermore, he was also stimulated by Mach's criticism of the principles of Newtonian mechanics, a criticism which at that time became popular among physicists. The elimination from physics of an absolute reference frame did actually take place. But the point is that it was not the theory which appeared as a result of this elimination, but the elimination itself was an essential result of the theory.

So long as we are dealing with a single initial theory, the argument concerning what is fundamental and what is a consequence may turn out to be scholastic. Differences of principle in the positions become clear when new theories are constructed, and when the chosen position becomes the guiding method of research.

This was also the situation in this case. The upheaval produced by Einstein in the real relations in his estimate of the causes of the appearance of relativity theory appeared to many natural and convincing. Einstein himself was led by this upheaval to the development of a methodology which was unique to him, and from which followed directly the task of further ordering of the "conceptual foundation" of physical theory.

It induced him to extend the meaning of the relativity principle, to formulate the latter as a general principle of relativity, encompassing arbitrary (also accelerated) reference frames; he started to consider this principle as an important landmark on the road toward the construction of rational physics.

But at this stage, Einstein's methodology encountered its first conflict with physics.

Let us consider the logic of his tendencies and the results obtained by him.

As stated above, Einstein started from the fact that the relativity principle eliminated from physics the idea of the special nature of a certain (unique) absolute system of reference, in which the laws of physics are formulated. He regarded this as a great, but nevertheless incomplete, accomplishment. In place of a single preferred system, there arose a whole class of systems, namely inertial systems. All the physical processes in them occur in identical fashion, but nevertheless this is a special class: outside this class there is the class of non-inertial (accelerated) systems, in which the processes do not occur in identical fashion.

The separation of a certain class of (inertial) systems into a separate category disturbed the logical harmony of physical thinking. Einstein presupposes that just as there is no single exclusive (absolute) system, there should also be no entire class of exclusive inertial systems. Such a situation also did not correspond to Einstein's methodological requirements that the theory be "internally perfect." This raised the following problem: to free oneself in the formulation of physical laws of that which is introduced in them by the non-inertial systems, or to find a unified form for the expression of physical laws, independent of the class of reference systems.

How is this to be realized?

The two theories produced by Einstein—the theory of relativity and the generalized gravitational theory—indicate the approach. By developing the theory of relativity (the principle of relativity for inertial systems), Einstein arrived at the model of the space-time continuum. The metric of this continuum has a pseudo-Euclidean character. In this pseudo-Euclidean nature are reflected the properties of the class of inertial systems. In formulating the generalized theory of gravitation, Einstein included the gravitational fields in the continuum by changing its metric. Operation with the metric of the continuum has simplified the "conceptual foundation," and has rid it of many concepts (long-range forces, inertial motion, etc.). The laws of motion in this physical continuum we have learned to express in a general-covariant form. This raises the question: can the influence of non-inertial systems on the motion be taken into account by the same method—via a space-time continuum through a suitable choice of its metric? If this could be accomplished, then the problem of the non-inertial system would be eliminated, and physics would deal only with the metric of the continuum, in which the law of motion is expressed in general-covariant form. This would mean, from Einstein's point of view, that a "general principle of relativity" was found. This "general principle of relativity" would differ from the previously formulated "special principle of relativity" (as Einstein called it) in the fact that it encompasses not only the class of inertial, but also the class of non-inertial systems. In other words, it would state that not only velocity but also acceleration is relative.

This was the problem posed by Einstein.

But the possibility of expressing the influence of non-inertial systems on the motion via the metric of the space-time continuum could be justified only if the equivalence of the acceleration and gravitational fields could be proved. It was to this that Einstein's attention was directed.

However, he presented no proofs of the equivalence of arbitrary acceleration fields and gravitational fields encountered in nature. He pointed to a Gedanken experiment with a closed elevator: the observer in such an elevator has no way of establishing whether his elevator moves with uniform acceleration, or is at rest but in a gravitational field: all the physical processes in both situations would proceed in identical fashion. But the idealized experiment with a falling elevator proves the equivalence only in the particular case of specially chosen homogeneous fields. In the general case, however, for example in rotating systems, the equivalence can be assumed only for an infinitesimally small space, reducible to a point, in which the fields can be assumed homogeneous. This can be alternately formulated as follows: the equivalence principle is a local principle. For the entire finite space, for the fields taken as a whole, equivalence is violated. The principle cannot be applied, for example, to the solar system. An idealized experiment with a falling elevator cannot serve as an argument in favor of the general principle of equivalence of arbitrary acceleration fields and gravitational fields.

The non-applicability of the equivalence principle to a finite space results also from the properties of the mathematical apparatus, by means of which the space-time continuum is expressed. As is well known, it is described by partial differential equations. Such a description can be equivalent to physical reality only when the so-called boundary conditions are specified. The boundary conditions in partial differential equations are inseparable elements of a theoretical representation of physical reality. The boundary-condition requirement cannot be ignored, for this would mean ignoring the properties of the physical system itself, as a whole.

