Chapter 2

Conventionality of Simultaneity (CS) Thesis

2.1 Conventionality of Simultaneity Thesis

The procedure for distant clock synchronization in the theory of relativity has an element of convention. This is known as the conventionality of distant simultaneity (CS) thesis. In literature the CS-thesis has been successfully used to deal with some interesting (apparent) paradoxes of relativity such as the twin paradox, tippitop paradox[1], Selleri paradox and the likes. As regards to the twin paradox, the thesis facilitates one to study the paradox and its variants in different worlds (other than the special relativistic world). In one of the most cited paper on the twin paradox[2] a novel approach to understanding the twin problem based on the conventionality of simultaneity has been presented providing a clearer way to settle the often discussed issue of twins relative aging. As stated earlier the CS-approach has also been fruitfully used to examine some other paradoxes of relativity[1, 3]. In the coming chapters the CS-thesis will be seen to play a significant role in dealing with the counter-intuitive problem, enlightening our understanding of certain subtle issues regarding the problem, a brief review of the CS-thesis of SR therefore may be in order.

The role of conventionality in defining simultaneity of distant events or in synchronizing spatially separated clocks in a given inertial frame is one of the most debated issue in literature[3, 4, 5]. In relativity theory the spatially separated clocks in a given inertial frame are synchronized by light signal whose one-way-speed (OWS) must be known beforehand. But to measure the OWS of the signal from one point to another one requires to have two presynchronized clocks and hence the whole process ends up in a logical circularity. To get out of this problem a convention is adopted in assuming the OWS of the signal within certain bound. (The round-trip speed or the two-way-speed (TWS) of the signal is however a convention-free entity since only one clock is employed for measuring it and hence the problem of synchronization of spatially separated clocks does not enter.) To break the circularity Einstein *stipulated* that the OWS of light is the same as its TWS. This stipulation of equality of to and fro speeds of light (along any given direction) in an inertial frame is known as *standard synchronization* (or Einstein synchronization) convention in the literature. The CS-thesis asserts that Einstein's convention is just one among the various possible alternative conventions (termed as non-standard synchronization) to synchronize clocks at different locations. This particular convention leads to a set of transformation equations in the relativistic world which are known as the Lorentz transformation (LT). Many of the results (or formulae) obtained by Einstein thus depended on his special choice of synchronization. Even the fact that two inertial observers in relative motion come to different conclusions regarding the simultaneity of two spatially distant events is also a matter of such a simultaneity convention.

The possibility of using a synchronization convention other than that suggested by Einstein was first discussed by Reichenbach[6] in 1928 and later by Grünbaum[7]. They claimed that the simultaneity between events in an inertial frame is a matter of convention and the conventionality lies in the assumption regarding the OWS of light. As according to Einstein's proposition for synchronizing distant clocks the time of arrival and the consequent reflection by a mirror at one clock position is determined by considering that the latter is halfway in time between the departure of the light signal and its arrival at the position of the other clock from where the light signal is sent out for synchronization. By specifying a value for the OWS of light one can obtain an unique light signal procedure for the synchronization of distant clocks, hence any prescription for OWS value(s) is equivalent to adoption of a convention for clock synchronization[8]. Different choices for the values of the OWS yield different synchronization conventions. Einstein himself referred to his choice of OWS as a free stipulation for giving an empirical meaning of distant simultaneity[9]. According to the CS-thesis a range of choices are possible, all fully equivalent with respect to experimental outcome. One needs to note here that the thesis allows any synchronization convention with the requirement that it is consistent with the round-trip principle, according to which the average speed of a light ray over any closed path has a constant value. It may not be out of place in this context to mention that the second relativity postulate should be restated by replacing the phrase "velocity of light" by "round trip speed of light" or "TWS of light". The round-trip principle should be satisfied by the conventions in SR as this principle is a consequence of the theory prior to adoption of any criterion for distant simultaneity and may in principle be tested with a single clock.

