CHAPTER - I

GENERAL INTRODUCTION

1.1 Introduction

The present study addresses itself to broadly two interesting foundational questions of current interest in relativity and gravitation. One of them deals with the so-called *Conventionality thesis* of special relativity, its implications, misinterpretations and finally its pedagogical importance. The other concerns the enquiry on the possibility of consolidating special relativity and gravitation in order to obtain a logically viable Lorentz-covariant theory. The main text of the present study comprises of chapters II - VII in two parts which report our observations and results that I have obtained during my studies in the last few years. Some of these observations have either been published or been reported in the national and international fora. Sometimes we have made independent observations and in another time we have played the role of a watch-dog when commenting on some recent articles on relativity foundations.

The apparently assorted compilation of papers which form the main text have one central feature in common that they all deal with foundational questions in relativity and gravitation, and everything is discussed in context of "standard" rods and clocks unlike some recent papers which discuss transformation laws for non-standard instruments.

The whole volume is organised as follows: Part I will deal with gravitation (particularly in regard to its logical possibility) in the framework of standard formulation of Special Relativity (SR) while part II will discuss the foundational questions on the standard formulation of SR itself. These two parts can stand alone in their own rights, however a sort of logical connection between these two parts will be provided in the epilogue section of chapter III.

All the chapters of the main text are self-contained particularly for those who are somewhat acquainted with the issues discussed. However for others we provide, in the next two sections of this introductory chapter, a brief review of the previous works as a background (Background I & Background II). These sections will also provide the scope and objective of the present work. Finally in the last section of this chapter summaries of all the present findings are given topic-wise. This section will provide a glimpse in advance of what lies ahead and the reader may be at liberty to skip some of the topics he may find not quite interesting for his first reading, even though as an author I would recommend that this volume be read from front to back.

1.2 BACKGROUND - I

Einstein's theory of General Relativity (GR) draws a very keen interest among the Physicists mainly for two reasons:

1. The theory is able to explain the secular motion of Mercury's perihelion and it gives for it a value of about 43" per hundred years, which is in splendid accordance to the corresponding value ascertained by the astronomers.

2. The theory is predicting a deflection of star light by the Sun, giving a deviation of about 1.72" from the straight line, which is observed value.

Furthermore, there exists until now no other theory, which can explain these two effects on the basis of well known, generally accepted and fundamental theories in mechanics and electrodynamics. So it seems that the theory of General Relativity is an unavoidable part of modern Physics. But despite these attributes, it suffers from a serious drawback in that the experimental support of GR is very limited in number and for that too one has to make use of a rather cavalier approximation of GR. This raises the interesting possibility of other theories predicting the same results. There have been some attempts which try to explain some general relativistic effects by extending Newtonian Gravity (NG) in the light of special theory.

Historically NG could successfully explain Kepler's laws. However under close scrutiny it was found to be inadequate in accounting for the residual perihelion precession of Mercury's orbit ($\simeq$ 43"/century) around the Sun. In 1919 Arnold Sommerfeld showed the usual way to obtain the precessing electronic orbits of a Hydrogen atom and then transformed his formulae for the pathways of the electron in the H-atom to the case of the Kepler motion of Mercury around the Sun. For this he first modified the equation of NG, namely

$$\frac{d}{dt}\, m_0\vec{v} = -\frac{GMm_0}{r^3}\,\vec{r} \qquad (1.1)$$

where m_0 is the mass of Mercury, M is the mass of the Sun, r is the distance of Mercury from the Sun and G is the gravitational constant. Sommerfeld replaced $m_0\vec{v}$ in the L.H.S. of equation (1.1) by the relativistic momentum $m_0\vec{v}/(1-v^2/c^2)^{1/2}$. One may easily show however that the equation that results following the modification of (1.1)

$$\frac{d}{dt}\left[m_0\vec{v}/(1-\beta^2)^{1/2}\right] = -\frac{GMm_0}{r^3}\vec{r}\ , \qquad \beta=v/c, \qquad (1.2)$$

though qualitatively admitting precession, can account for only about one sixth of the observed effect. By this way Sommerfeld came to the conclusion that Special Relativity (SR) cannot explain Mercury's motion of the perihelion. Still today this is the generally accepted opinion.