But boundary conditions for arbitrary acceleration fields and for gravitational fields will always be different. For example, in rotating systems the energy of the bodies would tend at infinity to infinity, whereas the gravitational forces would tend at infinity to zero. For inertial forces of a rotating system, we cannot choose in nature an equivalent gravitational-force field.

Thus, the idea of including the influence of arbitrary accelerated systems in the space-time continuum by suitable choice of its metric, in analogy with the procedure used for gravitational fields, could not be realized, and the general principle of relativity was not proved. This means that the accelerated systems really influence the course of the physical processes occurring in them. Acceleration is not relative, like velocity, but absolute.*

On the other hand, the possibility of expressing the laws of motion in covariant form does not in itself imply the statement of the general principle of relativity.†

Einstein, however, attempted to construct a rational physical theory in the spirit of his methodological ideas. The exclusive nature of inertial systems, in which the relativity principle is operative, and the presence of accelerated systems in which it does not operate, did not correspond to the spirit of rational physical theory. It seemed to him that there are sufficient grounds for assuming acceleration to be just as relative as velocity.

This led to the paradoxical conclusion that the systems (and even opinions!) of Ptolemy and Copernicus were equivalent. Such a statement is found, in particular, in the book "The Evolution of Physics." The authors, Einstein and Infeld, express it in very clear form, referring to the "latest physical discoveries"; by the same token, they place a very strong weapon in the hands of the reactionary clerical circles.

As shown above, there exist no physical grounds for stating that the Ptolemaic and Copernican systems are equivalent, for the relativity of acceleration has not been proved. As regards Copernicus' ideas, their progressive role in the struggle for the develop-

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[*] It must be recognized that the concept of "absolute acceleration" has a different meaning than the concept of absolute space and time in Newtonian physics.

[†] These problems are thoroughly reviewed in the book of V. A. Fock "Theory of Space, Time, and Gravitation," second edition, Moscow, Fizmatgiz, 1961.

ment of science, against the reactionary ideology of the church, is not subject to any doubt.

It is difficult to imagine that Einstein, this outstanding humanist of our time and a sincere opponent of clericalism, did not understand the progressive significance of Copernicus' ideas.

The situation, of course, is not so. This is attested, for example, by the message sent by Einstein to Columbia University on the occasion of the 410th anniversary of Copernicus' death, written in December 1953, a year and a half before Einstein's death.* In this message Einstein notes also Copernicus' contribution "to the liberation of the mind from the chains of clerical dominance," and the fact that "this great accomplishment of Copernicus. . . paved the way to modern astronomy" and showed the inconsistency of the "illusion of the central significance of man himself" in the cosmos.

The idea of the equivalence of the systems of Ptolemy and Copernicus, as expressed by Einstein, can be understood only as the result of the influence of the narrow professional tendencies in Einstein's own views. These tendencies led him to state that he succeeded in theoretically generalizing the relativity principle to include all accelerated systems. This idea was regarded by Einstein as completely revolutionary. But it was expressed in extremely abstract form and he, apparently, sought such a form for its exposition as would make it possible for the broad public to sense its revolutionary meaning. This was indeed the cause of this paradoxical announcement that the struggle between the views of Ptolemy and Copernicus was meaningless in the light of modern science. But the social response to such an action could not be foreseen by a scientist absorbed in professional aims.

This problem, Ptolemy vs. Copernicus, is only a regrettable dramatic episode, which had to be mentioned here in view of the great social response which it received, having appeared in works by venerable scientists and especially since it has been set forth in such a popular book.

From the theoretical point of view, we are interested on the other hand in the deduction that can be drawn from the foregoing. It consists in the fact that we cannot eliminate from physics the separation of systems into different classes—inertial and noninertial, and that we cannot go over from the "particular" ("special") principle of relativity to the "general," and prove the relativity of acceleration.

To be sure, the majority of leading physicists did not see Einstein's treatment of the "general principle of relativity" as an obvious contradiction with the development of science. Many physicists, using the term "general principle of relativity," understood it not in the sense of recognizing the relativity of acceleration, but in the sense of a method of including different fields in the metric of the space-time continuum. In practice, Einstein also used this term in the same sense. However, this raises the question, whether one can, following this method, exhaust all the possibilities of nature. Einstein himself answered this question in the affirmative: he believed that the entire world is a space-time continuum. We shall return to this question in Sec. 13.

No matter how we solve this general problem, we cannot, of course, deny that the inclusion of gravitational fields in the metric of the space-time continuum and the determination of the character of motion in this continuum, that is, the development by Einstein of the generalized theory of gravitation, is a real accomplishment of theoretical thinking, which has tremendous significance. The possibilities of a general gravitational theory have apparently not yet been exhausted. It can be assumed that its conclusions are not limited to the three conclusions indicated by Einstein himself (see Sec. 6, page 590). In their papers devoted to relativistic astrophysics, Ya. B. Zel'dovich and I. D. Novikov reach the conclusion that important consequences follow from it for the theory of evolution of stars, double stars, and stellar clusters.

