The Nature of Time

S.C. Tiwari
Department of Physics
Banaras Hindu University
Varanasi-221005, India

It is argued that Einstein's theory of relativity does not provide a new definition of time, and that it does not reject Newton's absolute time. The time dilation effect observed in the lifetime of a relativistically moving unstable particle is termed a paradox because of the equality of two times, based on kinematics and irreversible decay processes. Proposals based on a new definition of inertial frames and the non-equivalence of inertial frames are presented to resolve the problem within the framework of absolute time.

Introduction

Physicists believe that Einstein's theory of relativity has given a new meaning to the nature of time, that it rejects the absolute time of Newton, and that the time perceived by normal individuals has been proven illusory. Philosophical discussions on relativity in Western traditions have been of limited value in so far as new insights into the concepts of space and time are concerned. However, some critiques seem to have sharpened Einstein's own arguments, as we can see from the evolution of his thoughts on the subject after his first paper was published in 1905. The tentative nature of alternative ideas and the empirical support for the theory of relativity are the two main reasons for acceptance of Einstein's ideas on space and time.

My aim in this paper is twofold: 1) to elucidate the proposition that Einstein's theory of relativity is concerned with the relativity of simultaneity, and not with Newton's absolute and true time, and 2) to discuss the paradox concerning the verification of time dilation in the lifetime of an unstable particle. In order to follow Einstein's ideas faithfully, I will adopt the presentations given in his book (Einstein 1956) and his autobiographical notes (Einstein 1949). References to expositions by other authors can be found in a text by the author (Tiwari 1989a).

Absolute time and relativity

According to Newton (1934): "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." The commonly used time is some sensible and external measure of duration by means of motion.

Einstein poses the question as to the relation between the space coordinates and the time of an event in inertial frames of reference in uniform relative motion (1956, p. 24). He argues that in pre-relativity physics, the hypotheses of absolute time and space were unconsciously made. It is best to quote his explanation: "The time of an event, t', relatively to K' is the same as the time relative to K. If instantaneous signals could be sent to a distance, and if one knew that the state of motion of a clock had no influence on its rate, then this assumption would be physically validated." Einstein assumes that this is the meaning of Newtonian absolute time. However, it can easily be recognized that Einstein mistakenly identifies Newton's common time and its measure as absolute time. Newton allows the possibility of arbitrary standards of measurement of duration, while Einstein prefers a standard measurement convention, taking light signals as his device and the velocity of light in vacuum as the unit. The relativity of simultaneity is an intelligent scheme to achieve order and a correlation between measurements of duration in different frames of reference. Special relativity (SR) thus has to do with the common time of Newton; it does not reject absolute time, nor does it explore the nature of time. This becomes even clearer in Einstein's later writings (1949). There the absolute character of time is identified with simultaneity. However, he rightly does not claim that Special Relativity has provided a new insight into the nature of space and time, and ascribes the origin of relativity to electromagnetic phenomena.

Although Einstein does not examine the nature of time in General Relativity, in his remarks in connection with Gödel's essay, a paradoxical situation as regards the meaning of time is admitted. To appreciate Gödel's space-time, it is better to first understand the assumptions involved in the prescription for time coordinates in General Relativity. Local comoving inertial frames are assumed to exist such that an ideal clock placed in such a frame is not influenced by the gravitational force. A practical realization of such a clock is an atomic clock. This idealization reduces the General Relativistic time to the Special Relativistic one, and perhaps works satisfactorily because the gravitational fields encountered are practically very weak. However, near massive bodies or singularities this assumption will not work (Will 1985). Cosmologists use a concept of the age of the Universe, which is defined as the time measured by an ideal clock from the singularity to the present. Obviously, the ideal clock will loose its meaning at the singularity, and the whole concept of the age of the Universe breaks down even with simplifications introduced into General Relativity. In the space-time geometry of General

Relativity, to the best of my knowledge no satisfactory geometrical quantity has been found which approximates the singularity and keeps some sensible meaning to space-time.

In cosmological models based on General Relativity with non-vanishing matter density, a time common to the whole Universe arises, and this world time has the virtues of absolute time as understood by Einstein. Gödel (1949) considered a rotating Universe and Einstein’s equations with nonzero cosmological constant to obtain the exact solution of the field equations. This solution has some interesting properties: for example, there is no absolute time (in Einstein’s sense) and travelling into the past is possible. Some have suggested that the existence of closed time-like curves is unphysical (Hawking & Ellis 1973). Yet General Relativity provides no clues as to whether the solution is physical or unphysical. There are other exact solutions (hawking & Ellis 1973) with different properties. It thus seems reasonable to conclude that the only physically valid time in General Relativity is also the proper time of Special Relativity, and relativity theory does not provide any insight into the nature of time.