Although first eminently put forward by Reichenbach and Grünbaum, the thesis after formulation attracted a considerable amount of discussions in the literature. Possibility of using synchronization convention other than that adopted by Einstein has also been much discussed. John Winnie[10] was the first to study the consequences of this approach to establishing simultaneity where he made no assumption regarding the OWS of light. He developed the so called ϵ-Lorentz transformations (using Reichenbach's notation) adopting non-Einstein one-way velocity assumption or non-standard synchronization convention in general. ϵ is called the *synchronization* or *Reichenbach parameter* which is given by the equation

$$t_2 = t_1 + \epsilon(t_3 - t_1), \tag{2.1}$$

where t_1, t_2 and t_3 gives the time measured in two spatially separated clocks which are synchronized using light signals. t_1 and t_3 are the times of transmission and reception of the signal respectively by the first clock and t_3 is the time recorded by the second clock when the signal reaches it. For causality reason the value of ϵ is restricted as

$$0 < \epsilon < 1. \tag{2.2}$$

Note that Einstein's convention is equivalent to the assumption $\epsilon = 1/2$. While developing the ϵ-Lorentz transformation Winnie assumed a principle called "principle equal passage time" which he used in addition to the "Linearity principle" and the "Round-trip light principle". These principles were in fact shown to be independent of one-way velocity assumption and hence may form the basis of SR without distant simultaneity assumptions. Winnie's approach was extended by Ungar[11] who considered a generalized Lorentz transformation group that does not embody Einstein's isotropy convention. This approach suggested by Ungar suited well for establishing the results of Winnie as well as some new results. However these discussions were confined to only single dimension. It was noted later by some authors that at least a two-dimensional analysis was necessary as one-dimensional analysis restricts one from using the isotropy of one-way speed of light which follows from the modified second relativity postulate and therefore some subtleties and richness of the relativistic physics[12] will have to be sacrificed.

Mansouri and Sexl[13] in a series of important papers developed a test theory of SR and investigated the role of convention in various definitions of clock synchronization and simultaneity. They showed that two principal methods of synchronization could be considered: system internal and system external synchronization. Einstein's synchronization scheme (using the light signal) and slow clock transport synchronization (where all the clocks are collected at a given locality and synchronized and then after slowly transported back to their respective space points in a given reference frame) turn out to be equivalent if and only if and only if the time dilation factor is given by Einstein result $(1 - v^2/c^2)^{-1/2}$. The authors formulated an ether theory where simultaneity was absolute and was kinematically equivalent to SR.

Later Sjödin[14] developed the thesis by considering the whole issue more generally and also by assuming the role of synchronization in SR and some related theories. He gave all logically possible linear transformations between inertial frames depending on physical behavior of scales and clocks in motion with respect to the so called "physical vacuum" and then examined LT in the light of true length contraction and time dilation. In an effort to separate the true effects and the effects due to synchronization convention the author considered two special cases: The Newtonian world– without any contraction of moving bodies and slowing down of moving clocks and Lorentzian world– with longitudinal contraction of moving bodies and slowing down of clocks. The author then used *standard synchronization* in the Newtonian world (which was later termed as Pseudo-standard synchrony by Ghosal, Mukhopadhyay and Chakraborty[12]) and obtained the transformations which were already derived by Zahar[15][1]. These transformations show that in the Newtonian world the (apparent) relativistic effects are only due to choice of special synchrony. Using absolute synchronization in the Lorentzian world Sjödin obtained the transformations that were obtained by Tangherlini[?] which showed the "real" effects. In this way Sjödin concluded that the confusion regarding the existence of the ether and the reality of length contraction/time dilation effects was mainly due to the mixing up of the effects arising out of synchronization and the real contraction of moving bodies and retardation of moving clocks.

As said earlier, different choices for the values of the OWS yield different sets

[1]These transformations were seen to provide much clarity to some counter-intuitive issues of SR. In relation to the twin problem the importance of this transformation will be revealed in the coming chapters.

of transformation equations with varied structural features. LT is just one among them which is obtained by using Einstein convention. The other transformation equations although different outwardly, will predict the same kinematical world. These structurally different transformation equations have been found provide much insight into many conceptual issues including some interesting paradoxes in SR. (In the present investigation some of these have been used.) Some of these important transformation equations which explicitly incorporate the CS-thesis are given below. These equations relate coordinates x, y, z and time t in an inertial frame Σ with those (x',y',z',t') in another inertial frame Σ'.

