LETTERS TO PROGRESS IN PHYSICS

Reply to the "Certain Conceptual Anomalies in Einstein's Theory of Relativity" and Related Questions

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This paper answers twelve most common questions on the basics of Einstein's theory of relativity. The answers remove most key problems with a real, solid understanding of the theory.

Since its inception, *Progress in Physics*, has maintained the importance of freedom of expression in science [1]. As a result, the journal has sometimes published works even though the editorial staff differred either with the premise or with the conclusions of a paper. The editorial board maintains that it is best to disseminate works, rather than to unknowlingly suppress seminal ideas. The validity of all scientific arguments will eventually be discovered. For this reason, the journal strongly upholds the rights of individual scientists relative to publication. At the same time, many questions focusing on fundamental aspects of Einstein's theory of relativity have been submitted to the journal. Most of these letters were not published as they were concieved by authors who did not properly grasp the concepts outlined within the classic textbooks on this subject, such as *The Classical Theory of Fields* by Landau and Lifshitz [2] and others [3].

Recently, the editorial board made the decision to publish a work by Stephen J. Crothers [4] even though some questions remained relative to its basic premise. We chose to move to publication for two reasons. First, Crothers is a capable scientist who has already demonstrated substantial insight into General Relativity [5]. Indeed, the editorial board has written in support of these ideas [6]. Second, the journal has received substantial correspondance from both amateurs and established scientists. These letters have focused on perceived problems with Einstein's theory of relativity. The editors therefore feels compelled to address these concerns, both relative to Crothers [4] and to other serious scientists who had previously worked, with success, on numerous applications of the theory of relativity.

In general, the correspondance we have received has expressed doubt concerning the validity of some key points in Einstein's theory. We found that these questions originated in the fact that the scientists asking the questions were educated as physicists, while the base of Einstein's theory is Riemannian geometry. It is therefore not suprising that some confusion might arise. The meaning of Einstein's theory is the geometrization of physics, the expression of all physics through the geometrical properties of the four-dimensional pseudo-Riemannian space (the basic space-time of the theory of relativity) or its extensions. Many physicists came to the theory of relativity from the other fields of physics; they learned Einstein's theory through brief courses which gave the theory in its historical sense, often with artifically introduced principles and postulates. When the meaning of Einstein's theory, the geometrization of physics, was finally understood through the joint intellectual powers of Albert Einstein and Marcel Grossmann, all the physical principles came out from the consideration; they all became covered by the particular properties of the geometry within four-dimensional pseudo-Riemannian space. Such a "historical" approach, which is very common in most brief courses on the theory of relativity for physicists, often carries a student away with speculations on the principles and postulates, instead of studying Riemannian geometry itself. As a result, serious physicists erred relative to simple questions which remained open after their brief education. Only a small minority of physicists, who devoted their life to understanding the theory of relativity, were lucky enough to be able to study the special (more advanced) courses on this subject.

Here we collected twelve of the most common questions on the basics of Einstein's theory, asked by the readers and some of our colleagues. We hope the answers will remove most key problems with a real, solid understanding of the theory.

First. Naturally, each term in Einstein's equations in emptiness (i.e. with zero right-hand-side) vanishes. This is due to that fact that, in such a case, the scalar curvature is zero $R = 0$, so Einstein's equations become the vanishing condition for Ricci's tensor: $R_{\alpha\beta} = 0$. In the same time, Ricci's tensor $R_{\alpha\beta}$ isn't a number, but a 2nd-rank tensor whose components are 16 (only 10 of whom are independent). The formula $R_{\alpha\beta} = 0$, i.e. Einstein's equations in emptiness, means 10 different differential equations with zero elements on the right-hand-side. These are differential equations with respect to the components of the fundamental metric tensor $g_{\alpha\beta}$: each of 10 equations $R_{\alpha\beta} = 0$ is expressed in the terms containing the components of $g_{\alpha\beta}$ and their derivatives according to the definition of Ricci's tensor $R_{\alpha\beta}$. Nothing more. (With non-zero elements on the right-hand-side, these would be Einstein's equations in a space filled with distributed matter, e.g. electromagnetic field, dust, liquid, etc. In such a case these would be 10 differential equations with a free term.)

Therefore the vanishing of each term of Einstein's equations in emptiness doesn't matter with respect to the validity of the equations in both general and particular cases.

