ALBERT EINSTEIN'S Philosophical Views and the Theory of Relativity

D. P. Gribanov

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Д. П. Грибанов

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Preface

This book aims to bring out the place and role of philosophical science in the creation of the theory of relativity. That calls (a) for determination of real substance of Einstein's philosophical opinions, since he has been numbered in practice in all philosophical schools and trends, and (b) for clarification of the sources that influenced the shaping of his outlook. These sources were the works of the founders of classical mechanics and electrodynamics, separate propositions of the natural sciences, and the many philosophical works that Einstein was acquainted with. For this purpose I analyse his attitude to the ideas of ancient thinkers, to metaphysical materialism, to the works of Hume, Berkeley, Kant, and Mach, and to neopositivism, etc. An integral idea of Einstein's philosophical outlook can be reconstructed from his separate statements.

When surveying the scientific and philosophical premisses of the theory of relativity, I include the doctrine of matter in them, in addition to those of time, space, and motion (as is usual). I analyse the evolution of this category and also elucidate Einstein's role in affirming the idea of the existence of matter in the form of a field as well as substance. I thereby show that the sources of the theory of relativity are linked with his study of matter in its different forms and connections. The theory of relativity thus has its roots in the experimental and theoretical generalisations of Faraday and Maxwell, and not just in the experiments of Fizeau, Michelson, and others.

I have also demonstrated the role of philosophical ideas in Einstein's scientific work when creating the special and general theories of relativity. I elucidate the philosophical importance of relativistic physics, and investigate the epistemological roots of the distortions of its content.

There is a large literature on problems of principle of the theory of relativity. In that regard I draw attention to the philosophical conclusions of scholars in other countries and

analyse the Soviet literature on the philosophical problems of the theory of relativity.

In my work on the book I started from the fact that Einstein was influenced by various philosophical schools. He had to assimilate a great philosophical culture in order patiently to seek out in this heterogeneous philosophical atmosphere, and find the road leading to a new, imposing scientific picture of the world. Allowing for the lack of rigorousness in his ways of expressing philosophical ideas, his use of a peculiar apparatus of categories, his liberties and contradictions in the use of some terms, prompted me to approach analysis of his classical works all the more painstakingly. When one is analysing Einstein's philosophical views one has constantly to remember that he was a physicist and not a philosopher, and at the same time to rejoice that such a scientific genius, for all that came to philosophy, though shyly and sometimes groping, and found ideas in it adequate to reality.

I have not tried to trace how some of the propositions of the theory of relativity evolved in the history of physics. My main aim has been to study its classical foundations laid by Einstein. That approach has brought out most fully how far philosophical ideas influenced his creative quest.

My conception was moulded by the influence of two sources. In the first place I used Einstein's original works. And then, later, the philosophical methodological literature devoted to analysing and developing the theory of relativity. I did not try, when studying the latter, to appraise it. That path would lead to historical inquiries. In my book I employed the problems approach. Not having the space to cite the many works that influenced me in one way or the other, I have included them in the bibliography.

Part One

Philosophical Problems of the Theory of Relativity in the World and Soviet Literature

The relationship of materialist philosophy and natural science is an inner necessary condition of their development. From the time of their rise philosophy and natural science have been inseparable links in the chain of understanding the objective world. Science developed under the influence of philosophical knowledge. Philosophical science in turn could not develop *a priori,* without connection with reality.

At each stage of the development of knowledge the forms of this interaction have altered. The fullness and depth of the connections reflect the degree of philosophical analysis of the problems of natural science.

The theory of relativity is one of the most fundamental theories of nature that still, at the present time, calls for further philosophical substantiation. Its mathematical and physical aspects do not give rise to any substantial disagreements among researchers. It has a leading position by right among the achievements of the advanced physical thought of the twentieth century. It has had broad application in many experimental programmes. As regards its philosophical significance, however, especially as regards Einstein's outlook, the polemic in the world literature has not died down; and is characterised by the most contradictory and mutually exclusive appraisals. Einstein's ideas were sometimes linked with the most improbable philosophical conceptions.

It is sufficient, to become convinced of the permanent interest in the theory of relativity and the personality of Albert Einstein, to make acquaintance with work published in the world philosophical, methodological, and physics literature. Today, as at the beginning of the century, when the theory of relativity was created, many philosophers have tried their utmost to interpret it in the spirit of their philosophical systems, interpreting relativistic views of the world, and Einstein's views of the paths of development of knowledge, from the essence of their own outlook on the world. As Bertrand Russell justly remarked:

> There has been a tendency, not uncommon in the case of a new scientific theory, for every philosopher to interpret the work of Einstein in accordance with his own metaphysical system, and to suggest that the outcome is a great accession of strength to the views which the philosopher in question previously held.[1]

Many philosophers, including Bertrand Russell, have in fact used the ideas of the theory of relativity for their own ends. Russell, for example, tried to substantiate the adequacy of logical positivism and the methodology of relativistic physics. One of the first spokesmen of Western philosophy, perhaps, to turn to the authority of the theory of relativity was Samuel Alexander, who tried to find something in common between it and his own philosophical conception.[2]

Soon, after Einstein completed his work on the general theory of relativity, Alexander began to read a series of lectures on it which continued throughout 1916-18. In them he stressed that the theory's ideas were adequate to the basic tenets of objective idealism. His lectures were published in a large edition under the title *Space, Time and Deity* and were taken as philosophy's last word on interpretation of the theory of relativity. It followed from Einstein's theory, Alexander stressed, that time and space, and not matter, were the basis of the Universe, and the substance from which material things were constructed. 'All things, no matter what their qualities,' he wrote, 'are bits of Space-Time.'[3] The elements of space -time thus seemed to him to be ideal substances and not physical ones.

Philosophers apart, the content of the theory of relativity was widely interpreted in an idealist spirit in its initial period by eminent scientists. The most authoritative of them were Sir Arthur Eddington and Sir James Jeans. The former's analysis of the theory led him to the conclusion that space and time 'are not things inherent in the external world'.[4] According to him physical quantities were above all the result of measurements and calculations. The laws of the theory of relativity were essentially only the result of Einstein's mental inventions and in general did not reflect objective processes of nature.[5] 'Reality is only obtained when all conceivable points of view have been combined.'[6]

Roughly the same ideas were also expressed by Jeans. In his view the theory of relativity led to the notion that

> matter as ordinarily understood, the matter of solid objects and hard particles, has no existence in reality, and only appears to exist through our observing non-material things in a confused way—through the bias of our human spectacles.[7]

The theory of relativity, according to him, reflected a certain general picture of matter 'which must be more mental in character'.[8]

Among the critics of materialism who appealed to relativistic physics, the American philosopher Philipp Frank gained special popularity. He recognised that the mechanical picture of the world that had predominated in the nineteenth century had considerably stimulated a movement of philosophical thought toward materialism. But now, in his view,

> the impression gained ground that this mighty trend was stopped by twentieth-century physics, especially by the theory of relativity and quantum theory. It was obvious to many authors that the trend toward materialism had been stopped, and a sharp turn toward idealism had been taken.[9]

To substantiate his statement he relied on the new theory of matter, time, and space. 'In the theory of relativity,' he wrote, 'the conservation of matter no longer holds; matter can be converted into nonmaterial entities, into energy;'[10] and 'all statements about length or duration are no longer statements about "objective time or space", but are statements about our impressions.'[11] All that, he considered, reduced the role of matter to the minimum.

Analysis of the literature on relativistic physics published in recent years in the West also indicates its heterogeneous philosophical character.

Among those writing on this theme there is a group who hold to a religious-mystical interpretation of physical science. They include the American physicist H. P. Stapp, who tries under the influence of creationist views, to find a way of 'reconciling' the theory of relativity with the facts of our direct experience. He admits, moreover, that he resorts to the ideas of the improved ontology of Whitehead and Heisenberg. Stapp categorically states that 'the physical world ... is a structure of tendencies in the world of mind'.[12] Mind, in his view, is nothing other than an aggregate of 'creative acts', each of which 'is a grasping, or prehension, of all that has been created by prior acts in a novel but unified way'.[13] The creative activity within mind is 'physics'. By their nature 'creative acts' are strictly consecutive, which contradicts the theory of relativity (which insists on their dependence on the frame of reference). The possibility of their transmission at a velocity greater than that of light also contradicts his theory. Whitehead converted the propositions of the theory into 'dogmas' and introduced them into his philosophical ontology of the world process of creation. But he did not notice that the theory of relativity does not assume any pro-

cesses in general; it prescribes a static vision of reality.[14] In correcting his ideological predecessors Stapp calls for an orientation on quantum mechanics that would be able to incorporate the elements of mind in modern physics within the context of a consistent ontology of the world process of creation.

There is a certain distinguishing feature about those of these works that attempt to find something in common between the tenets of modern physics and ancient Oriental mystic ideas. Thus the American writer Michael Talbot, a physicist by training, has published a book *Mysticism and the New Physics* in which he tries to prove that physics has more and more merged, as it developed, with mysticism, which had been quite fully reflected in ancient philosophy. He came to that conclusion on the grounds that

> not only do our fundamental assumptions inhibit us in our understanding of physics and metaphysics, but language itself becomes a hindrance. Both physics and metaphysics have reached a point where *language no longer imparts any information.*[15]

He drew the conclusion that the theory of relativity struck the question of objectivity and determinacy from the agenda of modern science, as quantum mechanics did later with ideas of determinacy and determinism. In his view reality has been superseded by mathematics and the Einsteinian 'observer' by the Wheeler 'participant', by which consciousness has penetrated physics. Since certain ancient thinkers represented consciousness as a kind of field, Talbot sees a link in that between ancient mystics and the modern theory of field physics.[16] In his view the lines of force of the curved space-time gravitational field have something in common with the religious doctrine of the hairs of Siva. In the same way he sees a link between the writing of Sakti and the theory of modern physics about black holes, between Nada and Bindu and the notions of physics about waves and corpuscles. In short, in his view,

> the new physics is offering us a scientific basis for religion.... It is a religion based on the psychology of the human consciousness indeed, on the psychology of the entire universe as a conscious force acting upon itself.[17]

There are similar ideas in the works of the American physicist Fritjof Capra, who takes the stand that both the ancient mystics and modern physics have introduced first an 'observer' and then a 'participant' and consciousness into the theory of the Universe. But, he writes,

> in the twentieth century ... physics has gone through several conceptual revolutions that clearly reveal the limitations of the

> mechanistic world view and lead to an organic ecological view of the world which shows great similarities to the views of mystics of all ages and traditions. The universe is no longer seen as a machine, made up of a multitude of separate objects, but appears as a harmonious indivisible whole; a network of dynamic relationships that include the human observer and his or her consciousness in an essential way. The fact that modern physics, the manifestation of an extreme specialization of the rational mind, is now making contact with mysticism, the essence of religion and manifestation of an extreme specialization of the intuitive mind, shows very beautifully the unity and complementary nature of the rational and intuitive modes of consciousness... Modern physics can show the other sciences that scientific thinking does not necessarily have to be reductionist and mechanistic, that holistic and ecological views are also scientifically sound.[18]

Capra tries to give the ideas of ancient mystics the rank of the methodological basis of modern physics, stressing that

> an increasing number of scientists are aware that mystical thought provides a consistent and relevant philosophical background to the theories of contemporary science, a conception of the world in which the scientific discoveries of men and women can be in perfect harmony with their spiritual aims and religious beliefs.[19]

It is not only philosophers of a religious bias that give a subjective-idealist interpretation of modern physics from the standpoint of the Einsteinian concept of the 'observer'. We would note in this connection the West German Neokantian school of 'practical philosophy'. This trend starts from the idea that modern physics can only develop if it includes the element of the 'observer' in the description of phenomena of nature. Individual authors, moreover, claim that this orientation follows from the author of the theory of relativity himself, Albert Einstein.[20]

Another member of this school, Michael Drieschner, says that modern physics made the category of objective reality very abstract in the course of mathematisation, since time was linked with space in the special theory of relativity, and matter was reduced to space by Einstein's successors.[21]

The conventionalists also come to an absolutising of the role of the subjective factor of the 'observer' in understanding nature, and to an isolation of the concept of time from reality, reducing it to an *a priori* category. One of them, J. P. Hsu, claims that the conception of time developed by Einstein in the special theory of relativity does not correspond to physical knowledge since it is based on conventions rather than on empirical, objective facts. Among conventions he named the

proposition that the velocities of light rays spreading in opposite directions are equal, and the statement about the isotropism and invariance of the velocity of light. In his view physical theory should set out from an analysis of the categories of space and time. He suggests introducing a concept of universal time which, however, differs both from the Newtonian absolute time and the Einsteinian relativistic concept. The introduction of such a concept inevitably calls for rejection of the convention that the velocity of light is a constant in all systems. Hsu claims that it is a constant only in a frame of reference that the experimentor chooses. It will readily be seen that his approach comes into contradiction with the principle of relativity and leads to isolation of the category of time from objective reality.[22]

Conventionalists, like members of other philosophical trends, try to prove the heuristic character of their philosophy. For that purpose they employ the achievements of Henri Poincaré in physics. On that score the conventionalist Jerzy Giedymin writes that since Poincaré shared the ideas of conventionalism when setting out his philosophical views (he, of course, was at the threshold of the development of the theory of relativity), it would be more proper, in contrast to the generally accepted views of scientists, to consider conventionalist ideas as nothing else than the methodological foundation of modern physics.[23]

Many authors have devoted works to an analysis of Einstein's philosophical opinions. Each of them, however, misinterprets the real content of one and the same views, and as a rule in the spirit of his own philosophical convictions. Thus Einstein's statement that our knowledge of reality is the result, not of passive perception of sense data, but of their active reconstruction in the human mind, is singled out as positivist by Paul Feyerabend, an irrationalist in the field of the methodology of science.[24]

Einstein, of course, expressed an idea of the existence of a 'cosmic religion', his own kind of scientific fanaticism, which helped him in scientific creation. But the West German physicist Harald Fritzsch claims that the concept of a 'cosmic religion' meant Einstein's belief in the existence of 'immutable laws of nature' independent of 'everyday life'.[25]

The reflections of the American philosopher E.M. Mackinnon on Einstein's philosophical views merit attention; in my view he reflects them quite adequately. He recognises that Einstein's outlook was formed mainly through the influence of his scientific work. In Mackinnon's view Einstein saw the goal of science as ensuring

> a coherent world view based on general laws which have an objective validity. The confirmation or falsification of scientific laws is ultimately a matter of experiment and observation. Between these two positions, both of which Einstein had explicitly defended, there exists a logical gap. Experiment and observation test particular consequences of hypotheses introduced as laws, not their objective validity in a strong, or ontological, sense.[26]

He stresses that Einstein made attempts to bridge this gap and saw that other scientists, too, were trying to overcome the disparity: Mach and Pearson by the principle of the economy of thought; Poincaré by the idea of conventionalism; Duhem by introducing the proposition that an explanatory system consists of a theory (in its hypothetical-deductive model) buttressed by an auxiliary hypothesis.[27] But they did not satisfy Einstein. 'He defended causality as a principle of nature, not merely of man's reasoning about nature', Mackinnon writes.[28] Einstein supposed that

> the phenomena observed through our instruments must be explained through the underlying reality objectively responsible for the phenomena. The only way of representing such an underlying physical reality that has any real hope of success is through mathematical forms that are simple, natural and aesthetically pleasing.[29]

Mackinnon's book compares the theoretical, cognitive positions of Bohr and Einstein.

> Einstein took theories as cognitive units seriously. Bohr's analysis of meaning focused on key ordinary language terms and the proper modes of restricting and extending them. Einstein interpreted general scientific laws as expressions of, or approximations to, relations obtaining in reality. Bohr repeatedly manifested a willingness to sacrifice such general principles as energy conservation. Einstein interpreted the history of science as a series of conceptual revolutions. Bohr interpreted the same breakthroughs as rational generalizations of earlier stages of development.[30]

Many works on relativistic physics analyse the content and paths of Einstein's scientific work. The book of the American historian of science Gerald Holton is characteristic in that respect. He came to the conclusion that Einstein's methodology and outlook were wholly permeated by diametrical opposites. The image of Einstein, he stresses, combines the wisdom of an old man and a childish directness, personal reticence and a bent for social activity, an inclination to rationality and clarity of logical constructs, and irrational intuition. At the centre of Einstein's scientific work were such opposites as the continuum, expressed in the development of the concept

of field, and quantum theory with its ideas of atomistic discreteness. Einstein not only worked with contradictory concepts but could

> deal with, use, illuminate, transform the existence of apparent contradictories or opposites... One need only think of his bridging of mechanics and electrodynamics, energy and mass, space coordinates and time coordinates, inertial mass and gravitational mass.[31]

Attempts have been made in Western philosophical literature to find something in common between the philosophy of Hegel and Einstein's work. Samuel Sambursky, for example, claims that Hegel was the first philosopher to anticipate the theory of relativity.

> Through its double negativity the point is given as a spatio-temporal entity, and is thus defined by Hegel as *place* (Ort), as the posited identity of space and time, as a posited contradiction. Hegel's definition of Place as a 'Spatial Now' ... is indeed more than an ingenious formulation; it is an anticipation of the point in the fourdimensional relativistic universe.[32]

Motion, according to Hegel, Sambursky writes, is the disappearance and rebirth of space in time and of time in space, negation of place by another place. Matter appears to Hegel as a transition from the abstractness of space and time to concrete existence, from ideality to reality. The unity of the space-time characteristics of matter are manifested, according to Hegel, in gravitation. Gravitation expresses itself

> on the one hand ... by the *substantiality* of matter, its being-for-itself, which prevents one body from taking the place occupied by another, and on the other hand ... by the *striving* of a body towards a point *outside* itself, by the tendency of matter of being *self external*.[33]

When analysing Hegel's critique of the Newtonian interpretation of motion and force, and examining Hegel's contribution to discussion of the problem of gravitation, Sambursky claims that

> both Hegel and Einstein have one idea in common, namely that the Newtonian *dualism* of inertia and gravitation must be abolished and that the planetary motions must be explained as *free* movements. In this respect we see indeed Hegel at the threshold of general relativity.[34]

To conclude this brief survey of the Western philosophical literature I would like to cite the general conclusions drawn from the analysis of the theory of relativity in the anniversary monograph *Einstein: The First Hundred Years* dedicated to the centenary of Einstein's birth. It was concluded in it that 'Ein-

stein's special theory of relativity had rendered impossible the classical notion of matter';[35] that 'Einstein's theory completely undermines the natural distinction between motion and that which moves';[36] that the idea of an 'inventive universe'[37] predominates in Einstein's views. The contributors to the book try to find something in common between the relativistic and theological models of time.

> Time ... is an integral and basic constituent of nature, an aspect of space-time. Hence on any theistic view, it has to be regarded, like the rest of the created world, as owing its existence to God, as St. Augustine perceived.[38]

In their view the new point that scientific cosmology introduced into theology is the idea of the creation of the world from 'nothing'—

> this is the realisation that the cosmos which is sustained and held in being by God is a cosmos which has always been in process of producing new emergent forms of matter. It is a world which is still being made.[39]

Analysis of just a few works thus shows that there is no unanimity in the philosophical interpretation of the theory of relativity and of Einstein's outlook. Many of the conclusions contradict one another, and not all of them correspond to reality. Such interpretations, especially by certain well-known scientists whose influence on science has been authoritative, have evoked uneasiness among their fellows who hold a different view, since they could be passed off, and often are, as a kind of methodology of physics. That has been well understood by representatives of both the idealist and the materialist trend in philosophy.

Dialectical materialist philosophy has sound traditions of surveying both the methodological consequences of relativistic physics and its founder's ideological orientation. Yet, in spite of the immense work done by Soviet physicists and philosophers in discussing problems of the theory of relativity, separate aspects of it, and especially the philosophical one, are still contradictory.

In the early twenties two opposing trends were already noticeable in philosophical interpretation of the theory of relativity. Most Soviet scientists and philosophers held the view that this theory reflected real processes of the objective world, and did not disagree with dialectical materialism but confirmed its tenets. At the head of this trend were the physicists S. I. Vavilov, A. F. Joffe, Y. I. Frenkel, Igor Tamm, V. A. Fok, V. K. Fredericks, A. A. Friedman, and others, and the philosophers S. Y. Semkovsky, B. M. Hessen, and others.

At the same time a small group of scientists arose, and functioned for a long time (the physicists N. P. Kasterin, V. F. Mitkevich, A. K. Timiryazev, and the philosopher A. A. Maximov), whose estimate of the theory of relativity was inconsistent, confused, and ultimately boiled down to denial of its physical content and philosophical value and a claim that it was not consistent with the principles of dialectical materialism.

While employing the terminology of Marxist philosophy, these last-named scientists in fact analysed the data of physics from a standpoint of metaphysical materialism. They agreed essentially with the conclusions of a number of Western philosophers that the theory of relativity was aimed against the objective character of the laws of nature, and mainly on that basis criticised the theory.

Soviet physicist A. K. Timiryazev, for instance, analysing Einstein's book *On the Special and General Theory of Relativity* (which was published in Soviet Russia in 1921) admitted that no scientific theory had ever enjoyed such popularity among very broad circles of the intelligentsia as the theory of relativity. The interest in it, in his view, was due to the fact that

> some consider it a brilliant display of new, fresh scientific thought introduced into science by a convinced revolutionary who has openly sided with the struggling working class in recent post-war years. Others welcome this theory also as a great revolution in science and see its main achievement in its dealing a 'death blow' to materialism![40]

He was impressed by Einstein's admission that the results stemming from the theory of relativity could be obtained in another way, relying on prior knowledge. He also stressed

> that Einstein himself, though he sometimes expresses ideas that deviate from the point of view of materialists' philosophy, does not wage a campaign against the foundations of materialism.[41]

And he admitted that

> in Einstein's theory, there is much of great value apart from the theory of relativity. His attempt to substantiate the theory of universal gravitation is of immense interest, but it is not directly linked with the principle of relativity.[42]

A. K. Timiryazev, however, tried to find loopholes in the theory of relativity. He saw one of them in the fact that 'it is very well insured against experimental checking'.[43] Relativistic effects, of course, only manifested themselves quite fully at velocities close to that of light, for which the experimental techniques of the time were not ready. That fact forced him

to take a sceptical attitude toward the theory; yet these results, he stressed, could be obtained by other means, as Einstein himself had noted.

In addition, Timiryazev remarked, the principle of relativity on which Einstein based his theory, allegedly did not reflect objective processes; consequently, he concluded, the relativistic effects or new properties of time and space also did not correspond to objective reality. Einstein had had to assume them in order to save the principle of relativity.

> We have had to invent the changing rate of the clock, which we cannot check [he wrote], in order to impose Einstein's main proposition onto nature and so as not to fall into contradiction with the facts.[44]

The next weak spot in the theory, Timiryazev claimed, was Einstein's rejection of Euclidean geometry, which we use in our practical calculations and constructs, including the most intricate technical structures. He did not understand the point here that it was not a question of Einstein's having rejected Euclidean geometry in general but of the inadmissibility of making an absolute of it. Einstein had shown by his theory that Euclidean geometry was a limited theory.

Timiryazev also did not see that the non-Euclidean geometries on which Einstein had relied reflected real processes. In his view they were simply the fruits of imagination.

> In order to uphold his proposition about the invariability of the laws of nature in regard to the state of the movement and the observer studying them, Einstein was forced to substitute one of the imaginary constructs that have been built by the latest geometricians, including Lobachevsky, and which have great theoretical interest, for the Euclidean geometry we know. Einstein attributes real meaning to these imaginary constructs.[45]

This mechanistic approach to relativistic physics led Timiryazev to an incorrect evaluation of the physical content and philosophical significance of the theory of relativity, and to a distortion of Einstein's outlook. He wrote later that when

> we go deeper into Einstein's theory, and in particular into its philosophical consequences, which the author himself is trying to some extent to deduce, but even more so his often inordinately zealous admirers and followers, we immediately feel that we are in a realm of purely idealist philosophy. Einstein's philosophical views are largely diametrically opposed to the materialist philosophy of Marxism.[46]

And here is the view of the philosopher A. A. Maximov who, like Timiryazev, held an indeterminate, eclectic position from the very outset in regard to the theory of relativity

and its creator Einstein. Maximov also could not hide the popularity of the theory among scientists. 'The principle of relativity,' he wrote, 'has chafed a sore place in science and torn its dilapidated "absolute" rags from it, and so exposed its open flaws.'[47] In another article he wrote that

> the principle of relativity was fated in Russia, too, to become one of the fashionable new trends in science, very widespread in different strata of the population... The principle of relativity arose in connection with the content of science having outgrown its old forms, and is trying to discard them, i.e. it is a revolution of sorts in science.[48]

Maximov could not help seeing that the theory of relativity touched on matters that had long bothered advanced physical thought. He recognised Einstein as the outstanding scientist of the twentieth century.

> The problems on which the theory of relativity touches [he wrote] are the main ones for science, and various scientists have been coming close to a solution of them for a long time; Einstein's approach is only an episode in science's chain of development. The fact that it is Einstein's theory of relativity that has merited so much attention rests not only on the fact that Einstein himself is a profound and serious thinker, a brilliant mathematician, etc., but also on the features mentioned above of the age, in which we live.[49]

Maximov drew attention to the point that relativistic physics brought out most fully the realistic content of mathematics.

> Only the work of the advocates of the theory of relativity has provided firm ground [he noted] for considering all mathe matics in general, and not just geometry, a part of the sciences of nature, i.e. above all a part of physics; hitherto mathematics in general, and geometry in particular, have developed sponta neously and without any awareness that geometrical problems are in essence problems of study of the physical, spatial properties of matter.[50]

Maximov cautioned against the attempts that certain scientists and philosophers were making to assert the relativity of our knowledge in general and to boost this relativity to the rank of an absolute of sorts, against rejection of the objective content of science, and also against other distortions of the essence of the theory of relativity. He gave Einstein his due for developing the theory of time and space and criticising the absolute character attributed to them by Newton. 'His complete rejection of the notion of absolute space and time must be recognised as Einstein's outstanding service,' he wrote.[51] He attributed immense importance to Einstein's ideas about the new correlation of various fields (geometry and physics; the two

of them and astronomy), about the new understanding of the essence of gravitation, inertial and gravitational mass, the mathematical working out of the relativity of time and space, and so on.

Nevertheless, in spite of a correct evaluation of the theory of relativity, Maximov made many mistakes when analysing it, around which discussion raged for a long time. First of all he declared that, though Einstein was the man whose deeds had embodied the new possibilities latent in physics over a long period, and so stimulated its vigorous development, the method of his research was unacceptable to Marxists. He accused Einstein of giving primacy to thought when treating the problem of the relation of thought and experiment in scientific work. 'Not reality,' he wrote, 'but the free creations of the mind possess absolute authenticity, according to Einstein.'[52] He drew that conclusion from separate fragments of Einstein's work *Geometry and Experience*, in which the latter had dealt with questions of the origin of the axioms and concepts of geometry, such as 'point', 'circle', 'straight line', etc., and their relation to reality.

Maximov promoted his own conclusion about Einstein's views on the relationship of the products of thought and reality to the rank of the method by which the theory of relativity had allegedly been created. Einstein's mistake, Maximov considered, was that he had not followed the path taken by Lorentz and Fitzgerald. In his opinion, Einstein should first have explained the mechanism of light, assuming the constancy of its velocity, and inquired into the essence of the ether; instead Einstein had in general discarded the notion of a material vehicle of electromagnetic processes, the concept of ether'.[53] Maximov accused Einstein of having 'illegitimately' brought in the principle of relativity and the principle of the constancy of the velocity of light, and on that flimsy basis (in Maximov's opinion) had built the mathematical structure of the special theory of relativity, which led to the Lorentz transformation equations, which brought out the mathematical dependence of time and space on uniform, rectilinear motion. Maximov suggested that

> the relativity of time and space was obtained not through experimental investigation of the properties of matter but as a result of mental operations, of an assumption that in itself is not only not indisputable but should itself have been explained. Why does the velocity of light remain invariable? In what does the process of light consist in general? What material medium is it a property of? The special theory of relativity has not

only not provided an answer to that, but has even excluded and forbidden any answer whatsoever.[54]

Clearly, following Maximov, one could make the same accusation against Newton, who discovered the law of universal gravitation without studying the substance of gravitational processes; and likewise against the scientists who gave humanity electricity, radio, and television without disclosing the structure of the electron, the mechanism of the operation of electromagnetic waves, and so on.

Maximov also made similar complaints against Einstein's theoretical method when he was creating the general theory of relativity. He claimed that Einstein had constructed the general theory, like the special, speculatively, without relying on experimental data. However, Maximov stressed, '*mental experiment* flourished' in Einstein's scientific work:

> the mental assumption of observations of velocities vastly remote from everything accessible to us, mental juggling with clocks and determination of simultaneity, mental demonstration of the equality of inertial and gravitational mass.[55]

Neither the principle of relativity in the special theory nor general relativity corresponded to reality in Maximov's opinion, but was the result of Einstein's mental operations.

> The requirement of universal relativity [he wrote] is not substantiated with Einstein, apart from the requirement of his mind, and is imposed on nature in spite of everything known in it.[56]

Maximov saw the 'unscientific' nature of the principles of the constancy of light, and of universal relativity, as well, in the point that recognition of their universal character reflected in itself an absolute invariability, which contradicted the laws of nature.

> Having asserted the constancy of the velocity of light as an axiom, Einstein erected a metaphysical concept of absolute immutability in physics, which contradicts everything known to us about nature.[57]

Einstein's introduction of the proposition of the equivalence of inertial and gravitational mass into the general theory of relativity was also physically unjustified (in Maximov's view) since it signified ambiguity. Apropos of that he wrote:

> Einstein suggests that we also call these forces (forces of inertia *D. G.*) *forces of gravitation*, operating also proportion ally to masses and explain the same phenomena by them. Do we gain anything by this ambiguity? Nothing except a hypothesis of the *identity* of inertial and *gravitational mass*; at the same time

> we lose the unequivocal explanation of phenomena of nature. We can accept the hypothesis of gravitation given by Einstein as a hypothesis and subject it to experimental checking at the first opportunity, but we cannot accept the whole theory, or rather the philosophy of an explanation of natural phenomena that confirms ambiguity in physics, because the hypothesis mentioned, still not demonstrated by anyone, serves as one of the ambiguous explanations.[58]

This theory of Einstein's referred, of course, to the connection of time and space, and the dependence of their properties on motion and the distribution of mass. He was able, by means of it, to explain the bending of light in a gravitational field, and the shift of the perihelion of Mercury. For Maximov all these theoretical conclusions were doubtful since

> the dependence between space, time, motion, and other states of matter was only born from Einstein's head. The proofs of the bending of light rays in a gravitational field, and the explanation of movement of the perihelion of Mercury alleged to bear out Einstein's theory would not be taken as proofs, until it was shown that Einstein's axioms themselves were based on experiment and conformed with it, the more so that these facts are explicable in other ways than by Einstein's theory.[59]

He considered that the reason for Einstein's errors in the theory of relativity lay in the latter's philosophical position, which he classed as an idealist philosophical trend. 'While Einstein has his scientific-philosophical origin in Mach, his idealist dualism borders directly on Neokantianism,' he wrote.[60]

The scientists mentioned above, and several others, were essentially influenced in their appraisal of Einstein's theory of relativity and outlook by Western philosophers and physicists whose works had been published in Soviet Russia. In Felix Auerbach's *Space and Time*, Henri Bergson's *Durée et Simultanéité*, Ernst Cassirer's *Zur Einsteinschen Relativitätstheorie*, Sir Arthur Eddington's *Space, Time and Gravitation*, and other works, translated in the USSR, we find ideas that were afterward repeated in several Soviet publications, in which the theory of relativity was presented as subjectivist, and its author as a Machian, Kantian, conventionalist, and so on.

Russian followers of Mach's philosophy—P. S. Yushkevich, V. A. Bazarov, A. A. Bogdanov—also introduced a certain confusion. Yushkevich, for example, wrote:

> the whole theory of relativity is permeated with this spirit of conventionalism, and conventionality. It ... therefore does not claim to be the sole, adequate expression of reality. Other descriptions of the external world are possible, of equal standing in themselves. But they would be less simple, less visible, less lucid.[61]

In his view the theory was equatable with the ideas expressed by Mach and his followers. Its propositions did not reflect real processes of nature, he claimed, and were only symbols for their more convenient description. Apropos of that he wrote:

> As for the substance of physical theory, does it still need to be proved, after the work of a whole generation of philosopher scientists like Mach, Poincaré, Pearson, Duhem, and others, that it has always been a system of symbols that translate as fully as possible, the structural relations of experimental physics when taken separately? A physical theory, like any other, is a formal, deductive system, on which demand, common to all deductive systems, is made to be clear and economical in its premisses and axiomatics, and to be rigorous and consistent in its construction and its deductions.[62]

Yushkevich consistently held the view that the methodological foundation of relativistic physics was Machian philosophy. He demonstrated his claim by the example of the principle of invariance which 'has its own special significance [for philosophy], since it is only another expression of the standpoint of theoretical-cognitive relativism'.[63]

. Bogdanov also treated the theory of relativity in the same spirit. He admitted in words that it reflected objective processes of nature, but recognised as objective only that which was generally significant, i.e. what was recognised as truth by many people, and depended on collective awareness rather than on the individual *consciousness* (as with Mach). The theory of relativity, he claimed, recognised the objectivity, i.e. the *general significance* (my italics—*D. G.*), of the laws of nature and, by assuming an arbitrary transformation of the co-ordinate systems, discovered the general laws of this transformation. It only remains for us to add that experiment is treated by Bogdanov in the spirit of Mach, i.e., for him, consciousness and direct psychic experience were identical concepts. He reduced experiment and the right of all scientific propositions to exist (including those of the theory of relativity) to expediency. Bogdanov considered that each of the questions answered by the theory of relativity could also be resolved in accordance with the facts of experience on the basis of other premisses, but only certain ones in one case, and others in another, and so on. The scientific advantage of the theory of relativity was that it answered all these questions from one and the same premisses, and from a minimum number of them.

Some Soviet critics of the theory of relativity were influenced in their evaluations of it by the anti-relativist campaign that

developed in Einstein's homeland under the leadership of the German physicist Philipp Lenard. Einstein wrote as follows about this group of opponents:

> Under the pretentious title 'Worker Association of German Scientists' a motley society has been formed whose immediate aim is to debunk the theory of relativity in the eyes of non physicists, and with it me as its founder. Not long ago Herren Weyland and Gehrcke spoke with the same aim in the Philharmonic Hall with the first lectures that I, too, was at. I well understood that neither speaker deserved a written answer; for I have every ground to think that the intention behind this affair was by no means a striving for truth... As far as I know there is hardly a scientist today among those who have made a notable contribution to theoretical physics who would not acknowledge that the theory of relativity is logically fully closed and that it accords with all the firmly established facts of experience. The most eminent theoretical physicists I name H. A. Lorentz, Max Planck, Arnold Sommerfeld, Max Laue, Max Born, Joseph Larmor, Arthur Eddington, Peter Debye, Paul Langevin, Tullio Levi-Cività take their stand on the theory of relativity and themselves are working actively on it. Only Lenard, among the physicists who merit world recognition, can be counted an open opponent of the theory of relativity. I admire Lenard as a skilful experimenter; but he has not yet done anything in theoretical physics, and his objections to the general theory of relativity are so superficial that I have not considered it necessary until now to answer them in detail.[64]

This anti-Einstein echo reached Soviet scientists through the translated literature, which was commented on in the periodical press.[65]

But the constructive ideas of Soviet scientists gained the upper hand over the scepticism generated by the opponents of the theory of relativity. S. Y. Semkovsky made a serious analysis of the theory; apart from study of its physical and philosophical content, he actively opposed those who looked only for errors in the theory and its author, put the accent on unresolved matters, counteropposed or confused the respective theories of Einstein, Newton, and Lorentz, and tried to denigrate the role of the theory of relativity.

> Since *Einstein* employs the *Lorentz* transformation equations, [he wrote] many do not distinguish sufficiently clearly between Einstein's theory of relativity and Lorentz's point of view; the latter was diametrically opposed in essence to the theory of relativity *because it assumed an absolutely immobile ether* in which *absolute movements of bodies* took place. It is necessary, it seems to me, to go into these differences more deeply than is usually done by advocates of the theory of relativity; then many of the paradoxes of the latter will be eliminated.[66]

There was great confusion in analysis of the relation of the

theory of relativity to Newton's doctrine because some scientists misunderstood the essence of the categories of the absolute and relative. They identified the concept 'relative' with the subjective, and 'absolute' with the objective. They took Newtonian absolute motion, time, and space, for example, to be objective phenomena, while making the similar Einsteinian relative quantities wholly dependent on the subject. Hence it was claimed that the dispute between the theories of Einstein and Newton was one for recognition of the objectivity of time, space, and motion, and it was considered that victory of the theory of relativity would inevitably make them dependent on our consciousness. Belief in that interpretation of the theory of relativity understandably could not help leading members of different philosophical trends to a different attitude to it.

> The difference between the two points of view [Semkovsky wrote] is very essential and it is about it, and not about the objectivity of space and motion, that the dispute between Newton and Einstein is all about. Absolute motion presupposes *an absolutely privileged, i.e. quiescent, system of co ordinates*, in relation to which all 'true' motions take place; other, moving systems of co-ordinates are *in principle not equivalent* to it such is the standpoint of Newton. From the angle of relative motion, that Einstein takes, any absolutely privileged, i.e. quiescent, system of co-ordinates *is excluded*; all possible systems of co-ordinates, all 'bodies of reference', are themselves in motion and so are *in principle equivalent* ('in principle' in the sense that, for all the differences between them, no body can be singled out as absolutely privileged, remaining at absolute rest.[67]

Semkovsky drew attention to the fact that a number of physicists and philosophers interpreted the theory of relativity incompletely and in a one-sided way. They

> have perceived mainly that part which speaks of *relativity* and have rejected its other integral half, which ascends from the relativity of each observation point to the extrarelative world, to objective reality: *matter time space.*[68]

The most important feature of the theory of relativity, he said, was that it had taken the next step toward the objective world and deeper study of its physical essence.

> Some relativists [he wrote], 'deepening' Einstein, try to prove that the theory of relativity allegedly leads to a world of space-time 'relations' and not to one of matter. But even the *immaterialist* Berkeley understood that where there was a relation there must be members of it. And in any case this 'extrarelative', 'invariant' world at which Einstein arrives is constructed on profoundly *materialist* foundations. Starting from the 'principle of relativity' Einstein arrived at an *extrarelative, objective world*: its 'invariance' consists precisely in its picture not depending on the relative point of view of the observer. This picture, I would

have said, is materialistically more concrete than the former, Newtonian one of a world of abstract materialism.[69]

Disagreeing with those who tried to present the theory of relativity as if a conclusion about the subjective character of time and space should follow from its content, in contrast to the Newtonian theory, Semkovsky wrote that Newton

> regarded space, time, and matter as three separate independent substances; space and time were not dependent on variously moving matter and retained their own independence and uniformity, given once and for all. But the theory of relativity has demonstrated that the structure of space and the passage of time do not have an immutable uniformity at all, but alter in dependence on the gravitational field. It has *thus* integrally linked space and time with matter, and has confirmed the truth of materialism, reducing space and time to forms of the existence of matter in motion.[70]

A. K. Timiryazev identified Einstein's theory of space and time with Kant's. In Semkovsky's view Einstein and Kant differed radically from one another.

> Kant ascribed an immutable quality of *isotropism*, an absolute Newtonian and Euclidean uniformity, to space and time; Einstein, on the contrary, considers the structure of space and time to be *anisotropic*, lacking Newtonian and Euclidean uniformity... For Kant space and time depended on the mode of *representation*, for Einstein on *material masses*. Our penetrating critic overlooked this 'tiny difference', whereas that is *the whole difference between materialism and idealism*, and just that.[71]

Semkovsky did not agree with Timiryazev and other scientists that Einstein was a Machian and that his theory confirmed Mach's philosophical ideas. The desire to see an adequate reflection of the philosophy of Machism in the theory of relativity led the critics of the latter to a search for outwardly similar expressions and terms in the two scientists. Without going into their content, some made Einstein's 'observer', who allegedly reflects Machism, the centre of attention; others attempted to find something in common in the concepts 'experience', 'sensation', etc. Semkovsky wrote on that score:

> While Einstein illustrates his theory, for clarity of exposition, by examples of various 'observers' only complete incomprehension or deliberate distortion can palm off onto him the idea that the *mind* of the 'observer' creates the curvature of space. If light rays are bent close to the sun, that depends, according to the theory of relativity, not on the mind of the 'observer' but on *a curvature of space existing objectively, outside the mind of any 'observer', a curvature determined by the material mass of the sun*.... Everything boils down in the final analysis in the theory of relativity to *matter* and not to 'sensation-elements'.[72]

While confirming that the theory of relativity went against the grain of Machism, Semkovsky nevertheless wrote, as regards Einstein's outlook:

> The philosophical views of Einstein himself seemingly suffer from great indeterminacy, and he himself perhaps is the worst philosophical interpreter of his theory.[73]

B. M. Hessen's *Basic Ideas of the Theory of Relativity* also deserves attention. Like Semkovsky he saw in Einstein's theory a revolutionary explosion that had enormous influence on philosophical view as well as on science.

In addition to analysing the content of the theory of relativity, Hessen criticised the conclusions of individual popularisers who in one way or another put Einstein's theory in a bad light. The bitterest discussions between supporters and opponents of the theory of relativity centred on Einstein's principle of relativity. Along with recognition of it as the main component of the theory of relativity, stemming from the properties of nature, there was a view that it was an unnecessary side chain in Einstein's theory, and that it did not reflect real processes. Hessen did not share that view. He stated that the special and general principles of relativity were the consequence of a further generalisation of Galileo's principle that 'hides in itself a revolution of our main ordinary notions about space and time'.[74] He showed that this principle had not just arisen in Einstein's head but stemmed from reality itself and had well-founded experimental confirmation.[75]

In contrast to Newton's conceptions of space and time the theory of relativity brought out the material content of these categories. Nevertheless this new understanding of time and space was lost sight of in a number of works, and they were treated without connection with material processes. Hessen drew attention to that, expressing his idea as follows:

> We do not speak, in the theory of relativity, of the contraction of *space* but of the contraction of *bodies* and not about the slowing of *time* but about the *slowing of processes*. We do so because, in contrast to the Newtonian conception of classical physics, we consider space and time in themselves as empty abstractions that acquire reality only in matter. There is no time outside a process or space outside matter.[76]

One of the reasons why a number of scientists opposed the theory of relativity was the new view of the problem of time and space stemming from it, which was found to contradict the corresponding Newtonian theory. Citing dialectical materialism Hessen tried to show that Newton's theory was vulnerable

in the philosophic aspect.

> The unsatisfactory and undialectical character of the Newtonian conception [he wrote] consists in its objectivising and ascribing *an independent, separate, real* existence to abstract concepts of space and time. But space and time are *forms of the existence of matter*. We cannot perceive matter in other than space-time forms. In our perceptions we perceive space and time separately, but that does not mean we can really (and not mentally!) separate space and time from matter. Space and time only acquire objective reality in matter. Time acquires reality only in a process, in the real motion of matter.[77]

He saw the drawbacks of Newton's conception in its preserving their independent existence for time and space.

Hessen drew attention to the point that some commentators were endeavouring to make an absolute of the theory of relativity and to transfer its physical conclusions to chemical, biological, and social reality. The facts of the theory were thus illegitimately raised to the rank of a universal methodology. The concept of the relativity of time and space, for example, played a fundamental role in the special theory of relativity. On that basis it was concluded that there was a close relation between its physical content and philosophical relativism, though we know that the latter is not the methodological foundation of the theory of relativity.

> The essence of the theory of relativity [Hessen wrote] consists in establishing the relative character of temporal and spatial intervals or distances. The magnitude of the one and the other depends essentially on the state of the observer. If we stop at that statement and substantiate it by the arguments of philosophical relativism, rejecting the possibility of overcoming this relativity, we convert the theory of relativity into relativism in principle.
>
> But such a conclusion does not in any way necessarily follow from the theory of relativity. On the contrary, we see in the conception of a four-dimensional world an attempt to *overcome* the relativity of measurements of space and time and the next step toward absolute understanding of the external world, and of matter in motion.[78]

There is a view in Hessen's book that certain advocates of the theory of relativity make an epistemological mistake: starting from Einstein's theory they erect the idea of the relativity of our knowledge into a general principle of knowledge, thereby denying the possibility of limitless approximation to absolute knowledge.

> The theory of relativity [he wrote] is not a philosophical system and cannot be treated as an integral system of outlook on the world. It is first and foremost a certain conception of space and time founded on general epistemological premisses.[79]

Soviet scientists' attitude to the theory of relativity was discussed at the Second All-Union conference of Marxist-Leninist Scientific Institutions in 1929. In his paper at the conference Otto Schmidt analysed the various approaches to the theory. Members of idealist trends in philosophy, he said, in accepting the theory of relativity and switching attention mainly to the concept of the observer, drew the conclusion that time and space had no objective content but depended on our observations. Some mechanists denied

> not only Einstein's theory but also the contradiction on which it rested. They gambled on refuting its experimental side, but did not succeed. They did not see either those contradictions or the development of physics that were manifested in it. And of course they were far from understanding such associations as the unification of space and time... We were under the hypnotic influence of the idealist conclusions that have been drawn in the West from the theory of relativity and which have been the reason for its unbelievable popularity among the philistines of the whole world. This theory of relativeness, of relativity, is extraordinarily popular precisely among philistines, of course, because of the idealist conclusions. It was not Einstein's fault, although he is muddled he has Machian convictions along with materialist ones; he lacks consistency.[80]

Schmidt stressed that the attitude to the theory of relativity was markedly altering then. Its dialectical materialist essence was becoming more and more clear.

> What is our job now in regard to Einstein's theory? [he asked]. It is to continue it, to deepen it, to rid it of the idealist rubbish that is in Einstein, and even more in his followers, and to bring out and clearly present the dialectical kernel of the whole theory. In such an enriched, improved form it will gain new facts and lead to further mastery of phenomena, so that even in the narrow physical aspect it will be progress.[81]

A new wave of polemic was evoked by publication of V. F. Mitkevich's *Basic Physical Opinions*, which was aimed mainly against the theory of relativity. Mitkevich endeavoured to return physicists to the idea of ether rejected by Einstein. Modern physics, he suggested, could only develop if it returned to study of ether. Acceptance of some universal medium, call it ether, he wrote, was certainly necessary for the development of physical thought, which would otherwise lead to a number of substantial contradictions.[82]

Recognition of ether forced him to take the following step. As had been claimed before the appearance of the theory of relativity, electromagnetic waves did not really exist; they were a manifestation of ether. 'Is it plausible to assume

that an electromagnetic field can exist in itself, without any involvement of a material vector whatsoever?', he asked.[83]

Mitkevich saw one of the defects of the theory of relativity in its language, difficult to understand, and in its excessive mathematics. As an example of creative quest he cited Faraday, who built his theoretical constructions exclusively on the data of physics alone. In his view the absence of a mathematical apparatus in Faraday's work was a factor of great importance in the development of physical science. He called on young physicists to develop a bent for physical thinking freer from the influence of mathematics.[84]

Mitkevich did not wholly understand the conclusions of relativistic physics about time and space. Newton's ideas about them commanded his respect. He tried to turn physicists back to certain Faraday's and Maxwell's propositions.

His arguments were categorically opposed by the majority of Soviet scientists (V. Y. Frenkel, I. E. Tamm, and others). Let us consider, for example, what S. I. Vavilov and A. F. Joffe wrote.

> The astonishing feature of Mitkevich's book [Vavilov wrote] is that it does not contain a *single* new argument against 'action at a distance' or in defence of ether. Such a book would have been quite opportune at the end of the seventeenth century, but its appearance in our age is astonishing. It is as if there had never been Newton's books, Roger Cotes' preface, the polemics of Leibniz, Euler, and Lomonosov, and the endless attempts of Fresnel, Arago, Michelson, and others to discover ether, and it is as if the work of Lorentz and Einstein had not existed. The question is posed as it was in the late seventeenth and early eighteenth century in the disputes of the Cartesians and the Newtonians. In spite of a number of (outwardly) favourable mentions of the results of the new physics, they have not been employed for any new line of argument in support of Mitkevich's theses. Physics had already answered all his doubts and questions long ago with broad theoretical and experimental research.[85]

As for Mitkevich's attitude to the mathematical methods of modern physics, including Einstein's use of them in the special, and especially the general, theory of relativity, Vavilov wrote:

> The mathematical abstractness of the new theoretical physics is well known and incontestable, and of course little to the liking of all physicists and theorists, in particular experimenters. One asks how far this abstractness is necessary and inevitable, and if one needs, in fact, to force physicists to return to Faraday's clear, simple method.
>
> In an exact science like physics, mathematics is naturally obligatory and inevitable; its absence in Faraday is a defect, of

course, and not a merit. It must be remembered, however, that mathematics has a dual role in physical research: (1) auxiliary-technical and (2) heuristic.

When a physicist operates with clear, customary notions (including concepts of space, body, motion, force, etc.) that arise in him (as in any other man) from the day of his birth, many conclusions are 'intuitively' foreseen, without mathematical calculations. Such physical theories are amenable even to poetic exposition (the classic example being the poem of Lucretius). In this case calculations only refine a theory, and put it in order, and make it more accessible to and convenient for quantitative conclusions. Such is the role of mathematics in most of the chapters of classical physics, and there are sometimes justifiable grounds in it for protesting against superfluous abstraction, and against the use of special, very abstract mathematical functions, unnecessary auxiliary quantities, and so on.[86]

Here is the view of Joffe who, like Vavilov, condemned Mitkevich and physicists like him who continued to attack the theory of relativity.

> Back in 1905 [he wrote] Einstein led a whole revolution in physics, having suggested the theory of relativity, the theory of light quanta, and the theory of Brownian movement. The theory of relativity aroused particularly fierce opposition. A number of physicists could not reconcile themselves to the reconstruction of concepts inevitably entailed by a consistent theory of relativity. Its testing in experiment and its subsequent application to the phenomena of atomic physics made it as firmly an established principle of modern physics as the law of the conservation of energy. All scientists without exception, who have to deal with fast-moving particles, start from the theory of relativity. But there were still pre-relativist physicists who obstinately did not want to acknowledge the theory of relativity, namely Lenard and Stark in Germany, J. J. Thomson in England, A. K. Timiryazev and N. P. Kasterin in the USSR.[87]

The discussion organised by the journal *Voprosy filosofii* (1950-55) was a step toward philosophical substantiation and development of the theory of relativity. Summing it up the journal's editors commented:

> The aim of the discussion was to formulate propositions concerning philosophical evaluation of the theory of relativity, that would be shared unquestionably by the vast majority of researchers, through a constructive exchange of views between physicists and philosophers, and to elucidate the disputed unresolved questions requiring further work in the fields of both physics and philosophy.[88]

The majority of those taking part in the discussion pointed out the immense role of the theory of relativity in the development of physical science. Its unimpeachable mathematics, and the theoretical, practical, and ideological significance

of its conclusions were noted. The physicist Terletsky wrote:

> By leading to new physical notions about space and time, i.e. about the forms of existence of matter, the theory of relativity also disclosed a new content; it formulated general laws of the motion of matter in realms of high velocities and energies. These so-called relativistic laws have been broadly confirmed by practice and are the physical basis for several new fields of technique. The relativistic laws of the motion of fields and particles have been the foundation for the design of modern particle 'accelerators' (cyclotrons, synchrotrons, betatrons, etc.) and for analysing nuclear reactions.[89]

Several of the scientists who took part questioned the name of the theory, expressed the view that it did not correspond to its content. A. D. Alexandrov, for instance, claimed:

> The theory of relativity is a physical theory of space and time, or rather a general theory of the properties and relations of objects and phenomena. In its objective content it starts from the point that space and time are forms of the existence of matter and that spatial and temporal relations, consequently, do not exist in themselves in pure form but are determined by the material connections of objects and phenomena. Therefore, when formulating the general laws of spatial and temporal relations, the theory of relativity relies on investigation of concrete forms of the motion of matter; at the same time it necessarily abstracts from the concrete and singles out the objectively general in the concrete relations of objects and phenomena.[90]

Alexandrov started from the point that the physical theory of time and space had rested, before the advent of the theory of relativity, on data about the laws of motion of solid bodies. Its theoretical expression in mathematics had been Euclidean geometry, and in physics 'classical' kinematics. Study of electromagnetism had led to discovery of properties like invariance of its rate of propagation which had come into contradiction with the notion of absolute time. But since this basic property of electromagnetic processes underlay the theory of relativity, and velocity is the ratio of path to time, the existence of a universal velocity meant the existence of a universal connection between space and time. From that it was concluded that *'the main feature, the substance of the theory of relativity, is that it establishes this link of space and time'*.[91]

Terletsky took up a rather different position in regard to the name of the special theory of relativity. He started from the point that since the term 'principle of relativity' could be understood as an expression of choice of frames of reference, it did not in itself reflect the content of the special theory of relativity. He put forward the following

arguments for that. The main thing, he considered, was not that 'the choice of frame of reference is relative'. The nub of the matter, in his opinion, was that notions of space and time, and the laws of motion, included something absolute that existed independently of the choice of frame of reference. The concept 'relativity of the choice of frame of reference' should not be made an absolute, since the relativity was limited and conditioned by the real properties of time and space. From that he drew the conclusion that putting the stress on relativity did not correspond to reality. He suggested replacing the term 'principle of relativity' by 'postulate of covariance', or rather longer 'the postulate of the independence of physical laws from the choice of inertial frames of reference'.

> It would be more correct even, in accordance with the content of the theory of relativity, not to call it 'theory of relativity' (because 'postulate of covariance' still does not reflect its whole substance) but simply the 'four dimensional theory' in line with the notions put forward by Minkovsky. Of course, we may still argue about terms.[92]

Objections were also raised against the title of the general theory of relativity. D. I. Blokhintsev, for example, claimed that it was impossible to speak of the relativity of all motions. 'The general theory of relativity in fact is a theory of gravitation and not at all a doctrine of the relativity of all motions'.[93]

V. A. Fok expressed a unique view in relation to the general theory of relativity, claiming that

> use of the terms 'general relativity', 'general theory of relativity' or 'general principle of relativity' is impermissible. It not only leads to misunderstandings but also reflects an incorrect understanding of the theory itself.[94]

The concept of relativity used in the special theory, Fok said, was linked with the concept of the uniformity of space. The theory of relativity had been called the theory of Galilean space, the uniformity of which is reflected by the Lorentz equations. Fok acknowledged this title to be justified since generalisation of Galileo's principle of relativity played a big role in it. In the general theory of relativity, however, the concept of general covariance began to be expressed through the term 'general relativity'. But, Fok wrote,

> such a covariance has nothing in common with the uniformity of space, and this means that 'general relativity' has nothing in common with 'relativity simply'... The terms 'general relativity' or 'general principle of relativity' are also used (above all by Einstein) in the sense of a theory of gravitation. ... Since space is presumed to be non-uniform in the theory of gravita-

tion, and relativity is associated with uniformity, it emerges that there is no relativity in the general theory of relativity.[95]

Maximov's point of view was criticised in several papers; he, while recognising the correctness of the mathematical formalism of the theory of relativity, nevertheless rejected its physical significance. When summing up the discussion the editorial board of the journal said apropos of this:

> The conception that recognises the mathematical apparatus of the theory of relativity and at the same time completely denies its physical conclusions (A. A. Maximov) cannot be considered in any way convincing and consistent. The basic conclusions of the theory of relativity (about the relativity of the simultaneity of spatially isolated events and about the dependence of space time relations on velocity) follow inevitably from the physical theory itself and cannot be treated as due to Einstein's idealism.
>
> A. A. Maximov's disputing of this view demonstrated his vulgariser approach to tackling the most important problems of the relation of philosophy and science, and was essentially a substitution of subjectivism for dialectical materialism. That approach could not help but lead him to faulty nihilistic views on one of the most important theories of modern physics.[96]

The question of the content of the concept of frame of reference came up in the discussion; in the main, two points of view were expressed. In the opinion of A. D. Alexandrov, for example, the frame of reference was necessarily linked, or rather identified, with some material body of reference.