Winnie transformations:

Winnie obtained his ϵ-Lorentz transformations based on three synchrony independent principles "the round trip light principle, the "principle of equal passage times" and the "linearity principle" which is as follows (The interesting derivation of these transformation equations are in Ref[10]).

$$\begin{aligned} x' &= \alpha^{-1}(x - \vec{v_\epsilon} t), \\ t' &= \alpha^{-1} t[2\vec{v_\epsilon} c^{-1}(1 - \epsilon - \epsilon') + 1] - xc^{-2}[2c(\epsilon - \epsilon') + 4\vec{v_\epsilon}(\epsilon)(1 - \epsilon)], \end{aligned} \tag{2.3}$$

where $\vec{v_\epsilon}$ denotes the relative speed of Σ' with respect to Σ,

$$\alpha = [(c - \vec{v_\epsilon}(2\epsilon - 1))^2 - \vec{v_\epsilon}^2]^{1/2}/\epsilon, \tag{2.4}$$

and ϵ (as given by Eq (2.1))and ϵ' are Reichenbach parameters in the two frames which are in relative motions.

Regarding the vector sign over the velocity a clarification is needed. The vector sign does not imply that the transformation equations involve more than one dimension, the arrow sign only emphasizes the non-reciprocity of relative velocity when $\epsilon \neq 1/2$ (i.e for non-standard synchronization). The equation could also have been written in terms of $\overleftarrow{v_{\epsilon'}}$ which denotes the relative speed of Σ to Σ' and in general $\vec{v}_\epsilon \neq \overleftarrow{v}_{\epsilon'}$.

Selleri transformations:

Selleri gave the space-time transformation between frames Σ and Σ' whose general form is given by

$$\begin{aligned} x' &= (x - \beta ct)/R(\beta) \\ y' &= y \\ z' &= z \\ t' &= R(\beta)t + \epsilon(x - \beta ct) + e(y + z), \end{aligned} \tag{2.5}$$

where ϵ and e are two undetermined functions of relative velocity v, $\beta = v/c$ and $R(\beta) = (1 - \beta)^{1/2}$. The demand of rotational invariance around x-axis gives $e = 0$, giving the final form of these transformation equations as

$$\begin{aligned} x' &= (x - \beta ct)/R(\beta) \\ y' &= y \\ z' &= z \\ t' &= R(\beta)t + \epsilon(x - \beta ct). \end{aligned} \tag{2.6}$$

The transformation Eqs.(2.3) and (2.6) represent the relativistic world.

For absolute synchronization ($\epsilon = 0$) the consequent transformation equations are

$$\begin{aligned} x' &= \gamma(x - vt) \\ t' &= \gamma^{-1}t, \end{aligned} \tag{2.7}$$

which are known as Tangherlini transformations[16] or inertial transformations[17, 18, 19]. An interesting point to note here is that although the above equations represent the relativistic world, simultaneity is not relative in character i.e it is absolute. This transformation plays a significant role while dealing with the twin problem. This is reported in Chapter of this thesis.

Zahar Transformation:

The classical or Galilean world is a world where there is no time dilation and hence the clock transport synchronization holds without any ambiguity. The transformation equations generally used in this world are the well known Galilean transformations. However, by (playfully) incorporating Einstein's procedure of light signal synchronization in this world one observes that the Galilean transformations are replaced by the Zahar transformation (named after E. Zahar who obtained these transformation equations originally in 1977[3, 12, 14, 15]).

$$\begin{aligned} x' &= x - vt, \\ t' &= \gamma^2(t - vx/c^2). \end{aligned} \tag{2.8}$$

In addition to the above mentioned transformation equations there are some other interesting transformation equations following CS approach where synchronization is achieved by non-luminal signal (in general) using the standard synchronization procedure. The equations are quite general in nature in the sense that the world (classical or relativistic) is not specified beforehand. These equations are obtained in the next section.

