# RELATIVITY
# TIME AND REALITY

*A critical investigation of the Einstein Theory of Relativity from a logical point of view*

*by*

HARALD NORDENSON
D. Phil,

*London*
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To the memory of my revered friends

AXEL HÄGERSTRÖM

ADOLPH PHALÉN

to whom I owe my introduction into epistemology

*'Free thinking is great,*
*Right thinking is greater'*

(motto of the University of Uppsala)

# PREFACE

It is my long-time experience that when somebody allows himself to criticize, or even merely analyse the fundamental principles and definitions of the Theory of Relativity, he is inevitably told that he is unduly prejudiced and fettered by old traditions and conventional ideas, that he is *a priori* alien to these new revolutionary lines of thought and therefore more or less incompetent to deal with them.

I am therefore anxious to emphasize that when about fifty-five years ago I was first brought into contact with the Theory of Relativity, I was fascinated by the idea that physical experiments could lead to results that made it necessary to abandon and remould some of our most fundamental concepts. I was incited to my further studies merely by an earnest desire to grasp the real significance of the new concepts.[1]

It is also my experience that anyone who ventures to criticize the Theory of Relativity will invariably meet the objection from the faithful 'relativists' that the presentation of the Theory which is being scrutinized by the critic must be considered inadequate or too elementary, and that the Theory should be evaluated on the basis of some other book or paper which is alleged to be the accurate presentation of the fundamental ideas of the Theory. But if the reference to another paper is followed up by the critic, and he nevertheless feels justified in maintaining his criticism the result is as a rule a new reference to another paper and so on. Not unfrequently the effect of the criticism is a declaration from the 'relativist' that the deduction of the Theory is of secondary importance since the formulae of the Theory are supposed to have been corroborated by experiments.

With regard to these attitudes I have found it necessary to carry my analysis through on a rather broad front. My aim being to state the content of Einstein's new concepts and the principles on which they are based, I have in the first place taken up Einstein's original papers and furthermore some of the more encyclopedic presentations, as well as some of those dealing with the corroborations. Of the many voluble mathematical treatises I have only taken those into consideration, which touch upon the foundations of the Theory.

I wish to emphasize that in this study of the relativity problems I have not been guided by any preconceived opinion, as to how the

[1] The first results of my investigations were published in 'Einstein's relativitetsteori och den fysikaliska verkligheten', Stockholm 1922.

arising problems are to be solved. I have endeavoured to approach them without prejudice, except—if that is a prejudice—for a certain fascination as mentioned above at the idea of remoulding our fundamental concepts on the basis of experimental results.

With this background I can allow myself to make an appeal:

*Dear Reader,*

Accord me the favour of dropping any prejudice on the subject of this book before reading it. Otherwise spare yourself the trouble of reading it.

Danviksgatan 10
116 41 Stockholm
*December* 1968

HARALD NORDENSON



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# INTRODUCTION

Some sixty years have elapsed since Albert Einstein first presented his Theory of Relativity.[1] During this time it has—with few exceptions—been generally accepted by the scientific world as one of the greatest conquests of the spirit of man in the field of science.

But it is not only for our understanding of physical facts that the ideas of Einstein are presumed to have created a revolution in our thinking and to have done away with traditional ideas. With regard to our fundamental concepts of time and space the Theory is alleged to have thrown over our classical views and laid new foundations. Typical of this standpoint is the often-quoted proclamation by H. Minkowski in his lecture on 'Space and Time' in September 1908.[2]

'From now on the independent concept of space and the independent concept of time shall vanish as shadows and only a kind of union of them will preserve independence.'[3]

The concepts of time and space being two of the principal foundations for our study and understanding of the physical world as well as for our reasoning in general, it might well be expected that such 'revolutionary' ideas should have given rise to a very extensive literature on these matters. It has therefore seemed to me to be of interest to make a retrospective survey of what these ideas have brought forward over the years and to establish what the new concepts actually contain and what results they may have given us.

A closer study reveals, however, how limited the literature on this special side of the subject is. With very few exceptions those who have taken up a discussion of the Theory of Relativity—and they are indeed numerous—have in principle accepted Einstein's fundamental statements and proclamations and have mostly confined themselves to discussing and emphasizing the numerous and certainly remarkable consequences to which his ideas are declared to have led. The foundation-stones of the Theory have received notably little attention.

[1] 'Zur Elektrodynamik bewegter Körper', *Annalen der Physik* 1905.
[2] H. MINKOWSKI: 'Raum und Zeit', *Physikalische Zeitschrift*, X, 104, 1909.
[3] Translation: '*Von Stund an sollen Raum für sich und Zeit für sich völlig zu Schatten herabsinken und nur noch eine Art Union der beiden soll Selbständigkeit bewahren.*'

Since the most striking principle of the Theory is the negation of classical time and its replacement with a new concept, the leading team of this book has been:

*What is the content of Einstein's new time concept, what has been discarded of the classical concept and how does the new time concept influence our picture of the physical world?*

This being the purpose of the book it becomes wholly of epistemological character and it is based only on the rules of logic.



# 1
# THE CHARACTER OF THE 'RELATIVITY PROBLEM'

Attempts to analyse the Theory of Relativity and its new concepts are frequently met by the objection that the theory is of a purely mathematical nature and that anyone who is not a specialist in mathematics is excluded from the possibility of grasping its contents. Thus W. Wien has proclaimed:

*Jedem Nicht-Mathematiker is der Eintritt verwehrt.*'[1]

Nothing can be more erroneous. The Theory of Relativity deals with physical problems and has been evoked to explain the results of certain physical observations. It is therefore primarily a physical theory, as has been clearly emphasized by Einstein himself. The same is declared by A. S. Eddington in his book: *The Mathematical Theory of Relativity*:

'The subject of this mathematical treatise is not pure mathematics but physics.'

'The pure mathematician deals with ideal quantities defined as having the properties which he deliberately assigns to them. But in an experimental science we have to discover properties, not to assign them, and physical quantities are defined primarily according to the way in which we recognize them when confronted by them in our observation of the world around us.'

Thus, although the Theory of Relativity has been made the subject of far-reaching mathematical treatment, *it is fundamentally a theory for the explanation of physical facts and observations.*

The mathematical apparatus used to express its foundations and far-reaching consequences is auxiliary. This is also illustrated by the historical development of the Theory.

On the other hand, *through Einstein's introduction of new concepts*

[1] No entrance for non-mathematicians. Compare the inscription on Plato's Academia *Ageometretos medeis euseta.*

*of time and space, the Theory enters the epistemological field and therefore becomes liable to an epistemological approach.*

In order to understand the reasonings which led Einstein to proclaim his Theory of Relativity it is necessary to state the position of physical science in general and especially of mechanics before the appearance of his ideas.

## THE CLASSICAL (GALILEI–NEWTON) LAWS OF MECHANICS

The fundamental law of Galilei–Newton mechanics can be formulated thus:[1]

'A body removed sufficiently far from other bodies continues in a state of rest or of uniform motion in a straight line.' This is called the law of inertia.

'A system of co-ordinates of which the state of motion is such that the law of inertia holds relative to it is called a Galilean system of co-ordinates.'

Such a system is also called a system of inertia and it can be defined in the following way:

If from a point at rest in a system of co-ordinates three particles of mass are thrown out in three different directions and they will move along straight lines, the system is an inertial system and in this system any free particle of mass will follow the law of inertia and will thus either be at rest or move in a straight line with constant velocity. In such a system ('inertial' or 'Galilean' system) the laws of Newton mechanics will be valid (von Laue, p. 7).

Before embarking on a closer study of these laws I would refer the reader to the following graphical presentation of how events are described in relation to different inertial co-ordinate systems.

Let $K$ be a system of reference with the perpendicular axes $x\ y\ z$ meeting in the point $O$.

Let another system of reference $K'$ with the axes $x'\ y'\ z'$ coincide with $K$ at the moment $t = 0$ (zero), then $x'$ coincides with $x$, $y'$ with $y$ and $z'$ with $z$, and let us assume that $K'$ moves along the positive $x$ axis of $K$ with the velocity $v$. If we now want to characterize an

[1] Here I follow in the main two works:
ALBERT EINSTEIN: *Relativity. A popular presentation.* Methuen, London, 1954 (in the following called '*Relativity*'), p. 11.
MAX VON LAUE: 'Die Relativitätstheorie', Part I (*Wissenschaft, 38*), Vieweg & Sohn, Braunschweig, 1919.





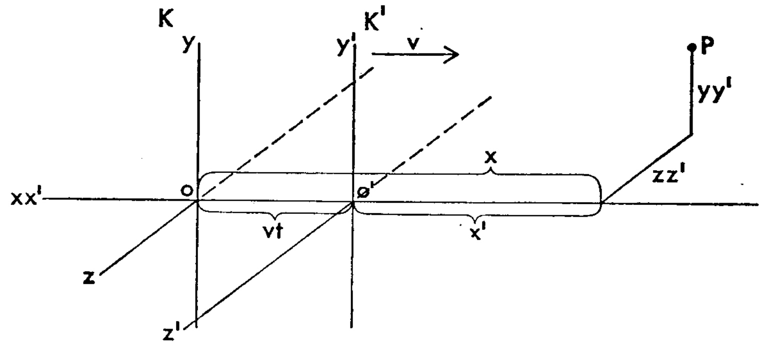



FIG. 1.

event in a point $P$ at a moment later than $t = 0$ (see fig. 1), this is done in $K$ by the co-ordinates $x\ y\ z$ and $t$. With regard to $K'$ the co-ordinates may be called $x'\ y'\ z'\ t'$, and it is easily found that the relation between these co-ordinates in the two systems is

$$x' = x - vt,$$
$$y' = y,$$
$$z' = z,$$
$$t' = t.$$

The fourth equation expresses that the time concept and the time calculation is the same for both systems.

It should be noted that the latter equation is not presented by Newton. By him as well as by all physicists up to the beginning of this century it has been considered self-evident that 'time' in $K'$ and 'time' in $K$ should be identical in conformity with the classical concept of a uniformly reigning time, which is in fact the basis of all our classical laws of physics and of all previously attained results. The equation $t' = t$ is the mathematical expression for this presumption.

The first three equations above are called '*the Galilean or Newtonian equations of transformation*' and the fourth equation is implicit in them. It is one of the rules of classical (Newtonian) mechanics that:

'*Every system of reference which is attained from an inertial system with the aid of these equations is also an inertial system*' (von Laue, p. 13).

Von Laue and other writers call this rule *the Principle of Relativity of Classical Mechanics.*

Another principal Newtonian law characterizing the motion of a mass particle in an inertial system is:

Mass × Acceleration = Force.

Mathematically this is expressed by the equation

$$\frac{mdq}{dt} = F,$$

where $m$ represents the mass of the particle, $q$ its velocity and $F$ the force acting on the particle. The law can also be expressed by the equation

$$ma = F,$$

where $a$ represents the acceleration given to the particle by the force $F$.

Another of Newton's laws is that if the above law is valid for one Galilean system, it is also valid for another Galilean system, say $K'$. The equation expresses the character of the movement of the particle in $K'$ just as well as in $K$.

A detailed and complete deduction of this fundamental rule of Newtonian mechanics is given by von Laue ('Relativitätstheorie', Vol. 1, p. 13) and for the sake of brevity I allow myself to refer to this deduction.[1]

It is this rule of the validity of the equation $ma = F$ (as well as other Newtonian rules) for all inertial systems, which is implied when so many authors refer to 'the principle of relativity of Newtonian mechanics'.

Thus Thirring in *Handbuch der Physik*, IV, p. 90 says that the fundamental rules of mechanics are invariant with relation to the Galilei–Newton transformation and denotes this as 'the Principle of Relativity of Classical Mechanics'.

Equally C. Möller (*The Theory of Relativity*, p. 2) writes after declaring that 'all systems of reference for which the law of inertia is valid are called systems of inertia':

'The Principle of Relativity in Mechanics states that the systems of inertia are also completely equivalent with regard to other laws of mechanics.'

Einstein, too, has accepted that the principle of Relativity of classical mechanics is implied in the rule:

[1] Another very detailed presentation of the Newtonian laws and their deduction is given by Aloys Müller in, *Die philosophischen Probleme der Einsteinischen Relativitätstheorie*, Ch. 25–26. Vieweg, Braunschweig, 1922.





Relative to $K'$ the mechanical laws of Galilei–Newton hold good exactly as they do with respect to $K$.[1]

In order to avoid misunderstanding it should be strictly kept in mind that the laws of classical mechanics only apply to particles of mass.

## EINSTEIN'S EXTENSION OF THE CLASSICAL PRINCIPLE OF RELATIVITY

Einstein maintains—and this is indeed the basic idea of his Theory of Relativity—that the classical Principle of Relativity, according to which the laws of mechanics are valid for all Galilean systems regardless of the system of reference, should be extended to apply to 'all natural phenomena'. He expresses this tenet thus:

*If relative to* K, K′ *is a uniformly moving co-ordinate system devoid of rotation, the 'natural phenomena' run their course with respect to* K *according to exactly the same general laws as with respect to* K (*Relativity*, p. 13.)

Einstein calls this '*the Principle of Relativity in the restricted sense*'.

This characterization of the proclaimed law seems somewhat misleading since the law contains a very remarkable and far-reaching extension.

The Galilean systems of reference should thus according to Einstein be equally valid also for other 'natural phenomena' than those of mechanical nature in the Newtonian sense. Just as in the case of Newtonian mechanics the laws of 'all natural phenomena' should remain 'invariant' when transformed from one Galilean system to another.

As Einstein points out his new ideas about relativity are the result of confronting the classical Principle of Relativity with the Maxwell–Lorentz theory of electro-dynamics. His motive for the extension of the classical principle to the electro-dynamic phenomena is:

'*It* [*the Principle of Relativity*] *appeals so convincingly to the intellect because it is so natural and simple*' (p. 19).

'*That a principle of such broad generality should hold with such exactness in one domain of phenomena and yet should be invalid for another is* a priori *not very probable*' (p. 14).

In this context it is important to observe the various meanings attributed to the term 'Principle of Relativity'.

[1] '*Relativity*', p. 13.

When Einstein calls his first presentation of the Theory 'the Principle of Relativity in the restricted sense' it is probably due to the fact that when he extends it to be valid also for other systems of reference than Galilean—such as rotating or accelerated systems and systems in fields with or without gravitation—he denotes this application as 'the General Theory of Relativity'.

To the writer, however, it seems more adequate to make the following distinctions:

### DEFINITIONS OF THE DIFFERENT PRINCIPLES OF RELATIVITY

1. '*The Classical Principle of Relativity*'. The Galilei–Newton principle valid for the laws of mechanics (mass particles).
2. '*The Extended Principle of Relativity*' or '*The Einstein Principle of Relativity*'[1] where the classical principle applies to 'all natural phenomena'. This principle has two sections:

   (*a*) *The Special Theory of Relativity* dealing with the phenomena with regard to Galilean systems of reference.

   (*b*) *The General Theory of Relativity* dealing with the phenomena in relation to other systems, such as rotating and accelerated systems in fields with or without gravitation.[1]

[1] It should be noted also that other authors have even before Einstein discussed the Principle of Relativity. This is the case with H. A. Lorentz and H. Poincaré and their views differ on certain points from Einstein's. But they all have in common that they accept a new symbol $t'$ for time in the moving system which differs from the time $t$ in the system at rest.

Among these different aspects on the relativity problem the most elaborate and subversive standpoint is that of Einstein and it seems therefore well justified to name the modern Principle of Relativity after him.

For a close discussion of the development of the modern Principle see Appendix p. 199.



# 2

# THE SPECIAL THEORY OF RELATIVITY

## EINSTEIN'S INTRODUCTION OF A NEW TIME CONCEPT AND NEW TRANSFORMATION EQUATIONS

When Einstein wishes to extend the classical Newtonian Principle of Relativity to a larger domain of the physical world and especially to the field of electro-dynamics, certain difficulties arise.

Let a ray of light start from the point $O$ (in fig. 1, p. 19) at the time $t = 0$ and move along the positive $x$ axis with the constant velocity $c$. The ray is then characterized in the system $K$ by the equation $x = ct$.

At a moment $t$ the ray will have arrived at a point $Q$ on the $x$ axis at the distance $ct$ from $O$. We now want to find out how far it has travelled in the system $K'$. The point $O'$ which coincided with $O$ at the moment $t = 0$ has in the time $t$ moved the distance $vt$ along the $x$-axis and the distance of the ray from $O'$ will therefore be

$$x' = x - vt = ct - vt = t(c - v).$$

The point $Q$ which the ray has reached lies at the distance $(c - v)t$ from $O'$ and the ray has thus moved in $K'$ with the velocity

$$\frac{x'}{t} = c - v.$$

In the system $K$ the ray has therefore moved with a velocity less than $c$. This, however, does *not* agree with the Maxwell–Lorentz theory when combined with Einstein's desire to apply the Principle of Relativity to electro-magnetic phenomena.

It is an essential implication of the Maxwell equations that electro-magnetic waves in empty space propagate in all directions with the velocity $c$ (approx. 300,000 km/sec.) independently of the way in which they are created, that is in the system for which the equations of the theory are supposed to be valid—often called the ether. Since light waves, according to Maxwell's theory of light, are special electro-magnetic waves, the velocity with which light is propagated *in vacuo* must also be independent of the state of motion of the light source and of the direction of the ray in the system of reference for which the equations are claimed to be valid, and have the value $c$.

If we now apply the Principle of Relativity of mechanics to the Maxwell equations, this would mean that if they are valid for one system of inertia (Galilean system) they must also be valid for any other such system. *The velocity of one and the same light ray must according to this have the same constant value* c *in all Galilean systems of reference, for instance in* K′ *as well as in* K.

But we have just seen that if the velocity is $c$ in one system $K$ it would be $c - v$ in at least one direction in the system $K'$ moving with velocity $v$. To say that also in $K'$ it travels with velocity $c$ would imply that at a moment $t$ it would be both in one point on the $x$-axis at the distance $ct$ from $O$ and also in a point on the $x$-axis at the same distance $ct$ counted from $O'$, which means that the ray should at a certain moment be in two points, or, otherwise expressed, *be in one point and at the same time not be in that same point. This is a clear contradiction which must be eliminated.*

Here, however, I wish to draw attention to the following observation: The assumption that there is *one* system of reference for the Maxwell equations where we can say that the velocity of a light ray *in vacuo* is independent of the motion of the light source and equal to the constant $c$, does *not* create any such contradiction. This system of reference would correspond to what has hitherto been called 'the ether' which has earlier been supposed to be the bearer—the privileged system of reference—of all electro-magnetic phenomena. This is sometimes called 'the principle of constant velocity of light'. In this form the principle does *not* conflict with the classical concept of time. The principle of constant velocity of light is sometimes used to indicate the result of the application of the classical Principle of Relativity to the Maxwell equations which implies that the velocity of one and the same light ray should have the same value regardless of whether it is referred to a Galilean system $K$ or to the system $K'$ moving with the velocity $v$ along the $x$-axis.

This is the fundamental idea of Einstein's Theory of Relativity. And it is when given this meaning that the principle leads to the contradiction Einstein has clearly realized and undertaken to solve by introducing a new concept of time.

From a mathematical point of view the problem can be formulated thus:

If an event takes place in a system with the co-ordinates $x, y, z, t$ in $K$, how do we find the co-ordinates $x', y', z', t'$ which characterize the





event in $K'$ if we require that the transformation equations should transform the light ray equation $x = ct$ for a light ray along the $x$-axis in $K$ into $x' = ct'$ for the same ray in $K'$, which is the mathematical formulation of the idea that the same ray should travel with the same velocity $c$ in both systems?

Einstein has shown that the invariant transformation of the equation $x = ct$ into $x' = ct'$ can be attained by the following equations:

$$x' = \frac{x - vt}{\sqrt{1 - \frac{v^2}{c^2}}},$$

$$y' = y, \quad z' = z$$

and

$$t' = \frac{t - \frac{vx}{c^2}}{\sqrt{1 - \frac{v^2}{c^2}}}.$$

Earlier H. A. Lorentz had produced somewhat similar transformation equations for the change of symbols and where $t'$ differed from $t$. He did *not*, however, embark on a discussion of the meaning of the new symbol $t'$. He confined himself to saying that it denotes something we might call the 'point time' or 'local time' ('*Ortszeit*') of the event. According to Lorentz's reasonings the symbol $t'$ remains an auxiliary mathematical symbol without assigned physical meaning. (Compare Appendix, p. 208.)

## CONSIDERATIONS ON THE INTRODUCTION OF A NEW TIME SYMBOL

It is at this point that Einstein initiates his speculation. He is fully aware of the fact that the application of the classical Principle of Relativity to the laws of electro dynamics, involving that the velocity of the light ray should remain invariant by transformation from $K$ to $K'$, can *not* be brought to comply with Newtonian transformation equations, since it would imply that a ray of light *is* in one point and at the same time is *not* in that point.

But as we have seen Einstein declares himself an eager adherent of the Principle of Relativity as a law of general validity for all 'natural phenomena'. Therefore he wishes to make it valid also for electro-dynamic phenomena. Appreciating that this leads to a contradiction Einstein concludes that the problem must be solved by a revision of our concept of time.

In '*Relativity*' (p. 19) he writes:

'*At this juncture the theory of Relativity entered the arena. As a result of an analysis of the physical conceptions of time and space it became evident that in reality there is not the least incompatibility between the Principle of Relativity and the law of propagation of light and that by systematically holding fast to both these laws a logically rigid theory could be arrived at.*'

In another presentation of his Theory he writes about the same conflicting principles:[1]

'*Before we draw any conclusions from these two principles* [*the Newtonian principle of relativity and the constant velocity of light*] *we must first review the physical significance of the concepts "time" and "velocity".*'

Also in his first paper 'Zur Electrodynamik bewegter Körper' Einstein makes it the foundation of his entire reasoning to establish what is to be understood by 'time' and how we are to measure time when comparing events in distant points of one and the same system of reference.

It is thus in full accordance with Einstein's own declarations to state that:

*The validity of his Theory of Relativity depends wholly on the justification of his criticism and rejection of classical time and of the validity of the new concept which he makes it his task to establish.*

But in trying to solve the contradiction in question through a revision of such fundamental concepts as 'time' and 'space' Einstein has radically changed the problem from one of physical character into one of epistemology, or logical analysis of the fundamental concepts of thinking and scientific research. Here the law of freedom from contradiction and from ensuing logical faults must rule supremely and be applied with the utmost stringency.

In other words, when Einstein starts to grapple with a new concept of time he embarks on a philosophical problem in the strictest sense of the word, and his theories must stand up to logical scrutiny.

In the discussion of the Theory of Relativity a critic naturally turns to the Special Theory of Relativity where the fundamental ideas are presented by Einstein himself. But without fail the critic will then be

[1] *The Meaning of Relativity*, 5th ed., Methuen, London, 1951, henceforth called '*Meaning*', p. 26.





told that the Theory of Relativity cannot be discussed on the basis of the Special Theory alone. The Theory is said to be fully presented and to yield its full value only if considered in its more extensive shape as encountered in the General Theory of Relativity.

This is an argument that must be categorically repudiated.

The General Theory of Relativity is, just as the Special Theory, based on the principle that the classical concept of time must be rejected. Neither the General Theory, nor the Special Theory accept the equation $t' = t$ which is an indispensable basis of all classical physics, although it is often overlooked that it is tacitly considered self-evident.

Also in the General Theory one of the problems can be reduced to the question:

If an event in a point $P$ in a system of reference $K$ is characterized by the co-ordinates $x, y, z, t$, how can it be characterized in a system $K'$ moving in an arbitrary way with regard to $K$ in a field with or without gravitation where its co-ordinates are called $x', y', z', t'$? But here as in the Special Theory it is assumed that $t'$ can have other values than $t$.

*As regards the introduction of this new symbol* t' *there is in principle no difference whatever between the General and the Special Theory of Relativity.*

In both theories we meet the problem of calculating the co-ordinates of an event in a moving system from the characterizing symbols in the primary system of reference. In both theories we face the fact that a new symbol $t'$ is introduced for time in a moving system assumed to be able to accept other values than $t$. We are therefore concerned with a symbol which, by differing from $t$, represents something other than time in the classical meaning where we necessarily have $t' = t$.

It is only when we have established the meaning of this new symbol that we can give any meaning to the formulae which are the basis of the whole theory. Before this is done we run the risk of using the word 'time' in two different meanings without knowing which meaning is implied in each case and thus not knowing what we are talking about.[1]

We can therefore establish as a fundamental fact:

*Einstein's Theory of Relativity, the General as well as the Special, is entirely dependent on the logical possibility of introducing a new time concept and on the possibility of stating the meaning of the new 'time' symbol* t'.

[1] The use of a word indiscriminately in two different meanings I will from here on refer to as 'double-talk'.

The analysis of the time concept undertaken by Einstein in order to solve the above-mentioned conflict between Maxwell's electrodynamic theory and the extended classical Principle of Relativity has often been acclaimed as a stroke of genius. In actual fact, however, *such an analysis is an absolute necessity, an unavoidable claim which faces the physicist the very moment he introduces the new symbol* t′ *differing from* t.

That introduction confronts us with a fundamental question for the whole science of physics, regardless of the Theory of Relativity:

*What is from now on to be understood by the two different symbols* t *and* t′ *and thus also by the word 'time'?*

The imperative necessity of an analysis of the concept of time is also emphasized by the fact that all our physical knowledge, built up before the presentation of Einstein's Theory of Relativity, is founded on the classical, universal time concept, and the overthrowing of this concept, which is the consequence of the introduction of the new symbol, brings fundamental parts of our physical knowledge into the danger zone.

We must ascertain the significance of the new symbol and the content of its proposedly revolutionizing consequences in order to know to what extent we can build on our earlier physical knowledge.

## THE CLASSICAL CONCEPT OF TIME

Before discussing Einstein's concept of time it is important to fix the contents of the classical time concept.

According to the classical view the time of an event in a system $K'$ in arbitrary motion in relation to a system $K$ is identical with the time of the event as judged from the system $K$, considered at rest. This, which can be expressed by the transformation equation $t' = t$, is in fact the basis of all classical laws of physics and all our previously acquired results.

Max von Laue gives some of Newton's observations with regard to the concept of time[1] which I here present in English translation:

'The absolute, true and mathematical time flows in itself and according to its nature uniformly and regardless of relation to any object. It is also called duration.

'The relative, apparent, usual time is a perceivable external, either precise or varied measure of duration which is usually employed—as in hour, day, month, year—instead of the true time.'

[1] MAX VON LAUE: 'Die Relativitätstheorie'. *Die Wissenschaft, 38*, Berlin, p. 4.





Furthermore:

'All movements can be accelerated and slowed down; the flow of time alone cannot be changed. The same duration and the same situation apply to the existence of all things, regardless of whether the movements are fast, slow or nil.'