> The frame of reference [he wrote] is the objective co-ordination of objects and phenomena in relation to the body of reference determined by their material connections with it. The system of coordinates is an abstraction of these real relations and so has an objective content. It is wrong to see only the mode of representation in the frame of reference, only the imaginary co ordinate/time grid, and to claim that the frame of reference is absurd without a perceiving subject. Any scientific 'mode of representation' reflects something that objectively exists, and it is this objectively existing something that is the subject-matter of physics.[97]

Terletsky understood by frame of reference the imaginary co-ordinate grid that made it possible to represent both spatial co-ordinates and the passage of time.

> The frame of reference [he stressed] is only the *mode of representation* of real space and time existing independently of our consciousness.
>
> From the angle of four-dimensional geometrical represen tations the frame of reference is a generalisation of the concept of a system of co ordinates for a four dimensional variety of space time. Like the system of co ordinates in analytical

> geometry, the frame of reference in the theory of relativity can to some extent be arbitrarily selected.[98]

The problem of absolute and relative trajectories also caused debate. On this point, too, as on the problem of the frame of reference, those involved in the discussion did not reach a common view. The debate was initiated by the paper of Maximov, who disagreed with Einstein (who in our view correctly claimed that there is no trajectory *per se*, and that any trajectory relates to a definite body of reference). On that score Maximov wrote:

> The argument, presented as a philosophical conclusion, that there is no objectively given trajectory of a body existing independently of the choice of one system of co-ordinates or another, is quite unscientific.[99]

G. I. Naan did not agree with Maximov's view. He suggested that in this case Einstein was right, who had spoken only of the physical relativity of a trajectory, which by no means implied that he denied its objectivity.

> The trajectory of a body relative to a given medium [Naan wrote] is obviously a trajectory in a frame of reference in which the medium (body) of reference is precisely the given medium. No independence of the frame of reference is obtained. The given trajectory moreover, is by no means the sole one; there are other trajectories of the same body in addition to it, trajectories of the body relative to other media or, in general, bodies, which (trajectories) are just as relative but just as objective as the first.[100]

Naan's statement that a body has a multitude of trajectories in its motion in turn provoked objections. G. A. Kursanov wrote on this point that there was a confusion here of the concepts of the objectivity of the motion of a material body in time and space and of the relationship of all material bodies in motion. He said that

> every material body has one real trajectory in its movement in space and time, and not five or twelve. At the same time the motion of each body takes place in an interaction with other bodies, and in relation to some bodies. The objectively real property of the body, its trajectory, can therefore be regarded only from the standpoint of the motion of other bodies, in connection with certain 'frames of reference'. It is from the angle of its motion and connection with certain frames of reference that a body's trajectory takes a certain geometrical form: a straight line, parabola, etc. And only in that sense can one speak, as is done in physics, of many 'trajectories' of a body.[101]

The scientists spoke sharply about the claims of a number

of Western scientists that it followed from the general theory of relativity that the systems of Ptolemy and Copernicus were of equal standing and that Copernicus' discovery had no scientific importance. Such a claim, in the opinion of participants in the discussion, did not correspond to reality. In N. N. Kharin's view, the epistemological reason for it was that

> relativists who regard the content of scientific theories from idealist, metaphysical standpoints, divorce the abstract from the concrete, exaggerate the abstract and raise it into an absolute, and discard the concrete. In other cases a consequence of the metaphysical approach is, on the contrary, an exaggeration of the concrete aspect and rejection of the abstractions, and an ignoring of their objective content. Relativists who exaggerate the role of mathematical abstractions limit the process of understanding to the formal, mathematical side and come to absurd conclusions.[102]

M. F. Shirokov devoted a paper specially to this problem. His analysis indicated that

> the concept of a preferred frame of reference formulated in Newtonian mechanics for matter concentrated in a limited area of space has not been altered in the light of subsequent discoveries of science, but only refined and generalised, extended to newly discovered forms of matter, the electromagnetic, gravitational, and other fields with new laws of motion. The significance of Copernicus' great discovery is not only not reduced but on the contrary has become even greater, going far beyond the framework of pure astronomical prob lems.[103]

The theory of relativity, of course, reached its conclusion about relativistic effects through study of kinematic changes rather than through disclosure of the physical nature of moving bodies. On those grounds there is no possibility of saying anything conclusive about the real physical processes of the moving bodies, and the special theory of relativity does not provide an answer. Kursanov drew attention to the point that

> the general theory of relativity makes a significant advance in trying to disclose the physical causes of the change, for example, in the metrics of space or the 'velocity' of the passage of time. That is the direction in which physics should develop and deepen the ideas of the theory of relativity.[104]

Attention was drawn to the role of Lobachevsky in the development of several ideas that furthered the development of relativistic physics. It was noted that he was best known for his geometrical works and not so well for his ideas on mechanics. On that point M. B. Vilnitsky wrote:

> Lobachevsky stood for the reality of motion; he started from recognition of the three-dimensional character of objective space;

> he rejected views that preached the possibility of the finiteness and limited nature of space; he was profoundly convinced of the inseparability of space and material bodies; he came close to recognition of the objectively existing, dialectical unity of the discreteness and continuity of space; he did not make an impas sable gulf between time and its measurement, between time and the definite motions of material bodies; he made it clear that the character of the measuring of time is governed by the physical conditions of motion, but at the same time did not identify time and its measurement; ...he was quite conscious of the indissoluble tie existing between time and space, at the same time seeing a difference between time and space and spatial elements; he foresaw a need for changes in mechanics itself such as were to find concrete embodiment in the future in the mechanics of the theory of relativity.[105]

There are often statements in the literature on the theory of relativity that the relative physical quantities of relativistic physics have no objective physical sense, and are quite fully expressed by mathematics alone. A. D. Alexandrov, replying to advocates of the idea of geometricising or fully mathematicising the theory of relativity, wrote that this theory was in fact

> a physical theory and is not reducible to a four dimensional geometry. The main thing in it is precisely the physical essence of its concepts, laws, and methods; the question of this physical essence is the main point in understanding the theory.... The possibility of a geometric interpretation is not at all specific to the theory of relativity.... Its problems of dynamics, furthermore, are not exhausted by geometrical notions about space-time relations.[106]

A number of papers stressed that the theory of the link of time, space, and motion had been developed in dialectical materialism long before creation of the theory of relativity, which had confirmed this idea in terms of physics.

Philosophical analysis of the conclusions drawn by Eddington, Jeans, Frank, and other Western physicists and philosophers from the theory of relativity had a big place in the discussion. The mistaken character of the conclusions that it refuted the idea of the objective character of a number of the concepts of physics, having established their relativity, was pointed out. Naan wrote that the claim

> that recognition of the physical relativity, for example, of the trajectory or spatial intervals, meant rejection of the objective content of these concepts was based on a sophism that consisted in *substitution of the observer and his point of view for the frame of reference, i.e. substitution of the subjective for the objective*.[107]

Several writers' denial of the objectivity of time and space

led them to conclude that the space-time properties of material objects were created in relations in the process of measurement, observations, etc. I. P. Bazarov wrote:

> No single phenomenon and no single property of a body can be brought out without examination of its relation to another body. The properties of a body are only disclosed in relations kinematic or dynamic (through interactions). It does not follow from that, however, that properties are generated by the relations; they can only be revealed through relations. Depending on these relations they will be quantitatively different (with kinematic ones) or qualitatively different (with relations through interactions).[108]

Attention was drawn to the illegitimacy of absolutising subjective elements and separating them from objective ones, and to the point that, as Kharin wrote,

> objective elements play a decisive, main role in the content of the special theory of relativity; subjective ones perform an exclusively subsidiary role, not a main one.[109]

He pointed out that material objects, while possessing a host of relative properties, at the same time also have absolute ones, and that objects of the external world contain a unity of the absolute and the relative.

> The concepts and formulas of the special theory of relativity reflect the properties of motion, space, and time, which embrace the absolute and the relative in their organic unity. The content of the theory of relativity, for example, does not provide grounds for saying that simultaneity is only relative and has no absolute properties. On the contrary, this concept is also absolute in this theory in the sense of recognising the objective, simultaneous existence of bodies and processes.[110]

In many of the papers it was said that the philosophical interpretations and physical content of the theory of relativity did not always coincide, that some of the philosophical interpretations did enormous harm to its further development by distorting its real contents. Individual scientists criticised the logic of the exposition of the theory, remarking that Einstein had departed from the traditional logic of exposition of classical physics.

Several speakers regretted that individual Soviet scientists and philosophers had followed Western philosophers, believing with them that the theory of relativity was idealist in content; and on those grounds they had criticised some of its physical propositions. Fok wrote that of late Western

> philosophers and physicists have made no few efforts to interpret the theory of relativity and quantum mechanics in an idealist sense, to show that the new theories in physics 'inevitably'

> lead to negation of the objective reality of the world around us or throw doubt on the existence of such a reality. Unfortu nately their activity has borne certain fruits among us, and not just abroad. Several of our Soviet philosophers have believed... that modern physics is based on idealist philosophical opinions.[111]

Participants in the discussion criticised Einstein's philosophical views. Several, besides Maximov, wrote in *Voprosy filosofii* at that time that Einstein had been influenced by Machism, Neokantianism, and other idealist philosophical schools. It was claimed that he answered idealistically the basic question of philosophy (about the relation between the external world and our consciousness). For that purpose quotations were cited from individual statements by Einstein on the origin and essence of scientific concepts, mathematical axioms, theory and mathematics in general, science, and the subject-matter of physics; references were made to the relation of the empirical and the rational in his scientific work, and to his treatment of the problem of religion. His treatment of the works of Mach, Berkeley, Hume, and others were cited as an argument to confirm his adhesion to idealist philosophy. M. M. Karpov, for example, wrote:

> A false idea that Einstein is a materialist has become entrenched among a number of physicists and philosophers. The statements of some authors who depict Einstein as very nearly a dialectical materialist are even more incorrect. ...Einstein has repeatedly declared that he is a follower of Spinoza, and that he does not consider himself an idealist; yet analysis of his philosophical statements, analysis of the theoretical and epistemological questions that he tackled shows that he is neither a disciple of Spinoza nor a materialist.
>
> Einstein's views and opinions were formed under the influen ce of such idealist philosophers as Hume, Mach, and Schopenh auer. That could not help influencing his philosophical views. Einstein answers the basic question of philosophy idealistically.[112]

As for Einstein's scientific work, it was recognised in the main as adequate to the real processes of nature. The editors' summing-up said apropos of that:

> The main conclusions of the theory of relativity, about the relativity of the simultaneity of spatially isolated events and the dependence of space time relations on velocity, inevitably follow from the physical theory itself and cannot be regarded as due to Einstein's idealism.[113]

The most representative forum to deal with problems of the theory of relativity after the discussion in *Voprosy filosofii* was the All-Union Conference on Philosophical Problems of Science (1958). A. D. Alexandrov's paper at it on the philosophical

content and significance of the theory of relativity evoked special interest.

Alexandrov's starting point was that the theory of relativity was a physical theory of time and space, and was therefore closely linked with philosophy, without which it was impossible to understand its philosophical foundations. Since space-time relations, however, did not exist by themselves unrelated to matter, but functioned as forms of its existence, understanding of them was directly linked with study of the properties of matter. In his view

> the true essence of the theory of relativity is not that it has established the relativity of time but that it considers phenomena in their relations to some frame of reference and finds the difference in their characteristics in relation to different frames of reference. The essence of the theory consists in disclosing that these relative characteristics are only aspects of the unrelative, the absolute. The main point is not the relativity of time and space but that they are simply aspects of a single, absolute form of existence of matter, i.e. space-time.[114]

Alexandrov drew attention in his paper to the point that, members of different philosophical schools tried, each in his own way, to interpret the theory of relativity with the result that both its philosophical and physical content and its concepts, were greatly distorted. That primarily concerned the concept of relativity, whose role in the theory was much exaggerated and furthermore often interpreted in a subjectivist spirit.

Alexandrov saw a source of the positivist distortion of the theory of relativity in the logic of its construction. Since the special theory was based on the principles of relativity and invariance of the velocity of light, it followed from that, he claimed, that its main concept was that of an inertial frame of reference or system of spatial and time co-ordinates, without which it was impossible to develop those principles. And it was clear in turn from Einstein's formulation of them that

> the initial point of view in the construction of the theory proves to be the point of view of relativity in which the question is posed first of all not about phenomena in themselves but about their relations to certain frames of reference. That point of view usually predominates in the further development of the theory when relative time, the Lorentz contraction, relative mass, etc., are considered. The starting point here is the manifestation of some body or process or another in relation to some frame of reference.[115]

That approach, he considered, had a right to exist since

it had led to an important discovery. It did not lead to dissolution of the objects in relations, as some often claimed. But there were certain difficulties in connection with it, since it did not correspond to the logic of the subject-matter accepted in science, in which the investigator passed from the absolute to the relative, from the object to study of its properties.

> The construction of a theory starting from relativity [he said], while not corresponding to the logic of the subject-matter, does correspond to the logic of the observation, measurement, and study of the object. The observer perceives, discovers, or measures, first of all, that aspect of the object by which it functions in relation to the observer himself or to his means of observation and measurement. The approach to the theory that starts from what the physicist measures or observes in his frame of reference therefore proves to be simpler and closer for him, in a certain sense.[116]

Positivists, he stressed, had firmly seized onto that approach, and had concluded from it that relativity had no objective content, and that it was subjective, since it allegedly depended completely on the point of view of the observer and on the measurement. In Alexandrov's view, these defects in the construction of the theory of relativity had led some Soviet scientists, too, to mistaken conclusions; they

> ascribed idealism to the conclusions of the theory of relativity themselves... The reason for these errors was the topsy-turvy logic of the structure of the theory, whose correct aspects they could not see.[117]

Alexandrov set out his understanding of the general principles of the structure of the theory of relativity, guided in his approach by the point that the external world is permeated by electromagnetic radiation, which establishes a material link between moving bodies in the Universe. In that connection he considered that (1)

> a rational theory of space-time should start from the material links of phenomena and to derive the concepts and laws of space time relations from the general laws discovered in these links. The theory should start, moreover, from quite general universal relations between phenomena, since space-time itself has a universal character.[118]

He considered that Einstein had fully met this first requirement since he (Einstein) had based the theory of relativity on the laws of electromagnetic processes.

> (2) The theory should be abstracted from the concrete character, and to some extent from the material content itself of the links between phenomena, fixing attention solely on their structure. Otherwise, it goes without saying, it would not be a theory

> precisely of the *form* of existence of matter. The requisite degree of abstraction is therefore inherent in the theory of space time.[119]

Starting from the point that this theory of Einstein's was in his (Alexandrov's) view a theory of space-time, (3) it

> should start from the aggregate of the relations between phenomena, taken as a whole, so as to bring out the space-time structure of the world and define the absolute space-time multiformity and not some relative aspects of it.[120]

(4) It was necessary for the theory of space-time, being guided by the requirements of the generally accepted logic of the structure of a physical theory,

> to establish the absolute first and then to pass from it to the relative, as to a side, facet, or aspect of the absolute.[121]

It was this last requirement, Alexandrov stressed, that had not been met by Einstein in the structure of the theory of relativity.

Guided by these principles, Alexandrov gave his own interpretation, in his paper, of the physical foundations of the theory of relativity; I shall not dwell on that here.

The speeches on his report made a critical analysis of his point of view. Shirokov agreed that the special nature of the theory of relativity was primarily a new understanding of time and space. In contrast to previous theories of them, he stressed, most of which were not based on experimental physical data, time and space were in the theory of relativity 'treated in an exclusively physical aspect'. In his view the theory could be defined more narrowly 'as one of the dependence of the properties of space and time on the motion of material bodies and the distribution of matter in space'.[122]

Shirokov did not agree with Alexandrov, however, who denied the objective reality of the general principle of relativity as a physical law. He drew attention to the following point:

> If we argue strictly consistently and logically, it follows from that position, for example, that optical and mechanical phenomena on earth, governed by its rotation, including such well known phenomena as the change of acceleration of the force of gravity with latitude, as trade winds, etc., are not objectively real, since they must be treated as the consequence of a transformation of the co-ordinates to a rotating frame of reference that has only a formal, mathematical sense and not a physical one.[123]

He also cited the fact that Alexandrov recognised the law of universal gravitation of the general theory of relativity, which

was also incompatible with denial of the objective character of the general principle of relativity.

V. I. Svidersky warned physicists that they should not conclude from the theory of relativity that the physical theory of time and space is also an absolute theory of those categories. In his view such a posing of the question led to identification of the physical and philosophical aspects of the problem of time and space. He pointed to such problems embraced by the theory of space and time as objectivity, absoluteness, relativity, substance, contradictoriness, continuity, intermittence, infinity, unity, difference, and interdependence. He criticised authors who made mistakes when interpreting the theory of relativity.

> A tendency has developed [he said] to interpret dependence on frames of reference, on systems of co-ordinates, and on an instrument as subjectivity... Many have begun to consider anything objective as absolute and to affirm that only the absolute is objective, and everything relative is subjective.[124]

N. F. Ovchinnikov supported Alexandrov's idea that the construction of the theory of relativity should start from material connections, i.e. from the absolute, and then pass to the relative from it, as a side, facet, or aspect of the absolute. But, he stressed,

> it turns out in practice that he (Alexandrov) sees the foundation of the theory from which one must start, the absolute with which one must begin, not in material connections but in space-time relations. And that means that the logic of the building of the theory of relativity remains topsy-turvy, as before.[125]

The article of the Hungarian physicist Lajos Janosy on philosophical analysis of the special theory of relativity, published in *Voprosy filosofii*, evoked a sharp negative reaction.[126] He tried to show the superiority of Lorentz' theory compared with Einstein's special theory of relativity when considering relativistic effects.

> I have tried to show [he wrote] that phenomena that are usually interpreted by the methods of the special theory of relativity can be interpreted by an alternative means, similar to the method proposed by Lorentz and Fitzgerald. I have also endeavoured to show that it is more advantageous from the physical point of view to stick precisely to those ideas.[127]

One of the advantages, in his view, was that Lorentz' theory embraced a wider range of natural phenomena than the special theory of relativity. Einstein's conception, he claimed,

> is forced in principle to exclude the possibility of any phenomena

existing that do not obey the Lorentz invariance, while it would be much easier from Lorentz' view to fit such phenomena into the theory, if they existed.[128]

Janosy tried to show that Einstein's principle of relativity (which he expounded as follows: 'the laws of nature are such that they have an identical form for different observers') did not fully meet the requirements of the theory.

> The real statement about the form of the laws of nature contained in the principle of relativity [he claimed] is obscured by idealist terminology directing our attention to what different observers *see* instead of what is happening independently of the presence or absence of any observer whatsoever. The laws of nature can and should be formulated so that no special references to an observer are made in them.[129]

Einstein's principle of relativity, Janosy suggested, should be replaced by Lorentz' principle, which he formulated as follows: the laws of nature are Lorentz-covariant or the Lorentz invariance expresses an inalienable mathematical property of the laws, and not their behaviour in the transformation of the co-ordinates. In his view

> Lorentz' principle, which reflects the general property of laws of nature without unnecessary references to observers, is mathematically equivalent to Einstein's principle. It therefore leads more simply to all the results that have already been obtained by the theory of relativity. The advantage of Lorentz' principle is that there is no need, when it is used, for involved idealist arguments about what the observer sees or does.[130]

He also claimed that Lorentz' principle was identical in its physical content with Einstein's principle of relativity, which could be postulated in rather different form on the basis of Lorentz' ideas.

Adoption of the Lorentz principle inevitably led Janosy to recognition of Newtonian absolute time and space, which he identified with objective time and space. He also drew other conclusions which I shall not go into here.

P. G. Kard raised well-founded objections to Janosy's conception. I shall therefore go into details about his point of view. He considered that, in spite of the fact that the theory of relativity is similar to Lorentz' theory in its mathematical form, they differ markedly from one another in their physical content.

> There is no sense in deducing the mathematical form of one theory from the identical mathematical form of another, above all because the physical substance of the two, in spite of this identity ... is quite different. The point that the content

> of a physical theory is not exhausted by its mathematical form is a quite well known proposition.[131]

Kard disagreed with Janosy on the point that these principles were identical in their physical content. It was 'absolutely impossible', he said, to deduce the principle of relativity from the Lorentz' principle because it 'essentially includes a denial of the principle of relativity'.[132]

In addition, Kard drew attention to the fact that many authors (including Janosy) ascribed a content of the principle of relativity to Einstein that he did not give it. Einstein took the view that this principle consisted in the following: the laws of nature are in agreement in all inertial systems of co-ordinates. This formulation of Einstein's is not associated with a subject, although we saw above that Janosy included an observer in his interpretation of it. And of course Janosy saw its principal defect in its being allegedly obscured by idealist terminology, which directed our attention to what different observers saw instead of what was happening irrespective of the presence or absence of any observer whatsoever.

> That reproach, however, is quite unjustified [Kard wrote], since there is no mention of observers in the formulation of the principle of relativity ... in Einstein... If anyone ever expressed the principle of relativity in such a form, it is clear that this 'idealist terminology' in no way can justify rejection of the principle of relativity in favour of the Lorentz principle, since it is extremely simple to remove it.[133]

Kard saw the reason why individual authors introduced observers into the formulation of the principle of relativity in the 'vague' concept of a law of nature, by which was meant in this formulation, in his view, not a law of nature in the strict sense, but its projection into an inertial system. From that, he wrote,

> it is only one step to introduce observers into the formulation of the principle of relativity itself. But in that case there would be nothing subjective idealistic in it, since it does not follow from anywhere that the observer's sensations and observations are considered something primary in this formulation. Such a suspicion might perhaps arise only when it is claimed that the observer can observe only in an inertial system in which he is at rest. But that is not so... The shortcoming characteristic of the standard formulation, and of its version that includes the concept of an 'observer' is not at all the supposed idealist character of the formulation, but the point that the essence of the principle of relativity is screened in it, by its main and inevitable manifestation, it is true, but still only by its manifestation.[134]

Finally Kard drew the conclusion that Einstein's principle of relativity and Lorentz' principle were incompatible in their physical content. Recognition of Lorentz' principle inevitably led to assertion of the idea of absolute time and space; Einstein's principle of relativity, on the contrary, was incompatible with the Newtonian concept of time and space, and consequently with the Lorentz' principle. The answer as to which of the two principles corresponded to the development of physical science was provided by practice. Disputing with Janosy whether absolute time existed, Kard wrote:

> The theory of relativity very categorically answers that in the negative. The point is not only the ineffectualness of the many, many attempts to discover absolute time; it is above all that the need to answer the question was dictated by a vital need of the development of physics. In addition, the main point is that only the theory of relativity, based on the principle of relativity, could make the gigantic breakthrough, explain the vast group of questions awaiting solution, and, perhaps most important of all, unerringly *predict* much that is new, and which, moreover, had not been dreamed of earlier. All that combined also demonstrates the correctness of the principle of relativity.[135]

Similar arguments were advanced against Janosy's conception by the Bulgarian physicist Polikarov, who said that Janosy's position was not supported by the fact of physical science, and that he relied mainly on philosophical considerations which, in Polikarov's view, had no serious basis.

> Even when an observer is introduced [he objected to Janosy], idealism is not automatically injected. But the concept 'observer' has a special sense for Janosy. He understands, of course, that the theory of relativity can manage quite well without an observer in the sense of a subject. But he does not have that in mind but rather something else, namely an 'observer' in the sense of a frame of reference *together with its own time*. The attacks on the observer are thus, in essence, directed against the new concept of time in the theory of relativity. But the latter has nothing in common with idealism. Consequently, it is quite out of place to intimidate with the spectre of idealism.[136]

Polikarov disagreed with Janosy's claim that the relativistic changes of space and time following from the theory of relativity were of a mystical character. That conclusion, he considered, 'stems from Janosy's mistaken conception, which consists in his regarding space and time as things and properties as such, and not (also) as *relations*'. [137]

Objecting to Janosy's claim that the theory of relativity had come about through Einstein's straining after simplicity,

Polikarov wrote that

> the point is not the simplicity but the truth of the explanation. Even if one agrees with the simplicity of the theory of relativity, moreover, that has nothing in common with Mach's principle of economy of thought, since the materialist position does not in the least oblige us to prefer intricate explanations.[138]

Again, objecting to Janosy's thesis of the physical equivalence of the Lorentz principle and Einstein's principle of relativity, Polikarov wrote:

> According to Lorentz' conception everything happens as if the laws of nature were uniform in these systems, i.e. *in this conception the conception of ether is reconciled with the relativity of motion by subordinating the latter to the former.* This means that the relativity is after all apparent while the essence of things is expressed by the classical picture of the world. The theory of relativity, quite on the contrary, radically denies the existence of a privileged frame of reference and brings out *the profound character of physical relativity,* and so leads to a new picture of the world. [139]

In the sixties a new stage began in discussion of the philosophical problems of the general theory of relativity. Evidence of that is the several Soviet symposia on problems of Einstein's theory of gravitation and relativistic cosmology, in which both physicists and philosophers took part. In order to present the problems that the scientists touched on, I shall analyse the proceedings of just one of them, held in Kiev in 1964, and touch briefly only upon the philosophical aspect of the general theory of relativity.

In his introduction P. S. Dyshlevy drew attention to the point that, after the appearance of the special and general theories of relativity, which laid the basis for physical study of the substance of time and space, these categories were significantly altered as regards their content. Geometrical and physical space-time were now differentiated, and in turn concrete properties were distinguished in each of them.

In Dyshlevy's view the interest in analysis of the nature of time and space was due to the following circumstance. During study of the objects of theoretical physics it turned out, when they were reflected in already known notions of time and space, that in some cases their nature (i.e. of time and space) did not play a substantial role in one theory (thermodynamics), but was of immense significance in others. A need arose to study not only the content of space but also its different role in physical theory.

Certain trends in the evaluation of the essence of space

were to be observed. Some scientists tried to distinguish a physical space in a class of other spaces, criticising those who recognise the idea of a diversity of real time-space. Others claimed that time and space had a macroscopic character. Materialist philosophy was not associated with any concrete notion of time and space; it therefore did not preclude reconsideration of their content.

> But that does not rule out the possibility [Dyshlevy said] that space-time is only one aspect of the infinitely varied connections of the material world; in that sense it is neither something independent (in the form of an 'arena' of events) nor an attribute of matter (but only an aspect of a more com plicated attribute); it is possible that the role of space-time notions in the future picture of the world will also not be as essential as it has been up to the present.[140]

Scientists, Dyshlevy remarked, had not reached unanimity on the object of the general theory of relativity. Some put the gravitational field at the centre, others physical (geometrical) space-time. Some paid main attention to study of the relative. The different aspects of the relative, he considered, could be a subject for philosophical analysis. In his view, for example, the theoretical-cognitive process in physics should include not only study of the essence of object and subject but also the conditions of cognition by which he understood both the material and the ideal premisses of the investigator's practical and theoretical assimilation of reality. Such an approach to cognition would make it possible to characterise the absolute and the relative in the theory of relativity

> as a certain degree of independence and dependence of the measuring data (on which the theory is based) of the fixed conditions of the inquiry ('degree of objectivity' in physical theory). 'Absolute' physical quantities (invariants), for example, reflect the physical properties 'proper' of objects, irrespective of the conditions of cognition, while 'relative' physical quantities reflect the relation of the object and the conditions of cognition (observations, measurements), bearing in mind that the choice of the latter largely depends on the subject (it is necessary, of course, to distinguish the material as primary, and the ideal as secondary and derivative in the relationship of object, subject, and conditions of cognition, and also to take into account the relativity of the division into object, subject, and conditions of cognition).[141]

M. B. Vilnitsky considered the application of the axiomatic method in physical science along with the methods of hypotheses and principles, though some physicists have a sceptical attitude to it. He suggested that

> the axiomatising of physical theories is not limited to the organisation and logical ordering of formulated, already obtained knowledge. It has a heuristic function as well as an organising one, a definite significance in quests for ways of obtaining new knowledge.[142]

In his view the axiomatic method could lead to new inquiries arising at the boundary of theoretical and empirical knowledge and prove a help in experimental development of the general theory of relativity, and make it possible to compare competing theories of gravitation. Of course, he said,

> the axiomatic criterion employed here to compare competing theories of gravitation can be considered only as an auxiliary indicator incapable in the last analysis of claiming equality with the experimental criterion. Only the latter, more broadly speaking practice, is the sole criterion of the truth of a theory.[143]

N. M. Rozhenko tried to bring out the content of the goals and tasks posed by classical mechanics and the general theory of relativity. The goal of the former was to give the fullest and simplest description of the motion of a natural object, in order to try and disclose and, in the course of the disclosure, explain its essence. That is to say, equations of the motion of the body that reflected the law of its motion were established by means of mathematics. The law of motion was thus a theoretical description and scientific explanation of physical phenomena not associated with it. So, Rozhenko said, we get

> a vicious circle of explanation of a phenomenon by a law and of a law by a phenomenon. Within the theory based on it a law is not explained but only expressed, i.e. described in the form of its mathematical expression and by empirical manifestations which, while being explained, do not themselves explain.[144]

In his view the feature of scientific explanation and description that distinguished the general theory of relativity from classical mechanics was (1) that 'geometry functions as a means of theoretical description' in Einstein's theory, and (2) that

> the equations of motion, which are not deduced from the equations of the field in classical field theory, 'are induced by the field' in relativistic theory and therefore must be obtained from the equations of the field. Philosophically that means that the theoretical cognitive programme of the 'description of motion' of classical physics finds its explanation in relativistic theory.[145]

M. E. Omelyanovsky, reading a paper on absoluteness and relativity in modern physics, made the point that there were many definitions of the concepts 'absolute' and 'relative' in the philosophical literature. He suggested that by absolute should be

understood

> that which exists (or has sense the latter refers to concepts and not to material realities) through itself or by itself. By the relative is understood that which exists (or has sense) through another.[146]

In relativistic physics the role of the absolute was played by invariance. Omelyanovsky stressed that each closed theory had its invariances and its relativities. One and the same quantity could be invariant in one theory, and in another relative, and vice versa. He considered incorrect the conclusion of certain scientists who 'find grounds in the idea of invariance for recognising the objective content of physical concepts'.[147]

A. I. Uemov drew attention to the fact that some scientists still did not differentiate between the concepts 'subjective', which signified dependence on the knowing subject, and 'relative', which had an objective character in physical science. They often spoke of the absolute and relative in general, but their use should be differentiated when things, properties, and relations were being examined. Hence there was a variety of concepts of the absolute and the relative. Uemov stressed that, whereas, in classical physics, one went from an absolutising of the properties of things to the relativity of the relations between them, the line of thought in the theory of relativity, on the contrary, began from an absolutising of relations. The future development of physical theory, he claimed,

> would follow the line of relativising things. It is quite admissible that similar revolutions will be possible in our ideas in this respect as that which the theory of relativity caused in its day... That does not mean that all relations will be absolute and all properties and things relative. It is as difficult to build such a conception consistently, it would seem, as to build the conception of universal absoluteness. We only mean that the absolutising of several relations will lead to relativisation of a certain number of properties and so of a certain number of things.[148]

I. S. Alexeev considered the problem of how classical and relativistic physics established previously unknown objects. In classical theory such a discovery was made in two ways: (1) through study of the experimental material amassed; (2) through analysis of the mathematical formalism that described the theory.

> There are situations in relativistic cosmology [he said] when theory unambiguously speaks of man's incapacity even to experiment mentally with things, whose possible existence it asserts. An example of such paradoxes is the existence of so-called 'semi-closed worlds'.[149]

M. A. Parnyuk made a dialectical-materialist analysis of the concepts of the absolute and the relative, bringing out their relationship and interdependence. He opposed certain scientists' identifying of the absolute and the infinite.

> In contrast to the absolute, the infinite represents those relations, aspects, and elements of all kinds of objects that are characterised by absence of beginning and end, in which the end of one object signifies the beginning of others, and vice versa. Only the absolute in 'pure form', isolated from the relative, can be identified with the eternal and infinite, being understood metaphysically moreover as equal to itself and immutable.[150]

There is a definition of the absolute as obligatory or necessary, determined by something in general. This definition, too, is not true 'because, from a certain aspect, both the individual relation, and specific ones, and not just universal ones, are characterised by absoluteness.'[151] The problem of the essence of a gravitational field was widely discussed at the symposium. The scientists tried to elucidate whether it was a purely geometrical object or whether gravitation was a physical reality. Views were divided on this score. Shirokov stressed that

> if it is taken as established that the doctrine of inertia and gravitation is a geometry of physical space-time (which the general theory of relativity is at this stage of the development of science) and that it will develop only along that road in the future, then the sole correct answer to the ... question posed will be: inertia and gravitation are forms of the existence of matter, but not matter.[152]

Dyshlevy considered that this question could only be answered after thorough study of the evolution of the concepts 'field' and 'space-time'. A possible path of this study might be found through application of the categories 'thing', 'property', and 'relation'. But the level of development of the general theory of relativity still 'cannot give an unambiguous answer to the question of the nature of a gravitational field'.[153]

Mitkevich took a more optimistic stand. He related the gravitational field to material, physical objects. 'Gravitation', he claimed, 'is one of many physical fields and should be treated as equal with them'.[154] All the data of science indicated that. Mitkevich based his arguments on gravitation's being stimulated by other fields and by substance and on the contrary exerting an influence on all material objects. Its material character was also suggested by the single theory of the field, in which it was conjoined with the electromagnetic field. Finally, a gravitational field interacted with itself and possessed energy, impulse, etc.

A. N. Petrusenko came close to an affirmative answer about the gravitational field as a form of matter, by singling out the essential traits inherent in material objects, among which he included interconversion, the capacity of matter for qualitative changes, the inner contradictoriness of matter as an expression of a universal interaction, degree of structure, the heterogeneity of matter, and objectivity.

> Application of the philosophical criteria of materiality to evaluation of the gravitational field [he concluded] helps us understand it as a qualitatively special form of matter capable of being converted into other forms, and provides sources for very fruitful hypotheses about the possibilities of the birth of particles and anti-particles in powerful gravitational fields interacting with high-energy photons.[155]

The problem of the finite and infinite was also discussed. Svidersky drew attention to statements often met in the literature that the cosmological model of the Universe as a whole had a right to exist. He justly considered that such a posing of the question was not legitimate.

> Any cosmological theory should be applied in principle only to a limited part of the material world and only to certain forms of matter in motion and their inherent space-time properties. In that case talk 'about the world as a whole' is empty talk without scientific sense.[156]

The question of whether the problem of infinity could be proved just by science alone was also disputed. Views on that differed among the philosophers and scientists. Svidersky, for example, considered it could only be finally resolved by means of philosophy, because

> it is necessary, for such proof, to absolutise some concrete form of matter in motion, in particular the gravitational field as a common property of physical forms of moving matter in our part of the Universe. Without such qualitative absolutisation it is impossible to speak of any quantitative infinity in general. Both sides can exist only in unity. But that ... is incompatible with dialectics.[157]

From that he concluded that cosmology, physics, and mathematics had no bearing on the problem of infinity. It was a matter of the primary position of philosophy, though the sciences mentioned could also make their contribution to proving the infinity of the Universe by studying the part of it accessible only to them.

Naan opposed this point of view, that the problem of infinity could only be finally resolved by philosophical science. This concept, he stressed, had undergone vast change in its evolution. Practical infinity had been understood by it at first.

Later it took the form of unlimited spatial extension. Relativistic cosmological science already relied on a concept of metric infinity. This, supposedly, was not the limit.

> For a long time [he stressed] philosophy did more for an understanding of infinity than the exact sciences could. Now the position is quite different. But the contribution that philosophy makes to resolution of the problem of infinity can also be very considerable so long as we do not counterpose it to mathematics and science, and do not look for a solution along the line of straining philosophical definitions. The solution has to be sought by way of concrete analysis of a concrete physical situation.[158]

V. A. Basenko saw the complexity of understanding infinity in its being studied through knowledge of the finite. The whole set of instruments by which we constructed the concept of the finite arose from notions about finite objects. There was no infinite existing in nature along with finite objects. But it was inseparable from the finite and was cognised through it.

> Just as space and time have no sense without the totality of cubic metres and hours and at the same time are not reducible to this totality (or their sum), so infinity cannot exist without finite things, but at the same time is not reducible to their totality, functioning as something other than the totality of finitudes. Infinity as such cannot be seen or experienced in any other sensual way. Since we cognise finite concrete things, we also cognise infinity as such.[159]

The infinity of matter is manifested in three main aspects, as S. T. Melyukhin stressed in his paper: viz., temporal existence, space, and the structure of matter. He formulated the most common definition of the infinity of time, which signified "unlimited duration of the existence of matter conditioned by its uncreatability and indestructibility". Spatial infinity meant

> the existence in the world of a countless number of material objects, levels of structural organisation, and their corresponding nodal lines of measurement expressing the boundaries of the existence of concrete, qualitative states.[160]

Some natural scientists, when considering the subject-matter of cosmology, define it as the science of the Universe. From that they conclude that it is sufficient, so as automatically to solve the problem of the finitude or infinity of the Universe, to construct a finite or infinite cosmological model. In this, understandably, priority in tackling the problem of infinity is yielded to the natural scientists. That point of view was criticised in Karmin's paper. In his view

> a cosmological model is one of cosmic matter but not of matter in general, a model of the Metagalaxy and not of the whole Universe. The question of the infinity of the material world, the infinity of the Universe, will not be resolved by constructing some model or another but by philosophical generalisation of all the scientific data amassed by humanity.[161]

E. M. Chudinov tried to show that assertion of the infinity of the Universe had an axiomatic character and did not depend on any physical or mathematical principles.[162]

The works published for the centenary of the birth of Einstein were a definite contribution to solution of the philosophical problems of the theory of relativity. Practically all philosophical and physical journals published articles that in one way or another made a philosophical analysis of the theory. A generalising volume was published for the anniversary, for example, written by well-known Soviet experts who had made a contribution to philosophical substantiation of the theory.[163] Several of the most interesting articles that had appeared earlier in the periodical press were republished in the book.

I shall not analyse the whole literature devoted to the Einstein anniversary but shall touch only on a few articles that appeared in the volume mentioned, in which a broad range of philosophical matters was reviewed that followed from the content of the special and general theories of relativity, relativistic cosmology, quantum mechanics, and the single theory of field. The work referred to opened with a paper, "Einstein's Philosophical World View", written by the author of the present monograph, which I shall not touch on since its ideas are more broadly represented here.

The next article, by M. E. Omelyanovsky, surveyed the question of the relation of relativistic physics and dialectical materialism. Its author claimed that since physics considered it its job to reflect nature as it is, that was a reason why outstanding scientists subjectively remote from conscious dialectics often applied its principles unconsciously in developing physics. Omelyanovsky saw the dialectical-materialist character of modern physics in its complete rejection of the idea of common sense being the exclusive basis of the scientific and philosophical values.

> Physics is becoming an experimental science; sense perception is combined in it with theoretical thinking; abstract methods and the closely related mathematisation of science are becoming common. Experimental data are no longer characterised as commonsense notions but are rather interpreted by scientific theory featuring concepts that are remote from sensual givenness both in their content and mutual relations.[164]

A distinguishing feature of modern physics is that the idea of evolution has penetrated all parts of it from philosophy. In Omelyanovsky's view that finds expression in the new physics' being

> in principle a unified science consisting of fundamental theories connected in their origins and forming a hierarchical spiral the length of which grows with the development of human culture, technology, industry, and society as a whole. In modern physics, experimental data are described in terms of classical physics and are given an interpretation in terms of non-classical theories.[165]

The spirit of dialectics had already made itself felt in the development of electrodynamics although a metaphysical (anti-dialectical) outlook prevailed at that time among scientists. In Maxwell's theory "such opposites as electricity and magnetism" were associated in a single whole.[166]

Einstein, by unconsciously applying the ideas of dialectics, Omelyanovsky stressed, created a special theory of relativity in which the dogmatic idea of the immutability of the main principles and concepts of classical physics was destroyed. The birth of relativistic physics became possible through resolution of the contradiction that had arisen on the boundary of classical mechanics and electrodynamics.

> Einstein solved the contradiction in a genuinely dialectical fashion. He combined, and not by means of logical conjunction either, the Galilean relativity principle and the constancy of light velocity principle, mutually exclusive in classical theory, within a unified whole, and that meant the birth of a new physical theory relativistic mechanics, in which both of these principles appeared in a new form and were necessarily linked with each other.[167]

Einstein's dialectical approach also had a place in creating the general theory of relativity, in which rest mass and gravitational mass, regarded in classical theory 'as absolutely separate and independent, proved mutually correlative and dialectically inseparable in Einstein's theory'.[168] The dialectical character of relativistic physics is seen in the special theory of relativity being the limiting case of Einstein's theory of gravitation.

B. G. Kuznetsov tried to take a retrospective look, from the standpoint of relativistic physics, at the place and role of classical physics in the present-day picture of the world, and to give a description of the stages of the scientific revolution that led to development of the theory of relativity. The first stage, in his view, was the age of the Renaissance, which already included rudiments of the new ideas but had not yet

shaken off the influence of Peripatetic notions of the universe. He suggested that one could speak of the scientific revolution of the sixteenth century.

> During the Renaissance [he stressed] the system of causal conceptions of the world based on logical analysis and experiment had not as yet been separated from the moral and aesthetic conceptions and was mostly expressed in natural-philosophic terms. However, these forms (aesthetics, ethics, and natural philosophy) were closely linked with such scientific discoveries as Copernicus' system and Columbus' feat. The singling-out itself of science as an autonomous component of culture was a result of the revolution in the views of the world and its cognition. The modern conception of science as a system free from external criteria arose out of the achievements of the 16th century.[169]

According to Kuznetsov, the second stage of the scientific revolution was the period of the late sixteenth century and early seventeenth, i.e. the time of the work of Giordano Bruno which included not only the past (Nicolaus Cusanus' ideas of neoplatonism) but also propositions that were considerably ahead of the science of the time. The third stage was the period of the predominance of Cartesian physics, when an attempt was made to understand the Universe as a whole. The fourth stage of the scientific revolution included Newton's dynamism. Kuznetsov tried to find the invariant that came into the paradigm of each scientific age and that was realised in the theory of relativity. In his view it was the problem of the uniformity and non-uniformity of the world, i.e. its isotropy and anisotropy, the change in which he traced right up to the development of relativistic physics.

Disputes have gone on for a long time, of course, around the problem of time in the special theory of relativity and the concept of simultaneity, given by Einstein, that is closely associated with it. Y. B. Molchanov devoted his paper to an examination of these questions, treating the various approaches to the concept of simultaneity that existed in pre-relativistic physical theories: Aristotle's (he drew attention to such a feature of simultaneity as its reflection of the absence of temporal relations between events); Newton's (simultaneity was associated with events' appertaining to a single point on the scale of absolute time); Samuel Clarke's (the correlation of those physical events that mutually assumed one another); Kant's (which linked the relation of simultaneity with that of integrity).

> All these rather meagre theoretical fragments scattered mostly in philosophical works that are not too readily available, if not exactly little known, did not offer a consistent and logically clear

> definition of simultaneity—they did not even facilitate the realisation that a search for such a definition was necessary.[170]

The problem of simultaneity attracted attention once more in the second half of the last century, when many attempts were made to give it an empirical substantiation, but without success. Henri Poincaré, who treated simultaneity on the subjective plane, also did not solve the problem. In contrast to Poincaré, Einstein proposed a famous solution that differed qualitatively from the definitions existing before him. The universal recognition of his solution, in Molchanov's view, was connected with the following two circumstances:

> First, it carried out the task that was shifted in the foreground of the methodological issues of physics as a result of the critique by positivists of the concepts of Newtonian absolute space and absolute time. Namely, it resulted in the establishment of the *empirical* status of the concepts of *'temporal relations'* and *"simultaneity"* or, to be more precise, it resulted in the empirical substantiation of these concepts, linking them up with the properties of *actual physical interactions.*
>
> Second, this empirical substantiation resulted in the establishment of a *materialist relational conception* of time which considers *temporal relations to be derivative from the properties of actual physical interactions.*[171]

I. A. Akchurin and M. D. Akhundov devoted their paper to the evolution of the concept of space in the history of physics; they analysed the Newtonian and Einsteinian conceptions, elucidated their historical place, and demonstrated in what direction the conception was developing today. In that connection they examined questions of topological stratified spaces, spaces with a variable topology, and the general topological structures of physics.[172]

G. E. Gorelik devoted his paper to dimensionality, one of the important properties of space-time. Being aware that this problem had a multiaspect character, he analysed it from the standpoint of mathematics, physics, and philosophy, although they did not exhaust the whole content of the concept. In spite of his historical approach, his main attention centred on an examination of dimensionality in Einstein's work, since the essence of time and space were most fully disclosed in it. The paper also touched on the empirical status and substance of the concept of dimensionality in the light of the facts of modern physics. Gorelik concluded that

> a philosophical, epistemological analysis of the problem of substantiating the dimensionality of space can not only demonstrate the possible non-universality of three-dimensionality but can also give mathematics and physics an 'order' to develop theoretical models of space in which dimensionality would depend

> on certain conditions, in particular on the scale of the phenomena. To insist on the definitiveness of the space-type models of *modern* mathematics means (from the standpoint of epistemology) not to allow for the relation between absolute and relative truth.[173]

A. M. Mostepanenko analysed the approaches of Einstein and Poincaré to the interdependence of physical science and geometry, and concluded that the road taken by Einstein had been the more fruitful for the development of physics. Einstein had managed an adequate space-time reflection of reality through a different treatment of the experimental data than Poincaré's, who tried to tackle the problem on the basis of agreement, as Poincaré himself admitted. The latter's statement that there must always be the simplest geometrical model at the bottom of a physical theory proved incorrect. But in Mostepanenko's view, the problem posed by Poincaré had not yet been finally resolved.

> Poincaré was right in asserting a kind of complementarity between the geometrical and the non-geometrical components of physical theory, which must be taken into account in constructing and developing the theory.[174]

E. M. Chudinov examined two problems. The first concerned disclosure of infinity in classical and relativistic physics. He came to the conclusion that the concept of infinity was not identical in them.

> Relativistic cosmology rejected the image of Euclidean infinity of the Universe as inadequate. Some of its results could be, and actually were, interpreted in the spirit of finitism. However, if we consider relativistic cosmology in the entire totality of its results, we shall have to draw the conclusion that in its spirit it is alien to the finitist view of the material world, offering a more profound and complete conception of its infinity than classical cosmology.[175]

The other problem was a critical survey of the philosophy of operationalism, and in particular of Bridgman's application of it to interpretation of the theory of relativity. Chudinov showed the superiority of Einstein's understanding of the substance of physical knowledge, in which, unlike Bridgman's, the empirical foundation of physical theory was recognised. But, he considered, Einstein's method should not be idealised; it was not wholly adequate to the real physical processes.

> There is a one-sidedness in his method which prevented his evaluating correctly quantum mechanics. Einstein believed that physical objects could be cognised more or less "speculatively", through construction of a corresponding mathematical model whose correctness could only be proved after the fact, by

verification of the empirical consequences which follow from the theoretical description.[176]

Probability and statistical ideas have now become commonplace in physical science. This new trend still calls for philosophical substantiation. Y. V. Sachkov devoted his paper to that point, endeavouring to approach its solution historically. He surveyed the corresponding ideas of Clausius, Maxwell, Boltzmann, and Gibbs, who had a decisive influence on the forming of statistical notions in physics. Sachkov drew attention to the link of the category of chance, and also of probability, with statistical methods. Defining the significance of probability in classical physics, he said that it

> is a structural characteristic of a definite class of physical systems. Its methods permit the discovery of interdependences and mutual transitions between the micro- and macrocharacteristics of the systems in question.[177]

Quantum mechanics gave another push to the development of probability methods. In that connection Sachkov put the stress on the famous discussion between Einstein and Niels Bohr and their attitude to the new methodological problems of the understanding of quantum mechanical objects. In his view

> the significance of probability in quantum mechanics lies first of all in that it permits the study and theoretical expression of the laws of objects with a complex, two-level structure including certain features of independence or autonomy. The principal meaning of probability lies in this connection with structure and methods of its expression.[178]

The content of the discussion between Einstein and Bohr was considered separately in the paper of S. V. Illarionov, who divided its course into three stages. In the first he put the polemic about the connection of quantum mechanics and the relation of indeterminacy, in the second the discussion of the fullness of quantum mechanics, and in the third the disputes of recent years when the depth and real content of the discussion began to be clarified.

The reason why this discussion had not only had a more than passing scientific significance but also a philosophical one, Illarionov saw in its ranging over

> a number of interconnected problems: the general principles from which a concrete type of physical laws may be deduced as against obtaining these laws by generalisation of experimental data; clarity and distinctness of knowledge as against its contradictoriness; continuity of processes and discreteness of the world; universal causality and chance. All these problems are most intimately connected with a scientist's general world outlook, with epistemology.[179]

Delokarov considered two matters in the book. One concerned the historical, methodological analysis of the theory of relativity in Soviet philosophy, the other included an examination of the "Einstein-Mach" problem.

I shall touch only on the second. Delokarov aimed at answering whether the theory of relativity was connected with Machism as a philosophical system. He endeavoured to find the reason why natural scientists were drawn to Mach and his followers. He saw it in the fact that the ideas of dialectical materialism, which were overcoming metaphysics, Kantian apriorism, etc., were not known to broad circles of scientists. In addition, he noted, any criticism of the foundations of Newton's mechanics caught scientists' attention insofar as it might serve better as a methodological support for the new physics. They therefore displayed an interest in Mach's ideas. He also indicated yet another circumstance that made them attractive.

> The influence of positivist aspirations, including Mach's ideas, among some natural scientists is partially explained by the fact that many other contemporary philosophical schools and sects in the West were clearly irrational, aprioristic, and subjectivist in nature, ignoring the attainments of natural science and taking a negative or sceptical attitude to the development of scientific knowledge.[180]

Delokarov claimed that Mach's epistemological ideas could not have helped Einstein discover the theory of relativity. On that point he polemicised against several Western philosophers.

> The new theory of space, time, and gravitation is linked with diverse variants of the epistemological conception of Mach and his followers mostly historically rather than conceptually or through common origin. The relativity theory could not in principle be methodologically stimulated by Machism, still less could it consistently implement its philosophical principles.[181]

A number of well-known physicists contributed to the volume, among them A. D. Alexandrov, V. A. Fok, M. A. Markov, V. L. Ginzburg, V. S. Barashenkov, and V. I. Rodichev. Their works had a predominantly scientific character and were not included in the analytical review cited.

I have presented only a few of the philosophical problems of the theory of relativity studied by Soviet scientists to the reader here, and they by no means exhaust the whole content of their work. It is not my purpose, however, to express my opinion at this point on the conceptions of the authors quoted, since many of them will be dealt with in other sections of the present treatise.

NOTES

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Part Two

The Evolution of Einstein's Philosophical Views

The theory of relativity, like any other generalising physical theory, could not, in Einstein's view, have been created or developed within a closed physical science.

> It is for this reason that the critical thinking of the physicist cannot possibly be restricted to the examination of the con cepts of his own specific field.[1]

Philosophical knowledge was a must for Einstein, and not a kind of hobby, as some represent it. Objecting to the natural scientists who had a scornful attitude to philosophical knowledge, he wrote:

> If I had devoted myself to science without being guided by such purely worldly motives as making money or satisfying my ambition, and (at least not only because) I considered it a sport, mental gymnastics, which gave me satisfaction, one question was of burning interest to me as a scientist. What aim should and could be set for the science to which I was devoting myself? How far are its main results 'true'? What was essential in them and what depended only on the chance of their development?[2]

The leading side of Einstein's scientific work was precisely that, unlike many of his colleagues, he rose to the heights of philosophical analysis, including problems of physics proper, its concrete methods of inquiry, and even its history. He was convinced that a radical transformation of the foundations of classical physics required the enlisting of philosophical knowledge.

Statements can sometimes be met that Einstein did not base himself on philosophical knowledge when creating the theory of relativity. It is impossible to accept that point of view. Study of his writings shows that he had assimilated the main ideas of scientific methodology before he created the theory of relativity. Evidence of that is his many statements about the philosophical foundations of classical mechanics, and about the philosophical works that he studied in the Technical High School and with his comrades in the 'Olympia' Academy. He

acquired a taste for the methodological problems of natural science even before entering the Technical High School. Apropos of that he wrote:

> I also had the good fortune of getting to know the essential results and methods of the entire field of the natural sciences in an excellent popular exposition, which limited itself almost throughout to qualitative aspects (Bernstein's *People's Books on Natural Science*, a work of 5 or 6 volumes), a work which I read with breathless attention. I had also already studied some theoretical physics when, at the age of 17, I entered the Polytechnic Institute of Zürich as a student of mathematics and physics.[3]

1

Philosophical Analysis of Classical Mechanics and Metaphysics

Einstein understood that the philosophy of materialism dominant in nineteenth century science, expressed in its metaphysical, mechanistic form, could not be employed as the methodological basis for nascent relativistic physics. He saw that several of its propositions were then outmoded, and that they were inadequate to the newly discovered physical phenomena, above all the maxim that objects and phenomena of the external world that allegedly existed in a fixed, immutable state should be treated as unconnected with one another. The world as a whole, and material objects, metaphysics asserted, could not be regarded as a process. Change, it was considered, only occurred in nature in the quantitative characteristics and external aspect of objects, and so their essential properties were not affected. From that it followed that scientific concepts that reflected the external world also did not need to be altered or revised, except those that had been mistakenly taken as scientific truths. Metaphysical philosophy did not admit the existence of relative truths. The metaphysician, Frederick Engels wrote,

> thinks in absolutely irreconcilable antitheses. 'His communication is "yea, yea; nay, nay"; for whatsoever is more than these cometh of evil'. For him a thing either exists or does not exist; a thing cannot at the same time be itself and something else. Positive and negative absolutely exclude one another; cause and effect stand in a rigid antithesis one to the other.[4]

Metaphysical ideas had penetrated people's consciousness not only through scientific literature but also through textbooks. A metaphysical view had taken root both in school and in specialised teaching institutions through one-sided, distorted views about natural phenomena. And that was why the struggle against metaphysics was so complicated. In the textbook on astronomy of the German scientist J. H. Mädler, it was said, for example, that

> All the arrangements of our solar system, so far as we are capable of comprehending them, aim at preservation of what exists and at unchanging continuance. Just as since the most

> ancient times no animal and no plant on the earth has become more perfect or in any way different, just as we find in all organisms only stages *alongside of* one another and not *following* one another, just as our own race has always remained the same in corporeal respects so even the greatest diversity in the coexisting heavenly bodies does not justify us in assuming that these forms are merely different stages of development; it is rather that everything created is *equally* perfect in itself.[5]

It would be an error, however, to suggest that Einstein's philosophical views were formulated under the influence of literature of that type. He had profoundly mastered natural science, not however as a simple sum of truths but as a progressive, contradictory process, and closely followed all its new advances and tendencies. He did not limit himself to problems of natural science. Public affairs interested him all his life. He soaked himself in all the advanced science and culture of his time, including classical German philosophy with its dialectical tendency, the pinnacle of which was Hegel's dialectics. He was not left unaffected by ideas of dialectical materialism, which had moved to the centre of ideological disputes. Hegel's words in his *Logic* apply fully to Einstein:

> In experience everything depends upon the mind we bring to bear upon actuality. A great mind is great in its experience; and in the motley play of phenomena at once perceives the point of real significance.[6]

Einstein formed his own special scientific and philosophical outlook, which differed at bottom from the ideas of metaphysics, under the influence of all the reality around him.

He read many scientific theories in a new way, seeing ideas in them that were in clear contradiction with the theoretical maxims of metaphysics, and which indicated the dialectical character of reality.