There is no doubt that with the development of astrophysics, the heuristic value of the generalized theory of gravitation will increase. However, this line of development does not mean at all the realization of that gnosiological idea which induced Einstein to work on the "general theory of relativity," and we are justified in summarizing the foregoing as follows: even during the first stage of Einstein's use of his "rational method of cognition," no convincing proof of its validity is apparent.

But at this stage the discrepancy with the real process of cognition did not become fully evident, and was not proved to all physicists; this is connected to a considerable degree with the fact that the concept "general theory of relativity" is given different meanings, which are not accurately defined.

This discrepancy, however, had an unavoidable effect on the following stages of the development of physics and in other fields of physics.

12. QUANTUM THEORY AND EINSTEIN'S GNOSIOLOGY

Could a theory of quantum phenomena be developed in the same way which Einstein regarded as the only correct one? Unconditionally, no.

Einstein's method included the correct premise that theory reflects a definite aggregate of phenomena of the external world only as a whole, defining the meaning and content of the concepts used in it (physical categories). We recall that the realization of this

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*Published in 1956 in the collection: "Ideas and Opinions by Albert Einstein," London, 1956.

fact led him to depart from Mach's positivism and from Bridgman's operationalism. But Einstein's methods included also the requirement of preliminary selection of the simplest concepts for the "conceptual foundation," from which the theory should then develop rationalistically; he prescribed also the type of relations between the physical categories.

But how could one state beforehand which concepts, among those developed by classical physics, should be selected for the "foundation" and applied in the theory of quantum phenomena? And could classical types of relations be used in it? The first period of accumulation of facts in this field disclosed without any doubt the impossibility of selecting beforehand initial concepts and types of relations between them, for the purpose of subsequently constructing a theory by rationalistic means. This was too obvious. It was necessary to seek a different path to the theory. And the physicists found it, not immediately, and of course not without hesitation.

If we discard those subjective factors which have been introduced and are being introduced by individual authors in the exposition and treatment of quantum theory, and formulate briefly the objective essence of the method by which quantum mechanics was created, then this essence can be expressed in the following manner.

In the region of atomic phenomena of physics, many basic experimental facts were encountered, which were unusual and even strange from the point of view of the already known classical laws. The investigator must start from these experimental relations and regard them jointly as a single logical system. He cannot make beforehand any assumptions concerning either the nature of the physical objects and their states, or the character of their interactions, and he cannot construct beforehand any definite models of the investigated world. He does not choose "for the foundation" any "simplest" concepts and he does not change their meaning beforehand, prior to the formation of the theory; in each individual experiment he uses simply the already formulated concepts, the concepts of classical physics. What must guide him in addition, is the premise that under certain physical conditions—when the quantum of action can be neglected—any new theory should assume the form of the already tested classical theory. This is the so-called correspondence principle. But even the correspondence principle is not a principle which is imposed by the nature from the outside, imperatively; in essence it also expresses an experimentally known fact—the reliability of the laws of classical physics under certain "classical" conditions.

Thus, as a result of the generalization of the basic experimental facts of atomic physics, a logical interconnection is established, the condition for their compatibility, namely quantum theory. The nature of the physical objects and their states, as well as the nature of their interactions, is assumed by the physicists to be such as they turned out as a result of the generalized theory. They undoubtedly are no longer those of the classical theories; the requirement for observing the "conditions of compatibility," of a new aggregate of experiments, that is, the new theory, has impressed its imprint on the nature of the categories and the relations between them. Inasmuch as the quantum theory constructed in this way is also confirmed by succeeding experiments, predicts new experiments which have not yet been encountered in the physics laboratories, and in addition satisfies further the correspondence principle, it is regarded as a theory truly describing the external world, just as all its component elements and the relations established in it are also truly representative.

Thus, in the region of atomic phenomena, the method of forming theories adopted was just of the type which made it possible to uncover in nature new facts, and made it possible to go outside the limits of the already known laws, of the already known notions concerning the physical objects and their characteristics.

In quantum mechanics this method leads to the deduction that the physical properties of an object must not be regarded absolute, inherent in the object itself, but only relative, defined by an interaction between objects in a whole indivisible system. By the same token, there were eliminated the concepts of classical physics not only concerning the existence of reference frames with absolute properties, but also the existence of physical objects with absolute properties. In this sense quantum theory continues and deepens Einstein's activity in the field of transformation of classical concepts. Quantum theory has also enriched the description of a state of a physical object, defining it by means of a set of its potential possibilities.