To this presentation of Newton's ideas von Laue adds the comment:

'His absolute time which flows regardless of relation to any object implies once and for all the idea that something independent of all experience is the basis of the conception of time—and 100 years later Kant clearly acknowledged this.'

The pre-relativistic concept of time which von Laue has described above is also the basis of Newton's laws of mechanics.

Einstein, in his presentation of the classical concept of time states that pre-relativistic physics makes—unconsciously—the hypothesis:[1]

'Time is absolute; the time of an event $t'$ relatively to $K'$ is the same as the time $t$ relatively to $K$. If instantaneous signals could be sent to a distance, and if we knew that the state of motion of a clock had no influence on its rate, then this assumption would be physically established. For the clocks similar to one another and regulated alike could be distributed over the system $K$ and $K'$ at rest relatively to them, and their indications would be independent of the state of motion of the systems; the time of an event would then be given by a clock in its immediate neighbourhood.'

To this description of the pre-relativistic time concept it may be remarked—with regard to the importance attached to the assumption that 'instantaneous signals could be sent to a distance'—that this assumption is *not* indispensable to the classical view.

According to Einstein's statement above we can let clocks similar to each other and placed close to each other be regulated so that they show time exactly alike, that is, show the same pointer position of hours at the *a priori* same moments. In case it is then assumed 'that the state of motion of a clock has no influence on its rate,' we can move the clocks to any point in our system and they would have the same rate, in other words show the same pointer positions at the

[1] *'Meaning'*, p. 24.

same moment as the original regulating clock. And this could be done for both systems.

If, therefore, the motion of a clock is presumed *not* to influence its rate, we can also put the clocks regulated in the system at rest into motion and thus bring them over into *another* system and they would still be running alike.

*We might thus in principle arrange for clocks in all moving systems to run alike and show the same pointer position at the* a priori *same moments.*

The time of an event in a point *P* would be given by the clock in its immediate vicinity and the time would be the same to whatever system we refer it since the clocks work alike.

Ultimately this reasoning is based on the classical *a priori* concept of time which we can express as follows:

*There is always for each moment in a point* P *in any other point* Q *a moment which is neither before nor after the moment in* P, *but simultaneous with it. The simultaneous moments in the two points follow each other in the same order. If two moments in distant points are simultaneous in one system of reference, they are also simultaneous in all other systems.*

These relations between moments are, according to the classical view, valid *a priori*, independently of all experiments and measuring. They are postulates which form the foundation of all classical reasoning with relation to 'time' in all domains of physical science. The assumption of instantaneous signals is therefore not necessary in order to constitute the classical time concept.

The content of this classical time concept as described above is also the basis of classical time measuring. For this purpose the assumption with regard to the character of the clocks used is sufficient. If clocks 'running alike' side by side are independent of motion, they can be distributed to all parts of a system and furthermore be brought into a moving system, and will then continue to show time correctly and alike in all systems independently of all signals.

The content of the classical time concept as postulated also by pre-relativistic physics can be summed up as the notion that:

*Time is* a priori *reigning universally and flowing uniformly throughout space independently of system of reference.*

We can then, in analogy with Einstein, but without reference to instantaneous signals, thus characterize classical time:

*If clocks similar to one another running at the same rate when placed side by side are presumed not to be influenced by their state of motion, they can be distributed over the whole of our systems of*





*reference, both the one 'at rest' and the moving one, and they will still run at the same rate, that is show the same clock position at the* a priori *same moments.*

*The time of an event would be given by the clock in its immediate vicinity and the time of the event would be the same in relation to all systems.*

Eddington also discusses the classical time concept.[1] With reference to what he calls 'the haphazard intuitions of pre-relativity physics' he writes:

'The popular outlook does not trouble to discriminate between the external events themselves and the events constituted by their light impressions on our brains, and here events throughout the universe are crudely located in our private time-sequence. Through their confusion the idea has arisen that the instants of which we are conscious extend so as to include external events and are world-wide; and the enduring universe is supposed to consist of a succession of instantaneous states. This crude view was disproved in 1675 by Römer's celebrated discussion of the eclipses of Jupiter and satellites; and we are no longer permitted to locate external events in the instant of our visual perception of them. The whole foundation of the idea of world-wide instants was destroyed 250 years ago and it seems strange that it should still survive in current physics. But as so often happens the theory was patched up although its original *raison d'être* had vanished.'

This is indeed an extraordinary way of characterizing the pre-relativistic time concept. In the first place it should be noted that the consequence of Römer's remarkable studies was that light takes time to travel, to be propagated from one point in space to another. This fact has also been accepted by pre-relativistic physics, and, long before the modern relativistic ideas were presented, the velocity of light had been established by different methods. Eddington's talk of ideas that 'although destroyed 250 years ago' have been 'patched up', is simply ridiculous and only shows how little he has striven to penetrate the pre-relativistic ideas of time. They are in full accordance with Römer's observations which, among other things, is illustrated by the experiments performed in order to measure the velocity of light long before the relativistic age.

Also Eddington considers instantaneous signals a necessary ingredient of the classical time concept. But the idea of instantaneous signals was only an early mode of explaining our perception of distant

[1] A. S. Eddington: *The Mathematical Theory of Relativity*, p. 24.

events. What Römer showed was that the light rays, enabling our perception, take time to travel to the observer. Whether we accept instantaneous signals or signals taking time to travel we base our observations on the same concept of time as ruling universally and flowing uniformly through all parts of space independently of system of reference.

*Römer's experiments have revolutionized our knowledge of the nature of light and the mechanism of our perceptions, but he has not in any way changed the classical concept of time. Eddington's reasonings must therefore be categorically rejected.*

The characterization of the classical time concept given here corresponds well with what H. Thirring writes in *Handbuch der Physik*, p. 92 ('Begriffssystem und Grundgesetze der Feldphysik').

He begins by quoting the above-mentioned Newtonian statements and then declares:

'To each event belongs an unambiguous time value independently of locality and independently of a system of reference of the observer. The time flows so to speak in parallel lines through the whole world. To the moment 'now' there is a certain corresponding moment in all points in the world. The proposition that an event taking place anywhere is simultaneous with the event in question is absolutely and universally valid.'[1]

It should be noted that in his characterization of classical time *Thirring does not mention anything about instantaneous signals.*

## THE MATHEMATICAL EXPRESSION OF THE CLASSICAL TIME CONCEPT

The above-mentioned characteristics of the classical time concept can all be expressed by the equation $t' = t$. In Einstein's relation between $t'$ and $t$ the symbol $t'$ is on the other hand dependent both of the spatial co-ordinate $x$ and of the velocity $v$ of the moving system.

From the classical point of view any change of time in one system has its exact correspondence in another system:

$$dt' = dt$$

1 Translation: '*Jedem Ereignis kommt unabhängig vom Orte und unabhängig vom Bezugssystem des Beobachters ein eindeutig bestimmter Zeitwert zu. Der Strom der Zeit fliesst gewissermassen in Parallellen Stromlinien durch die ganze Welt. Dem Augenblick 'jetzt' entspricht an allen Orten der Welt ein ganz bestimmter Zeitpunkt. Die Aussage, dass ein zu diesem Zeitpunkt irgendwo stattfindendes Erreignis gleichzeitig erfolgt, besitzt absolute und universelle Gültigkeit.*'





It is important to keep the equation $t' = t$ and its consequences in mind in the relativistic discussion, since *it is exactly this equation and what it stands for which is rejected by Einstein in his reasoning on time and it is on this rejection he has founded his whole Theory of Relativity.*

## EINSTEIN'S TIME CONCEPT

Einstein gives in fact *two* different definitions of time and time relations. I shall discuss them in the same order as he has presented them.

### EINSTEIN'S TIME CONCEPT NUMBER ONE

This time concept was published in Einstein's first paper on Relativity.[1] The question is how are we to compare the time of events occurring in two points at a considerable distance from each other in one and the same system of reference.

At this point Einstein denies the classical *a priori* concept of a universal time reigning uniformly in the whole of space and *gives us to understand that the time concept should instead be realized and defined by experiments*: Thus according to Einstein the definition must include the controlling experiment, and the experiment is therefore an essential part of the definition. The concept can be realized and defined only by means of experiments. This evidently is contrary to the classical *a priori* concept of time.

Einstein discusses the time definition problem in 'Elektrodynamik' in the following way:

Clocks are supposed to be placed in different points of a system of reference, and an observer in an arbitrary point is assumed to be able to register the time of an event 'in his immediate vicinity' with a clock in his vicinity. Each one of the two observers in two points at a considerable distance from each other thus register 'time' but only close to themselves. The time of an event in the immediate vicinity of an observer is given by the simultaneous position of the hands of the clock, close to the event. This is also expressed by Einstein in his later book *Relativity* (p. 24).

1 'Elektrodynamik bewegter Körper', *Ann. der Physik, 17*, 1905. This paper was reprinted in LORENTZ–EINSTEIN–MINKOWSKI: *Das Relativitätsprinzip*, Teubner, Leipzig, 1920.
English translation:
LORENTZ, EINSTEIN, MINKOWSKI, AND WEYL: *The principles of relativity*, Dover, New York, 1923.
I will refer to the above paper as 'Elektrodynamik' but for page numbers I will refer to the latter publications as being more accessible, giving first the page numbers of the German edition and then of the English edition.

'*By time of an event we understand the reading* [*position*] *of the hands of the clock which is in the immediate vicinity* [*in space*] *of the event*.'

Two events occurring in different points within 'the close vicinity' of the observer will be registered with the same clock and they will have a time relation directly determined by the positions of the hands. They will thus be before or after each other, or simultaneous, just as the registered positions of the hands indicate. Since the clock of an observer in a point $A$ can take up any position within the close vicinity of the observer and still register the time of any event in this vicinity we can state that for each moment in one point there is always in all other points in the vicinity a certain moment which is *a priori* simultaneous with the first-named moment.

*Therefore, in the close vicinity of an observer time is, also according to Einstein, supposed to reign uniformly exactly according to classical time concept.*

*It is with regard to events occurring outside the close vicinity—say outside the walls of the laboratory of the observer—that the classical time concept, the* a priori *time relations of events, are according to Einstein non-existent.*

This means that we have no possibility of comparing *a priori* the 'time' of an event, in, say, a point $A$ with the 'time' of an event in a distant point $B$. *We have an 'A-time' and a 'B-time' registered by the clocks in A and B but no time in common for the two points.*[1]

*This declaration can be considered the crucial point of the whole Theory of Relativity. It is here that Einstein rejects the classical concept of time reigning universally, flowing uniformly and independently of system of reference through the whole of space. And it is at this point that he sets himself the task of creating the new concept.*

This rejection of the classical time concept for distant points implies that the observer in $A$ cannot, for instance, say that an event in $A$ is either before, after or simultaneous with an event in $B$, because these time relations do not, according to Einstein, exist *a priori* for distant points. They can obtain a meaning only through the experiments assigned by Einstein.

With the classical time concept we can on the other hand always say *a priori* about any event taking place anywhere in a point distant from $A$ that it must occur at a moment which is either before, after or simultaneous with a certain moment in $A$.

[1] In the original book (*Electrodynamik*, pp. 28, 40) this is expressed thus:

'*Wir haben bisher nur eine "A-Zeit" und eine "B-Zeit" aber keine für A und B gemeinsame "Zeit" definiert.*'





*There is always in any points in space* a priori *a moment which is simultaneous with a certain moment in A and all moments follow each other uniformly in all points in space. To Einstein with his denial of the classical* a priori *time concept such a proposition has no meaning.*

Einstein then describes how we are to establish a time relation between the two distant points $A$ and $B$.

A ray of light is supposed to be sent from $A$ at the moment $t_A$ and to travel the distance $AB$ to $B$ where it is thought to arrive at the $B$-time $t_B$. It is reflected in $B$ and returns to $A$-time $t'_A$. The clock in $B$ should be regulated to satisfy the equation.

$$t'_A - t_B = t_B - t_A.$$

Einstein declares that if this condition is fulfilled the clocks are said to be running 'synchronically' and *the events in A and B which occur at moments with the same position of the hands of the respective clocks in A and B are said to be 'simultaneous'*. Apparently we have thus according to Einstein arrived at a meaning of the word 'time' and 'simultaneity' for events in $A$ and $B$ in relation to each other.

Einstein adds to this the declaration that the time difference in $A$ between the time of return of the ray $t'_A$ and the time of the departure from $A$, $t_A$, should be equal to twice the distance $AB$, divided by a 'universal constant $c$ (velocity of light in empty space)'.

That is

$$t'_A - t_A = \frac{2\,AB.}{c}$$

We find here that Einstein has laid down two rules for clock regulation in order to constitute his new time concept. The first rule indicates how clocks in distant points $A$ and $B$ should be regulated in relation to each other. The second rule indicates how a separate clock should be regulated independently of all other clocks. *This is evidently the fundamental rule which must be satisfied before the second is applied for the mutual regulation of two distant clocks.*

The fundamental rule implies that whenever a ray of light is sent out from the point $A$ at the moment $t_A$ to an *arbitrary* point at the distance $d$ and is reflected there and returned to $A$ at the time $t'_A$ *the clock in A should always satisfy the equation,*

$$t'_A - t_A = \frac{2d}{c}$$

*independently of which point in the system the ray is sent to.* Einstein does *not* discuss whether the clock in $A$ *can* always satisfy this equation for all points and for all systems of reference. He confines himself to declaring that this is possible 'according to experience' but without mentioning anything about this 'experience'. There is reason to suppose that he has had the Michelson–Morley experiment in mind. I shall return to this in the discussion of this experiment.

Before entering into the question how the regulation should be performed I shall touch on an important consequence of the negation of the classical time concept for the concept of 'synchronicity'.

### THE MEANING OF SYNCHRONICITY

With regard to the expression that the clocks in *A* and *B* are 'running synchronically' we observe that in Einstein's case it has received quite another meaning than in classical physics on the basis of the *a priori* time concept. According to the classical view the expression has the following meaning:

*The clocks will show the same position of the hands at the* a priori *same moment* (*simultaneously*). This has a meaning as long as we assume that there is always a moment in every point in space, thus also in *B*, registered by the *B*-clock, which is *a priori* simultaneous with a certain moment and the corresponding clock position in the point *A*. We suppose that the two clocks will register the same position in these *a priori* simultaneous moments and that they will go on doing this continuously. If that is the case, we say that the clocks 'run synchronically'. In order to attain this we presuppose that the clocks are of exactly the same construction and that they have continuously shown the same position of the hands when placed side by side. On this assumption we say that they are 'running at the same rate' or 'running synchronically'. We then suppose that the clocks when moved to distant points will continue to show the same position in the *a priori* simultaneous moments in the points *A* and *B*, and that we can therefore say that they are still 'going at the same rate' or 'running synchronically'. This means that they are showing the same position of the hands at the *a priori* same moments also in their new positions.[1] In case we want to control whether this is true we are faced with certain experimental problems which, however, we need not discuss here, because from the classical point of view this does *not* in any way influence what we *mean* by our declaration.

The expression, however, takes on another meaning if we accept

[1] This is in full accordance with Einstein's characterization of the classical time concept ('*Meaning*', p. 24).





Einstein's negation of classical time. He, too, assumes that the clocks in *A* and *B* are 'of identical construction'—'*von genau derselben Beschaffenheit*'—and on this he bases the assumption that the clocks 'go at the same rate'. This also has a clear meaning in Einstein's case as long as the clocks are placed side by side close to *A*, because for the vicinity of *A* the classical time concept has been accepted by Einstein. All events round *A* are supposed to be able to be registered with the aid of the *A*-clock, thus can be registered the position of the hands of another clock close by.

When on the other hand the clocks are in distant points the expression 'going at the same rate' takes on quite a different meaning.

In the classical sense the meaning is that the clocks register the same position of the hands in the *a priori* same moments. But in Einstein's case, where the *a priori* time concept is denied, the expression 'same moments' has the meaning 'moments of the same position of the hands of the clocks in the respective points'. '*Going at the same rate*' *does in this case only imply that* '*the clocks register the same position of the hands when they register the same position of the hands*'—a tautology of the type $A = A$.

'The clocks run synchronically' or 'the clocks run at the same rate' can also be formulated thus: 'The clocks undergo the same change in the position of the hands in the same time intervals.' But by time interval we must in Einstein's case understand the change of positions of the hands of the clock regulating the time in the point in question. And since we have no time concept in common for distant points—as with the classical time concept—*the time interval has a meaning only for each point alone, independently of all other points.*

Therefore, if in Einstein's case we say that the clocks in *A* and *B* go at the same rate, meaning that 'they undergo the same change in position of the hands in the same time interval', and the time interval only means *the change of position of the hands of the clock in that point*, then the whole statement is reduced to the following:

*The clocks in A and B undergo the same change of position of the hands, when they undergo the same change of position of the hands.* The declaration is again reduced to a tautology of the type $A = A$.

Thus the expression 'the clocks run synchronically' does *not* in this case—when we talk about clocks in *distant* points and without an *a priori* time concept in common for both points—say anything at all about the relation of the clocks. This is in clear contrast to the case when the clocks are close together, or when we assume the reign of classical time for the *whole* system, in which cases the expression has a distinct meaning. This completely negative result must be stated in spite of the fact that the clocks are declared to be 'of identical construction', a statement which alone cannot give a meaning to the proposition.

The only thing we can say about the two clocks in the distant points—except that they are of identical construction and go alike side by side—is that they are supposed to be repeatedly and reciprocally light-ray regulated.

Since it is solely on this ground that Einstein declares them to be 'running synchronically'—and this is in fact the only relation known with regard to their way of running—there remains no other meaning to attribute to Einstein's expression.

*'The clocks in A and B are running synchronically' has in Einstein's case only the meaning that 'the clocks in A and B are supposed to be reciprocally and repeatedly light-ray regulated.'*

I have elaborated this point at some length in order to show how deeply our problems and our possibilities of handling them change through Einstein's rejection of classical *a priori* time. It should, however, be emphasized that these reflections are only of secondary interest since, as I now propose to demonstrate, the possibility of regulating distant clocks is totally eliminated by Einstein himself on account of his own premises.

The question at this point is:

*What are the possibilities of regulating clocks in distant points with light rays on the basis of Einstein's rejection of the classical time concept?*

## THE REGULATION OF DISTANT CLOCKS WITH LIGHT RAYS

As I have pointed out, *Einstein has accepted the concept of time and its derivatives as existing* a priori *in their classical meaning for a limited space round the observer. And this must be valid in any system of reference.*

The difficulties arise, according to Einstein, when the observer has to fix the time of an event *outside* the limited area around him, and consequently also if he wishes to follow the progress of a process which takes place *outside* his limited neighbourhood.

To the classical physicist this does not present a problem because he assumes his concept of time and related concepts to be valid *a priori* not only for the close vicinity of the observer but throughout space. He can say that while the ray goes from $A$ at time $t_A$ to a distant point $B$, the clock in $A$ will move during the same time from the position $t_A$ to a position which is *a priori* simultaneous with the moment of arrival of the ray in $B$, say $t_B$ (independently of all measuring and experiments).





Einstein, on the other hand, having rejected the time concept *a priori* for events *outside* the limited area round the observer, *can* a priory *make no statement whatever as to the relation in time of any distant event to the time of the observer.* The observer in $A$ can release a flash of light in $A$ and he can state that it travels within his limited area of observation in the direction of for instance $B$. *But what happens outside this room is, and remains unknown to him.*

To say that the ray 'goes on' ('continues', 'proceeds') along the line $AB$ to $B$ implies that the ray arrives at $B$ 'later' than its departure from $A$. It means putting events outside the close vicinity of $A$ in time relation to $A$, which is impossible if one has, as Einstein, denied all *a priori* time relations between distant points. Such concepts as 'later', 'before', 'simultaneous' as well as any other time concept have as yet outside the close vicinity, with Einstein's premises, no meaning. It must be strictly kept in mind how different the classical aspect is.

When the classical physicist says the light ray goes from $A$ to $B$ this has a clear meaning, because he bases his reasoning on the *a priori* concept of time flowing uniformly through all parts of the whole system.

With Einstein's premises, however, *the proposition of an observer in A that 'a ray goes from A to B' is meaningless outside the close vicinity of A.*

He can *not*, as the classical physicist does, conclude that this should be possible on the basis of experiences from earlier experiments, previous to Einstein, concerning the progress of processes through space such as the travel of a ray, because all such experiments are based on the classical *a priori* time concept. *When Einstein declares the classical time concept null and void, he also shatters the foundations of all results which have been attained with this concept.* This may seem at first a surprising consequence of the denial of the classical time concept, but it will appear quite natural when we take into consideration how extremely fundamental the time concept is for all human reasoning.

The situation is the same if we consider the circumstances for the observer in $B$. He is supposed to receive the light ray from $A$ at the time $t_B$. But he can only register events that take place in his limited area of observation and nothing outside. He can observe and note the time when a flash of light appears in his limited area and state that it comes in the direction from $A$, but he cannot declare that this ray has been sent out from $A$ and has travelled along the line $AB$, because this would imply that something should have happened outside the limited area 'earlier' than the arrival thus putting events outside the limited observation area in time relation to the arrival of the observed ray. And, with lack of a time concept valid outside his close neighbourhood, this is meaningless.

*The fact that we cannot state anything about what happens outside the limited area round the observers makes it impossible to use light rays or any other message-carrier for the regulation of clocks in distant points.*

The impossibility of maintaining Einstein's ideas about time can be established in many ways. I shall here proceed to give a more detailed analysis of the difficulties involved.

Let us take the situation of the observer in $A$. What $A$ would be able to do according to Einstein is this: A light flash initiated in $A$ at the time $t_A$ is supposed to go to $B$, arrive in $B$ at time $t_B$, be reflected there and return to $A$ and arrive there at $A$-time $t'_A$. Now for the ray to 'go from $A$ to $B$ and back to $A$' means that the impulse initiated in $A$ proceeds along the line $ABA$. Since this is supposed to be stated by $A$, it implies that the progress of the ray must be put in relation to the time in $A$. There must be—in order to make this statement about the ray—an *a priori* time relation between, on the one hand the impulse travelling along $ABA$—also outside the limited area—including its arrival in $B$, and on the other the time of the observer in $A$, that is the clock position in $A$. If this is denied and we declare that there is no relation between the movement of the ray and the time in $A$ then it remains that $A$ can only say: '*A light-flash has been created in A and has within the limited space round A travelled in the direction of B*'*—and nothing else can be said.* Here, we can also conclude that the proposition 'the ray goes from $A$ to $B$' is in Einstein's case void of all meaning.

The fatal situation to which Einstein's rejection of classical time concept leads us, can also be demonstrated in another way.

If we maintain that the proposition 'a ray goes from $A$ at time $t_A$, arrives in $B$ at time $t_B$, where it is reflected and goes back to $A$ where it arrives at time $t'_A$', should have a meaning, we thereby presume that the arrival of the ray in $B$ is brought about by the light-flash in $A$. The arrival of the ray in $B$ is the effect of the light-flash in $A$. The two events are thus put in causal relation to each other. But causal relation between two events always and necessarily implies a time relation. A cause must always be *before* the effect, the effect always be *after* the cause. The arrival of the ray in $B$ must thus be after $t_A$ as judged from $A$ and the light-flash in $A$ must be *before* the arrival of the ray in $B$ as judged from $B$. Unless such a time relation between the two events is prevailing they cannot be put in causal relation to each other. Likewise the reflexion of the ray in $B$ must





be *before* the return of the ray to $A$, and the return to $A$ *after* the reflexion in $B$.

But all moments of which we can say that they are after $t_A$ and before $t'_A$ as judged from $A$, are represented by clock positions in $A$ between $t_A$ and $t'_A$. This implies that each one of these moments corresponds to one specific clock position in $A$. Therefore there must also be a clock position in $A$ which corresponds to the moment of arrival of the ray in $B$. Let us call this clock position in $A$ $t^0_A$. But this correspondence between the two moments $t_B$ and $t^0_A$, which amounts to their being neither before nor after each other, can only mean that they are 'simultaneous' in the classical *a priori* sense of the word.

We find thus that in order to realize the light ray regulation, it is necessary to presuppose an *a priori* relation between the moments in $B$ and a certain moment in $A$. All moments in $B$ are *a priori* either before, after or simultaneous with a certain moment $t_A$ in $A$. In order that the clock in $B$ should run synchronically with the clock in $A$—in the classical sense, which is the only possible sense since Einstein's definition of synchronically running clocks only means 'clocks supposed to be light-ray regulated'—we must be able to make the clocks register the same position in those moments in $A$ and $B$ which are *a priori* simultaneous. This is for instance the case with $t_B$ and $t^0_A$.

I have met the objection that it would be possible for an observer in $B$ to identify a ray coming in to his limited observation area in the direction from $A$ as having been initiated by a light-flash in $A$, if the observer in $B$ should have agreed with the observer in $A$ *at an earlier* moment that $A$ would—later than the agreement—send out light-flashes in the direction of $B$. This would make it possible to identify the incoming ray in $B$ as having been initiated in $A$.

When, however, the observer in $B$ at a moment later than the agreement was made, *as judged from B*, registers a ray in $B$ at time $t_B$ in the direction from $A$, he must, in order to say that the ray has been initiated by the agreed light-flash in $A$, suppose that it has been sent out from $A$ at a moment in $A$, say $t_A$, which is *later* than the agreement and *before* the arrival in $B$ at time $t_B$. He must be able to state that the moment $t_A$ of the light-flash in $A$ is *after* the agreement and *before* $t_B$ as judged from $B$. But this is a statement of time relation *a priori* of an event in $A$ *as judged from B* independently of all previous clock regulations, and *stands in clear and direct contradiction to Einstein's presupposition that there is no time relation* a priori *between events in distant points.*

We have here the same situation as above. All moments in $B$ that are after the agreement and before $t_B$ are represented by positions of the clock in $B$ in accordance with Einstein's declaration that all moments in $B$ should correspond to a position of the clock in $B$. Therefore when we state that $t_A$ is, *judged from B*, after the agreement and before $t_B$ and all moments of which this can be said correspond with a clock position of $B$, then there *must* be one of these positions, say $t^0{}_B$, which is neither before nor after $t_A$. This means that it is *simultaneous with* $t_A$ *as judged from B*. We thus find also here that in order to identify the rays and perform the light-ray regulation of clocks in distant points we must be able to put the departure and arrival of the rays in distant points in time relation to each other. *This presupposes an* a priori *time relation between the events in the distant points*, and this time relation is exactly the classical time concept accepted by Einstein for the limited area round the observer, but only there.