Copernicus, who, as Einstein himself recognised, 'more than almost anyone else, contributed to the liberation of the mind from the chains of clerical and scientific dominance in the Occident',[7] had a big influence on him. Frederick Engels had earlier drawn the same conclusion about Copernicus:

> The revolutionary act by which natural science declared its independence and, as it were, repeated Luther's burning of the Papal Bull was the publication of the immortal work by which Copernicus, though timidly and, so to speak, only from his deathbed, threw down the gauntlet to ecclesiastical authority in the affairs of nature.[8]

Study of the cosmological system of Aristotle and Ptolemy

showed Einstein its metaphysical and mythological character. It claimed that

> the center of the terrestrial sphere practically coincides with that of the universe. Sun, moon, and stars are prevented from falling toward the center of the universe by being fastened onto rigid (transparent) spherical shells whose centers are identical with that of the universe (or space). The outer shells with their heavenly bodies represent the 'celestial sphere' whose objects are envisaged as eternal, indestructible, and inalterable, in contrast to the 'lower terrestrial sphere' which is enclosed by the lunar shell and contains everything that is transitory, perishable, and 'corruptible'.[9]

Analysis of that system had led Copernicus to the conclusion that it was scientifically unsound, since it contradicted observations of the motions of the celestial bodies. Copernicus had criticised the idea of an exclusive position of Earth in the Universe, of its 'pre-eminence' over the other celestial bodies. He rejected the idea of the existence of two special worlds—the earthly and the celestial—different in their substance and independent of and unconnected with one another. Having calculated the relative distances of the five planets then known from the Sun, and their periods and velocities of revolution along their orbits, he had discovered a dependence between their periods of revolution and velocities of motion on their distance from the Sun. These theoretical conclusions led him to the surmise that the Sun and planets were not celestial objects isolated from one another, as should have followed from the assertions of metaphysical methodology, but were an interconnected system. Copernicus wrote:

> the orders and magnitude of all stars and spheres, nay the heavens themselves, become so bound together that nothing in any part thereof could be moved from its place without producing confusion of all other parts and of the Universe as a whole.[10]

Copernicus' analysis of existing cosmological theories, and the positive exposition of the new heliocentric picture of the world undermined the natural-science foundation to which metaphysics clung, and demonstrated the dialectical character of nature. Copernicus' theory had an immense influence on the outlook of natural scientists. As Einstein wrote:

> This great accomplishment of Copernicus not only paved the way to modern astronomy; it also helped to bring about a decisive change in man's attitude toward the cosmos. Once it was recognized that the earth was not the centre of the world, but only one of the smaller planets, the illusion of the central significance of man himself became untenable.

> Hence, Copernicus, through his work and the greatness of his personality, taught man to be modest.[11]

Einstein's philosophical views were also formed under the influence of Galileo's doctrine. He not only had a high opinion of Galileo because of his great contribution to the development of physical science, but also admired him as a profound thinker. In his foreword to the reissue of Galileo's *Dialogue Concerning the Two Chief World Systems*, he wrote that this work 'is a mine of information for anyone interested in the cultural history of the Western world and its influence upon economic and political development'.[12]

Humanity, Einstein stressed, had dreamed from time immemorial of reading the great story of the secrets of nature. But that had only become possible thanks to the inquiries of Galileo, whose methodological ideas helped scholars to understand the language of this story. According to Einstein Galileo clearly saw all the defects in philosophy that the mediaeval scholastics had left behind them. In their heyday many of the brilliant achievements of science of antiquity had been consigned to oblivion. Description of natural phenomena and of the structure of the universe had been impregnated with a mystic content. Anthropocentric conceptions had shackled scholars, and prevented them from going beyond the knowledge of ordinary common sense. Galileo, Einstein wrote, succeeded in overcoming

> the anthropocentric and mythical thinking of his contemporaries and to lead them back to an objective and causal attitude toward the cosmos, an attitude which had become lost to humanity with the decline of Greek culture.[13]

He saw that Galileo had come forward as a zealous champion of Copernicus' theory, and not only had defended the latter's ideas but taken several important practical steps to develop them.

> In advocating and fighting for the Copernican theory Galileo was not only motivated by a striving to simplify the represen tation of the celestial motions. His aim was to substitute for a petrified and barren system of ideas the unbiased and strenuous quest for a deeper and more consistent comprehension of the physical and astronomical facts.[14]

Using the telescope in his inquiries for the first time Galileo made several discoveries that made it possible to confirm the new view of the structure of the solar system. He discovered a similarity of the Moon to terrestrial topography. Against earlier views he showed that the Moon was

not an absolutely smooth body consisting of a 'perfect' substance. Galileo discovered the phases of Venus, and satellites of Jupiter similar to Earth's satellite, the Moon. Einstein stressed that Galileo demonstrated by this discovery that 'Jupiter with its moons represents so to speak a Copernican System in miniature'.[15] When studying the Sun Galileo discovered dark areas on its surface that changed with time, later called sunspots. That discovery, too, contradicted the then existing cosmological hypotheses and the methodological principles of metaphysics.

Defenders of the geocentric system of the world, who opposed Copernicus, based themselves on Aristotle's doctrine of motion that every body that did not experience an influence from outside always tended to a state of rest, from which it followed that, if the Copernican theory were true, it should be noticeable in the motions of material bodies found on Earth. But Galileo convincingly demonstrated that in a uniformly moving system the motion of bodies proceeded in the same way as in an immobile system, so that we could not observe the motion of the Earth around the Sun. He showed the scientific unsoundness of the theory of motion created by Aristotle, and for the first time formulated a first approximation of a fundamental law of nature, the law of inertia. He thus made an enormous contribution to solution of the problem of motion. That discovery had been possible, in Einstein's opinion, because of Galileo's rejection of a style of thinking that had retained its force since ancient times. The explanation of phenomena of the external world based only on appearance and direct observations had steered scientific thinking for more than two thousand years into the channel of the Aristotelean treatment of motion by which velocity was due solely to the action of external forces on a body. In spite of that Galileo asserted that if no forces acted on a body, it was either at rest or moved uniformly in a straight line. Velocity was thus not an indicator by which the action of external forces on a moving body could be determined.

In Einstein's view Galileo reached that brilliant conclusion through application of a scientific method of studying natural phenomena. In Galileo's inquiries the fantastic or intuitive principle, and belief in dogmas based on the authority of Aristotle and other thinkers, were superseded for the first time by experiment and theoretical substantiation. 'Only experience and careful reflection are accepted by him as criteria of truth,'[16] Einstein wrote of Galileo. When drawing attention

to these requirements of Galileo's, Einstein also criticised those who scorned empirical facts.

> Propositions arrived at by purely logical means [Einstein pointed out] are completely empty as regards reality. Because Galileo saw this, and particularly because he drummed it into the scientific world, he is the father of modern physics indeed, of modern science altogether.[17]

He formulated Galileo's scientific method as follows:

> First, thinking alone can never lead to any knowledge of external objects. Sense perception is the beginning of all research, and the truth of the theoretical thought is arrived at exclusively by its relation to the sum total of those experiences.[18]

He accepted these epistemological precepts of Gallileo's as necessary conditions of scientific research. During the whole of his life they served him as reliable methodological principles. He was conscious that 'the discovery and use of scientific reasoning by Galileo was one of the most important achievements in the history of human thought'.[19]

Objecting to scientists who tried to distort Galileo's methodological principles, Einstein wrote:

> It has often been maintained that Galileo became the father of modern science by replacing the speculative, deductive method with the empirical, experimental method. I believe, however, that this interpretation would not stand close scrutiny. There is no empirical method without speculative concepts and systems; and there is no speculative thinking whose concepts do not reveal, on closer investigation, the empirical material from which they stem. To put into sharp contrast the empirical and the deductive attitude is misleading, and was entirely foreign to Galileo.[20]

As we have seen, Einstein, following Galileo, did not recognise the dogmas of everyday consciousness prevailing in his day. He also did not see eye to eye with those who made an absolute of the role of 'pure' thought in the cognitive process. Galileo roused a striving in Einstein to penetrate the secrets of the universe. His rejection of the limitations of anthropocentrism helped Einstein to become convinced of the idea of causal dependence, the link between phenomena of nature, and the unity of the latter's structure.

Kepler, too, had a certain influence on the moulding of Einstein's philosophical views. Kepler's passionate desire to penetrate the essence of natural phenomena always enraptured him. He suggested that it was Kepler's philosophical intuition and profound faith in the law-governed relations

of phenomena and in 'the mysterious harmony of nature',[21] that had helped the latter to carry out a great many empirical inquiries that were crowned by such brilliant discoveries. 'In addition,' Einstein stressed, 'he dealt with a field of knowledge that immediately endangered the adherents of religious truth.'[22]

Einstein put the stress in his writings on the problems that Kepler had succeeded in solving and had then had an immense influence on scientists' philosophical views. The first problem was to repudiate illusory notions of the movement of the planets about the Sun and to determine their true motion.

> What had been observed and recorded with great diligence, therefore, was not actually the movements of the planets in space, but the temporal alterations which the direction earth-planet undergoes during the passage of time.[23]

Kepler, as we know, coped brilliantly with this difficult task. He examined the vast empirical material that Tycho Brahe left behind him. Thorough analysis led him to discover the real laws of the movement of the planets around the Sun. The Copernican heliocentric idea was thus given new scientific substantiation.

The conclusions obtained by Kepler needed mathematical substantiation. He also coped brilliantly with that requirement of science. The laws he discovered pointed to the existence of a necessary connection in the motions of celestial bodies and confirmed the Copernican proposition that the Sun and planets, including Earth, were not dissociated from one another, as it then seemed to scientists, but were a single interconnected system. Unlike Copernicus, who stated only a proposition about the interconnection of celestial bodies, Kepler substantiated the regularity of this connection mathematically. Einstein specially noted Kepler's contribution to discovery of the laws of motion of the planets of the Solar system. And it was 'particularly consoling', he said in admiration, that this discovery was made 'in an age in which the reign of law in nature was as yet by no means certain'.[24]

Kepler's scientific successes made it possible to reexamine the postulate rooted in the consciousness of naturalists about the 'natural place' of celestial bodies, and about motion as a 'striving to it'; they refuted Aristotle's doctrine of the perfect motions of celestial bodies and showed that the connecting thread of the planets of the Solar system proceeded from the Sun.

What were the ideas that made such vast achievements possible by a naturalist who lived at a time when an outlook on the world foreign to science was dominant. Einstein considered that Kepler's

> life work was possible only when he succeeded in freeing himself to a large extent from the spiritual tradition in which he was born. It was not only a question of religious tradition based on the authority of the church, but of the general notions about the conditioning of events in the cosmos and in human life, as well as ideas about the relative importance of thought and experience in science.[25]

Like the preceding work of the founders of classical mechanics Kepler's theory once more convinced Einstein that direct sense data alone could not guarantee the attainment of true knowledge. The empiricists' conception that direct sense data as such expressed the essence of a studied object without any mental treatment, was undermined by the discoveries of Copernicus and Kepler. 'Kepler's marvelous achievement is a particularly fine example of the truth that knowledge cannot spring from experience alone'.[26]

Einstein, however, did not just draw this epistemological principle from Kepler's work. The latter's path in science once more convincingly showed him that theorising divorced from reality also could not yield true knowledge. There were many examples of that when hypotheses put forward in isolation from reality had been refuted by scientists guided by a scientific methodology. It had become obvious that

> logical-mathematical theorizing, no matter how lucid, could not guarantee truth by itself; that the most beautiful logical theory means nothing in natural science without comparison with the exactest experience.[27]

Einstein thus saw in the person of Kepler a scientist who refuted both narrow empiricism and the methodology of the scholastics. While relying on experimental data he had equally turned to philosophical knowledge. 'Without this philosophic attitude, his work would not have been possible', Einstein wrote of Kepler.[28]

Einstein's attitude to Newton is of great interest. In his words 'destiny placed him at a turning point in the history of the human intellect'.[29] I spoke above of the world outlook that the Middle Ages left behind them. Its foundation—ideas of geocentrism and anthropocentrism, indeterminism, dogmas of ordinary consciousness, belief in 'pure' thought—had already been undermined to some extent by Copernicus,

Galileo, and Kepler. But Newton's theory was the cause of the real shaking of the old mode of thought. According to Einstein it was Newton

> who determined the course of western thought, research, and practice like no one else before or since. Not only was he brilliant as an inventor of certain key methods, but he also had a unique command of the empirical material available in his day, and he was marvelously inventive as regards detailed mathematical and physical methods of proof.[30]

Einstein drew attention to Newton's theoretical substantiation of the regularity of nature. In his view Newton was the first who succeeded in finding a clearly formulated basis from which he could proceed logically by means of mathematical thinking to a quantitative description of a broad field of phenomena that accorded with experience. Newton's belief in determined order and regularity in nature, and his conviction of the existence of dependence of certain phenomena on others, enabled him to discover the mathematical expression of these dependences and to create a method of 'fluxion', the foundation of modern differential and integral calculus. The possibility of applying a general mathematical description to the most diverse fields of knowledge indicated that the inner processes of the phenomena described mainly proceeded uniformly. Nature faced scientists as a single, interconnected system.

The idea of the existence of law-governed connections in nature developed in natural science found reflection in Newton's discovery of the three famous classical laws of motion and the law of universal gravitation. Guided by the laws of mechanics in study of the motion of heavenly bodies, Newton drew the conclusion that, if no forces acted on them, they would move in a straight line in accordance with the first law of mechanics. But in fact, according to Kepler's laws, planets moved in elliptical orbits. Consequently, Newton concluded, forces exerted an influence on them that constantly forced them to deviate from motion in a straight line. By analysing Kepler's laws he came to the conclusion that all the forces acting on the planets were rigorously directed toward the Sun. Calculation also showed him that the farther a planet was from the Sun the weaker was the force operating on it. By comparing two planets at different distances from the Sun, Newton found that central forces acted between them and the Sun whose magnitude was inversely proportional to the square of the distance between their cen-

tres. But in order to draw a conclusion about the universal character of this regularity, he had to become convinced that it could also be extended to the force of terrestrial gravitation that ensured centripetal acceleration of the Moon. By comparing the force of terrestrial gravitation with the centripetal force operating on the Moon, he saw a striking similarity between the two, previously considered different. He thus reduced the many forces of attraction to one gravitational force and so discovered the law of universal gravitation, from which it followed not only that the planets and their satellites, comets, and other bodies of the Solar system interacted on one another, but that it was obvious that all the material bodies of the Universe were linked with one another by forces of gravitation.

This discovery of Newton's was scientific proof of the material unity of the part of the Universe we observe, because it refuted the idea of the absolute separation of the terrestrial and celestial worlds. The fact of the discovery in all known celestial bodies of such a fundamental property as gravitation, inherent also in earthly bodies, in itself indicated the single material nature of the Universe. It followed that 'gravity' was a material property, that the connecting link in the Universe was not due to something external, spiritual as certain naturalists claimed, but to the properties of matter itself. Newton's world, unlike that of Aæistotle and Ptolemy, was a world of perpetual motion. Although the picture presented by him had flaws it ran counter on the whole to the metaphysical world outlook; Einstein understood that perfectly well. He believed that there were hardly any doubts left after these achievements that the development of all material phenomena in general occurred with a necessary regularity comparable with clockwork.

Newton's discoveries, Einstein said, were the first fullest physical confirmation of the philosophic idea of the causal connection of natural phenomena, since 'before Newton there existed no self-contained system of physical causality which was somehow capable of representing any of the deeper features of the empirical world'.[31] The posing of causality that Descartes had tried to suggest, following Demokritos and Epicurus, had 'remained a bold ambition, the problematical ideal of a school of philosophers'.[32]

While paying its due to Kepler's discovery of the laws of motion of the planets of the Solar system, Einstein showed that it had still not provided full understanding of the causality

of the world since the three laws were not logically connected together. But that was not the main defect, however, that prevented Kepler from disclosing a deeper causality in nature. His laws

> are concerned with the movement as a whole, and not with the question *how the state of motion of a system gives rise to that which immediately follows it in time.*[33]

Einstein considered that the Galilean laws of inertia and free fall in Earth's field of gravitation did not fully confirm the conception of physical causality since they, too, like Kepler's laws, related to motion as a whole. In Einstein's view the main argument bringing out causal connections in nature was the discovery of the differential form of the law by which change in the state of motion of a material point in an infinitely small interval of time could be made out. 'The differential law,' he wrote, 'is the only form which completely satisfies the modern physicist's demand for causality'.[34] But Newton took the final step toward affirming the idea of causality when he succeeded in linking the laws of motion with the laws of gravitation.

> It is the combination Law of Motion plus Law of Attraction which constitutes the marvelous edifice of thought which makes it possible to calculate the past and future states of a system from the state obtaining at one particular moment, in so far as the events take place under the influence of the forces of gravity alone.[35]

Einstein saw in Newton a scientist who, by his discoveries in natural science, realised the dreams of the materialist philosophers of antiquity, Demokritos and Epicurus, who had considered that there a causal connection must exist between all physical phenomena without exception.

The founders of classical mechanics thus had an immense influence on the forming of Einstein's philosophical views and on his philosophical approach to the problems and history of natural science.

He differentiated between the revolutionary and conservative aspects in classical mechanics. I shall speak about the conservative side below. As for the revolutionary side, it consisted, for Einstein, in the theories of Copernicus, Kepler, Galileo, and Newton being largely capable of overthrowing the religious, scholastic outlook and at the same time being a scientific confirmation of several brilliant ideas expressed by Greek thinkers. This revolutionary trend convinced Einstein of the need to employ philosophical knowledge in the natural sciences. Under the influence of these theories, he

finally came to the conclusion that the Universe has an objective character, that there is a universal connection and regularity in nature, and a causal dependence of all physical phenomena, and understood that pure thought could not in itself lead to any knowledge whatsoever, while empirical facts alone without theoretical analysis could not lead to the formation of scientific concepts. The history of science witnessed that knowledge based only on ordinary experience could not be relied on; scientific knowledge could not be absolutised, since it was not eternal truth, but had a relative character. It became clear to him, too, that such concepts as empirical and theoretical, and induction and deduction, could not legitimately be opposed to one another, or isolated from each other, but that they were mutually related.

The metaphysical idea of the isolation of natural phenomena was superseded not only in mechanics but also in other fields of natural science. An idea had predominated for a long time in physics, for example, that electrical and magnetic phenomena were not related. But the work of Oersted, published in 1820, in which he described experiments on the deflection of a magnetic needle by a wire along which galvanic electricity passed, indicated a close connection between quite common natural phenomena, to wit magnetism and electricity. (It was then known that a great many bodies possessed magnetic and electrical properties.) 'This experiment,' Einstein and Leopold Infeld wrote, 'is interesting, in the first place, because it shows a relation between two apparently quite different phenomena, magnetism and electric current.'[36]

Michael Faraday made an immense contribution to generalising ideas about electromagnetic phenomena. Before him there had been no single view on the nature of the forms of electricity then known. It was thought that 'galvanic electricity', the 'electricity of friction', 'thermoelectricity', 'magnetic electricity', and 'animal electricity' were different phenomena. Faraday proved experimentally that they were qualitatively identical, and that their nature was one and the same, irrespective of their source, be it a chemical cell, a living organism (certain species of fish), or whether it was the result of the friction of certain inorganic bodies. He thus discovered something common to organic and inorganic matter which called in question the idea of the existence of an absolute dividing line between these realms of nature.

Newton, being a prisoner of metaphysics, could not indicate the physical source of the planets' motion around the Sun.

He was forced to appeal to an 'initial impulse'. That limitation was overcome by Kant in his cosmogonic theory. As Engels wrote:

> Kant began his career by resolving the stable solar system of Newton and its eternal duration, after the famous initial impulse had once been given, into the result of a historic process, the formation of the sun and all the planets out of a rotating nebulous mass.[37]

After Kant the idea of development found support in the discoveries of Christian Wolff, who criticised the theory of the invariance of species, proposing a theory of evolution. Wolff's ideas found continuation in the theories of Lorentz Oken, Jean Lamarck, and Karl Baer. The idea of the dialectical development of the material world also found support in palaeontology, geology, and other sciences. In place of Cuvier's theory of 'catastrophes' came the better theory of Charles Lyell, which was greeted with great interest by the advanced thought of his time.

An immense advance had been made in the discovery of the connections and relations of the organic and inorganic worlds. The surmises of the French materialists of the eighteenth century, that animate and inanimate nature were not divided by insurmountable barriers, and differed only in degree of organisation of matter, had been scientifically substantiated by the chemical experiments of the German scientist Friedrich Wöhler, who was the first to synthesise an organic compound, urea, which is a product of metabolism in the organism of animals, from inorganic substances. That fact indicated the possibility of the formation of organic nature from inorganic, and the capacity of matter to evolve.

Dialectical ideas on the universal connection in nature also found support in the discoveries of William Grove, who showed that all the forces of nature—mechanical energy, heat, light, electricity, and magnetism were transformed into one another in certain conditions. That was also encouraged by the advances of mathematics which, as Engels put it, 'compelled the mathematicians to become dialectical, unconsciously and against their will'.[38]

But three great discoveries of the nineteenth century perhaps had the greatest significance for the moulding of a dialectical understanding of reality, viz., the law of the conservation and transformation of energy, cell theory, and Darwin's theory of the origin and evolution of species. These summed up the preceding development of science, as it were,

and generalised rich empirical material in which the outlines of the new outlook on the world were visible.

Discovery of the law of the conservation and transformation of energy is linked with the names of several scientists. The chain of their names can be begun with Descartes, who expressed the idea of the preservation of the quantitative state of motion. Further along the chain we find Lomonosov, J. R. Mayer, Joule, Helmholtz, Hess, Lenz, and others.

Mayer, studying the dependence between the work of the human organism and its loss of heat, came to the conclusion that the predominant theory, that all forms of 'force' were unrelated to one another and represented immaterial, imponderable fluids, was not true. He opposed the claim that they were created from nothing. In his view, only a transformation of substances and 'forces' (energy) took place in the organism. He showed that all the natural forces then known were different manifestations of one and the same universal motion. He suggested that they are not only mutually connected but capable of being converted from one form into another and, what was specially important, that *a given force remains a constant quantity in all chemical and physical processes.* In contrast to Descartes, who disclosed the quantitative side of the conservation law, Mayer also pointed out its qualitative aspect. It was that feature of his discovery that Engels stressed.[39]

The law of the conservation of energy was also developed independently of Mayer by Helmholtz, who wrote:

> From an analogous inquiry into all other known physical and chemical processes it follows that the whole of nature has a stock of work capable force which cannot in any way be either augmented or diminished, and that the quantity of work capable force in inorganic nature is eternal and constant in the same way as the quantity of matter.[40]

Helmholtz provided a mathematical substantiation of the law of the conservation of energy discovered by him.[41]

But a general surmise about qualitative transitions from some forces of nature to others did not wholly satisfy scientists. The law of the conservation of energy had to express the quantitative relation between natural forces in their reciprocal transformations. That was successfully done by Joule, who found the quantitative dependence between heat and mechanical motion, or the mechanical equivalent of heat. His discovery put the law of the conservation and transformation of energy on a firm scientific footing.

Thus, thanks to discovery of this law, the dialectical idea of the mutual link of natural phenomena was confirmed. The struggle against various assertions about the existence of extramaterial forces, or 'imponderable matter' on which not only certain philosophical schools but also individual scientists still based themselves, became better argued scientifically. The discovery swept aside notions about an 'initial impulse', having proved the uncreatability and indestructibility of matter and motion, and having related them. Engels considered the discovery of this law the greatest achievement of nineteenth century science because it physically confirmed that

> all the innumerable acting causes in nature, which had hitherto led a mysterious, inexplicable existence as so-called forces mechanical force, heat, radiation (light and radiant heat), electricity, magnetism, chemical force of association and dissociation—have now been proved to be special forms, modes of existence of one and the same energy, i.e., motion... The unity of all motion in nature is no longer a philosophical assertion, but a natural-scientific fact.[42]

Einstein and Infeld expressed similar ideas many years later:

> Once this important work was done [Joule's experiments—*D. G*], further progress was rapid. It was soon recognised that these kinds of energy, mechanical and heat, are only two of its many forms. Everything which can be converted into either of them is also a form of energy.
>
> The radiation given off by the sun is energy, for part of it is transformed into heat on the earth. An electric current possesses energy, for it heats a wire or turns the wheels of a motor. Coal represents chemical energy liberated as heat when the coal burns. In every event in nature one form of energy is being converted into another, always at some well defined rate of exchange. In a closed system, one isolated from external influences, the energy is conserved and thus behaves like a substance. The sum of all possible forms of energy in such a system is constant, although the amount of any one kind may be changing. If we regard the whole universe as a closed system, we can proudly announce with the physicists of the nineteenth century that the energy of the universe is invariant, that no part of it can ever be created or destroyed.[43]

Like the law of the conservation of energy, the cell theory of the structure of an organism of Schwann and Schleiden was also at the focus of philosophical thought and directly touched on problems of ideology. It was known to a broad range of scientists, and not just biologists. According to it a unity of structure was inherent in the vegetable and animal kingdoms. It was demonstrated that their main structural unit was the cell. That discovery became possible through recog-

nition of the idea of development, which contradicted metaphysics. It indicated the existence of connections not only between separate species of the animal and vegetable kingdoms but also between these kingdoms as a whole. Discovery of the cell theory, Engels noted,

> gave a firm basis to the investigation of the organic, living products of nature both comparative anatomy and physiology, and embryology. The origin, growth and structure of organisms were deprived of their mysterious character; the hitherto incomprehensible miracle was merged in a process which takes place according to a law that is essentially identical for all multicellular organisms.[44]

The cellular theory, by pointing out the unity of structure of living organisms, thus led scientific thought to the question of the causes of their diversity. That problem was brilliantly solved by the third discovery of natural science, to wit, Darwin's theory of evolution.

I remarked above that astronomy, physics, geology, mathematics, and other sciences had each in its field indicated the incompatibility of metaphysical precepts with the newly discovered phenomena of nature. These sciences required a different methodological approach to substantiate them. But there was perhaps one among the natural sciences, biology, that was still a prisoner of the metaphysical outlook. Many biologists believed there was a definite number of immutable and genetically unconnected species in nature. They also considered that 'someone' in nature imposed a purposive structure on organisms, as a consequence of which they proved adapted to performing previously foreordained tasks. The existing evolutionary doctrines did not provide a rational explanation of the purposiveness in animate nature, and did not demonstrate the fact of evolution itself. Only Darwin's theory fully cast doubt on the legitimacy of the metaphysical methodology for studying living organisms and species.

Drawing on numerous experimental data Darwin scientifically established that the numerous species of plants and animals were constantly changing. He saw the cause of this variability in the natural laws of nature herself. His theory was a kind of key to explaining the unity of the vegetable and animal kingdoms, brought out the close connection between many biological phenomena, and gave a scientific explanation of the existence of the infinite variety of organisms in nature. For the first time organic nature was described without reference to supernatural forces. Thanks to evolutionary theory light was thrown on the riddle of the origin of man; it became clear

that the organic world was the result of lengthy development.

At the same time there were essential changes in notions about the elements of the inorganic world. The classification of chemical elements made by several chemists before Mendeleev had not been based on the inner connections of the elements. All those then known were put into separate groups according to their externally similar properties. Unlike his predecessors, Mendeleev discovered a dependence of the chemical properties of elements on the magnitude of their atomic weights, and based his classification on real, inner properties rather than outward description. By means of the periodic law that he discovered, Mendeleev not only predicted the existence of previously unknown elements, but also indicated their chemical properties, which was evidence of the existence of inner connections between the elements, i.e. of regularities. His system of elements was a reflection and result of development in inorganic nature. It indicated the dialectical connection in inorganic nature.

All nature appeared to scientists as a connected material whole that was in perpetual motion and development.

> All rigidity was dissolved [Engels wrote], all fixity dissipated, all particularity that had been regarded as eternal became transient, the whole of nature was shown as moving in eternal flux and cyclical course.[45]

The searching mind of the scientist thus could not help seeing the limited character and contradictoriness of the metaphysical outlook, and the insolvency of metaphysics as the methodological basis of physical science. Under pressure of the numerous discoveries of science Einstein saw the outlines of the nascent new world outlook.

The limited character of Premarxian materialism was expressed, of course, not just in its metaphysical form but also in its mechanistic form. Mechanism, having attained philosophical status, like metaphysics, captured solid methodological positions in science, and in particular in classical physics. From many examples of developing natural science we have seen how the dialectical outlook was confirmed, displacing metaphysics. But not only was the fate of metaphysics thrown in doubt. There was an attack at the same time in the natural sciences on the methodology of mechanism which, having become common among scientists, had begun, like metaphysics, to block the development of science. Having arisen on the soil of the advances of classical mechanics, mechanism of course had its historical justification. For classical mechanics had

given a powerful impulse to the development of several branches of knowledge and so had by right captured a leading place in science. Its leading position led to making an absolute of the regularities of mechanical processes. Many naturalists imagined that classical mechanics could answer all questions relating to the material essence of the world; to some of them it seemed that mechanics also explained social phenomena.

A number of phenomena that were outside the limits of mechanical processes proper had in fact been successfully explained by mechanics. It had helped purge certain notions about natural phenomena of the mythological 'dress' in which they had been clothed by the mediaeval scholastics. In addition it had partly made up for the gaps in the metaphysical mode of thought. For example, the notion of the separateness and isolation of natural objects and phenomena had to yield to the onslaught of the idea of the 'mechanical universality' of the world. Mechanics, in its own way, promoted affirmation of the notion of the material unity of the world, but as a branch of physical theory and as the methodology of physics it was not equivalent to mechanism as a philosophical conception.

Einstein clearly understood that mechanism as a methodology of physical science had become a serious obstacle to the latter's development. He not only noted the existence of this philosophical outlook as such but analysed it, indicated the roots of its origin, stressed its historical role, and brought out its limitations. His idea of mechanism coincided in the main with the estimate of it given by the fathers of dialectical materialism. When analysing the sources of mechanism, Einstein wrote:

> The great achievements of mechanics in all its branches, its striking success in the development of astronomy, the application of its ideas to problems apparently different and non-mechanical in character, all these things contributed to the belief that it is possible to describe all natural phenomena in terms of simple forces between unalterable objects.
> Throughout the two centuries following Galileo's time such an endeavour, conscious or unconscious, is apparent in nearly all scientific creation.[46]

Engels also gave the concept of mechanism the same sense,

> Among natural scientists motion is always as a matter of course taken to mean mechanical motion, change of place. This has been handed down from the pre-chemical eighteenth century and makes a clear conception of the processes much more difficult... From the same misunderstanding is derived also the craze to reduce everything to mechanical motion.[47]

Einstein demonstrated the essence of mechanism from the examples of Helmholtz and Lord Kelvin (William Thomson). Helmholtz, he noted, by absolutising the forces of attraction and repulsion, had tried to reduce all the phenomena of the physical world to just these two properties of nature. The task of physical science according to Helmholtz, he stressed, was only wholly fulfilled when it could reduce all phenomena of the external world to simple forces and demonstrate that it was the sole possible reduction by which the physical world could be explained.[48] Kelvin developed the same idea; in his view Newtonian classical mechanics was the pinnacle of physical thought and all physical processes could be explained by it.

> He had a profound belief (Einstein wrote) in this striving of the mind after unity of knowledge, that all physical happening are reducible to movement [mechanical motion *D. G.*], and that Newton's mechanics in the long run offered the key to understanding any event.[49]

The unsoundness of mechanism as a methodological programme for developing the problems of non-classical physics was evident to Einstein. He could not agree with the mechanists' theory, from which it followed that the physical world was limited simply to mechanical phenomena. He denied a promising future for the research of those who tried to give a fuller picture of the physical world solely by means of knowledge of mechanical processes. On that score he wrote: 'The necessity of introducing many different kinds of force for different events is certainly unsatisfactory from a philosophical point of view'.[50]

While pointing out the limited character of mechanism, Einstein at the same time saw it as a necessary step in the history of physics. 'Nevertheless this so-called *mechanical view*, most clearly formulated by Helmholtz, played an important role in its time'.[51] He demonstrated that from the example of the kinetic theory of matter, in which qualitatively more complex natural phenomena that went beyond the limits of purely mechanical forms of motion were adequately explained from the mechanistic outlook.[52]

There are many other examples of this kind from which it follows that the quantitative methods of classical mechanics played a definite role in the development of other trends of non-classical physics. But the methodological principles of mechanics could not endlessly predominate. It was becoming ever more clear that terrestrial and celestial mechanics

as a science of the laws of the mechanical motion of macroscopic bodies did not cover the whole qualitative determinacy of a natural object. Engels, citing Hegel, stressed that the point of view by which 'matter must be looked upon as having only quantitative determination, but, qualitatively, as identical originally' was the standpoint of eighteenth-century French materialism, and furthermore that it was 'even a retreat to Pythagoras, who regarded number, quantitative determination, as the essence of things'.[53] And while problems of the qualitative aspect of material bodies were not sharply posed to science, and such sciences as chemistry, biology, physics, etc., had not been developed (in which qualitative characteristics were the essential element) naturalists explained natural phenomena rather easily by means simply of the laws of mechanics.

The development of science, however, and its emergence from the limits of classical mechanics, led to the conclusion that material objects were not qualitatively in a final and immutable state, but in process of development. Nature did not face scientists as a chaotic assemblage of facts given once and for all, of entities complete in themselves, but as a process. Scientists began to notice essential qualitative differences in natural objects, their stability and variability, and the interdependence of qualitative and quantitative determinacies. It was becoming obvious that separate fields of the material world were governed by special laws that went beyond the bounds of the mechanical form of motion. The laws of chemistry, biology, and other sciences gradually began to separate off from the laws of mechanics.

In addition to the singling out of specific regularities in the field of chemical, biological, and social matter, there was also a certain differentiation within physics itself. Apart from mechanical processes as such it began to study others requiring allowance for the specific qualitative aspects of material objects. Molecular states came into the field of view of thermodynamics, for example, and also molecular motions, which indicated the narrow framework of the concept of motion developed in classical mechanics. Electromagnetic processes were even more sharply differentiated, clearly not fitting into the concept of the mechanistic picture of the world. And Einstein saw that the decline of the mechanistic view in physics had begun mainly with the discovery and study of the properties of electrical and magnetic phenomena. He drew attention to the fact that there had already been a retreat

from the ideas of classical mechanics in the work of Oersted. Mechanics, for example, presumed the existence only of central forces in nature, but Oersted had shown that this did not hold in electromagnetic processes. The magnetic needle, for example, was not deflected toward the centre of the conductor. Pointing that out Einstein wrote:

> for the first time there appears a force quite different from that to which, according to our mechanical point of view, we intended to reduce all actions in the external world.[54]

Somewhat later H. A. Rowland's research led again to a conflict with classical mechanics.[55] According to its laws the interaction between natural phenomena was explained by forces that depended solely on the distance between the objects studied. But Rowland showed experimentally that it was impossible to make an absolute of that. The charge moving along a wire exerted an effect on the magnetic needle, but the strength of the effect depended not only on the distance between them, as the traditionalists of mechanics held, but also on the velocity of the charge.

The final blow to mechanism in physical science, however, was inflicted in Einstein's view by electrodynamics. Maxwell, having theoretically provided proof of the electromagnetic effects discovered by Faraday, created a physical theory of the electromagnetic field which did not, in its principles, fit into the mechanistic picture of the world. The electromagnetic field, whose reality was brilliantly confirmed by Hertz's experiments, could not be explained theoretically by the mechanistic form of motion. It was a qualitatively different matter requiring another understanding of motion to explain it, although the creators of electromagnetic theory considered themselves adherents of mechanism. Maxwell himself was still convinced, in Einstein's view, that electrodynamic processes could be considered as motion of the ether, and even employed mechanics when deriving the field equations. But it began to be understood more and more clearly with time that it was impossible to reduce the equations of the electromagnetic field to those of mechanics.

Developing natural science indicated the limited nature of the mechanistic notions of metaphysical materialism. On those grounds Einstein repeatedly stressed that mechanical processes had a partial character and that it was often not legitimate to make an absolute of mechanical motion and explain literally all processes of the material world by means of it. Today attempts to explain the external world as a whole by means

of some of the laws of mechanics alone have become rare. We know, for example, that animate matter is studied on different levels, biological and chemical, i.e. by means of knowledge of the biological and chemical forms of the motion of matter. The same applies to the objects of chemistry, which are investigated not only by means of chemical methods proper but also on the physical plane. But the main form of motion for biological objects is still the biological and not the chemical, which is a side or subordinate form. The same applies to chemical matter. For it the chemical is the main thing, and the physical subordinate or lower. Since the material bearers of the biological and chemical forms of the motion of matter are governed essentially by corresponding biological and chemical laws, the subordinate or lower forms of motion for these types of matter, although they influence their state, do not determine their being. But that dialectic of the world was comprehended in the history of science comparatively recently. The trend known as mechanism arose in the sixteenth century. It made an absolute of a subsidiary, i.e. mechanical, form of the motion of matter when studying its highest forms. It is interesting and important to note in this connection that Einstein rejected mechanism not only in its, so to speak, classical form but also in its modern one, when certain scientists were trying to explain the main forms of motion exclusively by means of subsidiary ones. He considered it illegitimate, for example, to explain social phenomena by the laws of natural sciences. In his view social affairs were governed by their own specific laws which determined the character of historical development.

> I believe that the present fashion of applying the axioms of physical science to human life is not only entirely a mistake but has also something reprehensible in it.[56]

Many scientists had noticed that the metaphysical and mechanistic outlook had a limited character and did not fulfil its methodological function in the new physics. An atmosphere of uncertainty and indeterminacy therefore reigned then among natural scientists. The most 'incredible' solutions of one theoretical problem or another were to be found in the literature. Engels wrote, apropos of that:

> One can scarcely pick up a theoretical book on natural science without getting the impression that natural scientists themselves feel how much they are dominated by this incoherence and confusion, and that the so called philosophy now current offers them absolutely no way out. And here there really is no other way out, no possibility of achieving clarity, than

> by a return, in one form or another, from metaphysical to dialectical thinking.[57]

Developing science had, in fact, in one part of it or another, undermined the foundations of the old outlook. But, since the latter was still firmly established in the minds of natural scientists and they had not yet assimilated a new system of views, this only made for confusion in their consciousness. Although Hegel had thoroughly criticised metaphysics and mechanism and had already created a system of dialectics, scientists' attitude to it was negative. The point was that Hegel repelled scientists by his devotion to a natural philosophy based on speculation not substantiated logically or by practice. At a time when the concrete sciences were in need of empirical substantiation of natural phenomena, Hegel, like other natural philosophers, was trying to return natural scientists exclusively to the realm of pure thought and speculation, which seemed an idea of yesterday to the scientists. They could not follow Hegel here after the brilliant advances of biological science, which had already confirmed the dialectical conception of development in nature in practice. In contrast his doctrine presented nature as the embodiment of the absolute idea, and deprived it of self-development. Hegel wrote, for example;

> It is a completely empty thought to represent species as developing successively, one after the other in time. Chronological difference has no interest whatever for thought.[58]

The Hegelian natural philosophy also could not attract natural scientists because it denied the atomic theory and with it all the achievements of chemical science, the molecular kinetics of gases, and the contribution to the development of atomic theory of scientists like Lord Kelvin and Lorentz. Chemists especially had no faith in Hegel since he attacked the theory of chemical elements which had great significance not only for them but also for allied sciences. For Hegel had written:

> In dealing with the physical Elements, we are not in the least concerned with elements in the chemical sense. The chemical standpoint is by no means the only one; it is only a peculiar sphere which has no right at all to extend itself to other spheres as if it were their essential principle.[59]

The physicists who kept up with achievements in the study of electromagnetic phenomena also criticised Hegel. The corpuscular theory of light, developed by Newton, and the wave theory of Descartes and Huyghens, had become well

known then. While the first received its experimental confirmation only in the twentieth century, the latter had already bewitched Hegel's contemporaries thanks to the research of Fresnel and Young. Nevertheless both points of view had been unacceptable to Hegel.

> The Newtonian theory according to which light is propagated in straight lines, or the wave theory which makes it travel in waves, are ... materialistic representations quite useless for the comprehension of light.[60]

Apart from his natural-philosophic strained interpretations and mistakes, Hegel undoubtedly also made conjectures and guesses of genius about the interconnections, development, laws, and properties of nature that far outdistanced science. In contrast to the mechanists, for example, he gave a broad interpretation of the concept 'motion', and extended it far beyond mechanical processes. He developed the dialectical method, which the natural scientists did not appreciate, and which could have helped them find their way in the complex labyrinth of the abundant empirical material about the being of nature. But their distrust of his idealist system was too great for them to find anything valuable in it. As Engels wrote,

> Not only Hegelianism but dialectics too was thrown overboard and that just at the moment when the dialectical character of natural processes irresistibly forced itself upon the mind, when therefore only dialectics could be of assistance to natural science in negotiating the mountain of theory.[61]

In the second half of the nineteenth century, furthermore, the Hegelian idealistic dialectics had already been reexamined by Marx and Engels and a new outlook on the world created that adequately reflected all the processes studied by natural scientists. The ideas of dialectical materialism could undoubtedly have helped overcome the confusion in their minds, if they had mastered them. But many did not understand the opposite character of the Marxist and Hegelian dialectics, equating the two. The functions of materialist dialectics, furthermore, were not limited simply to methodology alone. It fulfilled an ideological function. Its revolutionary conclusions were not accepted by some scientists. But by not adopting dialectics, they thereby deprived science of a methodological basis, and proved defenceless in face of the onslaught of scientific discoveries over a broad front, and the sudden break-up of accustomed notions.

Engels, having generalised the facts of contemporaneous science, laid a firm theoretical foundation that undermined the authority of mechanism, in particular as regards motion, space, and time. Most eighteenth and nineteenth century scientists, of course, generally understood by motion the simple shifting of bodies in space. They considered that motion had no influence on the qualitative characteristics of the moving object. Engels stressed that the concept of mechanistic motion had a partial character. Motion was a broader concept than the idea of mechanical change of place. It included not only simple spatial displacement but also a multitude of qualitative changes. Motion, he wrote,

> in the most general sense, conceived as the mode of existence, the inherent attribute, of matter, comprehends all changes and processes occurring in the universe, from mere change of place right up to thinking.[62]

Engels was the first to introduce a classification of the forms of the motion of matter. He showed that this motion had its own forms, that there was no motion in general just as there was no matter in general, but concrete forms of it that differed qualitatively from one another. According to that classification there were such forms of motion as mechanical, physical, chemical, biological, and social forms of the motion of matter. The role of the simplest form was assigned to mechanical motion. We can now say that the material bearers of mechanical motion, according to that classification, are only macroscopic bodies, while elementary particles, electromagnetic, gravitational, and other fields relate to objects governed by laws that lie outside mechanics. It is also impossible to identify chemical, biological, and social forms of motion with the physical one, especially the mechanical form.

This new outlook would undoubtedly have helped physicists to avoid metaphysical mistakes and an absolutising of mechanical motion. Its conscious application would have helped Einstein, too, in his fight against metaphysics and mechanism, which he waged spontaneously and without system; he would not have needed to discover what had been discovered before him. But many natural scientists, and Einstein among them, were at a crossroads, between metaphysical materialism and dialectical materialism. They left the former behind, throwing it overboard, and approached the latter, though spontaneously and inconsistently.

While rejecting metaphysical and mechanistic materialism, however, Einstein did not reject materialism in general as

a philosophical system. He was interested in its main ideas, and saw the continuity and historical justification of the existing forms of materialism. He saw both its weak points and its strong ones. He included the propositions about matter, the objective world, the material unity of the world, and the causal dependence of natural and social phenomena, the ideas of atomic theory, and the principle of the knowability of the world among the greatest achievements of philosophical, materialist thought. It astonished him that the sources of these brilliant ideas were already visible in Greek philosophy. It was no accident that many of its works were his favourite books. He repeatedly reread the works of Demokritos, Epicurus, Herakleitos, and Lucretius. He expressed his attitude to the materialism of the ancients in the foreword to the German edition of Lucretius' *On the Nature of Things*, and in several letters, and pointed out the link between separate propositions of their philosophy and modern times.

> Lucretius' work will exercise its magic on everyone who has not wholly surrendered to the spirit of our time but has a feeling at times to see his contemporaries, and especially their mental attitude, as an onlooker. One sees in it how the world presented itself to an artistic, thinking man gifted with a scientific and speculative interest and a lively feel and thought, who also had no notion of any of the results of today's science that are inflicted on us in childhood before we are conscious of them or can face them really critically.[63]

What he admired in the works of Lucretius, Epicurus, and Demokritos was that these thinkers were able to anticipate scientific discoveries of scores of centuries later. He appreciated the philosophical ideas of atomism and causality in their works, which strike one even today by their boldness. Einstein drew attention to the ancient atomists' belief in the knowability of the world. He saw in Lucretius a thinker who was on the brink of proclaiming a mechanistic, atomistic world outlook.

> But it seemed most of all necessary to him to convince his readers of the necessity of the atomistic-mechanical outlook on the world, though he did not risk saying so openly to the Romans, much more inclined to the practical.[64]

Einstein followed the development of the ideas of the ancient atomists in later philosophic materialist doctrines which enabled him to trace the evolution of materialism. He saw that materialism was constantly changing its form under

the impact of developing science. In place of the naive realism that identified objects of the external world with direct sense data there came a 'more sophisticated realism', as he put it. Einstein linked this new variety of materialism with the atomic theory, with recognition of ideas not based on direct observation, that rested together with sensuality, on the activity of the mind.

> The introduction of immutable masspoints, however, was a step in the direction of a more sophisticated realism; for it was obvious from the beginning that the introduction of these atomistic elements was not based on direct observation.[65]

The creation of the theory of the electromagnetic field convinced Einstein of the inevitability of a further development of materialism.

> With the Faraday Maxwell theory of the electromagnetic field a further refinement of the realistic conception was unavoidable. It became necessary to ascribe the same irreducible reality to the electromagnetic field continually distributed in space as was formerly ascribed to ponderable matter[66]

We have already said, however, that at the time of Maxwell's discovery, Marx and Engels had already created a conception like that Einstein dreamed of. In it the concept of matter was taken beyond the limits of the notion of 'ponderable matter', i.e. substance.

Below we shall show that not only the main ideas of materialism but also the main propositions of dialectics came into the system of Einstein's philosophical views.

NOTES

[1] Albert Einstein. Physics and reality. In: *Ideas and Opinions by Albert Einstein.* Based on *Mein Weltbild.* (Crown Publishers, New York, 1954), p 290 (cited from *The Journal* of the Franklin Institute, 1936, ***221***).

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2

Einstein and the Concepts of Idealist Philosophy

We remarked above that Einstein was not satisfied with a number of propositions of metaphysical materialism. In his quests for philosophical ideas adequate to the nascent non-classical physics, he turned to analysis of the ideas of other philosophical schools. In his articles he examined works of various trends: Aristotle, Plato, Lucretius, Demokritos, Lamettrie, Spinoza, Berkeley, Hume, Kant, Mach, Bertrand Russell, Philipp Frank, and others. The ideas in their works that attracted him most were those that pointed out the contradictory, dialectical character of the cognitive process. We said above that he borrowed many materialist propositions from Premarxian philosophic materialism; it was difficult for him, however, to extract knowledge of dialectics from them because they were extremely lacking in such. For ideas about dialectics he turned mainly to certain idealist systems in which they were intensively developed.[1]

The theory of materialist dialectics already existed at that time, but Einstein was not as familiar with its system of principles, laws, and categories, as he might have been, or with its role and functions. He was therefore compelled, when formulating his world outlook, to base himself on separate propositions of other philosophical systems. As a result he expressed his philosophical views in a specific form that was coloured by the notions of the systems to which he turned. That circumstance has sometimes been the excuse for counting him a supporter of one philosophical school or another. He has been represented as a Berkeleian, a follower of Hume, a Kantian, a Machist, a positivist, an empiricist, a rationalist, etc.

What did the concrete ideas that Einstein availed himself of from several non-materialist systems represent content-wise? Are there grounds for identifying his philosophical views as a whole with the content of the doctrines to which he turned?

The works of Berkeley, Hume, and Kant, for example, caught

his attention because they had clearly abandoned the propositions of metaphysical epistemology then generally accepted, and that predominated in classical physics. We have seen that he paid much attention to problems of epistemology when analysing separate propositions of classical mechanics. A definite idea about the dialectics of the cognitive process took shape with him under the influence of the founders of mechanics, but he had to consolidate this idea, and substantiate it philosophically, so to speak. He did not find the necessary substantiation in metaphysical materialism, since it often counterposed the empirical and the rational, or belittled the rational element in knowledge in general. That also compelled him to turn to the philosophies named above.

Einstein had to turn to Berkeley in order to borrow a proposition which stressed that our sense perceptions were not direct impressions of the essence of objects of the external world, as empiricists insisted.[2] But ideas foreign to him did not interest Einstein. On many questions he took other stands. For Berkeley, for example, objects of the external world represented sets of our ideas dependent on perception; materialist intuition told Einstein that the information perceived by our sense organs was causally linked with the substance of objects that existed objectively, independently of the subject's perceptions, and so on.

Einstein found roughly the same ideas in Hume and took the proposition from his philosophy that general concepts do not stem directly and logically from sense data.

> Hume saw that concepts which we must regard as essential, such as, for example, causal connection, can not be gained from material given to us by the senses.[3]

(Einstein was speaking here about the direct link of concepts with empirical data.)

Hume, of course, drew an agnostic conclusion from that about the unreliability of general concepts. Einstein, however, used the idea of the status of general concepts against extreme empiricism, and came to the conclusion that our knowledge of things consists exclusively in 'the sensory raw-material, the only source of our knowledge, through habit.'[4] He not only did not accept the agnostic conclusion of Hume's philosophy but also criticised it. 'Man has an intense desire for assured knowledge. That is why Hume's clear message seemed crushing'.[5]

Einstein understood that the break in the chain of knowledge maintained by Hume must be overcome. He found the

surmounting of this difficulty in Kant. While empirical data could not lead to reliable knowledge (Hume), and thinking was impossible without such general concepts as causality, time, space, etc., then, Kant concluded, reliable knowledge had an *a priori* character. It was not that aspect of Kant's doctrine, however, that caught Einstein's attention. The positive thing that he borrowed from Kant, he formulated as follows:

> I did not grow up in the Kantian traditions 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 conceptual construction for the grasping of the inter-personal, the authority of which lies purely in its validation.[6]

Einstein saw that Kant had not only made an advance toward solution of the Humean dilemma, but had also pointed out that sense data in themselves still did not give the necessary notion of the essence of the objects of the external world. They only provided material, which it was necessary to analyse logically, select the essential properties from it, and reject everything that did not express the thing's qualitative determinacy, and so to form a scientific concept. According to Einstein, scientific concepts are the result of the mental work of the brain and not of the sense organs. The reality of concepts depends on their validation in experience. He employed that proposition of Kant's to fight empiricists who considered knowledge to be obtainable directly from experimental data without resorting to mental activity.[7]

Einstein's recourse to the works of Berkeley, Hume, and Kant did not drive him into the camp of their philosophical systems. He read them as a natural materialist and dialectician. From them he took the posing of problems and elements of the dialectics of the cognitive process. Furthermore, he used some of their propositions to criticise idealism, agnosticism, and metaphysics as a whole, and in particular the two 'illusions' mentioned above of metaphysical and idealist views of the source of our knowledge.

Is it right to identify Einstein's philosophical views with the subjective idealist philosophy of Berkeley, as is sometimes done? The main content of the latter's philosophy boils down to identification of the external world with our perceptions. 'To exist means to be perceived' is the central idea of Berkeley's philosophy. He did not imagine the existence of things outside

human perceptions. His doctrine undoubtedly led to solipsism. It was aimed mainly against the basic proposition of materialism, to wit, the concept of matter.

Einstein, however, had different premisses here, and a different approach. Furthermore he sharply criticised the central idea on which Berkeley's system was based, and demonstrated its ideological affinity to positivism.

> What I dislike in this kind of argumentation (he wrote) is the basic positivistic attitude, 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*.[8]

He held firmly to the idea that the world around man exists objectively, independent of his consciousness. In his works he repeatedly developed this thesis, criticising subjective idealism for its reduction of the external world to perceptions. This is to be seen, for example, from his conversation with Rabindranath Tagore,[9] who claimed that the world did not objectively exist and that its reality depended on our consciousness. Tagore's views coincided with Berkeley's point of view, who wrote, objecting to materialists:

> The table I write on I say exists, that is, I see and feel it; and if I were out of my study I should say it existed, meaning thereby that if I was in my study I might perceive it.[10]

Einstein, replying to Tagore, stressed:

> Even in our everyday life, we feel compelled to ascribe a reality independent of man to the objects we use... For instance, if nobody is in this house, yet that table remains where it is.[11]

Einstein's statements like that give us grounds for thinking that his philosophical views cannot be confused with Berkeley's subjective idealist philosophy.

The same conclusion can be drawn in regard to Hume's subjective idealist philosophy. As we know, Einstein also rejected the main theses that constituted the core of Hume's system.

Hume's philosophy was permeated from start to finish by a scepticism that led to agnosticism. He considered that we cannot demonstrate by any arguments that our perceptions are evoked by external objects. The mind, in his opinion, never had anything before it except perceptions and it was unable to make any experiment whatsoever in regard to the relation between perceptions and objects. The assumption of such a relation therefore lacked any logical basis. That kind of pessimism, however, was alien to Einstein. He had a pro-

found faith in the possibility of knowing the essence of the objects of the external world. We have seen how he sought a way out of the blind alley in which Hume proved to be. For Einstein perception was nothing else than a photograph or copy of reality.

> Human nature [he wrote] always has tried to form for itself a simple and synoptic image of the surrounding world. In doing this it tries to construct a picture which will give some sort of tangible expression to what the human mind sees in nature.[12]

To know a thing, for him, meant to penetrate its essence by means of scientific concepts. Belief in the regularity and causality of the world inspired him with optimism and a conviction of the possibility of penetrating the secrets of nature.

Hume did not relate causality to the objective regularities of the world. He suggested that it could not be proved either in theory or in practice, but was the result of a habit of perceiving one event after another, i.e. a psychological phenomenon and not an objective pattern. Einstein, as we have seen, paid much attention to this problem. He was interested by its solution in the works of the classical thinkers Epicurus and Demokritos, and in the writings of Descartes and Spinoza, studied the manifestations of causality in classical and quantum mechanics, and carried on the famous discussion on it with Niels Bohr. And he himself tackled the problem of causality in a materialist way.

The philosophical views of Kant and Einstein also cannot be identified. Kant, for example, pictured the world as divided into 'things-in-themselves', existing objectively, and phenomena that allegedly arose as a result of the ordering of empirical material by means of the subjective forms of time and space. It was by means of the latter that sense data were converted into concepts. Kant considered that time and space, the laws of nature, and causality did not reflect objective natural processes but were subjective categories, which were *a priori*, 'innate' in man, eternal, and immutable in time. They preceded experience and played a decisive role in determining the picture of the world. It was impossible to go beyond subjective experience, Kant stressed, because we immediately fell into antinomies and irresolvable contradictions.

Einstein did not accept Kant's division of the world into one of 'things-in-themselves' and one of phenomena. He understood that, although phenomena were not in themselves

identical with the essence of an object, they all the same reflected it. He believed in the power of human reason, which was capable of going beyond everyday consciousness and leading to knowledge of the substance of the object studied. He developed this idea when analysing the heliocentric system of Aristotle and Ptolemy, the Aristotelean concept of motion, etc.