In an article, Roxburgh (1977) demonstrated that the concept of space-time curvature in GR has the status of a mere convention. According to his article, one can look upon a flat-space-time with a field embedded in it as a curved-space-time with no field. This idea justifies the recent efforts to obtain the so-called general relativistic effects without the use of any space-time metric whatsoever. Some such efforts (Sjödin 1982, Nandi 1984) have proved successful but not all. For instance, Bagge (1981) suggested recently that one can obtain, solely within the framework of special relativistic dynamics, the correct precession of the perihelion of Mercury. To obtain this, Bagge made an interesting suggestion that equation (1.2) was to be modified further by replacing the rest mass m_0 of Mercury by the so-called 'relativistic' mass $m_0/(1-\beta^2)^{1/2}$ in the right-hand-side of (1.2). The implication of this suggestion is that the Equivalence Principle (EP) in the context of SR should be interpreted as

$$m_g = m_0/(1-\beta^2)^{1/2} \qquad (1.3)$$

where m_g is the gravitational mass. It was claimed that after this modification of (1.1), the resulting equation

$$\frac{d}{dt}\,[m_0\vec{v}/(1-\beta^2)^{1/2}] = [GMm_0\ /\ r^3(1-\beta^2)^{1/2}]\vec{r} \qquad (1.4)$$

for the central force problem of Mercury's motion brought a good agreement with the known facts. However, later the claim was refuted in an article (Ghosal et all 1987). The authors showed that Bagge's approach, though interesting, did "not" yield the claimed value. Solving equation (1.4) analytically, and also numerically, they found that it yielded a precession of only 14"/century and not 42.087"/century.

In a fairly recent paper (Phipps 1986) a similar suggestion was made and in order to improve (1.2) in the light of the new (unusual) version of the EP (equation (1.3)) Phipps started from the non-covariant special relativistic Lagrangian

$$L = -\,m_0c^2\ (1-\beta^2)^{1/2} - GMm_g\ /r \qquad (1.5)$$

the Euler-Lagrange equation of which yields equation (1.2) if m_g is assumed to be equal to m_0 (usual version of the EP). Hoping to obtain correct precession for planetary orbits, the author replaced m_g by $m_0/(1-\beta^2)^{1/2}$ in the potential energy term in equation (1.5) and claimed to have obtained the desired result. However, later it was shown (Peters 1987, Phipps 1987) that Phipps's calculations were in error too. One may also observe that things do not improve even if one starts from the energy integral that the equation (1.2) implies, and then makes use of the unusual version of the EP in the potential energy term (Bagge 1981, Ghosal et al 1987).

It may thus appear at this point that the efforts to consolidate Newtonian gravity and special theory make a history of failures. However, the possibility of obtaining a suitable Special Relativistic extension of Newtonian Gravity (SRNG) may not be as bleak as it appears from the foregoing examples. Indeed one may argue that if, in the efforts to extend NG in the framework of SR, the 'complete' EP (Strandberg 1986) is allowed to play its due role from the onset, things may improve. To understand this, note that the principle of equivalence (in its weaker form) for the motion of material particles, is embedded even in Newton's law since m_0 cancels from both sides of (1.1) so that the motion of particles becomes independent of the mass of the test particles. The same also applies to Bagge's equation (1.4) and also to the equations that follow from Phipps's Lagrangian (equation(1.5)) where the unusual version of EP had been used in order to modify equation (1.2). However, EP in its stronger form suggests that all non-local (i.e tidal-force-independent) gravitational effects (not restricted to the motion of material particles alone) are equivalent to the effects of a uniformly accelerated system and it is well known that NG together with the EP in its stronger form indicates gravitational retardation of clocks.