But since $A$ and $B$ are arbitrarily chosen in our system and we can place them in any direction and at any distance, and since the time concept must be valid for all different systems of reference, we come to the conclusion that:

*In order to establish 'the new Einstein time concept' through light-ray regulation we must extend the classical* a priori *time concept, accepted by Einstein for the limited area round the observer, to be valid for the whole of space and for all Galilean systems of reference.*

*Thus, unless we accept the classical time concept, the exchange of rays between two distant points is impossible to perform because the rays cannot be identified. That can only be done on the basis that classical time is accepted* a priori.

I have met the objection that a criticism of the Theory of Relativity cannot be based on the pleading of the law of causality because this law is nowadays doubted and even to a certain extent negated.

The objection to the classical law of causality is the presumption that a cause may not always create the same effect. The effect of the cause is supposed to be a question of probability. The application of causality in the clock regulation case is, however, another namely:

If a causal relation is supposed to exist between two events, then the effect is in time *after* the cause and the cause is *before* the effect. Thus in order to state that a certain event is the effect of another event the latter must necessarily be supposed to be before the former.

In the extensive literature on causality this time relation between cause and effect is so far *not* negated. It has on the contrary been expressly declared *e.g.* by Mario Bunge.[1]

[1] *Foundations of Physics*, Springer, Berlin, Heidelberg and New York, 1962, p. 100.





'What is true is, that if $c$ does cause $e$, then $c$ is earlier than or simultaneous with $e$ in any frame.'

When discussing the light-ray regulation of clocks Einstein supposes that the observer in $A$ can say that the light flash emitted in $A$ arrives in $B$, is reflected there and returns to $A$.

But this implies that the emission in $A$ causes the arrival of the ray in $B$, and that the reflection in $B$ causes the return of the ray to $A$. *Causal relation is thus supposed to reign between the three events in A and B.* This in turn necessarily presupposes that time relation exists between the events. The emission in $A$ must be supposed to be *before* the arrival in $B$ and the arrival in $B$ thus *after* the emission in *B, as judged both from A and B.* The arrival and reflection in $B$ must be supposed to be *before* the return of the ray to $A$, which event must be *after* the reflection in $B$, *as judged both from A and B.* This has, however, a meaning *only* if we presume a time concept in common for the two distant points $A$ and $B$. Since no new time concept has so far been created by Einstein there remains nothing but the classical time concept to fall back upon for the space round $A$ and $B$. *The events in the two points must thus necessarily be supposed to stand in classical time relation to each other.*

Since $A$ and $B$ are arbitrarily chosen in our system of references we are obliged to extend the classical time concept to be valid for the whole of space. We can therefore state that *both the negation of classical time and the negation of causality between distant events excludes the establishing of Einstein's new time concept.*[1]

We have seen above that the expression 'the clocks in $A$ and $B$ are running synchronically' can in Einstein's case only mean that 'the clocks in $A$ and $B$ are *supposed* to be reciprocally light-ray regulated'. *But since we have now found that light-ray regulation of distant clocks cannot be performed on the basis of rejection of classical time we must state that the expression that 'the clocks in A and B are running synchronically'* has in Einstein's case no meaning at all.

The only thing we can say in Einstein's case is that the clocks in $A$ and $B$, although being of equal construction and running alike in the classical since when standing side by side, *will be running quite independently of each other when placed in distant points.* Their indications will have no known relation to each other since Einstein's rule of regulation cannot be realized.

[1] The idea of basing the Theory of Relativity on the rejection of both classical time and the law of causality gives me the same impression as a trial to raise the Empire State Building higher by pulling out its foundation stones. A somewhat risky job!

As for the concept of 'simultaneity' we come to the following result:

The expression that two events in distant points are 'simultaneous' should mean that they take place at equal position of the hands of the clocks in the two points, provided these are 'running synchronically'.

But since 'synchronically running clocks' in distant points cannot on the basis of Einstein's premises be given any distinct meaning, the clocks will be running independently of each other. The result is that any two events in distant points may well take place at the same position of the hands of their neighbouring clocks. But this would not indicate any relation whatever between the events. 'The concept of simultaneity' would thus lack all distinct meaning.

The observer in $A$ can *only* say that a light ray goes out from $A$ at time $t_A$ in direction to $B$, and a light ray comes in at time $t'_A$ in direction from $B$. The observer in $B$ can *only* say that a ray comes in direction from $A$ and is reflected back in direction to $A$, at the time $t_B$.

Nothing more can be said about these events. The times $t_A$ and $t'_A$ on the one hand and the time $t_B$ on the other will lack all known relations, and this will also be the case with the events in the two distant points.

*Summing up we can state that Einstein's time concept number one is impossible to establish for distant points on the basis of his rejection of classical* a priori *time. His rule for the establishing of the new concept—the light-ray regulation of distant clocks—presupposes necessarily—although this has not been realized by Einstein—the reign of classical time throughout space in order to identify the incoming rays and this makes a new time concept superfluous.*

*The long and short of it is that it is impossible to establish Einstein's time concept according to his definition number one.*

It should be noted that the light-ray regulation of a distant clock *can* be carried through if classical time is supposed to reign universally. This has indeed been pointed out before Einstein by H. Poincaré (*Oeuvres*, IX, p. 483) in 1900. But in that case we will in the distant point have both the classical time ($t$) reigning and also a clock giving time-indications differing from the classical time. But this does not imply any change in our concept of time.

See Appendix, p. 205.

## EINSTEIN'S TIME-CONCEPT NUMBER TWO

In his book '*Relativity*' Einstein again takes up the question of the meaning of 'time' and starts with the concept of 'simultaneity'.





The problem he raises is:

Two strokes of lightning are supposed to occur in two places $A$ and $B$ on a railway embankment at a considerable distance from each other and they are declared to be simultaneous. Einstein asks: 'What is the sense of this statement?' and then proceeds:

'The concept does not exist for the physicist until he has the possibility of discovering whether or not it is fulfilled in an actual case. We thus require a definition of simultaneity such that this definition supplies us with the method by means of which, in the present case, he can decide by experiment whether or not both the lightning strokes occurred simultaneously. As long as this requirement is not satisfied, I allow myself to be deceived as a physicist [and of course the same applies if I am not a physicist] when I imagine that I am able to attach a meaning to the statement of simultaneity [I would ask the reader not to proceed further until he is fully convinced on this point!]'.

*According to this declaration the concept of simultaneity does not exist* a priori. *It is only by performing certain physical experiments that the concept achieves a sense.* This is a most remarkable philosophical proclamation in any context. However, let us here confine ourselves to its bearing on the new definition of 'simultaneity'. Einstein requests the reader to think these matters over thoroughly. And, indeed, here is food for thought!

Einstein's definition of the concept 'simultaneity' is given thus: The two events in $A$ and $B$ are declared to be simultaneous if an observer placed in the mid-point $M$ of the distance $AB$ observes the two lightning strokes at the same time. With regard to the light rays by means of which the observer in $M$ perceives the strokes, and which are going from $A$ to $M$ and from $B$ to $M$ 'no supposition or hypothesis' is made as to their way of travelling, that is 'about the physical nature of light'. That the rays 'require the same time to traverse the path $A$–$M$ as for the path $B$–$M$' is but a 'stipulation' which I can make of my free will in order to arrive at a definition of 'simultaneity'.

This definition can in short be expressed thus:

*Two events in distant points* A *and* B *are simultaneous if they are observed at the same time in the midpoint M.* Let us call this 'mid-point co-observed'. But we have found before that according to Einstein's first definition the two distant events were to be considered simultaneous if they occur at the same position of the hands of the clocks in their immediate vicinity, provided the clocks were being reciprocally and repeatedly light-ray regulated. Einstein thus presents two different definitions of simultaneity for events in distant points.

Simultaneity I = *equal clock position of light-ray regulated clocks.*

Simultaneity II = *mid-point co-observed.*

One question arises immediately. What is the relation between these two definitions? Can they be brought into accordance with each other, or are we to operate with two different definitions for the same word? It is most remarkable that Einstein has never taken up this problem in his discussion. To the author it appears imperative to ascertain that we do not work with two different definitions for one and the same word, such as 'simultaneous', all the more so since this word has a meaning *a priori* previously unreservedly accepted as one of the most fundamental concepts of all human thinking.

Einstein does not provide such a comparative analysis as safeguard against confusion. However, as we have seen, his first attempt to define 'simultaneity' through light-ray regulation necessarily presupposes the acceptance of the classical time concept as reigning *a priori* in the whole of space and for all systems of reference. His definition is for most cases—distant points—inapplicable and therefore meaningless and for the cases where we *can* assign a meaning to it, in the close vicinity of the observer, the meaning of the concept coincides with the meaning of the classical *a priori* concept, its necessary presupposition.

The first definition can therefore be categorically dismissed. It remains to analyse the latter definition and its relation to the classical meaning.

In his first paper Einstein declares that there is no time relation between the observer in a point *M* and events or processes taking place outside his close vicinity, say his laboratory room. Since Einstein here too sets himself the task of giving a new definition of simultaneity for events in distant points, it is evident that he has also in this case rejected the classical *a priori* time concept. Consequently, there is also in this case no meaning *a priori* in a statement that an event, distant from *M*, is 'before', 'after', or 'simultaneous with' a certain moment and a certain clock position $t_M$ in *M*. For processes taking place within his vicinity the observer in *M* can, on the other hand, register their time, that is, their simultaneous clock position, and compare times. For this little section of space the classical *a priori* time concept is, as pointed out earlier, valid. The time concepts 'before', 'after' and 'simultaneous', as well as derived concepts such as 'movement', and 'velocity', have the classical *a priori* meaning. It is also considered possible for *M* to establish that a ray moving within his limited observation room is moving in a certain direction, say in the direction from *A* or from *B*, or to *A* or to *B*. But he cannot put





anything that happens *outside* his confined area in any time relation to the processes *in* his own close surrounding. This is the situation of the observer in *M* if Einstein's rejection of classical time as reigning universally all through space is accepted.[1]

As we have seen before it is from this new appraisal of the situation that the difficulties emanate.

The observer in *M* can register the arrival of the two rays coming to him in the direction from *A* and *B* and also state whether they have arrived simultaneously or at different times, as observed on his clock. But his difficulties arise when he has to establish that the ray coming in along the line *AMB* in the direction from *A* has been caused by the lightning stroke in *A*. As pointed out in the discussion of the light-ray regulation of the clocks (Simultaneity I) the very first condition to be fulfilled in order to declare that an event in *A* has caused the arrival of the light ray in *M* is that the observer in *M* should be able to say that the event in *A* has taken place *before* the event in *M* or—what implies the same relation—that the event in *M* is later than the event in *A*, *as judged from M*.

But every event of which we can say that it is 'before' the arrival of the light ray in *M* at, say $t_M$, is represented by a position of the clock in *M*. This is presupposed when we declare that the observer in *M* can register any event in his close vicinity, whenever they happen, on his clock. The implication is that there will always be a clock position of which we can say that it is simultaneous with an event taking place close round *M*, be it either before or after $t_M$. For *M* to say that an event is before the clock position $t_M$ in *M* is thus to say that there is a clock position in *M* before $t_M$ which is simultaneous with the event declared to be before $t_M$.

*If the moment of the lightning stroke in A is declared to be before* $t_M$*, it must thus necessarily be simultaneous in the classical meaning, that is simultaneous* a priori *with a certain clock position in M before* $t_M$*, say* $t'_M$*. The declaration that the event in A has caused the event in M at* $t_M$ *therefore makes it inevitable to declare that this moment in A is simultaneous in the classical* a priori *meaning with a moment in M before* $t_M$ *as judged from M.*

[1] I am fully aware that what I say here is a repetition of what I have said above about 'Simultaneity I'. But the situation created by the rejection of classical time is so peculiar, so absolutely different from what we generally consider as self-evident, and involves such a revolution in our apprehension of the outer world that it has seemed necessary to reiterate the consequences of this upheaval in our traditional ideas in order to make the new situation clear. Also in the following chapters of this book I have found it necessary when I discuss other presentations of the 'relativistic' ideas to repeat the inevitable conclusions from new suppositions.

We have thus found it necessary to extend the concepts of 'time', 'simultaneity', 'before' and 'after' of the close vicinity to be valid in accordance with classical views also outside the limited area round *M*, and at least so far as to include the whole area round *M*, *A* and *B* where the events take place which are being compared and put into causal relation to each other. Only in this way will it be possible to declare that the event in *A* is before the arrival of the ray in *M* which is necessary in order to say that it has caused the arrival of the ray in *M*.

*The mid-point observation thus implies a time relation* a priori, *independently of all experiments, between the strokes of lightning and the arrivals of the light rays in the mid-point M, in direct contradiction to Einstein's negation of time* a priori.

We can of course suppose, as was done also by the light-ray regulation of clocks, that the observer in *M* has at a certain moment $t^0{}_M$ been told that lightning strokes will take place in the points *A* and *B* in order that he should observe them. But if he declares on this ground that the two light rays coming in from *A* and *B* have been produced by these agreed lightning strokes in *A* and *B*, he puts these events in time relation to his observation at the moments, say $t'_M$ and $t''_M$, the moments of arrival of the light rays coming into *M* in direction from *A* and *B*. But all moments of which we can say that they are judged from *M* after $t^0{}_M$—the moment of agreement—and before $t'_M$ and $t''_M$ are registered by the clock positions in *M* and must therefore be simultaneous with one of them in the classical *a priori* sense. There is thus necessarily one moment in *M* after $t^0{}_M$ and before $t'_M$ which is in the classical sense simultaneous with the lightning stroke in *A*, and also one moment in *M* which is after $t^0{}_M$ and before $t''_M$ which is *a priori* in the classical sense simultaneous with the lightning stroke in *B* in both cases as judged from *M*.

*The classical time concept is thus necessarily assumed to be valid for the whole of the area round the points A, B, and M.*

Here we must state, exactly as was the case by the light regulation of clocks prescribed in 'Elektrodynamik', that in order to arrive at a definition of 'simultaneity' we must accept the classical time concept as valid for the area where the experiments are to be performed. And, as shown earlier, this implies that we have to extend the classical time concept to reign in the whole of space and for all systems of reference. The only thing an observer in *M* can say after negating the classical time concept is that a light ray arrives to him along the line *AM* and can be followed by him from the moment it appears on the borders of his close vicinity until it reaches him in *M*. He can likewise register that another light ray comes in along *BM*, and can follow it





from its appearance on the borders of his close vicinity till it reaches him. He can also register whether the two rays reach him simultaneously or not. But he can say *nothing* about what happens or has happened outside the close vicinity, for instance how the light rays have been initiated or how they have travelled, because all such propositions presuppose a time relation between the observer in *M* and events in points *outside* his close vicinity.

*In fact, a statement such as: 'A ray goes from the distant point A to M' lacks all meaning.*

*Einstein's definition of 'simultaneity' for events in distant points A and B through observation in the mid-point M 'by means of which the physicist can decide whether or not both the lightning strokes (in A and B) occurred simultaneously' cannot be applied, since the experiments cannot be performed. The rays supposed to be coming in to M in the direction from A and B cannot, after the rejection of classical time, be identified as having been initiated by the lightning strokes in the said points. No time relation can be stated by the observer in M with regard to events in A and B.*

Einstein's definition can *only* be applied in the close vicinity of the observer in *M*, but here there is no need of any new time concept since he has accepted classical time to be reigning in the close vicinity of the observer.

One thing, however, is remarkable in this connexion. In '*Relativity*' Einstein has primarily concentrated on giving a meaning to the concept of 'simultaneity' by basing it on 'mid-point co-observation', but he touches lightly on the problem of giving a meaning to the concept of 'time' which is fundamental for the registration of physical events.

In his definition of simultaneity he talks about the 'time' that light takes to traverse the path *AM* as being the same as for the path *BM*. It is evident that here he uses the word 'time' in the meaning 'time interval'. *But at this point in his discourse he has neither indicated what we are to understand by 'time' nor by 'time interval'.* So far we have *only* been told that 'the incompatibility between the principle of relativity and the law of propagation of light' should be eliminated by 'an analysis of the physical conceptions of time and space'. It is only after his 'stipulation' which requires a new meaning both to 'time' and 'time interval' that these concepts are taken up to analysis.

We are then told that the 'time' of a point-event is 'the reading (position of the hands) of the clock which is in the immediate vicinity (in space) of the event', provided the clock in question is regulated in a certain way.

With regard to the relation to be established between distant clocks Einstein makes the following declaration:

'Clocks of identical construction are placed at the points *A*, *B*, and *C* of the railway line (co-ordinate system) and they are "set" in such a manner that the positions of their pointers are simultaneously (in the above sense) the same.'

By 'simultaneous' pointer positions we are thus to understand that they are mid-point co-observed. But when this definition of time relations between distant points is given *Einstein does not at all indicate how the 'setting' of the clocks in the distant points should be performed in order to satisfy his rule for simultaneity. It is, however, evident that his definition makes sense only if such a 'setting' of clocks is possible.*

Most probably Einstein has meant that this 'setting' of the clocks should be attained with the aid of light rays as proposed in 'Elektrodynamik'. But it is to be noted that *Einstein does not give us any information whatsoever on this point.*

Earlier we have seen that a light-ray regulation of distant clocks is impossible to perform if classical time is rejected since the rays cannot be identified by the receiver.

Another possibility—though not mentioned by Einstein—could be that he has thought of some other method of regulation. However, *whatever method is applied it must be possible for the observer in M to send messages to the observers in A and B as to how their clocks should be adjusted in order to fulfil the condition that the same positions of the hands of their clocks should be mid-point co-observed.*

But any kind of messages from *M* to *A* and *B* can—just as the light rays—only be identified as coming from *M* if their arrival in *A* and *B* can be put in time relation to their departure from *M*. And this presupposes classical universal time. In other words, *we are here confronted with exactly the same difficulties as in* 'Elektrodynamik'.

We must therefore state that *the prescribed 'setting' of clocks according to the mid-point co-observation idea can not be carried out after the rejection of classical time.*

With both mid-point observation of incoming rays and light regulation of clocks ruled out as methods of establishing a time relation between distant clocks it follows that:

*In* 'Relativity' *Einstein has not been able to give the concepts of 'time' and 'simultaneity' any meaning, neither in principle nor physically.*

*The contradiction created by the proclamation of both the constant*





*velocity of light and the Extended Principle of Relativity thus also remains unsolved in* 'Relativity'.[1]

## EINSTEIN'S TWO POSTULATES

Before proceeding further there is reason to call attention to a point in Einstein's presentation of his Theory which has given rise to some confusion. He bases his reasonings on two fundamental presuppositions, frequently denoted as his two 'postulates' and they are:[2]

*Einstein's Principle of Relativity*
*The Principle of Constant Velocity of Light*

FIRST POSTULATE:

The laws according to which the conditions of physical systems change are independent of the systems of reference as far as these are moving uniformly and with constant velocity in relation to each other (Galilean systems).

SECOND POSTULATE:

All light rays move in relation to a system of reference considered at rest *in vacuo* with a certain velocity independently of the state of motion of the emitting light-source.

From the first postulate Einstein draws the following conclusion: For all systems of reference for which the mechanical (Newton) laws are valid (Galilean systems) the electro-magnetic and optical laws are also valid. A consequence of this is that a light ray which travels with the velocity $c$ in relation to one Galilean system will also travel in all other Galilean systems with the same velocity.

The second postulate can therefore be considered as a consequence of the first postulate, but both postulates thus lead to the contradiction created by the principle of constant velocity of light. Einstein is fully aware that the second postulate leads to a contradiction according to the classical view. He illustrates the situation with an example.[3]

A man walks in the corridor of a railway carriage with velocity $w$ and the train moves with velocity $v$ along the embankment. If he walks in the direction of travel his speed in relation to the embankment will be $W = v + w$. (If walking in the opposite direction his

[1] Owing to the above serious flaws in the characterization of the new time concept the presentation in '*Relativity*' of the Theory of Relativity stands out as remarkably incoherent.

[2] 'Elektrodynamik' ('*Relativitätsprinzip*', pp. 29, 41). [3] '*Relativity*', pp. 16, 18.

speed will be $W = v - w$.) With regard to the wandering of a light ray along the embankment with the velocity $c$ we find in analogy, according to classical view (as Einstein also points out) that the velocity of the ray with regard to the carriage would be $c - v$. (In the opposite direction $c + v$.) This Einstein declares to clash with the Principle of Relativity when applied to electro-magnetic phenomena, since according to this the velocity of the light ray should, in relation to the carriage, also be $c$ in both directions. The light ray should thus at a certain moment both be and not be in a certain point. This is an obvious contradiction created by the application of the second postulate. This contradiction Einstein undertakes to eliminate by introducing the new time concept.

Although the principle of constant velocity of light can be considered as a consequence of the first principle the two postulates are sometimes treated as two different fundamental presuppositions. Thus Born[1] states that the second postulate is experimentally established, but *without mentioning which the experiments are.* He thus accepts without discussion the very proposition which according to Einstein creates a contradiction. But this has escaped Born's attention. When examining the simultaneity problem he bases his reasoning on the clock regulation with light rays which I have shown to be impossible after the negation of classical time, and meets thus with the same difficulties as those which render Einstein's reasoning untenable.

1 MAX BORN: *Einstein's Theory of Relativity*, Dover, New York, 1962, p. 225.



3

# VARIOUS ASPECTS OF THE THEORY

## THE RELATIVITY OF SIMULTANEITY

The dissolution of simultaneity as an absolute concept is generally considered to be one of the most sensational consequences of the Theory of Relativity.

### SIMULTANEITY ACCORDING TO EINSTEIN'S FIRST TIME CONCEPT

We have seen that if Einstein's first time concept is applied, two events in distant points are simultaneous provided they occur at equal 'pointer positions' of the clocks in the points and provided these clocks are being reciprocally and continuously light-ray regulated so as to fulfil the condition:

$$t'_A - t_A = t_B - t_A.$$

Einstein then asks whether these events can be considered simultaneous also in relation to another Galilean system. In this context I shall disregard the fact that the light-ray regulation cannot be effected and only consider Einstein's reasoning with regard to his own preconceptions.

Einstein makes the following assumptions:[1] We have two clocks $A$ and $B$ at the distance $AB$ from each other *at rest in a system K'*. $K'$ is moving with velocity $v$ in relation to a system at rest $K$. The clocks $A$ and $B$ are so regulated that they show *the same time as clocks in the system at rest* which are:

(*a*) in the points corresponding to where $A$ and $B$ respectively are at the moment and,
(*b*) regulated according to Einstein's rule so as to 'run synchronically' in Einstein's meaning.

A light ray is then supposed to start from $A$ in the moving system at the time (of the system at rest) $t_A$ and to arrive and be reflected in

1 '*Relativitätsprinzip*', p. 30, p. 42.

$B$ at time $t_B$ and return to $A$ at time $t'$. According to Einstein we shall find:

$$t_B - t_A = \frac{AB}{V - v},$$

and

$$t'_A - t_B = \frac{AB}{V + v},$$

where $AB$ is the distance between $A$ and $B$ as measured in the system at rest, and $V$ the velocity of light.

According to Einstein the condition for synchronicity is, however,

$$t_B - t_A = t'_A - t_B,$$

which is *not* satisfied by the above equation.

Einstein concludes that the clocks in $A$ and $B$ do *not* 'run synchronically', and from this he draws the extremely important consequence:

'*We see thus that we cannot attribute any absolute meaning to the concept of simultaneity. Two events which considered from one system of reference are simultaneous can, considered from a system, moving in relation to the former, not be considered as simultaneous.*'

I shall now—still ignoring the fact that 'synchronically running clocks' cannot be effected—examine these formulae *from a purely mathematical point of view*. In the same paper,[1] seven pages later, Einstein presents the formulae which according to the Theory should be used for the addition or subtraction of velocities.

For a clock travelling with velocity $u$ in relation to a system moving with velocity $w$ in relation to another Galilean system the velocity $W$ of the clock in relation to the latter system is according to classical view, if $u$ and $w$ have the same direction, $W' = w + u$, and if they have opposite direction $W'' = w - u$. According to the relativistic view we get:

$$W' = \frac{w + u}{1 + \frac{uw}{V^2}},$$

and

$$W'' = \frac{w - u}{1 - \frac{uw}{V^2}},$$

where $V$ is the velocity of light.

[1] 'Elektrodynamik' ('*Relativitätsprinzip*, pp. 37, 50).'





If we now apply these formulae to the above case ($w = V$, $u = v$) and we call the results $W_1$ and $W_2$ we get

$$W_1 = \frac{V + v}{1 + \frac{vV}{V^2}} = \frac{(V + v) \cdot V}{V + v} = V$$

$$W_2 = \frac{V - v}{1 - \frac{vV}{V^2}} = \frac{(V - v) \cdot V}{V - v} = V$$

If we introduce these values *based on Einstein's own ideas* in the above formulae for the moving clocks we get

$$t_B - t_A = \frac{AB}{V},$$

and

$$t'_A - t_B = \frac{AB}{V},$$

and thus

$$t_B - t_A = t'_A - t_B.$$

*The condition of synchronically running clocks is thus also fulfilled by the clocks in the moving system.*

*The necessary conclusion of this reasoning, based on Einstein's own suppositions, must be that events that are simultaneous in relation to one inertial are also simultaneous with regard to all other inertial systems.*

Here, too, we find that if Einstein's ideas, preconceptions and formulae are *consequently* applied, we come to results contrary to his own proclamations but, also in this case, in full accordance with the classical view. This in turn is due to the fact that Einstein so often—although surely unconsciously—half-way through his reasonings neglects his own premises and their necessary consequences and falls back on classical modes of reasoning which he has rejected a moment before.[1]

[1] In this connection it is interesting to consider the categorical stop signal given by W. Wien—quoted above, p. 17—against non-mathematicians wishing to penetrate the Theory of Relativity:

'No entry for non-mathematicians.'

This may be applicable with regard to the very voluble and far-reaching *secondary* mathematical developments of the Theory. On the other hand formulae

Thus, on the basis of Einstein's own preconceptions in connexion with his first time concept, his conversion of the concept of 'simultaneity' fails to make sense. *The classical concept of simultaneity as valid for all Galilean systems still stands.*

### SIMULTANEITY ACCORDING TO EINSTEIN'S SECOND TIME CONCEPT

Two strokes of lightning are supposed to occur in the points $A$ and $B$ on a railway embankment. A train is travelling along the rails of the embankment in the direction from $A$ to $B$ with the constant velocity $v$. The lightning strokes are supposed to be 'simultaneous' in the meaning number two. That is, they have been observed simultaneously (in the classical sense) by an observer in the mid-point $M$ of the distance $AB$ and at rest with reference to the railway embankment (say system $K$). The lightning strokes are 'mid-point co-observed'. The lightning strokes will also be observed by persons on the train, and they will state that the strokes arrive in two points, which we can call $A'$ and $B'$ on the train. Einstein then raises the question:

Will the two lightning strokes, which are 'simultaneous' (mid-point co-observed) with reference to the embankment ($K$) also be simultaneous (mid-point co-observed) with reference to the train (system $K'$)?