We have spoken of Kant's contribution to solution of the Humean dilemma. But he blundered when examining it. Einstein, however, interpreted this problem from a standpoint of an intuitive materialism, and expressed his interpretation of Kant's position as follows:

> From Hume Kant had learned that there are concepts (as, for example, that of causal connection), which play a dominating role in our thinking, and which, nevertheless, can not be deduced by means of a logical process from the empirically given... What justifies the use of such concepts? Suppose he had replied in this sense: Thinking is necessary in order to understand the empirically given, *and concepts and 'categories' are necessa ry as indispensable elements of thinking.* If he had remained satisfied with this type of an answer, he would have avoided scepticism.[13]

Unlike Kant, Einstein came to the conclusion that the source of our knowledge of the external world lies in that reality itself. We get knowledge through mental processing of sense data. He did not share Kant's thesis about the existence of *a priori* concepts.[14] He saw the reason why Kant came to apriorism in the latter's having been misled

> by the erroneous opinion—difficult to avoid in his time—that Euclidean geometry is necessary to thinking and offers *assured* (i.e. not dependent upon sensory experience) knowledge concerning the objects of 'external' perception. From this easily understandable error he concluded the existence of synthetic judgments *a priori,* which are produced by the reason alone, and which, consequently, can lay claim to absolute validity.[15]

Einstein categorically disagreed with Kant's assertion that general principles and philosophic categories are absolute and immutable in time. In his view the fact that the edifice of our science rests and must rest on principles that themselves do not stem from experience had to be accepted without doubts of any kind. But doubts arose for him when he came to the question of the meaning of these principles or of their indispensability. In Einstein's view scientific concepts, principles, and theories were historical categories. From time to time they had to be reexamined, and

adjusted to fit reality. It was not by chance that he highly valued Mach's historical approach to the theses of classical mechanics, suggesting, moreover, against Mach, and Kant, that principles and categories have an objective character.

Mach's name keeps cropping up in Einstein's writings. In fact he was interested by Mach's scientific and philosophic works. As for the latter, they attracted Einstein not because of their idealist content but because of his treatment of epistemological problems as a physicist. The point is that not all natural scientists took the stand that physics could not be successfully developed without philosophical knowledge. Mach's interest in epistemological problems impressed Einstein, for he himself gave epistemology a major place in his own writings. He began his obituary of Mach precisely by stressing the latter's attention to the theory of knowledge.[16]

> How in general could a really talented scientist, moreover, care about the theory of knowledge? Didn't his field give him more valuable work? So I have heard some of my associates speak about this, or perceived even more that they felt so. I cannot share this sentiment. When I think of the very keen students I met during my lectures, i.e. such as were distinguished by independence of thought and not just by mere quickness, I noted that they cared about the theory of knowledge. They eagerly began discussions on the aims and methods of science and showed unequivocally by their obstinacy in defending their views that the subject seemed important to them. And this should cause no surprise, indeed.[17]

Einstein did not, of course, go deeply in the content of Mach's philosophic views at first. The fact that he was won over by the latter's writings on the history of mechanics may have got in the way. He did not understand that Mach's philosophical system was based on a thesis by which he identified a thing with the set of our sensations, as had been done earlier by his ideological predecessor Berkeley. Sensations, according to Mach, were not copies or prints from reality, but were the substance or basis of the world. Einstein saw that sensations represented an image or approximate copy in themselves that reflected objective reality. He therefore invested the thesis, for example, that the aim of science was to study and bring order into our sensations (which he used, following Mach) with quite a different content than Mach. Where it meant, for Mach, that physics, for example, studied ideal objects, it meant for Einstein that this science ultimately dealt with objective

reality, and that sense data conveyed definite information about objects of the external world and reflected them with a certain precision. Nevertheless, in spite of his conviction that an objective world lay behind sensations, Einstein could not at first discover the essence of the Machian epistemology. He did not allow for Mach's being able to understand the term 'sensation' in a subjective idealist way.

> This terminology is perhaps why the prudent, cautious thinker is often taken by those who do not go into his work thoroughly for a philosophical idealist and solipsist.[18]

Einstein drew that conclusion because he had first studied Mach's physical works in which the latter still held to a materialist position. Einstein's acquaintance with Mach's philosophical works therefore did not allow him to recognise the idealist essence of Mach's philosophy, which he did rather later.

We know that Mach's main thesis about things as a set of sensations stemmed from an idealist interpretation of time and space. According to him they were not objective forms of being but ordered systems of series of sensations. Lenin wrote that Mach

> constructs his epistemological theory of time and space on the principle of relativism, and that is all. In actual fact, such a con struction can lead to nothing but subjective idealism.[19]

But what was Einstein's view on the essence of time and space? Mach referred to the fact of the invariance of the space-time properties of objects in order to validate their subjective character. Einstein needed Mach's evidence in order to get away from the Newtonian absolutising of space and time. In his article 'Ernst Mach', when analysing the concepts of time and space, and noting Mach's conclusion about their invariance, he pointed out their objectivity, the 'earthly origin' of these concepts themselves, and the need from time to time to alter them. He considered they could be amended or replaced by new ones when they ceased to correspond to 'the things given'.[20]

Mach's philosophic system had yet another specific feature. For him the source of knowledge was exclusively experimental data. At first glance it seemed that he reflected materialist views, but by experimental data he meant sensations and not objective reality. Furthermore, he did not admit that the mental activity which, by processing the empirically given, led to the formation of general concepts and

scientific theories, was also a source of knowledge, in addition to sensory material. Einstein also did not notice this drawback of Mach's theory of knowledge at first, though he himself resolved the problems of epistemology in a natural dialectical way.

> In my younger years, however [he wrote], Mach's epistemological position also influenced me greatly, a position which today appears to me to be essentially untenable. For he did not place in the correct light the essentially constructive and speculative nature of thought and more especially of scientific thought; in consequence of which he condemned theory on precisely those points where its constructive speculative character unconcealably comes to light, as for example in the kinetic atomic theory.[21]

Mach came, on the basis of his epistemological mistakes, to a denial of the atomic theory, molecular kinetic theory, and other conceptions. In short he denied all the theories that substantiated regularities, and the existence of objects not accessible to human sensations; according to him what was not given in sensations did not exist. Einstein regretted that kind of error. When criticising Mach and Ostwald he wrote: 'The antipathy of these scholars towards atomic theory can indubitably be traced back to their positivistic philosophical attitude'.[22]

Mach, consistently clinging to his philosophic precepts, reduced the subject-matter of science to analysis of the connections between our sensations. Einstein considered that physical science should study objective reality independently, as it is. While Mach denied objective laws and objective truth, Einstein understood this truth as derived from objective reality.

The content of Mach's philosophic ideas thus did not become the basis for Einstein on which he formed his outlook on the world. It therefore did not enter the fabric of his physical ideas. Mach's idealism influenced the 'colouring' in Einstein work on separate problems of epistemology and physics.

As for Mach's historical scientific works, in particular his *History of Classical Mechanics,* Einstein took it very seriously. Mach was one of the first to employ the principle of historicism broadly in the investigation of a broad range of mechanical processes, and to trace their reflection in physical science. The historical approach enabled him to cast doubt on the absolutes of classical physics and to point out the relative character of Newton's mechanics

as a whole, and the relativity of a number of its concepts and principles considered unshakable. Mach's interpretation of classical mechanics' concepts of time and space interested Einstein most of all.

> By his historical-critical writings, in which Mach traced the progress of the individual sciences with such great love, and followed the particular field of pioneering scientists into their inner, mental closets, he had great influence on our generation of natural scientists.
>
> I ask the reader to take up Mach's work *Die Mechanik in ihrer Entwicklung* and to see in sections 6 and 7 of Chapter 2 ('Newton's Views of Time, Space, and Motion' and 'A Summary Critique of the Newtonian Propositions') how masterly he sets out ideas that have not yet by any means become the common property of physicists.[23]

Einstein's outlook is frequently linked with positivism but, as we have already remarked, he did not share the main ideas of one of its varieties, viz. Mach's philosophy. What did he write about positivist philosophy in general?

A main thesis of positivist philosophy is denial of the philosophical problematic, which has been at the centre of the struggle of the various philosophical schools for centuries. The root categories of 'traditional' philosophy have no scientific status in the opinion of positivists. The concrete sciences should be purged of former philosophic problems. Traditional philosophy could only be justified in the prescientific period. 'The metaphysical unconnectible way of research,' Richard von Mises, for example, wrote, 'is the prescientific stage, which precedes any disciplined research in the positive fields'[24]. Positivists claim that as science develops the need for philosophy more and more disappears. In their view Newton had already not needed traditional philosophy in his work on classical mechanics, let alone the authors of post-Newtonian physical theories.

Einstein however, held a different view on this. While, according to the positivists' doctrine, traditional philosophical thought was like 'the dead end of a river that after flowing through fertile lands dries out in the desert',[25] the creator of the theory of relativity constantly stressed that philosophy was revealing itself most fully precisely in the age of the development of the new physics. According to him,

> the present difficulties of his science force the physicist to come to grips with philosophical problems to a greater degree than was the case with earlier generations.[26]

Einstein regretted that Hume had already

> created a danger for philosophy in that ... a fateful 'fear of metaphysics' arose which has come to be a malady of contemporary empiricistic philosophizing.[27]

In the opinion of positivists the philosophic problematic should not go beyond the bounds of any concrete science in its content. Einstein interpreted philosophy extensively as a quest for knowledge in its most general and broadest form, and in that sense philosophy could be considered the mother of all scientific searches. He understood that natural science could not be developed without study of methodology and perfecting of the theory of knowledge. For 'the whole of science is nothing more than a refinement of everyday thinking'.[28] And this field went beyond the bounds of any concrete science and belonged to the sphere of philosophic reflection.

Unlike positivists Einstein saw that there was an intimate reciprocal relation and mutual dependence between philosophy and the concrete sciences. The ideas of philosophy were not postulates given for ever to which the sciences must adapt themselves. While having a stimulating influence on the development of the concrete sciences, philosophy in turn was enriched by their ideas, as a result of which, as Engels put it, it changed its form to some extent. On this score Einstein wrote:

> The reciprocal relationship of epistemology and science is of noteworthy kind. They are dependent upon each other. Epistemo logy without contact with science becomes an empty scheme. Science without epistemology is insofar as it is thinkable at all primitive and muddled.[29]

Einstein also did not share the positivist methodological stand according to which science should only describe the external attributes of and links between natural phenomena, but not go into their essence. He understood that this slogan of the positivists was a profound delusion and fraught with irreparable consequences for the development of science. He did not deny that science should establish connections between experimental facts so that we could predict the future development of events from already available experience.

But he doubted that such a primitive ideal could have aroused the strong investigatory passion that was the cause of truly great attainments. He thought there was another, stronger trend, albeit also more enigmatic, and masked by the researcher's untiring efforts, viz., an aspiration to understand reality.

Einstein opposed the positivists' position even more categorically in a letter to his friend Maurice Solovine.

> So a positivist, subjective exaggeration predominates in our day. It proclaims the pretention to comprehend nature as objective reality to be an antiquated prejudice, but it makes a virtue of the need of quantum theoreticians. Men are even as susceptible to suggestion as the horse, and a fashion governs every period without which the majority would even come to see the tyrant that rules over them.[30]

In his comments on Bertrand Russell's book *Meaning and Truth* Einstein pointed out what paradoxes the positivists' call to banish objective reality from the philosophic problematic could lead to.

> For this fear seems to me, for example [he wrote], to be the cause for considering of the 'thing' as a 'bundle of qualities' such that the 'qualities' are to be taken from the sensory raw material. Now the fact that two things are said to be one and the same thing, if they coincide in all qualities, forces one to consider the geometrical relations between things as belonging to their qualities. Otherwise one is forced to look upon the Eiffel Tower in Paris and that in New York as 'the same thing'.[31]

Einstein saw that the error of a number of scientists' scorning of atomic theory related not just to Mach but also to positivism as a whole.

> This is an interesting example [he wrote] of the fact that even scholars of audacious spirit and fine instinct can be obstruc ted in the interpretation of facts by philosophical prejudices. The prejudice which has by no means died out in the meantime consists in the faith that facts by themselves can and should yield scientific knowledge without free conceptual construction.[32]

According to Einstein, 'what exists' was the product of our speculative constructions, but he realised that knowledge was not the result of pure thought, that it was drawn from sense data which did not, of course, yield ideas about what existed by themselves without being rationally worked up.

Einstein saw the source of positivism, of course, in Berkeley's philosophy, which he rejected as a system because it was an expression of the extreme form of idealism, to wit, solipsism. Nevertheless some thinkers accused Einstein of solipsism, claiming, that it followed from his philosophical ideas and from his physical doctrine that only the individual and his consciousness existed, that the external world, including other people, existed only in the consciousness of the individual. In actual fact neither the physical

theses of the theory of relativity nor the philosophical views of its creator lead to that subjective idealist conception. If Einstein, like Berkeley or Mach, had made the existence of objects of the external world dependent on his individual consciousness, it would really have followed that the objects of the inorganic world, and also the people around him, would not have existed objectively, but only in his sensations and consciousness. But Einstein specially put the stress on the fact of the existence of an objective world, independent of consciousness, and regarded sensation and awareness as properties of it manifested in man's ability to reflect the external world.

Einstein sometimes also touched on problems of religion, which has given some students of his doctrine an excuse to number him among the advocates of a religious philosophy. But what, in fact, was Einstein's attitude to religion? In his biography he wrote that in his young years he actually was religious, like many of his coevals, but already, when twelve years old, his religiosity 'found an abrupt ending' [33]: 'through the reading of popular scientific books I soon reached the conviction that much in the stories of the Bible could not be true'.[34]

Einstein classed religion as a historical phenomenon that arose at a certain stage of human development and passed through a number of stages on its way. He considered that religious ideas developed under the influence of various human feelings and needs that underlay all aspirations. In his view one of the reasons that had led primitive man to religion was a feeling of fear of hunger, wild beasts, sickness, and death.

> Since at this stage of existence understanding of causal connections is usually poorly developed, the human mind creates illusory beings more or less analogous to itself on whose wills and actions these fearful happenings depend. Thus one tries to secure the favor of these beings by carrying out actions and offering sacrifices which, according to the tradition handed down from generation to generation, propitiate them or make them well disposed toward a mortal.[35]

He saw another source of religion in society's need to inculcate or preserve social and moral values in people's consciousness, in

> the God who, according to the limits of the believer's outlook, loves and cherishes the life of the tribe of the human race, or even life itself; the comforter in sorrow and unsatisfied longing; he who preserves the souls of the dead. This is the social or mo ral conception of God.[36]

Einstein also came close to an understanding of the class sources of religion. He saw one reason for its rise in leaders' striving to dominate big groups of people. He expressed the class essence of religion even more clearly when speaking of the role of so-called intercessors between God and man—of the special caste of priests who existed in the past. He drew attention to the fact that this social group reflected the interest of a certain class.

> In many cases a leader or ruler or a privileged class whose position rests on other factors combines priestly functions with its secular authority in order to make the latter more secure; or the political rulers and the priestly caste make common cause in their own interests.[37]

In spite of the fact that Einstein guessed the class character of religion, he still made its existence dependent on the level of scientific and philosophical-materialist knowledge, on how far this knowledge became the conviction of each person.

> The man who is thoroughly convinced of the universal operation of the law of causation cannot for a moment entertain the idea of a being who interferes in the course of events provided, of course, that he takes the hypothesis of causality really seriously. He has no use for the religion of fear and equally little for social or moral religion. A God who rewards and punishes is inconceivable to him for the simple reason that a man's actions are determined by necessity, external and internal, so that in God's eyes he cannot be responsible, any more than an inanimate object is responsible for the motions it undergoes.[38]

As for the relation of science and religion, Einstein noted their irreconcilability: 'When one views the matter historically, one is inclined to look upon science and religion as irreconcilable antagonists'.[39]

Despite his markedly negative attitude to religion, Einstein nevertheless speaks in his works of a so-called 'cosmic religious feeling', stressing that it had a beneficial influence on his scientific work. True, he counterposed this kind of feeling to that which is associated with true religion. What is this 'cosmic religion'? Disillusionment with the prevailing 'official' religion, and with the social set-up that inspired humility and 'pointed out the road to everlasting paradise', evoked in him the contrary, an interest in Cosmos, 'this huge world that exists independently of us human beings'.

> The contemplation of this world beckoned like a liberation, and I soon noticed that many a man whom I had learned to esteem

> and to admire had found inner freedom and security in devoted occupation with it... The road to this paradise was not as com fortable and alluring as the road to the religious paradise; but it has proved itself as trustworthy, and I have never regretted having chosen it.[40]

The mystery of the universe captivated Einstein. In meeting the unknown he sensed a profound and beautiful experience.

> It is enough for me to divine and have a shot at this astonishing riddle, and humbly to grasp a small mental image of the sublime structure of that which exists.[41]

Einstein believed in the power of human reason and its capacity to reveal the hidden secrets of the Universe. But he considered it was only possible to achieve that aim after man's emancipation 'from the chains of the "merely personal", from an existence which is dominated by wishes, hopes and primitive feelings'.[42] Only renunciation of earthly weaknesses and devotion to the cause of science gave a possibility of discovering and comprehending the structure of the Universe.

> To feel that direct experience there is something out of reach of our mind whose beauty and sublimity is only indirectly accessible to us in dim reflection, that is religiosity. In *that* sense I am religious.[43]

'Cosmic religious feeling, however ... can give rise to no definite notion of a God and no theology'.[44] It only inspires the scientist to realise the wonderful order of the Universe and its regularities.

Einstein thus did not share the essence of the philosophic systems of the classical writers of idealism mentioned above, although he employed their works from time to time for his own purposes. He either simply ignored them or openly expressed himself against their main theses, pointing out their bad effect on science. One can, of course, find separate, quite vague expressions in Einstein that have been employed by various philosophical schools. But it must be remembered that he distinguished between statements of a scientific character and literary turns of phrase, the 'literary fashion'.

> You must distinguish between the physicist and the *littérateur* when both professions are combined into one... What I mean is that there are scientific writers in England who are illogical and romantic in their popular books, but in their scientific work they are acute logical reasoners.[45]

Einstein tolerated certain 'liberties' in such literary enthusiasms, which must be taken into account when we study his works. If attention is paid, when reading his works, solely to the form of expression of an idea and to his separate statements, without allowing for their context, then Einstein can be taken for a Machian, a Kantian, and a Humean. One must remember that this style of exposition of scientific ideas was characteristic not just of him.

The following question is natural when we are examining Einstein's attitude to philosophic schools of various kind. How far and on what arguments can his name be ascribed to a school to which he turned for clarification of separate theoretical theses? For his reference to some philosopher has sometimes been pretext for linking his world outlook with a certain philosophic conception.

Philosophic systems differ from one another, of course. Berkeley's system, for example, has to be distinguished from the school of Kant or Hume, though they all have something in common that unites them in one trend, to wit subjective idealism. Several idealist philosophic systems contain certain (different) rational ideas in latent form that have later been borrowed, thoroughly revised, and developed by materialist philosophic thought. In Plato's philosophy, for instance, the rudiments of a theory of knowledge were a rational element, and in Hegel his dialectical method; Kant left behind, apart from the antinomies, the idea, too, of the activity of processes of consciousness. It must also not be forgotten that idealist philosophers were occupied with other allied problems, in addition to philosophy, which went beyond it. Hume, for instance, was famous as a historian and an economist. His *History of England* became widely known. In it he tried to reflect the events of the English revolution. His passionate anti-religious books were put in the Index by the Church of Rome. Kant was the first to apply the dialectical idea of development to consideration of the evolution of the Solar system. Mach was a physicist and historian of physics and did much for the development of the science. Einstein saw Mach primarily as a physicist.

> In his mental development [he wrote] Mach was not only a phil osopher who chose the natural sciences as the object of his spec ulations, but also a versatilely interested, assiduous scientist.[46]

Consequently, we cannot include Mach's physical ideas in the concept 'Machism', just as we should not include the

achievements of the pre-critical period of Kant's work in the term 'Kantianism', while it is wrong to link the ideas set out in Hume's economic theory, *History of England,* and *The Natural History of Religion,* with the essence of Humean philosophy.

All these points compel us to approach the very fact of Einstein's turn to one philosophy or another in an exclusively concrete, historical way as the founders of dialectical materialism used to do. Marx, for example, did not share Hume's agnosticism, but that did not prevent him from assigning Hume his due place in the creation of classical political economy. Furthermore, Marx drew attention to the ideas of dialectics in Leibniz's idealist philosophy while at the same time rejecting the philosophical essence of his monadology. Engels, besides criticising Kant for agnosticism, valued him for his discovery of certain elements of dialectics expressed in his doctrine of antinomies and the idea of the development of the Solar system. Lenin, while criticising Hegel, called on us to be friends of the Hegelian dialectic, given its materialist revision.

As we have seen, Einstein, too, did not turn to Berkeley in order to draw the theses from his works that constitute the basic essence of Berkeley's philosophic system. Hume did not interest him for his agnostic ideas and repudiation of objective causality. The subjective idealist ideas of Kant, Mach, and the other idealist philosophers that he studied, did not interest him. It is therefore not legitimate to identify his philosophic outlook with the above-mentioned (and not mentioned) idealist schools. Einstein did not accept the essential features of these schools and even subjected them to sharp criticism.

NOTES

[1] In this chapter I do not analyse how far adequately Einstein reproduced the propositions of idealist philosophy but discuss his interpretation of them in the light of the methodological tasks facing physics at the beginning of the twentieth century.

[2] See Albert Einstein. Remarks on Bertrand Russell's theory of knowledge. In: Paul A. Schilpp (Ed.). *The Philosophy of Bertrand Russell* (Northwestern Univ., Evanston, Ill, 1944), p 285.

[3] *Ibid.*

[4] *Ibid.*

[5] *Ibid.*

[6] Albert Einstein. Reply to criticisms. In: Paul A. Schilpp (Ed.). *Albert Einstein: Philosopher Scientist* (The Library of Living Philosophers,

Evanston, Ill, ß?'?), p 680.
[7] *Ibid.*
[8] *Ibid.*, p 669.
[9] The Nature of Reality. A conversation between Rabindranath Tagore and Professor Albert Einstein, July 14th, 1930. *The Modern Review* (Calcutta), 1931, *49*, 1: 42.
[10] *Berkeley's Principles of Human Knowledge, New Theory of Vision* (J. M. Dent, London. Everyman's Library, No. 483), § 3.
[11] The Nature of Reality. *Op. cit.*, p 43.
[12] Albert Einstein. Preface to Max Planck. *Where Is Science Going?* (Allen & Unwin, London, 1933), p 10.
[13] *Idem.* Reply to criticisms. *Op. cit.*, pp. 678 679.
[14] See Albert Einstein. Autobiographical notes. In: Paul A. Schilpp (Ed.) *Op. cit.*, p 11.
[15] Albert Einstein. Reply to criticisms. *Op. cit.*, p 679.
[16] See Albert Einstein. Ernst Mach. *Physikalische Zeitschrift*, 1916, *17*, 7.
[17] *Ibid.*, p 101.
[18] *Ibid.*, p 104.
[19] V. I. Lenin. *Materialism and Empirio Criticism* (Progress Publishers, Moscow, 1977), p 178.
[20] Albert Einstein. Ernst Mach. *Art. cit.*, p 102.
[21] *Idem.* Autobiographical notes. *Op. cit.*, p 21.
[22] *Ibid.*, p 49.
[23] *Idem.* Ernst Mach. *Art. cit.*, p 102.
[24] Richard von Mises. *Positivism* (Harvard U. P., Cambridge, Mass., 1951), p 268.
[25] H. Reichenbach. *The Rise of Scientific Philosophy* (U. of Cal. Press, Berkeley, 1954), p 122.
[26] Albert Einstein. Remarks on Bertrand Russell's theory of knowledge. *Op. cit.*, p 279.
[27] *Ibid.*, p 289.
[28] *Idem.* Physics and reality. In: *Ideas and Opinions*, p 290.
[29] *Idem.* Reply to criticisms. *Op. cit.*, pp 683-684.
[30] *Idem. Lettres à Maurice Solovine* (Gauthier-Villars, Paris, 1956), pp 70-71.
[31] *Idem.* Remarks on Bertrand Russell's 'Meaning and Truth'. In Paul A. Schilpp (Ed.). *The Philosophy of Bertrand Russell*, p 289.
[32] *Idem.* Autobiographical notes. *Op. cit.*, p 49.
[33] *Ibid.*, p 3.
[34] *Ibid.*, p 5.
[35] Albert Einstein. Religion and science. In: *Ideas and Opinions*, p 37.
[36] *Ibid.*
[37] *Ibid.*
[38] *Ibid.*, p 39.
[39] *Ibid.*
[40] Albert Einstein. Autobiographical notes. *Op. cit.*, p 5.
[41] *Idem.* Mein Glaubensbekenntnis. Cited from Friedrich Herneck. *Albert Einstein. Ein Leben für Wahrheit, Menschlichkeit und Frieden* (Buchverlag der Morgen, Berlin, 1967), p 255.
[42] Albert Einstein. Autobiographical notes. *Op. cit.*, p 5.
[43] *Idem.* Mein Glaubensbekenntnis. *Op. cit.*, p 255.
[44] *Idem.* Religion and science. in: *Ideas and Opinions*, p 38.
[45] In Epilogue to Max Planck. *Op. cit.*, p 211.
[46] *Idem.* Ernst Mach. *Art. cit.*, p 104.

3
THE SUBSTANCE OF EINSTEIN'S PHILOSOPHIC VIEWS

Einstein did not leave an integral system of his philosophical views, although ideas of the 'science of sciences' permeate much of his work, and the whole spirit of it. Let us try therefore to create a picture of his philosophical outlook from the separate fragments.

First of all we must stress that he distinguished two trends in philosophy, and consequently two points of view about the external world, viz., materialist and idealist.

He did not share the view of philosophers who tried to find some third direction in philosophy that would go along neither with materialism nor with idealism. (Mach and his followers firmly took such a stand. Their attempt proved fruitless, however, because Machism as a philosophical current in the end expressed the idealist direction in philosophy.)

In contrast to Mach, Avenarius, and others, it was clear to Einstein that philosophers were divided into two camps as regards the answer to the main question of philosophy, which corresponds to the question of the relation of man's consciousness and the world around him.

> There are two different conceptions about the nature of the Universe:
> (1) The world is a unity dependent on humanity.
> (2) The world is a reality independent of the human factor.[1]

Which of these two conceptions did he himself hold? A thorough, detailed reply can be obtained from his talk with the Irish writer James Murphy, who reminded him: 'You have already been widely quoted in the British Press as subscribing to the theory that the outer world is a derivative of consciousness'[2]. Einstein gave Murphy the following answer to that:

> No physicist believes that. Otherwise he wouldn't be a physicist. ...You must distinguish between what is a literary fashion and what is a scientific pronouncement... Why should anybody go to the trouble of gazing at the stars if he did not believe that the stars were really there?... We cannot logically prove the existence of the external world, any more than you can logically prove that I am talking with you nor that I am here. But

> you know that I am here and no subjective idealist can persuade you to the contrary.[3]

Apart from that view about the external world, however, the following pronouncements can also be found in Einstein: 'The object of all science, whether natural science or psychology, is to co-ordinate our experiences and to bring them into a logical system',[4] or 'The only justification for our concepts and systems of concepts is that they serve to represent the complex of our experience'.[5]

In fact, if we were to start just from the content of the last two citations, it could be concluded that Einstein held Machist views as regards the main question of philosophy, treating sensations as the first principle or main foundation of the world. But deeper inquiry into his work shows that, while Einstein sometimes put the stress on sensations, he still saw the reality of the external world behind them. For him, in contrast to Berkeley and Mach, sensations were not something primary in relation to objective reality; for him, as we have already said, they were images, approximate copies of objects of the objective world. On that point he wrote:

> The belief in an external world independent of the perceiving subject is the basis of all natural science. ...Sense perception only gives information of this external world.[6]

The same conclusion follows from analysis as well of Einstein's understanding of the subject-matter of sciences, in particular of physics. His recognition of the objectivity of nature and the subjective character of sensations in itself excluded his reducing the aim of science simply to study of the connections between sensations. He suggested that science should study the connections between things and objects of the world because the reality of material objects was hidden behind sensations. 'Physics,' he wrote 'is an attempt conceptually to grasp reality as it is thought independently of its being observed.'[7]

Authors who numbered Einstein among supporters of the subjective trend in philosophy often turned for justification to his statements about the origin of scientific concepts. It has become a common idea that he represented scientific concepts as cut off from reality as a result of free mental activity.

In fact, as regards the origin of concepts, Einstein wrote that they were the result of the free activity of man's reason and, from the logical aspect, not strictly connected with empirical data:

> ...The concepts which arise in our thought and in our lin guistic expressions are all when viewed logically the free creations of thought which cannot inductively be gained from sense experiences.[8]

How then is this idea of Einstein's to be understood? Does it mean that, according to him, scientific concepts, the axioms of geometry, etc., are isolated from sense data and the external world, and that man's reason in itself is the source of knowledge?

Such a conclusion would contradict Einstein's philosophical maxims. On epistemological matters he started, in fact, from the objective existence of the world, which was reflected by human consciousness through sensations. For him general concepts were the abstract quintessences of the most essential features of a certain range of phenomena and processes given to man through sensations. 'The concepts originate from experience by way of "abstraction", i.e., through omission of a part of its content'.[9] They had sense only in their connection with sensations and the external world.

> Ideas that proved useful for ordering things easily get such an authority over us that we forget their worldly origin and take them as unalterably given. They are then labelled 'logically necessary', 'a priori given', etc. The road of scientific advance is made impassable for a long time by such misconceptions. It is therefore not for the fun of it that we try to analyse long familiar ideas and demonstrate the circumstances on which their title and unimpeachability depend and how, as minute inquiry shows, they grow from the data of experience. It is by this means that their all too great authority is broken. They must be rejected if they cannot really be legitimised and corrected, if their connection with the given facts has been all too carelessly replaced by another, and if a new system has been built that we prefer on some other grounds.[10]

According to Einstein sensations were not in themselves identical with the content of concepts. They were only the initial material for the formation of the conceptual apparatus of science. 'Our psychological experience contains, in colourful succession, sense experiences, memory pictures of them, images, and feelings.'[11] These pictures, images, and feelings were also insufficient by themselves to establish a science, although they were a necessary stage in the development of knowledge. They had to be subjected to rational analysis, through which only could general concepts be formed. For that, Einstein considered,

> out of the multitude of our sense experiences we take, mentally and arbitrarily, certain repeatedly occurring complexes of sense impressions (partly in conjunction with sense impres-

> sions which are interpreted as signs for sense experiences of others).[12]

The transition of consciousness from sensory forms to the formation of concepts is not, of course, a simple process. There have been many disputes around this problem in the history of philosophy. It proved no easy task for Einstein, too. He interpreted the complex transition from sensory forms of reflection to concepts as the 'free' creation of concepts by the human brain. But he understood this 'freedom' in his own way.

> The liberty of choice, however, is of a special kind [he wrote], it is not in any way similar to the liberty of a writer of fiction. Rather, it is similar to that of a man engaged in solving a well-designed word puzzle. We may, it is true, propose any word as the solution; but, there is only *one* word which really solves the puzzle in all its parts. It is a matter of faith that nature as she is perceptible to our five senses takes the character of such a well-formulated puzzle. The successes reaped up to now by science do, it is true, give a certain encouragement for this faith.[13]

The 'free' formation of scientific concepts by no means signified their isolation from objective reality for Einstein. He introduced this term in order to stress that concepts differed qualitatively from sense data and did not coincide with them in content, and that they could not be derived directly from the empirical data, contrary to the opinion of empiricists, without preliminary theoretical analysis of them. The thesis of the free formation of scientific concepts arose in Einstein as the antipode of the empiricists' idea of the direct, logical deduction of concepts from reality, which, in their opinion, did not require the abstracting activity of thought.

Yet another argument is adduced to prove Einstein's subjectivist views, namely his statements about certain general problems of mathematics. Separate theses from his *Geometry and Experience* are often cited for this purpose; in it he wrote, in particular, that 'the propositions of mathematics referred to objects of our mere imagination, and not to objects of reality', and that mathematics was 'after all a product of human thought which is independent of experience'.[14]

In fact one can arrive at such a conclusion from those two quotations, but analysis of the work as a whole, and of Einstein's other works dealing with the general methodological problems of mathematics, shows that the subjectivist views about the nature of mathematics ascribed to him have no justification. He did not deny that mathematics was linked by its roots with the external world and that it arose from people's practical needs.

> It is certain that mathematics generally, and particularly geometry, owes its existence to the need which was felt of learning something about the behavior of real objects. The very word geometry, which, of course, means earth measuring, proves this. For earth measuring has to do with the possibilities of the disposition of certain natural objects with respect to one another, namely with parts of the earth, measuring-lines, measuring-wands, etc.[15]

He also understood that mathematics, which arose from society's practical needs, took shape gradually as an independent discipline. Drawing new material from the external world only from time to time, it was converted more and more into an abstract science. It was this abstract character of mathematics that made it possible for individual scholars to attempt, at certain stages of its development, to isolate its propositions mentally from the real world. That, too, has been exploited by philosophers who try to relate Einstein's philosophical views to subjectivism. Einstein tried to find the epistemological principles that led scholars to isolate the propositions of mathematics from the real world, and wrote on that score:

> The fatal error that logical necessity, preceding all experience, was the basis of Euclidean geometry and the concept of space belonging to it, this fatal error arose from the fact that the empirical basis, on which the axiomatic construction of the Euclidean geometry rests, had fallen into oblivion.[16]

Mathematics, he pointed out, was not only linked with the external world by its origin but its propositions reflected reality in both the past and the present. 'Our experience hitherto,' he wrote, 'justifies us in believing that nature is the realization of the simplest conceivable mathematical ideas.'[17] He saw the criterion of the truth and reliability of mathematics in the final count in practice. 'Geometry may be true or false, according to its ability to establish correct and verifiable relations between our experiences.'[18]

Analysis of Einstein's works shows that he held wholly materialist views when examining the essence of mathematics. They coincide with the solution of mathematics given by Engels.

> Like all other sciences, mathematics arose out of the *needs* of men. ...But, as in every department of thought, at a certain stage of development the laws, which were abstracted from the real world, become divorced from the real world, and are set up against it as something independent, as laws coming from outside, to which the world has to conform. That is how things happened in society and in the state, and in this way, and not otherwise, *pure* mathematics was subsequently *applied* to the world, although it is borrowed from this same world and represents only one part of its forms of inter-

> connection and it is only *just because of this* that it can be applied at all.[19]

Einstein thus understood that the propositions of mathematics were dependent on real material relations existing between objects of the world. If that is so, the reader may ask, how does it accord with the statement above that 'the propositions of mathematics referred to objects of our mere imagination, and not to objects of reality'? In my view, there is no contradiction here, since Einstein was speaking in the first case of the origin of mathematics and its link with reality, and in the second about its objects. Mathematics, as we know, is the science of spatial forms and quantitative relations. The objects of mathematics are abstractions and idealisations divorced from the qualitative content and reflecting quantitative aspects of such processes and objects of the external world as, for example, a point, line, circumference, etc. Einstein was drawing attention to that aspect when he said that the propositions of mathematics referred not to real objects but to objects of our imagination. And in fact the latter arose as a result of rational abstraction.

Einstein's attention was also focused on the question of the substance of scientific theory. Some of his contemporaries suggested that the laws of science did not reflect real processes but were arbitrary agreements that simplified the description of phenomena of the world for the scientist. The French scientist Henri Poincaré, for example, held that view. Lenin demonstrated the link between Poincaré's philosophical ideas and the philosophies of Hume and Kant.

> The essence of this point of view does not necessarily lie in the repetition of Kant's formulations, but in the recognition of the fundamental idea *common* to both Hume and Kant, viz., the denial of objective law in nature and the deduction of particular 'conditions of experience', particular principles, postulates and propositions *from the subject,* from human consciousness, and not from nature.[20]

Scientific theories, according to Einstein, like scientific concepts, reflect phenomena of nature. They arise as a result of rationalising and processing information about the external world given to us through sensation.

> The theoretical idea [atomism in this case] does not arise apart from and independent of experience; nor can it be derived from experience by a purely logical procedure. It is produced by a creative act. Once a theoretical idea has been acquired, one does well to hold fast to it until it leads to an untenable conclusion.[21]

Any theoretical proposition, Einstein stressed, reflects processes of the external world in its content or, as he put it, 'every magnitude and every assertion of a theory lays claim to "objective meaning" (within the framework of the theory)';[22] or 'the most important demand to be made of every scientific theory will always remain that it must fit the facts'.[23] For a theory cannot be made to agree with itself or with 'the eternal idea' on which some philosophers insist. For Einstein a scientific theory was always verified by the supreme judge, viz., experience. Its content could not be made dependent on man's consciousness. In his conversation with Rabindranath Tagore, Einstein stressed:

> I cannot prove that scientific truth must be conceived as a truth that is valid independent of humanity, but I believe it firmly. I believe, for instance, that the Pythagorean theorem in geometry states something that is approximately true, independent of the existence of man.[24]

Thus, when answering the main question of philosophy, i.e. the question of what is primary—consciousness, sensations, or being, the external world, Einstein took a materialist position in principle. He had no doubt that nature existed before man, that it could not be made dependent on sensations and consciousness. He also did not waver on the question of the origin of scientific concepts, categories, and the laws of science, mathematical propositions, etc., and did not divorce them from material reality.

The main question of philosophy on which materialist philosophy is based has a second aspect, about the knowability of the world. Engels formulated its substance as follows: 'Is our thinking capable of the cognition of the real world? Are we able in our ideas and notions of the real world to produce a correct reflection of reality?'[25]

Einstein attached great importance to the problems of understanding the external world and had no doubts about human reason's capacity to grasp its secrets. 'The basis of all scientific work', he wrote 'is the conviction that the world is an ordered and comprehensive entity.'[26] In his view, to understand the essence of things was to reflect them in concepts, and to compare these concepts with reality.

> In speaking here of 'comprehensibility', the expression is used in its most modest sense. It implies: the production of some sort of order among sense impressions, this order being produced by the creation of general concepts, relations between these concepts, and by definite relations of some kind between the concepts and sense experience. It is in this sense that the world of our sense experiences is comprehensible.[27]

Einstein's conviction of the comprehensibility of the world was based on a profound faith in the existence of regular relations and causality in nature. When dealing with problems of knowledge he started from recognition of the external world, and not sensations, as the object of knowledge. For him sense data reflected the external world as well when they themselves functioned as the object of knowledge. In contrast to Berkeley and Mach he saw the external world behind sensations. In contrast to Hume, for whom knowledge based on empirical data was unreliable, Einstein asserted that sense data were the source of our knowledge. 'The sensory raw-material' was, he wrote, 'the only source of our knowledge'.[28] But that material in a logically untreated form, 'may lead us to belief and expectation but not to the knowledge and still less to the understanding of law-abiding relations'.[29] For him knowledge was based on the formation of scientific concepts, and discovery of the regularities of nature, which could be arrived at through rational analysis of sense data.

Agnosticism in the spirit of Kant was also unacceptable to Einstein; for Kant the substance of objects of the external world was in principle unknowable. For him phenomena did not reflect things and were not essentially connected with them. Einstein, however, started from the possibility of comprehending the essence of material objects. It was not the formal, external properties of an object that interested him but its real properties, which are not given to us directly in sensations, which do not lie, so to speak, on the surface but must be abstracted or, as he sometimes put it, guessed by us from the aggregate of sensations. These essential properties also express the main content of an object, and form scientific concepts. According to Einstein the synthesis of concepts is 'a transcript of the empirical world'.[30] But their content is not identical with that of the aggregate of sensations.

Dialectical materialism is an organic unity of materialism and dialectics. Lenin called dialectics the 'living soul' of Marxism. What was Einstein's attitude to it? What was his notion of the essence of dialectics? He did not express his attitude to the theory of dialectics, but study of his work indicates that it is impossible to class him among metaphysically thinking (i.e. anti-dialectical) scientists. His outlook was in essence dialectical. I shall not refer here to the elements of objective dialectics that follow from analysis of this special and general theories of relativity. Let us simply examine his views on physical science as a whole and his statements on

general epistemological questions, from which it follows not only that he had a profound dialectical intuition but also that he turned consciously to dialectics and creatively applied it. Here it is not only the intuitive dialectics about which Engels spoke when he wrote that 'men thought dialectically long before they knew what dialectics was, just as they spoke prose long before the term prose existed'.[31]

In the seventeenth and eighteenth centuries a certain style of thinking took shape in rapidly developing natural science that was gradually raised to the rank of a universal philosophical methodology. For several centuries the metaphysical outlook reigned supreme, treating the separate elements of nature, and consequently also the concepts of them, outside development, outside universal connections. Yet, in spite of that, individual dialectical ideas made their way in the course of scientific progress that expressed the unity and connection of the phenomena of the world and its development. Scientists who had enough empirical material to draw generalising conclusions, went beyond the metaphysical outlook. Copernicus, Galileo, Kepler, and Newton were led to their main discoveries by the dialectical idea of the universal connection and unity of nature, and Einstein noted that (as was said above).

A contradictory situation took shape in the consciousness of eighteenth and nineteenth century scientists. On the one hand the metaphysical methodology dominated them; on the other hand the reality they studied more and more indicated the dialectical character of the objective world. Einstein proved to be in the same position. In his 'Autobiographical Notes' he wrote that 'the mental grasp of this extrapersonal world ... swam as highest aim half consciously and half unconsciously before my mind's eye'.[32] The rich empirical material suggested to him that the external world developed according to definite laws, and represented a single material entity.

Einstein's dialectical materialist view of nature can well be illustrated by his interpretation of the conception of determinism. The question of the universal causal connection of the world is not only of immense ideological importance, as we know, but is also of methodological importance. It is one thing when we recognise that all phenomena in nature are causally determined and another when we suggest they arise in themselves without connection with other phenomena. In the first case the scientist comes to study a problem quite differently than he does in the second. It is not necessary to prove how profoundly the idea of determinism brings out the dialectical

nature of the external world. Einstein also displayed immense interest in this conception, and that was not due just to an idle interest in one of the main problems of philosophy. He saw, from many examples, that natural phenomena are interconnected; one of the most important tasks of science, in his view, was to establish these connections. He saw the goal of theoretical physics in its creating a system of concepts based on as few logically independent hypotheses as possible, which would enable the causal interconnection of the whole complex of physical processes to be established.

Einstein approached the problem of causality as a historical category. In his view it developed as the content of science changed. When studying the works of ancient thinkers he appreciated the idea of determinism as the outstanding achievement of antique materialism. 'The strong belief in physical causality, which does not even stop at the will of *homo sapiens*, is admirable.'[33] He also turned to that problem in the foreword to Lucretius' *On the Nature of Things*.

He understood that the materialists of antiquity had formulated it correctly in principle but only in general form. Their doctrine of causality was based mainly on the atomistic doctrine by which they explained all the processes taking place in the world, spiritual phenomena included. It caught his attention that Aristotle, the mediaeval schoolmen, and Kant were also concerned with the problem of causality. But in his view the weak spot in their notions about determinism was that they were not based on scientific material but interpreted causality purely speculatively and metaphysically.

Einstein gave Spinoza a worthy place in the development of the problem of causality. Spinoza, he wrote,

> was utterly convinced of the causal dependence of all phenomena, at a time when the success accompanying the efforts to achieve a knowledge of the causal relationship of natural phenomena was still quite modest.[34]

Only the development of science and scholars' turn to study of nature provided the possibility of coming to a true validation of the conception of determinism. In that Einstein attributed an immense role, as we said above, to the founders of classical mechanics—Kepler, Galileo, and Newton.

Einstein unreservedly adopted the conception of the causal relationship of natural phenomena. In his view these relations had an objective character. He rejected any kind of subjectivist interpretation of causal connection according to which no other necessary connection existed except a logical one.

> Natural occurrences seem to be so broadly determined that not only the succession in time but also even the initial state is broadly governed by law.[35]

In Einstein's view determinism was inherent not just in the objects of physics. He shared Spinoza's point of view that not only natural phenomena, but also social and psychic ones were causally determined and mutually interconnected.[36]

He condemned those philosophers who, when trying to refute the conception of causality, claimed that human actions and man's will were not subject to any influence, that they were the embodiment of true freedom and contradicted the conception of causality. He stressed that our idea that we were free in our acts was nothing but an illusion, though it was difficult, of course, to consider displays of our will to depend on a rigorously consistent chain of events and to reject the conviction that our actions were not in any way connected.

Einstein also did not share the view that all events in human life are predetermined, governed by the existence of some mysterious force. He did not agree with those who identified causality with predestination. 'Fate, or destiny, and the principle of causation are not the same thing'.[37]

He condemned the idea, common in the literature, of indeterminism in inorganic nature. It was being stated that indeterminist processes occurred mainly in the microworld. Einstein categorically opposed the conception of indeterminism in whatever form it was proposed. This idea, he wrote, 'is not merely nonsense. It is objectionable nonsense... Indeterminism is quite an illogical concept'.[38]

But, although he regarded causality as a historical category, his position nevertheless did not take fully into account quantum mechanics' development of the idea of causality, which differed rather from classical physics in its approach to the study of natural phenomena.

Classical physics' objects of study were macrobodies, which were regarded either in a static state or in movement with relatively low velocities. And they were mainly studied directly. When an instrument was employed between the observer and the studied object it did not in general either influence the latter's properties or did so in a way that could easily be allowed for and corrected, without distorting the general idea of the object. The motion of macro-objects was governed by dynamic laws according to which the behaviour of a physical body relative to a given system of co-ordinates could be determined unambiguously at any moment of time. The causality

of classical physics was also based on dynamic laws, but these did not in themselves fully express the diversity of the connections and reciprocal influences between natural objects. This one-sidedness and incompleteness of the dynamic laws were reflected in the limited character of the content of causality in classical physics. The theory of relativity also did not introduce any hesitations or doubts into the classical idea of causality. Niels Bohr wrote apropos of that:

> Relativity theory, which has endowed classical physics with unprecedented unity and scope, has just through its elucidation of the conditions for the unambiguous use of elementary physical concepts allowed a concise formulation of the principle of causality along most general lines.[39]

The course of studying phenomena of the microworld proved more complicated, it being impossible to observe its objects directly. The motion of electrons, for example, can be studied through the optical microscope, but it is much more difficult to control the effect of the light on an electron than its effect on macro-objects. To get an increasingly exact measurement of the position of an electron we have to shorten the wavelength of the light (in order to avoid its diffraction by electrons, which prevents exact determination of the position of the object). But, by reducing the wavelength we thus increase its energy and impulse, and as a result strongly influence the movement of the studied object (electron). So it happens that more exact determination of the position of a particle automatically leads to deformation of the idea of its velocity and, on the contrary, attempts to find the velocity of movement exactly lead to distortion of ideas of the position of the electron. That fact reflects the relation of indeterminacy between the conjugate quantities known in physics (in this case between the impulse and the co-ordinates).

As we see, the properties of objects of the microworld are such that it is necessary, when studying them, to allow for the corpuscular-wave dualism, which does not allow the impulse and the co-ordinates to be measured simultaneously. The techniques of classical physics proved useless here. It was necessary to look for other ways of cognition. And they were found. Scientists came to the conclusion that the behaviour of micro-objects abided by statistical laws and could be studied by statistical methods which, in contrast to classical physics, also allowed for chance phenomena. This technique made it possible to predict the probability of the behaviour of micro-objects in time.

The attitude to the statistical-probability presentation of phenomena of the microworld, however, was not unambiguous. Some saw in it the way out of the difficulties arising in quantum mechanics. Others concluded that the retreat from dynamic laws and introduction of probability were nothing else than rejection of the principle of causality. Conclusions were drawn from quantum mechanics about the 'free will' of the electron, about confirmation of the idea of vitalism by the methods of physics, and so on.

Scientists had in fact discovered a new form of causal connection. In contrast to the causality of classical physics it took in account the objectivity of chance phenomena, distinguished between external and internal, main and subsidiary causes, etc. Dialectical materialism considers that it is impossible to make an absolute of causality since new notions about the connecting threads between natural phenomena may appear in the future. The time will come when this form of causal connection, like causality based on dynamic laws, will prove to be relatively true.

Einstein, as I said above, had a negative attitude to the statistical character of the laws of the microworld.

> The question is whether or not the theoretical description of nature should be determinist. Hence there is the question in particular of whether there is actually a mental picture of reality (in each separate case) that is complete and free in principle of statistics. But there are differences of opinion on that.[40]

His scepticism was due to several circumstances. First of all, causality, based on dynamic laws, seemed more obvious, simple, and reliable for common sense, since physics was abstracted here from many other connections, which was justified in the macroworld. For many physicists, including Einstein, it seemed closer to truth, although, of course, what is simplest to understand is not always true. In dialectical materialism truth is associated above all with the objectivity and correctness of the reflection of reality.

In addition Einstein saw a serious danger for the doctrine of causality from those philosophers who claimed that the introduction of probability into quantum mechanics was accompanied with rejection of this doctrine. He categorically opposed such conclusions. 'Even though modern quantum theory contains a weakening of the concept of causality, it does not open a back-door to the advocates of free will'.[41]

But the attitude of certain scientists and philosophers

to the concept of physical reality in connection with the creation of quantum mechanics perhaps aroused the greatest disquiet in Einstein. In the view of Heisenberg, for example, 'observation plays a decisive role in the event and ... reality varies, depending upon whether we observe it or not'.[42] Hence, he considered, the micro-object we observe, in reality, 'is not a material particle in space and time but, in a way, only a symbol on whose introduction the laws of nature assume an especially simple form'.[43] Einstein was afraid that the subjectivist interpretation of the concept of physical reality might affect not only the conception of causality but also the fate of physics as a whole. Max Born wrote in that connection:

> From the cited passages of letters and the correspondence mentioned later, it follows that Einstein's rejection of today's quantum physics is due not so much to the question of determinism but to his belief in the objective reality of physical events irrespective of the observer.[44]

In Einstein's statements about causal connections in the microworld, however, there was also something optimistic, as well as scepticism. He did not try to turn scientists back to a mechanistic understanding of causality or to the methods of classical physics when studying it, as he is often accused of having done. He did not consider the content of cause and effect relations solvable by classical physics to be absolute truth. Yet he nevertheless liked the ideal possibilities by which physical reality was depicted directly in time and space. As we have noted, he also did not agree with the view of those who claimed that the probability character of causality was the last word in solution of this problem. He called on scientists to go further, to cognition of the deeper properties of matter, to the creation of new methods that would make it possible to reflect the connections in nature more adequately. He suggested that science would not remain in the form employed by quantum mechanics.

> Now I believe that events in nature are controlled by a much stricter and more closely binding law than we suspect to-day, when we speak of one event being the *cause* of another. Our concept here is confined to one happening within one time-section. It is dissected from the whole process. Our present rough way of applying the causal principle is quite superficial. We are like a child who judges a poem by the rhyme and knows nothing of the rhythmic pattern. Or we are like a juvenile learner at the piano, just relating one note to that which immediately precedes or follows. To an extent this may be very well when one is dealing with very simple and primitive compositions; but it will not do for the interpretation of a Bach Fugue. Quantum physics has presented us with very complex processes

> and to meet them we must further enlarge and refine our concept of causality.[15]

The subsequent development of physics has shown how right Einstein was in defending that point of view. At present it is clear only that the forms of causal connection will constantly alter the more deeply our knowledge penetrates the material world.

The dialectical character of the thinking of one scientist or another is also disclosed in his analysis of the essence of scientific concepts, laws, and science as a whole. As I have already said, the objects of the external world and the world as a whole are imagined by the (undialectical) metaphysician as immutable in time, and he therefore considers their reflection in scientific concepts and theories as complete and true in the final instance. I shall not touch here on the work of the founders of dialectical materialism to overcome the metaphysical outlook. Let us look at how Einstein understood this problem and how he tackled it.

He approached examination of the essence of scientific concepts from an intuitive dialectical position. He specially noted the mistaken character of the metaphysical approach to this problematic, and criticised those who perceived scientific concepts as something immutably given. He considered that scientific concepts must be reexamined from time to time if we wanted them to further the development of science, and deepened in a way adequate to knowledge of the external world.

> The situation is different, however, when a habitually used idea has to be superseded by a more exact one because the development of the science concerned requires it. Then those who do not clearly handle their own ideas raise a vigorous protest and complain about a revolutionary threat to the holy of holies. The voices of philosophers chime into these cries who cannot do without that idea as they have subsumed it in their jewel box of 'absolutes' and 'a prioris', or in short have proclaimed them unalterable in principle.[46]

Since scientific concepts are not absolute quantities, and promote the formulation of laws of nature by reflecting real connections, the laws following from them cannot be made absolutes. Like the concepts they are altered and deepened from time to time. 'A law cannot be definite,' Einstein wrote, 'for the one reason that the conceptions with which we formulate it develop and may prove insufficient in the future.'[47]

He drew the same conclusion as regards physics as a whole. He criticised those scientists who made an absolute of it. In contrast to a number of scientists he saw physics as a dynamic,

historical science. According to him

> our notions of physical reality can never be final. We must always be ready to change these notions that is to say, the axiomatic basis of physics in order to do justice to perceived facts in the most perfect way logically. Actually a glance at the development of physics shows that it has undergone far reaching changes in the course of time.[48]

The attitude of physicists to Newton's mechanics is well known. Right down to the twentieth century many represented it as an immutable science by which all questions of the structure of inorganic nature could be answered, and some saw in it the key to understanding organic matter as well. Einstein, however, understood that the propositions of Newton's mechanics were relative truths.[49] In his article on the centenary of the birth of William Thomson (Lord Kelvin), one of the most brilliant defenders of the infallibility of Newton's mechanics, Einstein, while giving him his due for his contribution to the development of physics, at the same time saw 'something tragic' in his scientific work. This something tragic, in Einstein's opinion, was that

> Thomson, to whom the ultimate foundations of physical knowledge seemed secure almost to the end of his life, would have shuddered if he could have cast an unprepared glance at our current literature.[50]

Individual scientists came to a conclusion from this fact that ideas of the properties, laws of motion, and development of nature altered with time, that there was no objective truth, and that truth was a value that depended on our consciousness. But the conclusion about the relativity of the truth of physical knowledge did not lead Einstein to denial of the external world and the objectivity of truth. Lenin regarded the reason that led scientists of that sort to deny objective reality and objective truth to be their ignorance of dialectics, and in particular their making an absolute of the relative.

> The principle of *relativism* [he said], the relativity of our knowledge, a principle which, in a period of abrupt break down of the old theories, is taking a firm hold upon the physicists, and which, *if the latter are ignorant of dialectics*, inevitably leads to idealism.[51]

Though Newton's mechanics had a relative character, Einstein nevertheless did not discard it. He gave it its proper place in the structure of physical knowledge, considering that its theoretical conclusions were suitable for only a certain range of phenomena.

> First [he said] we try to get clearly in our minds how far the

> system of classical mechanics has shown itself adequate to serve as a basis for the whole of physics.[52]

Against the metaphysicians Einstein stressed the continuity of physical theories. As for the question of the influence of Newton's mechanics on the forming of a number of new problems of theoretical physics, he wrote: 'The whole evolution of our ideas about the processes of nature ... might be regarded as an organic development of Newton's ideas.'[53]

The following statement by Lenin is well known now.

> Human thought then by its nature is capable of giving, and does give, absolute truth, which is compounded of a sum total of relative truths. Each step in the development of science adds new grains to the sum of absolute truth, but the limits of the truth of each scientific proposition are relative, now expanding, now shrinking with the growth of knowledge.[54]

Einstein's idea of the relation of relative and absolute truth, and his attitude to their dialectical reciprocal influence, deserve attention in this connection. How did the founder of relativistic mechanics treat this problem? Let me note at once that he had no final system of views on this point, but he saw that our knowledge, in reflecting relative truths, were steps toward a full picture of the world. Einstein expressed the dialectical materialist conception of truth in the language of intuitive dialectics. He considered, for example, that Newton's fundamental concepts and hypotheses were only a certain approximation of the truth. As for the possibility of creating a full physical picture of the world, he claimed that while it could be theoretically supposed, it was impossible in practice.

> The fact that in science we have to be content with an incomplete picture of the physical universe is not due to the nature of the universe itself but rather to us.[55]

(Engels explained this point as follows: 'Each mental image of the world system is and remains in actual fact limited, objectively by the historical conditions and subjectively by the physical and mental constitution of its originator.')[56] All the same, however, Einstein pointed out, when examining the dynamic of scientific thought, that the amassing of knowledge led to ever fuller knowledge.