In an interesting paper Strandberg (1986) argued that not only time but also the radial length (in the spherically symmetric situation) should exhibit change once the full power of EP could be exploited. The author then demonstrated the heuristic power of SR to show how the above implications of strong EP (the 'complete' EP) could correctly explain the bending of light and the precession of Mercury's orbit around the Sun.

It is thus evident that the efforts to extend Newtonian gravity along the lines of special relativity (i.e SRNG) go broadly along two distinct directions: (1) modifying the Newtonian force law in the light of SR and (2) modifying the length and time scales as required by the full implications of EP postulated by Einstein. The paper of Strandberg and a number of other earlier works cited therein fall in the latter category. While, as we have seen, the former approach fails to predict observations the latter one, though somewhat successful in this respect, seems to mutilate the very fabric of special relativity since SR cannot afford to accommodate tampering of rigid lengths and standard clocks in a given inertial frame. In fact this was the precise reason why Einstein did not pause to consolidate his own EP into the SR and instead, in order to repair the breaks in the logical structure of SR that were created by the inclusion of EP, Einstein had to generalize his earlier work (Einstein 1923) to come out with his celebrated 1915 paper on GR.

Indeed in order to reconcile NG with SR not only the equation of motion has to be changed but also Newtonian field equation has to be modified. The previous examples only tried the former. Some authors sometimes do just the opposite. For example, Rawal and Narlikar (1982) modified the field equations of NG to include the gravitational energy as a source of gravitational potential. The modified theory, as expected was found to be self-coupled and non-linior which was derived from a Lorentz-invariant action principle. The authors considered the scalar field (ϕ) and the modified "Poisson equation" looked like

$$(1 + \phi/c^2)\ \nabla^2\phi - (1/2c^2)\ (\nabla\ \phi)^2 = -4\pi G\rho_m \tag{1.6}$$

where ρ_m denotes the matter density. It was shown that the solution of the above equation (1.6) assuming spherical symmetry gives

$$\phi = \frac{GM}{r} + \frac{G^2M^2}{4c^2r^2} \tag{1.7}$$

where M is the mass of the spherical object that produces the gravitational field. After the solution has been obtained the authors treated this potential in a purely non-relativistic way when they considered the equation of motion. In a subsequent paper (Narlikar & Padmanabhan 1985) though this drawback has been taken care of by introducing a suitable interaction term in the Lagrangian and even though the previous work has been generalised to all orders in which the feedback of gravitational energy on ϕ in turn modified the energy which further modified ϕ and so on, correct general relativistic results could not be predicted. The theory failed to explain correctly (i) the bending of light and (ii) the precession of planetary orbits. The bending of light in this theory was zero. It was suggested further that these inadequacies of the qusi-Newtonian framework call for more sophisticated approaches to gravity.

The consolidation of SR and NG has also been considered in a series of interesting articles by Petry (1976,1977,1979,1981,1982,1988,1990,1991). In his theory the Lagrangian for the gravitational field was constructed in analogy to the Hamiltonian for a particle in the gravitational field (g^{ij}) where the four-momentum (p_k) of the particle was replaced by the variation of the field in the direction of space and time (x_k), i.e, $\partial g^{ij}/\partial x_k$. The field equations were obtained by considering the energy -momentum tensor of matter and of gravitational field together to be the source for the field (g^{ij}). However, both physically and mathematically the ideas are more involved in our opinion and for the sake of heurism and pedagogical interest we keep our discussions confined to simple minded theories. However, the impressive list of references above on the attempts on flat-space-time theories of gravity will at least bear testimony to the existence of a general urge among scientific communities for understanding gravity in the framework of special relativity. In the second chapter we shall briefly outline the general reason for this. As a passing remark and for the sake of completeness we may also list as a motivation for "other" theories of gravitation, the well known foundational questions raised against GR by Logunov (1983):

(i) The GR has not, and cannot have, energy-momentum conservation laws when a gravitational field and matter are taken in conjunction.

(ii) The inertial mass defined in the GR has no physical meaning.

(iii) Einstein's quadrupole formula for gravitational radiation is not a corollary of the GR.