Second. A common mistake is that a gravitational field is described by Einstein's equations. In fact, a gravitational field is described not by Einstein's equations, but the components of the fundamental metric tensor $g_{\alpha\beta}$ of which only 10 are substantial (out of 16). To find the components, we should solve a system of 10 Einstein's equations, consisting of $g_{\alpha\beta}$ and their derivatives: the differential equations with zero right-hand-side (in emptiness) or non-zero right-hand-side (with distributed matter).

Third. The condition $R_{\alpha\beta} = 0$ doesn't mean flateness, the pseudo-Euclidean space ($g_{00} = 1$, i.e. the absence of gravitational fields), but only emptiness (see the first point that above). Only a trivial case means flatness when $R_{\alpha\beta} = 0$.

Fourth. A mass, the source of a gravitational field, is contained in the time-time component g_{00} of the fundamental metric tensor $g_{\alpha\beta}$: the gravitational potential expresses as $\mathrm{w} = c^2\sqrt{1-g_{00}}$. Therefore Einstein's equations in emptiness, $R_{\alpha\beta} = 0$, satisfy a gravitational field produced by a mass ($g_{00} \neq 1$). The right-hand-side terms (the energy-momentum tensor $T_{\alpha\beta}$ of matter and the λ-term which describes physical vacuum) describe distributed matter. There is no contradiction between Einstein's equations in emptiness and the equivalence principle.

Fifth. In the case of geometrized matter, the most known of which are isotropic electromagnetic fields (such fields are geometrized due to Rainich's condition and Nortvedt-Pagels' condition), the energy-momentum tensor of the field expresses itself through the components of the fundamental metric tensor. In such a case, we can also construct Einstein's equations containing only the "geometrical" left-hand-side by moving all the right side terms (they consist of only $g_{\alpha\beta}$ and their functions) to the left-hand-side so the right-hand-side becomes zero. But such equations aren't Einstein's equations in emptiness because $R_{\alpha\beta} \neq 0$ therein.

Sixth. Minkowski's space, the basic space-time of Special Relativity, permits test-masses, not point-masses. A test-mass is one which is so small that the gravitational field produced by it is so negligible that it doesn't have any effect on the space metric. A test-mass is a continous body, which is approximated by its geometrical centre; it has nothing in common with a point-mass whose density should obviously be infinite.

The four-dimensional psedo-Riemannian space with Minkowski's signature $(+---)$ or $(-+++)$, the space-time of General Relativity, permits continuosly gravtating masses (such a mass can be approximated by the centre of its gravity) and test-masses which move in the gravitational field. No point-masses are present in the space-time of both Special Relativity and General Relativity.

Seventh. Einstein's theory of relativity doesn't work on infinite high density. According to Einstein, the theory works on densities up to the nuclear density. When one talks about a singular state of a cosmological solution, one means a so-called singular object. This is not a point, but a compact object with a finite radius and high density close to the nuclear density. Infinite high density may occur on the specific conditions within a finite radius (this is described in the modern relativistic cosmology [7]), but Einstein's theory does consider only the states before and after that transit, when the density lowers to that in atomic nuclei. Such a transit itself is out of consideration in the framework of Einstein's theory.

Eighth. Einstein's pseudotensor isn't the best solution for elucidating the energy of a gravitational field, of course. On the other hand, the other solutions proposed to solve this problem aren't excellent as well. Einstein's pseudotensor of the energy of a gravitational field permits calculation of real physical problems; the calculation results meet experiment nicely. See, for intance, Chapter XI of the famous *The Classical Theory of Fields* by Landau and Lifshitz [2]. This manifests the obvious fact that Einstein's pseudotensor, despite many drawbacks and problems connected to it, is a good approximation which lies in the right path.

Bel's tensor of superenergy, which is constructed in analogy to the tensor of the electromagnetic field, is currently the best of the attempts to solve the problem of the energy of the gravitational field in a way different from that of Einstein. See the original publications by Louis Bel [8]. More can be found on Bel's tensor in Debever's paper [9] and also in Chapter 5 of *Gravitational Waves in Einstein's Theory* by Zakharov [10].

Besides Bel's tensor, a few other solutions were proposed to the problem of the energy of the gravitational field, with less success. Einstein's theory of relativity isn't fosilized, rather it is under active development at the moment.