In the same way this method made objective a new form of causal relations—statistical laws. The latter follow here from the nature of the theory itself, confirmed by practice, and not as a temporary replacement of "exact" dynamic laws, which we used under conditions when our knowledge was still inadequate.

By way of illustration of the power of this method, we present here only a few examples of the discovery of new facts of nature.

But such a method of constructing theories and the consequences following from it did not fit in any way into Einstein's system of concepts concerning the structure of the world, the ways of determining it, the fact that the only form of causal relations in nature can be the single-valued relations reflected in "structural" or differential equations. The idea of the continuum, on which Einstein leaned both in relativity theory and in the generalized theory of gravitation, as well as in the development of the unified field theory, is compatible with only the one type of causal relations, indicated above. All this has caused Einstein, by starting from his own method of constructing theories, to be unable to agree with the main ideas of quantum physics.

Einstein, of course, presented his arguments against the acceptance of quantum ideas. At first glance they also seem convincing. But a more careful analysis shows clearly that they are based on a priori notions concerning the nature of quantum objects and processes, and this is precisely what does not allow the development of a method for the examination of the conditions of compatibility of the experimental facts such as would lead to a new theory, or present an image of the new objective reality.

Coming out against Bohr, Born, Pauli, Heitler, and others, Einstein in his "Reply to Criticisms" indicates that the wave function does not present a complete description of the decay of a single individual atom, since it does not imply any assertion concerning the time instant of the disintegration of the radioactive atom (emphasis by Einstein)." And yet one is, first of all, inclined to assume"—continues Einstein—" that the individual atom decays at a definite time." In this formulation of the problem we see clearly the a priori approach of Einstein: the picture of the process is done before the theory has been created, and from the point of view of this "intuitive picture" he criticizes the new theory. The arguments and their consequences are presented here "with the cart before the horse."

We recall that quantum theory appeared as a result of a search for the conditions of compatibility of experimental fact in the given field of microphenomena, and that it also predicted new facts, and that it even goes over into the classical (verified!) theory under "classical conditions," and consequently this theory, and no other, not some "intuitive picture," represents faithfully the image of physical reality. And it is precisely this theory which leads to a different "picture" of the decay of the atom. According to this theory (which is a generalization of experiment, and numerous consequences of which are likewise confirmed by experiment!) the decay time and the energy are connected in such a way that the more accurately the time is determined ($\Delta t \rightarrow 0$), the more uncertain becomes the change in the energy (the uncertainty relation: $\Delta E \cdot \Delta t \geq \hbar$). Our concepts concerning the "mechanism" of the decay must change, they must correspond to the theory. This requirement is not new, it is analogous to the manner in which Einstein required in his own time that our concepts concerning the structure of a liquid correspond to the verified theory of Brownian motion. On this basis we had to admit the existence of atoms and molecules, although they had not been directly observed.

However, although *Einstein* in his time reached the conclusion that theory must be regarded in its entirety, the "mechanism" of radioactive decay was regarded by him not in the light of his quantum theory, but on the basis of the customary notions, which in this case were advanced already as a priori concepts.

In his "Reply to Criticisms" he describes a small discussion between a critic and a defender of quantum mechanics ("theoretical physicist"). He puts in the latter's mouth the following argument in defense of quantum ideas: "The assertion of the existence of a definite time-instant for the disintegration makes sense only if I can in principle determine this time-instant empirically. . . The entire alleged difficulty proceeds from the fact that one postulates something not observable as real. (This is the answer of the quantum theorist)."

It is precisely this proposed answer (and there is no doubt that such answers were given) which was called by Einstein (see page 585) positivistic, leading to the Berkeley principle: existence means observability. But there is no logic here. Positivism states: Only my own sensations, observations, perceptions exist; they reflect nothing outside myself ("sensations can be similar only to sensations" stated Berkeley). Quite different is the following statement: A certain concept corresponds to nothing in a given region (is there nothing in the real world that correspond to the concept of the devil?). Einstein's arguments against Mach were convincing: atoms were not observable directly, but they existed, and therefore were observed indirectly, and particularly via the theory of Brownian motion, as was indeed proved by Einstein. Einstein's arguments against quantum mechanics are not convincing because he wants us to believe in the existence of an observable fact which is not reflected in the theoretical image of physical reality, but, to the contrary, is excluded by it.

A similar criticism was raised in its time against the uncertainty principle of the coordinates and momentum of the quantum object: "Is it impossible to determine simultaneously precisely the coordinates and the momentum? But this is only at the present state of technology; in the future, when the techniques become perfected, the coordinates in momenta will be measurable with absolute accuracy. One cannot impose a limit to our knowledge!"

This criticism started from the premise that the coordinates and the momenta of a quantum object always exist in a strictly defined sense, unrelated to each other, and that the only impossible thing is a procedure for simultaneously measuring accurately these values at the present state of the technology.