2.2 Non-Luminal Clock Synchronization in Different Worlds

The CS-thesis of SR can be understood more clearly by developing relativity within a medium. In an interesting paper Ghosal et.al [12] dealt with the CS issue in a novel way by considering "Relativity in a substrate". There instead of using light, spatially separated clocks were imagined to be synchronized using "acoustic signal" following Einstein's mode of synchronization. It has been shown there that transformation equations obtained by synchronizing clocks using non-luminal signal following Einstein convention in the relativistic world helped to visualize clearly the conventionality ingredients in the standard formulation of SR.

Before discussing the content of the paper let us start with the following observations. In the standard formulation of SR light has two different roles to play. On the one hand it acts as a synchronizing agent, on the other hand it has invariant two-way-speed (TWS) in vacuum. The second role has a basis in the empirically verifiable property, but the first one is purely prescriptive in origin. In the derivation of the LT, these two roles are mixed up. The inseparability contributes to several misconceptions and prejudices in relativity theory. In an effort to separate these two roles one may introduce non-luminal signal to synchronize clocks and re derive the transformation equations. To achieve this the authors[12] considered reference frames submerged in a substrate. In order to derive the transformation equations, they proposed to synchronize the clocks by some other signal (acoustic signal (AS)) which is a characteristic of the substratum. To start with the authors considered that an acoustic wave is generated at $t = 0$ at the common origin of the frames S_i and S_k. Except for the frame S_0 which is at rest relative to the substratum, in all other frames the velocity of AS in the positive and negative x-directions will not be the same. Using the CS-thesis they defined the synchronization of clocks so that these two velocities are equal in all frames although their values vary from frame to frame. This synchrony is called the *pseudo-standard synchrony* other than Einstein's standard synchrony. According to pseudo-standard synchrony along the x-axis, the one dimensional wave front equation will be

$$x_k^2 = a_{kx}^2 t_k^2, \tag{2.9}$$

where x_k denotes the co-ordinates of a frame S_k which is moving with respect to S_0 frame which is fixed in the substrate and a_{kx} is the TWS of the AS in the x-

direction.

Two-way-speed (TWS) of AS will not be the same in all directions, for example along the y-direction the wave front equation will be

$$y_k^2 = a_{ky}^2 t_k^2 \tag{2.10}$$

where a_{ky} is the TWS of AS along y-direction and may have different value from a_{kx}. Hence the acoustic wave front will not be spherical in frames other than in S_0 frame.

The Derivation of Transformation Equations:

To derive the transformation equations (TE) between two arbitrary inertial frame S_i and S_k moving with relative velocity v_{ik} the authors used TE in the linear form as,

$$\begin{aligned} x_k &= \alpha_{ik}(x_i - v_{ik}t_i), \\ y_k &= y_i, \\ t_k &= \xi_{ik}x_i + \beta_{ik}t_{ik}, \end{aligned} \tag{2.11}$$

where α_{ik}, ξ_{ik} and β_{ik} are constant that were determined using pseudo-standard synchrony. By virtue of the chosen synchrony, one can set the condition

$$x_k^2 - a_{kx}^2 t_k^2 = \lambda_{ik}^2(x_i^2 - a_{ix}^2 t_i^2), \tag{2.12}$$

where λ_{ik} is a scale factor that is independent of the space and time coordinates. Using Eqs.(2.11) and (2.12) the transformation coefficients were obtained as

$$\alpha ik = \lambda_{ik}\gamma_{ik} \tag{2.13}$$

$$\beta_{ik} = \alpha ik/\rho_{ik} \tag{2.14}$$

$$\xi_{ik} = -\frac{\alpha_{ik}/\rho_{ik}}{v_{ik}/a_{ix}^2} \tag{2.15}$$

with

$$\gamma_{ik} = (1 - v_{ik}^2/a_{ix}^2)^{-1/2}. \tag{2.16}$$

and

$$\rho_{ik} = a_{kx}/a_{ix} \tag{2.17}$$

Incorporating these the transformation Eqs.(2.11) was written as,

$$\begin{aligned} x_k &= \lambda_{ik}\gamma_{ik}(x_i - v_{ik}t_i), \\ t_k &= (\lambda_{ik}/\rho_{ik})\gamma_{ik}(t_i - v_{ik}x_i/a_{ix}^2). \end{aligned} \tag{2.18}$$