A test of sorts for many scientists is the differentiation of knowledge. Not all have passed it in the history of science. In the years when classical science flourished, it led to a forgetting of the universal dialectical approach to understanding nature that had been bequeathed by the ancients. The creators of dialectical materialism linked the reason for the

appearance of the antipode of dialectics—the metaphysical outlook—precisely with the differentiation of science. Engels wrote:

> The analysis of nature into its individual parts, the grouping of the different natural processes and objects in definite classes, the study of the internal anatomy of organic bodies in their manifold forms these were the fundamental conditions of the gigantic strides in our knowledge of nature that have been made during the last four hundred years. But this method of work has also left us as legacy the habit of observing natural objects and processes in isolation, apart from their connection with the vast whole; of observing them in repose, not in motion; as constants, not as essentially variables; in their death, not in their life.[57]

Einstein also cautioned against the same danger. He saw that the differentiation of knowledge was a progressive phenomenon and furthered deeper penetration into the essence of the separate phenomena of the world, but it could nevertheless lead to their mental division and in consequence to loss of the thread connecting them, of what they have in common, so necessary for deeper knowledge of them. He demonstrated this idea by an example from medical science.

> In medicine, too, considerable specialisation has become unavoidable with increasing knowledge; but in this case specialization has its natural limits. If some part of the human body has gotten out of gear, a person with sound knowledge of the whole complex organism is needed to put it right; in a complicated case, only such a person can obtain an adequate understanding of the disturbing causes. For this reason, a comprehensive knowledge of general causal relations is indispensable to the physician.[58]

Einstein's dialectical thinking was also manifested in his interpretation of the relation of theoretical and empirical knowledge. Earlier I touched on this point only partially, discussing it in connection with analysis of classical mechanics and a number of philosophic systems. Here I would like to dwell on it in more detail, the more so that there is no unanimity in the philosophic and scientific literature about its solution in Einstein's theory.

When studying the works of the founders of mechanics Einstein was interested by such epistemological problems as the possibility of obtaining knowledge solely through pure thought, independent of sense data, the relation of the sensory and rational in knowledge, etc. He found various answers to these questions in philosophic works, and an incredible chaos of views. At the same time he noted that the single process of cognition was artificially broken down into its separate aspects. Empiri-

cists, for example, were mainly interested in sense data. The empirical aspect of the cognitive process was initially made an absolute in the English and French metaphysical materialism respectively of the seventeenth and eighteenth centuries; later empiricism constituted the basis of the epistemology of positivism. The role of abstract thought in the process of cognition was also disparaged in both the materialist and the idealist variants of empiricism, but whereas in the former this was at the cost of its struggle against theological methodology, a consequence of its increased attention to nature, in the latter the belittling was due to the critique of 'traditional' philosophy and attempts to reduce epistemology simply to a description of given sensations without going into the substance of the natural phenomena.

Einstein also drew attention to the deficiencies of the opposite epistemological conception, that of rationalism, in which the second aspect of the cognitive process, i.e. man's mental activity, was made an absolute. Rationalism arose as an attempt to explain the origin of universal mathematical and scientific propositions whose content it was difficult to substantiate solely from sense data, and also as a reaction to the existing methodological principle of the primacy of faith over reason. The advocates of rationalism (Descartes, Spinoza, Hegel, and others) each disparaged the role of sensuality in cognition in his own way, giving the rational principle a decisive place in his epistemology.

Einstein could not agree with these one-sided notions of the cognitive process. The mounting scepticism in regard to attempts to obtain knowledge of the external world solely through 'pure' thought, for example, impressed him.

> It was an illusion which any one can easily understand if, for a moment, he dismisses what he has learned from later philosophy and from natural science; he will not be surprised to find that Plato ascribed a higher reality to 'Ideas' than to empirically experienceable things. Even in Spinoza and as late as in Hegel this prejudice was the vitalizing force which seems to have played the major role.[59]

But Einstein did not share the ideas of the philosophers who made an absolute of sensory cognition.

> This more aristocratic illusion [he wrote] concerning the unlimited penetrative power of thought has as its counterpart the more plebeian illusion of naive realism, according to which things 'are' as they are perceived by us through our senses.[60]

While paying its due to logical thought in the cognitive process, Einstein did not divorce it from the objective world.

He represented this dialectical idea of his schematically in a letter to Maurice Solovine, in which he broke the process of cognition down into a series of stages.[61]

Knowledge, he considered, took its beginning from a sum-total of sense data E. The empirical material was basic for forming the system of axioms A. But although the system A was based on E, there was no logical path leading from E to A. Partial statements were deduced logically from the axioms and then compared with the sense data E. Thus, according to Einstein, 'all knowledge of reality starts from experience and ends in it'.[62] This conclusion of his corresponds in general with dialectical materialism's requirement concerning the path of knowledge, most aptly expressed by Lenin: 'From living perception to abstract thought, and from this to practice—such is the dialectical path of the cognition of truth, of the cognition of objective reality.'[63]

So Einstein waged a struggle on the question of the relation of the empirical and the rational against those philosophers who belittled the role of empirical data and made an absolute of the rational moment in cognition, and against the positivists and metaphysical materialists who neglected rational thought. He considered that analysis of the creative process should inevitably presuppose allowance for both these factors. In that connection his reply to Henry Margenau in his 'Reply to Criticisms' is of interest. Margenau had suggested that Einstein's position contained features of rationalism and extreme empiricism. Einstein gave the following explanation, recognising Margenau's comment as quite justified. But where did the wavering come from, he asked himself, and replied:

> A logical conceptual system is physics insofar as its concepts and assertions are necessarily brought into relationship with the world of experiences. Whoever desires to set up such a system will find a dangerous obstacle in arbitrary choice...
>
> 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 it 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 more 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 to be unavoidable.[64]

In spite of his correct interpretation of the relation of the sensory and rational, Einstein at the same time often stressed the need to raise the role of theoretical thought in modern physics. Does that give grounds for accusing him of concessions to philosophy of a rationalist hue?

One must make allowance for the fact that in the latter half of the nineteenth century the ideas of metaphysical and mechanistic materialism still had great influence on the minds of scientists; as a rule they made absolutes of the sensory forms of knowledge. That had its historical justification because, during the dominance of Premarxian materialism, natural science was, as Engels wrote, primarily a collecting science.[65] Problems of the theoretical substantiation of the accumulated empirical material faced scientists rather seldom in all their fullness. The special need for it came later.

The need for theoretical thinking was posed particularly acutely in physical science at the turn of the century, when many facts had been accumulated that required generalisation. Einstein, who was engaged in that work, subconsciously understood that success was inconceivable without investigation of general matters of epistemology, in particular of the relation of the sensory and rational, empirical and theoretical. In a polemic with empiricists (and they held a dominant position in the methodology of natural science) he drew attention, while giving their due to sense data, to the need to raise the role of rational thinking.

Let us note that Einstein was not acquainted with dialectical materialism and did much in fact that had already been done by it. Engels, of course, had expressed concern in regard to the inattention of scientists who were influenced by empiricism to theoretical thinking.

> The bulk of natural scientists [he wrote] are still held fast in the old metaphysical categories and helpless when these modern facts, which so to say prove the dialectics in nature, have to be rationally explained and brought into relation with one another. And here *thinking* is necessary: atoms and molecules, etc., cannot be observed under the microscope, but only by the process of thought.[66]

The founders of dialectical materialism foresaw that the development of science itself would compel scientists to reject the one-sidedness of empiricism and rationalism. Engels stressed that

> empirical natural science made such an advance and arrived at such brilliant results that not only did it become possible to overcome completely the mechanical one sidedness of the eight

> eenth century, but also natural science itself, owing to the proof of the inter connections existing in nature itself between the various fields of investigation ... was transformed from an empirical into a theoretical science.[67]

While appealing to the 'light of reason', however, Engels warned against attempts to divorce thinking from reality. He blamed Kant for apriorism as Einstein did several decades later. Engels' aphorism—'a nation that wants to climb the pinnacle of science cannot possibly manage without theoretical thought'—was aimed against empiricism in science.[68]

As we see, the founders of dialectical materialism also called for rehabilitation of the role of reason in knowledge just as Einstein did later. Therefore there are no grounds for classing him among supporters of rationalist philosophers. Einstein was not one, since he was trying to overcome the metaphysical limitations of the natural science outlook through a spontaneous transition from the ideas of Premarxian materialism to the ideas of dialectical materialism, which assigned a worthy place in knowledge to both the empirical and the rational elements. By stressing the role of theoretical thinking in creating the new physics, Einstein was trying to raise it to the cognitive level to which the founders of dialectical materialism had raised it before him, as required by developing science. It is therefore incorrect to put him among the rationalists on the grounds of his frequent stressing of the importance of thinking in scientific knowledge. That conclusion is confirmed, in particular, by the answer he gave to a number of workers that the creation of the special, and even more, of the general, theory of relativity established the full superiority of the theoretical over the empirical. That interpretation of the methodological basis of the theory of relativity did not satisfy him; he analysed fundamental problems of physical science as a whole in several works, and discussed the factors that had a stimulating influence on the creation of the main physical theories. As a result he came to the following conclusion, which he formulated in a letter to Michele Besso:

> I find something on re reading your last letter that makes me really angry: that speculative thinking has proved superior to empiricism. You imply by that the development of the theory of relativity. But I find that this development teaches something else, that is almost the opposite: namely that a theory that merits confidence must be built on generalisable facts. Old examples:
>
> the principles of thermodynamics on the impossibility of perpetuum mobile; mechanics on the empirically perceived law of inertia; the kinetic theory of gases on the equivalence

> of heat and mechanical energy (also historical), special relativity on the constancy of the velocity of light; Maxwell's equations for the vacuum, which in turn rest on empirical foundations. It is the same with relativity. Translation is an *empirical fact.* General relativity: *the equivalence of inertial and gravitational mass.*
>
> A genuine, useful, profound theory has never been built purely speculatively. The closest to that is the Maxwellian hypothesis of displacement currents. But it is valid in that connection that the fact of the propagation of light is met.[69]

A reason for the various interpretations of the role of the empirical and the rational factors in the cognitive process is the variability of these concepts in the history of science. There are often cases when the development of a scientific category, and consequently a change in its content, leads those who do not know dialectics to deny the objectivity of categories. Let us recall here the history of the evolution of the concepts of time and space, causality, etc., when deepening of knowledge of their substance led to their revision, which gave some scholars grounds for concluding that the existence of these categories depended wholly on our sense organs and consciousness, and was dictated by them.

The same fate befell the concepts of the empirical and the theoretical. In the past century there have been significant changes in their content. Up to a certain time theoretical and practical activity were blended together, and only the division of labour into mental and physical led to an independent development of theory and practice. And as they developed they underwent big changes. In classical mechanics cognitive activity was more obvious and habitual for ordinary consciousness than happens, for example, in quantum physics. As I have already said above, the objects of investigation in classical mechanics were macro-objects moving at not very high speeds. The investigator, studying objects of that kind, was directly in contact with them, which gave him the possibility of depicting the properties of the studied object correctly.

As a result of the penetration of human genius into finer layers of the material world, and into the separate parts of it that are hidden from direct perception, the process of cognition has become more and more complicated. In order to determine the property of a micro-object, the researcher has to turn to the aid of rational activity.

Quantum mechanics tells us that the concept of sensual practical activity is a historical category and has undergone considerable change in our century, has become less customary,

has required rethinking and far-reaching concrete scientific and philosophical analysis. But the same also applies to the theoretical side of the cognitive process, which has also become more complicated, and more removed from the immediate sensual world. Modern theory does not boil down only to a simple classification of the data of sense experience. It presupposes a high level of generalisation and developed abstraction. It has acquired relative independence and to some extent exerts a stimulating influence on its own development, on the discovery of new properties and new aspects of an object, and helps disclose connections that are more and more remote from direct sense experience. An example of the fruitful role of theory is the method of mathematical hypothesis successfully employed in modern science. As the Soviet physicist S. I. Vavilov stressed, the change and development of the concepts of theory and experience have not led to a negation or rejection of their objectivity. The practical activity inherent in modern physics proves to be 'refined experience' which, relying

> on new, intricate instruments, brings to consciousness a reflection of regions of the world that are quite unaccustomed and foreign to the normal man. The usual images and concepts are not enough for a visual, model interpretation of the picture, but logic with its boundless breadth embodied in mathematical forms, remains valid, establishing order in the new, incomprehensible world and revealing possibilities of physical predictions.[70]

There is a dialectical connection between theory and practice. Theory affects practical activity, and vice versa. It is difficult at times now, to trace the thread that links separate theoretical ideas and sense data, but the complex character of theory and practice, and the complication of the links between them, do not alter the dialectical materialist theory of the paths of understanding reality.

Distortion and confusion still occur in theoretical and cognitive questions of this kind because they are often discussed on a specifically scientific level in the literature and not on a philosophical one. When it is a matter of the relation of the theoretical and the empirical in knowledge of objective reality, it is not always remembered that we intrude into the field of philosophical science and therefore have to analyse this question as a trend, as a universal initial principle, as a fundamental principle of activity that can be extended to study of all material reality. This point is sometimes forgotten, and a separate segment of the complex general path of cognition is made an absolute and represented as a general principle binding in all cases of life. That approach reduces philosophy

to a specific science, and the universal method to a partial, special one, which ultimately leads to distortion of the general notion of the world and the ways of understanding it.

Einstein, as we have seen, did not consider the sensual and the rational as concepts given for once and all. He saw them in development, motion, and interaction. But their flexibility and mobility did not lead him to reject the main philosophical thesis he had formulated about the paths of cognising truth and objective reality, which he represented as movement from the empirically given to abstract generalisation and then to practice.

To sum up, we can conclude that Einstein arrived, through study of philosophy and natural science, and use and development of philosophical and special knowledge, at a philosophical outlook which coincided in principle with the content of the main propositions of materialism and dialectics.

Einstein and Social Phenomena

I have analysed Einstein's main philosophical views. The study has shown that the matured system of his philosophical ideas was aimed at an adequate reflection of the objective world. An integral idea of his outlook implies also examination of his views on social phenomena. He was not specially engaged, of course, in working out problems of social development, but an idea of his social views can be got from certain fragments of his writings.

Einstein lived and worked in an epoch of acute social upheavals—the years of the First and Second World Wars, the complicated postwar period (a period of historic victories of the socialist and national liberation movements; a period of the struggle of world socio-political systems and ideological trends). He lived in the age of the building of a socialist civilisation, fundamentally new, at first in one country, Russia, and then in a whole number of regions. All that, of course, could not help influencing the evolution of his socio-political position.

One of the central ideas of historical materialism, around which disputes have raged for decades between the various philosophical schools, is the proposition of the law-governed link and causal dependence of social events. Some thinkers affirm that the history of society does not have a regular character, that indeterminate processes take place both in nature and in society, and that all social phenomena depend on chance and the free will of people. A characteristic expression of that is

the view, for example, of Otto Kraus: 'There is nothing else in history than an irregular succession of chance occurrences.'[71] Einstein did not agree with such an appraisal of historical processes. He considered that social phenomena, like those of nature, were governed by certain laws of development, which were causally conditioned and mutually linked with one another. As I said above, he shared Spinoza's view that the idea of the causal dependence of all phenomena applied to social phenomena and human deeds as well as to inanimate nature.

> The habit of causal interpretation of all phenomena, including those in the psychic and social spheres, had deprived the more wide-awake intellectual of the feeling of security and of those consolations which traditional religion, founded on authority, offered to earlier generations.[72]

Einstein also did not accept the theory, fashionable among some sociologists, that social processes could be explained by means of the natural sciences alone. That view was popular during his lifetime, but he understood that 'living' matter and social phenomena had their own inherent specific laws of development, and condemned the modish passion for transferring the axioms of physical science to the life of society.

At the same time he rejected the assertion of man's so-called free will, considering it illusory. According to him, people were not free in their actions. It only seemed to a person that his acts were not governed by any objective law. Einstein considered that social phenomena also had their causes, like those of inorganic nature.

He understood that the main reasons motivating men, or even society, to some action or other, were the material conditions of life. It was they that determined the occurrence of social upheavals. In a speech in London in 1933 he said:

> It cannot be doubted that the world crisis and the suffering and privations of the people resulting from the crisis are in some measure responsible for the dangerous upheavals of which we are the witness.[73]

He saw that people's hard living conditions could ultimately lead to such social conflicts as revolution or war. He was always, therefore, bothered by problems of social inequality, which he considered very important and calling for urgent solution. 'Social agreement and economic protection of the individual always seem to me,' he wrote, 'the essential goal of civil society.'[74] 'My love for justice and the striving to contribute towards the improvement of human conditions,' he stressed, 'are quite independent from my scientific interests.'[75]

In his young years Einstein was already aware of the anomaly of the social atmosphere around him.

> Youth is intentionally being deceived by the state through lies; it was a crushing impression. Suspicion against every kind of authority grew out of this experience, a sceptical attitude towards the convictions which were alive in any specific social environment an attitude which has never again left me, even though later on, because of a better insight into the causal connections, it lost some of its original poignancy.[76]

Einstein's life was an example of a kind of protest against the social contrasts of society. He was always distinguished by modesty and simplicity; excessive luxury and a thirst for money were foreign to him.

> I never strove for the fleshpots and luxury, and I even have a good deal of disdain for them. My passion for social justice often brought me into conflict with people, and likewise my antipathy for any joining and dependence that did not seem absolutely necessary to me.[77]

He understood that the society in which he lived in the twentieth century had already ceased to play the progressive role inherent in it in its earlier stage of development. 'The confidence in the sure and constant progress of mankind that inspired people in the nineteenth century,' he wrote in this connection, 'has given way to a crippling disillusionment'.[78] It had, of course, made great advances in the development of science, engineering, and technology, but these achievements did not equally have a beneficial influence on all aspects of the working people's life.

> No one, it may be presumed, can deny the progress made in the realm of knowledge and in the field of technological invention; but we have experienced the disillusioning fact that all these advancements have not essentially alleviated the hardships of man's destiny; nor have they ennobled his actions.[79]

Einstein did not like it that a person was not valued in the world around him for his true merits, personal qualities, and capacities but primarily for his inherited wealth and the position he occupied in the social structure. 'The privileges springing from position and possessions are always, it seems to me, only unjust and pernicious.'[80]

He expressed his disappointment in the existing order in his famous letter to posterity immured in a special capsule in the grounds of the New York World Fair to be opened five thousand years later in 6939. In this message he said:

> Our time is rich in inventive minds, the inventions of which could facilitate our lives considerably. We are crossing the seas by power and utilize power also in order to relieve humanity

from all tiring muscular work. We have learned to fly and we are able to send messages and news without any difficulty over the entire world through electric waves.

However, the production and distribution of commodities is entirely unorganized, so that everybody must live in fear of being eliminated from the economic cycle, in this way suffering for the want of everything. Furthermore, people living in different countries kill each other at irregular time intervals, so that also for this reason any one who thinks about the future must live in fear and terror... I trust that posterity will read these statements with a feeling of proud and justified superiority.[81]

In 1949 Einstein wrote an article 'Why Socialism?' for the New York magazine *Monthly Review*. In it he attempted to analyse capitalist social relations and to disclose their weak sides. He condemned the spontaneous, elemental character of the economy based on private property. He considered that the uncontrolled character of production and distribution was the main reason for the ruin of many proprietors.

> The economic anarchy of capitalist society as it exists today is, in my opinion, the real source of the evil. We see before us a huge community of producers the members of which are unceasingly striving to deprive each other of the fruits of their collective labor not by force, but on the whole in faithful compliance with legally established rules. In this respect, it is important to realize that the means of production that is to say, the entire productive capacity that is needed for producing consumer goods as well as additional capital goods may legally be, and for the most part are, the private property of individuals.[82]

The problem of the ratio between the value of the goods produced and the payment for labour was an acute problem. All the shortcomings of the system were rooted precisely in that, he remarked.

> The owner of the means of production is in a position to purchase the labor power of the worker. By using the means of production, the worker produces new goods which become the property of the capitalist. The essential point about this process is the relation between what the worker produces and what he is paid, both measured in terms of real value. Insofar as the labor contract is 'free', what the worker receives is determined not by the real value of the goods he produces, but by his minimum needs and by the capitalists' requirements for labor power in relation to the number of workers competing for jobs. It is important to understand that even in theory the payment of the worker is not determined by the value of his product.[83]

Among the drawbacks to which private ownership of the means of production leads, Einstein included the concentration of capital in the hands of a small group of people.

> Private capital tends to become concentrated in few hands, partly because of competition among the capitalists, and partly because technological development and the increasing division of labor encourage the formation of larger units of production and the expense of the smaller ones. The result of these developments is an oligarchy of private capital the enormous power of which cannot be effectively checked even by a democratically organised political society.[84]

He stressed that the concentration of big capital in a few hands could lead to infringement of democracy, since

> private capitalists inevitably control, directly or indirectly, the main sources of information (press, radio, education).
>
> It is thus extremely difficult, and indeed in most cases quite impossible, for the individual citizen to come to objective conclusions and to make intelligent use of his political rights.[85]

Among the shortcomings of the capitalist system Einstein included the fact that it constantly gave rise to mass unemployment. He understood that unemployment stemmed from the very nature of economic relations since the attention of property-owners was focused on profit and not consumption.

> There is no provision that all those able and willing to work will always be in a position to find employment; an 'army of unemployed' almost always exists. The worker is constantly in fear of losing his job. Since unemployed and poorly paid workers do not provide a profitable market, the production of consumers' goods is restricted, and great hardship is the consequence. Technological progress frequently results in more unemployment rather than in an easing of the burden of work for all. The profit motive, in conjunction with competition among capitalists, is responsible for an instability in the accumulation and utilization of capital which leads to increasingly severe depressions.[86]

The effect of the relations of production on the state of social consciousness, and the education of people, perhaps, however, bothered Einstein most.

> Unlimited competition leads to a huge waste of labor, and to that crippling of the social consciousness of individuals... Our whole educational system suffers from this evil. An exaggerated competitive attitude is inculcated into the student, who is trained to worship acquisitive success as a preparation for his future career.[87]

He dreamed of a social system in which full social justice would be achieved, in which people would not have to be satisfied with tackling only questions of minimum satisfaction of their physical needs. He considered that satisfaction of these needs was simply a necessary precondition of all-round spiritual

development of the individual. Furthermore he pointed out that there was not always a direct connection between the quantity of products of labour and the real emancipation and happiness of man. He drew attention to this in other writings:

> Never forget that the fruit of our labor does not constitute an end in itself. Economic production should make life possible, beautiful, and noble. We must not permit ourselves to be degraded into mere slaves of production.[88]

For that, however, it was necessary to build a society in which all its members would have the chance to develop their individual capacities.

> The satisfaction of physical needs is indeed the indispensable precondition of a satisfactory existence, but in itself it is not enough. In order to be content, men must also have the possibility of developing their intellectual and artistic powers to whatever extent accords with their personal characteristics and abilities.[89]

In order to deal with the problem of the individual's intellectual development, it was necessary to emancipate man from monotonous work, and to ensure that he had time and the opportunity for harmonious development.

> Man should not have to work for achievement of the necessities of life to such an extent that he has neither time nor strength for personal activities. Advances in technology would provide the possibility of this kind of freedom if the problem of a reasonable division of labor were solved.[90]

Einstein saw that science did not always fully serve the interests of the workers.

> Why does this magnificent applied science, which saves work and makes life easier, bring us so little happiness? Instead of freeing us in great measure from spiritually exhausting labor, it has made men into slaves of machinery, who for the most part complete their monotonous long day's work with disgust, and must continually tremble for their poor rations.[91]

He dreamed that the centre of attention of any science should first and foremost be man and his needs and requirements. When addressing the students of the California Institute of Technology, he said:

> It is not enough that you should understand about applied science in order that your work may increase man's blessings. Concern for man himself and his fate must always form the chief interest of all technical endeavors, concern for the great unsolved problems of the organization of labor and distribution of goods in order that the creation of our mind shall be a blessing and not a curse to mankind. Never forget this in the midst of your diagrams and equations.[92]

He was an opponent of the common idea that held that science should serve only a narrow group of people, and primarily the scientist himself.

> I can think of nothing more objectionable than the idea of science for the scientists. It is almost as bad as art for the artists and religion for the priests.[93]

Einstein had an extremely negative attitude to displays of nationalism, whatever forms it took. He called nationalism an obtuse and pernicious phenomenon. Its worst version—the racist 'mass psychosis' that gained ascendency in Germany after the fascist seizure of power—he had experienced on himself. He saw that nationalism led to the self-isolation of a nation, suppression of political freedoms, and scorn for the cultural heritage of other nations, and prevented the development of international scientific, cultural, and economic ties.

Compelled to quit Germany in 1933, and living in several European countries and then in the USA, Einstein condemned the activities of the fascist government aimed at suppressing the political rights and freedoms of the working people, and in particular of citizens of Jewish origin. As a protest against the order existing in Germany he renounced German citizenship and resigned from the Prussian and Bavarian Academies of Sciences. He addressed an open letter to the Prussian Academy in which he said:

> The information I have given to the press was that I would resign my position in the academy and surrender my rights of German citizenship; I gave as my reason the fact that I did not want to live in a country where equality before the law and freedom of speech and of teaching were not granted to the individual.
>
> In addition I explained the state of present-day Germany as one of psychic illness in the masses and said something about the causes. In an article which I gave for circulation purposes to the International League for Combating Anti-Semitism, and which was in no way intended for the press, I further summoned all thoughtful people who remain true to the ideals of a threatened civilization to do everything possible to prevent this mass psychosis, which has manifested itself in such an appalling way in Germany, from spreading further.[94]

He believed, however, that the German people would ultimately cope with the nationalist frenzy and return its good name to its nation that it had previously enjoyed by right in the civilised world. He wrote in 1933:

> Any social organism can become psychically distempered just as any individual can, especially in times of difficulty. Nations usually survive these distempers. I hope that healthy conditions

> will soon supervene in Germany and that in future her great men like Kant and Goethe will not merely be commemorated from time to time but that the principles which they taught will also prevail in public life and in the general consciousness.[95]

He considered himself 'an ardent pacifist and anti-militarist'.[96] He had already joined the anti-war struggle in the years of the First World War. In 1919 he and a number of other leading scientists and cultural figures signed a number of appeals to the nations of the world expressing alarm at the fact that the war had led to a breaking of all contacts between the progressive intelligentsia of many countries, and that the fruits of intellectual activity had proved to be in the service of militarist-minded figures. Here is what the eminent physicist Max Born wrote about that period in Einstein's public activity:

> Already at that time parties began to form for and against him. True, he never concealed his opinions, but he also never forced them on anyone. But people knew that he was a pacifist, held military decisions to be senseless, and did not believe in a German victory. Toward the end of the war a group of important people, which included the historian Delbrück, the economist Brentano, Einstein, and others, organised evening meetings to which top officials of the Foreign Office were invited. Up for discussion mainly was the unrestricted U boat warfare demanded by the Supreme Headquarters, which would certainly lead to America's entry into the war. Einstein persuaded me to take part in these sessions, which I as an officer had no right, properly speaking, to do. I was one of the youngest of the circle, and never opened my mouth. But Einstein spoke several times, calmly and clearly, as if he were dealing with theoretical physics.[97]

Immediately after the fascist coup in Germany, Einstein, having experienced the First World War, saw the real face of Nazism and could not help warning against its consequences. He was convinced that a new explosion was maturing in Europe and posed the question of how humanity and its spiritual values could be saved, and how Europe could be rescued from a new catastrophe.

He saw the focus of the new war in Germany. And it was no accident that, when he received information about the heightened interest of certain German scientists in the problem of a chain reaction of uranium, he appealed to President Roosevelt, asking him to concentrate attention on the state of the experimental work on this problem being done by American scientists. He was afraid that Germany might get the atomic weapon first, and therefore considered it necessary to speed up work on making it in the USA as a counterweight to the militarisation of

Germany. He wrote to President Roosevelt as follows on 2 August 1939:

> Some recent work by E. Fermi and L. Szilard, which has been communicated to me in manuscript, leads me to expect that the element uranium may be turned into a new and important source of energy in the immediate future. Certain aspects of the situation seem to call for watchfulness and, if necessary, quick action on the part of the Administration. I believe therefore that it is my duty to bring to your attention the following... It is conceivable ... that extremely powerful bombs of a new type may ... be constructed. A single bomb of this type, carried by boat or exploded in a port, might very well destroy the whole port together with some of the surrounding territory. However, such bombs might very well prove to be too heavy for transportation by air... I understand that Germany has actually stopped the sale of uranium from the Czechoslovakian mines which she has taken over. That she should have taken such early action might perhaps be understood on the ground that the son of the German Under-Secretary of State, von Weizsäcker, is attached to the Kaiser Wilhelm Institute in Berlin, where some of the American work on uranium is now being repeated.[98]

When he sent his letter to Roosevelt, Einstein did not foresee the tragedy of Hiroshima and Nagasaki. But when, after the crushing defeat of fascist Germany, and the defeat in fact of her ally in the East, the birth of the new weapon was demonstrated over these cities, he immediately understood that another danger had arrived in place of the former one. And then, in spite of his having drawn the U.S. President's attention to the need to speed up work on fission of the atomic nucleus, he joined the struggle against the menace of atomic war, because he understood that a danger of the complete self-annihilation of humankind had arisen.

As if apologising for his appeal to Roosevelt, Einstein wrote in 1951:

> My share in the production of the atom bomb consisted in a single act. I signed a letter to President Roosevelt in which I stressed the necessity of making experiments on a large scale to check the possibility of making an atom bomb. I was fully aware of the dreadful risk which the success of these undertakings implied for humanity.
>
> But the likelihood that the Germans might be working on the same problem with a prospect of success compelled me to this step. There was no other way for me, although I have always been a convinced pacifist.[99]

The problems of peace and disarmament became the aim of his life, in addition to those of physics. For he was aware that the idea of the unrestrained arms race that militarist

circles were persistently carrying out was directed, apart from everything else, against democratic freedoms and the dignity of the individual.

> The planned militarisation of our nation is leading not simply to an immediate danger of war; it will also slowly and surely destroy the democratic spirit and the dignity of the individual in our land. The assertion that events abroad compel us to rearm is a perversion, and we must resolutely reject it. The effect of our own rearmament will actually be to bring about in the other nations just the situation that its supporters cite as an argument for their proposals.[100]

Einstein was disturbed by the fact that disagreements between East and West flared up from time to time with new force. He sharply criticised those public figures who saw a solution of the conflict solely in military force, considering that it was impossible to find any solution through war, since an atomic war could not only not lead to solution of the problem but would be the cause of unprecedented destruction and devastation of both sides. He specially followed the development of relations between the Soviet Union and the United States of America, considering that the fate of humankind largely depended on them.

> There are no problems so vital that a conflict between the United States and the Soviet Union is unavoidable. Even if the two countries were completely cut off from each other because of an earthquake or some similar accident of nature they both could well continue to exist. This is why it should be possible to find a *modus vivendi* through negotiations.[101]

The Russell-Einstein Manifesto, drawn up by Bertrand Russell and agreed with Einstein, played an immense role in mobilising scientists for peace. It was first published in *The New York Times* on 10 July 1955, just after Einstein's death. It was his last appeal to the reason and conscience of humanity and was a kind of tocsin sounding the alarm about a danger that humanity had never faced in its history. The Manifesto said:

> We have to learn to think in a new way. We have to learn to ask ourselves, not what steps can be taken to give military victory to whatever group we prefer, for there no longer are such steps; the question we have to ask ourselves is: what steps can be taken to prevent a military contest of which the issue must be disastrous to all parties.[102]

Einstein understood that a peaceful settlement of conflicts between nations, and the maintenance of peace on earth could not be ensured by itself without the active work of the progressive public. It bothered him that not all members of this

public were socially active and not all aware of the danger of war. In 1954 he wrote:

> Although I am a convinced democrat I know well that the human community would stagnate and even degenerate without a minority of socially conscious and upright men and women willing to make sacrifices for their convictions. Under present circumstances this holds true to a higher degree than in normal times.[103]

He was an advocate of the peaceful development of relations between countries and nations irrespective of their social system, nationality, or religious persuasions. He was aware that co-operation between states in the economic, scientific, and cultural fields was mutually beneficial and was the firmest guarantee of the maintenance of peace. But such co-operation was only possible with affirmation and observance of lofty principles of morality and mutual respect. In the *UNESCO Courier* (December 1951), he remarked:

> A world federation presupposes a new kind of loyalty on the part of man, a sense of responsibility that does not stop short at the national boundaries. To be truly effective, such loyalty must embrace more than purely political issues. Understanding among different cultural groups, mutual economic and cultural aid are the necessary additions.
>
> Only by such endeavor will the feeling of confidence be established that was lost owing to the psychological effect of the wars and sapped by the narrow philosophy of militarism and power politics. No effective institution for the collective security of nations is possible without understanding and a measure of reciprocal confidence.[104]

Being himself a highly moral man, Einstein saw a great force of social development and prosperity and of the maintenance of truly human relations in our civilised world in this valuable quality.

> The most important human endeavor is the striving for morality in our actions. Our inner balance and even our very existence depend on it. Only morality in our actions can give beauty and dignity to life.
>
> To make this a living force and bring it to clear consciousness is perhaps the foremost task of education.[105]

The following fact testifies to the lofty humanist principles that guided Einstein. In 1932 the daughter of a neighbour came to him at his cottage in Caputh near Berlin with a request to tell what he would wish her. In response he wrote the following:

> O Youth: Do you know that yours is not the first generation to yearn for a life full of beauty and freedom? Do you know

> that all your ancestors felt as you do—and fell victim to trouble and hatred?
>
> Do you know, also, that your fervent wishes can only find fulfilment if you succeed in attaining love and understanding of men, and animals, and plants, and stars, so that every joy becomes your joy and every pain your pain? Open your eyes, your heart, your hands, and avoid the poison your forebears so greedily sucked in from History. Then will all the earth be your fatherland, and all your work and effort spread forth blessings.[106]

Einstein's attitude to the Soviet Union was always friendly. He followed the development of the fundamentally new civilisation with great interest, displayed an interest in its socio-economic and cultural development, and maintained contacts with Soviet scientists. He studied the content of socialist social relations, and recognised that they could help solve many social problems that the world had not succeeded in dealing with. In his article 'Why Socialism?' he wrote:

> I am convinced there is only *one* way to eliminate these grave evils, namely through the establishment of a socialist economy, accompanied by an educational system which would be oriented toward social goals. In such an economy, the means of production are owned by society itself and are utilised in a planned fashion. A planned economy, which adjusts production to the needs of the community, would distribute the work to be done among all those able to work and would guarantee a livelihood to every man, woman, and child. The education of the individual, in addition to promoting his own innate abilities, would attempt to develop in him a sense of responsibility for his fellowmen in place of the glorification of power and success in our present society.[107]

In a letter to Soviet scientists he stressed that

> one day certainly all nations (as far as they still exist then) will be grateful to Russia for her having, for the first time in spite of the very great difficulties, demonstrated the practical possibility of the planned economy.[108]

Einstein did not belong to any party, though he was often considered a socialist. He was close to socialists in spirit, however, and maintained friendly, close relations with some of them. In an obituary he wrote in memory of the German scientist Leo Arons he said that Arons' civic feeling and striving for justice had led him into the circle of socialists, compelled him to defend his socialist convictions publicly, in spite of all the obstacles and hostility he encountered in a state ruled by reactionaries. He had been one of those rare individuals among the members of the Academy who was distinguished not only by independence of thought but also by independence of

character. He had full scorn for the prejudices of his caste and a readiness for self-sacrifice. For Arons what he did was something that went without saying. He performed his duty modestly, without making sweeping gestures and without picturing himself a martyr.[109]

Einstein was also united by ideological ties with the famous French physicist, progressive social figure, and Communist, Paul Langevin, sharing many opinions with him on social events and problems of peace and war, and was smitten by the latter's death.

> The news of the death of Paul Langevin has overwhelmed me more than most of the events that have happened during these deceptive, tragic years.
>
> The grief his death caused me was so great because it made me feel a disconsolate solitude.
>
> Langevin, throughout his life, suffered from the thought of the deficiencies and injustices of our social and economic institutions. For all that he had a firm belief in the power of reason and knowledge. Being the real man that he was, he was convinced that all human beings were ready, whatever the personal sacrifice, to devote themselves wholly to what they recognised as just and reasonable. Reason was his religion; it should bring not only light but also redemption. His desire to help men to attain a happier existence was perhaps even stronger than his passion for pure and intellectual knowledge.[110]

Einstein had a high opinion of Lenin, which he expressed as follows:

> I admired in Lenin a man who applied all his strength, to the complete sacrifice of his person, to realising social justice... Men like him are the guardians and innovators of the conscience of mankind.[111]

Analysis of Einstein's beliefs thus gives us grounds to conclude that, although he was not a specialist in the theory of social development, he all the same saw many very important social phenomena more deeply than his fellow natural scientists and many social scientists. His views on these were also determined by his time. Many human frailties were foreign to him; he was distinguished by a purity of soul, modesty, kindness, and sense of justice; he was a great humanist, internationalist, and passionate fighter for peace and social justice.

NOTES

[1] Albert Einstein. The nature of reality. *The Modern Review* (Calcutta), 1931, *49*, 1: 42.

[2] See Epilogue to Max Planck. *Where Is Science Going?* (Allen & Unwin, London, 1933), p 212.

[3] *Ibid.*, p 213.
[4] Albert Einstein. *The Meaning of Relativity* (Princeton U.P., Princeton, N. J., 1955), p 1.
[5] *Ibid.*, p 2.
[6] Albert Einstein. Maxwell's influence on the evolution of the idea of physical reality. In: *Ideas and Opinions by Albert Einstein* (Crown Publishers, New York, 1954), p 266.
[7] *Idem.* Autobiographical notes. In: Paul A. Schilpp (Ed.). *Albert Einstein: Philosopher Scientist* (The Library of Living Philosophers, Evanston, Ill., 1949), p 81.
[8] *Idem.* Remarks on Bertrand Russell's theory of knowledge. In: Paul A. Schilpp (Ed.). *The Philosophy of Bertrand Russell* (Northwestern Univ., Evanston, Ill., 1944), p 287.
[9] *Ibid.*
[10] Albert Einstein. Ernst Mach. *Physikalische Zeitschrift*, 1916, *17*, 7: 102.
[11] *Idem.* Physics and reality. In: *Ideas and Opinions*, p 290.
[12] *Ibid.*, p 291.
[13] *Ibid.*, pp 294 295.
[14] Albert Einstein. Geometry and experience. In: *Ideas and Opinions*, p 233.
[15] *Ibid.*, p 234.
[16] Albert Einstein. Physics and reality. In: *Ideas and Opinions*, p 298.
[17] *Idem.* On the method of theoretical physics. In: *Ideas and Opinions*, p 274.
[18] Dr. A. Einstein's letter to Herbert Samuel, 13.X.1950. In: Herbert L. Samuel. *Essay in Physics* (Harcourt, Brace & Co., New York, 1952), pp 159-160.
[19] Frederick Engels. *Anti Dühring* (Progress Publishers, Moscow, 1975), p 52.
[20] V. I. Lenin. *Materialism and Empirio-Criticism* (Progress Publishers, Moscow, 1977), p 149.
[21] Albert Einstein. On the generalised theory of gravitation. *Scientific American*, 1950, *182*, 4: 14.
[22] *Idem.* Critical remarks. In: *Albert Einstein: Philosopher Scientist*, p 680.
[23] *Idem.* The new field theory II. Structure of space-time dualism overcome. *The Times*, 5.2.1929.
[24] The nature of reality. A conversation between Rabindranath Tagore and Professor Albert Einstein, July 14th, 1930. *The Modern Review* (Calcutta), 1931, *49*, 1: 43.
[25] Frederick Engels. Ludwig Feuerbach and the End of Classical German Philosophy. In: Karl Marx and Frederick Engels. *Selected Works*, Vol. 3 (Progress Publishers, Moscow, 1970), p 346.
[26] Albert Einstein. *Cosmic Religion with Other Opinions and Aphorisms* (Covivi-Friede Publishers, New York, 1931), p 98.
[27] *Idem.* Physics and reality. In: *Ideas and Opinions*, p 292.
[28] *Idem.* Remarks on Bertrand Russell's theory of knowledge. In: *The Philosophy of Bertrand Russell*, p 285.
[29] *Ibid.*
[30] Albert Einstein. Preface to Max Planck. *Where Is Science Going?*, p 12.
[31] Frederick Engels. *Anti Dühring*, p 170.
[32] Albert Einstein. Autobiographical notes. *Op. cit.*, p 5.
[33] *Idem. Lettres à Maurice Solovine* (Gauthier-Vallars, Paris, 1956), pp 54, 55.
[34] *Idem.* Introduction to Rudolf Kayser. *Spinoza. Portrait of a Spiritual Hero* (Philosophical Library, New York, 1946), p XI.
[35] Prof. Einstein's address to Prof. Planck. *Forschungen und Fortschritte*,

1929, *5*, 21: 248.
[36] See Einstein's introduction to Rudolf Kayser. *Op. cit.*, p XI.
[37] *Idem.* Epilogue to Max Planck. *Op. cit.*, p 204.
[38] *Ibid.*, pp 201-202.
[39] N. Bohr. On the notions of causality and complementarity. *Dialectica*, 1948, *2*, 3/4: 312.
[40] Albert Einstein. *Briefe an Maurice Solovine* (Deutscher Verlag der Wissenschaften, Berlin, 1960), pp 98-99.
[41] *Idem.* Physics, philosophy and scientific progress. *Art. cit.*, p 758.
[42] Werner Heisenberg. *Physics and Philosophy* (Allen & Unwin, London, 1959), p 52.
[43] *Idem. Philosophic Problems of Nuclear Science.* Eight Lectures (Faber & Faber, London), p 55.
[44] Max Born. Albert Einstein und das Lichtquantum. *Die Naturwissenschaften*, 1955, *42*, 15: 430.
[45] See Epilogue to Max Planck. *Op. cit.*, pp 203 204.
[46] Albert Einstein. Ernst Mach. *Art. cit.*, p 102.
[47] *Idem.* Cosmic Religion with Other Opinions. *Op. cit.*, p 100.
[48] *Idem.* Maxwell's influence on the evolution of the idea of physical reality. In: *Ideas and Opinions*, p 266.
[49] *Idem.* Autobiographical notes. In: Paul A. Schilpp (Ed.). *Albert Einstein: Philosopher Scientist*, p 19.
[50] *Idem.* Zum hundertjährigen Gedenktag von Lord Kelvins Geburt. *Die Naturwissenschaften*, 1924, *12*, 30: 601.
[51] V. I. Lenin. *Materialism and Empirio Criticism*, p 288.
[52] Albert Einstein. Physics and reality. In: *Ideas and Opinions*, p 301.
[53] *Idem.* The mechanics of Newton and their influence on the development of theoretical physics. In: *Ideas and Opinions*, p 261.
[54] V. I. Lenin. *Op. cit.*, p 119.
[55] Albert Einstein. Preface to Max Planck. *Op. cit.*, p 12.
[56] Frederick Engels. *Anti-Dühring*, p 50.
[57] *Ibid.*, p 31.
[58] Albert Einstein. Physics, philosophy and scientific progress. *Art. cit.*, p 755.
[59] *Idem.* Remarks on Bertrand Russell's theory of knowledge. In: *The Philosophy of Bertrand Russell. Op. cit.*, p 281.
[60] *Ibid.*
[61] See Albert Einstein. *Lettres à Maurice Solovine.*
[62] *Idem.* Physics and reality. *Op. cit.*, p 271.
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Part Three

The Development of the Theory of Relativity and Philosophy

Philosophical ideas had an enormous influence on developing theoretical physics. It is therefore also necessary to study its genesis and evolution from the philosophical aspect. And it is sometimes necessary to turn to an analysis of mathematical science in order to understand the source of development of the problems of physics.

The notions of classical mechanics, for example, rested on such physical and philosophical concepts as matter, time, space, and motion. The theory of relativity is also associated with them. It was not by chance that disputes developed around them between spokesmen of various philosophical trends in connection with interpretation of the fundamentals of the theory of relativity.

Many scientists who have studied the development of relativistic physics have unfortunately put the stress only on problems of time, space, and motion, and have avoided analysis of the category of matter. In my view, the historical, scientific, and philosophical premisses of the theory of relativity are also associated with matter, and I shall endeavour below to show how philosophical knowledge, including the categories mentioned, influenced the development of this theory.

1

The Concept of Matter and the Development of Physics

It helps, when the philosophical and physical fundamentals of the theory of relativity are being analysed, to turn to the doctrine of matter not only in order to examine the theory from the quantitative, mathematical aspect (as is often done), but also so as to bring out the qualitative features that found expression in it. That approach also makes it possible to settle the old dispute about priority in discovery of the theory of relativity. Discussion of its authorship is now limited in the main to investigation only of its mathematical aspect. But Wolfgang Pauli had already pointed out two possibilities of its development in 1956.

> The development of electrodynamics had culminated at that time in the partial differential equations of Maxwell and H. A. Lorentz. It was evident that these equations did not admit of the transformation group of classical mechanics, especially since they assumed as a consequence the independence of the velocity of light *in vacuo* from the state of motion of the light source. Did one have to grant the group the quality of an only approximately valid law of nature, or possibly treat the group of mechanics as approximate? Or did the latter have to be replaced by a more general one, valid for both mechanical and electromagnetic processes? The answer fell to a choice between these two alternatives. This postulate could be reached in one of two ways. First, one could search purely mathematically for what was the most general transformation group in relation to which the then well-known equations of the Maxwellian-Lorentz electrodynamics retained their form. That was the way taken by the mathematician H. Poincaré. Or one could critically ascertain the physical assumptions that had led to the special group of Galilean-Newtonian mechanics. Einstein took the second way.[1]

Einstein paid much attention to the philosophical premisses of the theory of relativity, and constantly stressed that both the special and the general theory had arisen through study of the properties of matter located in a field.

> A new concept appears in physics [he and Leopold Infeld wrote], the most important invention since Newton's time: the field. It needed great scientific imagination to realize that it is not the charges or the particles but the field in the space between

> the charges and the particles which is essential for the description of physical phenomena...
>
> The theory of relativity arises from the field problems.[2]

In his view the theory of relativity was no more than the next step in development of field theory, which had shaken the fundamental concepts of time, space, and matter. In that connection the theory of relativity, in its modern form, can be considered a section of field theory.

The question arises: what is the connection between the physical concept of field and the philosophical category of matter? For a long time both of these concepts were to be found together in the history of physics at the focus of attention of certain physicists, especially Einstein. The material status of the electromagnetic field was interesting scientists. The fate of the development of relativistic physics hung on the answer. In order to demonstrate the role of philosophy in the development of the theory of relativity I must turn to certain points in the history of physical science.

The birth of physics is usually associated with the name of Galileo. Einstein called him the father of physical science not just because he had enriched our knowledge of nature by his own achievements but because he introduced generally significant methods of experimental and laboratory analysis to the science that came after him. That statement cannot, of course, be understood in simplified form, in the sense of belittling the contribution of such great scientists as Copernicus, Kepler, or Giordano Bruno. The point is that it was Galileo who most fully embodied the spirit of science in its modern sense in his own investigations. After him physics developed at an accelerated pace, and reached its apogee in the classical period in the work of Newton.

> But the importance of Newton's achievement was not confined to the fact that it created a workable and logically satisfactory basis for the actual science of mechanics; up to the end of the nineteenth century it formed the program of every worker in the field of theoretical physics.[3]

Physics has undergone immense changes in both form and content in its development. It was differentiated into many independent branches of knowledge. Its field of view now takes in the most remarkable natural objects—from 'virtual particles' to 'black holes', from the fields well-studied by science to physical vacuum—which are investigated from various aspects: their interaction, motion, structure, etc. But the whole development of physics as the science of nature can obviously be divided into *two stages*, the transition between which is associated with

a radical change in the physical notions of matter, time, space, and motion, which entails a substantial change as well in the content of the corresponding philosophical categories. The first stage is limited to the time when physics studied only the material form of matter; the second began when physics discovered the field form of matter and proceeded to study it.

Einstein devoted many of his works to this aspect of the question and repeatedly stressed that substance was the material reality of classical physics.

> For the physicist of the early nineteenth century, the reality of our outer world consisted of particles with simple forces acting between them and depending only on the distance.[4]

He associated the second stage in the development of physics with the researches of Oersted, Faraday, Maxwell, and Hertz, who discovered the new form of physical matter, i.e. the field.

> It was realized that something of great importance had happened in physics. A new reality was created, a new concept for which there was no place in the mechanical description. Slowly and by a struggle the field concept established for itself a leading place in physics and has remained one of the basic physical concepts.[5]

In actual fact, up to the mid-nineteenth century, the whole material world was identified with substance in physics as a whole, and in classical mechanics in particular; it was then known in the solid, liquid, and gaseous states. Knowledge of substantial matter took shape through the development of the natural sciences and the philosophy of materialism, which supplemented each other. The objective basis of material bodies was studied by means of philosophy. Physics promoted development of knowledge of the structure and physical properties of substance, and the laws of the motion of the studied objects. Chemistry and biology studied properties governed by corresponding chemical and biological forms of motion, and astronomy provided ideas about outer space.

The roots of knowledge of substantial matter go deep into ancient natural philosophy, in which the scientific and philosophical ideas of matter were merged together. Many thinkers imagined the world as a single material whole. It was thought that some objective initial principle underlay natural objects. The material substratum was identified with concretely observed substances (water, earth, fire, etc.). But it became obvious with time that it was impossible to explain the so very varied world of nature by ideas of such a sort. The idea of causal links between phenomena pushed thinkers to study the microscopic structure of matter, motion, space, and time. A brilliant guess was made about the atomic structure of the microworld,

based on analogies with the structure of macroscopic nature.

Atomic theory helped bring out the physical properties of substantial matter with a certain degree of accuracy, and in some cases predicted the structure of material bodies. The atomic theory underwent great changes in its development, and took the road from the status of a 'brilliant guess' to a rigorous scientific theory. After antique natural philosophy atomism got its 'second wind' only in the seventeenth century. Its development was linked with the rise of a number of specific sciences such as classical mechanics, chemistry, and biology, brought into being by the practical needs of rapidly developing industry, which necessitated deeper study of the processes of nature.

But apart from brilliant ideas of atomism, and propositions about the material character of nature, the ancient thinkers also developed a whole number of mistaken natural-philosophical theses about the structure of the world which then, having prevailed over the minds of naturalists, interfered for ages with knowledge of the essence of the universe. The cosmology of Aristotle and Ptolemy still made itself felt in the sixteenth and seventeenth centuries. According to it cosmic matter was some sort of 'ethereal medium' or 'ideal substance' thought to differ in principle from earthly matter. According to Ptolemy celestial bodies could not be compared with earthly ones because this was a completely different reality. That affirmation was logically reinforced by the idea of geocentrism.

I drew attention above to the services of the founders of classical mechanics who encouraged spread of new methodological maxims through their teaching. The discovery of a number of propositions that developed the ancient thinkers' doctrine of matter was also to their credit. One of these was the heliocentric theory of Copernicus.

But Copernicus' doctrine had several flaws in addition to positive knowledge. It admitted only 'perfect' circular motion of the planets of the solar system. The Sun was given the same exclusive role in the Universe that had previously been attributed to Earth, and this contained a possibility of counterposing cosmic and terrestrial nature. The theory required scientific, theoretical substantiation, since there was room in it for various kinds of deviations that provided excuses for reducing it to a working hypothesis. But heliocentrism struck deep roots in science, and was developed in the works of Copernicus' successors.

It followed from the work of Galileo that nature everywhere —on Earth and in outer space—was one and the same, existed objectively, and was governed by one and the same laws of motion. Galileo identified the concept of matter with that of substance. Unlike many of his contemporaries he ascribed such objective properties to matter as time, space, and motion.

An able combination of the empirical and rational aspects in cognition, and exact observations of external natural phenomena and processes in unity with rigorous logical and mathematical arguments, enabled Galileo to open a window onto the microworld and draw a conclusion about the atomic structure of matter. When studying natural processes associated with condensation and rarefaction of matter he reached a conclusion about its atomic structure.

The teaching of Descartes, who attempted, in the struggle against the scholastic tradition, to explain the existence of the Universe solely from scientific knowledge of matter and the mechanical laws of motion, presents considerable interest. He saw the world in universal connection and development, and thus stimulated a search for the causes of its material organisation; he himself tried to find them in nature herself and her laws of development, although he did so in a context of mechanistic notions. He rejected the conclusions of a number of natural philosophers about the existence of empty space in isolation from matter. In his view matter was limitless in space and infinitely divisible. He rejected Aristotle's idea of primary matter which, when completely deprived of its forms and qualities, was transformed into something inaccessible to understanding.

Descartes' idea of the existence of an 'element of fire' or 'finer matter', in addition to ordinary substances, is of interest. It seems that, to some extent, it anticipated discovery of the field form of the material world, merging with space. Descartes came close to the idea of the laws of conservation by which many 'mysterious' material processes were later explained.

Newton made a great contribution to confirmation of the idea of the material unity of nature, thanks to discovery of the law of universal gravitation, mathematical substantiation of the regularities of nature, experimental confirmation of the existence of causal connections in nature, etc. Like Galileo Galilei he identified the concepts of matter and substance. He pictured matter only in the form of microparticles which, by

merging, formed macrobodies of various magnitude. According to Newton all bodies (or material formations) 'seem to be composed of hard Particles... Even the Rays of Light seem to be hard Bodies'.[6] He confused such terms as 'quantity of matter', 'body' (substance), and 'mass'.

> *The quantity of matter (mass*) is the measure of the same, arising from its density and bulk conjointly.* It is this quantity that I mean hereafter everywhere under the name of *body* or *mass*.[7]

This definition evoked many criticisms in its time and introduced great confusion into the interpretation of the materialist conception of matter. We hear echoes of it to this day (see below).

Natural science still contained views, however, that held back development of the conception of matter. For a long time naturalists could not give a scientific explanation of such natural phenomena as fire, heat, and electromagnetism. It was suggested that phenomena of that kind were caused by the existence of special weightless substances in bodies; these were endowed with a number of frequently contradictory properties—great penetrating capacity, elasticity, weightlessness, etc.—which were due to the difficulties of adopting a consistently mechanical approach to all phenomena. An idea predominated in chemistry that combustion was nothing but the liberation of a special substratum—phlogiston—present in bodies. Up to the beginning of the nineteenth century physicists considered all heat phenomena to be caused by the existence in bodies of a weightless, imponderable heat-creating material. The phenomena of electromagnetism were explained in the same way.

There was historical justification for the existence of these hypotheses. A number of phenomena observable in nature could be successfully explained with a certain degree of accuracy by means of them. In addition, they stimulated scientific thought to search for and explain new types and forms of matter, such as (for example) the electromagnetic field. At the same time hypotheses of imponderable substances contradicted the notions then held about matter, since these substances were endowed with immaterial properties that were not present in ordinary matter. A scientific solution of these problems was of immense philosophical importance.

The phlogiston hypothesis was the first of the notions

* The word 'mass' was inserted by the translator of the *Principia*.

about imponderable substances to be subjected to criticism. The discovery of oxygen gave Lavoisier the opportunity to conclude that combustion was not caused by the presence of a mysterious phlogiston in bodies. He demonstrated that it was a process of oxidation, the combining of oxygen with a substance. In that way one of the ideas of 'mysterious matter' was refuted experimentally.

The same fate then overtook 'heat-creating matter'. This had already been predetermined by the work of Rumford, who published the results in 1798 of experiments on drilling gun barrels, in which the temperature of the barrel was shown to depend on the number of turns of the drill. Rumford showed that heat was not an invariable substance as had been considered. Its dependence on mechanical energy became obvious.