But such a criticism reflects lack of understanding of the fact that quantum theory (the heuristic significance of which was always admitted by Einstein!) has radically changed our concepts of a quantum object and of the processes occurring in the quantum region.

We recall the powerful impetus which Einstein himself gave to the development of statistical methods of physics. Nonetheless, during the entire second half of his life he categorically denied their objective meaning. In a letter to Max Born dated December 3, 1947 he wrote: "My physical position I cannot justify to you in such a way that you would consider it reasonable to any degree. Of course, I understand that in principle the statistical point of view, the necessity for which within the framework of the existing formalism was first clearly realized by yourself, contains a considerable part of truth in it. However, I cannot believe in this theory seriously, because it is not compatible with the main premise that physics must represent reality in space and in time without any mystical action at a distance. . . I am firmly convinced of this, as well as of the fact that ultimately we will arrive at a theory in which the facts connected by regular laws will not be probabilities, but real facts, as was regarded as self-evident a short while ago. As a justification for this conviction I can present not logical proof, but my little finger as a witness, that is, authority which does not inspire faith beyond the limits of my skin."

Einstein was troubled all his life by the dual, corpuscular-wave nature of quantum objects (the so-called "dualism"). He who discovered the photon structure of light stated now that all the discrete formations—elementary particles, atoms, photon, etc.—are singularities ("singular regions") of a field, in other words, they should be reducible to the field in which differential equations are operative, for nothing except these equations, according to Einstein, can be a form of an expression of causal relations. This pertains first of all to statistical laws. But modern quantum electrodynamics shows that the field also exhibits statistical behavior. The differential (Maxwell) equations of the electromagnetic field reflect only that aspect of the field which is regarded in macroscopic electrodynamics, that is, laws concerning processes in which an appreciable role is played by changes of the average values of the variables. In microprocesses we deal with fluctuations of alternating fields about mean values and with field quantization. Therefore, the transition to the field concept cannot free physics from statistical laws.

Some authors discuss the following question: Does not Einstein's negative position with respect to quantum theory follow from some insight into future paths of development of physics, paths which his companions have not yet seen, but which have already become uncovered for his mental horizon?

No, we see that it follows from his methodology, from his understanding of the ways of constructing theory, from his a priori treatment of the structure of the external world, from the fact that certain types of relations are prescribed beforehand for this world.

This attitude to quantum mechanics appeared in his views not as a result of an accumulation of new experimental material, which cast doubts on the principles of the theory, and not as a result of some of his own accomplishments or even those of others. It appeared shortly after he constructed the generalized theory of gravitation, the success of which he regarded as a confirmation of the "general principle of relativity" and as a motivation for the rationalistic methodology which was already developed by him then.

As early as March 8, 1920 Einstein wrote to Max Born: "In my free time I always meditated on quantum problems from the point of view of relativity. I do not think that this theory can get along without a continuum. However, I did not succeed so far in obtaining a tangible image for my favorite idea—the understanding of quantum mechanics with the aid of differential equations, employing conditions for singular solutions." And somewhat earlier in the same year (January 27th) he wrote to Born: "I am also greatly troubled by the problem of causality. Will the absorption and emission of light in quanta ever be understood in the sense of complete causality or will a statistical remainder be preserved? I must confess that I lack the strength of conviction. But I am very very reluctant to forego complete causality. . ."

According to Einstein, the world is manifest only in the image of a continuum, and the theory must express it by means of differential equations which are the only form of a causal relation—this is the meaning of his letters. Even at that time they reflected clearly Einstein's complete methodology. Nothing had changed in it to the very end of his life.

Now this methodology is clearly out of line with the main development of physics.

13. UNIFIED FIELD THEORY AS A GENERAL LINE OF DEVELOPMENT OF PHYSICS

Einstein did not criticize quantum theory passively, he attempted to find another foundation for physics. It seemed to him that his own experiment of constructing relativity theory and gravitation theory showed him the true path. It is necessary to find the simplest "conceptual foundation" and to develop from it in a rational manner all the laws of nature. Matter, electromagnetic field, gravitational field—does not man subdivide nature too much? Nature is unified and its laws should be expressed in a unified theory.

These ideas have led Einstein to a development of his own general line of development of physics. We can trace four steps of development, indicated by Einstein. The first is the formulation of the theory of the electromagnetic field, invariant for all inertial systems, and the development in this connection of relativity theory. The second—generalization of the relativity principle to include all systems including non-inertial ones, and the development of the "general theory of relativity" (more accurately—generalized theory of gravitation). Third—generalization of fields, the electromagnetic and the gravitational ones, on the basis of the latter and development of a "unified field theory." Fourth—generalization of particles of matter as singularities (singular regions) of the field and the development of a unified physical theory of the external world—the continuum. All other physical theories drop out from this scheme; in the best case they should be transformed and made subordinate to the following idea: all laws of nature are laws of the continuum.