As in the preferred frame S_0 according to adopted synchronization scheme, the TWS of AS is isotropic for

$$a_x^2 + a_y^2 = a_0^2, \tag{2.19}$$

where a_x and a_y are the x and y components of the velocity of the wavefront and a_0 is the isotropic signal speed.

The TWS in an arbitrary frame S_k along x- direction was obtained as

$$a_{kx} = \frac{\alpha_{0k}a_0(1 - v_{0k}^2/a_0^2)}{\beta_{0k} + \xi_{0k}v_{0k}}, \tag{2.20}$$

Similarly the TWS in y- direction in S_k

$$a_{ky} = \frac{a_0(1 - v_{0k}^2/a_0^2)}{\beta_{0k} + \xi_{0k}v_{0k}}. \tag{2.21}$$

For any other signal whose isotropic TWS (equal to its OWS) in S_0 is a_0' (which may differ from a_0) the TWS along x- direction was

$$a_{kx}' = \frac{\alpha_{0k}a_0'(1 - v_{0k}^2/a_0'^2)}{\beta_{0k} + \xi_{0k}v_{0k}}, \tag{2.22}$$

and along the y-direction

$$a_{ky}' = \frac{a_0'(1 - v_{0k}^2/a_0'^2)}{\beta_{0k} + \xi_{0k}v_{0k}}, \tag{2.23}$$

where a_{kx}' and a_{ky}' are the TWS of the signal as measured from S_k in the longitudinal and in the transverse directions respectively. One needs to note here that in order to obtain these relations it has been assumed that with respect to S_0 under the chosen synchrony, the OWS of "other" signal is isotropic and is equal to its TWS. It has thus been tacitly assumed that in the preferred frame S_0 the pseudo-standard synchronization with AS and with the "other" signal are equivalent.

Making use of Eqs.(2.13), (2.20) and (2.21) the scale factors were obtained as

$$\lambda_{0k} = a_{kx}/a_{ky} \tag{2.24}$$

Also

$$\lambda_{ik} = \frac{\lambda_{0k}}{\lambda_{0i}} = \frac{a_{kx}\, a_{iy}}{a_{ky}\, a_{ix}}. \tag{2.25}$$

Using this value for λ_{ik} Eq.(2.18) becomes

$$\begin{aligned} x_k &= (a_{kx}/a_{ky})(a_{iy}/a_{ix})[(x_i - v_{ik}t_i)/(1 - v_{ik}^2/a_{ix}^2)^{1/2}], \\ t_k &= (a_{iy}/a_{ky})[(t_i - (v_{ik}/a_{ix}^2)x_i)/(1 - v_{ik}^2/a_{ix}^2)^{1/2}]. \end{aligned} \tag{2.26}$$

With respect to preferred frame S_0 (where $a_{0x} = a_{0y} = a_0$) the TE from S_0 to any other inertial frame S_k was thus obtained as

$$\begin{aligned} x_k &= (a_{kx}/a_{ky})[(x_0 - v_{0k}t_0)/(1 - v_{0k}^2/a_0^2)^{1/2}], \\ t_k &= (a_0/a_{ky})[(t_0 - (v_{0k}/a_0^2)x_0)/(1 - v_{0k}^2/a_{0x}^2)^{1/2}]. \end{aligned} \tag{2.27}$$