(iv) The idea that a double star system loses its energy by gravitational radiation, in principle, does not follow from the GR.

(v) The GR does not satisfy a fundamental physical principle, that is the correspondence principle since it does not have the classical Newtonian limit.

However, we are not here to discuss the controversial "defects" of GR. Nevertheless we shall maintain that GR as it stands now is entirely different from other physical fields and it is not a field in the Faradey Maxwell spirit (Logunov 1983). In the next two chapters we shall only contest the commonly held thesis that the concept of flat-space-time and gravitation logically cannot go together (Schield 1960).

In the main text of part I we shall focus on a simple minded SRNG due to Biswas (1988). He tried to develop a relativistic theory of gravitation purely from heuristic considerations. The approach of Biswas, was commendably different from that of others broadly in two respects. Firstly, it did not only incorporate some results of special relativity into the Newtonian *force law* alone but instead in a bid to modify NG, it kept the *full* Newtonian field theory in view. In other words instead of trying just to modify equation (1.1) of NG, Biswas tried to systematically introduce special relativity into the following equations of NG

$$\Delta^2\phi = 4\pi G\rho \tag{1.8a}$$

$$\frac{d}{dt}(mv) = -m\Delta\phi \tag{1.8b}$$

where ϕ and ρ represent the scalar potential of NG and the mass density respectively.

Secondly, in his SRNG approach, Biswas tacitly made use of only that version of EP which was directly suggested by NG and the implication of mass energy equivalence of SR and justifiably the author did not stretch its meaning any further. That would have tampered with length and time scales affecting the standard flat-space-time metric which was to be left untouched for any special relativistic theory. The importance of this aspect of Biswas's Paper (BP) will be discussed in the next chapter.

However, in obtaining the solutions of the field equations Biswas made a mistake and this has been pointed out recently by Peters (1990). Also for some strong reasons, BP needs certain modifications to the equation of motion part in order to make the theory more acceptable and beautiful. In part I of this volume (next chapter) we shall present heuristically a new version of a flat-space-time theory of gravitation consistent with the demands of special relativity and it will be shown that our version of SRNG will be able to duplicate all the major verifiable effects of GR.

1.3 BACKGROUND-II

In the last section we have reviewed some recent attempts to obtain a theory of gravitation in the frame-work of Special Relativity (SR). It has been pointed out that these efforts are not always problem free. In different chapters, which form the first part of this volume, we shall present our humble efforts to obtain a special relativistic theory of gravitation. In part II we shall show that everything is not right even in SR. The need for revisiting special relativity arises out of recognizing the role of conventionality in the standard formulation of SR.

It is well-known that Einstein started with two simply stated and intuitively satisfying postulates, viz., the Principle of Relativity (PR) and the Constancy of Velocity of Light (CVL). But that was not enough. In order to arrive at SR, Einstein added four operational definitions or conventions of measurements. According to Prokhovnick (1967) they are (i) How to use light signal to synchronize two separated stationary clocks. (ii) The time coordinate of an event is the reading on an adjucent stationary synchronized clocks. (iii) How to use a light signal to measure a space interval from an observer to a distant event and (iv) How to measure the velocity of an object relative to an observer.

Sherwin (1992) pointed out another convention:

(v) What instruments are chosen for all these measurements.

The role of conventionality regarding synchronization of spatially distant clocks are much discussed in the literature. Once the choice of instruments is made (convention v) and there is an agreement as to the operational definition of different instruments [conventions (ii) – (iv)], the first convention (regarding synchrony) stands out in prominence. The present section will discuss the meaning and the role of conventionality in the standard formulation of SR and below we shall review some existing important works in this direction:

The role of convention in the definition of the simultaneity of distant events is one of the most debated problems in special relativity. The source of this problem lies in the fact that in SR distant clocks in a *given* inertial frame are synchronized by light signals, the one-way speed of which has to be known beforehand for the purpose. To know the one-way speed of light on the other hand one requires to have presynchronized clocks and the whole process of synchronization ends up in a logical circularity which forces us to introduce a degree of arbitrariness in assigning the value for the one-way velocity of light. However, Einstein synchronized spatially distant clocks by assuming the equality of the velocity of light in two opposite directions. Einstein's procedure to synchronize clocks at different space points is but one of several possible alternative conventions and it is now known that many of the results he obtained depended on his special choice of synchrony. As an example the question of the discordant judgements of simultaneity by two inertial observers moving with respect to each other is also a matter of such a simultaneity convention.