Thus, in spite of separate incorrect interpretations of the nature of scientific phenomena, the advances of science as a whole, and especially of astronomy, mechanics, chemistry, and mathematics, promoted development of the doctrine of matter. Following the English materialist Francis Bacon, there came a pleiad of thinkers like Spinoza, Holbach, Diderot, Feuerbach, and Herzen, who tried to explain the world, starting from it itself, by means of natural causes, relying on the achievements of the natural sciences. Matter presented itself to them as reality, independent of consciousness. They concluded that the concept of matter could not be identified with notions of the concrete forms of substance observable in nature, as had been done by the ancients. But matter was still interpreted as the first principle, a sort of building material for everything that exists. The atom endowed with definite mechanical properties was thought to be this first principle. Since the objects of study of classical physics were solely moving material bodies in the form of substance, and natural science did not then know other forms and states of matter, apart from substance (electromagnetic processes were classed either as substance or as properties of same), the mechanical properties of substance were recognised as universal properties of the physical world as a whole. That also served as the epistemological basis for many philosophers and scientists to make an absolute of matter as the sole and only first cause or origin of everything that exists, and to identify the general concept of matter with the data on the concrete mechanical properties of substance. The physical properties of substance, like extent, weight, inertia, indivisibility, impermeability, etc., also came to be understood as properties of matter (objective

reality was a property of it as well). The concept of matter was sometimes identified with the idea of the physical property of bodies, mass.

The illegitimacy of Premarxian materialism's identification of matter with the concept of substance did not make itself felt up to a certain time, at least clearly, though the latter concept did not embrace all the objects of nature. Matter, existing in the form of a field, could not be explained by means of mechanical images and notions. Yet this region of the material world was more and more manifesting itself.

The discovery of the electromagnetic field was perhaps one of the most fundamental achievements of physical science. A special material reality presented itself to scientists, study of which had a great influence not only on theory and practice, but also on outlook on the world. Physics took quite a long time to reach this remarkable discovery. The reality of electromagnetic processes was not scientifically substantiated for some time, and their nature remained unclear right down to the middle of the nineteenth century. The field was endowed with very fanciful properties, and represented as some 'imponderable', 'all-penetrating', 'insensitive' substance, as a variety of ether, as something enigmatic, that could not be classed either as ether or as ordinary ponderable matter, and finally as pure motion. Here are several examples. Newton supposed that light was not ether, nor its oscillating motion, but something different propagated from shining bodies. Benjamin Franklin explained electrical phenomena by the presence in nature of a special 'electrical matter' that consisted

> of particles extremely subtile, since it can permeate common matter, even the densest metals, with such ease and freedom as not to receive any perceptible resistance.[8]

Aepinus stressed that magnetic phenomena were due to a mechanical or material cause that had to be sought simultaneously in the inner structure of the magnet and in the matter existing outside it.[9] Coulomb drew attention to the fact that it was necessary, in order to explain magnetic phenomena, to resort to attractive and repulsive forces of nature which we are obliged to use to explain the weight of bodies and celestial physics.[10] According to Euler light had the same relation to ether as sound to air.

Thus, in the period when classical physics flourished, there were contradictory notions about the material essence of a field and its connection with matter. Yet, in spite of there being no consistent explanation of the material essence of elec-

tromagnetic processes in classical physics, several profound ideas were expressed then about the structure of electromagnetic phenomena, much work was done on quantitative description of their regularities, and empirical material was accumulated that largely served as the premisses for the development of a new field physics.

The development of the theory of field as an independent physical form of matter existing alongside bodies was mainly linked with the development of three spheres of physical science—optics, magnetism, and electricity. Optics had taken shape quite early as a branch of physics. Two brilliant ideas had already been expressed in the eighteenth century about the nature of light phenomena: the corpuscular and the wave. Their authors were respectively Newton and Huyghens, though they had their predecessors (even in antiquity). Without going into the history of the development of these ideas, let me just note that the struggle between them was the driving force that promoted development of knowledge of the field form of matter. Both claimed to describe one and the same physical events. And both led to discoveries that did not fit into the scheme of the rival idea's explanation. The Newtonian corpuscular conception that phenomena of light were nothing other than a discharge of particles from luminous bodies had great success at first. But, Einstein wrote,

> even at that time the question, What in that case becomes of the material points of which light is composed, when the light is absorbed?, was already a burning one. Moreover, it is unsatisfactory in any case to introduce into the discussion material points of quite a different sort, which had to be postulated for the purpose of representing ponderable matter and light respectively. It was, further, a fundamental weakness that the forces of reciprocal action, by which events are determined, had to be assumed hypothetically in a perfectly arbitrary way.[11]

The contradictory character of the initial principles of the corpuscular and wave theories of light, and the difficulties associated with making sense of the phenomena of interference and diffraction in the context of the former, helped draw the attention of natural scientists to Huyghens' wave theory, which already seemed to have been forgotten. Huyghens had affirmed that light was not a stream of particles of shining matter, as Newton thought, but a wave, like sound, propagated in a dense medium, ether, which filled world space. The revival of the wave theory was due in large measure to Thomas Young, who disclosed a number of weak points in the corpuscular theory.

He drew attention to the difficulties and contradictions in using it to explain the constant velocity of propagation of the light received from various sources, the facts of its reflection and absorption, the refraction of light beams of various colour, and so on. Basing himself on wave notions, Young made a bold attempt to explain the phenomena of refraction and reflection, Newton's rings, diffraction, interference, etc. After him, and independently of him, the wave theory was perfected by his contemporary Fresnel. The latter's object of study was the same wave effects of the propagation of light, but unlike Young he substantiated them more deeply.

It was later elucidated that the wave theory, like the particle one, reflected only one aspect of the complex electromagnetic substance. Einstein wrote, apropos of that:

> But the story of the search for a theory of light is by no means finished. The verdict of the nineteenth century was not final and ultimate. For the modern physicist the entire problem of deciding between corpuscles and waves again exists, this time in a much more profound and intricate form.[12]

Simultaneous with investigation of the properties of light there was intensive study in physics of the essence of magnetism and electricity. Up to a certain time all these three kinds of natural phenomena (light, electricity, and magnetism) had been studied separately, and were related to different substances. For a long time magnetic and electrical processes were explained by the existence of corresponding magnetic and electric fluids.

But, with time, there began to be discoveries that made it possible to establish the real interconnection of electrical and magnetic phenomena. These included the discoveries of Oersted and Ampère. Oersted drew attention to the fact that an electrical current flowing along a wire influenced a magnetic needle located near the wire. It did not just follow from this that the change in the electric field produced by the movement of the charge was always accompanied with a magnetic field. In Einstein's view Oersted's experiment covered much more than that, namely 'recognition that the association of an electric field, changing in time, with a magnetic field is essential for our further argument'.[13]

Ampère's experiments were another step toward discovery of the unity of electricity and magnetism. Having passed a current along two wires located parallel to one another, he observed a reciprocal influence similar to magnetic attraction or repulsion. He also observed several manifestations of similar

currents which he supposed to be in the terrestrial globe. He thus reduced all magnetic phenomena to purely electrical events.

These discoveries helped considerably to confirm the idea, as well, of the material nature of electricity and magnetism, and they underlay the further fundamental investigations of the problem of field undertaken by Michael Faraday.

While Oersted had shown that a changing electrical field was accompanied with a magnetic one, it followed from Faraday's experiments that a changing magnetic field excited an induced current in a wire, and consequently an electric field. His experiments suggested that electrical and magnetic phenomena were interconnected. But statement of the fact alone did not satisfy him. He investigated the geometrical structure of each point in the space in which electrical and magnetic forces acted, and so came to the conclusion of the *physical* nature of field. The facts, he wrote,

> point to the existence of physical lines of force external to the magnets as well as within. They exist in curved as well as in straight lines... Curved lines of force can, as I think, only consist with physical lines of force.
>
> The phenomena exhibited by the moving wire confirm the same conclusion... There must have been a state or condition around the magnet and sustained by it, within the range of which the wire was placed; and this state shows the physical constitution of the lines of magnetic force.[14]

He drew the same conclusion in regard to electrical lines of force. In his opinion, they, like magnetic ones, really existed.

> Turning to the case of Static Electricity we find here attractions (and other actions) at a distance as in the former cases... When we pass to Dynamic Electricity the evidence of physical lines of force is far more patent.[15]

Faraday's ideas played a substantial role in forming the field conception of matter. He not only disclosed the interconnection of magnetic and electrical fields, but also (as Maxwell justly noted)

> saw lines of force traversing all space where the mathematicians saw centres of force attracting at a distance: Faraday saw a medium where they saw nothing but distance: Faraday sought the seat of the phenomena in real actions going on in the medium, they were satisfied that they had found it in a power of action at a distance impressed on the electric fluids.[16]

The great experimental material presented to science by Oersted, Ampère, Faraday, and other scientists called for theoretical substantiation. That was given by James Clerk Maxwell

who laid the foundation of modern ideas of electromagnetic processes, employing this material. He did what Oersted, Ampère, and Faraday before him could not do. He was bothered by the question of the physical nature of the medium that filled the space between bodies. Starting from the fact of the reality of electrical and magnetic fields, he created the theory of the electromagnetic field.

> The theory I propose may therefore be called a theory of the *Electromagnetic Field*, because it has to do with the space in the neighbourhood of the electric and magnetic bodies, and it may be called a *Dynamical Theory*, because it assumes that in that space there is matter of motion, by which the observed electrodynamic phenomena are produced.[17]

Maxwell thus introduced the concept 'electromagnetic field' into his theory, using it for the medium that contained and surrounded bodies in an electric or magnetic state. This name for the medium studied by physicists was not accidental. It stemmed from the experimental fact (later substantiated theoretically by Maxwell) of the interconnection of magnetism and electricity.

An essential step toward recognition of the idea of field as an independent form of being was the discovery in a field of a property like energy.

> Starting as a helpful model, the field became more and more real... The attribution of energy to the field is one step farther in the development in which the field concept was stressed more and more, and the concepts of substances, so essential to the mechanical point of view, were more and more sup pressed.[18]

Maxwell also discovered that the electromagnetic field and light were propagated at one and the same velocity.

> This velocity is so nearly that of light, that it seems we have strong reason to conclude that light itself (including radiant heat, and other radiations if any) is an electromagnetic disturbance in the form of waves propagated through the electro magnetic field according to electromagnetic laws.[19]

That and other facts led Maxwell to recognition of the single nature of electromagnetic waves and light.

Having shown that an electromagnetic field, once created, can exist independently, irrespective of its source, Maxwell however, did not see material nature in the field. Like Faraday, he attributed substantial significance to ether, and considered the electromagnetic field a modification of it.

The point is that attempts to present a single material picture of the world inevitably pushed workers to seek for ether, and for an explanation of its relationship with material real-

ity. And although there were many mechanistic models of ether, it never, however, manifested itself in observations. Such phenomena as the emanation and absorption of light by bodies convinced supporters of the ether conception of the existence of connections between matter and the electromagnetic field (ether).

Essential results were obtained in this sphere after Maxwell by Hertz and Heaviside. Lorentz' electron theory was also meant to further discover the connection between ether and matter. While the charge generating the electromagnetic field was considered formally in Maxwell's theory, in Lorentz' theory electrons were considered the physical source of a field. Lorentz' theory helped undermine the metaphysical and mechanistic view of matter and, on the whole, of a material world. The work of W. Wien, M. Abraham, and J. J. Thomson, and other scientists devoted to demonstrating the electromagnetic origin of mass served this same end. The classical theory of matter (substance), which focused attention on mass as the quantity of matter, now came up against fundamental difficulties. The idea of the universal character of the mechanistic picture of the world was essentially shaken.

Yet, in spite of some advances in confirming the idea of the reality of the electromagnetic field, there were still difficulties in explaining its link with matter, and consequently in materialising it. The properties of substance and field were too sharply opposed to each other. In spite of some common properties having been found, physicists still lacked more profound notions of their structure. There was also no adequate philosophical analysis of the concepts themselves of field and substance and of some of their properties. If substance, according to classical physics, was a discontinuous material formation, field was thought of as a continuous medium. Physicists unacquainted with dialectics, and accustomed to think of the phenomena of substance and field as incompatible, could not accept the idea of their unity. Attempts to reduce all the properties of matter to either those of substance or those of a field therefore did not cease. Supporters of the atomic theory made an absolute of discontinuity, and spokesmen for the electromagnetic picture of the world an absolute of continuity. And that in spite of the fact that dialectics had already pointed out the way, in general form, to tackle this question. For Hegel, in developing Kant's doctrine of antinomies, had come to the conclusion that the concepts of discontinuity and continuity were compatible.

Only development of the physics of the microworld, and a dialectical materialist analysis of these discoveries, could confirm the idea of the unity of substance and field and so prove the material nature of electromagnetic reality. That came about through deeper penetration into the microstructure of the world, as a result of which the concepts themselves of field and substance (particles) were essentially altered. The first step toward that was taken by Max Planck, who comprehended the processes of the radiation and absorption of light by substance in a new way. It had previously been considered that these processes took place continuously. Planck showed that the energy of an oscillator altered discretely, in portions, rather than continuously.

Einstein drew a more profound conclusion about the properties of the electromagnetic field. He showed that light had a discrete character not just when radiated or absorbed by a substance. According to him the field was in a state of quanta during the process of propagation as well.

> It seems to me, as a matter of fact, that observations of 'black radiation', photoluminescence, the generation of cathode rays by ultraviolet light, and other radiation due to the transformation of light connected with this group of phenomena are best understood by the hypothesis that the energy of light is propagated discontinuously in space. According to the hypothesis adopted here the energy of a light beam coming from a point of emission is not propagated continuously over an increasingly greater space, but continues to consist of a finite number of energy quanta localised at a point in space, which can move without dividing and are only generated and absorbed as a whole.[20]

Einstein ascribed impulse as well as energy to a quantum of light. His research along those lines laid the basis for the quantum theory of light in which its corpuscular-wave nature was reflected.

Louis de Broglie, stressing the immense role of this discovery of Einstein's, remarked that his brief but brilliant paper, quite apart from the question of the nature of light itself, was like thunder from an almost clear sky, and that the crisis created by it had still not been eliminated 50 years later; this revolution made by Einstein in theoretical physics was in no way inferior to that caused a few months later by his first major work on the theory of relativity.

The concept of field was thus given new content with each step in the evolution of physics. It turned out that a field possessed the properties of corpuscles, discrete particles, in addition to the wave properties expressed in interference and

diffraction. That was an important step toward 'bringing together' the two physical forms of matter—field and substance—and so toward confirming the idea of the material nature of a field. But that discovery itself raised many problems for physicists, and for a long time they could not explain the combination in one and the same object (field) of 'mutually exclusive' corpuscular-wave properties, although their existence had been convincingly confirmed in practice. A so-called corpuscular-wave dualism arose in field physics. Some scientists drew subjectivist conclusions from that. Since the properties of one and the same material object—a field—were incompatible, they argued, these properties had no objective status.

In 1924 Louis de Broglie made the next significant step demonstrating the material nature of the electromagnetic field and its relation with corpuscular matter. He made the bold guess that not only did light possess corpuscular properties but that microparticles also possessed wave properties. Schroedinger, developing de Broglie's idea, created wave mechanics. At roughly the same time, Heisenberg, following Bohr's path and guided by the principles of observability and correspondence, created matrix mechanics. Soon (in 1926) Schroedinger demonstrated the mathematical equivalence of matrix and wave mechanics. Bohr, trying logically to substantiate the situation created, put forward the principle of complementarity.[21]

De Broglie's idea was soon checked in experiment. By passing beams of microparticles through a crystal lattice, scientists observed interference patterns as happened with light. It became obvious that particles displayed wave properties in certain conditions.

The results obtained from study of light and of corpuscular matter were interpreted differently. Some accepted that a corpuscular-wave dualism was admissible in one and the same object; others considered that one and the same particle could not possess both wave and corpuscular properties. Typical in that respect is Reichenbach's statement that:

> de Broglie's discovery does not have the direct meaning that both waves and corpuscles exist at the same time, but has the indirect meaning that the same physical reality admits of two possible interpretations, each of which is as true as the other, although the two cannot be combined into one picture.[22]

This statement is based on a mechanical transfer of the notions of wave and corpuscular properties developed in classical physics to the study of micro-objects. The fact that some

physicists had not refrained from applying the classical concepts of wave and particle when studying the microworld, in itself led to great difficulties in the study of its objects. A search for non-classical means of applying the concepts of classical physics therefore began. It became commonplace that it was necessary, when studying the essence of micro-objects, to allow for the complementarity of wave and corpuscular properties. Today this thesis of complementarity plays a vital role in the orthodox (Copenhagen) interpretation of phenomena of the quantum world.

Adherents of dialectical materialism had their own approach to interpretation of the properties of micro-objects. The eminent Soviet physicist S. I. Vavilov wrote:

> Matter, i.e. substance and light, simultaneously possesses the properties of waves and particles, but on the whole it is not waves and not particles and not a mixture of the two.[23]

He thereby stressed not only the non-classical nature of micro-objects but also the inapplicability of classical concepts to them without a change in their content. In other words, natural scientists who take such a stand proceed from the fact that physics has discovered qualitatively new objects that in contrast to those of the macroworld have their own specific properties that are not identical with those of particles and waves in the classical understanding of the latter. In a certain sense these new objects demonstrate a unity and synthesis of the one properties and the others.

Discovery of the properties of the matter of the micro-world called for the development of new concepts for them, which could help better to express the link between the different forms of matter, i.e. field and substance. As M. E. Omelyanovsky has written, in quantum mechanics

> the synthesis of the corpuscular and wave notions of matter referred to substance and the behaviour of its particles. The quantities characteristic of moving particles of matter thus acquired the features of wave motion. That united substance and field, but the reverse transition from field to substance could not be made in quantum mechanics; from the angle of quantum mechanics a field remained 'classical', and the kind and number of particles of substance remained unaltered.[24]

The quantum theory of field, however, successfully copes with the second problem, introducing the concept of a quantised field, which differs from the concept of field in classical physics. A quantised field is a special form of matter possessing its own specific properties. It can be met both in the state of a field and in that of a particle (but not in the old sense of these

terms). An elementary particle here is an excited state of a quantised field. The field is the same special form of matter as is characteristic of a particle, but is in an unexcited state. V. S. Gott has written in this connection:

> With the deepening of our knowledge of microprocesses, the concepts of substance and field have undergone such a profound evolution that the division of matter into substance and field can now only be considered justified in the main for macroprocesses and had almost wholly lost its sense in phenomena of the microworld.[25]

The most convincing evidence of the material nature of a field, and of the existence of a universal link between field and substance, is the discovery of the interconversion of particles of substance and the corresponding fields. Many experiments in that respect are now well known to physicists. It has been found, for example, that if the energy of a quantum of an electromagnetic field achieves a certain value, greater than the energy of a positron or electron, and this quantum collides with a nucleus, an electron in a pair with a positron results. This experiment is evidence of the conversion of field matter into substantial or particle matter. The reverse process is also possible. If a beam of positrons is aimed at a metallic plate, it will be converted into a source of gamma rays, due to the fact that positrons, in annihilating free electrons of the metal, radiate quanta of an electromagnetic field. Here substantial matter is converted into the matter of an electromagnetic field. Such interconversions of field and substance are characteristic not only of pairs of electrons and positrons but also of all other particles and their anti-particles. They may all, when interacting with each other, be converted into quanta of electromagnetic or other physical fields while, vice versa, the interaction of physical fields with substance leads to the birth of particles and anti-particles of substance. All that points to a close interconnection of the substance and field forms of matter.

The material nature of all other physical fields (nuclear, meson, etc.) raises no doubts. They, too, are associated with elementary particles. In certain situations they are converted into substance or particle matter, and the latter into fields, which has been demonstrated experimentally by modern physics.

It would be a mistake to consider in advance that the objective physical world can manifest itself only in two material forms, substance and field. The properties of matter are richer

in their manifestations than our notions about them. That is indicated by both the downfall of mechanistic materialism and the discoveries of recent decades. For physics not only encounters quantised fields today but also non-conservation of the energy of gravitation, and notions of 'creation' from 'nothing' and the conversion of already known material objects into 'nothing'. The existence of such paradoxes in the physical sciences is a warning against a metaphysically limited view of the Universe through the prism only of modern knowledge of substance and field, about whose properties science naturally still does not know everything.

Physics has thus influenced the development of the philosophical category of matter from two sides. (1) As ideas of the existence of a field as a specific reality entered science, the question of a review of the conception of matter inherent in Premarxian materialism, and firmly established in natural science, became a more and more urgent matter. It became obvious that the facts of science contradicted this conception, since it was impossible to explain such a new realm of the material world as the electromagnetic field by the mechanical properties of substance that it was based on. (2) Physical discoveries were made at the turn to the twentieth century that disclosed new, previously unknown properties of substance itself that also did not conform with the philosophical metaphysical and mechanistic understanding of matter that had arisen through generalisation of the notions of classical mechanics. In 1895 Roentgen discovered rays (later known after him) that had the surprising capacity to penetrate 'opaque' objects. That refuted such a property of substance as impenetrability. In 1896 Becquerel discovered natural radioactivity. The atom, considered to be indivisible, proved to decay spontaneously. Then, in 1897, William Thomson and Wiechert discovered the electron, a particle with a mass several orders smaller than the atom. It became clear that it was a component part of the atom. The property of the 'indivisibility' of matter (atom) proved relative. Subsequent study of the electron led to a new notion of the physical properties of matter. Mass, which had been counted invariable, proved to be a variable quantity that increased with growth of the velocity of an electron's motion.

The limited nature of the former concept of matter, and the impossibility of explaining electromagnetic processes by it, had already been noted by individual Premarxian materialists, who considered that the concept had been illegitimately associated with the concrete, mechanical properties of substance. But

a full understanding of this problem was only attainable in dialectical materialism, according to which the concept of matter is an abstraction in which the whole of objective reality and the whole external world are reflected.

Matter, Lenin wrote,

> is a philosophical category denoting the objective reality which is given to man by his sensations, and which is copied, photographed and reflected by our sensations, while existing independently of them.[26]

It is important to single out the following three elements in this definition of matter: (1) *matter is objective reality;* (2) *matter is that which exists outside and independent of consciousness;* (3) *matter is that which is reflected in consciousness.*

The first element means that, as regards matter, any things, phenomena, or objects existing outside and independent of consciousness constitute it. This part of the definition contains a warning against identifying matter simply with some concrete things and phenomena. The second element indicates a distinct boundary separating the two main trends in philosophy, viz., the materialist and the idealist. The third element is directed against agnosticism and stresses the knowability of the world.

It is stressed with special force in dialectical materialism that it is inadmissible to confuse matter as a philosophical category and natural science notions of the structure and properties of matter. The concept of matter should not be identified with notions (1) of the concrete properties of substance such as impenetrability, indivisibility, inertia, mass, etc., as was done by metaphysical materialism; (2) of the concrete forms of material objects (e.g. of atoms or water, fire, air); (3) of the concrete states in which these objects may find themselves (e.g. substance or field). The material world has many different properties, but they are concrete physical, chemical, biological, and other properties. It is not legitimate to include them in the philosophical concept of matter. The latter is associated with one property only, viz. of being objective reality.

> The *sole* 'property' of matter with whose recognition philosophical materialism is bound up [Lenin wrote] is the property of *being an objective reality*, of existing outside the mind.[27]

This concept of matter as a maximally broad philosophical category extends to all discovered, and not yet discovered, objects of the external world. Whatever objects may be discovered

in the future, whatever properties they will possess, and whatever states they will be in, they will all be covered by the dialectical materialist concept of matter.

Apart from the concept of matter the term 'physical reality' is also met in the philosophical and physical literature. Einstein also used that term. What were the reasons for his introduction of it? And what content did he give it?

Einstein employed the term 'physical reality' in various senses in his writings. He treated it (1) as a methodological category and (2) as an equivalent of the concept of matter. But why did he need to introduce such an 'equivalent'? Here one can agree in advance with the view of certain philosophers who considered that the question of physical reality had acquired a special ring because the phenomena and processes that modern physics is concerned with were embraced by its theories by means of methods and abstractions that sometimes seemed strange from the standpoint of classical physics. Einstein, it must be noted, was apparently not sufficiently acquainted with the dialectical materialist conception of matter. He considered it his duty, starting from the latest discoveries of physical science, to introduce the concept 'physical reality' in place of the conception of 'naive realism' which identified the concept of matter with that of substance. I have already remarked that Einstein assumed the existence of an external world independent of the perceiving subject when dealing with physical problems. He considered that this truth underlay all natural science. Physical objects therefore did not exist for him other than as material objects reflected in scientific concepts. When dealing with the question of objective reality he wrote: 'Since, however, sense perception only gives information of this external world or of "physical reality" indirectly, we can grasp the latter only by speculative means.'[28] As we see, he treated the concepts 'external world', 'matter', and 'physical reality' as concepts of the same order.

The problem of the content of these concepts always worried Einstein. He saw that metaphysical materialism narrowed the concept of matter, identifying it with that of substance.[29] But the discoveries of Oersted, Faraday, and Maxwell had pointed to the existence of a new region of the material world hitherto unknown to physics.

> In the beginning, the field concept was no more than a means of facilitating the understanding of phenomena from the mechanical point of view. The recognition of the new concepts grew steadily, until substance was overshadowed by the field.[30]

For Einstein the field was not a concept divorced from reality. It existed objectively like material bodies. (His view on this point was cited above: 'The electromagnetic field is, for the modern physicist, as real as the chair on which he sits.')[31]

Thus Einstein understood by physical reality the external world, divided by physics into substance and field. This concept covered all the nature known to science: the particle and field objects of the world. It was wider than Premarxian thinkers' notion of matter, since it went beyond the bounds of the concept of substance. Einstein did not consider that the content of the concept 'physical reality' could not be altered by developing physics.[32] He extended this concept as well to objects of the physical world that might be discovered in the future. Yet his concept of matter was narrower than the dialectical materialist one since it did not extend to social phenomena. The notion of physical reality cannot be raised to the rank of a philosophical category since it is associated only with study of the physical state of matter. It plays a positive role of its own in science insofar as many physicists need it as a synonym of objective reality.

Einstein also employed the concept of physical reality so as to distinguish forms of material objects with which certain branches of the physical sciences were associated. He not only divided the objective physical world into two large, relatively independent spheres—substance and field—each of which had its qualitatively specific kind of motion, but he also divided physical science into areas that arose through reflection of the existence of objects of these two spheres. He saw a direct link between the material world and its physical reflection. Since our knowledge of the external world alters, we must, he stressed, in time alter the axiomatic basis of physics. After Newton physical postulates had been altered precisely when the material field was discovered.

> The greatest change in the axiomatic basis of physics in other words, of our conception of the structure of reality since Newton laid the foundation of theoretical physics was brought about by Faraday's and Maxwell's work on electromagnetic phenomena.[33]

Einstein also extended the concept of physical reality to quantum-mechanical processes. He understood, moreover, that the material objects that quantum physics studied differed in their properties from the objects of classical mechanics and electrodynamics.

> The last and most successful creation of theoretical physics,

> namely quantum-mechanics, differs fundamentally from both the schemes which we will for the sake of brevity call the Newtonian and the Maxwellian. For the quantities which figure in its laws make no claim to describe physical reality *itself*, but only the *probabilities* of the occurrence of a physical reality that we have in view.[34]

He did not agree with the interpretation of quantum-mechanical reality given by the Copenhagen school of physicists. He considered that this interpretation indicated only a temporary way out of the difficult correlation of quantum theory and the reality it described. Physicists were searching, he said, for a means of direct (non-stochastic) representation of the corpuscular-wave reality of micro-objects.

> Some physicists, among them myself, cannot believe that we must abandon, actually and forever, the idea of direct representation of physical reality in space and time; or that we must accept the view that events in nature are analogous to a game of chance. It is open to every man to choose the direction of his striving; and also every man may draw comfort from Lessing's fine saying, that the search for truth is more precious than its possession.[35]

Probability notions now made it possible to solve the problems of quantum physics. Scientists suggest that these notions reproduce objective relations in the structure of quantum-physical reality. That does not mean, however, that the dispute begun by Einstein and Niels Bohr about the fullness and adequacy of the quantum-theoretical description of reality is yet finished. Quantum mechanics, like other physical theories, is not ultimate truth. It may be that future theories of the microworld will somehow confirm Einstein's hopes. And it may be that this will not happen. But one point is already clear today: Einstein's search for a more consistent theory of the microworld, and his objections to the quantum-mechanical mode of description, necessitate a quest for deeper understanding of physical reality.

NOTES

[1] W. Pauli. Fünfzig Jahre Relativitätstheorie. Jubilee of Relativity Theory. *Helvetica Physica Acta*, 1956, Suppl. IV, pp 282 283.
[2] Albert Einstein and Leopold Infeld. *The Evolution of Physics* (Simon & Schuster, New York, 1942), p 259.
[3] Albert Einstein. The mechanics of Newton. In: *Ideas and Opinions* (Crown Publishers, New York, 1954), p 257.
[4] Albert Einstein and Leopold Infeld. *Op. cit.*, p 311.
[5] *Ibid.*, p 158.

[6] Isaac Newton. *Opticks: or a Treatise of the Reflections, Refractions, Inflections and Colours of the Light* (London, 1718), p 364.
[7] *Idem. Mathematical Principles of Natural Philosophy* (Cambridge U. P., Cambridge, 1934), p 1.
[8] Benjamin Franklin. *Experiments* (Harvard U. P., Cambridge, Mass., 1951), p 213.
[9] See F.U.T. Aepinus. *Tentamen Theoriae Electricitatis et Magnetismi* (St. Petersburg, 1759).
[10] Cited from Jean Daujat. *Théorie de phénomenes électriques et magneti ques.* Vol. 3 (Herman & Co., Paris, 1945), p 500.
[11] Albert Einstein. Maxwell's influence on the evolution of the idea of physical reality. In: *Ideas and Opinions*, p 267.
[12] Albert Einstein and Leopold Infeld. *Op. cit.*, p 120.
[13] *Ibid.*, p 141.
[14] Michael Faraday. *Experimental Researches in Electricity*, Vol. III (Richard Taylor, London, 1835), pp 442 443.
[15] *Ibid.*, pp 439, 441.
[16] James Clerk Maxwell. *A Treatise on Electricity and Magnetism*, Vol. I (Clarendon Press, Oxford, 1873), p X.
[17] *Idem.* A dynamical theory of the electromagnetic field. *Philosophical Transactions of the Royal Society of London*, 1865, *155*, 1:460.
[18] Albert Einstein and Leopold Infeld. *Op. cit.*, p 148.
[19] James Clerk Maxwell. *Art. cit.*, p 466.
[20] Albert Einstein. Über einen die Erzeugung und Verwandlung des Lichtes betreffenden heuristischen Gesichtspunkt. *Annalen der Physik*, Vierte Folge 1905, *17*, 6:133.
[21] It is not my aim to analyse the history of the shaping of quantum mechanics. I recall it insofar as it is necessary to throw light on the problems of the relation of field and substance.
[22] H. Reichenbach. *The Rise of Scientific Philosophy* (University of California Press, Berkeley, 1954), p 175.
[23] S. I. Vavilov. Eye and Sun. In: Sobraniye Sochinenii, Vol. 4, (Nauka, Moscow, 1956), p 191.
[24] M. E. Omelyanovsky. *Filosofskie problemy fiziki elementarnykh chastits* (Philosophical Problems of the Physics of Elementary Particles), Nauka, Moscow, 1964, p 60.
[25] V. S. Gott. *Filosofskie voprosy sovremennoi fiziki* (Philosophical Problems of Modern Physics), Vysshaya shkola, Moscow, 1967, p 96.
[26] V. I. Lenin. *Materialism and Empirio-Criticism* (Progress Publishers, Moscow, 1977), p 114.
[27] *Ibid.*, p 241.
[28] Albert Einstein. Maxwell's influence on the evolution of the idea of physical reality. In: *Ideas and Opinions*, p 266.
[29] Albert Einstein and Leopold Infeld. *Op. cit.*, pp 310-311.
[30] *Ibid.*, pp 157 158.
[31] *Ibid.*, p 158.
[32] See *Ideas and Opinions*, p 266.
[33] *Ibid.*
[34] *Ibid.*, pp 269 270.
[35] Albert Einstein. The fundaments of theoretical physics. In: *Ideas and Opinions*, pp 334-335.

2

Time, Space, and Motion in Physics and Philosophy

Let us look first at the problem of time and space.

As concerns modern notions of time and space, their development was promoted by several sciences, primarily physics and mathematics, and by philosophy. The data of these specific sciences and of philosophy mutually influenced one another, and helped bring out more fully the essence of time and space.

Newton's doctrine was the first major generalisation of the problem of time and space in the history of science. It had its roots in the mathematical ideas of Euclid, and in the philosophical opinions of Demokritos, Epicurus, and Lucretius, and was based on the conclusions of classical mechanics.

Newton distinguished absolute, or objective, concepts from subjective, or apparent ones.

> *Absolute space*, in its own nature, without relation to anything external, remains always similar and immovable. *Relative space* is some movable dimension or measure of the absolute spaces; which our senses determine by its position to bodies; and which is commonly taken for immovable space (my italics—*D. G.*).[1]

It followed from these propositions of Newton's that space was not connected with matter, and was not one of its properties, but existed as some independent substance. Space was represented as a kind of receptacle filled with material bodies. The main limitation of this conception, around which scientific dispute raged for more than two centuries, was linked with just that proposition.

Newton drew the same conclusion in regard to time. He distinguished absolute and relative time. Absolute time he represented as uniform, pure duration, existing independently of the material world and not connected with events taking place in nature. It was one-dimensional, continuous, and homogeneous throughout the Universe.

> *Absolute, true, and mathematical time*, of itself, and from its own nature, flows equably without relation to anything external, and by another name is called duration: *relative, apparent,*

> *and common time*, is some sensible and external (whether accurate or unequable) measure of duration by the means of motion, which is commonly used instead of true time; such as an hour, a day, a month, a year (my italics—*D.G.*).[2]

In addition, time and space were considered independent not only of mechanical processes (independent in relation to moving matter) but also relatively to one another.

Analysis indicates that Newton's doctrine of time and space was *the consequence of his identifying of the material world with substance or particle matter,* the result of that level of development of science when natural objects were represented only in the shape of formations limited and localised in space. Such an understanding of matter had led ancient thinkers to the conception that there were only atoms and void in the world. That conception was the philosophical and natural-science foundation of the substance notions of time and space associated mainly with the name of Newton, which treated them as independent entities, isolated from matter.

Another conception of time and space had made its way parallelly, alongside the Newtonian doctrine, though with certain difficulties, and despite the fact that the latter's authority was incontestable. This other conception took its beginning from Aristotle and found further reflection in the philosophy of Descartes, Leibniz, Toland, and other thinkers. Unlike Newton, Leibniz, for example, approached the problem of time and space from the angle of a broader notion of matter. (I shall not go into philosophical essence of the Leibniz' concept of matter here. He interpreted it as spiritual substance.) First of all, Leibniz saw that Newton based himself, in his conclusions about time and space, on a limited metaphysical notion of matter, and saw that as the main reason preventing disclosure of the deeper space-time properties of nature. Leibniz stressed that the ancients' idea of the existence only of atoms and void had impoverished our notions of the world, and reduced material reality simply to the existence of the simplest elements of matter. According to him the material world was not limited just to the existence of substance-matter.

> It cannot be said, that the present quantity of matter is the fittest for the present constitution of things. And supposing it were, it would follow that this present constitution of things would not be the fittest absolutely, if it hinders God from using more matter. It were therefore better to choose another constitution of things, capable of something more.[3]

Leibniz extended the concept of matter not only to materi-

al objects but also to light and magnetic phenomena and other 'non-sensual media'. Like Aristotle, and later Descartes, he did not admit the existence of vacuum or void, and considered that matter was present everywhere.

> The author objects against me [he wrote] the vacuum ... which is made by pumping the air out of a receiver; and he pretends that there is truly a perfect vacuum, or a space without matter (at least in part) in that receiver. The Aristotelians and Cartesians, who do not admit a true vacuum, have said ... that there is no vacuum at all in the tube or in the receiver; since glass has small pores, which the beams of light, the effluvia of the load-stone, and other very thin fluids may go through. I am of their opinion.[4]

Leibniz' recognition of the qualitative diversity of the forms of matter, and reduction of substance only to a partial case, enabled him to reject the Newtonian idea of an absolute vacuum and consequently of absolute space as a separate, self-contained principle existing alongside matter and independent of it. In his view, time and space could not be considered outside things and processes, but were properties of matter. The necessity for matter to exist only in a certain order and in certain relations followed from this character of it. Matter, Leibniz considered, played a decisive role in the space-time structure; his notion did not find confirmation, however, in contemporaneous science and was therefore not accepted by scientists.

The Irish philosopher John Toland came to the same conclusion about the limited nature of the Newtonian doctrine of time and space. Like Leibniz he came to study of space and time from matter, and considered that this latter concept needed development. In contrast to Leibniz, however, matter was objective reality for him and not a spiritual substance.[5]

Toland criticised the Newtonian ideas of vacuum, and absolute time and space. He suggested that one would arrive at these ideas if one simply accepted existing notions of matter as local material bodies unconnected with one another. In his view, however, these notions were limited and wanting. The material world was divided into parts only in our imagination, while an absolute vacuum did not in fact exist. The division of material formations was relative and due to the incompleteness of our notions of matter.

> The Opinion of a Void is one of the numberless erroneous Consequences of defining Matter only by Extension, of making it naturally inactive, and of thinking divided into real Parts every way independent of one another. On these Suppositions it

> is impossible there shou'd not be a Void, but 'tis impossible that ten thousand Absurditys shou'd not follow from thence. What we call Parts in Matter, may be prov'd to be but the different Conceptions of its Affections, the distinctions of its Modifications, which Parts are therefore only imaginary or relative, but not real and absolutely divided.[6]

In Toland's view time and space did not exist outside matter and outside its processes as an independent substance. Space and time were properties of the material world.

> Yet because the Mathematicians had occasion to suppose Space without Matter, as they did Duration without Things, Points without Quantity, and the like; the Philosophers, who cou'd not otherwise account for the Generation of Motion in Matter which they held to be inactive, imagin'd a real Space distinct from Matter, which they held to be extended, incorporeal, immovable, homogeneal, indivisible, and infinite.[7]

A new trend in mathematical science—non-Euclidean geometry—played an immense role in development of the theory of time and space. The Russian scientist N. I. Lobachevsky, who came to the creation of his geometry from deeper notions of the properties of the material world, laid the foundations of this trend. Before him there had been a single mathematical science of the spatial forms of matter, viz., Euclid's geometry, the theorems of which had been confirmed in practice. That fact had given Euclid's theory an absolute character. For Newton and for other scientists it was the theoretical basis that most deeply revealed the properties of space. For more than two thousand years the authority of the sole geometry had been indisputable. And when Lobachevsky first tried to throw doubts on its absolute character many scientists did not understand him. His undoubted merit was that he was able to refute the stability of Euclid's fifth postulate (about parallelism), by constructing a new geometry in which this postulate was not satisfied. He thereby demonstrated that objective reality could be reflected by other geometries as well. The spatial properties of matter, it turned out, were richer than had previously been thought and as recorded in Euclid's geometry.

Lobachevsky's success was due to his taking a philosophically deep approach to contemplation of the essence, unity, and diversity of nature, and to his understanding that our knowledge of nature was a far from full, rough reflection. He was convinced that nature dictated knowledge to us, and not vice versa, and that it was necessary to start in cognition from an analysis of reality.

> Stop toiling irrationally, trying to derive all wisdom from

> reason alone [he appealed]; ask Nature, she guards all truths, and will answer all your questions certainly and satisfactorily.[8]

The initial object of geometry, according to Lobachevsky, should be material bodies. Geometrical concepts like surface, curve, straight line, point, etc., were abstractions, the result of analysis of reality.

> We know only bodies in nature; consequently, concepts about lines and surfaces are derived concepts and not acquired ones, and so must not be taken as the foundation of mathematical science.[9]

Lobachevsky's postulate that several lines parallel to a given straight line can be drawn through a point, and likewise his propositions derived from it, contradicted the Newtonian doctrine of space and time. But that did not bother him, since he considered that his theoretical conclusions about spatial relations followed from the properties of the physical world. Space was inconceivable, he stressed, without physical bodies. And if geometry demonstrated that the constancy of the sum of the three angles of any rectilinear triangle was not a necessary consequence of our concepts of space, then

> experience alone can confirm the truth of this proposition, for example, by measurement in fact of the three angles of a rectilinear triangle, a measurement that can be made in different ways. The three angles of a triangle drawn on an artificial plane can be measured, or the three angles of a triangle in space. In the latter case triangles must be preferred whose sides are very long, because according to the theory of pangeometry the difference of the sum of the three angles of a triangle with two right angles is the greater, the longer the sides.[10]

Some time later other non-Euclidean geometries appeared. The Hungarian János Bolyai and the German mathematician Bernhard Riemann confirmed Lobachevsky's idea of the possibility of there being properties of space different from Euclidean ones. Riemann, for example, created a spherical geometry that defined the geometrical properties of a spherical surface. It was thus once more demonstrated that Euclid's geometry had a partial character and that it had been illegitimately made an absolute and extended to all material reality. Its absolutising had also created an appearance of the autonomy of geometrical properties. Like Lobachevsky, Riemann pointed to the connection of spatial characteristics with the physical properties of natural objects. He assumed that the space between bodies was filled with a substance that could be represented as 'a physical space the points of which move in geometrical space'.[11]

Alongside the progress of physics, which had revealed mat-

ter in the state of a field, and of the mathematics that created non-Euclidean geometries, development of the doctrine of time and space received a great impulse in dialectical materialism.

As we know time and space had a different treatment in the various philosophical schools. Some represented these categories as *a priori*, without an origin in experience; others posed them as fully dependent of man's perception; a third school saw them as divorced from material reality and existing alongside the material world, and so on.

Dialectical materialism asserts that time and space reflect the external world and are fundamental properties, modes of existence of matter. The general properties and relations of objective reality are abstracted in them. They have a universal character. No material formation is conceivable without them. According to Engels, 'being out of time is just as gross an absurdity as being out of space'.[12]

The classical writers of dialectical materialism substantiated their conclusion about the objective character of time and space from their answer to the main question of philosophy. Lenin stressed that

> Recognising the existence of objective reality, i.e. matter in motion, independently of our mind, materialism must also inevitably recognise the objective reality of time and space.[13]

At the same time they based themselves in this question, as well, on the achievements of natural science, which assumed the reality of space and time in its constructs.

> Science does not doubt that the substance it is investigating exists in three-dimensional space and, hence, that the particles of that substance, although they be so small that we cannot see them, must also 'necessarily' exist in this three-dimensional space.[14]

Materialist dialectics has shown the relative character of notions of time and space, proceeding from the point that relative knowledge is a stage toward achieving fuller knowledge. The incompleteness and imperfection of knowledge of time and space, and their variability, are not grounds for supposing that these categories do not reflect objective time and space or that they are only products of human thought. Time, space, and motion are interconnected.

It follows from the theory of dialectical materialism that the world is infinite in time and boundless in space. That statement rests on the facts of science and has a principled character, since there are often various kinds of speculation

here. For Dühring's denial of the objectivity of time and space, and his attempt to prove that the idea of a beginning of the world in time and its limitedness in space did not diverge from materialism and was a condition of the existence of the world, led him to recognise 'a first impulse' and 'final cause'.

In dialectical materialism such widely known subjectivist conceptions of time and space as the following have been criticised: that of Ernst Mach, in which time and space were presented as ordered systems of series of sensations; of Henri Poincaré, who considered them logical categories that we find convenient; of A. A. Bogdanov, who suggested that space and time were forms of social agreement; of Karl Pearson, who claimed that they signified only our mode of perceiving things, and so on. Lenin wrote:

> There *is* an objective reality that *corresponds* to the teaching of science (although the latter is as relative at every stage in the development of science...) that the earth existed *prior* to any society, *prior* to man, *prior* to organic matter, and that it has existed for a *definite* time and in a *definite* space in relation to the other planets.[15]

He also pointed out that the main epistemological mistake of subjectivist interpretations of time and space was their denial of matter as objective reality and stemmed from making an absolute of the factor of the relativity of objective truth in knowledge of it.

As for the problem of motion, it has often been the focus of attention in the history of science in research and discussions among both scientists and philosophers. As a rule the polemic has concerned the essence of the concept of motion, and its relations with the material world. The question not only has immense ideological significance but is also of methodological importance. Success in studying certain natural phenomena has often depended on the interpretation of the problem of motion. As for mechanistic materialism, I have said that the absolutising of the mechanical form of motion could have an immense negative role on the advance of the natural sciences. The problem of motion has more than once been the subject of dispute, as well, in connection with philosophical analysis of the theory of relativity, a fact that compels me to return again to consideration of the essence of the concept of motion.

The problem has its roots deep in history. The ancient thinkers had already expressed several correct surmises about it. They drew attention to the universal character of motion,

and to the fact that it was an inherent property of matter. The scientific understanding of motion in general form was most clearly expressed in the doctrine of Herakleitos who said that the world was in eternal flux and change [All is flux, nothing stays still], and passed from one state to another. He saw the source of movement and development in matter itself. Any change in reality, he suggested, happened of necessity through the struggle of opposites.

But the general philosophical guesses of the ancients about motion required specific scientific substantiation, which only became possible in the heyday of classical mechanics, when it became the central problem of scientific thought. The conception of motion was most fully developed in the theories of Galileo and Newton. I drew attention to that aspect of the matter above; at the same time, however, I said that, although the doctrines of the fathers of mechanics were a significant step toward understanding of the physical properties of motion, they were vulnerable philosophically. One indication of this vulnerability was the absolutising of mechanical motion and its elevation almost to the rank of a philosophical category by which any phenomena in nature or society could be explained. In addition, motion was treated in classical mechanics in a certain sense as a substance isolated from matter, as a simple displacement of bodies in a space-time continuum unconnected with them. The view was held that the motion of objects did not affect their internal state.

> *Absolute motion* [Newton wrote] is the translation of a body from one absolute place into another; and *relative motion*, the translation from one relative place into another.[16]

His appeal to non-material forces as the source of the motion of cosmic bodies indicated that it was impossible to solve problems of motion as an attribute of matter solely within the mechanical form of motion.

Long before natural science penetrated the structure of the microworld, which disclosed the physical essence of motion, philosophy had shown that motion was inherent in all material objects and did not come from outside, but was a property of nature itself. The ideas of several eighteenth-century materialists present interest in this respect; they tried, when developing the doctrine of motion, to refute the widely accepted Newtonian conception of a 'first impulse', and to find the connecting thread between the established notion of 'inert', 'immobile' matter and the observed processes of nature.

In that connection one may cite the profound analysis of

the problem of motion given in John Toland's work. Careful observation of nature had led him to the conclusion that matter could not be represented, as many scholars did, without its inherent activity. 'I deny that Matter is or ever was in inactive dead Lump in absolute Repose, a lazy and unwieldy thing.'[17] Toland distinguished between mechanical motion and motion as a whole, which applied to the whole material world. While the former was a simple translation of bodies in space, or only a state or consequence of material activity, the latter was the cause, the motive force of nature.

> So, the better to be understood, I wou'd have this Motion of the Whole be call'd *Action,* and all local Motions, as direct or circular, fast or slow, simple or compounded, be still call'd *Motion,* being only the several changeable *Determinations* of the *Action* which is always in the Whole, and in every Part of the same, and without which it cou'd not receive any Modifications.[18]

Toland drew attention to the inadmissibility of confusing these concepts, of identifying cause and effect, and of mechanical translation and motion in general. Such confusion drove scholars as a rule to seek the sources of motion outside the material world.

> ...Yet the Action or moving Force is likewise often call'd by the name of Motion, and thus the Effect is confounded with the Cause, which has occasion'd a world of Perplexitys, and Absurditys. But all those who have treated of the Diversitys that happen in Matter, must have meant this Action as their Cause, or labor'd to no purpose: for this being once explain'd, we can easily account for local Motion as its Effect, and not otherwise.[19]

Toland warned scholars against trying to divorce mechanical motion from matter, and presentation of motion as some independent immaterial reality. According to him, rest should not be treated as the absolute absence and negation of motion. Like the mechanical translation of bodies in space it was relative.

> So is Rest, which is now generally acknowledg'd to be no Privation nor a State of absolute Inactivity, as much Force being necessary to keep Bodys at rest as to move them; wherefore local Motion and Rest are only relative Terms, perishable Modes and no positive or real Beings.[20]

Toland came to the conclusion that there were no absolutely immobile particles in nature. Everything in it was in motion and flux. Like extension, motion had to be related to the real properties of matter.

> I hold then that *Motion is essential to Matter...* I hope to

> evince that this Notion alone accounts for the same Quantity of Motion in the Universe, that it alone proves there neither needs nor can be any Void, that Matter cannot be truly defin'd without it, that it solves all the Difficultys about the moving Force, and all the rest which we have mention'd before.[21]

Toland thus in general correctly expressed the idea of the link between matter and motion to which natural science came much later.

The problem of motion was developed in the philosophical works of the eighteenth-century French materialists, whose arguments had already been reinforced by certain facts of natural science. Diderot, for example, criticised philosophers who suggested that material bodies did not in themselves possess either activity or force, and that the activity was allegedly lent to bodies only by effects external to them. An external mechanical effect, he suggested, did exert an influence on bodies, but this influence was insignificant and short-term. The main motor of matter was within it itself, within molecules and atoms. And this inner force was practically unlimited in quantity. While an external force acting on molecules became exhausted, he stressed, the internal force of a molecule was inexhaustible. It was immutable and eternal.[22]

We find something the same in Holbach. He also classified motion into two main forms, putting mechanical or external motion in the first, and inner forms of motion in the second. The first was accessible to our perception, the second could not be observed directly but only through external changes and transformations. He considered that motion was not some chance occurrence proper only to separate parts of nature, but covered all objective reality. Motion was not introduced into nature from outside but was internally inherent in it, came from it, and was its main attribute and mode of existence.

> The idea of nature necessarily includes the idea of movement ... movement is a fashion of being that flows necessarily from the essence of matter, that matter moves by its own energy, that its movements are due to forces that are inherent in it, that the variety of its movements and of the phenomena that result from them come from the diversity of the properties, qualities, and combinations that are originally found in the different original substances of which nature is the aggregate.[23]

Holbach considered that some scholars were trying to divorce motion from matter and to identify its source with external force on the simple principle that they did not give the concept of matter the meaning that should follow from the content

of nature itself. If naturalists paid more attention to study of nature they would come to a different conclusion, he explained.

> If we understand by nature a mass of dead matter deprived of all properties and purely passive, we shall undoubtedly be forced to look outside this nature for the principle of its movements; but if we understand by nature what it really is, i.e. a whole whose diverse parts have diverse properties, which consequently act according to these same properties, which are perpetually in an action and reaction with one another, which have weight, which gravitate to a common centre while others distance themselves and go to the circumference, which attract and repulse, which unite and separate, and which produce and decompose all the bodies we see by their collision and coming closer together; then nothing will oblige us to have recourse to supernatural forces so as to understand the formation of the things and of the phenomena that we see.[24]

The development of the philosophical doctrine of motion is deservedly associated with the name of Hegel, although he departed far, in separate aspects of his analysis of motion, from the truths already discovered by certain philosophers of the seventeenth and eighteenth centuries. The reality analysed by Hegel was a process, i.e. universal motion and development.

He was one of the first to subject mechanistic philosophy to convincing criticism, show the limited character of the views of metaphysical materialists who identified motion with mechanical translation, and broaden the notion of motion. By motion he understood not just mechanical translation but also physical, chemical, biological, and social processes. The source of motion, he considered, was the struggle of opposites. Contradiction was the root of all motion and vitality; in so far as anything had a contradiction in itself it moved and possessed impulse and activity. It was Hegel's merit, as well, to have disclosed the general laws of development. But the dialectical interpretation of motion given by him required a new meaning. It was not the material world that moved, he suggested, but the absolute spirit embodied in material objects. 'Nature is to be regarded,' he wrote, 'as a *system of stages,* one arising necessarily from the other and being the proximate truth of the stage from which it results.'[25]

The doctrine of motion was developed in dialectical-materialist philosophy through generalisation of the achievements of preceding materialism, development of the propositions of the Hegelian dialectic and, finally, of the achievements of the natural and social sciences. Above all the founders of dialectical materialism substantiated the proposition of the universal

character of motion and extended it to the material and spiritual world and to social phenomena.

They stressed that motion could not be identified as a philosophical and scientific category with notions of any one form of movement, as happened, in fact, in mechanistic materialism. The motion of matter was not only mechanical translation; it was also heat and light, and electricity and magnetism, and chemical combination and dissolution, and life and, finally, consciousness. Dialectical materialism understands by motion not only quantitative changes but also qualitative transformations of material objects. 'Motion,' Engels wrote, 'is not merely change of place, in fields higher than mechanics, it is also change of quality.'[26] In that connection he drew attention to the limited interpretation of the law of conservation and transformation of energy, which consisted in its consideration only from the quantitative aspect. He put the stress on the qualitative content of the processes of motion, and on the transformation of energy of one sort into another. His classification of the forms of the motion of matter, which I have already mentioned, helped bring order into the many isolated, contradictory facts about motion and transform them into a single, harmonious system.

Dialectical materialism supposes that it is impossible to make an absolute of any immobile object or any equilibrium. Rest and equilibrium are relative concepts which have sense only in relation to some form of motion. Knowledge of motion cannot be completed by the now known facts of sciences like physics, chemistry, biology, astronomy, political economy, history, etc. It is not legitimate to identify it with the concrete types and forms now discovered, because (as Engels said) 'motion, as applied to matter, is *change in general*'.[27]

That definition of motion is maximally general. It covers mechanical, physical, biological, social, and all other types and forms of motion that are known or may be discovered in the future.

Dialectical materialism considers motion only in connection with study of matter. Matter is inconceivable without motion, and motion without matter. These categories of philosophy are interconnected.

> Neither motion as such nor any of its forms, such as mechanical force, can therefore be separated from matter nor opposed to it as something apart or alien, without leading to an absurdity.[28]

Motion, consequently, is not created; like matter it exists eternally. In nature only mutual transformations of one type of motion into another occur. But motion, like matter, can only be under-

stood through study of its concrete types and forms:

> matter as such and motion as such have not yet been seen or otherwise experienced by anyone, but only the various, actually existing material things and forms of motion... Motion as such [is] nothing but the totality of all sensuously perceptible forms of motion; words like matter and motion are nothing but *abbreviations* in which we comprehend many different sensuously perceptible things according to their common properties.[29]

For dialectical materialism motion as an inseparable, internally inherent, innate property of matter is in the first rank among all its attributes. 'Among the qualities inherent in *matter,*' Marx said, '*motion* is the first and foremost...'[30] And according to Engels, '*motion is the mode of existence of matter,* hence more than a mere property of it'.[31]

Science thus had a theory of motion in the mid-nineteenth century which was a reliable methodological basis within the context of philosophy for explaining natural and social phenomena. Nevertheless individual scientists made methodological mistakes when considering the problem of motion. Let us take as an example the physical chemist Wilhelm Ostwald.

Ostwald drew a number of conclusions from the new discoveries of physics anent the essence of motion, which diverged from the point of view generally accepted in science at that time. Taking the attribute of matter, energy, as the most common and sole substance (i.e. the same as matter), and isolating it not only from matter but also from motion (of which it is primarily an attribute), he represented the world as consisting, in his view, 'exclusively of energy material', of motion alone without matter. According to him, natural science had no need of a concept of matter, which, he said, could neither be understood nor defined without mentioning the properties of energy.

> Whereas energy is more and more establishing itself as reality the claims of matter are evaporating, and it has no further right left than tradition. It must not only tolerate energy alongside it, as advanced textbooks of natural science already require, but it must absolutely yield place to energy and retire to its old place as the outserved sovereign, where it can expect to be gradually liquidated along with its court of respected elders.[32]

Ostwald also reduced thinking to energy processes, because this kind of activity, in his view, could not take place without conversion of energy.

> That all external events may be presented as processes between energies can be most simply explained *if our mental processes* are themselves energetic and impose *(aufprägen)* this property of theirs on all external phenomena.[33]

Ostwald endeavoured to substitute the concept of energy for matter because he considered it the maximally general, initial concept of the categorial explanation of the world, and thereby tried to remove the perennial question of the relation of matter and consciousness.