In a lighter vein the authors termed this set of transformation equations as dolphin transformations (DT) as if these transformations are perceived by intelligent dolphins equipped with standard rods and clocks under water. As can be seen the Dolphin transform in the present form can be used as a space-time relation between two frames provided one knows the TWS of AS in these two frames. If instead of AS light signal was used for synchronization of clocks, then by virtue of CVL postulate in SR

$$a_{ix} = a_{iy} = a_{kx} = a_{ky} = c, \tag{2.28}$$

which gives the familiar LT. However in absence of any communication with the outside world, *apparently* c does not play any role in DT even though the dolphins live in the relativistic world where we know c plays a fundamental role! As said in the article, in DT, c will appear as a *physical constant* through a_{kx} and a_{ky}. In order to make DT usable, the dolphins will have to measure the TWS of AS in S_k as a function of velocity v_{0k} and one can anticipate that they will eventually find that

$$\begin{aligned} a_{kx} &= a_{kx}(v_{0k}, c), \\ a_{ky} &= a_{ky}(v_{0k}, c), \end{aligned} \tag{2.29}$$

where c would appear not as the speed of light but as some physical constant. Putting $a'_{kx} = a'_{ky} = a'_0 = c$ in the two-way velocity transformation given by Eqs.(2.22) and (2.23 and using Eqs(2.13-2.16) it was demonstrated that

$$\rho_{0k} = \frac{(1 - v_{0k}^2/a_0^2)}{(1 - v_{0k}^2/c^2)}, \tag{2.30}$$

and

$$\lambda_{0k} = \frac{(1 - v_{0k}^2/a_0^2)^{1/2}}{(1 - v_{0k}^2/c^2)^{1/2}}. \tag{2.31}$$

or by Eqs.(2.17) and (2.24)

$$a_{kx} = a_0 \frac{(1 - v_{0k}^2/a_0^2)}{(1 - v_{0k}^2/c^2)}, \tag{2.32}$$

and

$$a_{ky} = a_0 \frac{(1 - v_{0k}^2/a_0^2)^{1/2}}{(1 - v_{0k}^2/c^2)^{1/2}}. \tag{2.33}$$

By inserting Eqs.(2.31) and (2.32) in Eq.(2.27) the DT for the relativistic world was obtained as

$$\begin{aligned} x_k &= (x_0 - v_{0k}t_0)/(1 - v_{0k}^2/a_0^2)^{1/2}, \\ t_k &= (1 - v_{0k}^2/c^2)^{1/2}(1 - v_{0k}^2/a_0^2)^{-1}[t_0 - (v_{0k}/a_0^2)x_0]. \end{aligned} \tag{2.34}$$

The authors note down certain important consequences of DT which are the following:

1. The transformation equations contain TWS of synchronizing signal. The simultaneity is relative. Under this synchrony relative speeds are not symmetric in general.

2. The speed of AS a_0 is conventional. c appears as a physical constant - the TWS of light - and is not based on any convention. The factor $(1 - v_{0k}^2/c^2)^{1/2}$ is due to real effects. The other factor, $(1 - v_{0k}^2/a_0^2)$ arises from the synchronization procedure which is evident from the presence of the term a_0. Thus this clarifies that different synchronization procedure may not have relativity of simultaneity but they can predict length contraction and time dilation effects. From the DT, the length contraction factor (LCF) and time dilation factor (TDF) were calculated to be

$$\begin{aligned} LCF &= (1 - v_{0k}^2/a_0^2)/(1 - v_{0k}^2/c^2)^{1/2}, \\ TDF &= (1 - v_{0k}^2/c^2)^{1/2}/(1 - v_{0k}^2/a_0^2). \end{aligned} \tag{2.35}$$

3. In the derivation of DT the two roles of the light signal which are mixed up in standard SR (as discussed before) are clearly separated.

An important point regarding DT is that it can be well used to obtain some important transformation equations in relativistic and classical worlds by making use of the properties of the synchronization signal:

Lorentz transformation *(relativistic world with Einstein synchronization)*:

In the standard synchrony the synchronization agent is light. Putting $a_0 = c$ in DT one obtains the Lorentz transformation.