Einstein reasons as follows:

'Let $M'$ be the mid-point of the distance $A'B'$ on the travelling train. Just when the flashes (as judged from the embankment) of lightning occur, this point $M'$ naturally coincides with the point $M$, but it moves with the velocity $v$ in the direction of the train. If an observer sitting in the position $M'$ in the train did not possess this velocity, then he would remain permanently at $M$, and the light rays emitted by the flashes of lightning in $A$ and $B$ would reach him simultaneously, i.e. they would meet just where he is situated. Now in reality (considered with reference to the railway embankment) he is hastening towards the beam of light coming from $B$, whilst he is riding on ahead of the beam of light coming from $A$. Hence the observer will see the beam of light emitted from $B$ earlier than he will see that emitted from $A$. Observers who take the railway train as their reference-body must therefore come to the conclusion that the

which are so simple that they postulate only elementary mathematical knowledge do not seem to interest the mathematically highly learned relativitists. Such formulae seem to be ignored, possibly owing to the fact that their application leads as shown above to disastrous consequences for the Theory.





lightning flash $B$ took place earlier than the lightning flash $A$. We thus arrive at the following important results.

'Events which are simultaneous with respect to the embankment are not simultaneous with respect to the train and vice versa (relativity of simultaneity). Every reference-body (co-ordinate system) has its own particular time, unless we are told the reference-body to which the statement of time refers, there is no meaning in the statement of the time of an event.'

Einstein declares that, 'just when the flashes of lightning occur (as judged from the embankment) this point $M'$ naturally coincides with the point $M$'. This means that the observers in $M$ and $M'$ will register a certain moment when they coincide with each other and this is declared to be the moment 'just when the flashes of lightning occur in $A$ and $B$'.[1]

If this is to have any meaning at all it must indicate that *the moment of the lightning stroke in* A, *and the moment of the lightning stroke in* B, *and the moment of coincidence of* M *and* M′ *are one and the same moment*. That is: they are 'simultaneous', and this can have a meaning *only* in the classical sense of the word since we have so far no other time concept.[2] It also implies that he has thus accepted the classical time concept to be reigning in the whole of the system.

It might be rejoined that we have to understand this in the sense of the time concept established by Einstein through his clock regulation. We have, however, seen earlier that both Einstein's attempts to establish his new concept with light-ray regulation directly, and by means of mid-point observations have failed. *The events declared to take place at one and the same moment must therefore be 'simultaneous' in the classical* a priori *meaning of the word.*

It may be observed that if we should apply Einstein's definition of 'Simultaneity II' in order to state the relation between the stroke of lightning for instance in $A$ with the coincidence of the two observers in $M$ and $M'$, this would imply that these two events should be mid-point co-observed. Light rays should go out not only from $A$—which is in full accordance with our suppositions—but also from $M$ at the moment of coincidence with $M'$ in the direction against $A$, and these rays would have to be co-observed by an observer in the

[1] The German text on this point is still more explicit in identifying the moments: '*Dieser Punkt M fällt zwar im Augenblick der Blitzschläge (vom Fährdamm aus beurteilt) mit dem Punkte M zusammen.*'

[2] This has also been pointed out by Adolf Phalén in his treatise 'Über die Relativität der Raum—und Zeitbestimmungen', Uppsala and Leipzig, 1922.

mid-point between $A$ and $M$ if the two events are to be considered simultaneous.

But this has not been done and we have learnt from Einstein that:

'As long as this requirement is not satisfied, I allow myself to be deceived as a physicist when I imagine that I am able to attach any meaning to a statement of simultaneity.'

Thus the expression 'just when the flashes of lightning occur this point $M'$ naturally coincides with the point $M'$' has with Einstein's presumptions and declarations *no meaning at all.* It *has* a meaning, however, and a very distinct meaning when the classical time concept is accepted.

What we have are three moments in distant points $A$, $M$, and $B$ which are declared to be 'just the same moment', and this can have no other meaning than 'simultaneous' in the classical sense. Through this reasoning Einstein has indirectly and necessarily accepted the classical concept for the whole system $K$. But when we say that this moment is also identical with the moment of coincidence between the two observers in $M$ and $M'$, we have in fact declared that the moment is identical for the three points also judged from $M'$ in $K'$. This is, as shown later, (p. 67) the consequence of the idea of transformation, when the two observers coincide. They identify the moment of coincidence as one and the same moment *as judged from both systems,* and any events which are simultaneous to the observer, say $M$ in $K$, are thus also simultaneous to the observer $M'$ in $K'$ as they occur at the moment of coincidence. This being the case, the lightning strokes which *are* simultaneous in $K$ (classical sense) are *also* necessarily simultaneous for the observer $M'$ in $K'$.

Earlier we saw that Einstein himself has accepted classical time to be reigning in the close vicinity of $M'$ in $K'$. Thus we find that classical time must be supposed to reign in that part of $K'$ which is near $M'$. But the events we are discussing can just as well take place in $K'$ as in $K$, and we would then come to the necessary conclusion that classical time would be reigning in the whole of $K'$ and in the limited area round $M$ in $K$.

This follows from the fact that the systems of reference must in principle be equivalent.

*We have thus been obliged to extend the area where the classical time concept is prevailing from the limited vicinity of the observer to his whole system of reference. But since this must be the same for both systems we have in fact extended the area where classical time reigns*





*from the limited area round the observers to the whole space for both systems.*

*Einstein's reasonings in this connexion also make it necessary to presume time in the classical meaning to be reigning in both systems.*

We can sum up:

*The necessity of putting events outside the limited areas of the observers in relation to events close to them which we must do in order to make our judgements with relation to time—e.g. put in causal relation—or in order to perform and discuss prescribed experiments—such as mid-point co-observation—obliges us to accept the classical* a priori *time concept as valid for the whole of space and for all systems of reference.*

But this completely changes the problem with which we are dealing. Both lightning strokes being simultaneous in the classical sense as seen from both systems of reference, the problem is now reduced to this:

*Two events in* A *and* B *are simultaneous in the classical meaning of the word with regard both to* K *and* K′ *and also mid-point co-observed in the system* K.

The question then becomes:

*Will* A *and* B *also be mid-point co-observed in the system* K′ *moving with velocity* v *with regard to* K*?*

The fact that the simultaneous events in $A$ and $B$ are mid-point co-observed implies that the light rays from $A$ and $B$ to the mid-point of $AB$ must move with the same velocity, and since the systems of reference are arbitrarily chosen, light rays in the system $K$ must travel in all parts and all directions with the same velocity. The system $K$ has thus the qualities we ascribe to the hypothetical ether. But this being the case, the velocity with which the same rays travel as seen from the train $K'$ will be $c + v$ and $c - v$ (exactly as pointed out by Einstein in *Relativity*, p. 18). The rays from the events in $A'$ and $B'$ will travel along the train with *different* velocities and they will *not* arrive simultaneously in the mid-point $M'$ of $A'B'$.

They will *not* be mid-point co-observed. Einstein too comes to this result for the simple reason that he has unconsciously presupposed simultaneity of the events in the classical sense, and his reasoning about the movement of the rays is in full conformity with classical views.

If on the other hand we would follow the general principle of constant velocity of light proclaimed by Einstein as the fundamental idea of his theory, that is 'the constant velocity of one and the same light ray in *all* Galilean systems of reference', we would come to the result that the rays from *A′* and *B′* would go with the same velocity in *K′* as in *K* and thus travel the equal distances *A–M* and *B–M* in the same time and thus arrive simultaneously in *M′*.

*The two events in* A′ *and* B′ *will thus, if we apply Einstein's principle, be not only simultaneous in the classical meaning but also 'simultaneous' in the meaning mid-point co-observed in the moving system (the train).*

*Einstein has here, by introducing a definition giving a new meaning to the word 'simultaneity' and a moment later unconsciously but necessarily applying the word in the classical meaning, arrived at a result, which is correct according to classical view, but false according to his own principles. This he proclaims as an epoch-making discovery but it is attained only thanks to an ambiguous way of using the word 'simultaneity'.*

Indeed a remarkable performance of intellectual conjuring!

The declaration that 'simultaneity' has a meaning only with reference to a special system must therefore be categorically rejected. Both in 'Elektrodynamik' and '*Relativity*' Einstein has failed to give any tenable argument for this idea. His reasoning is on the contrary a striking illustration of the fact that he himself also accepts unconsciously the classical time concept as prevailing throughout space, independent of system of reference. And without this presupposition his reasoning comes to nothing.

*We are thus on Einstein's presuppositions brought back to the classical view that events which are simultaneous in relation to one Galilean system of reference are also simultaneous in relation to other Galilean systems.*

We can come to this result also more directly. It was found in the discussion of Einstein's first time concept that the formulae presented by him for the addition and subtraction of velocities when *consequently* applied gave the result—contrary to Einstein's declaration—that two events in distant points, simultaneous in one inertial system, must necessarily be simultaneous in all inertial systems. With this mathematically binding background we can declare *a priori*





that the results Einstein comes to with regard to 'simultaneity' on the basis of his second time concept must be rejected.

### THE POSSIBILITY OF MID-POINT OBSERVATION IN THE MOVING SYSTEM

Einstein's attempt to remould our concepts together with the presuppositions he makes in this connexion creates very serious practical difficulties, for instance with regard to mid-point observation on the train of the events in *A′* and *B′* in order to decide if they are simultaneous. A fundamental idea of Einstein's is that 'the concept does not exist for the physicist until he has the possibility of discovering whether or not it is fulfilled in an actual case'.

It has therefore no meaning to say whether the events in *A′* and *B′* are simultaneous or not, as seen from the train, until the experiment is performed, by which we ascertain whether they are 'mid-point co-observed' or not.

The question therefore is how are we to make this observation? It is evident that we can place an observer beforehand in the point *M* mid-way between the points *A* and *B* on the embankment because we are supposed to know that the events (strokes of lightning) are expected to occur in these points. But the difficulty arises when we are to place the observer in *M′*. We do *not* know beforehand which are the points *A′* and *B′* on the train where the light rays will strike, nor where the mid-point *M′* is. *The points* A′, B′ *and* M′ *are unknown in advance.* Nor can they be calculated beforehand since according to Einstein we have so far no time relation between events on the train and events on the embankment.[1]

But the observer on the train must know beforehand where he has to place himself in order to be on the right spot, that is the mid-point of *A′B′* when the light rays from *A′* and *B′* arrive. Now, if we do not know the location on the train of *A′*, *B′* and *M′*, the observer on the train who has to ascertain whether the 'co-observation' takes place does not know where he should place himself. This means that *the experiment cannot be performed* and according to Einstein it means that the concept 'simultaneity' does not exist. As we have seen (p. 45) Einstein is extremely explicit on this point.

His declaration in this context, together with the fact that we lack the possibility of placing the observer on the train and thus also of

[1] This calculation might possibly be done on the basis of the classical time concept if we knew *exactly* beforehand the time when the strokes will occur as judged from the embankment and also with very high accuracy the position of the train at a certain moment—embankment time—and the velocity of the train.

performing the observation, is a striking illustration of the fact that *Einstein himself has eliminated the applicability of his own definition to the moving system.*

A faithful relativist has rejoined that the placing of the observer on the train can be solved in the following way:

The train should be exactly of the same length as the distance between two poles *A* and *B* on the embankment and an observer *M* be placed in the mid-point of *AB*. One of the light flashes should be initiated when the front of the train passes the pole furthest in front of the train and the other light flash when the end of the train passes the other pole. The observer *M′* should be in the mid-point of the train.

The light flashes from *A* and *B* are supposed to be 'mid-point co-observed' by *M*. With regard to Einstein's negation of classical time the events in *A* and *B* *cannot* be put in causal relation to the light-ray observation in *M* (see p. 47) and therefore the observer in *M* can *only* say that light rays have arrived simultaneously in the directions from *A* and *B*, and *he can draw no conclusion about the simultaneity of the events in A and B, neither from the embankment nor from the train.*

From the classical point of view the events in *A* and *B* are simultaneous—provided the light rays from *A* and *B* to *M travel with the same velocity*—both judged from the embankment and the train.

If on the other hand we accept Einstein's supposition in *Relativity* (p. 26) that the observers *M* and *M′* coincide 'just when the flashes occur'—a typically classical expression, but meaningless if classical time is rejected—this implies that the three events *are simultaneous in the classical sense*, seen not only from the embankment but also from *M*, on the train and thus simultaneous *also* 'as judged from the train'. There is in this case no need of mid-point co-observation since we know already from the declaration made by Einstein that they *are* simultaneous in the classical sense for both systems. No other meaning can be given to his expression.

Einstein's statement that simultaneity should be defined by experiments, together with the extreme difficulty of placing the observer in the exact mid-point on the train and the impossibility of drawing conclusions from the observations in *M* and *M′*, shows in a striking way that Einstein has himself eliminated the possibility of applying his own definition to the moving system. The concept cannot be established, the word 'simultaneous' therefore has no meaning for the moving system in Einstein's case.

Now it may be objected and has been objected by supporters of the Theory of Relativity that Einstein declares in one paper





('Elektrodynamik') that the meaning of concepts such as 'time' and 'simultaneity' have been attained by 'imaginary' physical experiments:

'We have thus with the aid of certain—"imaginary"—physical experiences settled what should be understood by synchronously running clocks at rest in different points and thereby also attained a definition of "simultaneity" and of "time".'[1]

But the 'imaginary' experiments cannot be realized owing to the fact that the clocks cannot even in our imagination be regulated with light rays, or the lightning strokes not be mid-point co-observed in the moving system. Furthermore, the speculation on the 'imaginary' experiments contradict the assumptions made by the 'imaginer' himself. In fact the 'imaginary' experiments are 'unimaginable'.

The idea of 'imaginary' experiments also stands in clear contradiction to Einstein's declaration in '*Relativity*' (p. 22) that 'we should *decide by experiment* whether or not both the lightning strikes occur simultaneously'. (Author's italics.) Here there is no talk of 'imaginary' experiments.

## THE CONCEPT OF MOTION

Since the fundamental preconceptions which lead Einstein to the relativity problem turn out to be meaningless when classical time is rejected, the derivatives of the time concept will also fail to make sense.

Take for instance 'movement'. In the context of physical phenomena discussed here the word 'movement' means 'change of position with the flow of time'. But flow of time implies 'before', 'simultaneous' and 'after' which for distant points become meaningless to an observer when classical *a priori* time relations are negated. Nothing that happens outside his close vicinity can be put in time relation to him, and *therefore 'flow of time' can mean nothing to him outside his close vicinity.*

Furthermore it follows that the negation of the *a priori* time relation between distant points deprives words like 'velocity', 'acceleration', 'retardation' and 'rotation' as well as phrases such as 'something moves from *A* to *B*' of all meaning. Therefore such fundamental propositions of the Theory as

[1] Translation: '*Wir haben so unter Zuhilfenahme von gewisser—gedachter—physikalischer Erfahrungen festgelegt, was unter synchron laufenden, an verschiedenen Orten befindlichen ruhenden Uhren zu verstehen ist und damit offenbar eine Definition von "gleichzeitig" und "Zeit" gewonnen.*'

'The system $K$ moves with constant velocity $v$ along the $x$-axis of the system $K'$' and 'A light ray goes from $A$ to $B$' cannot mean anything outside the close vicinity of an observer.

On the other hand they have a clear meaning if we accept the classical *a priori* time concept.

The difficulties can also be illustrated by practical examples.

Einstein begins with the assumption that the system of reference $K'$ moves with the constant velocity $v$ along the positive $x$-axis of the system $K$ and this is expressed by the equation $x = vt$ for the point $O'$ in $K'$.[1]

An example of this is the train problem where the train is supposed to 'travel along the rails with the constant velocity $v$'.[2] But this means that at a certain time $t$—i.e. at the clock-position $t$ for an observer in the point $O$ in $K$—the point $O'$ in $K'$ arrives at a point $P$ in $K$ at the distance $vt$ from $O$ *as judged from K*. The arrival of $O'$ in $P$ and the clock-position $t$ in $O$ are, therefore, if the equation is to have any physical meaning, necessarily declared simultaneous for the observer in $O$. *And this declaration is also accepted by Einstein independently of all clock regulation and all mid-point observation.* Such a proposition then implies that the two distant events, clock-position $t$ in $O$ and arrival of $O'$ in $P$, are *simultaneous in the old, classical,* a priori sense.

Here the faithful 'relativist' would probably retort—indeed I have met the answer: The proposition, '$O'$ arrives in $P$ at time $t$', is possible to make according to Einstein because in all points in $K$ where events are expected there are clocks placed and regulated by light rays to run 'synchronically' and thus the time of the arrival of $O'$ in $P$ would be measured by such a clock in $P$ and the statement would have a meaning.

The answer to this is that—as has been shown earlier—*the regulation of clocks with light rays or mid-point observations as well as the supposition that the clocks 'run at the same rate' are all lines of thought which inevitably presuppose the acceptance of time* a priori *in the classical meaning for the whole system of reference. If the classical time concept is rejected this kind of reasoning lacks all sense.*

It should also be noted that Einstein talks about the movement of the system of reference $K'$ in relation to $K$ with the velocity $v$ along the $x$-axis of $K$ *before he has presented his new time concept*,[3] and if this fundamental basis of the whole relativity problem is to have any

[1] The time is supposed to be registered from the moment of coincidence between the Origins $O$ and $O'$, when we have $t' = t = O$.

[2] '*Relativity*', p. 25. [3] '*Relativity*', p. 13.





meaning at all *he must base his statements on the only meaning so far existing of 'time', 'movement', 'velocity' and so on, that is on the classical meaning of these words.*

With regard to the propagation of light, we come to exactly the same result. If we suppose that a flash of light is created in $O$ of the system $K$ and we follow the ray of light moving along the positive $x$-axis we are supposed to be able to say that it moves with the constant velocity $c$ according to the equation $x = ct$ (fig. 1A). This

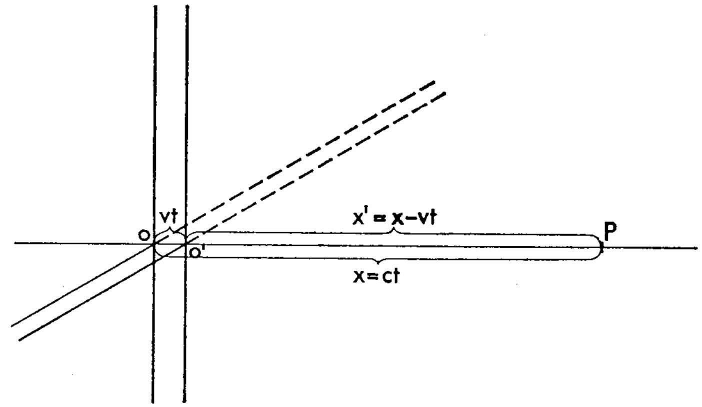



FIG. 1A.

implies that after, say a second, the observer in $O$ is supposed to be able to state that the light ray has arrived in a point $P$ on the $x$-axis at the distance $c$ from the point $O$. The arrival of the light ray at the point $P$ on the $x$-axis and the clock position $t = 1$ in $O$ are thereby *declared to be simultaneous*. Since this proposition is made independently of all clock regulation and all mid-point observation, in fact independently of all experiments, it must necessarily be based on the classical time concept *a priori*. If we accept Einstein's presumption (the rejection of classical time for the system $K$ in general) the two statements

The system $K'$ moves with constant velocity along the $x$-axis of the system $K$

and

A light ray travels with the velocity $c$ along the $x$-axis of the system $K$

*mean nothing outside the close vicinity of an observer* where also Einstein accepts classical time and where there is consequently no need to create a new time concept.

But if these two propositions, which are fundamental for the constitution of the whole relativity problem, thus fail to make sense, then the problem which Einstein has set out to solve is eliminated.

Having stated this, it is of a certain interest to note how for instance the 'simultaneity rule' of 'mid-point co-observation' would work out in practice.

If we say 'A light ray has in the time $t$ travelled from origin $O$ to a point $P$ on the $x$-axis of $K$', it implies that the arrival of the light ray in $P$ is simultaneous with the clock-position $t$ in $O$. In order to arrive at this result by mid-point observation, a light flash would have to go from $O$ at the moment of the clock-position $t$ along the $x$-axis towards $P$. Another light flash would have to go from $P$ at the moment of arrival of the light ray in $P$, but in direction *towards* $O$. The observer would have to be placed in the *exact* mid-point of $O$ and $P$. And *only* if he observed these two light rays simultaneously could we say that the arrival of the light ray in $P$ and the clock-position $t$ in $O$ would be simultaneous. *Only* in this case would it be meaningful to say that the light ray had travelled the length $OP$ in the time $t$.

The task of the mid-point observer is, however, somewhat complicated because if we say that $t$ has the value 10 seconds as measured by the clock in $O$ he would have to place himself in a point about 1,500,000 km from $O$ on the $x$-axis. And since the value of $c$ is known to us only approximately he would not know *exactly* where to place himself. But only if he happened to arrive *in the exact mid-point* of $OP$, and only if he observed the light rays coming in from $O$ and $P$ simultaneously could he say that the light ray arrival in $P$ and the clock position $t$ in $O$ would be simultaneous. *Only* then would it have a meaning to say that the light ray had travelled with the velocity $c$ to $P$ in the time $t$.

Einstein's speculations on 'time' have thus charged the unfortunate physicist with an extremely complicated task in order to give a meaning to the seemingly very simple proposition: 'A ray has travelled the distance $ct$ along the $x$-axis in the time $t$'.

The inevitable retort from the relativists that the time in $P$ is measured with the aid of light-ray regulated clocks spread out in the system miscarries for two reasons:

(*a*) The proposition is set forth *before* the light-ray regulation is even mentioned.





(*b*) It is impossible to regulate clocks in distant points after rejecting classical time.

In fact this rejection cripples the physicist: It denies him every chance of registering the time of any events outside his close vicinity. Only in this limited area can he make such observations, and they will all be—according also to Einstein—based on classical *a priori* time.

A new time concept is here superfluous.

## THE MEANING OF TRANSFORMATION

Let us now examine another presupposition—which Einstein accepts as self-evident—i.e. *the possibility of transformation.* He as well as the classical physicists assumes that if we know the co-ordinates $x, y, z, t$ of an event in a system $K$, we can also find the co-ordinates in a system $K'$ whether we call them as Newton does $x', y', z', t$ or whether we say $x', y', z', t'$.

The background and consequences of this assumption are that we measure the co-ordinates $x, y, z,$ in $K$ and the co-ordinates of the same event $x', y', z',$ in $K'$ along the respective axes in the systems of reference. But in order to establish the time of the event in the two systems we must have an agreement about the starting point of our time-measuring.

Both in pre-relativistic and in relativistic physics it is agreed that we reckon time in the systems from the moment when the intersectional points $O$ and $O'$ of the axes in $K$ and $K'$ coincide. It is thus presupposed that *both the observer in* O *and the observer in* O′ *can fix this moment and that this is identically* the same moment both as judged from $O$ as from $O'$. Both in classical and in relativistic physics we generally denote this moment as $t = 0$ in $K$ and $t' = 0$ in $K'$.

According to Einstein all events in the close vicinity of an observer in $O$ are registered with the clock beside the observer. Two events in different points of this vicinity which are both registered as taking place at the clock-position $t = 0$ will thus *a priori* be called simultaneous. But since they take place at the moment of coincidence between $O$ and $O'$, which is identical for both systems, they also occur at the moment $t' = 0$ as judged from $K'$.

Consequently they will be simultaneous also for the observer in $O'$ of $K'$. Reciprocally we can state that two events in points within the limited area round $O'$ in $K'$, which both take place at the time $t' = 0$, and which are thus simultaneous for the observer in $O'$, both take place also at the identical moment $t = 0$ as judged from $O$ in $K$.

For the two coinciding observers in $O$ and $O'$ we thus find that *two events simultaneous in one system are also simultaneous in the other system provided they take place within the limited area round the observers* for which the classical *a priori* time concept is supposed to be valid, and the time is registered by the clocks in $O$ and $O'$.

But previously we have seen that Einstein necessarily must, in order to regulate the clocks in distant points—although he does not realize it himself—presuppose that the classical *a priori* time concept is valid throughout the system of reference in question. This being the case, we find that we must also extend the area in which we can judge the time relation between distant events in a moving system. We find accordingly that *two events in any distant points in one system, which are judged to be simultaneous by an observer in any point in this system, will also be judged as simultaneous by an observer in that same point in the moving system.*

Summing up, we can therefore state that there are three assumptions which Einstein must make in order to carry his reasoning through:

(*a*) 'Time *a priori*' in the classical sense is valid within the limited observation area of an observer. It follows that also all derived concepts like 'before', 'after', 'simultaneous', 'movement', 'velocity', and so on are valid in their classical sense within this limited area. The time of any event in the limited area is registered by the clock position in its vicinity.

(*b*) The creation of the new time concept presumes the possibility of sending and identifying light rays going from one point to another distant point in the same system. This implies necessarily the extension of the classical *a priori* time concept to apply to the whole system of reference, in order to identify and register the rays. And this must therefore be the case for all systems of reference.

(*c*) The possibility of transformation.

In order to attain the transformation of the co-ordinates of an event in one Galilean system to another Galilean system, it is assumed that the moment of coincidence of two points, one in each system, is one and the same moment *as judged from both systems.* For instance the Origins of the two Galilean systems $K$ and $K'$ are supposed to coincide at one and the same moment as observed from both systems, and this moment is generally labelled $t = 0$ in $K$ and $t' = 0$ in $K'$.





This, in combination with the result under (*b*), leads to the conclusion that any two events which are simultaneous with reference to one Galilean system are simultaneous with reference to all Galilean systems.

We thus find that *if we strictly follow the presuppositions necessary for Einstein's reasoning we come to results wholly contrary to those proclaimed by Einstein but in full accordance with classical time concept.* On the other hand Einstein's reasoning and experiments *cannot* be carried through on the basis of his own presupposition—the rejection of classical time.

The fact that two events simultaneous with regard to one system must also be simultaneous in relation to all other Galilean systems on the basis of the above-named three necessary presumptions can be demonstrated in the following way:

Suppose one light flash takes place in a point $P$ and is registered there by the observer $M$ in $K$ and by $N$ in $K'$ and that they register the event as taking place at $t_M$ and $t_N$ respectively. We can then state that the three events, the light flash in $P$, the clock position $t_M$ in $M$ and $t_N$ in $K'$ are one and the same moment—the fundamental basis of transformation.

We also suppose that another light flash takes place in the point $Q$ and is registered by the observer $R$ in $K$ at the time $t_R$ and by $S$ at $t_S$ in $K'$. Then the light flash in $Q$, the clock position $t_R$, and the clock position $t_S$ are one and the same moment.