The first two steps were realized approximately during the years 1900—1916, and Einstein proceeded to the third step, on which he worked to the end of his life.

The method of generalization of fields in unified field theory, without entering into details, consists in the following.

According to Einstein, the gravitational field determines the geometrical structure of the space-time continuum, producing in it a definite metric; this continuum is a set of certain functions, components $g_{\alpha\beta}$ of a metric tensor. In Einstein's theory of gravitation, account was taken only of the influence of the energy-momentum tensor, produced by the mass distribution, on the metric of space. But the electromagnetic field also produces an energy-momentum tensor; consequently, it should also make a contribution to the metric of the continuum. This raised hopes of successfully developing a unified field theory. From the point of view of the adherents of this idea, it was only necessary to find certain supplementary arbitrary functions which describe a nongravitational field. However, there exist no objective indications whatever as to how to realize the inclusion of these new functions. Einstein himself and others have proposed several variants, the number of which already exceeds 20. The way of formal generalization turns out to be ambiguous.

By virtue of this, as correctly noted by the well-known investigator of "Einstein spaces" A. Z. Petrov, none of the existing unified theories went beyond the framework of abstract constructions, and have led to no substantial discoveries or consequences which admit of experimental verification. Their heuristic significance is equal to zero.* The resultant situation is reminiscent of that faced by Descartes in his time.

This raises naturally a general question: Is the very formulation of the problem of creating a unified physical theory as the end purpose of physics valid? What does this purpose consist of, and what are the ways of its solution?

According to Einstein, it consists of reducing all types of laws for all types of objects to a unified law and to a unified object—a generalized geometrical image, described by continuous differential equations which reflect a unique connection between the field components. This is how Einstein understood the unity of the world, and this treatment, in the philosophical sense, is in no way deeper than the mechanistic treatments of the unity of the world at the end of the nineteenth century. Only its physical basis is deeper.

But the unity of the world consists not in reducing qualitative manifolds of the world to quantitative differences (see page 594), but in the fact that the various qualitative formations in the world are mutually interrelated and go over into one another under certain conditions. Whereas physics of the last century discovered the mutual transformations of various types of energy, in our time it has already discovered the mutual transformations of elementary particles into one another. With each year greater possibilities are uncovered of their mutual transformations. It can be assumed that mutual transformation is a generalized law of nature.

The presence of regular laws and mutual transitions of qualitative formations in nature leads naturally to the idea of the potential possibility of creating a unified theory which encompasses at least all the physical processes in the world. In fact, to the extent to which in these transformations some physical categories go over into others, to that extent we can, apparently, strive to find such a physical theory as would generalize all these categories in a single logical system.

Consequently the dispute can concern not the formulation of the problem of the unity of the world itself, but the treatment of the meaning of unity and the ways of realizing a unified physical theory. Obviously, the unified theory should satisfy many requirements; we note here the most important conditions for its realization, as they appear to us.

It is clear that a unified physical theory can be obtained not by a rationalistic method of generalization, in which all the manifold fields and systems reduce to a geometrical image-continuum with extremely complicated metric, but by means of a generalization in which the theory appears as a condition for the compatibility of different phenomena, pertaining to a single object, or else—for the given problem—as the condition for compatibility of partial physical theories. This means that in constructing a unified theory we cannot ignore those theories, with respect to which it has already been established that they reflect certain real processes of the world, although these theories do not fit the rationalistic scheme. A unified physical theory cannot ignore, for example,

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*A. Z. Petrov, Principal Stages of Development of the Gravitational Field, Voprosy filosofii (Problems of Philosophy) No. 11, 1964.

the laws discovered by quantum theory: the quantum nature of micro-objects and processes, their dual nature, the statistical laws, the definition of states in terms of potential capabilities, etc.

It is all the more necessary to take these laws into account because it is now clear that the very image of the field, in which Einstein desired to find a sanctuary, does not at all remove all the problems and difficulties which he strived to ignore or circumvent. Fields are continuous only on the macroscopic scale. On the microscopic scale fields are discontinuous, and Einstein himself was the pioneer in the formulation of the quantum structure of the electromagnetic field.

Einstein's theory of gravitation was developed by him as a nonquantum theory; but it is applicable for bounded regions of space, and the lower limit of which is 1.6×10^{-33} cm. "In smaller scales, quantum fluctuations of the metric must become essential."* This possibility was not provided for by Einstein. The problem of the agenda became the experimental establishment of gravitational waves. Einstein did not exclude the possibility of their discovery. But the observation of gravitational waves will undoubtedly be accompanied by the discovery of quanta of the gravitational field—gravitons.

The discovery of gravitational waves and gravitons, of course, calls for improvement of the experimental methods. This will undoubtedly uncover a new extensive region of facts, as occurred upon the discovery of electromagnetic waves. In particular, it will make it possible to approach a solution of the problem of the energy of the gravitational field, which within the scheme of the unified theories cannot be solved because the energy is not expressed uniquely and depends on the choice of the reference frame.