Tangherlini transformation *(relativistic world with absolute synchronization)*:

If in the *preferred frame* the speed of synchronization signals $a_0 \to \infty$ then we obtains (for $S_0 \to S_k$) the Tangherlini transformation

$$\begin{aligned} x' &= \gamma(x - vt) \\ t' &= \gamma^{-1}t, \end{aligned} \tag{2.36}$$

Zahar transformation *(Einstein synchronization and classical world)*:

In the classical world the velocity addition law is the Galilean one. Then the TWS of AS is obtained to be

$$\begin{aligned} a_{kx} &= a_0(1 - v_{0k}^2/a_0^2), \\ a_{ky} &= a_0(1 - v_{0k}^2/a_0^2)^{1/2} \end{aligned} \tag{2.37}$$

Inserting these expressions for a_{kx} and a_{ky} in the DT (and in particular in Eq.(2.41) we obtain DT in in classical world

$$\begin{aligned} x_k &= (x_0 - v_{0k}t_0), \\ t_k &= [t_0 - (v_{0k}/a_0^2)x_0]/(1 - v_{0k}^2/a_0^2). \end{aligned} \tag{2.38}$$

In the standard synchrony, ($a_0 = c$) DT then becomes Zahar transformation (ZT) as we have discussed earlier

$$\begin{aligned} x_k &= (x_0 - v_{0k}t_0), \\ t_k &= [t_0 - (v_{0k}/c^2)x_0]/(1 - v_{0k}^2/c^2). \end{aligned} \tag{2.39}$$

Galilean transformation *(absolute synchrony and classical world)*:

It has been shown that in the classical world if the synchronizing signal's speed is assumed to be arbitrarily large (hypothetically) so that one may put $a_0 \to \infty$ in Eq.(2.38), one is then seen to retrieve the familiar form of GT.

DT thus is shown to act as an originator of these various important transformation equation with varied structural features. This has been seen to throw light on various counter-intuitive issues of Relativity.

References

[1] S. K. Ghosal, Biplab Raychaudhuri, Anjan Kumar Chowdhuri and Minakshi Sarker, *Found. Phys. Letters* **16**(6), 549-563 (2003).

[2] M. Redhead and T. A. Debs, *Am. J. Phys.* **64**(4), 384-392 (1996).

[3] S. K. Ghosal, Biplab Raychaudhuri, Anjan Kumar Chowdhury, and Minakshi Sarker, *Found. Phys. Lett.* **17**(5), 457-478 (2004).

[4] R. Anderson, I. Vetharaniam and G. E. Stedman, *Phys. Rep.* **295**, 93-180 (1998).

[5] S. K. Ghosal, P. Chakraborty, and D. Mukhopadhyay, *Europhys. Lett.* **15**(4), 369-374 (1991).

[6] H. Reichenbach, *The Philosophy of Space and Time* (Dover, New York, 1958).

[7] A. Grünbaum, *Philosophical Problems of Space and Time* (Alfred A. Knof. Inc., New York, 1963).

[8] B. Townsend, *Am. J. Phys.* **51**, 1092 (1983).

[9] A. Einstein, *The Principle of Relativity* (Crown, New York, 1961).

[10] A. Winnie, *Phil. Sci.* **37**, 81 (1970).

[11] A. Ungar, *Philos. of Sci.* **53**, 395-402 (1986).

[12] S. K. Ghosal, D. Mukhopadhyay, and Papia Chakraborty, *Eur. J. Phys.* **15**, 21-28 (1994).

[13] R. Mansouri, and R. U. Sexl, *Gen. Rel. and Grav.* **8**, 497 (1977).

[14] T. Sjodin, *IL Nuovo Cimento* **51**(B), 229 (1979).

[15] E. Zahar, *British. J. Phil. Sci.* **28**, 195 (1977).

[16] F. R. Tangherlini *Suppl. Nuovo Cimento* **20**, 1 (1961).

[17] F. Selleri, *Found. Phys.* **26**, 641-664 (1996).

[18] F. Selleri, *Found. Phys. Lett.* **10**, 73-83 (1997).

[19] F. Selleri, *Open Questions in Relativistic Physics*, Ed. F. Selleri, (Apeiron, Montreal, 1998) page 69-80.