If we are now told that the light flash in $P$ and the light flash in $Q$ are simultaneous in the classical meaning—the only one at our disposal—as judged from the system $K$, then we can say that $t_M$ and $t_R$ represent the same moment.

But since $t_S$ is identical with $t_R$ which is simultaneous with $t_M$, and $t_N$ is identical with $t_M$, we can say that $t_S$ and $t_N$ are also one and the same moment. That is: the light flash in $P$ at the time $t_N$ is simultaneous with the light flash in $Q$ at the time $t_S$ *also* as seen from $K'$.

Result: *Two events simultaneous with regard to one Galilean system are simultaneous with regard to all other Galilean systems.*

Having thus stated that the establishing of Einstein's first time concept necessarily presupposes the acceptance of classical time to be valid throughout all Galilean systems, we can conclude that his new time concept as presented in 'Elektrodynamik' lacks all reasonable justification.

By an analysis of the concept of transformation we thus find that Einstein has, by accepting the possibility of carrying out the idea of transformation together with the possibility of light ray regulation, logically bound himself to accept classical *a priori* time for the whole of space and for all systems.

## THE TIME-UNIT OF THE THEORY

For all comparisons of different processes, such as the movement of a system of reference, a light ray or a mass particle, we must have a common unit of time. In classical physics we practically always reckon with the 'second' as our time unit. This unit is based on the rotation of the earth round its axis in a celestial system of reference considered at rest, the rotation being completed in 24 hours of 60 minutes each, each minute representing 60 seconds. *This time unit is considered valid for the whole of space and for all systems of reference, just as the classical time concept.*

When in the Theory of Relativity we are told that the classical time concept must be rejected and replaced by a new concept, one question arises spontaneously:

*What is to be used in the Theory as the basis and common unit for our time calculation?*

First we can state that owing to the rejection of universal classical time we lose the possibility of comparing processes in distant parts of a system of reference. We can have clocks at different points in a system, but they cannot be regulated reciprocally, and consequently *they will run independently of each other.* We can therefore have no common time unit. Each point and each clock will have its own time unit independently of all other clocks. This implies that *the second is eliminated as time unit.*

The problem of time unit is however touched upon in two of Einstein's fundamental papers, and it is of interest to see how he treats it.

### THE CONSEQUENCE OF EINSTEIN'S FIRST TIME CONCEPT

In his first paper[1] Einstein declares as 'a result of experience' ('*der Erfahrung gemäss*')[2] that if a light ray goes from a point $A$ to a distant point $B$ at the time $t_A$, is reflected in $B$ at the $B$-time $t_B$ and returns to $A$ at the time $t'_A$, then the quantity

$$\frac{2\,AB}{t'_A - t_A} = V,$$

[1] 'Elektrodynamik', p. 29.

[2] What this 'experience' is, is not mentioned! We may however guess that he alludes to his interpretation of the Michelson–Morley experiment, p. 98.





is a 'universal constant' denoted as 'the velocity of light in vacuum'. With regard to this 'universal constant' it is important to note that in this connexion *neither a time unit nor a value for this 'velocity' is expressly indicated.*

The only basis for the determination of a time interval is given by the rule that in a system considered at rest a ray of light travels independently of the motion of the source of light according to the principle

$$\text{Velocity} = \frac{\text{light ray distance}}{\text{time interval}},$$

where time interval has to have the sense earlier indicated in the same paper.

Bearing in mind the fundamental definition of time relation between distant points given there we find that by definition the time it takes for a light ray to go from $A$ to $B$ should be equal to the time it takes for the ray to go from $B$ back to $A$:

$$t'_A - t_B = t_B - t_A.$$

But this presupposes that we are able to say that the light ray coming to $A$ at $t_A'$ is the same ray as the one initiated at $A$ at $t_A$, and that it has been reflected in $B$ at the time $t_B$. That, however, is possible *only* if we can put the events in $A$ and $B$ in causal relation to each other (as cause and effect), and that cannot be done if classical universal time is negated. *The rays cannot in this case be identified.* The observer in $A$ who has to register the time intervals in order to compare them cannot fix the values of the distant clock $B$, nor can the observer in $B$ decide anything about the position of the clock in $A$. The definition is thus inapplicable and *leaves the term 'time interval' not only undefined but in fact meaningless.*

In 'Elektrodynamik' Einstein leaves the reader completely in the dark as to the meaning of 'time' and 'time interval' between distant points, and this is due to the rejection of classical time. We can therefore also state that no time unit is given for the space including both the points in question.

In this connexion the unit of the second is not even mentioned. Later in the same paper, however, it is pointed out that a moving clock will travel more slowly than the clock at rest in the system of reference, and as a consequence of this it is stated that the 'second' is dilated. But this statement is *only* based on purely mathematical calculation attained with the aid of the transformation equations. It is *not* shown that the new symbols attained by these calculations really represent any physical quantities. The conclusions drawn from the calculations that the moving clock runs more slowly than the clock at rest and that the 'second' can be said to be dilated are mere *mathematical constructions*.

No analysis or motivation is given as to what the symbols introduced represent or whether they represent any physical quantities at all. No time unit is established.

With regard to Einstein's second time concept the situation is somewhat different.[1]

Here Einstein begins by stating the velocity of light to be 300,000 km per second and has thereby accepted the second as our time unit. But later this inference is abandoned. Discussing the mid-point observation in *M* of the two strokes of lightning in *A* and *B* at equal distances from *M* along the railway embankment in order to ascertain whether the two strokes are co-observed in *M* he declares:

'That light requires the same time to traverse the path *AM* as for the path *BM* is in reality *neither a supposition nor a hypothesis* about the physical nature of light but a *stipulation* which I can make of my own free will in order to arrive at a definition of simultaneity.'

First we can note that the time intervals in question are declared alike without reference to any time unit. They are only put in relation to each other. The 'second' is *not* used as the time unit. It is the way the rays travel independently of all other processes which constitutes their time unit.

But since the clocks in *A*, *B* and *M* by which the time intervals should be determined can *not* be regulated in relation to each other, neither by light rays nor by any other message-carriers after the rejection of classical time (owing to the impossibility of identifying the rays), *the clocks will be running quite independently of each other*. Therefore the time intervals cannot be fixed but will remain wholly undecided. Consequently the 'stipulation' that the 'time intervals' should be equal loses all meaning for events in distant points.

If on the other hand we consider the close vicinity of an observer where classical time is valid also according to Einstein, the stipulation in '*Relativity*' which is made for the two rays independently of all other processes implies that for each ray the 'time unit' is the time it takes the ray to travel a certain distance. *The rays constitute their own time units, and these 'time units' can therefore differ* from each other.

The law of constant velocity of light implies, however, that a

[1] '*Relativity*', pp. 17–24.





light ray always travels equal distances in equal time intervals. But equal time intervals are here the intervals it takes the ray to travel equal distances. This being the case we come to the same result as earlier when we considered Einstein's first time concept:

*According to Einstein's 'stipulation' the law of constant velocity of light implies for the close vicinity of an observer (the only case where the stipulation has a meaning) that the rays travel equal distances, when they travel equal distances.* Again a tautology.

The reasoning conducted by Einstein in 'Elektrodynamik' and '*Relativity*' on 'time intervals' and 'time units' on the basis of the rejection of classical time leads to the following results:

(*a*) The 'second' is abolished as time unit.
(*b*) For processes such as the movement of a light ray, assumed to be continuing outside the close vicinity of the observer we have no time concept valid outside this close vicinity, and to say that the ray 'goes on', 'continues' outside the vicinity has no meaning. It follows that we have no time unit valid outside the vicinity, and processes assumed to be taking place outside the vicinity cannot be compared.
(*c*) The law of constant velocity of light rays is applicable *only* to the close vicinity of the observer, and here it is in both presentations reduced to a tautology.[1]

## DIFFERENT POSSIBILITIES OF CLOCK REGULATION

To the foregoing reasoning a staunch supporter of the Theory has objected that the stipulation that light rays always travel equal distances in equal time intervals can be made and have a meaning because we are dealing with something so unique as the propagation of light rays which is assumed to follow its own special laws. This remark gives rise to the most serious objections from a logical point of view since it implies a *relativity of concepts*, that a concept such as motion or velocity would have different meanings for different moving objects. Such a supposition would undermine all consistent thinking. I shall, however, not dwell on this because the idea can be categorically rejected: A statement that the velocity of the time-

[1] It may be noted that a 'stipulation' of this kind hardly solves any problems. If I have difficulty in being back home for dinner at eight o'clock, owing to much work or traffic jams, I can of course 'stipulate' that the clock in the dining room should always point at eight when I come home. But I am afraid that neither my wife nor the cook—if we had one—would be satisfied with the arrangement.

regulation process is constant amounts, as we have seen above, to a tautology, no matter which kind of process we use.

It is, however, of interest to note Einstein's own declaration that the regulation of the clocks can in principle be brought about by means of *any* process, and whatever process we use the 'stipulation' must be made. Einstein writes ('*Meaning*', p. 27).

'In order to give physical significance to the concept of time, processes of some kind are required which eneable relations to be established between different places. It is immaterial which kind of processes one chooses for such a definition of time.'

Einstein adds that it is advantageous to choose only those processes concerning which we know something for certain, and expresses a preference for light rays as regulating process. But he still holds that *in principle any process may be used.* This implies that the process used to regulate the clocks is only to be considered as a message-carrier from one point to another to inform the observer in the latter point how he should adjust his clock.

Let us now for a moment assume that we use a well-known kind of message-carrier, a number of messenger boys. It is thereby anticipated that we do not know how the messenger boys move. One may walk, another may run, a third messenger may use a bicycle and so on. The observer in $A$ sends a messenger boy to $B$ from where he is assumed to return to $A$ and so on.

According to the analysis on page 35 we must always have, regardless of which messenger boy is used, the following equation satisfied:

$$t_A^{n+1} - t_B^n = t_B^n - t_A^n.$$

And the same should apply to any pair of points. But this is not always fulfilled by the messenger boys. One boy may start at $t_A$ to $B$ and another with the same aim at $t_A'$. Since, however, they travel differently it may so happen that they both arrive back in $A$ at the same time $t_A^0$. But both time differences are to be alike. $t_A^0 - t_A$ should be equal to $t_A^0 - t'_A$. How is the observer in $A$ to satisfy this? He would have to place his clock finger at *two* different places at the same time, which is impossible. The whole process of regulation comes to nothing. In direct contradiction to Einstein's first declaration that any process is applicable we must fall back on the statement that a process we know something about is not only preferable but indispensable. But it is absolutely necessary to know exactly the character of the process. If, on the other hand, we accept as our basis





classical physics, *where the concept of constant velocity of light has a meaning* a priori *in one system of reference*, light rays are most useful as message carriers, but only in that system—sometimes called the ether—in which we assume that the light rays are moving with one and the same velocity in all directions and between all points.

The clocks in that system will, with the help of the light rays, be made to indicate time in accordance with the classical concept. Here clocks of 'identical construction' can be supposed to indicate time alike in *a priori* simultaneous moments and thus be said to 'run synchronically'. The rays used in this system can, however, *not be used as message-carriers in another system in motion with relation to the first*, because in the latter system they do *not* move uniformly and with the same velocity in all directions and between all points.[1]

When it is said to be possible to regulate clocks with light rays in all Galilean systems, this is on the other hand based on the assumption of the constant velocity of light in *all* Galilean systems as being valid and proved. But Einstein has underlined (in '*Relativity*') that it is this assumption which creates the contradiction he undertakes to eliminate with the new time concept. Therefore, in order to lay the foundation of the new time concept, the relativists quote exactly that assumption which led to the contradiction Einstein sets as his task to eliminate. The circle in the relativistic reasoning is thus closed.

## EINSTEIN'S OTHER PRESENTATIONS OF THE THEORY OF RELATIVITY

'Relativitätsprinzip und die aus demselben gezogenen Folgerungen' (*Jahrbuch der Radioaktivität*, *4*, 1907, p. 411) is one of Einstein's more representative presentations of his theory.

In this paper Einstein starts from the assumption that clocks are spread out in the system of reference and that they are 'of identical construction' (*gleichwertig*) and that they 'go at the same rate when standing side by side' (*d.h. die Differenz der Angaben der Uhren soll ungeändert bleiben*, *falls sie neben einander angeordnet worden*).

The time of an event is given by the simultaneous position of the clock in its immediate vicinity. But this according to Einstein does *not* give us the time concept needed for the purpose of physics. *We need one more principle for regulating the clocks in relation to each other.*

For this purpose Einstein resorts to his rule that the clocks should be regulated with the aid of light rays, so that the velocity of propagation of the light ray always remains equal to the same constant **c**.

[1] See Einstein, '*Relativity*', p. 18.

The rule is expressed just as in earlier publications: The time it takes for a light ray from point $A$ at the moment $t_A$ to the point $B$ at the distance $r$ where it arrives at the time $t_B$ should satisfy the equation,

$$t_B - t_A = \frac{r}{c}.$$

This corresponds to the rule of clock regulation presented in 'Elektrodynamik' and '*Meaning*' and all the arguments presented earlier against this clock regulation are applicable here. The light-ray regulation cannot be carried through after the negation of classical time, because the light rays cannot be identified.

Since the creation of the new time concept can thus *not* be attained all the consequences drawn from his fundamental reasoning such as 'relativity of simultaneity', change of length of moving bodies, must also here be categorically repudiated.

Therefore this paper does no more than Einstein's other papers present any ground for his new ideas.

The above rule of light-ray regulation is here denoted as 'The Principle of Constant Velocity of Light' and this is in fact a third meaning given to this principle. I have therefore found it necessary to state different meanings of this expression more closely in order to keep them apart.

### DIFFERENT MEANINGS OF 'THE PRINCIPLE OF CONSTANT VELOCITY OF LIGHT'

*The first principle*: There is at least one system of reference where light rays are propagated in all parts and directions with the same constant velocity, regardless of the state of motion of the source of light in relation to the system in the moment of the light ray emission, that is a system with the qualities of the hypothetical ether. This is fully compatible with the classical idea of time.

*The second principle* is, that one and the same light ray should have the velocity $c$ in *all* Galilean systems of reference. This can also be called the 'general' or 'the extended principle of constant velocity of light'. This principle leads—as Einstein has admitted—to contradictions which must be eliminated. Einstein's intention was to attain this by introducing his new time concept. As this has proved impossible because all his reasonings necessarily presuppose classical *a priori* time, the contradiction remains unmitigated.

*The third 'principle* of constant velocity of light' is the aforesaid rule





for regulation of clocks according to which the time it takes for a ray to go from $A$ to $B$ should always be $t_B - t_A = AB/c$, and this implies *that the light ray is a time-regulating process*. The application of this principle is, however, dependent on the possibility of performing such a regulation. But we have seen that this regulation can only take place in a system where we accept classical time as prevailing *a priori* in order to put events in distant points in time relation to each other and thereby identify them.

Both these latter 'principles' presuppose according to Einstein a new time concept. But since the light-ray regulation of clocks can not be carried through if classical time is rejected, they lose all practical sense and meaning. The only 'principle' that remains is thus the one of classical physics based on classical time and valid for *one* system of reference, namely the one to which we attribute the qualities of the hypothetical ether.[1]

### LATER EINSTEIN PRESENTATIONS

In several later papers Einstein discusses the consequences of the Theory, but also in these he bases his reasonings on the supposed results of his earlier papers.

ALBERT EINSTEIN: *Mein Weltbild*, Frankfurt, 1934.

Here he gives an extensive discussion of the general ideas of physics, but does not enter on the basic ideas of the Theory.

ALBERT EINSTEIN: *Philosopher Scientist*, New York, 1951.
I. *Autobiographical Notes*, p. 57.[2]

The universal principle of the special theory of relativity is contained in the postulate: *The laws of physics are invariant with respect to the Lorentz transformations.*

This declaration implies the universal constancy of light velocity for all inertial systems, which creates the contradiction, acknowledged also by Einsten, and which he tries to eliminate through the introduction of his new time concept, but with the above stated negative result.

[1] This mention of hypothetical ether does not necessarily imply an acceptance of its existence. It is only a way of characterizing the system of reference to which we refer the principle.

[2] ALBERT EINSTEIN: *Philosopher Scientist* pp. 57 and 665.

II. *Results concerning the essays brought out in this co-operative volume*, p. 665.

Also here his reasonings are concerned with questions of very general character, and the consequences of his new ideas are regarded as proved. He does not enter on the validity of the ultimate foundations of the Theory.

## MATHEMATICAL EXPRESSION OF THE CONCEPT OF 'DISTANCE'

In connexion with Minkowsky's ideas of the four-dimensional world Einstein presents yet another approach to the problem of relativity.[1] He writes:

'Let us consider two neighbouring events, the relative position of which in the four-dimensional continuum is given with respect to a Galilean reference-body $K$ by the space co-ordinate differences $dx$, $dy$, $dz$ and the time difference $dt$. With reference to a second Galilean system we shall suppose that the corresponding differences for these two events are $dx'$, $dy'$, $dz'$, $dt'$. Then these magnitudes always fulfil the condition

$$dx^2 + dy^2 + dz^2 - c^2dt^2 = dx'^2 + dy'^2 + dz'^2 - c^2dt'^2.$$

The validity of the Lorentz transformation follows from this condition. We can express this as follows: The magnitude

$$ds^2 = dx^2 + dy^2 + dz^2 - c^2dt^2,$$

which belongs to two adjacent points of the four-dimensional space–time continuum, has the same value for all selected (Galilean) reference-bodies. If we replace $x$, $y$, $z$, $-ict$ by $x_1$, $x_2$, $x_3$, $x_4$, we also obtain the result that

$$ds^2 = dx_1{}^2 + dx_2{}^2 + dx_3{}^2 + dx_4{}^2$$

's independent of the choice of the body of reference. We call the magnitude $ds$ the "distance" apart of the two events or four-dimensional points.'

These declarations are entirely based on the introduction of the new symbol $t'$ for time in the moving Galilean system and on the validity of the Lorentz transformation equations.

[1] '*Relativity*', pp. 91–2.





The characterization of the difference in space and time co-ordinates of the two events by the use of differentials shows that the two events are supposed to take place infinitely close to each other both in space and time.

But we have found earlier that for two neighbouring events judged by an observer in their close vicinity we must presume—and so does Einstein, although probably unconsciously—that time is ruling in this vicinity in the classical *a priori* sense, and this is the case for the observers in *both* systems. This being so, we can state that we have necessarily $t' = t$ and $dt' = dt$. That in turn rules out the Lorentz equations in the actual context, since they can give $t' = t$ only for $v = 0$, and we are thus brought back to the Newtonian equations.

If for the sake of simplicity we choose point-events on the $x$-axis, we have $y' = y = 0$ and $z' = z = 0$, and considering that we must put $t' = t$, our magnitudes will now be

$$ds^2 = dx^2 - c^2dt^2 \text{ in one system,}$$
$$\text{and } ds^2 = dx'^2 - c^2dt^2 \text{ in the other system.}$$

But since $dx' = dx - vdt$ we find that the values of $ds$ for the two systems are *not* alike.

This whole reasoning about the character of the Einstein–Minkowsky four-dimensional world is based on the supposition that time $t'$ in the moving system is different from time $t$ in the other system. Therefore, when we find that also Einstein's reasoning—carried through correctly—makes it necessary to accept that $t' = t$, the four-dimensional argumentation loses all relevance for the study of the relativity problem. *The formulae presented are just beautiful mathematical constructions without known physical meaning.*

## MAX VON LAUE'S PRESENTATION OF THE SPECIAL THEORY OF RELATIVITY

In a following chapter I shall discuss some more presentations of the Theory. Here I take up von Laue's treatise[1] which is of special interest since he describes an approach to the problem somewhat different from Einstein's.

In Vol. 1, p. 49, von Laue discusses how a ray of light initiated in a certain point will spread in two different Galilean systems $K$ and $K'$ which are in rectilinear movement with the constant velocity $v$ in relation to each other.

[1] 'Relativitätstheorie I and II', *Die Wissenschaft in Einzeldarstellungen*, Vols *38* and *68*, 1919 and 1921, Veiweg u. Sohn, Braunschweig.

A short light flash is presumed to be sent out from the point $A$ in the origo of $K$ at the time $t = 0$.[1] The points, which at a time later than $t = 0$, receive the signal are declared to be located on a sphere round the origin whose equation is $x^2 + y^2 + z^2 = c^2t^2$, where $c$ is the velocity of light which is thus assumed to be the same in all directions of the system in question. (See Fig. 2.)

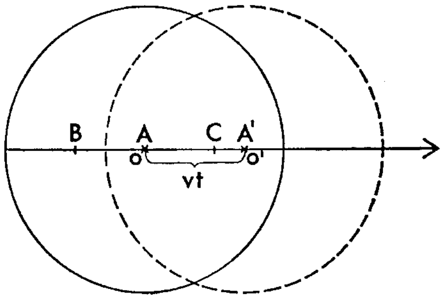



FIG. 2.

Two points $B$ and $C$ at the same distance from $O$ on a line through $A$ are declared to receive the signal simultaneously, that is with the same value of $t$.

Since no reference is made here to any clock regulation with rays, or any mid-point observations, or any other reference to a new time concept, time relations such as 'simultaneity' must be taken in their classical sense, the only meaning so far known.

Einstein's statement that he cannot talk about a time relation between events in distant points *a priori* is here completely disregarded by von Laue.

When he declares that the two points receive the time signals at the same time $t$ and that all points on the sphere have received the light signal at a moment that is simultaneous with the clock position $t$ in $A$, *von Laue has unreservedly accepted classical time as valid for the whole system K.*

This implies that there is always in every point of the system a moment which is simultaneous in the classical sense with a certain moment $t$ in $O$.

Von Laue then proceeds to discuss the position of the same light flash in the moving system $K'$. The co-ordinates in $K'$ describing the position of the ray are here assumed to be $x'$, $y'$, $z'$, $t'$ with $t' = 0$, when the signal is sent out from $O$, that is the moment when the intersectional points $O$ and $O'$ in $K$ and $K'$ coincide. The light signal

[1] The moment when the intersectional points of the axes in $K$ and $K'$, i.e. $A$ and $A'$, coincide is called $t = 0$ in $K$, and $t' = 0$ in $K'$.





is supposed to have arrived at the time $t'$ in all points in $K'$ according to the equation

$$x'^2 + y'^2 + z'^2 = c^2t'^2.$$

He continues:

'Since the point $A$ has meanwhile moved from $O$ the distance $vt$ to the point $A'$, there will be no value for $t'$ for which the two points $B$ and $C$ at the same distance from $A$ (and resting in the system $K'$) will be lying on such a sphere, answering to this equation. The two points will therefore *not* be reached by the signal at the same time.'

And from this von Laue concludes:[1] 'Two events which are simultaneous in one system are not simultaneous in the moving system $K'$.'

Remembering that all von Laue's arguments so far must be based on classical time as the only time concept at his disposal, it must be stated that this is an indisputable contradiction which he, however, completely disregards.

The contradiction arises in the following way: With only a cursory mention of the Michelson–Morley experiment von Laue declares as a fundamental basis of his reasoning that one and the same light ray is spread uniformly and with the constant velocity $c$ round the point in the system where the source of light was at the moment of light emission, and he assumes this to be the case in *all* Galilean systems of reference. This is what I have called 'the extended principle of the constant velocity of light', and implies as we have seen that the ray of light is as well on a sphere round $A$ as on a sphere round $A'$, i.e. the two points in $K$ and $K'$ from which the light emission started.

But when von Laue states this he has not in any way modified the concept of time, he has not even mentioned anything about Einstein's extremely important attempt to establish a new time concept in order to eliminate the contradiction arising from the Principle of Relativity in its extended application. It follows that when von Laue describes the movement of the light rays and discusses how the points $B$ and $C$ receive the rays he has only classical time to go by. *And according to the classical concept 'time' is the same in all systems, in other words $t' = t$.*

[1] In the original German text these quotations read (p. 50):

*'Da aber A sich inzwichen aus O um die Strecke vt' bis nach A' entfernt hat, so gibt es keinen Wert t' für den die von A gleich weit entfernten materiellen Punkte B und C auf einer derartigen Kugel liegen; sie werden also nicht gleichzeitig vom Signal erreicht.'*

*'Zwei Erreignisse welche im System Kgleichzeitig sind, sind es also im System K' im allgemeinen nicht.'*

According to his reasoning a flash of light should have spread not only to all points on a sphere round $A$ in $K$, but also at the same time round the point $A'$ in $K'$. The ray should thus be and not be in different points at the same time. We are back to the contradiction which Einstein encounters. But by the time von Laue realizes that there is a problem he merely refers to and accepts without reservation Einstein's idea of clock regulation with the aid of light rays and bases his reasoning on the *claim* (*Forderung*) that the ray of light should have the velocity $c$ in the system $K$ in all directions. No mention is, however, made about how the rays are supposed to travel in $K'$ and consequently nothing said about the possibility of regulation in this system. Nor does he discuss the possibility in principle of sending rays from one point to another distant point and of putting the emission of the ray and its arrival at the other point in time relation to each other and thereby identifying them.

In spite of this von Laue concludes categorically:

'That for every legitimate system one arrives at a particular time, whereby the system is distinguished from the other legitimate systems, is shown already by the example mentioned (the regulation of several clocks in relation to each other). . . . This is just the boldness and the high significance of Einstein's reasoning, in that it disposes of the old prejudice of a time which is valid for all systems. However violent the revolution is, which this ("reasoning") forces all our thinking to accept, it does nevertheless not imply the slightest difficulty for the theory of knowledge.'[1]

It is striking to note how superficially von Laue deals with this intricate problem of epistemology. Let us consider some of the questions arising spontaneously in the situation created by the overthrowing of one of our most fundamental and deeply founded concepts, the time concept.

What is to be understood by movement and velocity without a time concept? How can we study processes in and between distant points without a time concept in common? What are the possibilities

[1] This quotation is a strictly literal translation from von Laue's German original which reads:
'*Dass man für jedes berechtigte System zu einer besonderen Zeit kommt, durch die es sich von den anderen berechtigten Systemen unterscheidet, zeigt schon das obige Beispiel. Darin liegt gerade die Kühnheit und die hohe philosophische Bedeutung der Einsteinschen Gedanken, dass es mit dem hergebrachten Vorurteil einer für alle Systeme gültigen Zeit aufräumt. So gewaltig die Umwälzung auch ist, zu welcher es unser ganzes Denken zwingt, so liegt doch nicht die mindeste erkenntnistheoretische Schwierigkeit in ihr.*'





of putting events in distant points in relation to each other? What shall be our time measure from now on? Of all our scientific experience hitherto gained on the basis of classical time what can be upheld and what must be scrapped?