> The simple and natural removal of the old difficulties in the way of uniting the concepts of matter and mind by subordinating both to the concept energy seems to me so great a gain that when today's proposed effort proves impracticable, it will itself include new efforts in the same direction in the future development of philosophy.[34]

When Lenin was analysing the reasons for the crisis in physics, in his *Materialism and Empirio-Criticism,* he was critical of Ostwald's 'energetics', stressing that

> to divorce motion from matter is equivalent to divorcing thought from objective reality, or to divorcing my sensations from the external world in a word, it is to go over to idealism. The trick which is usually performed in denying matter, in assuming motion without matter, consists in ignoring the relation of matter to thought. The question is presented as though this relation did not exist, but in reality it is introduced surreptitiously; at the beginning of the argument it remains unexpressed, but subsequently crops up more or less imperceptibly.[35]

In spite of the fact that many philosophers and scientists sharply opposed Ostwald's conception, and subsequent science did not confirm his ideas, some scholars resurrect him from time to time. His new disciples try to reduce matter to energy, basing themselves now on the theory of relativity. I shall come back to a consideration of this point when I examine the philosophical essence of the theory of relativity below.

NOTES

[1] *Sir Isaac Newton's Mathematical Principles of Natural Philosophy and His System of the World* (Cambridge U. P., Cambridge, 1934), p 6.
[2] *Ibid.*
[3] H. G. Alexander (Ed.). *The Leibniz Clarke Correspondence* (Manchester U. P., Manchester, 1956), p 40.
[4] *Ibid.*, pp 65-66.
[5] John Toland. *Letters to Serena* (Bernard Lintot, London, 1704), pp 165-167.
[6] *Ibid.*, pp 172-173.
[7] *Ibid.*, p 181.
[8] N. I. Lobachevsky. *Tri sochineniya po geometrii* (Three Works on Geometry), Gostekhizdat, Moscow, 1956, p 16.
[9] *Ibid.*
[10] *Ibid.*, pp 214-215.
[11] See *Bernhard Riemann's gesammelt mathematische Werke und Wissen*

schaftlicher Nachlass (Verlag von B. G. Teubner, Leipzig, 1892), p 533.
[12] Frederick Engels. *Anti-Dühring* (FLPH, Moscow, 1959), p 76.
[13] V. I. Lenin. *Materialism and Empirio Criticism* (Progress Publishers, Moscow, 1977), p 158.
[14] *Ibid.*, p 163.
[15] *Ibid.*, p 169.
[16] *Sir Isaac Newton's Mathematical Principles*, p 7.
[17] John Toland. *Op. cit.*, p 159.
[18] *Ibid.*
[19] *Ibid.*, pp 140-141.
[20] *Ibid.*, p 142.
[21] *Ibid.*, pp 159-160.
[22] See Denis Diderot. *Pensées sur l'interprétation de la nature*, London, 1754.
[23] P. H. D. d'Holbach. *Système de la Nature ou les loix du Monde physique et du Monde moral*, Part I (London, 1770-1771), p 19.
[24] *Ibid.*, p 22.
[25] *Hegel's Philosophy of Nature*, being Part Two of the *Encyclopaedia of the Philosophical Sciences*. Translated by A. V. Miller. (Clarendon Press, Oxford, 1970), p 20.
[26] Frederick Engels. *Dialectics of Nature* (Progress Publishers, Moscow, 1977), p 252.
[27] *Ibid.*, p 247.
[28] Frederick Engels. *Anti Dühring*, p 467.
[29] *Idem. Dialectics of Nature*, pp 235-236.
[30] Karl Marx and Frederick Engels. The Holy Family. *Collected Works*, Vol. 4 (Progress Publishers, Moscow, 1975), p 128.
[31] Frederick Engels. *Anti Dühring*, p 402.
[32] Wilhelm Ostwald. *Die Forderung des Tages* (Akademische Verlagsgesellschaft, Leipzig, 1910), p 21.
[33] Idem. *Vorlesungen über Naturphilosophie* (Verlag von Veit & Comp., Leipzig, 1902), p 394. (See also V. I. Lenin. *Op. cit.*, p 252).
[34] *Ibid.*, p. VIII. (Cited from V. I. Lenin. *Op. cit.*, p 252).
[35] V. I. Lenin. *Op. cit.*, p 248.

3

The Genesis of the Special Theory of Relativity and Philosophy

The theory of relativity has a multi-aspect character. It concerns first of all the physical problem of time and space. In the history of science the theory of time and space has been developed on the basis of several sciences, above all physics, mathematics, and philosophy. Among the outstanding names who made major contributions to establishing and developing this doctrine, there are the mathematicians Euclid, Lobachevsky, and Riemann, the physicists Newton and Einstein, the philosophers Aristotle, Leibniz, and Toland.

The theory of relativity, and the new view of space and time arose through Einstein's generalisation of the physical, mathematical, and philosophical sciences. He was influenced not only by his immediate predecessors but also by remote ones. He paid tribute to them and honoured them. He devoted much attention to studying the ideas developed by the ancients, and saw that many of the scientific propositions on which modern physics is based had been developed in antiquity.

> We reverence ancient Greece as the cradle of western science. Here for the first time the world witnessed the miracle of a logical system which proceeded from step to step with such precision that every single one of its propositions was absolutely indubitable I refer to Euclid's geometry. This admirable triumph of reasoning gave the human intellect the necessary confidence in itself for its subsequent achievements. If Euclid failed to kindle your youthful enthusiasm, then you were not born to be a scientific thinker.[1]

He had the same high opinion of the philosophical ideas of the Roman thinker Lucretius and other thinkers of the past (as I have already said above).

In spite of his seeing the shortcomings and limited character of classical mechanics, Einstein nevertheless considered that its founders played an immense role in the development of many of the ideas of relativistic physics. 'The thinking of physicists today', he wrote, 'is conditioned to a high degree by Newton's fundamental conceptions.'[2] He also gave his due to Galileo who

first formulated the principle of relativity according to which the laws of mechanics are formed identically in all systems of co-ordinates moving uniformly in a straight line. Development of that principle led to the theory of relativity.

Einstein assigned an immense role in preparation of the theory of relativity to the epistemological ideas developed by the founders of classical mechanics. In contrast to several scientists he saw elements of the dialectics of the cognitive process in their work, and the commencement of a new style of thinking.

But Einstein's immediate predecessors Hendrik Lorentz and Henri Poincaré made the most notable contribution to the development of relativistic physics. These few examples alone already show that a scientific analysis of the theory of relativity (including the question of priority in its creation) must be made with due allowance for the three aspects enumerated. In my view a common fault of many works on the theory of relativity is their absolutising of some of these aspects. Exaggeration of the role of the mathematical side often leads to giving priority to Lorentz and Poincaré. A philosophical and physical excursus leads to Einstein.

Einstein affirmed that the theory of relativity was the result of study of the properties of the objective reality newly discovered by physical science, viz., field matter, which had demonstrated its 'bizarre' properties to scientists.

How did Einstein arrive at discovery of the theory of relativity, and what was the contribution of his immediate predecessors, Lorentz and Poincaré? To answer that one must remember what the state of physics was on the eve of the appearance of the theory of relativity. It had received most development in study of the properties of particle matter. Classical physics had quite fully, of its time, brought out the laws of the existence of this region of the material world. As for study of the properties of the field forms of matter, there were many puzzles for scientists. Such manifestations of light as interference and diffraction pointed to its wave character. Physicists suggested that light was the result of mechanical vibration of a certain hypothetical medium, ether.

An important milestone in discovery of the essence of light (which I have already mentioned) was the work of Faraday and Maxwell, which indicated its electromagnetic nature. Maxwell interpreted light as an electromagnetic (and not mechanical) manifestation of ether.

Insofar as it was considered that there was, in addition to ponderable matter, a matter called ether that was said to

be the material medium of light, physicists were faced by the question of the character of the interaction of 'ponderable' matter and ether. Several hypotheses were put forward about that, the simplest of which were the following two, which competed with one another: (a) the hypothesis of the full involvement of ether by moving matter, and (b) the hypothesis of the absolute immobility of ether. The first was refuted by the results of Fizeau's experiment; he tried to determine how far the movement of matter affected ether by passing a beam of light through water flowing in a tube and then through still water (substance). It turned out that the velocity of the movement of substance had practically no effect on the velocity of propagation of light. The second hypothesis had great philosophical as well as physical significance. In fact, if the proposition of the immobility of ether had been confirmed that in itself would have demonstrated its identity with Newtonian absolute space.

Lorentz, guided by ideas of immobile ether, created a theory of electromagnetic phenomena which made it possible to explain both Fizeau's experiment and other electromagnetic processes. Since ether, according to Lorentz, was absolutely immobile, that should be noticeable in experiments carried out on Earth, moving in ether. People would observe, it was thought, how this relative movement would be reflected in the propagation of beams of light. Lorentz showed theoretically that it was impossible to discover the absolute movement of Earth in ether through an experiment in which calculation of the ratio of the relative velocity and the velocity of light was based on quantities of the first order. But the more exact experiment carried out by Michelson and Morley, based on quantities of the second order, led to a negative result and so proved the inadequacy of Lorentz' theory.

To save his theory Lorentz proposed a hypothesis of contraction. According to him bodies moving relative to ether would contract by a certain amount during their movement. The instruments used in the experiments would consequently also contract, the hypothesis affirmed, which would offset the expected result.

In developing his theory Lorentz introduced the concept of local time, which was another step toward creation of the theory of relativity. He also discovered formulas for the transformation of time and co-ordinates in various moving systems. These constituted the mathematical basis of the special theory of relativity. When we speak in general of the significance

of Lorentz' work for the development of relativistic physics, its creation would have been considerably delayed without his electron theory and theory of electromagnetic and optical phenomena, and without a number of ideas developed by him that explained the problem of ether. Einstein highly valued Lorentz' discoveries:

> Upon this simplified foundation Lorentz based a complete theory of all electromagnetic phenomena known at the time, including those of the electrodynamics of moving bodies. It is a work of such consistency, lucidity, and beauty as has only rarely been attained in an empirical science. The only phenomenon that could not be entirely explained on this basis, i.e., without additional assumptions, was the famous Michelson-Morley experiment.[3]

Einstein drew attention to the fact that Lorentz' work furthered development of notions of the electromagnetic field as an independent entity. 'He brought about a change here in a convincing fashion. In principle a field exists, according to him, only in empty space.'[4]

Lorentz' discovery of the transformation of time and coordinates had great significance for the development of science. The Soviet physicist P. P. Lazarev considers that it stimulated development of the principle of relativity.

> Subsequently [he wrote], this transformation was one of the results of Einstein's principle of relativity. We must thus consider Lorentz one of the founders of the modern theory of relativity in its theoretical part.[5]

When paying its due to this discovery of Lorentz', Einstein also drew attention to his shortcomings in interpreting the transformations. Lorentz, he wrote,

> even discovered the 'Lorentz transformation', later called after him, though without recognizing its group character. To him Maxwell's equations in empty space held only for a particular coordinate system distinguished from all other coordinate systems by its state of rest. This was a truly paradoxical situation because the theory seemed to restrict the inertial system more strongly than did classical mechanics. This circumstance, which from the empirical point of view appeared completely unmotivated, was bound to lead to the theory of special relativity.[6]

The weakest spot in Lorentz' theory was the hypothesis of a quiescent ether. Einstein saw that it was in clear contradiction with the principle of relativity, which had been confirmed in practice. The contradiction was that the principle of relativity, on the one hand, required that the laws of nature be identical in all inertial systems, but at the same time Lorentz' main hypothesis of a quiescent luminous ether singled out

systems with a certain state of motion from all systems moving uniformly and in a straight line, i.e. those which were at rest relative to ether.

Lorentz' unshakable attitude to the idea of a quiescent ether was a real obstacle to his creating a theory of relativity, and largely prevented him from bringing out fully the essence of the principle of relativity. Max Planck described this point as follows:

> All his life he would sooner have renounced the introduction of the postulate of relativity than accept the laws of the theory of relativity as to some extent chance relations valid everywhere, and resolve to abandon the hypothesis of a material medium of light waves, and with it determination of a first rate system of reference.[7]

Although Lorentz' hypothesis of contraction, of course, expressed the essence of the special theory of relativity, yet he did not understand its content. The concepts like 'local time' introduced by him were fictitious quantities for him that did not reflect actual reality. In spite of the fact that he was the author of the hypothesis it was Einstein who brought out its real content. Apropos of that Max Born wrote:

> Einstein had then inverted the line of reasoning; what had been a conclusion for Lorentz he put at the start as the postulate of relativity (1905). All the relatively moving systems of reference were of equal status, and each had its own measure of length and time.[8]

As for Poincaré, one must recognise that his study and development of the achievements of the physics of the end of the nineteenth century, and especially the work of Lorentz, helped him to discover many propositions independently of Einstein that later became the physical basis of the theory of relativity and came quite close to completing it. Poincaré steadily followed Lorentz' work, whose success was then the focus of attention of physical scientific thought.

Poincaré saw that physicists' attempts to discover the absolute movement of Earth, i.e. its movement in respect to immobile ether, had not been crowned with success. Study of the phenomena of the refraction and reflection of light had led Fresnel to the conclusion that Earth's motion did not influence their character. Fizeau had come to the same conclusion from the experiment that bears his name, that of passing light through water moving in a pipe. Michelson had also obtained a negative effect. All these experimental data led Poincaré to the idea that it was necessary to extend Galileo's principle of relativity,

based on generalisation of mechanical phenomena, to the electromagnetic field as well.[9]

I said above that the experiments indicating the impossibility of discovering the absolute motion of Earth had led Lorentz to the contraction hypothesis. But it also evoked a need to carry out more exact experiments, since it did not agree with the principle of relativity. That circumstance compelled Lorentz to develop his contraction hypothesis. He created the well-known transformations that Poincaré named after him. Poincaré saw that Lorentz interpreted them in a limited way, and made an attempt to extend their real content.

> The importance of the question determined me to take it up; the results that I obtained agree with those of Lorentz on all the important points; I have only been led to modify them and to complete them in several points of detail.[10]

Poincaré came to the conclusion that the Lorentz' transformations had a group character and agreed with the principle of relativity. He interpreted them as follows:

> Lorentz' idea can be summarised as follows: if one can, without any of the apparent phenomena being modified, impart a common translation to the whole system, it is because the equations of an electromagnetic medium are not altered by certain transformations, which we call the *Lorentz transformations;* two systems, one immobile, the other being translated, thus become the exact image of one another.[11]

In addition Poincaré drew attention to Lorentz' idea in which, trying to extend the sphere of action of the principle of relativity, he affirmed that this principle should hold with the existence not only of electromagnetic forces, but of all other natural forces, as well. Under the influence of this idea of Lorentz', Poincaré attempted to study the changes that Lorentz' hypothesis could introduce into the laws of gravitation.

> Is it possible to find a law [he asked] that satisfies the condition imposed by Lorentz, and at the same time is reducible to Newton's law every time the velocities of stars are small enough for their squares to be neglected (likewise the product of the accelerations by the distances) compared with the square of the velocity of Light? One must respond in the affirmative to this question, as we shall see later.[12]

In 1898 Poincaré, like several of his predecessors, expressed his view of the arbitrary character of such concepts of classical physics as 'absolute time', 'the simultaneity of two events', 'the equality of two intervals of time'. But he clearly understood that when we tried to measure physical time, we encountered great difficulties. First of all, it was impossible to take psycholog-

ical time as the standard of physical time. To measure physical time, he said, scientists usually employed a pendulum, but the amplitude of its swing was not a constant value because it depended on temperature, air resistance, and atmospheric pressure. A more exact measurement of the duration of time was got by the rotation of Earth around its axis. But that, too, Poincaré noticed, was not constant, according to scientists' statements. It could be affected by tides and the gravitational forces of other planets. But if our instruments were imperfect we could take the duration of two identical phenomena as the standard for measuring the time interval. In terms of time it should be the same. But since effects in physical reality were not generated by one cause, this determination of time, too, would be inexact, according to Poincaré, and so on.

One means of determining simultaneity, he said, could be the velocity of light, which physicists took to be a constant quantity. That postulate was conditional in his view, but it provided a new rule for quests for simultaneity.

In spite of the fact that Poincaré had found a new, convincing argument for criticising the Newtonian notion of time as an indicator of the constancy of the velocity of light, he nevertheless reduced it, in the spirit of his philosophical views, to a most 'convenient' rule which, like other definitions, was 'the fruit of an unrealised agreement' since neither the simultaneity nor the equality of two intervals of time could be determined directly or through intuition; rules therefore had to be resorted to, but there was neither a general rule nor a rigorous one; there was a host of partial rules employed in each separate case, and they were taken not because they were true but because they were the most convenient ones.

How important it was to turn to the postulate of the velocity of light for studying the concept of time is clear from Einstein's analysis of Mach's similar work devoted to study of the theoretical values of Newtonian physics. He drew attention to the fact that the defect of Mach's critique of Newton's notions of the absolute character of time was that it was not based on this postulate.[13]

Poincaré examined the defects of the hypotheses of local time and contraction introduced by Lorentz when he tried to reconcile his theory with experiment. Poincaré considered them unnecessary 'accumulations'.

> Everything thus seems in order, but are all the doubts dispelled? What would happen if we could communicate by signals that were not luminous and whose velocity of propagation differed from that of light? If, having set watches by the optical

> process, we wanted to check the timing by means of these new signals, we would record divergences that would bring out the joint translation of the two stations.[14]

All these facts, which indicated the need to alter several of the concepts and principles of classical physics, led Poincaré to conclude that it was necessary to create a new mechanics different from Newton's.

> Perhaps we must also construct a quite new mechanics ... in which, inertia increasing with velocity, the velocity of light would become an impassable limit. The more simple vulgar Mechanics would remain a first approximation, since it would be true for not very great velocities, so that we would still encounter the old Dynamics under the new.[15]

As we see, many of the ideas of the theory of relativity had been examined in Poincaré's works on the eve of its creation.

> In 1904 (Louis de Broglie wrote), on the eve of Albert Einstein's decisive works on this subject, Henri Poincaré had all the elements of the theory of relativity. He had investigated all the difficulties of the Electrodynamics of bodies in motion and he knew the contrivances that had been successively introduced under the title of Lorentz' local time and Fitzgerald's contraction... He had clearly seen that these fragmentary hypotheses, introduced arbitrarily one after the other, would have to give way to a general theory of which they would be only particular consequences... Poincaré knew the formulas of the relativist summation of velocities before Einstein.[16]

Why was Poincaré, who had done so much for the development of separate propositions that later became essential elements of the theory of relativity, unable to take the decisive step?

The amassing of empirical material, we know, leads as a rule to new generalisations, a new quality, and the discovery of phenomena that cannot be explained in the language of previous concepts. This creative process forces theoretical scientists to turn to philosophical knowledge broader in scope than physics. But not any philosophy can provide the answer to questions posed by nature. The philosophical ideas must above all objectively reflect the processes taking place in nature; otherwise inadequate ideas not only do not help the scientist, but lead him astray and confuse him. That is clear from examples of the attitude of positivist-minded scientists to atomic, molecular-kinetic, and other theories. As Engels wrote:

> ... the revolution which is being forced on theoretical natural science by the mere need to set in order the purely empirical discoveries, great masses of which have been piled up, is of such a kind that it must bring the dialectical character of

> natural processes more and more to the consciousness even of those empiricists who are most opposed to it.[17]

Like Einstein, Poincaré paid much attention to the philosophical problems of natural science. His books on philosophy like *La science et l'hypothèse, La valeur de la science, Science et methode,* and *Dernières Pensées* are well known.[18] His philosophical views, reflected in these works, differed sharply in substance from Einstein's outlook.

When Einstein analysed a scientific proposition from philosophical standpoints, he turned, often unconsciously, to the ideas of materialism and dialectics.

Here, for example, is how Einstein and Poincaré understood the essence of matter. Einstein, as we saw above, drew attention to the existence of two conceptions of the nature of the Universe, viz., the materialist one according to which the external world exists independently of consciousness, and the idealist one that makes nature dependent on the perceiving subject. In several of his works he condemned both the idealist interpretation of matter and that given by metaphysical materialism, and noted that belief in the existence of an external world independent of the perceiving subject underlay natural science.[19] But he saw that the concept of matter in metaphysical materialism was narrow, extended only to substance, and called for changes in the conception of reality. The electrodynamic field, he said, was as real as substance.[20] He criticised the views of those scientists who exaggerated the role of the subjective factor in the cognitive process.[21]

For Poincaré the external world was dependent on man's consciousness:

> ...a reality completely independent of the mind that conceives it, sees it, or feels it, is an impossibility. A world as external as that, even if it existed, would always be inaccessible to us.[22]

Poincaré, it is true, employed the term 'objective' in his works; let us see, however, what content he invested it with. For the materialist, 'objective' signified nothing other than existing independent of consciousness. For Poincaré objectivity meant something generally valid that could be transmitted by means of human reason:

> ...what is objective must be common to several minds, and consequently be able to be transmitted from one to another, and as this transmission can only be affected through this 'discourse' ... we are therefore forced to conclude: without discourse, no objectivity.[23]

What was this something common that functioned for Poincaré as objective? In his view the common something was not things but their relations. 'It is therefore this harmony that is the sole objective reality, the sole truth that we can attain.'[24] Lenin noted, when criticising this idea, that Poincaré

> ...in a purely subjectivist manner ... destroys objective truth, as do all the Machists. And as regards 'harmony', he categorically declares in answer to the question whether it exists *outside of us* 'undoubtedly, no'. It is perfectly obvious that the new terms do not in the least change the ancient philosophical position of agnosticism, for the essence of Poincaré's 'original' theory amounts to a denial (although he is far from consistent) of objective reality and of objective law in nature.[25]

When defining the essence of science Poincaré remarked that if things were inaccessible to man and the relations between them were the sole objective reality, then obviously only they should be the subject-matter of science.

> But what it can attain is not the things in themselves, as naive dogmatists think, but only the relations between the things; outside these relations there is no knowable reality.[26]

Such a philosophical position understandably led him to a profound agnosticism. The reduction of science simply to a description of phenomena or as he put it to the manner of bringing together separate facts, i.e. simply to their classification, resulted in his not believing in knowledge of the essence of physical objects. His analysis of science appeared therefore as follows:

> When a scientific theory, then, claims to teach us what heat or electricity, or life is, it is condemned in advance; all it can give us is only a rough picture. It is therefore provisional and transitory.[27]

And how did Einstein understand science? In spite of the view of positivists, he thought, as I noted above, that it was impossible to reduce physics simply to a description of external phenomena and to the establishing of connections between them. The aim of physics, he stressed, was to study the essence of objects and to penetrate the deep-seated processes of nature.

Unlike Poincaré he believed in the power of human reason and its capacity to penetrate to the essence of material objects. His faith in the knowability of the world was founded on his recognition of the conformity of nature's processes with law and their causal conditionality.

In Poincaré's view scientific concepts and theories did not reflect real processes of nature. The truths of science, he

considered, were a kind of symbol, conventional signs. When considering the relation of the theories of Fresnel and Maxwell he said:

> They [the differential equations *Ed.*] inform us, now as before, that there is such a relation between something and something else; only we used to call this something *movement*, and now we call it *electric current*. But these names are only images substituted for real objects that nature will eternally hide from us.[28]

Poincaré did not deny that it was necessary to resort to generalisations in order to discover a law of science, but the attempt to interpret the road to the discovery of a law by them turned on an irresolvable difficulty.

> Every particular truth can evidently be understood in an infinity of ways. We must make a choice, at least a provisional one, from among these thousands of ways that are open to us. But who will guide us in it? It can only be analogy.[29]

The mathematical mind, he considered, taught us to understand true analogies, and gave us the possibility of calling all substances that differed only in content by one and the same name.

Why, in that case, were scientific concepts, principles, and laws needed? What was their value? Poincaré rejected the established point of view of materialist scientists who assumed that the criterion of the scientific character of the propositions of physics was the degree to which they reflected the essence of the object studied. In his view these propositions only served the convenience of scientists. His standpoint was as follows: science foresees and that is why it can be useful and serve as a rule for action.[30]

Poincaré's philosophical outlook was his guide to philosophical evaluation of the physical and mathematical sciences. Analysis of classical mechanics had led him to the conclusion that its postulates

> amount in the last analysis to a simple convention that we have the right to make because we are certain in advance that there will be no experience to contradict it.[31]

A physical property of matter like mass was only a convenient coefficient, he considered, which it was useful for us to introduce into our calculations. He said the same about time: 'There is no way of measuring time that would be truer than another; what is generally adopted is only the most *convenient* one.'[32]

After Einstein had created the theory of relativity, Poincaré maintained his previous philosophical convictions about the essence of science. Speaking about the revolution that the new physics was bringing about, he remarked:

> What is our position going to be in view of these new conceptions? Are we going to be forced to modify our conclusions? Certainly not. We adopted a convention because it seemed to us convenient, and we said that nothing could compel us to abandon it. Today certain physicists want to adopt a new convention. It is not that they are obliged to do so; they judge this new convention to be more convenient, that is all. And those who are not of that opinion can legitimately maintain the old one so as not to upset their old habits.[33]

For Poincaré the theory of relativity did not open up the new perspectives in the content of time and space that most scientists saw in it. He considered that the new notions of time and space, like the old Newtonian understanding of them, were only conventions that we could accept or not. The same applied to the principle of relativity. He considered it, too, a convention.

How did Einstein interpret scientific concepts, principles, theories, etc? Contrary to the assertion of positivists, he supposed (as I have already said) that knowledge cannot arise from sense data alone, without resort to mental activity, just as theorising divorced from reality could not lead to true knowledge.[34]

For him the process of cognising the external world began with the formation of scientific concepts and passed to the creation of physical theories. Concepts were not identical with the aggregate of sensations and perceptions.[35] He suggested that concepts, principles, and theories were not symbols or signs but approximate reflections of reality, and that they were constantly being enriched with new content.[36] And he drew scientists' attention to the point that it was necessary to reexamine concepts and theories from time to time and to replace them by new ones, so changing the foundations of physical science.

Einstein had no doubt that physical propositions were closely linked with experience and that they reflected an external world. Unlike Poincaré he saw no sense in science without reflection of objective reality in theory. According to him the first demand on a theory was that it should not contradict experience:

> Without the belief that it is possible to grasp the reality with our theoretical constructions, without the belief in the inner harmony of our world, there could be no science. This belief is

> and always will remain the fundamental motive for all scientific creation.[37]

Einstein's philosophical analysis of the theory of relativity indicates that he interpreted it materialistically. He understood that there could be no concepts in physical science that could be established *a priori* and that could contradict the facts of nature.[38]

As for the propositions of mathematics, Poincaré presented them, like the concepts of physical science, in a distorted light. He did not agree with materialists who affirmed that geometry had an experimental origin. 'Is geometry derived from experience?' he asked. 'Deeper discussion will show us that it is not.'[39]

Poincaré doggedly maintained that the basic principles of geometry did not reflect reality but were only the conditions in which a scientist had to work, and that 'its principles are only conventions'.[40] Experience, he stressed, could not resolve the problem of choosing between the geometries of Euclid and Lobachevsky.[41]

If one follows Poincaré's maxims, it is impossible, as we see, to say anything about how exactly the geometries of Lobachevsky and Euclid reflect reality. They can only be regarded as geometries convenient or inconvenient for the scientist.

> ...our mind *is adapted* by natural selection to the conditions of the external world and has adopted the geometry *most advantageous* to space... That is absolutely conformable with our conclusions; geometry is not true, it is advantageous.[42]

Einstein looked upon these matters quite differently, as we have seen. In his view mathematics arose from the needs of practice.[43]

Mathematical propositions, he considered, reflected real processes observable by us in nature. He saw the reason why some scientists divorced geometrical propositions from reality in axiomatic geometry's having consigned the empirical basis of Euclidean geometry to oblivion.

According to Einstein a geometry could be true or false according to how faithfully it reflected the reality it studied.[44]

He saw one of the reasons why Poincaré could not arrive at discovery of the theory of relativity in the fact that the latter had not found the connecting thread between Euclidean geometry and reality. As a result Poincaré had considered it necessary to reject physical laws because he clung to the propositions of Euclidean geometry. It was that, in Einstein's view, which constituted Poincaré's error.

> If we reject the relation between the body of axiomatic Euclidean geometry and the practically-rigid body of reality [he wrote], we readily arrive at the following view, which was entertained by that acute and profound thinker, H. Poincaré: Euclidean geometry is distinguished above all other conceivable axiomatic geometries by its simplicity. Now since axiomatic geometry by itself contains no assertions as to the reality which can be experienced, but can do so only in combination with physical laws, it should be possible and reasonable whatever may be the nature of reality to retain Euclidean geometry. For if contradictions between theory and experience manifest themselves, we should rather decide to change physical laws than to change axiomatic Euclidean geometry. If we reject the relation between the practically-rigid body and geometry, we shall indeed not easily free ourselves from the convention that Euclidean geometry is to be retained as the simplest.[45]

Louis de Broglie expressed roughly the same idea of the reasons that prevented Poincaré from completing creation of a theory of relativity:

> Why didn't Poincaré get to the end of his thought? Undoubtedly it was the rather too hypercritical cast of his mind, due perhaps to his training in pure mathematics, that was the cause ... of his having a rather sceptical attitude toward physical theories, considering there to be an infinitude of different points of view and of various images that were logically equivalent, and between which the scientist chose only for reasons of convenience. That nominalism seems to have made him sometimes distrust the fact that, among the logically possible theories, it is those, however, that are closest to physical reality that are best adapted in any case to the physicist's intuition, and so better adapted to promote his efforts.[46]

De Broglie stressed that, although Einstein's mathematical knowledge might not have been comparable with Poincaré's profound understanding, nevertheless Einstein preceded Poincaré in finding a synthesis for all the separate views of the universe, at one stroke removing all the difficulties occurring in physics. De Broglie assigned a special place in the creation of the theory of relativity to the fact that Einstein was able to penetrate and profoundly understand the essence of physical reality. It was a 'master stroke of a vigorous mind guided by a profound intuition of *physical realities*! (my italics—*D. G.*)'[47]

Einstein and de Broglie thus, without naming Poincaré's philosophical views, came to the conclusion in the language of science that he held subjectivist positions when considering the essence of physical and mathematical propositions.

Poincaré, like Lorentz, clung to classical notions when interpreting the electrodynamics of moving bodies. He interpret-

ed the Lorentz transformations, for example, in the spirit of the electromagnetic field conception and was far from a relativist understanding of them. And that, perhaps, was the weakest spot in his doctrine. These physical mistakes, plus his philosophical position, prevented Poincaré, who had done so much to prepare the edifice of the theory of relativity, from understanding the whole depth of the new physics and taking the decisive step toward completing it.

What Lorentz and Poincaré did not succeed in doing, was done by Einstein. His success, it seems to me, depended largely on determination of the philosophical essence of the electromagnetic field. It was obvious to him that this new form of reality differed qualitatively from the usual particle objects of classical mechanics. But as with substance, whose material nature evoked no doubts among scientists, Einstein related the magnetic field to objective reality.[48] For a long time other physicists and philosophers could not establish the objective status of electromagnetic phenomena, but solution of that problem was of fundamental importance for creating the theory of relativity. Understanding of such phenomena as the independence of the velocity of light from inertial frames of reference depended on its solution. If the objects of electrodynamics existed objectively, then the phenomenon of the independence of the velocity of light must be classed as a material property. Einstein saw, however, that this contradicted the requirement of metaphysical materialism, for which the properties of a field did not fit into the concept of matter. Einstein's requirement of a replacement of the conception of reality was due precisely to that point. In contrast to a number of physicists he came to the conclusion that it was necessary to reexamine existing notions about matter.[49] The philosophical approach to analysis of electromagnetic phenomena was thus a necessary link in the series of steps leading to discovery of the theory of relativity. Without this approach to the problem of matter Einstein could not have found the fundamental physical basis (the independence of the velocity of light) from which the special theory of relativity arose.

Einstein drew attention as well to the principle of relativity developed in classical physics. Having extended it to the newly discovered laws of electromagnetic phenomena, he formulated a general principle of relativity according to which the laws of nature did not depend on the motion of the frame of reference.[50] It followed from the generalised principle of relativity that there were no phenomena in the objective

world that would indicate the existence of absolute motion, i.e. motion relative to absolute space, and that there were only relative movements, i.e. motions of some material objects relative to others.

The principle of the constancy of the velocity of light and the principle of relativity thus underlay the special theory of relativity.

> These two postulates suffice for the attainment of a simple and consistent theory of the electrodynamics of moving bodies based on Maxwell's theory for stationary bodies.[51]

Einstein's reference to these propositions of physics was due to the fact that they reflected real processes of nature and that they were the most fundamental properties connecting the two material spheres of the world, viz., field and substance. While the principle of the constancy of the velocity of light referred primarily to field matter, the principle of relativity extended to both material spheres; field and substance occurred in both mechanics and electrodynamics. It was this principle that, so to say, linked the two physics together, one of which had already been elevated into an absolute, while the other was still only being timidly developed, scientists trying in every way to squeeze it into the framework of the conceptual system established during the dominance of classical mechanics.

Since these principles had been substantiated experimentally, there were no grounds for rejecting either the one or the other. Nevertheless, they were incompatible from the standpoint of classical mechanics. In order to get round this incompatibility Einstein had to answer the following questions. Is the standpoint of classical mechanics absolute, or do its statements have a relative character and can be revised? If that is so, how far are its statements true? He successfully answered both. He rejected the view of Newton and his followers about the universal status of classical mechanics, demonstrated the illegitimacy of reducing all physics to mechanical laws, and established the limits of the latter's validity. Philosophy helped him do that. Analysis of the philosophical foundations of classical mechanics gave him the chance to chart the path of his quest for truth. By analysing physicists' conclusions about the impossibility of reconciling the principles of the constancy of the velocity of light and of relativity, he came to consider that these conclusions had come about because tacit assumptions had been made, which it was necessary to discard in order to reach a simpler understanding of things that

was not contradictory.

He understood that scientific concepts played a most important role in the development of theoretical physics. Law-governed connections could be established by means of them between the natural phenomena studied.

But he also knew something else, namely that scientific concepts were only approximate reflections of reality, that our knowledge was enriched as we penetrated more deeply into the essence of matter and our concepts themselves were consequently altered.

Einstein guessed that creation of the new physics had to begin with an analysis of the conceptual apparatus of classical mechanics. But such an analysis presumed investigation of the philosophical problem of the origin of scientific concepts in general. He made such an investigation.[52]

I said above that Einstein came across various contradictory statements about the origin of scientific concepts in his philosophical studies. Starting from the point that concepts reflected reality, but were not logically deduced from it, he proposed a unity of empirical, practical, and abstracted, rational reality. He censured the Hegelian and Kantian approaches to the problem of concepts, moreover, and also 'bare' empiricism, mataphysical limitedness, and the idea of the immutability of concepts. Those were the philosophical premisses from which he started when he critically analysed the conceptual apparatus of classical mechanics.

His analysis of the essence of Newton's mechanics led him to the conclusion that not all its concepts had been experimentally substantiated.

> We can indeed see from Newton's formulation of it that the concept of absolute space, which comprised that of absolute rest, made him feel uncomfortable; he realized that there seemed to be nothing in experience corresponding to this last concept. He was also not quite comfortable about the introduction of forces operating at a distance. But the tremendous practical success of his doctrines may well have prevented him and the physicists of the eighteenth and nineteenth centuries from recognizing the fictitious character of the foundations of his system.[53]

Einstein's conclusion was that the absolutising of time and space, and of the other definitions derived from them, sprang from the fact that the practical side of physical science had been at a comparatively low level of development.

> The illusion which prevailed prior to the enunciation of the theory of relativity that, from the point of view of experience the meaning of simultaneity in relation to spatially distant events

> and, consequently, that the meaning of physical time is *a priori* clear this illusion had its origin in the fact that in our everyday experience we can neglect the time of propagation of light. We are accustomed on this account to fail to differentiate between 'simultaneously seen' and 'simultaneously happening'; and, as a result, the difference between time and local time is blurred.[54]

Therefore,

> today everyone knows, of course, that all attempts to clarify this paradox satisfactorily were condemned to failure so long as the axiom of the absolute character of time, viz., of simultaneity, unrecognizedly was anchored in the unconscious.[55]

At the same time he drew the conclusion that the unsubstantiated character of the concepts of time and space in classical mechanics was historically justified. He considered that if it had been practically possible then to disclose their inadequacy for the processes of nature, that could have endangered the creation of classical mechanics.

> It was fortunate for the development of mechanics and hence also for the development of physics in general, that the lack of definiteness in the concept of objective time remained hidden from the earlier philosophers as regards its empirical interpretation. Full of confidence in the real meaning of the space-time construction, they developed the foundations of mechanics.[56]

Einstein linked success in discovering the special theory of relativity largely with breakdown of the notions of time and space accepted in physics. 'Clearly to recognise this axiom (of the absolute character of time and simultaneity—*D. G.*) and its arbitrary character really implies already the solution of the problem.'[57] And, in his conviction, philosophical knowledge played the key role in this solution. 'No one can deny to epistemologists,' he wrote, 'that they cleared the way here for development'.[58]

A scientific and philosophical analysis of the foundations of Newtonian mechanics led him to conclude that its concepts like 'simultaneity', 'moment of time', 'earlier', and 'later' could not be extended to all moving systems and the whole Universe. The same applied to making an absolute of the spatial notions of classical mechanics, if only because the velocity of light was finite. Let us assume that two electric lamps are flashing at two points A and B on Earth (on stationary platforms, say). Will these events (the flashes) seem simultaneous to observers located respectively at an immobile point of Earth (e.g. on a platform) and in a train moving past? Obviously they will seem simultaneous to the

observer on the platform when the beams of light from lamps A and B reach him simultaneously. Let him be located at point C midway between A and B. But what will the passenger in a train moving past say when he comes alongside the stationary observer? He will say that the lamp at point B, toward which he is moving, flashed earlier than the lamp at point A that he is travelling away from, since the train is moving toward the beam coming from point B, and getting further away from that coming from point A. The observer in the train will say that the events on Earth did not occur simultaneously. Which is right? According to Einstein's theory both are right, because absolute simultaneity does not exist for all frames of reference. In this case, the events are simultaneous in relation to the platform and not simultaneous in relation to the train. Every body of reference has its own time so that the course of time always has to be related to some material system. Non-relative, absolute time passing at an identical rhythm throughout the Universe, i.e. exactly the kind of time postulated by Newton, simply does not exist. The magnitude of the time interval between two events depends on the state of motion of the material system in which it is considered. Time is closely linked with motion.

By analysing the concept of the spatial distance between two points in moving and stationary systems Einstein demonstrated the interconnection of space and motion. Let us assume that we have to measure the length of a body located in a moving train. By laying a measuring rod on the body being measured the experimenter who is in the train easily gets the desired result. The length of the body will coincide with the number of intervals marked off in the selected unit of length. But let us now try to measure the body's length when we are outside the train, on the embankment, for example. For that purpose we shall have to observe the instant when its ends coincide with the position of the immobile observer, or to measure the section of the railway that coincided with the length of the body at a certain moment of time of the stationary observer. We will have no grounds to expect the results of the measurements in the train and on the embankment to be identical. For time passed differently in the different (rest and moving) frames of reference.

Einstein thus refuted the two following hypotheses of classical physics on which the Newtonian notions of absolute time and space rested: (a) the interval of time between two events does not depend on the state of motion of the body of reference;

(b) the distance between two points of a body does not depend on the state of motion of the body of reference. His working analysis of the concepts of time and space entailed revision of the theory of the transformation of time and spatial co-ordinates, since that was the scientific theoretical basis on which the metaphysical doctrine of the attributes of matter rested. According to the classical theory the transition from one inertial frame of reference to another was made by means of the Galilean transformation equations: $x' = x - vt$; $y' = y$; $z' = z$; $t' = t$. The equation $t' = t$ expresses the immutability here of Newtonian absolute time. It follows from it that time is not linked either with space or with matter, and passes identically throughout the Universe in any frame of reference. It also follows from the Galilean transformation equations that an interval of space also does not alter in various inertial frames of reference. Having passed from a moving system to an immobile one by means of these equations we find that $l' = l$. That is valid for all inertial systems.

Not satisfied with the transformation equations of classical physics, considering them suitable only for the partial case of low velocities, Einstein introduced new transformation equations of co-ordinates and space:

$$x' = \frac{x - vt}{\sqrt{1 \quad v^2/c^2}};\ y' = y;\ z' = z;\ t' = \frac{t - v/c^2 x}{\sqrt{1 - v^2/c^2}} \qquad (1)$$

He arrived at them by extending the principle of relativity to electromagnetic phenomena. These equations are called the Lorentz transformation equations in honour of their author, though Lorentz himself, being trapped by the Newtonian notion of absolute time and space, did not understand their true physical sense, considering the form of the transformation for time fictitious since it did not accord with the Newtonian doctrine of time.

Einstein demonstrated the continuity of classical mechanics and the theory of relativity. If we rejected the principle of the constancy of the velocity of light and took it that this velocity was much in excess of any velocity with which ordinary macroscopic bodies could move, we would then obtain the Galilean transformation equations instead of the Lorentz ones.

Acquaintance with the mathematical formalism of the special theory of relativity helps bring out the physical sense of time and space and to confirm the correctness of the dialectical-materialist doctrine of time and space as attributes of matter.

The Lorentz transformation equations witness to the existence of a profound objective link between time and space. In the formulas (1) the spatial co-ordinates depend on the time one and the latter, on the contrary, on the spatial ones. It also followed from the Lorentz equations that space and time were linked with motion. That was shown by the dependence of the spatial and time co-ordinates on the relative velocity of motion of inertial systems. Analysis of the formula of the transformation of time in various systems of co-ordinates leads to a conclusion that the notion of time in classical physics, in which it has an absolute character, is unsound. According to the theory of relativity, each system of co-ordinates has its own time, which depends on the system's velocity of motion. The quantitative dependence of the spatial dimensions of bodies on the velocity of their motion also follows from the theory of relativity. The length of a moving body can be expressed as follows: $l' = l\sqrt{1 - v^2/c^2}$. It follows from this that a body's spatial dimensions are not an absolute quantity, but alter in accordance with its velocity in relation to a stationary observer. A body is longest when at rest in relation to its frame of reference. Its dimensions will contract as its velocity rises.

Such a pattern also occurs in the passage of time. When we employ the transformation equations of the theory of relativity to compare intervals of time in stationary and moving systems we get the equation $\Delta t' = \Delta t\sqrt{1 - v^2/c^2}$ where Δt and $\Delta t'$ are respectively the time intervals in moving and stationary systems. The time interval proves to be a variable quantity changing in accordance with the body's velocity. The temporal rhythm slows $\frac{1}{\sqrt{1 - v^2/c^2}}$ times with increase in the body's velocity. It passes most rapidly in a stationary system.

The special theory of relativity thus undermined the Newtonian metaphysical notion of time and space. While it had previously been held that bodies existed in time and space, the theory of relativity demonstrated that a change in the velocity of a thing led to a change in its space-time characteristics. Summing up the achievement of the theory of relativity in development of the doctrine of time, space, and motion, Einstein wrote:

> The special theory of relativity has led to a clear understanding of the physical concepts of space and time and in connection with this to a recognition of the behavior of moving measuring rods and clocks. It has in principle removed

> the concept of absolute simultaneity and thereby also that of instantaneous action at a distance in the sense of Newton. It has shown how the law of motion must be modified in dealing with motions that are not negligibly small as compared with the velocity of light.[59]

The special theory of relativity made it possible consistently to interpret the theory of electromagnetic processes differently. As Einstein wrote:

> It has led to a formal clarification of Maxwell's equations of the electromagnetic field; in particular it has led to an understanding of the essential oneness of the electric and the magnetic field.[60]

The natural connection of mass and energy $E = mc^2$ following from the special theory of relativity is of enormous significance for science and practice. According to this theory the mass of a body increases with an increase in its velocity. Einstein expressed the proposition that if the accretion to the mass of a moving body was due to its kinetic energy, the mass proper of a stationary body was connected with an energy which, however, though hidden from us, was the internal energy of the body. Einstein's theory thus indicated the inseparable connection of matter and motion.

Einstein considered that the special theory of relativity, 'from a *formal* point of view' (my italics—*D. G.*)

> has shown generally the role which the universal constant c (velocity of light) plays in the laws of nature and has demonstrated that there exists a close connection between the form in which time on the one hand and the spatial coordinates on the other hand enter into the laws of nature.[61]

One may add that from the *content,* physical point of view, this theory demonstrated the role that the discovery of field matter and its properties played in the development of physical science. It linked the two material spheres of the objective world—substance and field—physically, and through that link expressed previously unknown space-time properties of matter.

NOTES

[1] Albert Einstein. On the method of theoretical physics. In: *Ideas and Opinions by Albert Einstein.* Based on *Mein Weltbild.* Translated by Sonja Bargmann (Grown Publishers, New York, 1954), p. 271.

[2] Albert Einstein. Isaac Newton. In: *Out of My Later Years* (Philosophical Library, New York, 1950), p. 222.

[3] Albert Einstein. H. A. Lorentz, creator and personality. In: *Ideas and Opinions,* p 75.

[4] Albert Einstein. Autobiographical notes. In: P. A. Schilpp (Ed.), *Albert Einstein: Philosopher Scientist* (The Library of Living Philosophers, Evanston, Ill., 1949), p 35.
[5] P. P. Lazarev. Hendrik Antoon Lorentz. In: *H. A. Lorentz. Starye i novye problemy fiziki* (Nauka, Moscow, 1970), p 248.
[6] Albert Einstein. H. A. Lorentz, creator and personality. *Op. cit.*, p 75.
[7] Max Planck. *Physikalische Abhandlungen und Vorträge,* Vol. 3 (F. Vieweg und Sohn, Brunswick, 1958), p 346.
[8] Max Born. *Ausgewählte Abhandlungen.* Vol. 2 (Vandenhoeck und Ruprecht, Göttingen, 1963), p 609.
[9] See *Oeuvres de Henri Poincaré*, Vol. 9 (Gauthier-Villars, Paris, 1954), pp 494 495.
[10] *Ibid.*, p 495.
[11] *Ibid.*
[12] *Ibid.*, p 497.
[13] See Albert Einstein. Ernst Mach. *Physik. Zeitschrift,* 1916, *17*: 103-104.
[14] Henri Poincaré. L'état actuel et l'avenir de la physique mathématique. *Bulletin des sciences mathématiques,* 1904, 2nd series, *28*, 1: 312.
[15] *Ibid.*, p 324.
[16] Louis de Broglie. In: *Oeuvres de Henri Poincaré,* Vol. XI, (Gauthier-Villars, Paris, 1956), p 65.
[17] Frederick Engels. *Anti Dühring* (Progress Publishers, Moscow, 1975), p 18.
[18] I am not concerned with his concrete methodological investigations of scientific thought.
[19] See Albert Einstein. Maxwell's Influence on the Evolution of the Idea of Physical Reality. In: *Ideas and Opinions*, p 266.
[20] See Albert Einstein and Leopold Infeld. *The Evolution of Physics* (CUP, Cambridge, 1938), p 158.
[21] See Albert Einstein. Reply to criticism. In: P. A. Schilpp (Ed.), *Op. cit.*, p 674.
[22] Henri Poincaré. *La valeur de la science* (Flammarion, Paris, 1905), p 9.
[23] *Ibid.*, p 262.
[24] *Ibid.*, p 10.
[25] V. I. Lenin. *Materialism and Empirio Criticism* (Progress Publishers, Moscow, 1977), p 148.
[26] Henri Poincaré. *La science et l'hypothèse* (Flammarion, Paris, 1923), p 4.
[27] *Idem. La valeur de la science*, p 267.
[28] Henri Poincaré. *La science et l'hypothèse,* p 190.
[29] *Idem. La valeur de la science*, p 142.
[30] See *Ibid.*, pp 57 58.
[31] Henri Poincaré. *La science et l'hypothèse*, pp 162-163.
[32] *Idem. La valeur de la science*, p 44.
[33] *Idem. Dernières pensées* (Flammarion, Paris, 1913), p 54.
[34] Albert Einstein. Physics, philosophy and scientific progress. *The Journal of the International College of Surgeons,* 1950, *14*, 6: 757 758.
[35] *Idem.* Remarks on Bertrand Russell's theory of knowledge. In: Paul A. Schilpp (Ed.). *The Philosophy of Bertrand Russell* (Northwestern Univ., Evanston, Ill., 1944), p 287.
[36] See Einstein's preface to M. Planck. *Where Is Science Going?* (Allen & Unwin, London, 1933), p 12.
[37] Albert Einstein and Leopold Infeld. *Op. cit.*, p 312.
[38] See Albert Einstein. *Lettres à Maurice Solovine* (Gauthier-Villars, Paris, 1956), pp 20, 21.
[39] Henri Poincaré. *La science et l'hypothèse,* p 5.
[40] *Ibid.*
[41] *Ibid.*, p 95.

[42] *Ibid.*, p 109.
[43] *Albert Einstein. Geometry and experience. In: Ideas and Opinions,* p 235.
[44] *Ibid.*, pp 237 238.
[45] *Ibid.*, pp 235-236.
[46] Louis de Broglie. Henri Poincaré and physical theories. *Art. cit.*, p 66.
[47] *Ibid.*
[48] See Albert Einstein and Leopold Infeld. *Op. cit.*, pp 148 156; Albert Einstein. Maxwell's influence on the evolution of the idea of physical reality. *Op. cit.*, p 266.
[49] See Albert Einstein. Physics, philosophy and scientific progress. *Art. cit.*, p 756.
[50] See Albert Einstein. Über das Relativitätsprinzip und die aus demselben gezogenen Folgerungen. *Jahrbuch der Radioaktivität und Elektronik,* Vol. 4, 1907 (Verlag von S. Hirzol, Leipzig, 1908), p 454.
[51] Albert Einstein. On the electrodynamics of moving bodies. In: H. A. Lorentz, A. Einstein, H. Minkowski and H. Weyl. *The Principle of Relativity.* Translated by W. Perrett and G. B. Jeffery (Dover Publications, New York, 1923), p 38.
[52] See Einstein's preface to Max Planck. *Op. cit.*, pp 11 12; and his following articles: On the method of theoretical physics. Physics and reality. The fundamentals of theoretical physics (in: *Ideas and Opinions,* pp 274, 290-291, 323-324); his remarks on Bertrand Russell's theory of knowledge in: Paul A. Schilpp (Ed.) *The Philosophy of Bertrand Russell,* p. 287; and his autobiographical notes in: Paul A. Schilpp (Ed.) *Albert Einstein: Philosopher Scientist,* pp 15 17.
[53] Albert Einstein. On the method of theoretical physics. In: *Ideas and Opinions,* p 273.
[54] *Idem.* Physics and reality. In: *Ideas and Opinions,* p 299.
[55] *Idem.* Autobiographical notes. In: Paul A. Schilpp (Ed.). *Albert Einstein: Philosopher Scientist,* p 53.
[56] *Idem.* Physics and reality. In: *Ideas and Opinions,* p 299.
[57] *Idem.* Autobiographical notes. *Op. cit.*, p 53.
[58] *Idem.* Ernst Mach. *Art. cit.*, p 102.
[59] *Idem. Out of My Later Years* (Philosophical Library, New York, 1950), p 44.
[60] *Ibid.*
[61] *Ibid.*, p 45.

4

The Development of the General Theory of Relativity

The general theory of relativity, like the special theory, was prepared by preceding research. It was a logical development of the special theory of relativity, in which the work of Minkowski played an important role. Einstein himself stressed:

> The generalising of the theory of relativity was greatly facilitated by the form that the special theory of relativity was given by Minkowski, the mathematician who first clearly recognised the *formal* equivalence of the spatial co-ordinates and the time co-ordinate and utilised it for construction of the theory.[1]

A previously developed special mathematical apparatus was also a precondition of creation of the general theory of relativity. As Einstein noted:

> The mathematical means needed for the general theory of relativity lay ready to hand in the 'absolute differential calculus' that was grounded in the investigation of Gauss, Riemann, and Christoffel into non-Euclidean geometries and systematised by Ricci and Levi-Civita, and already applied to problems of theoretical physics.[2]

The general theory of relativity arose through extension of the principle of relativity to the gravitational field. Einstein understood that gravitation, like electromagnetism, was a field area of the material world. Its properties, like those of electromagnetism, were not something seeming for him, some subjective phenomenon, but were manifestations of matter that he had to take into account when studying the structure of the material world. Finally, the development of the general theory of relativity was a consequence of generalisation of experimental facts already known, such as the equivalence of inertial and gravitational mass. That had been discovered quite a long time before, during study of the properties of gravitation. In that connection Einstein stressed that

> in contrast to electric and magnetic fields, the gravitational field exhibits a most remarkable property, which is of fundamental importance for what follows. Bodies which are moving under the sole influence of a gravitational field receive an

> acceleration, *which does not in the least depend either on the material or on the physical state of the body.*[3]

The theoretical generalisation of those observations led him to establish the principle of equivalence. Thus, while the special theory of relativity arose from study of the properties of the electromagnetic field, which followed from the constancy of the velocity of propagation of light, creation of the general theory was stimulated by discovery of the fact of the equivalence of inertial and gravitational mass.

First of all Einstein tried to extend the principles of the special theory of relativity to the gravitational field. That led him to the conclusion that it was impossible to explain the properties of gravitation satisfactorily within its context. In fact, it followed from the special theory that the inertial mass of a body increased in proportion to the increase in its velocity. Its gravitational mass, consequently, should also increase by virtue of the equivalence of inertial and gravitational mass. But this last conclusion could not be explained within the framework of the special theory. A way out of its limits was required. A new theory was needed. In that connection Einstein wrote:

> That the special theory of relativity is only the first step of a necessary development became completely clear to me only in my efforts to represent gravitation in the framework of this theory.[4]

He also drew attention to the limited character of the principle of relativity developed by him in the special theory in connection with the description of electromagnetic processes. This principle affirmed that there were no preferred systems among ones moving uniformly in a straight line, and that they were all equivalent as regards formulation of the laws of mechanics and electrodynamics. The principle of relativity of the special theory, Einstein concluded, thus held only in inertial systems. But in actual fact other systems also existed that were in accelerated, slow-speed, circular, and rotational motion. Was the principle valid for systems of that kind? Einstein admitted that his first acquaintance with this question yielded a negative answer. In non-inertial systems we necessarily perceived phenomena of the acceleration or slowing down of the moving body. Later, however, the idea came to him that these perceptions were not necessarily connected with changes in the velocity of the system; they could be the consequence of the action of gravitational forces. As evidence

for the validity of this surmise he cited the following mental experiment.

He imagined two experimenters sitting in a closed, moving room, who did not know either their location in world space or their state of movement. How could they determine what was happening to them: was their room in motion or in a state of rest? They could try dropping various objects onto the floor. If they fell, then one of the experimenters had the right to say that their quarters were at rest on some celestial body, and the objects were drawn by this body toward its centre. But the other experimenter could equally rightly say that their laboratory was moving in cosmic space with an acceleration due to some mechanical force. The objects retained their state of rest as a result of inertia and only created an impression of falling.

Was there a criterion that could enable the dispute to be settled? Citing Ötvös' experiment, Einstein said that there was none. He concluded from the fact of the equality of inertial and gravitational mass, proved by this experiment, that all processes occurred in a uniform gravitational field in the same way as in a space in which there was no gravitation, but which had an equivalent field of inertial forces generated by uniformly accelerated motion. The indistinguishability of the effects of inertia and gravitation thus suggested that an inertial system with a uniform gravitational field was physically equivalent to a certain non-inertial system. And that already gave grounds for extending the principle of relativity to non-inertial systems.

