Energy and Entropy as the Fundaments of Theoretical Physics

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Abstract:

Einstein's article titled, "The Fundaments of Theoretical Physics", from Science, Washington, D.C., May 24, 1940, is presented in its entirety as it is an outstanding presentation of the history and status of the foundations of theoretical physics as it stood in 1940. Further, it provides the background for discussing the new view of the fundaments of theoretical physics provided by the energy and entropy foundation of the Dynamic Theory.

Keywords: *Energy, Entropy, Equations of motion, Quantum Mechanics, Gauge fields*

Introduction

Einstein spent virtually his entire working life in theoretical physics. He had an extremely clear view of what the foundations of theoretical physics was and should be. He was able to express this view so vividly that it is hard to imagine being able to improve upon his words. Here is the article, published in 1940, in which Einstein sets forth the fundaments of theoretical physics as he understood it then. Little has changed in the fundaments until recently. Following Einstein's article there is a brief discussion of more recent developments in the foundations of theoretical physics that display the fundamental roles of energy and entropy in fundaments of theoretical physics.

Science is the attempt to make the chaotic diversity of our sense-experience correspond to a logically uniform system of thought. In this system single experiences must be correlated with the theoretic structure in such a way that the resulting coordination is unique and convincing. The sense-experiences are the given subject-matter. But the theory that shall interpret them is manmade. It is the result of an extremely laborious process of adaptation: hypothetical, never completely final, always subject to question and doubt. The scientific way of forming concepts differs from that which we use in our daily life, not basically, but merely in the more precise definition of concepts and conclusions; more painstaking and systematic choice of experimental material; and greater logical economy. By this last we mean the effort to reduce all concepts and correlations to as few as possible logically independent basic concepts and axioms. What we call physics comprises that group of natural sciences which base their concepts on measurements; and whose concepts and propositions lend themselves to mathematical formulation. Its realm is accordingly defined as that part of the sum total of our knowledge which is capable of being expressed in mathematical terms. With the progress of science, the realm of physics has so expanded that it seems to be limited only by the limitations of the method itself. The larger part of physical research is devoted to the development of the various branches of physics, in each of which the object is the theoretical understanding of more or less restricted fields of experience, and in each of which the laws and concepts remain as closely as possible related to experience.

The theory of relativity arose out of efforts to improve, with reference to logical economy, the foundation of physics as it existed at the turn of the century. The so-called special or restricted relativity theory is based on the fact that Maxwell's equations (and thus the law of propagation of lightin empty space) are converted into equations of the same form, when they undergo Lorentz transformation. This formal property of the Maxwell equations is supplemented by our fairly secure empirical knowledge that the laws of physics are the same with respect to all inertial systems. This leads to the result

VOL- XI ISSUE- VII JULY 2024 PEER REVIEW e-JOURNAL IMPACT FACTOR 8.02 ISSN 2349-638x

that the Lorentz transformation--applied to space and time coordinates--must govern the transition from one inertial system to any other. The content of the restricted relativity theory can accordingly be summarized in one sentence: all natural laws must be so conditioned that they are covariant with respect to Lorentz transformations. >From this it follows that the simultaneity of two distant events is not an invariant concept and that the dimensions of rigid bodies and the speed of clocks depend upon their state of motion. A further consequence was a modification of Newton's law of motion in cases where the speed of a given body was not small compared with the speed of light. There followed also the principle of the equivalence of mass and energy, with the laws of conservation of mass and energy becoming one and the same. Once it was shown that simultaneity was relative and depended on the frame of reference, every possibility of retaining actions-at-a-distance within the foundation of physics disappeared, since that concept presupposed the absolute character of simultaneity (it must be possible to state the location of the two interacting mass points "at the same time"

The general theory of relativity owes its origin to the attempt to explain a fact known since Galileo's and Newton's time but hitherto eluding all theoretical interpretation: the inertia and the weight of a body, in themselves two entirely distinct things, are measured by one and the same constant, the mass. From this correspondence follows that it is impossible to discover by experiment whether a given system of coordinates is accelerated, or whether its motion is straight and uniform and the observed effects are due to a gravitational field (this is the equivalence principle of the general relativity theory). It shatters the concepts of the inertial system, as soon as gravitation enters in. It may be remarked here that the inertial system is a weak point of the Galilean-Newtonian mechanics. For there is presupposed a mysterious property of physical space, conditioning the kind of coordinate systems for which the law of inertia and the Newtonian law of motion hold good.

Discussion

The last paragraph states Einstein’s lifelong belief that quantum mechanics should not ultimately form the foundations of physics. Today it is difficult to find a physicist publishing such a belief. Such is the belief in the fundamental nature of quantum mechanics. The success of the predictions of quantum mechanics and the vast growth of experimental data throughout the 20th century only adds to this conviction. A further impediment to looking into the foundations of physics is provided by the various branches of physics and the increased degree of specialization that exists today.

Einstein was not afraid of thinking thoughts not previously held. Yet when he contributed so much to the beginnings of quantum mechanics, those who pursued quantum mechanics as a fundamental basis for physics felt they had lost a leader when Einstein steadfastly refused to follow their path. It is now possible to show how correct he was in maintaining his stand with the same rigorous logic that Einstein demanded of himself. There does indeed exist a simple set of fundamental postulates from which it may be shown that the basis of all the various branches of physics are but subsets of the totality of their description. The starting point of this new line of thinking is so improbable as to be easily overlooked and yet it is the only foundation that has never been seen to offer predictions that differ from experience. This starting point is the laws of classical thermodynamics! There are at least two reasons that classical thermodynamics would not be expected to provide such a foundation. First, thermodynamics, as currently studied, does not provide a description of motion like the mechanistic theories do. Secondly, texts teach, as Einstein believed, that classical thermodynamics might be obtained from statistical procedures applied to Newtonian mechanics.

Another way new fundaments of theoretical physics may have an impact upon humans is to provide new logical basis upon which to look at our universe. This can lead to new understandings of known phenomena or to exciting predictions of new physics. For example, the study of the energy radiating from a blackbody led Planck to the first assumption of quanta and the first successful equation of quantum mechanics. What of the study of the blackbody itself? Obviously, a system radiating energy should not be considered to be isolated. Non-isolated systems have not been discussed above where the concentration was on isolated systems. An electron under the accelerating influence of a force that radiates energy is an example of a non-isolated system. So is a blackbody. The new fundaments of theoretical physics provides a variational principle in the minimum free energy principle and this principle should provide the equations of motion for these systems.

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