These are questions which one would have expected to see more thoroughly discussed. But they are brushed aside by von Laue's categorical declaration that this 'violent revolution' of our thinking does not present the slightest difficulty for the theory of knowledge!

Although von Laue conducts his reasoning on somewhat other lines than Einstein, the result is that he meets with exactly the same insoluble difficulties as Einstein.

The kind of reasoning applied in von Laue's discussion of the spreading of a light flash in the two systems $K$ and $K'$, moving in relation to each other, can be illustrated by an analogy.

Let us suppose that a long train is moving along the platform of a station with the velocity $w$. The station master stands in the midpoint of the platform at equal distances from two poles at each end of the platform. On the train the chief guard is standing in the middle of the train. The moment the chief guard and the station master 'coincide', both of them send out message-carriers in opposite directions. The station master sends a porter in each direction to the end poles of the platform and these porters are moving in relation to the platform with the velocity $v$. The chief guard sends two subguards, one in the direction of the front of the train, the other towards the end. These two are supposed to move with the velocity $v$ *in relation to the train*. It is evident that the two porters will reach the end poles on the platform at the same time. This is also accepted by von Laue in the analogous case of the light rays. Furthermore, we can say that the guards on the train will simultaneously reach two points *on the train* which are at the *same* distance, reckoned from the chief guard, as the poles on the platform are from the station master.

But if we ask at what moments the train guards will coincide with the poles on the platform we naturally find that the guard moving to the front of the train and thus approaching the pole on his side will, owing to his own velocity and to the velocity of the train in the same direction, reach his pole earlier than the other guard who is moving towards the pole on his side with velocity $v$ but at the same time moving away from the pole with the velocity $w$ of the train. He must therefore reach his pole *later* than the guard walking towards the front.

(We suppose $v > w$. If $w > v$ he will never reach the pole.)

This argument is based on the classical view and whether we look from the platform or from the train upon the coincidence of the guards with the poles we come to the result that the coincidences of the guards with the poles are *not* simultaneous whereas—as mentioned above—the arrival of the porters to the poles is simultaneous, *judged from both systems.*

This situation is quite analogous to the case discussed by von Laue with the one difference that in his case it is light rays which are moving in both systems. The coinciding points $A$ and $A'$ in von Laue's case are here represented by the station master and the chief guard on the train, the points $B$ and $C$ are the poles, the porters are the light rays in $K$, the guards the light rays in $K'$. It is quite correct that the guards will *not* coincide with the poles at the same time. The extraordinary conclusion von Laue draws from this fact is that the arrival of the porters at the poles, which is simultaneous in the system $K$ should *not* be regarded as simultaneous as seen from $K'$.

At first we must observe that when von Laue conducts his reasonings he stands principally on the foundation of classical time concept. No other concept has so far been constituted by him. And from that point of view two events, which are simultaneous in one system *are a priori* simultaneous in all other systems.

Von Laue's reference to the Michelson–Morley experiment is of no significance since the supposed result of this experiment—the constant velocity of one and the same light ray in all Galilean systems—is also by Einstein declared to be incompatible with the classical time concept. It is exactly this incompatibility that Einstein sets himself the task to eliminate with his new time concept. Von Laue on the other hand considers the universal constancy of the velocity of light as *proved* by the Michelson–Morley experiment which it in no way is. The admissible consequence to be drawn from the Michelson–Morley experiment will be treated in a later chapter (p. 100).

Von Laue's supposition, in the experiment he describes, that the light emissions from $A$, $A'$ when they coincide should spread uniformly *both* round the point $A$ in $K$ and round $A'$ in $K'$ is from the classical point of view—which von Laue necessarily must presume, since he has *not* defined a new time concept—impermissible. The light flash may well spread symmetrically round $A$ in $K$, but if that is the case it will in $K'$ necessarily travel with velocity $c + v$ in one direction and with velocity $c - v$ in the opposite direction along the $x'$-axis of $K'$, just as Einstein has pointed out in '*Relativity*' (p. 18). The idea of a light flash going out from $A'$ and spreading symmetrically round $A'$ in $K'$ means introducing *another phenomenon* than the flash spreading uniformly round $A$ in $K$.

The way von Laue describes these light emissions, they are *two*





*different phenomena*, just as the movement of the porters on the platform and the movement of the guards on the train are two distinctly different proceedings, and *his results are obtained only by identifying two distinctly different proceedings as one and the same. If we keep the two phenomena apart von Laue's entire reasoning collapses.*

In later editions of the same work ('Die Relativitätstheorie', Part I 1952, Part II 1953) von Laue only repeats summarily the fundamental reasonings of the earlier editions and, having arrived at the Lorentz equations of transformation and the equation for the quantity '*ds*', the 'distance' apart of two neighbouring events, he builds up a large edifice of magnificent mathematical formulae which only have the drawback that they cannot be applied to physical quantities. This is due to the fact that they are based on the acceptance—although unconsciously—of two different meanings of the word 'time'.

All the later chapters in von Laue's books are based on the Lorentz equations and the consequences derived from them. Since these consequences imply a double meaning of the word time they are inapplicable. Therefore we need not follow his reasoning further.

Although von Laue's presentation of the Theory of Relativity is very elaborate and presents interesting details it must be established that—contrary to Einstein—he has not really grasped the crucial problem, the necessity of establishing and motivating a new time concept.

The astonishingly superficial reasoning in this context by a scientist of otherwise so high standing as von Laue can only be explained by the fact that he—like the majority of Einstein's followers—has been so impressed by the boldness ('*Kühnheit*') of Einstein's ideas that he has accepted them without hesitation, unconditionally and uncritically.

## MINKOWSKI'S INTERPRETATION OF THE LORENTZ EQUATIONS AND THE NEW TIME CONCEPT[1]

It has often been suggested that the ideas of the Theory of Relativity, although they are fully expressed by the transformation equations and the consequences derived from them, can from a mathematical point of view be more harmoniously expressed in the way proposed by Herman Minkowski.

[1] H. MINKOWSKI: *Vortrag gehalten auf der 80-ten Versammlung Deutscher Naturforscher und Ärzte zu Köln am 21. Sept. 1908. Electrodynamik*, p. 54.

According to Minkowski—as presented also by von Laue[1]—the world is supposed to be a four-dimensional multiplicity (*eine vierdimensionale Mannigfaltigkeit*) where a 'world-point' (*ein Weltpunkt*) in this multiplicity is represented by three spatial co-ordinates $x$, $y$, $z$ and the 'time co-ordinate' $u$. The 'world-point' represents an event which takes place in the locus characterized by the spatial co-ordinates $x$, $y$, $z$ at the moment $t$ where the symbol $t$ is given the value $\frac{u}{c}$.

Although it is not explicitly indicated by von Laue, we may suppose that $c$ stands for the velocity of light *in vacuo* since this is the meaning earlier attributed to this symbol ('Relativitätstheorie' I, p. 49) with the value $3 \times 10^{10}$ cm/sec. Minkowski also declares:

'For $c$ the speed of light transmission in empty space will take place.'[2]

Since $c$ stands for a velocity, we can state that $u = ct$ stands for a distance, and with regard to the value given to the symbol $c$ we find that the second is chosen as time unit and consequently—until otherwise stipulated—*the second is also the basis of the time-reckoning by the symbol $t$.*

In the four-dimensional world here discussed, for a 'world-point' with the co-ordinates $x$, $y$, $z$, $t = \frac{u}{c}$ the symbols $x$, $y$ and $z$ are supposed to represent the co-ordinates along the ordinary spatial axis and $t$ is the time of the *event in $x$, $y$, $z$.*[3]

Since $u$ is equal to $ct$ it represents also a length co-ordinate along an 'imaginary' axis. It is expressly admitted that the four-dimensional world is only a symbolic representation of certain analytical relations between four variables, and it is 'inaccessible to our apprehension'.[4] Even if this need not 'frighten us', as von Laue puts it, it does raise the question of how this symbolic representation of imaginary

[1] Von Laue: 'Die Relativitätstheorie', p. 66.

[2] Translation: '*Für c wird die Fortpflanzungsgeschwindigkeit des Lichtes im leeren Raum eintreten.*'

[3] Von Laue, p. 67: 'A world-point represents an event occurring in the place $x$, $y$, $z$ at time $t = \frac{u}{c}$.'

[4] Von Laue, p. 67: '*Es handelt sich um die symbolische Darstellung analytischer Beziehung zwischen vier Variabeln.*'

'*Dass eine solche (vierdimensionale Mannigfaltigkeit) unzugänglich ist darf uns nicht schrecken.*'

'We are here concerned with the symbolic representation of analytical relations between four variables.

'The fact that such a four-dimensional manifoldness is inaccessible to us must not frighten us.'





symbols can explain and register the physical realities accessible to our apprehension. This is explained neither by von Laue nor by Minkowski.

It is, however, of interest to assess, what we can state with regard to what the symbol $u$ stands for. If we suppose, as von Laue does earlier, that a light signal is sent out from the origin $O$ of the system ($x = y = z = 0$) at the moment $t = 0$ (also $u = ct = 0$) we would find that at a later moment $t$ the light signal would have reached a sphere with its centre in $O$ and with the radius $R = ct = u$.

We thus find that any 'world-point' is characterized by its ordinary spatial co-ordinates ($x$, $y$, $z$) and a co-ordinate along a fourth imaginary axis with the value of the radius $R$ of the sphere attained at the moment $t$ by a light emission in origo at the moment $t = 0$.

Let us now take the case that we want to characterize an event in a point $P$ on the $x$-axis at the moment $t$ and we are informed that the distance of $P$ is 100 metres and the event takes place at $t = 10$ seconds from our basis of time reckoning. According to ordinary registrations of the event we would state that it occurs in the point $x = 100$, $y = 0$, $z = 0$, at the time $t = 10$. But in Minkowski's world we would be told that the event is characterized by the co-ordinates $x = 100$, $y = 0$, $z = 0$, $u = 3 \times 10^9$ metres on an 'imaginary' dimension-axis.

Here somebody might well raise the question: Why make comprehensible statements incomprehensible by introducing a co-ordinate along an 'imaginary' axis where the co-ordinate for no known reasons assumes astronomical values?

No motive is given for this extreme complication of our comprehension of physical facts, neither by von Laue nor by Minkowski. But we may suppose that the purpose is to achieve equations of appealing appearance from a purely mathematical point of view.

The most remarkable fact in this connexion is that neither of them has got down to the fundamental problem of *what we are to understand by the symbol for time in the moving system.*

They have *not* gone into Einstein's reasoning, in which he points to the necessity of remoulding the time concept. They only mention his new time concept as an established fact. Their thinking is concentrated on the task of finding the transformation equation which should transform the equations of electro-magnetic phenomena, among them the law that light propagation is invariably $x = ct$, into the symbols of the moving system, that is into $x' = ct' = u$. This purely mathematical problem naturally leads them as it led Einstein to the so-called Lorentz transformation equations which with Minkowski's symbols have the form:

$$x' = \frac{x - u}{\sqrt{1 - \beta^2}}; \; u' = \frac{u - x}{\sqrt{1 - \beta^2}}, \text{ where } \beta = \frac{v}{c}.$$

But we have found that, when Einstein takes up the inevitable problem of analysing the time concept in order to eliminate the contradiction created by the assumption of constant velocity of light propagation in all Galilean systems, he is obliged—although he does not realize it himself—to accept such premisses with regard to his light-ray experiments that he is necessarily brought back to the classical concept of time as ruling universally and flowing uniformly through all parts of space independently of system of reference. This is mathematically expressed by the equation $t' = t$ for all systems. But from this it follows directly that $u' = u$.

Since the transformation equation should apply to all values of $x$ and should ultimately result in $u' = u$, we find that the Lorentz transformation equations *can only be valid for the value* $v = 0$, which represents the case that the two systems are at rest in relation to each other. This in turn nullifies the whole relativity problem. In addition, if $v = 0$ Minkowski's whole system of equations and all his reasonings come to nothing.

## TIME DETERMINATION WITH SYNCHRONOUS CLOCKS

Before leaving Einstein's two time concepts I wish to mention Ragnar Liljeblad's proposal to establish a new time concept with the aid of synchronous clocks *without* resorting to light-ray regulation.[1]

His idea is to give time for a system of reference a meaning by distributing in the system clocks of certain specifications.

He says (as translated from the German original):[2]

[1] RAGNAR LILJEBLAD: 'Die Begriffe Länge und Zeit in der modernen Physik', *Theoria*, Gothenburg, 1938, p. 265.

[2] The original reads: '*Von philosophischer Seite ist behauptet worden, dass der Einsteinsche Zeitbegriff ein Widerspruch enthält, da er an sich den alten Zeitbegriff voraussetzt. Diese Behauptung will ich vor allem näher undersuchen. Mittels des exakten Zeitmessers, das wir durch die Uhr erworben haben, haben wir nunmehr auf emirischem Weg eine Mechanik aufgebaut, die in ihrer klassischen Form ihren Ausdruck in den Newtonschen Bewegungsgezetzen gefunden hat. Die Entdeckung der Relativitätstheorie besteht darin, dass wir in Widersprüche geraten, wenn wir an einem durch derartigen ideale Uhren bestimmten universellen Zeitbegriff festhalten. Man kan jedenfalls bei Beschränkung auf Galileisysteme eine für jedes Bezugssystem gültige Zeit, die durch in Relation zum System ruhende Uhren bestimmt wird, beibehalten. Aber jedes System erhält eine durch deren eigenen Uhren bestimmte Zeit.*'





'It has been said in philosophical quarters that Einstein's time concept implies a contradiction because it presupposes the validity of time in the old sense. In the first place I wish to examine this statement.

'Owing to the development of the clock into an exact time-measuring instrument, we have nowadays access to an empirically obtained technique which in its classical form has found its expression in the Newtonian laws of motion.

'The Theory of Relativity has revealed that if we hold on to a concept of universal time determined through such ideal clocks we end up in contradictions. By limitation to Galilean systems one can always maintain, as valid for every system of reference, a time determined by clocks at rest in relation to the system. But each system obtains a time determined by its own clocks.'

With regard to these statements it is first of all necessary to underline that the classical time concept and classical mechanics have *not at all* led to a *logical* contradiction. What has happened is that the Michelson-Morley experiment has made it considerably difficult to explain its result in conformity with Maxwell's electromagnetic theory. It is, however, very simple to explain the result of this experiment on the basis of an emissionary theory of light. On the other hand such a theory does not give a satisfactory explanation of a number of other observations of light phenomena. This very marked problem is indeed one of the starting points for the Theory of Relativity. But we are not confronted with a *logical* contradiction. *It is a lack of conformity between our hypothesis about the nature of light and our experimental observations, something we must always be prepared to meet in our experimental work.*

What we can say is that we lack a theory of light which covers *all* our experiments. On the other hand, it is the application of Newton's Principle of Relativity to the Maxwell equation as proposed by Einstein which leads to an obvious logical contradiction—i.e. that a ray of light should be in a certain point and at the same time *not* be there.

When Einstein faces this contradiction and tries to maintain the Extended Principle of Relativity, he proposes to regulate the clocks, spread out in a system of reference, in relation to each other, by exchange of light rays. Liljeblad, on the other hand, makes the following suggestion:

'We can synchronize the clocks in a system by making the hands of each clock coincide with the hand of a standard clock and thereafter *slowly* bring the clocks to different points in the system.'[1]

This is, however, a typically classical way of reasoning. Since no special meaning of 'synchronizing' is indicated the word must have its generally accepted meaning. The clocks should thus be brought to show the same position of the hands at the same moments and undergo the same change of position of hands in the same lapse of time.

We have previously seen that this makes sense so long as the clocks are placed side by side in the close vicinity of the observer where classical time is accepted as valid, but that as soon as we move the clocks outside the close vicinity we have, owing to Einstein's rejection of classical time, no possibility of comparing the clocks. Einstein tries to solve this problem by creating a new time concept with the aid of light regulation, but this light regulation is, as shown earlier, impossible after the rejection of classical time.

Liljeblad on the other hand believes it possible to arrange 'synchronically running clocks' in distant points *without* light-ray regulation and thus takes up a position in direct conflict with that of Einstein.

Clocks which have been made to 'run synchronically' side by side are supposed to be moved 'slowly' ('*langsam*') to different points in the system, and evidently he means that this would make it possible to have clocks running synchronically also in the distant points. If this is not what he means his reasoning would lack all meaning.

But regardless of whether the clocks are moved 'slowly' or quickly they will necessarily, since they are to be spread throughout the system, by and by leave the close vicinity of the observer with his standard clock, and—if Einstein's rejection of classical time is accepted—it means that no time relation *a priori* exists between the clocks. With no common time concept for the clocks the expression 'run synchronically' loses its classical meaning. *Each clock now has its own time independently of all other clocks.*

A moment in each of the distant points now only means the moment of a certain position of the hands of the clock in that point. 'The same moment' only means the moment for each clock of a certain position of its hands and cannot be used for comparison.

If we now say that the clocks take up the same pointer positions

[1] The original German text reads: '*Wir können die Uhren in einem System synchronisieren, indem wir den Zeiger jeder Uhr mit dem Zeiger einer Normaluhr zum Zusammenfallen bringen und danach die Uhren* langsam *an verschiedene Stellen im System bringen.*'





at the same moment, it can but mean that each clock independently of all other clocks 'takes up the same pointer-position when it takes up the same pointer-position', which is merely a tautology.

The case is analogous if by 'running synchronically' we understand that they undergo the same change of pointer position in the same time interval. The 'same time interval' now has a meaning for each clock separately and is there represented by equal changes of pointer position. If therefore we declare that the clocks run 'synchronically' and by that mean that they undergo the same change of pointer position in the same lapse of time, this has only the meaning: 'The clocks undergo the same change of pointer-position when they undergo the same change of pointer-position.' Again a mere tautology.

Liljeblad's arrangement for synchronically running clocks has a meaning *only* if he accepts classical time to be ruling uniformly—in full accordance with Einstein's description of classical 'time'—in the whole system of reference. And in that case he puts himself in clear opposition to Einstein's rejection of classical time. The discrepancy between Einstein's and Liljeblad's way of treating the problem of 'synchronizing' clocks in a system is very clearly illustrated by Einstein's discussion of the problem in another of his presentations mentioned above.[1] Einstein writes (p. 415):

'*Wir denken uns in vielen Punkten, relativ zum Koordinalensystem ruhende Uhren geordnet, dieselben seien alle gleichwertid, d.h. die Differenz der Angaben zweier solcher Uhren soll ungeändert bleiben falls sie nebeneinander angeordnet werden. Denkt man sich diese Uhren irgendwie eingestellt, so erlaubt die Gesamtheit der Uhren falls letztere geringend kleinen Abständen angeordnet sind, ein beliebiges Punkteregenis etwa mittels der nächst gelegenen Uhr—zeitlich zu werten.*

'*Der Inbegriff dieser Uhrangaben liefert uns aber gleichwohl noch keine "Zeit", wie wir sie für physikalische Zwecke nötig haben. Wir bedürfen vielmehr noch einer Vorschrift, nach welcher diese Uhren relativ zueinander eingestellt werden sollen.*'[2]

[1] 'Relativitätsprinzip und die aus denselben gezogenen Folgerungen', *Jahrbuch der Radiaktivität*, 1907, p. 411.

[2] Translation: 'We assume that clocks are arranged in many points at rest in the co-ordinate system and that the clocks are equivalent, i.e. the difference in the readings of such clocks should remain unchanged if they are placed beside each other. If these clocks are presumed to be set in some way ("*irgendwie*") then the total of these clocks, provided they are placed at very small distances, permit an arbitrary point-event—say with the aid of the nearest clock—to obtain time

According to Einstein the regulation of the clocks should be attained with the aid of light rays. Contrary to him, Liljeblad does *not* claim this regulation in order to 'synchronize' the clocks. The discrepancy is obvious. *Liljeblad places himself wholly on classical ground, not on relativistic ground, and has therefore nothing to do with the Einstein theory.* His ideas on this point must be categorically dismissed. Later Liljeblad takes up another position and describes a method of defining simultaneity of distant events—a superfluous task as he has already unconsciously accepted the classical time concept. He also describes a method of controlling whether two events in distant points are simultaneous. This method is in principle analogous with the mid-point co-observation Einstein introduces when presenting his second time concept. Liljeblad's description of the supposed experiment is thus like Einstein's based on the possibility of exchanging and identifying light rays between distant points, and since these light rays can be identified and registered *only* if classical time is presupposed in the system, the experiments cannot be performed on the basis of denial of classical time.

Therefore, when Liljeblad at a later stage accepts Einstein's second principle of establishing simultaneity and implicitly becomes liable to the same objections as raised against Einstein, it might. seem unnecessary to give so much attention to his first definition But it is of interest as an example of the frequently recurring fact that even ardent adherents to Einstein's theories also make statements and proclamations which go clearly contrary to Einstein's ideas—although they do not realize it themselves.

It follows from what has been said in this chapter that Liljeblad gives no contribution to the solution of the fundamental relativity problem. On the contrary, he makes a declaration with regard to the time concept which clashes with Einstein's presuppositions.

In a recent publication[1] Liljeblad first proclaims on the basis of various experiments that the velocity of light *in vacuo* is for all Galilean systems equal to $c$, but admits, like Einstein, that this necessarily demands a new time concept. With regard to this he falls back on his earlier ideas, on the one hand the *spreading slowly to different points in a system of clocks running alike side by side*, and on the other hand *Einstein's light-ray regulation of distant clocks.* The first system is an evident relapse into classical views and in clear

characteristics. Nevertheless, the total of these clock readings does not yet give us a "time" of the kind we need for physical purposes. We need one more ruling for the setting of these clocks in relation to each other.'

[1] RAGNAR LILJEBLAD: *Klarhet i dunkel*, Stockholm, 1965.





contradiction to Einstein's ideas. The second system presupposes necessarily classical time in order to identify the light ray.[1]

All his following deductions are pursued along the lines laid down by Einstein and most of his other adherents, and the criticism I have expressed in this work also applies to these parts of his book.

## MATHEMATICAL CONSEQUENCES OF THE ANALYSIS OF THE NEW TIME CONCEPT

As shown above, both Einstein's trials to establish by experiments a new time concept necessarily presuppose—although this has not been realized by him—the acceptance of classical *a priori* time to be reigning in the whole of space and for all systems of reference.

This fundamental fact must also be expressed in a mathematical formula representing our ideas. The transformation equation regarding time must express that 'time' is identical for all systems of reference and independent of the co-ordinates of space and this brings us necessarily back to the equation[2]

$$t' = t$$

If we apply this value for $t'$ we find that *the Lorentz equation for time can only be valid for* $v = 0$ *and this brings all these transformation equations back to those of Newton. All the derivatives of the Lorentz equations are also swept away.*

It is, however, of interest to point out some of the most important consequences.

### RELATIVITY OF LENGTH

Einstein reasons thus:[3]

'A metre-rod is placed in the $x'$-axis of $K'$ in such a manner that one end (the beginning) coincides with the point $x' = 0$, whilst the other end (the end of the rod) coincides with the point $x' = 1$. What is the length of the metre-rod relatively to the system $K$?'

[1] The idea of establishing the time concept by the distribution of clocks, running alike side by side without light-ray regulation has also been accepted by Max Born in *Einstein's Theory of Relativity*, Methuen, London, 1924, p. 226, but must, on the same grounds, be dismissed.

[2] In a more general form the equation should be $t' = kt + a$ where $k$ and $a$ are constants. But if we choose the moment of coincidence of the origins of the systems of reference as starting points in our reckoning of time in both systems we find $a = O$, and if we measure time with the same unit in both systems we find $k = 1$.

[3] *'Relativity'*, p. 35.

According to Einstein the distance between the points should be

$$x = \sqrt{1 - \frac{v^2}{c^2}}.$$

This reasoning is based on the first Lorentz equation, but as shown above the Lorentz equations can only be applied for the value $v = 0$ which gives $x' = x$.

*The length reduction vanishes altogether.*

## RETARDATION OF TIME

Einstein writes:[1]

'Let us consider a seconds-clock which is permanently situated at the origin ($x' = 0$) of $K'$. $t' = 0$, and $t' = 1$ are two successive ticks of the clock. The first and fourth equations of the Lorentz transformation give for these two ticks $t = 0$ and

$$t = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

'As a consequence of its motion the clock goes more slowly than when at rest.'

The objection to this is necessarily the same. Also here Einstein's reasonings are based on the classical time concept expressed by $t' = t$ which in turn leads to $v = 0$. If these values are introduced *we find that the clocks go alike.*

## ADDITION OF VELOCITIES

Let a particle wander along the $x'$-axis in $K'$ with velocity $w$. What is the velocity $u$ of the particle in relation to $K$? According to classical view we have,

$$u = v + w.$$

According to Einstein this should be found by expressing the motion in $K'$ by the equation $x' = wt'$ and the transformation of this with the aid of the Lorentz equations. This gives

[1] '*Relativity*', p. 36.





$$u = \frac{v + w}{1 + \frac{vw}{c^2}}.$$

But as we must put $t' = t$, the first Lorentz equation becomes $x' = x - vt$ and the equation $x' = wt'$ becomes

$$x' = x - vt = wt \quad x = t(v + w)$$

but as the velocity in $K = u = \frac{x}{t}$

we get $u = v + w$.

All these results are self-evident the moment we realize that the classical time concept is necessarily at the bottom of all Einstein's reasonings, and consequently $t' = t$, which leads to the conclusion that the Lorentz equations are *valid only for* $v = 0$, which extinguishes their application for the relativity problems. If on the other hand we stick to $t' = t$ for the relativity problems we are necessarily brought back to the Newton equations.

We can also say that the Lorentz equations are not applicable for the problems of relativity on the ground that the symbol $t'$ of the equations *cannot* represent time. The results we get by applying them for all the new symbols emerging, which are supposed to represent the corresponding concepts in the moving system must be rejected. The only thing we can say of the outcoming indexed symbols in the moving system $K'$ is that *they have so far no known physical meaning and will remain unknown until a new investigation on other lines eventually gives them a meaning.* This holds with one exception. We can tell for sure that the symbols resulting from the application of the Lorentz transformation for other values than $v = 0$ *can in no case represent the concepts or physical quantities which they are supposed and indicated by the relativists to represent.*[1]

[1] If we want to name a quantity such as $t'$, the physical meaning of which we know so far nothing about, not even whether it has a physical meaning or not, it stands inevitable to use a word which has no meaning beforehand. We could with regard to the fact that $t'$ is a mathematical function containing the symbol $t$, representing time in the system at rest, choose a word which alludes to this, *f.i.* the word 'chronity' which has no meaning *a priori*. We can then say that $t'$ represents the 'chronity' of an event in a point $P$ with the co-ordinates $x, y, z, t$ in a system $K$ (where $y = z = 0$) and taking place at the time $t$, and we might appropriately denote it with the symbol $\kappa$ (kappa).