Historically the role of convention in the synchronization of clocks has been advocated especially by Reichenbach (1958) and later by Grünbaum (1963). They claimed that the relation of simultaneity *within* an inertial frame of reference contains an ineradicable element of convention and the conventionality lies in the assumption regarding the one-way speed of light. To clarify this point further recall that Einstein originally proposed that the criterion for the synchrony of distant clocks be that the time of arrival and reflection of a light ray as determined at one clock be precisely halfway between the time of its departure and its return upon reflection as determined at the other clock. This criterion clearly presupposes that light has the same speed in all directions. Indeed, because the specification of a value for the one-way speed of light enables directly a simple light-signal procedure for the synchronization of distant clocks, any assumption of one-way speed values is equivalent to the assumption of a criterion for synchrony. It follows that the specifications of either distant simultaneity criterion or one-way light speeds will alike be referred to as synchrony conventions (Townsend 1983).

Einstein himself referred to the distant simultaneity criterion he proposed as a free stipulation of the empirical meaning of distant simultaneity (Einstein 1961), and at issue is whether other criteria leading to different distant simultaneity judgements and consequently different one-way speeds might not have been chosen without compromising the empirical success of the theory. The conventionalist thesis holds that a range of choices are possible, all fully equivalent with respect to experimental outcome. According to the conventionalist thesis, any synchrony convention will be admissible so long as it is consistent with the round-trip principle, the principle which holds that the average speed of a light ray over any closed path has a constant value (Reinterpreted second relativity postulate, vide sec.3 of chapter V). A convention within the SR must be consistent with the round-trip principle since this principle is a consequence of the theory prior to the adoption of any criterion for distant simultaneity and may in principle be tested with a single clock. This thesis which shall here be called the thesis of the *Conventionality of distant Simultaneity* (the C-S thesis). According to the C-S thesis the conventional ingredient of SR which logically cannot have any empirical content, gives rise to results that are often erroneously construed as the new philosophical imports of special relativity theory.

There has now been a substantial amount of clarification of the C-S thesis due to a number of authors. Possibility of using synchronization convention other than that adopted by Einstein has also been much discussed.

Winnie (1970) first studied the consequences of special theory when no assumption regarding the one-way speed of light was made and then developed the so-called ε-Lorentz transformations adopting non-Einstein one-way velocity assumption or non-standard synchronization convention in general. In developing the ε-Lorentz transformation Winnie assumed a principle called the "Principle of equal Passage time". This was used in addition to the "Linearity Principle" and the "Round-trip light Principle". These principles were then shown to be independent of one-way velocity assumptions and thus may form the basis of a SR without distant simultaneity assumptions. In fact Winnie's theory was one dimensional. Unger (1986) extended Winnie's idea by considering a generalised Lorentz transformation group that does not embody Einstein's isotropy convention. The approach seems to be well suited for establishing the results of Winnie as well as some new results. However, these discussions were confined to one-dimension only. Later it will be noted that at least a two-dimensional analyses is a must. Otherwise the isotropy of two-way speed of light which follows from the reinterpreted second relativity postulate (vide sec. 3 of chapter V) cannot be used and therefore some subtlities and richness of the relativistic Physics (Ghosal et al 1991b) have to be sacrificed.

In a series of important papers Mansouri and Sexl (1977) 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. Synchronization by the Einstein procedure (using the light signal) and by slow clock transport (to correct all clocks at a given locality and then place them at all space points of a given reference frame)* turn out to be equivalent if and only if the time dilatation factor is given by the Einstein result $(1-v^2/c^2)^{1/2}$. The authors constructed an ether theory that maintains absolute simultaneity and is kinematically equivalent to SR.