A. Z. Petrov correctly notes the urgent necessity for experimental investigations of the gravitational field. "So long as the theory will be fed with such skimpy factual material as was the case so far, one cannot speak at all of any serious physical science in the modern meaning of this world" he writes. The same author notes the characteristic statistics of scientific papers, indicating a strong decrease in the number of papers devoted to the formal development of "unified theories," and to the contrary an increase in the number of papers devoted to the problem of field energy, analysis of the main premises of the theory, and their physical validity.

But what does this conclusion, of the necessity of increasing experimental research, and these statistics describing the change in character of research, denote other than an admission that the new theory must not be a result of speculative methods, but a consideration of the conditions of compatibility of experimental facts?

All the foregoing means that even the problem of the gravitational field cannot be regarded in its entirety from the point of view used by Einstein. Naturally, this non-quantum aspect cannot serve as the basis for a "unified field theory."

In general no single separate theory—be it the theory of gravitation (as thought by Einstein himself), or the theory of elementary particles, or any other—can be the only basis for a unified physical theory. But inasmuch as it can only be a generalization of several partial physical theories—quantum mechanics, quantum electrodynamics, theory of elementary particles, nuclear theory, the future quantum theory of gravitation, etc.—it is also obvious that for a generalized unified theory it is necessary that a specific correspondence principle be satisfied, just as for any generalized theory, but perhaps in some "extended" form. This means that under certain limiting values of the corresponding characteristic parameters, the generalized physical theory should assume the form of those particular theories which served as the initial elements for the generalization.

It is clear that the prospects of such a generalization are still not very close to us. We know the still unsurmountable difficulties encountered in quantum field theory, which has not yet been cast in an anywhere near final form. It is far from clear whether there are enough presently known "basic theories," which can serve as elements of a unified theory. And at any rate, it would be correct to conclude that a unified physical theory, representing all the physical processes in nature, will never be closed and complete, since the process of discovery of new properties of nature, as well as the process of their occurrence, is never completed. A unified physical theory is only a certain ideal, to which one can and one should strive, recognizing, however, that no unified theory can exhaust the wealth of the world.

The idea of creating a unified field theory engaged Einstein for the last four decades of his life. And during that time experimental and theoretical physics was faced with numerous urgent problems, and new theories were developed, such as quantum mechanics, nuclear physics, physics of elementary particles, quantum electrodynamics, solid state physics, and others. These problems did not interest Einstein. Einstein apparently saw no material for a theoretical physicist to speculate on the evolution of physics and its problems in the vigorous flow of discoveries of new elementary particles, new fields (electron-positron, meson, etc.), or interactions of the new types. It is no accident that in a book devoted to the evolution of physics there is no discussion of the problems of nuclear physics; the authors themselves ascribed it to the fact that they are interested only in the general ideas of physics. The experimental material

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*Ya. B. Zel'dovich and I. D. Novikov, Relativistic Astrophysics. I, UFN 84 (3), 377 (1964), Sov. Phys. Uspekhi 7, 763 (1965).

of nuclear physics did not fit in their scheme of the evolution of physical ideas. According to the evidence of I. E. Tamm, Einstein's maintained in a private conversation that "the very fact of the existence of the electron should be sufficient for the construction of the principles of the general theory of elementary particles."* If this were so, then from this it would follow that the general theory of elementary particles could have been constructed in 1905—the time when relativity theory appeared. And the tremendous new material, which was accumulated by experimental physics during the last decades—the discovery of many new elementary particles, including antiparticles, the discovery of their mutual transformations and their new properties (for example, parity, strangeness) turns out not to have any bearing on the general theory of elementary particles!

The foregoing statement by Einstein, as well as his attitude towards the discoveries of modern physics, characterizes his rationalistic method, his extreme unilateral purposefulness, his striving to find a formal method of eliminating from physics the electron, of which he stated in the conversation mentioned by I. E. Tamm, that he always regarded it as a "foreigner in the country of classical electrodynamics" and indeed, these ideas were advanced by Einstein already in 1909 in an article "Concerning the Modern Status of the Problem of Radiation."

Outstanding physicists, friends of Einstein, who greatly admired him as a scientist, were skeptical of his attempts to create a unified field theory. Thus, from a scientist in which they saw earlier a "leader and standard bearer," Einstein turned into an isolated scientist, who not only followed his own way in physics but also denied many of the principal ideas of modern quantum physics, although he admitted its tremendous factual accomplishments. He negated precisely those ideas, to the development of which he himself contributed so vigorously in earlier years.

His isolation was recognized by Einstein himself, as he noted many times in correspondence with friends, the greatest contemporary physicists. He also realized well the difficulties of his path. Many times Einstein was inspired with the hope that he had finally attained his purpose, and the unified field theory was created. But each time he himself found flaws in his work and again undertook the difficult research. This continued for many decades. What strength, what conviction and will power must have been shown by the aging scientist in this stubborn work which did not yield the desired results!