Nineth. Another very common mistake is the belief that Einstein's equations have no dynamical solution. There are different dynamical solutions, Peres' metric for instance [11]. Peres's metric, one of the empty space metrics, being applied to Einstein's equations in emptiness (which are $R_{\mu\nu} = 0$), leads to a solely harmonic condition along the x^1 and x^2 directions. One can read all these in detail, for instance, in Chapter 9 of the well-known book *Gravitational Waves in Einstein's Theory* by Zakharov [10].

Tenth. The main myths about Einstein's theory proceed in a popular misconception claiming the principal impossibility of an exceptional (absolute) reference frame in the theory of relativity. This is naturally impossible in the space-time of Special Relativity (Minkowski's space, which is the four-dimensional pseudo-Euclidean space with Minkowski's signature) due to that fact that, in such a space, all space-time (mixed) components g_{0i} of the fundamental metric tensor are zero (the space is free of rotation), and also all non-zero components of the metric are independent from time (the space deformation is zero). This however isn't true in the space-time of General Relativity which is pseudo-Riemannian, so any components of the metric can be non-zero therein. It was shown already in the 1940's, by Abraham Zelmanov, a prominent scientist in the theory of relativity and cosmology, that the space-time of General Relativity permits absolute reference frames connected to the anisotropy of the fields of the space rotation or deformation of the whole Universe, i. e. connected to globally polarized (dipole-fit) fields which are as a global background gyro. See Chapter 4 in his book of 1944, *Chronometric Invariants* [7], for detail.

Eleventh. Another popular myth claims that an experiment, which manifests the anisotropy of the distribution of the velocity of light, is in contradiction to the basics of the theory of relativity due to the world-invariance of the velocity of light. This myth was also completely shattered [12]. According to the theory of physical observables in General Relativity [7], the observable velocity of light lowers from the world-invariance of the velocity by the gravitational potential and the linear velocity of the space rotation at the point of observation. The vector of the observable velocity of light directed towards an attracting body is carried into the direction of our motion in the space. As a result, the distribution of the vectors of the velocity of light beams has a preferred direction in space, depending on the motion, despite the fact that the world-invariance of the velocity of light remains unchanged. In such a case the field of the observable velocities of light is distributed anisotropically. If the space is free from rotation and gravitation (for instance, Minkowski's space of Special Relativity), the anisotropic effect vanishes: the spatial vectors of the observable velocity of light are distributed equally in all directions in the three-dimensional space. The anisotropic effect hence is due to only General Relativity. Here is nothing contradictory to the basics of Einstein's theory.

Twelfth. About Friedmann's models of a homogeneous universe, including the Big Bang scenario. It was already shown in the 1930's [7] that Friedmann's models have substantial drawbacks both in its principal and mathematical approaches. Friedmann's models are empty (free of distributed matter), homogeneous, and isotropic. They were only the first, historical step made by the scientists in the attempt to create physically and mathematically valid models of relativistic cosmology. There are hundreds of thousands of solutions to Einsten's equations. True relativistic cosmology should be stated by models of an inhomogeneous, anisotropic universe, which meet the real physical conditions of the cosmos, and can be applied to only a local volume, not the whole Universe [7]. A classification of the cosmological models, which are theoretically thinkable on the basis of Einstein's equations, was given in the 1940's. See Chapter 4 of *Chronometric Invariants* by Zelmanov [7], for detail. Many different cosmological scenarios are listed there, including such exotics as the transits through the states of infinite rarefraction and infinite density on a finite volume (that is possible under special physical conditions). The Big Bang model, the model of expansion of a compact object of a finite radius and nuclear density, where the space is free of gravitating bodies, rotation, and deformation, is just one of many. Aside for this model, many other models of an expanding universe can be conceived on the basis of the solutions of Einstein's equations.

Relativistic cosmology is based on the time functions of the density, volume and others obtained from solutions to Einstein's equations. Therefore, only those states are under consideration, which are specific to Einstein's equations (they work up to only the nuclear density). Relativistic cosmology points out only the possibility of the state of infinite density as a theoretically extrem of the density function, while the equations of the theory are valid up to only the nuclear density. It is a very common mistake that Einstein's theory studies the state of infinite density, including a singular point-state.

Submitted on February 10, 2008
Accepted on February 16, 2008

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