A new paradox in relativity

Special Relativity has not brought any changes to the Maxwell equations or the Lorentz force law in electrodynamics. It is only the ether hypothesis that is discarded by the postulates of relativity. Elementary particle physics provides experimental verifications of the equations of Special Relativity. The most important empirical evidence comes from the time dilation of the lifetime of an unstable particle moving at very high speeds. However, it should be remembered that the time dilation hypothesis existed before relativity, and its confirmation cannot be regarded as a proof of Einstein’s ideas on space-time. Though this is a minor point, it is nevertheless worth noting. There is another more significant point which now seems so obvious to me, which I am surprised was not noticed before. And this concerns a paradoxical situation of principle. The decay of a particle is an irreversible process, so life-time measures a unidirectional lapse of time. Time dilation is a kinematic process which possess time reversal symmetry. There is no reason to believe that time dilation should apply to the decay time of a particle. But experiments show that the lifetime of an unstable particle moving at relativistic speeds is longer than when it is at rest, and the change is accurately described by the time dilation obtained from the SR. The equivalence of two time intervals based on entirely different physical processes is a new paradox in relativity. One can argue that the time lapse is recorded by a mechanical clock such that the creation and the disintegration events of an atom are marked by the clock. But this argument misses the central issue that by merely changing inertial frames of reference one can influence the decay process.

This paradox in a slightly modified form appears in the case of the relativistic Doppler shift in the frequency of a single photon. In the case of the light pulse where a large number of photons are involved this paradox can be circumvented. However, for a single photon moving in vacuum the change in frequency amounts to the change in total energy of photon. Without any mechanism for the energy exchange process it is difficult to understand this phenomenon.

Interestingly Einstein considered the problem of a decaying atom as another version of the EPR paradox to show that quantum theory is incomplete, (Einstein 1949). From the present discussion it emerges that the physical interpretation of time in relativity is unsatisfactory.

An alternative theory

If relativity theory does not provide a new definition of time, then we might ask why the formalism based on the Minkowskian geometry of space-time has been successful. There are several reasons for this. First, Special Relativity does not require four dimensional geometry, yet, once this approach is adopted the covariant formulations and Lorentz transformation follow quite naturally. But the indefinite metric requires additional considerations in order to choose the physical quantities, and SR does not say anything about this. In the second quantization this problem becomes more difficult, e.g. the Gupta-Bluerer scheme for the EM field quantization.

In all the recent discussions the time coordinate, even in relativity, is treated differently from the space coordinates. Though the relativity of simultaneity is a new idea, the flow of time in the Newtonian sense is implicit in all discussions on relativity. This becomes very clear if one asks: What is the meaning of time at a point in an inertial frame of reference? An event is characterized by space coordinates and a time coordinate, and supposedly the time coordinate is measured by an ideal clock placed in the inertial frame in which event takes place. But, what is the time that is measured by this clock? Unless one implicitly makes the hypothesis of the existence of something which is called time, the time coordinate of an event cannot make any sense. Einstein assumes that this time flows differently in different inertial frames; the time as such remains undefined, and this assumption of implicit, undefined time is not stated in the discussions on relativity.

Thus, Einstein presupposes the existence of undefined time which elapses differently in different inertial frames. Newton states clearly the perception of time which flows equitably everywhere and is not influenced by anything external. Perhaps the most perspicacious observation on Newton's absolute time is Cajori's statement (in

Newton 1934) that it is a metaphysical concept. Obviously, Einstein's implicit time is also metaphysical. It may, however, be reasoned that these metaphysical concepts are not illusory, because they originate in the mind, which is a part of the Universe. To take an example, one really does not observe the homogeneity of space in the whole of the Universe, but physicists believe in it. Newton's absolute time is, I believe, based on the perception of the totality of reality. We usually analyze parts, and then build a picture of the whole. But if one considers the creation of the Universe and a harmony in the structure of an evolving Universe, then a synchronization of clocks in the entire Universe by a cosmic principle can be visualized, and hence a concept of absolute time can be forged.

In order to resolve the conflict between absolute time and observations on light propagation, I will make the following propositions:

> *Proposition I: Time is absolute, unidirectional and discrete, as determined by a Cosmic principle.*

> *Proposition II: The scattering limited average drift velocity defines an inertial frame. At the basic level no two inertial frames are equivalent.*

> *Proposition III: Newton's second law of motion is based on statistical averaging.*

The addition law for velocities in Newtonian mechanics is not applicable to photons or, alternatively photons travel with the velocity c in vacuum in all inertial frames because they move without collisions. Phenomenologically, an inertial frame can be ascribed a constant potential U. Different values of U define different frames, and the potentials U are constant only on certain time and space scales which depend on the distribution of the scattering centres. An inertial frame with relative motion close to c corresponds to the case of depleted scattering centres. If an unstable particle moves in such a frame, then it will undergo fewer collisions and consequently its decay time will be increased. I use the expression 'scattering centres" to denote all sorts of fields which are in continuous flux. Thus the new paradox in relativity discussed in the previous section can be resolved satisfactorily as a manifestation of the unobservable potentials U and the non-equivalence of the inertial frames.