In 1979 Sjödin developed the C-S thesis and consolidated it in a beautiful paper by considering the whole issue more generally and also by assuming the role of synchronization in SR and some related theories. Sjödin presented all logically possible linear transformations between inertial frames depending on physical behaviour of scales and clocks in motion with respect to physical vacuum and then examined Lorentz Transformations (LT) in the light of true length contraction and time dilatation. In his article Sjödin tried to separate the true effects and the effects due to synchronization convention. For this the author considered two special cases. The Newtonian world, without any contraction of moving bodies and slowing down of moving clocks and the Lorentzian world, with longitudinal contraction of moving bodies and slowing down of clocks. The author then used standard synchrony in Newtonian world and got the transformations which were already derived by Zahar (1977). These transformations show that the

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*For some remarks on slow-transport synchrony vide Podlaha (1980). In the present volume we would not take up this issue.

relativistic effects are only due to choice of special synchrony. But when Sjödin used absolute synchronization in Lorentzian world, the relevant transformations were due to Tangherlini (1961) which shows the real effects. In this way Sjödin came to the conclusion that the confusion regarding the existence of the ether and the reality of the length contraction / time dilatation effects is mainly due to the non-separation of the effects due to synchronization and the real contraction of moving bodies and retardation of moving clocks.

Although many articles have been written on this thesis of Conventionality of Simultaneity, most Physics texts on relativity, except a few (Taylor & Wheeler 1963), do not bring this topic into question. The fact that the C-S thesis has not yet gained wide spread attention among Physicists may be attributed to the fact that there is a tendency to regard the C-S thesis as an antithesis of SR and anything that seems contrary to the standard formulation of relativity is viewed with skepticism. In fact there are non-believers of the C-S thesis too. Among the oponents, are the authors (for example vide Fung & Hsieh 1980; Nissim-Sabat 1982) who proposed numerous experiments over the years which have been claimed to allow for an empirical test which might distinguish among the admissible synchrony conventions and thus refute the conventionalists thesis that all admissible conventions are empirically equivalent. To comment on this however, it is enough to say that every such test proposed can be shown to involve in its analyses and assumptions logically equivalent to the adoption of the standard synchrony and thus to amount to a simple begging of the question rather than an independent empirical test

(Townsend 1983).

Indeed in our opinion the C-S thesis complements SR and the understanding of the former helps clear out confusions that sometimes occur in SR. As we have pointed out, the claim that the relativity of distant simultaneity is a new non-classical philosophical import is one example of various such confusions. In spite of SR, being one of the most simple physical theories, it is the most prolific in giving birth to falacies, riddles, confusions and misconceptions. We identify at least two reasons for them: (i) Overlooking of the C-S thesis and (ii) Misconstruing of the subtlities of the C-S thesis.

As an example of one of such misconception whose origin may be attributed to the reason no. (i) above is the common belief that relativistic transformations can be derived using the first relativity postulate alone. Indeed the literature is abundant with the so-called one-postulate derivation of Lorentz transformations (Ignatowasky 1910, Frank and Rothe 1911, Wiechest 1911, Pars L A 1921,Terletskii 1968, Sussmann 1969, Arzelies H 1966, Lee A R and Kalotas T M 1975, Levy-Leblond J M 1976, Srivastava A M 1981). In order to criticize the "overemphasized" role of the the second relativity postulate (round-trip light principle according to the C-S thesis) in the standard two postulate derivations of SR these authors have shown that the existence of a limiting universal speed is a necessary consequence of the First Relativity Postulate (FRP) alone. Apparently these approaches make the Second Relativity Postulate (SRP) superfluous, but practically that is not so because the authors obtained only the Lorentzian *form* of transformation equations where c (the velocity of light) is replaced by an unknown constant velocity parameter ['σ' according to Lee and Kalotas 1975] to be determined empirically. Thus unless a further empirical information is supplemented with, nothing prevents the transformation equations to become even Galilean (σ = ∞). In order to develop LT without the SRP, no reference of clock synchronization has been made: this is a feature which is common to all the articles mentioned above is the root of all confusions. We shall later (chapter VII) show how important it is to incorporate round-trip light principle in order to derive relativistic transformations.