> The fact of the equality of inert and heavy mass thus leads quite naturally to the recognition that the basic demand of the special theory of relativity (invariance of the laws under Lorentz-transformations) is too narrow, i.e. that an invariance of the laws must be postulated also relative to *non linear* transformations of the co-ordinates in the four-dimensional continuum.[5]

By means of the general principle of relativity, according to which all frames of reference, including non-inertial ones, are equivalent as regards description of nature, Einstein passed to study of yet another form of field matter, i.e. gravitation. He argued as follows. The space-time development of a certain natural process is known to the researcher. This process takes place in Galilean space (without a field of gravitation), relative to a Galilean body of reference K. The course of this process relative to a body of reference K', moving with acceleration relative to body K, can then be determined by simple calculations. But, Einstein wrote,

> since a gravitational field exists with respect to this new body of reference K, our consideration also teaches us how the gravitational field influences the process studied.[6]

We may find, for example, that the body moving uniformly in a straight line relative to K is moving with acceleration and, generally speaking, curvilinearly relative to K'. The magnitudes of the acceleration and curvature quantitatively represent the influence that the gravitational field existing relative to the body of reference K' exerts on the moving body. The influence of the gravitational field on the motion of bodies had previously been known, of course, but the fundamentally new result connected with the general theory of relativity was that gravitation acted on electromagnetic radiation: '*...in general, rays of light are propagated curvilinearly in gravitational fields*'[7] (my italics—*D. G.*).

This theoretical conclusion was of interest to Einstein in two respects. It could be tested experimentally. According to his calculations the bending of rays of light in the Sun's gravitational field would be 1.7 seconds of arc. The phenomenon could be observed during a total eclipse of the Sun; it would seem to us that stars near the Sun were shifted by that amount in relation to their real position. Einstein drew attention to the fact that

> the examination of the correctness or otherwise of this deduction is a problem of the greatest importance, the early solution of which is to be expected of astronomers.[8]

And in fact the effect he predicted was confirmed by British scientists with a high degree of accuracy during the eclipse of the Sun in 1919. That date was the beginning of the triumph of the theory of relativity.

In addition, the fact of the bending of the trajectory of a ray of light in a gravitational field was evidence that the law of the constancy of the velocity of light in *vacuo*, which was one of the main principles of the special theory of relativity, had a relative character. It compelled us to ponder over the limits of the application of the special theory. The sphere of its operation, like that of the operation of classical mechanics and all other physical theories, was limited to a certain framework. As Einstein wrote:

> We can only conclude that the special theory of relativity cannot claim an unlimited domain of validity; its results hold only so long as we are able to disregard the influences of gravitational fields on the phenomena (e.g. of light).[9]

Thus Einstein, employing the principle of equivalence, came to discover such an important property of gravitation as its influence on the course of electromagnetic as well as of mechanical processes. But that was only the first step in a study of this form of field matter.

> But the most attractive problem, to the solution of which the general theory of relativity supplies the key, concerns the investigation of the laws satisfied by the gravitational field itself.[10]

To solve this problem Einstein had to reexamine the Euclidean notions of time and space of the special theory of relativity. He demonstrated the direction of this review by the following mental experiment. Let us imagine a disc rotating at a constant angular velocity as a non-inertial frame of reference. Its axis of rotation coincides with the axis of a stationary inertial system. If we now put two clocks on the disc, respectively at the centre and on the periphery, they will travel at different rates, since the outside one is moving and the inner one is at rest. The temporal rhythm of the clock moving together with the disc, on its periphery, will slow down in proportion to its distance from the centre of the disc, but will accelerate the closer it is to the centre. Since, according to the principle of equivalence, a non-inertial system is indistinguishable physically from an inertial one with a corresponding uniform gravitational field, it can be concluded that the gravitational field must also affect the working of the clock. In other words the temporal metrics must depend on the effect of gravitational forces.

This mental experiment also served Einstein as proof of the influence of gravitation on the metrics of space. For the lengths of measuring rods fastened to a rotating disc tangential to its circumference and along its radius should differ by virtue of the fact that moving bodies are contracted from the point of view of a stationary observer.

Einstein satisfied himself in this experiment that the laws of the geometry of solid bodies in non-inertial systems were not in agreement and were not Euclidean. The example showed him that the propositions of Euclidean geometry had a relative character, and that its application was limited to a certain framework. Thus, he stressed,

> this proves that the propositions of Euclidean geometry cannot hold exactly on the rotating disc, nor in general in a gravitational field, at least if we attribute the length 1 to the rod in all positions and in every orientation. Hence the idea of a straight line also loses its meaning. We are therefore not in a position

> to define exactly the co-ordinates x, y, z relative to the disc by means of the method used in discussing the special theory.[11]

Space and time thus could not be defined in a non-inertial system by the means assumed by the special theory of relativity for inertial systems. Another mathematical principle, different from Euclidean geometry, and a new generalisation of the concepts of time and space were needed. It took Einstein no little time to find a geometry adequate to the reality he encountered when studying the phenomena of gravitation. Study showed that there was such a geometry, for decades before, mathematicians (Lobachevsky, Riemann, and others) had shown the possibility of other, non-Euclidean geometries. Einstein employed their achievements. Use of analysis, philosophical analysis included, of the principles of mathematics, and of geometry in particular, helped him in this.

Einstein was aware that indisputable faith in Euclidean geometry had been engendered by nothing else than the confirmation of its propositions in practice. At the same time he also saw something else, namely that it was necessary to reexamine both the notion of geometrical operations itself and the interpretation of the essence, subject-matter, and origin of mathematics. He stressed that

> one reason why mathematics enjoys special esteem, above all other sciences, is that its propositions are absolutely certain and indisputable, while those of all other sciences are to some extent debatable and in constant danger of being overthrown by newly discovered facts.[12]

In fact, its primary concepts like 'point', 'straight line', 'plane', etc., were not deduced directly from reality, being the result of the abstracting activity of the mind. On the other hand, however, the theorems of geometry that met practical needs, were deduced logically from axioms that were statements about these abstractions. Why then, Einstein asked,

> can it be that mathematics, being after all a product of human thought which is independent of experience, is so admirably appropriate to the objects of reality? Is human reason, then, without experience, merely by taking thought, able to fathom the properties of real things?[13]

Einstein sought the answer to these questions in the axiomatics of geometry, which distinctly demarcated the objective and logically formal. By disengaging itself from the concrete content it treated the relations between its ideal objects.

> This view of axioms advocated by modern axiomatics, purges

> mathematics of all extraneous elements, and thus dispels the mystic obscurity which formerly surrounded the basis of mathematics. But such an expurgated exposition of mathematics makes it also evident that mathematics as such cannot predicate anything about objects of our intuition or real objects. In axiomatic geometry the words 'point', 'straight line', etc., stand only for empty conceptual schemata. That which gives them content is not relevant to mathematics.[14]

At the same time geometry owed its origin to the needs of practice. The term itself means nothing else than measurement of the spatial characteristics of earthly objects. Rods, rules, triangles, and other rigid bodies were needed, of course, for such measurements. But axiomatic geometry was not concerned with the behaviour of real objects. So that it could solve matters with a content, as well as formal logical problems, its axioms and concepts therefore had to be juxtaposed with objects of experience and practical operations on them. It was sufficient, for that, to assume that real, rigid bodies behaved like the objects of Euclidean geometry. That simple assumption had already made geometry a natural science. Now it contained statements that did not simply rest on logical deductions but also related to experimental facts. This 'practical geometry' as Einstein called it, solved physical and astronomical problems connected with measurement.

> I attach special importance [he wrote] to the view of geometry which I have just set forth, because without it I should have been unable to formulate the theory of relativity. Without it the following reflection would have been impossible: in a system of reference rotating relatively to an inertial system, the laws of disposition of rigid bodies do not correspond to the rules of Euclidean geometry on account of the Lorentz contraction: thus if we admit non-inertial systems on an equal footing, we must abandon Euclidean geometry. Without the above inter pretation the decisive step in the transition to generally covariant equations would certainly not have been taken.[15]

Einstein showed, at the same time, that the separation of axiomatic Euclidean geometry from its ties with practical operations on rigid bodies inevitably led to conventionalism. As I said above, Poincaré came to the conclusion, starting from the point that Euclid's geometry was the simplest compared with other axiomatic geometries, that it had to be given preference even if it were necessary to alter the laws of physics artificially in order to maintain its validity. Einstein saw Poincaré's mistake; for the latter geometry was an abstract science that did not reflect any real physical facts, and any axiomatic geometry could be used in principle, in his view,

to describe these facts. All the more so, Poincaré thought, because it had long been known that physical bodies and media altered their spatial characteristics under the influence of thermal, electrical, magnetic, and other disturbances.

Einstein remarked about this that in principle he could agree with Poincaré, for there were no really rigid bodies in fact in nature that met the requirements of measuring operations in the theory of relativity. But the objection that there were no such bodies in nature and that the properties ascribed to them did not correspond to physical reality

> is by no means so radical as might appear from a hasty examination. For it is not a difficult task to determine the physical state of a measuring-body so accurately that its behavior relative to other measuring-bodies shall be sufficiently free from ambiguity to allow it to be substituted for a 'rigid' body.[16]

It was necessary to have just such measuring bodies in mind when speaking of rigid bodies.

Einstein thus agreed with Poincaré that the concept of a rigid body was quite conventional and had the status of a relative truth but, unlike Poincaré, he suggested that it reflected an objective content. He agreed with Poincaré that from a principled point of view there were really no objects in nature absolutely identical to the concept of measuring rods. But he denied that it was impossible to find objects in nature that could meet the requirements of standards for measuring length (and duration) with a degree of accuracy justified by the needs of practice. It followed from Poincaré's point of view that what was not absolute had a relative character, was not objective, and could not be employed as a standard of measurement.

A careful epistemological analysis of the relation of geometry and physics led Einstein to conclude that the use of measuring rods and clocks within certain limits to determine space-time properties did not contradict the laws of Euclidean geometry, but that we could not extrapolate the concepts of 'practical geometry' to spaces of cosmic dimensions.

> According to the view advocated here, the question whether this continuum has a Euclidean, Riemannian, or any other structure is a question of physics proper which must be answered by experience, and not a question of a convention to be chosen on grounds of mere expediency.[17]

As we know, Einstein linked construction of the theory of gravitation with Riemann's geometry, which he did, not because that geometry proved more convenient than others, but because he saw an adequate reflection in its propositions of the

physical properties of the objective world on a cosmic scale. In this connection Max Born wrote:

> If we would choose a special non-Euclidean geometry of this kind to represent the physical world we should simply be substituting one evil for another. Einstein went back to the physical phenomena, namely, the concept of space-time coincidence or the event represented by a world point.[18]

The general theory of relativity made it possible for Einstein to solve the difficulties existing in Newton's mechanics. In classical mechanics, of course, as in the special theory of relativity, the laws of nature are invariant not in any system but only in those that move uniformly in a straight line. As Einstein wrote,

> I seek in vain for a real something in classical mechanics (or in the special theory of relativity) to which I can attribute the different behaviour of bodies considered with respect to the reference-systems K and K′. Newton saw this objection and attempted to invalidate it, but without success.[19]

Einstein's theory of gravitation provides a satisfactory interpretation of the bending of rays of light in the gravitational field of the Sun, in the light of the law of the equivalence of gravitational and inertial mass. The motion of the planet Mercury was explained by means of it. In the last century the slow rotary motion of its orbit had been observed, which it was endeavoured to explain by the effect of the heavy planets, primarily Jupiter, on Mercury. But the appropriate calculations based on the Newtonian theory of gravitation did not agree with the observed effect. The classical theory of gravitation could not explain this deviation.

> On the basis of the general theory of relativity, it is found that the ellipse of every planet round the sun must necessarily rotate in the manner indicated above; that for all the planets, with the exception of Mercury, this rotation is too small to be detected with the delicacy of observation possible at the present time.[20]

The general theory of relativity made a substantial contribution to the physical theory of time and space. From it, for example, it follows that 'the gravitational field influences and even determines the metrical laws of the space-time continuum'.[21] In the general theory of relativity the metrics and gravitation proved to be identical in a certain sense because they were ultimately determined by the distribution of masses. As Einstein wrote, 'according to the general theory of relativity, the geometrical properties of space are not independent, but

they are determined by matter'.[22] In spite of Newton's view, space proved to be non-uniform; it was deformed by the influence of gravitation. The denser material objects are the greater is the distortion of the space around the bodies. The gravitational field also determines the rhythm of time. The more massive cosmic bodies exert a stronger effect on slowing its rhythm, and vice versa.

Discovery of the fact that the mass of bodies determines the geometric structure of time and space indicated the existence of an organic link between time, space, and matter. While this link was determined in the special theory of relativity solely by external material factors (it depended on the relative position and movement of the material bodies), in the general theory inner connections were discovered and it was shown that the metrics of the space-time continuum depended on the distribution of matter in the Universe. The theory of dialectical materialism about time and space as forms of the existence of matter thus not only received scientific confirmation but also was given further development.

The general theory of relativity has found wide application in cosmology. The discovery of gravitation and study of its laws had introduced a certain degree of order into cosmology. The material connecting thread between cosmic bodies had been found that made it possible to get rid of the fantastic inventions that had abounded in the cosmological and cosmogonic doctrines of the Ancients and of mediaeval natural philosophers. Recognition of the existence of material cosmic objects and of the forces operating between them suggested study of problems like the finiteness and infinity of the Universe, and the density of its matter.

Einstein's theory of gravitation made it possible to give a more substantiated answer to the question of the structure of the Universe that agitated both scientists and other thinkers. The Newtonian cosmological doctrine according to which there was a great concentration of stars at the centre of the Universe, while their density decreased with distance from the centre, no longer suited scientists.

> This conception [Einstein wrote] is in itself not very satisfactory. It is still less satisfactory because it leads to the result that the light emitted by the stars and also individual stars of the stellar system are perpetually passing out into infinite space, never to return, and without ever again coming into interaction with other objects of nature. Such a finite material universe would be destined to become gradually but systematically impoverished.[23]

Basing himself on the physical evidence of the material conditionality of space-time properties, Einstein made a bold attempt to determine the geometrical structure of the visible part of the Universe. If the velocity of motion of cosmic bodies was small compared with the velocity of light, he suggested, the former could be ignored and cosmic material objects could be considered nearly at rest. Since the influence of gravitation, or of the distribution of matter, on space and time was also known, the geometrical properties of the latter could not be Euclidean in the stellar world (the Euclidean structure being deformed by the effect of material bodies). Taking the mean density of matter in the Universe as other than zero, and the distribution of matter uniform, Einstein concluded that the world was a finite spherical formation.

> The universe [he wrote] would necessarily be spherical (or elliptical). Since in reality the detailed distribution of matter is not uniform, the real universe will deviate in individual parts from the spherical, i.e., the universe will be quasi-spherical. But it will be necessarily finite. In fact, the theory supplies us with a simple connection between the space expanse of the universe and the average density of matter in it.[24]

His model of the Universe was static.

This cosmological model suffered from an essential defect. So that the object corresponding to it would not collapse through the effect of gravitational forces, Einstein had to assume the existence of certain hypothetical forces of repulsion in the Universe (i.e. to introduce a cosmological term into his equations of the gravitational field). But further research disclosed the non-obligatory character of several of his suppositions about the structure of the Universe. The Soviet scientist A. A. Friedman showed that one of these assumptions was the hypothesis of the stationary character of the Universe, and the invariance of its radius in time. He theoretically substantiated the dynamic character of the Universe, and pointed to its expansion. The world, according to him, was not a closed system.

Einstein wrote then, apropos of Friedman's research:

> My original reflections on the subject were based on two hypotheses:
> (1) there is a mean density of matter throughout space, differing from zero, which is everywhere the same;
> (2) the magnitude (i.e. 'radius') of space is independent of time.
> These two hypotheses together proved compatible with the general theory of relativity, only if one added a hypothetical term to the field equations that was neither required by the theory itself nor appeared natural from the theoretical standpoint...

> Already in the 20s, however, the Russian mathematician Friedman discovered that a different assumption was natural from a purely theoretical standpoint. He perceived precisely that it was possible for hypothesis (1) to be retained without introducing an unnatural cosmological term into the equations of the gravitational field, if one decided to drop hypothesis (2). The original field equations admitted of a solution precisely in which the 'world radius' depended on time (expanding space). In that sense one can say with Friedman that the theory requires an expansion of space.[25]

Friedman's theoretical conclusion obtained several experimental confirmations. The red shift of the spectral lines of cosmic objects was one. The amount of this shift was proportional, in accordance with the Hubble constant, to the distance of the object from the point of observation (the shift itself is explained by the Doppler effect). This inhomogeneity of the magnitude of the shift is evidence of a dispersing of the galaxies. (There are other interpretations of the red shift, it should be noted. One is based on Einstein's prediction that the gravitational field influences the length of electromagnetic waves, which increases in proportion to growth of the field's intensity).

The observations initiated by Friedman's conception of an expanding Universe led in turn to the assumption that the visible part of the Universe was formed as the result of a 'big bang'. According to this hypothesis the metagalaxy was once a superdense point body. Several hypotheses of the character of the Universe's evolution appeared on that score. Some scientists claim that the dispersing of the galaxies is an eternal process. Others consider that the Universe is pulsating (oscillating), in which case the stage of expansion would give way to a reverse process of collapse after a certain time, as a result of which the galaxies would merge into a single material formation which will lead once more to a 'big bang' and repetition of the cycle of expansion.

An answer to the question of the character of the evolution of the Universe should be provided by the resultant of the mean density of matter in it; if it is greater than or equal to 10^{-29} g/cm^3, that would mean, in accordance with relativistic cosmology, that the process of dispersal of the galaxies would cease after a certain time and the reverse movement begin. But if the density is less than this critical value, the galaxies will disperse forever. The whole complexity of the experimental investigations required for this depends on how fully all the real states and forms of matter in the Universe are taken into account. Today particle matter is mainly

studied, and field matter much less, but there are no grounds for thinking that the material world is represented just by these forms. It is not excluded that the physical vacuum or neutrino, which have given physicists one surprise after another in recent years, will reveal new stores of matter.

The idea of the 'big bang' (and through it Friedman's conception) has recently had an important new confirmation. In 1965 the physicists Penzias and Wilson, trying to eliminate radio noise from a receiving installation, came to the conclusion that it was impossible to do so. The noise, it turned out, was due to some background radiation filling the whole Universe, which had a relict character and, it was suggested, developed as a consequence of the 'big bang'.

The 60s gave a new impetus to development of the theory of relativity. Discoveries were made one after the other, that again attracted close attention to this theory. In 1963 quasars were discovered. The properties of these astronomical objects did not fit into the framework of existing notions. Quasars are receding from us at very great velocities and, moreover, emitting colossal energy. Modern science is still unable to provide an unequivocal answer about their nature and behaviour. Later, in 1967 cosmic material formations given the name of 'pulsars' were found, which radiate electromagnetic waves of high intensity at quite definite intervals of time. It is supposed that they are neutron stars.

The discovery of pulsars is evidence that stars, like the Universe as a whole, are evolving. Gravitation affects them, constantly altering their qualitative state. The immense temperatures and pressures within them create conditions for the synthesis of chemical elements, a process that gradually leads to loss of their energy and to cooling. As a result a moment may set in when non-gravitational forces are unable to check the forces of gravitation, which will compress the star more and more. For bodies whose mass is less than 1.5 times that of the Sun, compression will continue until the electrons of the shells of atoms, that counteract the compression, stop the process. Stars of that mass are transformed into white dwarfs, whose existence was previously known to science. But if the mass of a star is greater than this magnitude, the forces of counteraction of the electron shells of atoms will be unable any longer to check the pressure of gravitation. Under its effect they will be disrupted and the electrons compressed into protons, which leads to the formation of neutrons. A neutron object (pulsar) arises, the space and

time of which are strongly deformed by the gravitational field. Elementary particles (photons included) have difficulty in leaving the surface of neutron stars. If the mass of a star is several times greater than that of the Sun, however, it would be subjected to the action of a force of gravitation that would break down even the nucleus of atoms. The matter of the star would then pass into a state that is a sort of 'energy trap' that has been called a 'black hole'. The field of gravitation of black holes is so great that no material objects, including quanta of light, can break away from them.

In proportion as the size of a cosmic body decreases, as a result of its gravitational compression the passage of its own time slows down. The passage of time stops completely when this body reaches a critical size equal to its gravitational radius. The gravitational radius of the Sun is 3 km, that of Earth 8 mm. But a body's reaching of its gravitational radius is not the limit of compression; after this point is reached gravitational collapse sets in, a catastrophic compaction that brings the body to a superdense state.

Study of the evolution of the visible part of the Universe, including stars, has led to a revolution of sorts in astronomy that has evoked a need to reject many accustomed concepts. An acute need has arisen in philosophical analysis of such concepts as the Universe, its 'initial' moment, and its radius, and of the concepts 'megaworld', 'microworld', etc. It would seem that science is coming to a conclusion today about the relativity of the concepts of a macrocosmos and microcosmos. Many physicists are inclined to think that knowledge of the structure and properties of neutrons will help study celestial bodies, e.g. pulsars, which in turn can be regarded as a 'macroscopic form of nuclear matter'.

NOTES

[1] Albert Einstein. *Die Grundlage der allgemeinen Relativitätstheorie* (Barth, Leipzig, 1916), p 5.
[2] *Ibid.*
[3] *Idem. Relativity. The Special and General Theory.* Translated by Robert W. Lawson (Hartsdale House, New York, 1947), p 76.
[4] *Idem.* Autobiographical notes. In: Paul A. Schilpp (Ed.). *Albert Einstein: Philosopher-Scientist* (Library of Living Philosophers, Evanston, Ill., 1949), p 63.
[5] *Ibid.*, p 67.
[6] Albert Einstein. *Relativity*, p 87.
[7] *Ibid.*, p 88.

[8] *Ibid.*, p 89.
[9] *Ibid.*, p 90.
[10] *Ibid.*, p 91.
[11] *Ibid.*, p 97.
[12] Albert Einstein. Geometry and experience. In: *Ideas and Opinions*, p 232.
[13] *Ibid.*, p 233.
[14] *Ibid.*, p 234.
[15] *Ibid.*, p 235.
[16] *Ibid.*, p 237.
[17] *Ibid.*, p 238.
[18] Max Born. *Einstein's Theory of Relativity* (Dover Publications, New York, 1962), p 334.
[19] Albert Einstein. *Relativity*, pp 85 86.
[20] *Ibid.*, p 123.
[21] Albert Einstein. *The Meaning of Relativity* (Methuen, London, 1950), p 59.
[22] *Idem. Relativity*, p 135.
[23] *Ibid.*, p 126.
[24] *Ibid.*, pp 136 137.
[25] Albert Einstein. *Über die spezielle und die allgemeine Relativitätstheorie (gemeinverständlich)* (F. Vieweg & Sohn, Brunswick, 1972), pp 86 87.

5

The Philosophical Essence of Relativistic Physics

The theory of relativity, I said above, like any physical theory aroused heated interest in literally all philosophical trends and schools. It has been subjected to all-round philosophical analysis, and the conclusions drawn from its ideas are very contradictory. What, in my view, is the philosophical content reflected by the special and general theories of relativity?

First of all, relativistic physics more and more strongly stresses the genetic link of physical science as a whole, while the content and methods of physics themselves point to the material unity of nature. The theory of relativity did not, in fact, arise of itself on bare ground, but was the result of Einstein's critical interpretation of existing physical knowledge. He understood that every new scientific theory is a step toward fuller knowledge. It was not by chance that he denied the absolutism of Newton's doctrine, criticising its separate propositions, and at the same time paid its due to classical mechanics as a science adequate to reality within certain limits. That was his approach, too, to the research of Faraday, Maxwell, and of the direct forerunners of the theory of relativity, Lorentz and Poincaré. Apropos of that he wrote as follows:

> The special theory of relativity is an adaptation of physical principles to Maxwell-Lorentz electrodynamics. From earlier physics it takes the assumption that Euclidean geometry is valid for the laws governing the position of rigid bodies, the inertial frame and the law of inertia. The postulate of equivalence of inertial frames for the formulation of the laws of Nature is assumed to be valid for the whole of physics (special relativity principle). From Maxwell-Lorentz electrody namics it takes the postulate of invariance of the velocity of light in a vacuum (light principle).[1]

In spite of the theory's being the completion of several trends of physical science, it is not, however, absolute truth and is only a stage in understanding the infinite properties and profundities of nature. While it solved a number of

theoretical problems, it presented new problems whose solution called for departure from its limits. Whereas Newton's doctrine was taken as ultimate truth for decades, Einstein showed, immediately after completion of work on creating the theory of relativity, that it was relative truth. He indicated the road, moreover, that physics would have to follow if it wanted to answer the problems posed by the theory of relativity. He objected many times to opponents who tried to present matters in such a way that the special theory of relativity was refuted by the general theory, and that there was no connecting thread between his theories and those of preceding physics. In that connection he pointed out, for example, that the link between the special and the general theory came out within the limits of the action of Earth's gravitation field.

> For an infinitely small area the co-ordinates can always be so taken that no gravitational field exists in it. The special theory of relativity may then be presumed to be valid for such an infinitely small area. In that way the general theory of relativity will always be linked with the special theory and the results of the latter can be made applicable to the for mer.[2]

The discoveries of physics of recent decades have indicated the limitation of the general theory of relativity and deprived it of its status of incontestable truth. The need for a new theory of gravitation to replace the general theory of relativity stems, for example, from the impossibility of giving a physically satisfactory interpretation of the phenomena of singularity by means of it. The material processes taking place beyond the event horizon can seem absurd in the present-day language of science. It is to be hoped, however, that this position, which leads to 'paradoxical', 'absurd' results, will be temporary when physics has studied these new phenomena. As the history of science indicates, and scientific philosophy confirms, such contradictions are inevitable, and are most likely caused by inadequacies in the available scientific arsenal but tend to be overcome.

The theory of relativity has had an enormous influence on scientists' outlook. It brought out the law-governed character of the universe more profoundly than classical physics did. The Newtonian notion of the world has largely been altered through the influence of Einstein's physical theory, and a picture of the world has grown up in which matter, motion, time, and space, previously considered disconnected and separate, are united. This theory was an immense qualitative step forward in interpretation of the structure of the

Universe. While physics had made relatively little advance in the period between Newton and Einstein in its study of the Universe, and the latter had been regarded (even by Einstein!) as something stationary, relatively quiescent and undeveloping, the contribution of the general theory of relativity was a veritable revolutionary explosion in cosmology, which has had two peaks, one linked with the first experiments that confirmed the conclusions of the only just created general theory of relativity and the second with the discovery in the 60s of a number of important structural elements of the Universe that reinforced and developed the conclusion about its evolution. These discoveries were prepared by the revolution in experimental technique.

Individual scientists claim, when interpreting the theory of relativity, that it does not stem from study of the objective properties of nature. In fact, however, analysis of the fundamentals of the theory indicates that it arose from study of the objective properties of the material world. Its empirical origin is obvious; underlying the special theory are the principles of relativity and constancy of the velocity of light, which were the result of generalisation of much experimental material; underlying the general theory is the principle of the equivalence of gravitational and inertial mass. The objectivity of the theory of relativity is also established by the agreement of its theoretical conclusions with experimental data and the application of these conclusions in practice. In fact, the special theory is not just, by right, the theoretical foundation of modern physics; it is impossible to tackle many concrete research and engineering problems today without it. Relativistic effects are not a mathematical device and not the subjective views of an observer. The interpretation of the space-time properties of matter with allowance for them makes it possible to explain many natural phenomena. The special theory is successfully employed today in atomic and nuclear physics and in the physics of elementary particles. Only it can explain, for example, why short-lived pi-mesons formed in the upper layers of the atmosphere succeed in reaching the surface of Earth, flying dozens of kilometres in so doing. For if it were not for relativistic effects, pi-mesons could only fly a distance of a few metres during their life. Atomic power engineering and the accelerator installations of the physics of elementary particles are simply inconceivable without the theory of relativity. The experimental validity of the general theory also does not evoke

any doubts. It already has a number of experimental arguments to its credit. Without the relativistic theory of gravitation it is impossible to explain many phenomena discovered in recent years by astrophysics.

One can find statements in the literature that the theory of relativity has removed the question of the absolutes of physical science. But more careful study shows that this is not so. It does not follow from the theory that it disregards absolute quantities and reduces all quantities to relativity. Max Planck, and even earlier Minkowski, said that this theory did not deny absolute quantities at all. As Planck wrote:

> The absolute is not uprooted in the much misunderstood theory of relativity; on the contrary it has attained even sharper expression in it since physics is based everywhere in that respect on an absolute underlying the external world.[3]

In actual fact a whole number of absolute quantities (only new ones!) have been disclosed in the theory of relativity that were previously not known to science. Indeed, although this theory reduced separate concepts that used to be considered absolutes to the relative, it thereby disclosed the laws of nature more profoundly. Without recognition of absolutes there could be no forward movement of science. In physics there has been a reinterpreting and reassessment of concepts and principles, a refining of the limits of their applicability, degree of generality, precision, etc. That has also brought out the dialectics of the cognitive process of many-sided reality.

There is a widely held view in the Western literature that philosophical subjectivist ideas of various kinds are the methodological basis of the theory of relativity. Let us recall what physicists themselves, including Einstein, think on that score.

You can find statements in Einstein's works that the subjectivist approach cannot lead to any success in understanding nature.

> Science searches for relations which are thought to exist independently of the searching individual. This includes the case where man himself is the subject; or the subject of the scientific statements may be concepts created by ourselves, as in mathematics. However, all scientific statements and laws have one characteristic in common; they are 'true' or 'false' (adequate or inadequate).
>
> The scientific way of thinking has a further character istic. The concepts which it uses to build up its coherent systems do not express emotions. For the scientist, there is only 'being', but no wishing, no valuing, no good, no evil...
>
> There is something like a Puritan's restraint in the scientist

> who seeks truth: he keeps away from everything voluntaristic or emotional.[4]

When drawing attention to Emile Meyerson's comparison of the theory of relativity with the systems of Descartes and Hegel, Einstein wrote, incidentally:

> The human spirit is not content to pose relations, it wants to *understand*; and the superiority of Relativity over the two preceding conceptions is due, according to M. Meyerson, to its quantitative precision and to its adaptation to many experimental facts.[5]

Even more clear, however, was Max Born's answer on this point. 'It [the theory of relativity],' he wrote, 'is a pure product of the striving after the liberation of the ego, after the release from sensation and perception.'[6]

It does not follow from the theory of relativity that matter depends on consciousness, as is constantly written.

One often comes across statements that the special theory of relativity refutes the thesis of the uncreatability and indestructibility of matter. In that respect reference is made to the famous equation of the relation of energy and mass $E = mc^2$, from which this statement is claimed to follow.

In my view there are no serious grounds for that conclusion. The misunderstanding here arises from the existence of competing interpretations of the concepts that comprise this equation, i.e. matter, mass, and energy. These concepts are often confused, which leads to conclusions about the 'disappearance' of matter and its conversion into energy. Dialectical materialism draws attention to the erroneousness of confusing philosophical and physical concepts. Matter is a philosophical category that is not connected with the concrete physical concepts which, as I showed above, were inherent in metaphysical materialism. The philosophical concept of matter reflects only one property, objectivity, i.e. the capacity to exist independently of our consciousness. Mass and energy are physical properties. Mass is the measure of inertia and gravitation, energy is the common measure of various kinds of motion of matter. In Einstein's formula the point concerns mass, not matter. It therefore does not follow from it that matter is transformed into energy; the equation is an expression only of the quantitative relation of mass and energy.

A recognition of 'the disappearance of matter' sometimes comes as well through distortion of the notion of the material essence of electromagnetic and other fields held by the old view of matter as a substantial substratum. Such physical

phenomena as the interconversion of fields and elementary particles, and annihilation, are depicted as processes of the disappearance of matter and its conversion into energy. In fact there is a conversion in the microworld of matter that is in the state of substance into matter that is in the state of field. But electromagnetic and other fields are material objects, just like elementary particles (substance).

The contradictory interpretations of these natural phenomena by various philosophers disturbed Einstein. It is conceivable that these facts pushed him to reconsider the metaphysical concept of matter. He repeatedly pointed out the reality of the field, discovery of which had led to the formation of a new trend in physics differing from classical mechanics.

As for statements about energy as substance, which allegedly succeeded matter, there is nothing new about them. Attempts had already been made before the appearance of the theory of relativity to separate the concepts of matter and energy, but they did not stand the test of time and led only to absurdities.

It also does not follow from the theory of relativity that time and space are subjective forms of contemplation, as is often said in the philosophical literature. This theory discovered new properties of time and space, and pointed out their profound link with each other and with matter. It thus confirmed that time and space are nothing else than forms of the existence of matter. Einstein, characterising the objectivity of space, wrote:

> Considered, then, from the point of view of sense experience, the development of the concept of space seems, after these brief indications, to conform to the following scheme solid body; spatial relations of solid bodies; interval; space. Looked at in this way, space appears as something real in the same sense as solid bodies.[7]

The existence of nature in space, and also in time, measured in thousands of millions of years before the genesis of the human race and human experience, indicates the absurdity of the theory that they are subjective forms of human contemplation.

Individual scientists, by making an absolute of the concept of space, came to the conclusion that the theory of relativity allegedly led to dissolution of physical magnitudes in the concept of space. That conclusion was noted by Einstein.

> [Meyerson] when examining the revolution brought about by the new theories from the philosophical point of view, saw in it a manifestation of a trend already noted by previous

> scientific progress, but more obvious still here, a tendency to reduce the 'diverse' to its simplest expression, that is to say to its dissolution in *space*.[8]

In Einstein's view that was not a legitimate conclusion from the theory of relativity:

> That this complete reduction which was Descartes' dream is impossible in reality, is what M. Meyerson has shown in the theory of relativity itself.[9]

There is another view, close to this one, which claims that the concepts of time and space lose their independence in the theory of relativity and merge into a single whole. The pretext for views of that type was provided by Minkowski's interpretation of the theory of relativity who deemed it possible to make statements in the following vein:

> Henceforth space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality.[10]

Einstein, the author of the theory of relativity, considered this conclusion to distort the theory's real content.

> Time and space are well grounded in one and the same *continuum*, but it is not isotropic. The characteristics of the element of spatial distance and those of the element of duration remain distinct from one another, and that is so in the formula that gives the square of the interval of the universe between two infinitely close events.[11]

Some scientists, when referring to the general theory of relativity, have attributed substantial properties to geometry, suggesting that physics does not reflect material processes, and that its propositions are completely reducible to geometry. In actual fact the general theory brought out the very close link between geometry and physics. Einstein affirmed that it united geometry and the theory of gravitation in a single whole.[12]

Making an absolute of the mathematical formalism of the general theory of relativity, having divorced it from its physical content, led individual scientists to conclude that there was no difference from its standpoint whether we thought that a ship moved relative to the quay or the quay relative to the ship, whether we thought that Earth rotates around the Sun or the Sun around Earth. It has been claimed that Ptolemy's system is physically equivalent to that of Copernicus.

I must note that the statements of Einstein and Leopold Infeld in their *Evolution of Physics* provided the excuse for such statements; in it they wrote when analysing the possibility of discovering physical laws for non-inertial systems:

> Can we formulate physical laws so that they are valid for all CS, not only those moving uniformly, but also those moving quite arbitrarily, relative to each other? If this can be done, our difficulties will be over. We shall then be able to apply the laws of nature to any CS. The struggle, so violent in the early days of science, between the views of Ptolemy and Copernicus would then be quite meaningless. Either CS could be used with equal justification. The two sentences, 'the sun is at rest and the earth moves', or 'the sun moves and the earth is at rest', would simply mean two different conventions concerning two different CS.[13]

In the same book, however, we also find another interpretation of the relations of the Ptolemaic and Copernican systems. While stressing that there were no grounds for preferring the one system of co-ordinates to the other, Einstein and Infeld at the same time wrote:

> Physics again intervenes and changes our commonsense point of view. The CS connected with the sun resembles an inertial system more than that connected with the earth. The physical laws should be applied to Copernicus' CS rather than to Ptole my's. The greatness of Copernicus' discovery can be appreciated only from the physical point of view. It illustrates the great advantage of using a CS connected rigidly with the sun for describing the motion of planets.[14]

Comparison of these quotations shows the authors' vagueness in expressing their thoughts. It is clear, however, that they did not identify the mathematical formalism of the theory of relativity with its physical interpretation. Evidence of that is the fact that Infeld later wrote that he wanted to remove one of the many misunderstandings in the interpretation of the theory of relativity, when it was sometimes said that relativity denied the difference between the theories of Copernicus and Ptolemy, and that they were one and the same from its standpoint. Remarks of that kind were caused either by misunderstanding or by incomprehension. Popularisers who did not express themselves precisely enough were in fact guilty of it, but in any case no one who had studied the theory of relativity could come to such a conclusion. As for the mathematical structure of the theory, invariance meant, in fact, that the concept of a system was not necessary, and that there was no difference from the standpoint of the mathematical treatment, between the systems of Ptolemy and Copernicus. But things looked quite different as regards the physical content.

The mathematical description of such a concrete fragment of reality as the motion of a planet, the motion of two bodies,

the bending of light rays, is quite objective and relates either to the system associated with the Sun or to the system connected with the centre of mass, i.e. to the Copernican systems.[15]

Finally, the theory of relativity gave a marked impulse to naturalists' (especially physicists') interest in the philosophical problematic, and showed the need for a methodological and epistemological analysis of the conceptual apparatus of physical science. As Einstein wrote: 'It enforced the need for a clarification of the fundamental concepts in epistemological terms.'[16] For it, together with quantum physics, was a new stage in the revolutionary breaking of the concepts of classical physics, and affected an even broader range of scientific concepts than quantum physics. Its field of view took in not only concepts directly connected with matter, like those of field, substance, ether, mass, etc., it also revolutionised notions about time, space, and motion. The general theory of relativity touched on cosmological questions. The content of many of the scientific concepts of classical physics, characterising the structure of the Universe, were largely altered under its impact. In addition the theory of relativity made big changes in the methodological notions of physics.

The distortions of the substance of its ideas listed above had epistemological causes. They included the mathematising and relativity of our knowledge, as Lenin brought out when analysing the reasons for the crisis of physics at the beginning of the century. The theory of relativity in fact drew on a complicated mathematical apparatus that did not reflect objective reality directly. The thread binding its theoretical propositions with the material world was lost in a maze of mathematical formulae, and it required the help of philosophical thinking to find it. The mathematising of physical knowledge compelled scientists who took a not very firm materialist stand to equate the physical conclusions of the theory with its formal relationships. They regarded the concepts of frame of reference, trajectory of a body's motion, etc., in isolation from reality, as concepts without objective content.

The other reason that led to denial of the objective character of the content of physical ideas is explained in dialectical materialism. In fact, starting from the proposition of the inexhaustibility of the properties of matter, and its infinity in depth (which has been quite convincingly confirmed by physics), it follows logically that our knowledge must be altered from time to time. Each structural level of the

material world, and change in the conditions in which one and the same material process takes place, open new ideas up to us about the properties of matter. It does not follow from that, however, that the previous knowledge completely loses its adequacy and does not reflect real natural processes. It is only approximate knowledge and includes objective information about a certain structural level of the material world. It is necessary, of course, to distinguish between the relative character of knowledge and errors and misconceptions. While the former implies that a theoretical proposition is only true within certain limits and in certain conditions, the latter are propositions mistakenly taken for objective truth. The theory of relativity deepened knowledge about time and space. The special theory deprived time and space of their absolute meaning and ended their isolation from one another. The general theory showed that space and time are not only connected with one another but also with matter. Taken separately they have a relative status, and the idea of time-space-matter alone has an absolute character. That does not mean, however, that each of these concepts taken separately lost its objective properties in the theory of relativity and depended entirely on the observer's standpoint. In Einstein's view

> space and time were thereby divested [in the theory of relativity] not of their reality but of their causal absoluteness i.e., affecting but not affected which Newton had been compelled to ascribe to them in order to formulate the laws then known.[17]

One can agree with those authors who consider that the epistemological source of the seeming negation of objective reality is also the logic of the exposition of the theory of relativity.[18] As a rule the construction of a physical theory begins with an analysis of matter and material connections, and then deduces certain properties from that, including space-time ones. In the case of the theory of relativity this logic is usually not observed. If matter and material connections had been initially in the field of view of the authors who expounded the essence of the theory, and then the space-time relations themselves, it would not have led individual scientists to subjectivism when considering the theory of time and space.

Even Einstein himself focused attention in his first and succeeding works on the theory on the inertial system of co-ordinates and the relative manifestations of time-space in various inertial systems. He often, moreover, invoked an observer, using

such expressions as 'seeming' time-space. He did not always fix attention, moreover, on matter and material links as the causes determining space-time properties and relations. This dependence of the latter, it goes without saying, was primary for Einstein. In his doctrine he started from recognition of objective reality and the material nature of the electromagnetic field. That is clearly demonstrated, for example, by his foreword to Max Jammer's book *Concepts of Space*, in which, when analysing the two conceptions of space—the Newtonian and the Leibnizian—he linked their roots and grounds with a different understanding of the structure of matter. He also said that the concept 'time' should precede the concept 'material object'.[19] One can only regret that he expounded his views on the reality of substance and field in isolation from the basic works on the theory of relativity.

Another reason leading to distortion of the theory of relativity was the terminological inexactitude of which Einstein himself, as well as popularisers, was often guilty. As I have already pointed out, he was not always rigorous in his use of one scientific term or another. Expressions borrowed from positivist philosophy, too, can be found in his works; for example, he sometimes used the term 'mass' instead of 'matter'. When discussing the conversion of substance into field, he wrote that matter was converted into energy. He frequently abstracted material links and spoke only of the links between sensations, stressing the role of the observer, measurement, etc. All that also gave a pretext for interpreting the propositions and concepts of the theory of relativity in a distorted form.

NOTES

[1] Albert Einstein. Fundamental ideas and problems of the theory of relativity (Lecture delivered to the Nordic Assembly of Naturalists, July 11, 1923). In: *Nobel Lectures Including Presentation Speeches and Laureates' Biographies. Physics, 1901 1921* (Elsevier Publ. Co., Amsterdam, 1967), p 484.

[2] *Idem.* Die Relativitätstheorie. In: E. Lecher (Ed.). *Physik* (Verlag von B. G. Teubner, Leipzig, 1925), p 795.

[3] Max Planck. Wege zur physikalischen Erkenntnis. In: *Reden und Vor träge von Max Planck*, Vol. 1 (Verlag von S. Hirzel, Leipzig, 1943), p 112.

[4] Albert Einstein. The laws of science and the laws of ethics. Foreword to Philipp Frank. *Relativity. A Richer Truth* (The Beacon Press, Boston, Mass., 1950), pp v-vi.

[5] *Idem.* A propos de 'La déduction rélativiste' de M. Émile Meyerson.

Rêvue philosophique de la France et de l'êtranger, 1928, *105*, 1/2: 164.

[6] Max Born. *Physics in My Generation* (Pergamon Press, London & New York, 1956), p 5.

[7] Albert Einstein. The problem of space, ether, and the field in physics. In: *Ideas and Opinions by Albert Einstein* (Crown Publishers, New York, 1954), pp 278-279.

[8] *Idem.* A propos de 'La déduction rélativiste' de M. Émile Meyerson. *Art. cit.*, p 165.

[9] *Ibid.*

[10] H. Minkowski. Space and time. In: H. A. Lorentz *et al. The Principle of Relativity* (Dover Publications, New York, 1923), p 75.

[11] Albert Einstein. Apropos of "La déduction rélativiste' de M. Émile Meyerson. *Art. cit.*, p 165.

[12] See *Die Neue Rundschau* (Berlin), 1925, 1: 20.

[13] Albert Einstein and Leopold Infeld. *The Evolution of Physics* (Simon and Schuster, New York, 1942), p 224.

[14] *Ibid.*, p 223.

[15] See L. Infeld. *Twórczość*, (Warsaw, 1955), p. 41. See also *Einshtein i sovremennaya fizika* (Einstein and Modern Physics), Gostekhizdat, Moscow, 1956, p 237.

[16] Albert Einstein. Fundamental ideas and problems of the theory of relativity. In: *Nobel Lectures*, p 485.

[17] *Idem.* The Mechanics of Newton. In: *Ideas and Opinions*, p 260.

[18] See *Filosofskie problemy sovremennogo estestvoznaniya* (Philosophical Problems of Modern Science. Proceedings of the All-Union Meeting on Philosophical Problems of Science), Moscow, 1959, pp 97 103.

[19] Max Jammer. *Concepts of Space. The History of Theories of Space in Physics.* Foreword by A. Einstein (Harvard U. P., Cambridge, Mass., 1954), p 14.

Conclusion

Analysis of the problems studied above leads to the following conclusions. Einstein should be considered a consistent defender of the union of philosophy and science.

There are no grounds for accusing him of a denial of materialism in general. While criticising the metaphysical and mechanistic limitation of Premarxian materialism, he also saw its strong points. He counted affirmation of the material unity of the world, the causal conditioning of natural phenomena, the ideas of atomic theory, the knowability of the world, propositions, etc., to be great achievements of materialism. But he also saw the limitedness of metaphysical materialism. From study of the works of the founders of classical mechanics (Copernicus, Kepler, Galileo, and Newton), the ideas of electrodynamics, and other problems of science, he came to the conclusion, that later became his conviction that it was necessary to turn to dialectics. His philosophical outlook was not only moulded by the influence of science, but also by a critical reinterpreting of the propositions of Greek philosophy and metaphysical materialism, and by the ideas of dialectics from various philosophical systems. His outlook was clearly displayed in his evaluation of the works of classical mechanics, electrodynamics, his interpretation of the essence of causality, scientific concepts, and theories, the relationship of absolute and relative truth, the empirical and the rational, etc. Einstein can be numbered among the intuitive materialists and dialecticians.

Study of his works has shown that there are no grounds for accusing him of Berkeleianism, Machism, neopositivism, conventionalism, theology, etc. His philosophical views were not identical with any one of these systems. He turned to their aid in order to borrow individual propositions of dialectics. The works of Berkeley, Hume, and Kant helped him overcome the idea of the metaphysical counterposing of the empirical and rational in knowledge. Mach interested Einstein because of his historical, critical works in which he was one of the first to overthrow the absolutes of classical mechanics and point out the relative character of its concepts and principles. The 'cosmic religion' about which Einstein wrote expressed nothing else than the creative impulse, the fanaticism that a scientist needed in his work.

Matter must also be included, along with time, space, and motion, in the scientific and philosophical premisses of the theory of relativity, in contrast to the generally accepted view, when only the last three categories are considered. The two opposing trends in the development of the doctrine of time and space in the history of physics and philosophy are ultimately linked respectively with study of the properties of matter found in the state of substance and field. The sources and foundation of the theory of relativity must be transferred to the plane of regarding material connections and not just space-time relations, and approached not only from the experiments of Fizeau and Michelson, but also from the experimental and theoretical generalisations of Faraday and Maxwell. That approach helps one to see Einstein's theory not only from the quantitative, mathematical aspect but also from the qualitative, and to resolve the old dispute about priority in its discovery.

Methodologically it is sometimes expedient to regard physical science as divided into two stages of development, linking them respectively with study of the properties of particle and field matter. Einstein must be considered one of the founders of the doctrine of field as an independent sphere of the material world, which had an immense influence on development of the theory of relativity.

The theory of relativity arose through Einstein's unconscious use of the basic ideas of materialism and dialectics. It follows from its content that the physical laws formulated in it correspond fully to the philosophical conclusions that had earlier been drawn by dialectical materialism in regard to the categories of time and space.

The theory of relativity had a stimulating effect on the marked turn of physics toward a philosophical problematic. It led to a revolutionary breaking up of scientific concepts, and indicated the need for a methodological and epistemological analysis of the conceptual apparatus of physical science. Not only problems connected directly with matter, like field, substance, ether, mass, etc., proved to be within the theory's field of view; it also revolutionised notions about time, space, and motion, and introduced radical changes into cosmological and cosmogonic problems and the treatment of a number of concrete physical concepts.

The theory of relativity, as no other field of knowledge, has confirmed Lenin's scientific conclusion that modern physics was giving birth to dialectical materialism.

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Professor D. P. Gribanov, D. Sc. (Phil.), is a leading Soviet scholar in the realm of the philosophical problems of physics, who has taken part in many international philosophical congresses and symposia. He is the author of several monographs on the theory of relativity, some of which have been translated into various languages. His most important works (in Russian) are: *The Material Unity of the World in the Light of Modern Physics* (1976), *Materialism and Dialectics in Einstein's Scientific Work* (1979), *The Philosophical Basis of the Theory of Relativity* (1982), and *Philosophical Problems of the Theory of Relativity* (1984).

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D. P. Gribanov

Einstein's Philosophical Views

پڑهندڙ نَسُل . پ ن

The Reading Generation

1960 جي ڏهاڪي ۾ عبدالله حسين " اُداس نسلين" نالي ڪتاب لکيو. 70 واري ڏهاڪي ۾ وري ماڻڪ "لُڙهندڙ نَسُل" نالي ڪتاب لکي پنهنجي دورَ جي عڪاسي ڪرڻ جي ڪوشش ڪئي. امداد حُسينيءَ وري 70 واري ڏهاڪي ۾ لکيو:

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ايندڙ نسل سَمورو هوندو گونگا ٻوڑا ٻارَ

هر دور جي نوجوانن کي اُداس، لُڙهندَڙ، ڪَڙهندڙ، ڪُڙهندڙ، ٻَرندڙ، ڇُرندڙ، ڪِرَندڙ، اوسيئڙو ڪَندَڙ، پاڙي، ڪاڪُو، ياڃوڪَڙُ، ڪاوڙيل ۽ وڙهندڙ نسلن سان منسوب ڪري سَگهجي ٿو، پَر اسان اِنهن سيني وِچان "**پڑهندڙ**" نسل جا ڳولائو آهيون. ڪتابن کي ڪاڳر تان کڻي ڪمپيوٽر جي دنيا ۾ آڻڻ، ٻين لفظن ۾ برقي ڪتاب يعنيe-books ناهي ورهائڻ جي وسيلي پڑهندڙ نسل کي وَڌڻ، ويجهَڻ ۽ هِڪَ ٻِئي کي ڳولي سَهڪاريِ تحريڪ جي رستي تي آڻِڻَ جي آسَ رکون ٿا.

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جَهڙيءَ طَرَح وٽن جا پَنَ ساوا، گاڙها، نيرا، پيلا يا ناسي هوندا آهن اَهڙيءَ طرح پڑهندڙ نَسُل وارا پَـنَ بہ مختَلِف آهن ۽ هوندا. اُهي ساڳئي ئي وقت اُداس ۽ پڙهندڙ، بَرندڙ ۽ پڙهندڙ، سُست ۽ پڙهندڙ يا وِڙهندڙ ۽ پڙهندڙ بہ ٿي سگهن ٿا. ہيءَ لفظ ہِ پَـنَ کا خُصوصي ۽ تالي لڳل کِلَب Exclusive Club نہ آهي.

ڪوشش اها هوندي تہ پَـنَ جا سي ڪَم ڪار سَهڪاري ۽ رَضاڪار بنيادن تي ٿين، پر ممڪن آهي تہ ڪي ڪم اُجرتي بنيادن تي بہ ٿين. اهڙي حالت ہِ پَـنَ پاڻ هِڪَڙِئي جي مدد ڪَرڻ جي اُصولَ هيٺ ڏي وَڻُ ڪندا ۽ غيرتجارتي non-commercial رهندا. پَـنَ ياران ڪتابن کي ڊِجِيٽائِيز digitize ڪرڻ جي عَملَ مان کو بہ مالي فائدو يا نفعو حاصل ڪرڻ جي ڪوشش نہ ڪئي ويندي.

ڪتابن کي ڊِجِيٽائِيز ڪرڻ کان پو ہيو اهم مرحلو وِرهائڻ distribution جو ٿيندو. اِهو ڪم ڪرڻ وارن مان جيڪڏهن کو پيسا ڪمائي سگهي ٿو تہ يلي ڪمائي، رُڳو پَـنَ سان اُن جو کو بہ لاڳاپو نہ هوندو.

پڑهندڙ نَسُل . پَ نَ The Reading Generation

پَڻ کي ڪُليل اکرن ۾ صلاح ڏجي ٿي تہ هو وَسَ پتاندڙ وڌِ کان وَڌِ ڪتاب خريد ڪَري ڪتابن جي ليکڪَن، ڇپائيندڙن ۽ ڇاپيندڙن کي هِمتائِن. پر ساڳئي وقت عِلم حاصل ڪرڻ ۽ ڇاڻ کي ڦهلائڻ جي ڪوشش دوران ڪَنهن بہ رُڪاوٽ کي نہ مڃن.

شيخ اَياز علمَ، ڇاڻَ، سمجهَ ۽ ڏاهپَ کي گيتَ، بيتَ، سِتَ، پُڪارَ سان تَشبيهہ ڏيندي انهن سيني کي بَمن، گولين ۽ بارودَ جي مدِ مقابل بيهاريو آهي. اياز چوي ٿو تہ:

گيتَ بہ ڇڻ گوريلا آهن، جي ويريءَ تي وار ڪَرن ٿا.

... ...

جئن جئن جاڙ وڌي ٿي جَڳَ ۾، هو ٻوليءَ جي آڙ چُپن ٿا؛
ريتيءَ تي راتاها ڪن ٿا، موٽي مَنجهہ پهاڙ چُپن ٿا؛

... ...

ڪالهہ هُيا جي سُرخ ڪُلن جيئن، اڇڪلهہ نيلا پيلا آهن؛
گيتَ بہ ڇڻ گوريلا آهن.....

... ...

هي بيتُ اَتي، هي بَم- گولو،
جيڪي بہ ڪٽين، جيڪي بہ ڪٽين!
مون لاءِ ٻنهي ۾ فَرَقُ نہ آ، هي بيتُ بہ بَمَ جو ساٿي آ،
جنهن رِڻ ۾ رات ڪيا راڙا، تنهن هَڏَ ۽ چَمَ جو ساٿي آ ـ

اِن حسابَ سان اڄاڻائي کي پاڻَ تي اِهو سوچي مَڙهڻ تہ "هاڻي ويڙهہ ۽ عمل جو دور آهي، اُن ڪري پڙهڻ تي وقت نہ وڃايو" ناداني‌ءَ جي نشاني آهي.

پَڻ جو پڙهڻ عام ڪِتابي ڪيڙن وانگر رُڳو نِصابي ڪتابن تائين محدود نہ هوندو. رڳو نصابي ڪتابن ۾ پاڻ کي قيد ڪري ڇڏڻ سان سماج ۽ سماجي حالتن تان نظر کڄي ويندي ۽ نتيجي طور سماجي ۽ حڪومتي پاليسيون policies اٽڄاڻن ۽ نادانن جي هٿن ۾ رهنديون. **پَڻ** نِصابي ڪتابن سان گڏوگڏ ادبي، تاريخي، سياسي، سماجي، اقتصادي، سائنسي ۽ ٻين ڪتابن کي پڙهي سماجي حالتن کي بهتر بنائڻ جي ڪوشش ڪندا.

پَڙهندڙ نَسُل جا پَڻ سيني کي **چو، چالاءِ ۽ ڪيئن** جهڙن سوالن کي هر بَيانَ تي لاڳو ڪرڻ جي ڪوشَ ڏين ٿا ۽ انهن تي ويچار ڪرڻ سان گڏ جوابَ ڳولڻ کي نہ رڳو پنهنجو حق، پر فرض ۽ اٽلُ گهرج unavoidable necessity سمجهندي ڪتابن کي پاڻ پڙهڻ ۽ وڌ کان وڌ ماڻهن تائين پهچائڻ جي ڪوشش جديد ترين طريقن وسيلي ڪرڻ جو ويچار رکن ٿا.

توهان بہ پڙهڻَ، پڙهائڻ ۽ ڦهلائڻ جي اِن سهڪاري تحريڪ ۾ شامل ٿي سگهو ٿا، بَس پنهنجي اوسي پاسي ۾ ڏِسو، هر قسم جا ڳاڙها توڙي نيرا، ساوا توڙي پيلا پن ضرور نظر اچي ويندا.

وڻ وڻ کي مون ياڪي پائي چيو تہ "منهنجا پاءُ
پهتو منهنجي من ۾ تنهنجي پَـنَ پَـنَ جو پڙلاءُ".
- اياز (ڪلهي پاتم ڪينرو)