This is only an arbitrary function of the co-ordinates $x$ and $t$ of the event in

## THE MICHELSON–MORLEY EXPERIMENT

Practically all relativists emphasize that the Michelson–Morley experiment supports the declaration that the velocity of one and the same light ray should have the same value in any two Galilean systems of reference, moving in relation to each other with the velocity $v$. Mathematically this is expressed by the invariant transformation of the equation $x = ct$ into $x' = ct'$ with the aid of the Lorentz transformation equations.

The extremely important part this experiment has thus come to play in practically all reasonings on the Theory of Relativity makes it necessary to state its content and discuss its results more closely.

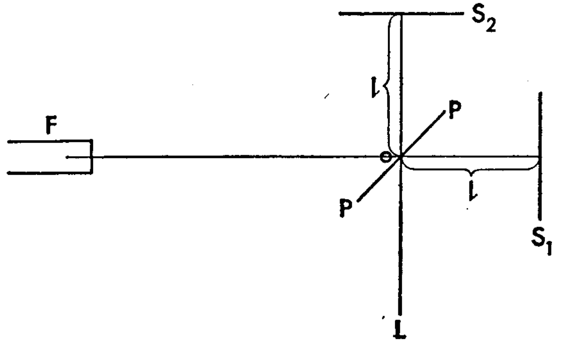



FIG. 3.

A light ray from the light source $L$ meets a plate of glass $P$ at an angle of 45° in the point $O$.

It is partly reflected in $O$ to the mirror $S_1$. Part of the ray passes through $P$ and continues to the mirror $S_2$. Both mirrors $S_1$ and $S_2$ are at the same distance $l$ from $O$. Reflected at $S_1$ and $S_2$ the rays return to $O$ and the ray from $S_1$ goes partly through $P$ and continues to $F$. Both rays thus meet on the line $PF$ and are observed in a tube in $F$. On their way from $O$ to $F$ the rays will interfere with each other, and the observer in $F$ will see an interference band in the tube.

If the whole is at rest in a system where the light rays are presumed to propagate uniformly and with constant velocity in all directions,

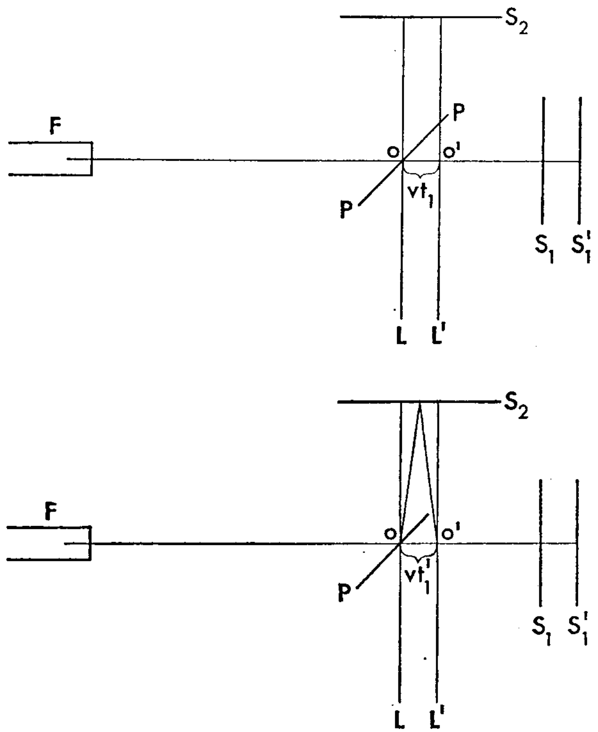
the system at rest and the velocity $v$ of the moving system and since we have no tenable deduction *it does not tell us anything about the characterization of the event as seen from the moving system and has consequently no interest for the relativity problem.*





that is at rest in the hypothetical ether, both rays will travel the same distance from the glass plate to the mirror $S_1$ and $S_2$ and back. If we then turn the whole 90° the distances the rays will have to travel will still be alike and there would therefore be no change in the interference band.

If on the other hand the setup moves in relation to the hypothetical ether in the direction $F$–$S_1$ and we then turn the setup 90°,




FIGS. 4 and 5.

the rays will travel different distances on their ways $O$–$S_1$–$O$ and $O$–$S_2$–$O$ and this would result in a displacement of the interference band, which would be observed in $F$. The times the rays would take to travel these distances under the latter conditions can be easily calculated.[1]

If we put the velocity of light in the ether equal to $c$ and the velocity of the earth along the line $FPS_1$ to $v$, we can state that for the

[1] Here I follow the analysis given by von Laue 'Relativitätstheorie', 1, p. 28.

first ray it takes the time $\frac{l}{c-q}$ to go from $P$ to $S_1$ and the time $\frac{l}{c+q}$ to go from $S_1$ back to $P$ (see figure 4). Together this gives the time $t_1$ the ray to go $PS_1P$:

$$t_1 = \frac{2cl}{c^2 - q^2} = \frac{2l}{c}(1 + \frac{v^2}{c^2} + \ldots)$$

For the ray going from $P$ to $S_2$ and back the time $t_2$ will be (see figure 5):

$$t_2 = \frac{2l}{\sqrt{c^2 - q^2}} = \frac{2l}{c}\left(1 + \tfrac{1}{2}\frac{v^2}{c^2} + \ldots\right)$$

The time difference will be:

$$t_1 - t_2 = \frac{lv^2}{2c^2}$$

With regard to the fact that $v$ has a considerably high value (30 km per second) there is full reason that by turning the setup 90° there would be a considerable change in the interference band that could be observed in $F$.

*No such change has, however, been observed in any of the many experiments performed. The Michelson–Morley experiment has always given negative result.*

Lorentz explains the result of the experiments by his theory of contraction of matter through its movement in the ether.

Einstein does not directly take up the Michelson–Morley experiment to discussion but mentions the result as an illustration to his ideas.

He thus declares in one of his papers when discussing how the spreading of light rays will turn out in two systems moving in relation to each other with constant velocity:

'We make the simplest possible supposition close at hand with regard to the Michelson–Morley experiment: *Laws of natural phenomena are independent of the motion of the system of reference at least if the system is not accelerated.*'[1]

[1] *Jahrbuch der Radioaktivität*, 1907, p. 416:
'*Wie werden die Naturgesetze ausfallen, wenn man die Vorgänge auf das nunmehr in einem anderen Bewegungszustande befindliche Bezugssystem bezieht?*
'*In Bezug hierauf machen wir nun die denkbar einfachste und durch das Experiment*





By this declaration Einstein intimates that the Michelson–Morley experiment has made it probable that one and the same light ray should have the same velocity in all Galilean systems.

Later, in 1921, Einstein takes up a much more definite position with regard to the consequences of the Michelson–Morley experiment.[1]

At first he states that the Maxwell–Lorentz equations for electromagnetic phenomena are not covariant with regard to the Newton transformation equations and that there is thus one privileged system of reference where these equations are valid (corresponding to the hypothetical ether). He then declares that all our experiences and, *above all, the Michelson–Morley experiment, have shown that the electro-magnetic phenomena are independent of the celestial movement of the earth.* From this he concludes that:

'The validity of the principle of special relativity can therefore hardly be doubted.'

As a consequence of this it is declared proved that the velocity of one and the same light ray is the same in all Galilean systems.

Von Laue is more direct. He declares[2] that it *has been established* through the Michelson–Morley experiment with an accuracy hardly attained by other methods of physical measurings that the propagation of light in all Galilean systems is in all directions uniform.

As this implies a contradiction—also admitted by Einstein—we find that *the conclusion drawn from the Michelson–Morley experiment is that a contradiction is supposed to have been proved or made highly probable.*

To this I wish to declare categorically:

It is appalling that it should be necessary to call attention to the indisputable and irrefutable fact that:

*No experiment in the world could ever prove or 'make highly probable'*

*von Michelson–Morley nahe gelegte (!) Annahme: Die Naturgesetze sind unabhängig vom Bewegungszustande des Bezugssystems, wenigstens falls letzterer ein beschleunigungsfreier ist.*'

[1] Four lectures on the Theory of Relativity, Stafford Little Lectures, Princeton 1921, Revised Edition 1951, under the title *The Meaning of Relativity*, earlier referred to as '*Meaning*', p. 25.

[2] 'Relativitätstheorie' I, p. 49: '*Es ist doch durch den Michelsonschen Versuch mit einer bei sonstigen physikalischen Messungen kaum erreichten Genauigkeit festgestellt dass sie (die Lichtfortplanzung in Vakuum) bezogen auf alle Systeme nach allen Richtungen gelichmässig erfolgt.*'

*the correctness and validity of a proposition which is in itself or directly implies a contradiction.*

CONTRADICTIONS ARE ALWAYS FALSE!

The *only* conclusion we can draw from the result of an experiment which is *not* in accordance with what we have expected and foreseen from our assumptions and reasonings is the following:

*Provided our reasonings have been correctly conducted one at least of the suppositions, on which the reasonings are based, must be false.*

And here we must make full stop![1]

Whether we declare that the Michelson–Morley experiment supports the Theory of Relativity, or we say that the Theory of Relativity explains the Michelson–Morley experiment, we ultimately imply that one and the same ray of light wanders with the same velocity in all Galilean systems. We are thus in both cases brought back to the fundamental contradiction which Einstein set out to eliminate with his new time concept. Therefore all the consequences drawn from the Michelson–Morley experiment by the relativists necessarily presuppose Einstein's new time concept (whether this is realized by them or not). But we have seen above that the new time concept is based on certain experiments—the exchange of light rays between distant points—which *cannot* be performed on the basis of Einstein's rejection of the classical, *a priori* time concept. The fundamental contradiction of the Theory of Relativity remains unmitigated and no explanation of the Michelson–Morley experiment has thereby been given.

Attempts have been made to explain the Michelson–Morley experiment on the basis of physics. An example of this is the Fitzgerald–Lorentz theory, which presumes that a body undergoes a contradiction in the direction of its motion, when moving in relation to the ether. But as Bergson[2] and Broad[3] have pointed out this necessarily implies also a 'dilation of the second', a most sensational consequence, which has, however, not been more closely analysed and discussed by them. The Theory of Relativity has, however, brought this contraction theory to the side.

[1] Here I wish to adopt Einstein's summons (*'Relativity'*, p. 22) 'I would ask the reader not to proceed farther until he is fully convinced on this point.'

[2] H. BERGSON: *Durée et simultanéité*, Bibliotèque de philosophie contemporaine, Paris, 1922.

[3] C. D. BROAD: *Hibbert Journal*, London, April 1920.





Another explanation is given by the assumption that the experimental set-up is always resting in the ether. A turn of the set-up 90° would *not* have any influence. This is, however, very improbable, as it would mean that the ether would always follow the celestial movement of the earth.

The result of the Michelson–Morley experiment may also be explained by an emissionary theory of light, according to which impulses from a light source would be sent out and spread uniformly round the source. This theory, presented by W. Ritz (see von Laue I, p. 29) is, however, very difficult to bring in accordance with the results of *other* experiences, such as De Setter's observations of light rays coming from distant stars, Fizeau's experiments and many other observations. This may well be the case, but it does *not* in any way justify the proclamation of a solution which in fact implies a contradiction, and into the bargain declares this solution to have been proved. This must be categorically repudiated.

If we cannot offer an explanation *free of contradictions* and covering *all* the results attained by different light-phenomena, *we must confine ourselves to the humbler statement that our present knowledge of the nature of light is so incomplete that we have so far not been able to form a theory which covers all the facts hitherto observed.*

This is the only really tenable attitude from a strictly scientific point of view. Under no conditions can we draw a conclusion that implies a contradiction from this or any other experiment. To do this in order to explain and cover disparate results would mean supplementing the apparent incompatibility of different observations with a contradiction, which is impermissible.

If we pretend that a velocity could be proved to be the same in all Galilean systems independently of their motion in relation to each other, along the axis of motion, we make a statement which from a logical point of view is of the same kind as though we would declare that we have found by experience that the distance a ray of light travels in a second is equal to 300,000 units of length, whether we measure this distance in kilometres, metres, yards or feet. It would be the same kind of statement as to say that the age of a person has the same numerical value whether measured in years, days or minutes. Such statements are obviously contradictory and therefore false.

Regardless of whether we speak of velocity, length or age we deal with *concepts of relation* which have their value only with reference to a certain system of reference or a certain unit of measure. Propositions of the above-named kind would amount to treating them as *concepts of absoluteness*. This is exactly what Einstein does, when he declares that the velocity of light has the same value $c$ in relation to *all* Galilean systems. *He makes the velocity of light a concept of absoluteness.* He admits, however, that this is possible only if we remould our concept of time. As we have seen above this remoulding is a complete failure owing to the fact that the experiments to be performed for this purpose *have* never been performed and *will* never be performed because they *cannot* be performed on the basis of Einstein's rejection of classical time. But the moment we state that Einstein's time concept is untenable we must also state that the law of constant velocity of light remains a contradiction and must be abolished.

With regard to the fact that the absoluteness of the velocity of light is the fundamental idea of Einstein's Theory of Relativity it would be much more adequate to call this theory '*Einstein's Theory of Absoluteness*'.

From the above reasonings we can draw the conclusion that the Theory of Relativity does not explain the Michelson–Morley experiment, nor does this experiment support the Theory of Relativity. The Theory remains an unfounded declaration involving a contradiction. The Michelson–Morley experiment awaits its explanation through an *all-round* theory of electro-magnetic phenomena.[1]

## ANOTHER ASPECT OF THE PROBLEM OF TRANSFORMATION

In relativistic literature we are sometimes told that a certain quantity or phenomenon has a certain value in relation to a moving system and its observer, but that the observations registered by the moving observer *assume other values when 'judged', 'seen' or 'viewed' from the system at rest.*

I have for instance met the following reasoning from a relativist:

Two observers $O$ and $O'$ in the systems $S$ and $S'$ are in rectilinear motion in relation to each other with the constant velocity $v$. $O'$ passes $O$ at the time $t = 0$ and moves along the positive $x$-axis of the system $S$. We suppose that a light signal is initiated at $O$ at the time

[1] In the discussion of the Michelson–Morley experiment I have often been told that a critic who rejects the Einstein explanation of the Michelson–Morley experiment as well as a number of other light-phenomena must needs present another explanation of our experience in this field. This is, however, a grotesque argument. It is as if a judge, who has established that a person, accused of murder, has brought out evidence of his innocence, would declare: 'It may well be that you have proved your innocence but I cannot release you unless you find who the murderer is.'





$t = 0$. Both observers measure the velocity of the ray in relation to *their own systems* and they will—if we accept the fundamental theses of the Theory of Relativity, i.e. the universal constancy of velocity of light—find the value $c$ for all directions.

According to the relativist in question the observer in $O$ is on the other hand supposed to state that the velocities of the light rays in opposite directions along the $x$-axis *in relation to the moving system and its observer*, when 'judged' from the system at rest, would have *different* values in the opposite directions. In fact it was assumed that the result obtained by the observer in the system at rest would be that the velocity of the rays is $c + v$ and $c - v$ *in relation to* $S'$ and as observed by the observer $O'$.

This implies two different opinions with regard to the evaluation of one and the same process, i.e. the movement of a light ray in relation to a system ($S'$) and its observer ($O'$). This was also by the relativist in question considered to be fully compatible with the Theory.

A non-relativist, who has been told that the velocity of light could *never* diverge from the value $c$, would expect such a proposal to be categorically turned down by a relativist. But this was not at all the case. This duplicity of judgement of one and the same process was wholly accepted.

The reason why I have taken up this most remarkable standpoint for discussion is the fact that Einstein himself conducts his reasonings with regard to the lightning strokes along the railway embankment ('*Relativity*', p. 26) along such lines.

It has been pointed out earlier (p. 56) that according to Einstein's description of the events the lightning strokes *are simultaneous* both with each other and with the coincidence of the mid-points $M$ and $M'$ between the lightning strokes $A$ and $B$ in $S$, and $A'$, $B'$ in $S'$, and this is the case as judged both by the observer in $M$ and the one in $M'$. The lightning strokes in $A$ and $B$ are also mid-point co-observed in $M$.

It is here that Einstein makes a most remarkable reflexion with regard to the observer in $M'$. He points out that the observer in $M'$ moves with the train, 'and (considered with reference to the railway embankment) he is hastening towards the light coming from $B$ whilst he is riding on ahead of the beam of light emitted from $A$. Hence the observer in $M'$ will see the beam of light emitted from $B$ earlier than he will see that emitted from $A$.'

With regard to the fact that $A$ and $A'$ coincide at the moment of their lightning strokes, and $B$ and $B'$ coincide at the moment of their lightning strokes, we can here identify $A$ with $A'$ and $B$ with $B'$

as light sources. But with regard to the fact that the distances $A'M'$ and $B'M'$ are supposed to be alike ($M'$ is the mid-point of $A'B'$) Einstein's reasoning implies that the light ray from $B'$ is supposed to travel the way $B'M'$ in a shorter time than the light ray from $A'$ takes to move to $M'$. The light ray from $B'$ is thus supposed to have a greater velocity than the light ray from $A'$. Presumably the velocities would be $c + v$ from $B'$ and $c - v$ from $A'$. *In any case the velocities of the rays travelling from $A'$ and $B'$ to $M'$ must, according to this reasoning necessarily differ both in relation to each other and from the value c.*

This implies two opposite descriptions of one and the same process. *In both cases the question is how the observer in the moving system S′ observes and registers the movement of the light rays from the lightning strokes in relation to his own system.* On the one hand the observer in the moving system must, according to the fundamental theses of the Theory (the constant velocity of light) state that the light rays in his system travel in all directions with the velocity $c$. On the other hand it is here declared that this same process, when 'judged' from the system at rest, is supposed to present itself in such a fashion that *the light ray velocity in relation to the moving system and its observer has different values in different directions.*

We are here faced with two different and contradictory statements with regard to one and the same process. The explanation for this is the following:

The relativity problem is to find, on the basis of the quantities which characterize physical phenomena in relation to one system and its observer considered at rest, how they present themselves to an observer in another moving system if we know the motion of the system. If we can solve this problem, *we obtain certain new physical quantities characterizing the phenomenon in question in relation to this second system and its observer*, and thereby our problem is solved. It should be kept in mind that the relativity theories—whether we take the classical or the Einstein theory—do not primarily attempt to tackle any other task.

But Einstein raises another question, i.e. *how these quantities, characterizing the event or procedure in relation to the moving system, present themselves when 'judged', 'seen' or 'viewed' from the system at rest.* And here he comes to the result that the characterizing quantities take *other* values when thus 'viewed' from the system at rest. Since the results of the relativistic calculations—the classical as well as Einstein's—are certain numerical values, Einstein's reasonings imply that numerical values should undergo a change when 'viewed' from a moving system. However, a numerical value remains the same from





whatever system it may be 'viewed' by an observer. The numerical value 4 cannot, when 'judged' from another system, change to say 3·99. That does not make sense.[1]

The reason why Einstein arrives at his ideas is that in his discussion of the 'simultaneity' problem in connexion with the train problem he oscillates between two standpoints. In the midst of his relativistic reasonings based on his own presuppositions he falls back on classical views and thereby naturally comes to contradictory results which he, however, accepts.

The whole complication can be totally avoided if we consider, that the question how the observer *in the system at rest* 'judges' the 'judgement' of the moving observer of the event or process observes, is a question void of all interest for the relativistic problems. And *if* it is raised, *the answer is that the 'judgements' of the two observers are in this case necessarily identical.*

It is Einstein's—certainly unconscious—oscillation between two different and incompatible views which has induced him and his followers *to raise a superfluous question and to give it a wrong answer.*

[1] If we suppose that the temperature in London at a certain moment has been observed to be 65°F, then this numerical value as characteristic of this quantity is *valid for all places and all systems of reference.* Whether we are in London, New York or Tokyo or on a train, a boat or on our way to the moon, the number 65 in all these cases characterizes the temperature in question and it does *not change* when *viewed* from one of them, for instance to 64·5°.

# 4

# THE GENERAL THEORY OF RELATIVITY

## THE TIME CONCEPT OF THE GENERAL THEORY OF RELATIVITY

### PRESENTATION IN 'RELATIVITY'

Earlier it was pointed out (p. 27) that one of the problems of the General Theory of Relativity is to calculate the co-ordinates of an event in an arbitrarily moving system $K'$, with or without gravitation, characterized by the co-ordinates $x', y', z', t'$ in relation to this system, when we know the co-ordinates of the event in a primary system $K$ considered at rest and there characterièed by the co-ordinates $x, y, z, t$.

The important question that arises here is whether a new meaning is given to the time concept, other than in the Special Theory of Relativity.

The contents of the two different parts of the theory, the Special and the General, are given thus by Einstein:[1]

'According to the Special Theory of Relativity, the equations which express the general laws of nature pass over into equations of the same form when, by making use of the Lorentz transformation, we replace the space–time variables $x$, $y$, $z$, $t$ of a (Galilean) reference-body $K$ by the space–time variables $x'$, $y'$, $z'$, $t'$ of a new reference-body $K'$.'

Earlier (p. 32) he states that:

'An event, wherever it may have taken place, would be fixed in space with respect to $K$ by the three perpendiculars $x$, $y$, $z$ on the co-ordinate planes, and with regard to time by a time-value $t$. Relative to $K'$ *the same event* would be fixed in respect of space and time by corresponding values $x', y', z', t'$ which of course are not all identical with $x$, $y$, $z$, $t$.'

The problem is then to find the relation between these magnitudes

[1] '*Relativity*', p. 97.





so as to satisfy the law of the constant velocity of one and the same light ray with respect to both $K$ and $K'$. The result is, as we have seen, the transformation equations where the time symbols $t$ and $t'$ can take different values and where the classical time concept is thus rejected.

In this connexion the main facts are that the symbols $x$, $y$, $z$, as well as $x'$, $y'$, $z'$, represent spatial co-ordinates, whereas $t$ and $t'$ represent time. The fact that $t'$ differs from $t$ creates the demand for a new time concept. With regard to the General Theory, Einstein states the situation as follows:[1]

'According to the general theory of relativity, on the other hand, by application of *arbitrary substitutions* of the Gauss variables $x_1$, $x_2$, $x_3$, $x_4$, the equations must pass over into equations of the same form.'

The Gauss co-ordinates are characterized (p. 94) in this way:

'We refer the four-dimensional space–time continuum in an arbitrary manner to Gauss co-ordinates. We assign to every point of the continuum (event) four numbers, $x_1$, $x_2$, $x_3$, $x_4$ (co-ordinates), which have not the least physical significance, but only serve the purpose of numbering the points of the continuum in a definite but arbitrary manner. This arrangement does not even need to be of such a kind that we must regard $x_1$, $x_2$, $x_3$ as "space" co-ordinates and $x_4$ as a "time" co-ordinate.'

Thus, in the General Theory *the symbols or co-ordinates only represent arbitrary numbers, which have not the least direct physical significance*. This constitutes a deep difference in principle between the co-ordinates of the Special and the General Theory.

In spite of this wholly indeterminate character of the co-ordinates of the General Theory we are also told (p. 95):

'Every physical description resolves itself into a number of statements, each of which refers to the space–time coincidence of two events $A$ and $B$. In terms of Gaussian co-ordinates, every such statement is expressed by the agreement of their four co-ordinates $x_1$, $x_2$, $x_3$, $x_4$.'

With events we have been told to understand such physical happenings as a light flash in a point, the arrival of a light ray in a point,

[1] '*Relativity*', p. 98.

a lightning stroke in a point, a pointer position of a clock, etc. An event can also be the arrival of a point, say the origin of a moving system $K'$, in the point $P$ in another system $K$.

In the Special Theory these events are characterized by the spatial co-ordinates $x, y, z$ and the time co-ordinate $t$. These variables thus represent physical quantities. In the General Theory we are told that these same symbols should represent Gaussian co-ordinates 'which only serve the purpose of numbering the points of the continuum in a definite but arbitrary manner' and 'which have not the least direct physical significance'. That the Gaussian co-ordinates can be used to characterize an event in space can possibly be accepted, but the characterization of the time of the event stands out as a more complicated problem. Here Einstein declares that for a material point moving relative to a body of reference 'we can also determine the corresponding values of the "time" by the observation of encounters of the body with clocks, in conjunction with the observation of the encounter of the hands of clocks with particular points on the dials'.[1]

This shows that with regard to time measurement Einstein does not choose an arbitrary numbering, but falls back on the observation of such a physical phenomenon as the position of a clock just as in the Special Theory.

The question is then how these clocks are characterized. In the Special Theory we have found that the time of a point event is characterized by the pointer position of a clock in its immediate vicinity, which is supposed to register the time for the whole of the close vicinity of the point event and the adjacent observer.

With regard to the clocks in the General Theory we are informed that:[2]

'Clocks, for which the law of motion is of any kind, however irregular, serve for the definition of time. We have to imagine each of these clocks fixed at a point on the non-rigid reference-body. These clocks satisfy only the one condition, that the "readings" which are observed simultaneously on adjacent clocks (in space) differ from each other by an indefinitely small amount.'[3]

Now, on p. 24, Einstein speaks of 'reading' (as position of the hands) of a clock in the immediate vicinity (in space) of the event.

[1] '*Relativity*', p. 95. [2] *Ibid.*, p. 99.
[3] Incidentally 'indefinitely small amount' must be a misprint in the English translation. Einstein's original reads '*unendlich wenig von einander abweichend*'. The English for this should evidently be 'infinitely small amount'.





The question here is what are we to understand by 'simultaneously' observed readings. No new definition of 'simultaneously' is given in this discussion of the General Theory, and therefore we must fall back on the definitions given in the Special Theory. The second definition—mid-point co-observation—was introduced for the comparison of distant clocks and cannot be applied since the two clocks discussed are closely adjacent so that no observer can be mid-point placed between them. The 'simultaneity' of the pointer positions of the two clocks must be taken in the sense of Einstein's first time concept. 'Simultaneous' events must mean events taking place at the same pointer position of the clocks, at the points of the events, the clocks being supposed to be light-ray regulated in relation to each other. This is the only meaning we are entitled to give to these concepts on the basis of earlier declarations, as no new definition is given.[1]

If we now consider that light-ray regulation can only be performed on the basis of the classical time concept, which is negated, we come to the conclusion that there is no known relation between the clocks.

If we, however, consider two clocks 'adjacent' in space, the condition they are to fulfil is the following:

*When two 'adjacent' clocks take up the same pointer position (simultaneity) their pointer positions should differ from each other by an infinitely small amount.*

This may sound very simple and natural to a relativist, but I feel obliged to draw attention to the fact that the proposition that two quantities, declared to be equal, should at the same time differ from each other even if it be 'by an infinitely small amount' means a negation of the law of identity, $A = A$. The condition in question can be expressed by the equations $x = x$ and $x + dx = x$, where $dx$ is not equal to 0 to be valid at the same time.