Here is how Einstein himself described the results of this work in "Autobiographical Notes" (March, 1955): "From the time of completion of the theory of gravitation 40 years have now elapsed. They were almost exclusively devoted to efforts to derive, by generalizing the theory of gravitational fields, a unified field theory, which could serve as a basis for all physics. Many have worked towards this purpose. Some hopeful attempts I subsequently discarded. But the last ten years have finally led to a theory which seems to me natural and full of hope. I am unable to state whether this theory can be regarded as physically valuable; this entails still unsurmountable mathematical difficulties, which, incidentally, are encountered in the use of any nonlinear field theory. In addition, it seems doubtful in general whether it is possible to derive from field theory the atomistic structure of matter and radiation, and also quantum phenomena. Most physicists answer without any doubt a convincing "no," since they assume that the quantum problem must be solved in principle in a different manner. Be it as it may, we are left in consolation with the words of Lessing: the striving for the truth is more valuable than its guaranteed possession."

Thus his own last estimate of his efforts to derive, by generalizing gravitational fields, a unified field theory, which could serve as a basis for all our physics. This estimate was given by Einstein a month before his death. It does not stimulate physicists to follow his path.

14. CONCLUSION

We present a brief summary. Einstein's theory of cognition, developed by him on the basis of a unique treatment of his own successful construction of the theory of relativity and the generalized theory of gravitation, was not justified. Highly valuing the significance of theory as an indivisible unit, rising in this respect above the gnosiology of positivism, Einstein was unable to extract fully from this idea its deep meaning, and even impoverished it, since he did not understand the logical and genetic connection between theory and experiment. His main premise, that there is no way from experiment to the construction of the theory, remained incorrect. This premise led Einstein not only to deny the main ideas of quantum physics, but to create an artificial barrier to the recognition of a new type of relation in physics. It led to the development of a rationalistic theory of cognition and to the formulation of an unrealizable program for the development of physics.

Einstein himself, however, never succumbed to despondency. He firmly believed in his way and hope never left him. This steadfastness of spirit can be learned from Einstein.

Steadfastness of spirit. . . one cannot help but be overcome with deep respect for Einstein as a human being. Einstein's high moral purity; his deepest devotion to science; his unassuming personal life; his

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*I. E. Tamm, Einstein and Modern Physics, UFN 59 (1), 5 (1956). This statement pertains apparently to the end of the Thirties.

sincere scorn for fame, external well-being, money; his spiritual relation to persons and the continuous readiness to help morally and materially all those of whose honesty he was convinced; his ardent dislike for bureaucratism of any kind; his love for freedom and the fearlessness with which he hurled accusations against the leaders for forgetting the interests of humanity; his persistent struggle against war as a means of solving disputes between nations and especially against atomic war—all this shows in him a man of great and noble spirit. Yet for all these qualities he was extremely individualistic and solitary. His selfless service to science made him into a strange eccentric in the eyes of the citizens and businessmen of the capitalist world among whom he lived; his musings on the present and future of humanity were combined in him with naivete in social-political affairs; in his philosophy he was subject to criticism from all sides. And even in his own element—in physics—he remained alone in his declining years.

The overwhelming majority of physicists did not follow Einstein to the end. Life caused them to seek a different line of development of physics. But in their eyes Einstein remains as before the great physicist of our time. What he did for physics in its critical period will always retain its significance in its development. We shall not call him an "unprincipled opportunist" in philosophy. This designation is deserved by those who compromise with their conscience. Einstein was not such. He was convinced of the correctness of his way, but we cannot help but state that in the theory of cognition he was in error. In developing it he leaned on too narrow a base of his professional experience and interpreted it too one-sidedly. This exerted also an influence on his understanding of the ways of further development of physics. The accusation which in his time he addressed to Mach can be returned to him himself: philosophical preconceptions and prejudices hindered him also in a correct determination of the ways of cognition and the prospects of the development of physics.

Einstein's scientific path is very instructive. It shows the necessity for a deeply professional development of gnosiological problems arising during the course of development of modern natural science. No matter how complicated these problems are, they can be resolved, in spite of Einstein's understanding, from the point of view of a unified philosophy, the basis of which is the recognition of the external world and the correct interpretation of ways of its reflection in cognition.

This unified theory—materialism, was raised to the level of a genuine science by the works of Marx and Engels, and in our century by those of Lenin. The very rich experience in the development of society and natural science teaches us that the method of philosophical materialism is equivalent to the real process of cognition. We need not seek a new gnosiology. However, we must penetrate deeper and more boldly into the nature of the problems which are posed by modern natural science, and further develop a materialistic gnosiology as bidden by our great teachers.

Translated by J. G. Adashko