There are other examples of common misconception that arises from overlooking of the role of conventionality ingredients of SR. It is a still prevailing belief among Physicists that SR goes over to Galilean Relativity (GR) for relative speeds that are very small compared to the speed of light in vacuum. This is not correct. In fact it can be shown that if the belief is taken to be true it would have led to an interesting fallacy which we shall discuss in chapter IV. It will be argued that Galilean synchrony and Einstein synchrony are different and we will show that small velocity approximation cannot alter the convention of distant simultaneity.

Misconstruction of the C-S thesis itself is also not uncommon. For example in a recent article (Cavalleri & Bernasconi 1989) it has been erroneously suggested that light speed invariance in SR is a trivial matter and as if, by virtue of the C-S thesis, even Galilean Physics can be reformulated so that light speed remains invariant. We shall show in chapter V that these claims are not quite correct and it will be presented that the above claims have their origin in the misconstruction of the Reichenbach-Grünbaum thesis of conventionality of distant simultaneity in SR.

There are other examples also. Schlegel (1973,1975,1977) in his papers claimed that it is possible to construct theoretically a Lorentz Invariant (LI) clock whose rate does not depend on its state of motion and also stated that the PR does not come in the way in conceiving such a clock. As a counter claim then Rodrigues (1985), in connection with the enquiry whether Lorentz Invariant (LI) clocks can exist without violating the PR, incorrectly remarked that the possibility of having absolute synchrony is an antithesis of the relativity principle! In chapter VI we will address ourselves to the task of clarifying these issues. The definition of a LI clock will be reexamined in the light of the C-S thesis.

Sometimes in connection with the C-S thesis, the debatable issue of ether (as a *hypothetical* substrate providing a preferred inertial frame) often crops up (Sjödin 1979; Mansouri & Sexl 1977; Cavalleri & Bernasconi 1989). But questions have been raised whether considerations of synchronization alone can distinguish an ether frame or not (Spinelli 1983; Cavalleri & Spinelli 1983; Stone 1991). As it stands now, as if the existence of a real physical ether as a preferred frame would have placed the C-S thesis on a stronger footing. In fact efforts are still on to give a physical support to this preferred frame of ether. We shall later see in chapter VII that for the understanding of the C-S thesis at least, one can bypass the debate concerning the existence of ether by introducing at the out-set a real physical substrate through which different inertial frames may be considered to be in relative motion.

Given this perspective of confusion, misconstruction and polemics regarding the C-S thesis or SR for that matter, we are led to conclude that everything of SR is still not well understood and we hope that all the chapters (IV, V, VI, VII) which form the part II of this volume will demonstrate that the C-S thesis, instead of being an adversary to SR may aid us indeed to resolve confusions in SR itself.

1.4 TOPIC - WISE SUMMARY OF THE PRESENT INVESTIGATIONS:

(I)

ON THE VIABILITY OF A FLAT-SPACE-TIME THEORY OF GRAVITATION

An improved version of the flat-space-time theory of gravitation has been presented. To obtain the equation of motion of test objects a covariant Lagrangian formulation has been developed heuristically and a non-general-relativistic tensorial field equations have also been proposed. It has been shown that with these results the present theory when applied to a matter-free spherically symmetric situation, produces correct values for the advance of the perihelion of Mercury's orbit and bending of light near the Sun. The energy integral for a particle trajectory has been calculated and this has been used to obtain the general red-shift formula.