Implications for electrodynamics

For macroscopic bodies, instantaneous velocity is identical to the average velocity, and because of the large length and-time scales involved, two inertial frames are equivalent. At the elementary particle level, or for the case of light propagation, the Newtonian mechanics must be modified by discarding the usual concept of an inertial frame, but retaining the concept of absolute time.

The dynamics of macroscopic bodies is the observational basis for Newtonian mechanics; similarly, Maxwell-Lorentz electrodynamics is based on macroscopic phenomena. At a fundamental level, the concepts of macroscopic measurable quantities may not be applicable to elementary objects such as an electron or photon. A geometric model of the electron, neutrino and photon has been proposed (Tiwari 1990, 1991) in which the electron is massless and the electric and magnetic fields are zero for the electron and photon. Planck's constant h and the rest mass m of the electron merely serve as unit conversion factors. The classical charge radius (r_e) and the Compton wavelength (l_c) are two quantities which characterize an extended spatio-temporal bounded structure called the electron. Geometrically, an electron is represented as a circular spatial region of radius l_c with a hole of dimension r_e moving normal to the plane of the circle with velocity c, while a structure without hole is neutrino. The time periods of the internal orthogonal fields f and g determine the energy of the system. Assuming that both retarded and advanced wave solutions are admissible for the internal fields, only four states are possible, given by:

$$n_e = (f_+, g_-) \quad \bar{n}_e = (f_-, g_-)$$
$$n_m = (f_-, g_+) \quad \bar{n}_m = (f_+, g_+)$$

where $f_\mp = f(x \pm ct)$ and similarly for $g_\mp$. A hole in the circular region is represented as a travelling wave field attached to the bounded fields (f, g) and corresponds to electric charge. The outgoing, (incoming) field corresponds to positive (negative) charge; thus the electron and positron are time-reversed states of each other. The photon is a composite structure with two states, (n_e, n_m) and $(\bar{n}_e, \bar{n}_m)$. Geometrically, two moving circular neutrinos give a helical structure for the photon. In contrast to de Broglie's point field theory and massless photon, here the photon is an extended geometrical structure moving with velocity c.

The electron is distinct from the neutrino and photon because of the travelling wave field $\bar{f}$. The neutrino and photon, being spatio-temporally bounded fields, are less susceptible to scattering with other surrounding fields, and therefore move with velocity c in vacuum. The electron (or positron) gets scattered by surrounding fields due to the field $\bar{f}$. One can represent the system (electron + surrounding fields) by a particle having mass m and velocity u, and set up classical dynamics, introducing force and acceleration. In this formulation, it is not the free electron, but the electron + environment which enters into the Lorentz-Dirac equation of motion. Contradiction with experimental observations, *e.g.* electron motion in atomic orbits, arises because of this. However, the new mechanics, *i.e.* quantum mechanics, retains unphysical features for the electron, leading to mysterious interpretations. It has been shown (Tiwari 1989b) that, taking mass equal to zero, it is possible to reinterpret the Schrödinger equation as an approximate field equation. Thus the problem with quantum theory lies at the level of the formalism: it is not merely a problem of interpretation.

Obviously, classical electrodynamics also needs to be reformulated in this new model of the electron and photon. It has been argued that electric and magnetic fields are macroscopic quantities, and for a single electron or single photon, the electromagnetic field is equal to zero (Tiwari 1990, 1991). The equation of motion for an electron derived in Weyl geometry (Tiwari 1992) has the following interesting properties: 1) a massless electron is allowed as a solution in the absence of electromagnetic potentials; 2) electromagnetic potentials affect the motion of the electron at the classical level even for zero electromagnetic field; and 3) standard classical electron dynamics results can be obtained under suitable conditions. Since the gauge connection A_m appears with the dimension of $(\text{length})^{-1}$ in the Weyl geometry, we interpret A_m with the wave vector k_m for a single photon. Thus, electromagnetic potentials are fundamental, and for a single photon they represent the wave vector. It has been suggested (Tiwari 1987) that for a large number of photons one can introduce macroscopic quantities corresponding to the usual electromagnetic potentials and derive the Maxwell equations.

In conclusion, a revision of our ideas concerning elementary particles, quantum theory and the electromagnetic field theory are necessary for a deeper understanding of the reality of space and time. (for further discussion see Tiwari 1990, 1991).

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