PARTICLE TRAJECTORIES IN SRNG

In the light of a Lorentz covariant theory of gravitation, the radial and the circular trajectories of test objects have been studied in a static spherically symmetric situation. It has been found that the gravitational field is characterised by a characteristic radius $r_c \simeq 1.58 r_s$ (r_s = Schwarzschild radius) which defines the surface of infinite red-shift. For a radial free fall it has been shown that a particle coming from a large distance first gets accelerated towards the source. However, as the velocity increases and the particle penetrates deep into the field, the non-Newtonian features of gravity begin to show up. From some point along the radial trajectory, depending on the initial energy, the particle starts getting retarded and finally stops at r_c. It is therefore observed that the radial fall in general is characterised by a "terminal velocity" in the velocity field. Another non-Newtonian character of the present flat-space-time gravity concerns the question of existence of circular orbits. Calculations revealed that circular orbits cannot exist below a limiting radius which is approximately equal to 2.23 r_s.

The last section of the paper (chapter III) discusses some objections which may be raised against the consolidation of gravitation & special relativity and it is remarked that the content of part II of the present volume (particularly the chapter VII) may come out with the answer.

(II)

PASSAGE FROM EINSTEINIAN TO GALILEAN RELATIVITY AND CLOCK SYNCHRONY

There is a general belief that under small velocity approximation, Special Relativity goes over into Galilean Relativity. However, a misconception could easily arise that would stem from overlooking the role of conventionality ingredients at Special Relativity Theory. It is observed that the small velocity approximation cannot alter the convention of distant simultaneity. In order to exemplify this point further, the Lorentz transformations are critically compared, under the same approximation, with the two other space-time transformations, one of which represents an Einsteinian world with Galilean synchrony whereas the other describes a Galilean world with Einsteinian synchrony.

CONVENTIONALITY OF DISTANT SIMULTANEITY AND LIGHT SPEED INVARIANCE

A recent claim that it is possible to formulate Galilean Physics so that the light speed remains invariant and also that Special Relativity (SR) can be reformulated in such a way that the constancy of light speed is no longer maintained, has been refuted. Had it been correct, it would have rendered the second relativity postulate trivial! It is held that the above claim has its origin in the misconstruction of the Reichenbach - Grünbaum thesis of conventionality of distant simultaneity in SR.

ON THE DEFINITION AND EXISTENCE OF LORENTZ INVARIANT CLOCKS

In the light of the Conventionality of distant Simultaneity thesis (C-S thesis) the definition of a Lorentz Invariant (LI) clock has been reexamined. A recent definition of a LI clock has been found to be logically unsound. The C-S thesis has been clarified in order to obtain a synchrony independent definition of a LI clock. General transformations of coordinates between two inertial frames when standard clocks are replaced by LI clocks have been obtained in order to understand the question of incompatibility of LI clocks and relativity. It is held that contrary to some statements in the literature the theory of relativity *does* forbid the existence of LI clocks but a recent approach which tries to establish the above fact seems to be unsatisfactory.

THE ROLE OF c IN SPACE-TIME TRANSFORMATIONS : RELATIVITY IN A SUBSTRATE

Reichenbach – Grünbaum thesis of the Conventionality of distant Simultaneity of special relativity is clarified by developing relativity within a medium. Instead of light, spatially distant clocks are imagined to have been synchronized by "acoustic signal". Einstein's procedure for synchrony which assumes that the two-way-speed of the synchronizing signal along a given line is the same as its one-way-speed, has however been retained. It is shown that by deliberately opting for the non-luminal synchrony (but at the same time following Einstein's procedure for it) and hence by obtaining the transformation equations for the relativistic world one is able to visualize more clearly the conventionality ingredients in the standard formulation of special relativity. The Sjödin point of view of clock synchronization which requires the concept of a preferred inertial frame is seen to be more appropriate in the present context. First the transformations have been obtained generally and later some special cases have been investigated. The common confusions regarding the "real" and "apparent" effects in special relativity have been made clear by studying the transformation equations for the relativistic world and that for the Galilean world under the non-luminal synchrony. It is shown that γ-factors of special relativity *partly* originates from Einstein's procedure for clock synchrony.

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