Since this is obviously a contradiction, *the condition can never be fulfilled.* It is probable that Einstein has intended to express something quite different, but this is nowhere developed and we are left in the dark on this point. As a contribution to the knowledge of the time concept of the General Theory of Relativity the characterization of the time-constituting clocks appears obscure in the extreme, not to say meaningless.[2]

[1] '*Relativity*', p. 24.
[2] This way of reasoning may possibly account for a noteworthy remark made by an ardent amateur student of modern physics and mathematics. Full

The above characterization of the clocks which should 'serve for the definition of time' has some important consequences. In spite of the contradiction we can assume that Einstein has meant that two clocks standing close side by side should *not* run alike as in the Special Theory, but each show a different 'time', although 'differing by an infinitely small amount', which can have a meaning on the basis of classical time concept. However, since we do not know the difference, they cannot be used for comparative time measurement. In the Special Theory we were told that the time of an event in a point could be registered by the pointer position of a clock in its 'immediate vicinity' and the whole clock was included in the limited area round the observer. When we are now told that clocks *adjacent* to an event in a point show pointer positions *differing* from the time in the point of the event, we must draw the conclusion that *in the General Theory classical time is not ruling even in the close vicinity of a point or an observer*. This creates considerable difficulty. Earlier it was said that the time of an event, say the arrival of a light ray in a point, should be stated by fixing the pointer position of a neighbouring clock. Now, however, we are told that the pointer position of this neighbouring clock does not give the time in the point of the event close by. But if we have to register the time of arrival of a light ray in order to fix the time difference between distant points, a very high degree of precision is necessary in order to attain correct regulation. Even small differences in clock position can create considerable uncertainty in our 'readings'. With this definition of time we are incapable of attaining exact time values.

The negation in the General Theory of classical time concept also for the close vicinity of the event and the observer leads to another difficulty. According to the Special Theory the clocks will have a certain volume since it is the change of their pointer position (position of the hands) on the dial which registers the time. The time intervals in a point are thus registered through spatial measuring. This causes no difficulty in the Special Theory because the same time is ruling in the whole of the close vicinity of the event and the observer, and also for the whole time-measuring clock. But in the General Theory, where every point—including points close to each other—register their own specific 'time', we cannot know for which point in the area round the clock the pointer position indicates the time. Therefore, no kind of spatial clocks could be used in the General

of admiration he told a friend: 'Modern scientists have found out something marvellous! They have found that *A* is no longer equal to *A*, but to *A* plus another quantity, and this additional quantity is very small, and they don't know what it is.'





Theory. Since no other kind of clocks and no other methods for the registering of time are indicated *we are left in complete ignorance of how to register the time of events in the General Theory*.

The faithful relativist would probably rejoin that the ideas of the General Theory should be found elsewhere and that the book I refer to (*Relativity*) is only a popular presentation. I have therefore undertaken a study of Einstein's other papers dealing with the General Theory, viz.

(*a*) 'Die Grundlage der Allgemeinen Relativitätstheorie.' *Annalen der Physik 49*, 1916, reprinted in *Relativitätsprinzip*.

(*b*) 'Stafford Little Lectures', 1921, reproduced in *Meaning of Relativity*. Princeton University Press, 1950.

In the first of these papers the fundamental idea is: 'The laws of physics must be of such nature that they apply to systems of reference in any kind of motion.'[1]

One of the first questions arising here is how the events and processes are to be characterized in the General Theory.

With regard to the Special Theory we have found that the characterization of an event, just as in classical physics, should be attained by measuring its spatial co-ordinates $(x, y, z)$ in relation to a system of reference considered at rest,[2] and the time of the event can be registered with the aid of a clock in the immediate vicinity where[3] classical time is supposed to rule.

With regard to the General Theory Einstein declares that for all infinitely small four-dimensional regions, the Special Theory is applicable for a suitable choice of co-ordinates.[4]

A similar declaration is made in '*Meaning*', p. 57: 'There are finite regions, where with respect to suitably chosen space of reference, material particles move freely without acceleration, and in which the laws of the Special Theory of Relativity hold with remarkable accuracy. Such regions we shall call "Galilean regions".'

From these declarations it seems legitimate to draw the conclusion that for such limited regions we can also in the General Theory state the spatial co-ordinates $(x, y, z)$ and the time co-ordinate of an event, the latter with the aid of a clock in its immediate vicinity.

This, however, is in direct contrast with what we have met in '*Relativity*' with regard to the time concept of the General Theory. If the definition of the time-regulating clocks given there (p. 99) is to make any sense at all, it implies that the time varies from one point

[1] '*Relativitätsprinzip*', pp. 83 and 113. [2] '*Relativity*', p. 9. [3] *Ibid.*, p. 24.
[4] 'Elektrodynamik', pp. 87 and 118.

to another *also* if they are in the close vicinity of each other. And this excludes the possibility, as postulated in the Special Theory, of determining the time of a point event by an adjacent clock.

The discrepancy between the Special and the General Theory is aggravated by Einstein's further reasonings. He points out[1] that as soon as we allow the use of arbitrarily moving systems of co-ordinates 'we come into conflict with that physical interpretation of space and time to which we were led by the Special Theory of Relativity'.

This is illustrated in the following way:

In a Galilean system $K$ (free of gravitation) with the co-ordinates $x, y, z, t$ another system $K'$ $(x', y', z', t')$ is rotating round the $z$-axis in common with constant velocity. What Einstein wants to show is that for the measuring of time and space in $K'$ the concepts of distance and time of the Special Theory cannot be maintained.

Suppose we have a plane circular disc in the $x$–$y$ plane with its centre on the $z$-axis and an observer on the disc performing experiments with clocks and measuring rods, one of two identically constructed clocks at the centre, the other at the edge of the disc. The latter is in motion with regard to $K$ and, according to the results obtained by Einstein when calculating time and distance with the transformation equations, he declares that the clock on the edge goes at a slower rate than the clock at the centre which is at rest in relation to $K$.

He further applies equal measuring rods—short as compared with the radius of the disc—tangentially to the edge of the disc. Since the rods are moving in relation to $K$, he declares them to be shortened in the direction of the motion. From this he concludes that by measuring the circumference of the disc with these shortened rods he would come to the result that—since the radius does not undergo any shortening—the measuring would give another value than $2\pi$ for the relation between circumference and radius *as judged from K*.

This, however, is wholly based on the application of the transformation equations. And, as we have seen earlier (p. 93), owing to the fact that Einstein unconsciously presupposes classical time to be ruling in the whole system, which gives $t' = t$, these equations can *only* be applied for $v = 0$. This makes them useless for the problem in question. Einstein's arguments thus lose all foundation. There is no reason why the clocks on the edge of the disc should go slower than the clock at the centre, and no reason why the rods applied along the circumference should be shortened.

However, from the experiment of the rotating system of reference,

[1] '*Meaning*', p. 58.





Einstein draws the conclusion that in the General Theory the quantities of space and time cannot be defined so as to be measurable with length and time-measures.[1] As a consequence of this he declares that in the General Theory the characterization of an event should be attained merely by attributing to each event certain values of four variables $(x_1, x_2, x_3, x_4)$ without connecting these variables with any concept of space and time. Just as when introducing the Gaussian co-ordinates in *Relativity* (p. 94), he declares that 'they have not the least physical significance'. In 'Elektrodynamik' (p. 86, p. 117) he says that the claim for general co-variance when transferring from one system to another *deprives space and time of the last vestige of physical reality.*

It may be mentioned that very few other authors have taken up the question of the content of the space and time concepts of the General Theory. I shall here confine myself to two writers.

Von Laue[2] speaks of 'individual time' (*Eigenzeit*) as the 'invariant length of a time world-line'. This is supposed to be measured with clocks close to one another and 'running alike'. But we are also told that placed in different points in the system of reference they can run differently. What we are to understand by this is not stated, nor how it should agree with Einstein's idea that adjacent clocks show different times 'simultaneously'. Von Laue, however, winds up his description by declaring that, just as the time co-ordinate $x_4$ lacks all physical meaning, this is also the case with the other co-ordinates, and he ends by quoting Einstein's declaration that the General Theory deprives space and time of the last vestige of physical reality.

C. Möller[3] maintains that, with regard to the difficulties arising in rotating and accelerated systems by the use of a time-variable defined by standard clocks, a simpler description may be obtained by using clocks of different rate. But a closer motivation for the use of these 'differently running' clocks and what is to be understood by 'time' on the basis of them is not given. He, too, finishes by emphasizing that: 'In accelerated systems of reference the spatial and time co-ordinates thus lose every physical significance. They simply represent a certain arbitrary but unambiguous numbering of physical events.'

We can therefore state that there is a striking discrepancy between the Special Theory where the symbols are supposed to represent

[1] 'Elektrodynamik', pp. 85 and 117: '*In der allgemeinen Relativitätstheorie können Raum- und Zeitgrössen nicht so definiert werden, dass räumliche Koordinatendifferenzen unmittelbar mit dem Einheitsmasstab zeitlich mit einer Normaluhr gemessen werden können.*'

[2] 'Relativitätstheorie', II, p. 25.

[3] C. MÖLLER: *The Theory of Relativity*, Clarendon Press, Oxford, 1952, p. 226.

physical quantities, which can also be registered by measuring, and the General Theory where the numbers that should characterize the events are arbitrarily chosen and 'lack all physical significance'.

How this divergency is to be explained or eliminated neither Einstein nor any of his followers tells us.

It should be noted that the method presented in the Special Theory for the creation of a new time concept through light-ray regulation of clocks in distant points after the rejection of classical time meets with exactly the same difficulties if applied to the cases of the General Theory.

The impossibility of stating that an outgoing ray travels to a certain distant point, or that an incoming ray is coming from a certain distant point excludes the application of light-ray regulation.

Indeed, the mere statement 'a light ray goes from $A$ to a distant point $B$' is also meaningless in the General Theory since we have no time concept.

Just as in the Special Theory the establishing of time concept in the General Theory of Relativity by light-ray regulation or mid-point observation cannot be carried out on the basis of rejection of classical time.

## THE CHARACTERIZATION OF THE MOTION OF THE SYSTEM OF REFERENCE IN RELATION TO EACH OTHER IN THE GENERAL THEORY

When Einstein enters on his discussion of the General Theory he already speaks of 'uniformly accelerated motion' and of 'a system $K$ rotating uniformly with respect to $K'$'. Here the question necessarily arises as to how these motions are characterized.

Take the first case and presume that the system $K'$ moves with accelerated speed (acceleration $= a$) in straight line along the $x$-axis of the system $K$, considered at rest. The classical formulae—no other are so far given—tell us that, if we reckon the time in $K$ from the moment of coincidence of the origins $O$ and $O'$ of the systems, we find that $O'$ will have travelled to a point $P$ on the $x$-axis of $K$ at the distance $d$ from $O$ where

$$d = \frac{at^2}{2}.$$

This indicates that $O'$ will have arrived at $P$ at the time $t$ as judged from $O$ in $K$, and it follows that the arrival of $O'$ in $P$ is simultaneous with the clock position $t$ in $O$. This has a quite clear meaning on the





basis of classical *a priori* time ruling throughout space in the system. But if classical time is rejected there is no relation between the arrival of $O'$ in $P$ and the clock position in $O$. That $O'$ has arrived at $P$ at the time $t$, then lacks all meaning, *and the proposition that* K' *moves in relation to* K *with accelerated speed also becomes meaningless. We are left in complete ignorance of the motion of the system in relation to each other, and the relativity problem disappears.*

The relativistic rejoinder that the time is measured on clocks spread out in the system including in $P$, which clocks are supposed to have been regulated beforehand, collapses because the regulation is made impossible by Einstein's rejection of classical time.

The other case is the rotation of a system $K'$ round the $z$-axis of a system $K$ with constant velocity $v$, making each rotation in the time $T$. If we take a point $P$ with the distance $r$ to a point $O$ on the $z$-axis, the point $P$ will describe a circle round $O$ with the radius $r$. We then have:

$$v = \frac{2\pi r}{T}.$$

If the angle between $OP$ and the $x$-axis is $\alpha$ and the point $P$ has started on its way from the $x$-axis at the time $t = 0$ the situation will in a later moment $t$ be

$$r\alpha = vt$$
$$\alpha = \frac{vt}{r}.$$

If we presume that a point on the circle with the radius $r$ has taken the time $t$ to travel from the $x$-axis to a point $P$, the co-ordinate of this point will be

$$x = r\cos\alpha = r\cos\frac{vt}{r}; \qquad y = r\sin\frac{vt}{r}$$

This implies that the end-point of the radius $r$ had its end-point on the $x$-axis at the moment $t = 0$ and that it has arrived in the point $P'$ with the above co-ordinates at the moment $t$. In other words the arrival in the point $P'$ is simultaneous with the clock position $t$ in $O$.

This has a meaning on the basis of classical time, but after the rejection of classical time the statement has no meaning at all.

To talk about one system rotating with constant velocity round the $z$-axis of another system has no meaning outside the close vicinity of an observer in *O* where time is ruling in the classical sense.

We find thus that also in the General Theory the rejection of classical time excludes the possibility of characterizing the movement of the systems in relation to each other.

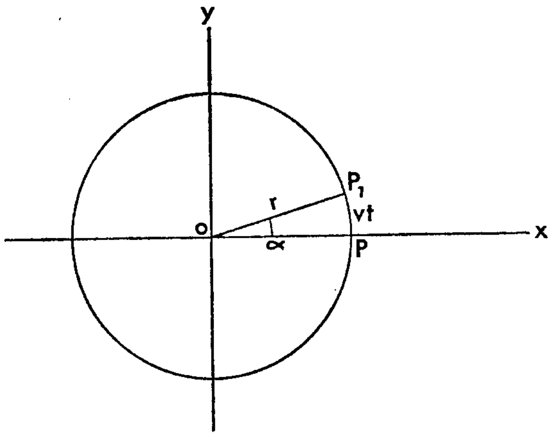



FIG. 6.

But these two cases are only examples of systems moving arbitrarily in relation to each other in fields with or without gravitation. And we can generalize here:

*Whatever be the motion of a system* K′ *in relation to another system* K, *supposed to be the one at rest, we must be able to characterize the movement of* K′ *in relation to* K *in order to discuss their relativity problem. Therefore we must be able to state how a point* P *of the system* K′ *travels in the system* K *from a point* Q *in* K *to another point* R, *also in* K, *during a certain time interval as judged from an observer in the origin* O *of* K, *say from* t = 0 *to a time* t *as measured on the clock of* O. *But this involves necessarily that there is a moment in* Q*—the moment when* P *and* Q *coincide—which is simultaneous with the clock position* t = 0 *in* O, *and also a moment in* R*—the moment when* P *and* R *coincide—which is simultaneous with the clock position* t *in* O. *Unless we can make such a statement we are unable to characterize the movement of* K′ *in relation to* K. *And such a statement can only be made on the basis of classical* a priori *time. On the basis of rejection of classical time the character of the movement would be unknown and there would exist no relativity problem. But when these assumptions are made, there is no other concept of time at our disposal than the classical one.*





It is not sufficient to accept classical time for the close vicinity of an observer, because this would confine our study of physical phenomena to this limited area.

As a result of this investigation we can conclude both with regard to the Special and the General Theory of Relativity that on the basis of rejection of classical time we must declare that the following propositions, fundamental for constituting the relativity problem

'A light ray goes from *A* to a distant point *B*.'

'An inertial system is supposed to be in motion with constant velocity *v* in relation to another inertial system.'

'A system of reference is supposed to be in motion with accelerated velocity in relation to another system of reference.'

'A system of reference is supposed to rotate with constant velocity round the *z*-axis of another system of reference.'

*are all meaningless.*

Also in all other cases of motion of the systems the characterization of the motion will be impossible on the same grounds.

This, however, deprives the Theory of its ultimate foundation. It is true that Einstein himself declares that the co-ordinates of his formulae in the General Theory 'have not the least direct physical significance'. But that being the case we must necessarily state that the symbols in the whole enormous edifice of formulae created to express the Theory lack all 'physical significance'. The fatal consequence of this is that *neither Einstein nor anybody else can know anything about the physical meaning of all these formulae. They are all mathematical constructions without known physical meaning.*

My analysis could very well be terminated here, but I wish to touch upon another aspect of the General Theory and also discuss the alleged corroborations of the Theory.

## A MATHEMATICAL ASPECT OF THE GENERAL THEORY

From a mathematical point of view the General Theory is sometimes based on the quantity '*ds*' called the 'distance' between two adjacent events.

This quantity was introduced and discussed also in the Special Theory. But the necessity of presupposing $t' = t$ led, as shown above, to the result that '*ds*' did *not* remain invariant even for the transformation from one Galilean system to another.

Also in the General Theory Einstein declares that for infinitesimally small four-dimensional areas and for certain co-ordinates the special theory is valid.[1] The co-ordinates are treated as three spatial ones and one for the time. On the basis of these assumptions Einstein here, too, arrives at the equation:

$$ds^2 = -dx^2{}_1 - dx^2{}_2 - dx^2{}_3 - dx^2{}_4$$

where *ds* stands for the so-called 'distance' between two point-events in close vicinity of each other. The fundamental rule of the Theory is, then, that this quantity should remain 'invariant' with regard to all transformations.

But here as in the Special Theory we must inevitably fall back on the equation $t' = t$ in order to be able to characterize the motion of the systems without which no relativity problem exists. This in turn makes the fourth term $dx^2{}_4$ identical for *all* cases and for *all* transformations. Since the Special Theory also here is admitted to be valid for infinitesimal areas, we find as shown earlier (p. 79) that '*ds*' does *not* remain invariant for the transformation from one Galilean system to another. This, however, means that the fundamental law of invariance of '*ds*' proclaimed in the General Theory as valid for *all* transformation fails already for the simplest case and must therefore be discarded.

The presentation of the General Theory in '*Meaning*' does not in any principal point differ from those presented in the former works, and the mathematical expressions are exactly the same.

With regard to the General Theory we can therefore state:

(*a*) The task of characterizing the motion of the systems of reference in relation to each other, whatever be the nature of their motion, presupposes in itself that the classical *a priori* time concept is valid for the whole of both systems. Otherwise no judgement of the character of their movement is possible, and this in turn removes the whole relativity problem.

(*b*) In the discussion of '*ds*' we meet a remarkably ambiguous use of the word distance. It is declared that for extremely small four-dimensional spaces we can presume also in the General Theory that the Special Theory is valid. But in the Special Theory we assume the space–time continuum to be Euclideian.[2] According to this geometry we have a quantity $\Delta$ characterized by the equation

[1] '*Für unendlich kleine vierdimensional Gebiete ist die Relativitätstheorie im engeren Sinne bei passender Koordinatenwahl zutreffend.*'

[2] '*Relativity*', p. 92. 'Elektrodynamik', pp. 87 and 118.





$$\Delta^2 = dx^2 + dy^2 + dz^2,$$

which represents the 'distance in space' between the two events. On the other hand we are presented with an entirely different concept '*ds*', which is *also called* '*distance*' and defined by the equation

$$ds^2 = dx^2 + dy^2 + dz^2 - c^2t^2.$$

The result is that on the basis of the premisses we have two different meanings to the word 'distance'—another remarkable example of the relativistic tendency towards ambiguous use of the words (double-talk).

# 5

# SUMMARY OF THE ANALYSIS OF TIME

Both in the Special and the General Theory the characterization of the movement of our system of reference $K'$ in relation to another presupposes a time concept valid for the whole of space.

Since Einstein rejects classical *a priori* universal and uniform time, his first task is to create a new time concept, and this he undertakes to do with the aid of the light-ray regulation of clocks. This, however, presupposes time relation between distant points in order to identify them and through his reasonings Einstein unconsciously presupposes time in the classical sense. All statements made by Einstein with regard to events and processes in relation to a system in which the observer is at rest are necessarily based on the classical time concept.

On the other hand Einstein uses the word 'time' for the values of the symbol $t'$ as they are calculated on the basis of his new formulae, and these values practically always differ from the classical symbol $t$.

*The result is that Einstein's Theory of Relativity is based on the indiscriminate use of the word 'time' in two different meanings which makes his Theory untenable from a logical point of view.*



# THE CORROBORATIONS OF THE THEORY OF RELATIVITY

## THE SPECIAL THEORY OF RELATIVITY

The ultimate argument of the relativists is that the Theory is supposed to have been corroborated by experiments. Among these the Michelson–Morley experiment is one of the most cited. It is said to have established that one and the same light ray travels with the same velocity in all Galilean systems. On the basis of the classical view this implies that a ray of light should be, and at the same time should *not* be in a certain point, which is an obvious contradiction.

To begin with Einstein admits that this proposition, being a contradiction, is unacceptable, and he sets himself the task of eliminating it by introducing a new time concept. Later, however, he approaches the idea that the experiment in question could be interpreted as a proof of the rule of constant velocity of light. His standpoint is therefore ambiguous here also.

Von Laue, like most of Einstein's other followers, declares[1] that this experiment has *proved* the Theory regarding the travelling of a light ray. To this I can only repeat that the idea that an experiment should be able to prove the validity of a contradiction is preposterous.

The Michelson–Morley experiment *cannot* be used as a proof of the constant velocity of light, and therefore not of the Theory of Relativity either.

On the other hand it gives an extremely important contribution to the study of the nature of light. But it underlines the serious fact that we lack a theory of light that covers all our experimental experiences.

Before entering on the question of other supposed corroborations of the Theory of Relativity—the General as well as the Special—I must once more emphasize that in both parts of the Theory we are in order to characterize the motion of the two systems of reference in relation to each other and thereby arrive to the problem of relativity faced with the necessity of accepting the classical *a priori* time concept expressed by the equation $t' = t$.

[1] 'Die Relativitätstheorie', I, p. 49.

This has two overwhelming consequences for the pillars of the Theory:

*The so-called Lorentz equations are only valid for* v $= 0$. *The* '*distance*' 'ds' *for two adjacent events will not be invariant.*

The result is that the mathematical relations derived on the basis of these two fundamental equations of the Theory will apply to symbols and quantities *other* than the relativists suppose although they use words from classical physics to denote them. In case our experimental results correspond numerically with the values of certain symbols attained with the relativistic equations, *we can only say that we corroborate certain purely mathematically derived symbols the physical meaning of which we know nothing about, except that they cannot represent the quantities by which they are denoted.*

To call for instance the symbol $t'$ of the Relativity formulae the time of the moving system, both in the General and Special Theory, when we must presuppose the rule of classical time $t' = t$ (as shown above) *means to base the whole Theory of Relativity deliberately on an ambiguous use of the word* '*time*'.

The numerical corroborations all apply to secondary formulae which in principle are deduced on the basis of the fundamental formulae of the Theory. Since these must be declined *the symbols of the deduced formulae can in principle not represent the quantities they are supposed to denote. The result is that the corroborations have nothing to do with the quantities involved in the fundamental relativity problem.*

*The so-called corroborations of the Theory of Relativity must therefore in principle be discarded.*

However, the extreme importance attached by the relativists to the supposed corroborations gives reason to take up some major points on this matter to a closer discussion.

As examples of formulae deduced with the Lorentz equations we can choose the following:

(*a*) The shortening of a length in a moving system from $l$ to $l'$ which is given by

$$l' = l\sqrt{1-\beta^2}.$$

(*b*) The retardation of the time unit in the moving system from $s$ to $s'$ is given by

$$s' = \frac{s}{\sqrt{1-\beta^2}}.$$





(*c*) The addition of velocities $u$ and $w$ to $W$

$$W = \frac{u+w}{1+\frac{uw}{c^2}}.$$

Since we must accept $t' = t$ the Lorentz transformation equations become useless, and we have to fall back on Newton and we get

$$l' = l,$$
$$s' = s,$$
$$W = u + w.$$

To this comes the fact that:

*None of these relativistic formulae has been directly corroborated by experiments.*

The most interesting conclusion on the basis of the transformation equations is the formula for kinetic energy $E$ of a material point of mass, moving with velocity $q$ in relation to a system of reference. According to classical mechanics the kinetic energy $E$ is expressed by the well-known equation:

$$E = \frac{mq^2}{2}.$$

Here Einstein comes to quite a different formula. Before discussing it I shall consider Newton's deduction of the classical formulae.

If in Newton's mechanics we call a force acting on a particle $K$, the mass of the particle $m$, and the velocity of the particle $q$, the acceleration produced by the force $a$, and the impulse $G$, sometimes called the motion quantity of the particle, we have

$$G = mq;\ K = \frac{dG}{dE} = \frac{mdq}{dt} = ma.$$

If we suppose that the particle has in the time $t$ travelled the distance $x$ under the influence of the force $K$ and has the velocity $q$ in $x$ and $q = 0$ in $x = 0$, we get

$$q = \frac{dx}{dt};\ a = \frac{dq}{dt};\ a = q\,\frac{dq}{dx}$$

$$K = mq\,\frac{dq}{dx} = \frac{d}{dx}\left(\frac{mq^2}{2}\right).$$

By integration

$$Kx = \frac{mq^2}{2} + C.$$

For $q = 0$ when $x = 0$ we get $C = 0$.

$Kx$ represents the work effected by the force $K$ when the particle has moved the length $x$ and this is by definition called the kinetic energy of the particle.

$$Kx = \frac{mq^2}{2}$$

If we go over to another Galilean system $S'$ moving with velocity $v$ and call the velocity of the particle in $S'$, $q'$, we get according to Newton

$$q' = q - v$$
$$S' = m(q - v)$$

$$\frac{dS'}{dt} = \frac{mdq}{dt} = ma$$

Further, we have

$$K' = \frac{dS'}{dt} = \frac{mdq}{dt}$$

Thus $K' = K$

The Kinetic energy $E'$ will be

$$E' = \frac{mq^2}{2} = \frac{m(q-v)^2}{2}$$

For $v = q$ which means that the particle is at rest in $S'$ we get $E' = 0$ which expresses that as the particle is at rest in $S'$ it has, as seen from this system, no Kinetic energy.

When the relativists treat this problem they apply the Lorentz equations and after many calculations[1] they arrive at the following formulae for the quantities in question[2]

$$m_r = \frac{m}{\frac{q^2}{c^2}}$$

[1] For these calculations see *e.g.* Einstein, *Jahrbuch d. Radioaktivität*, 1907, or von Laue, 'Die Relativitätstheorie', Part I.

[2] I have indicated the new, relativistic symbols with the index $r$ in order to keep them apart from the classical concept.





$$E_r = \frac{mc^2}{\sqrt{1 - \frac{q^2}{c^2}}}$$

The latter equation can be developed into

$$E_r = mc^2 + \frac{mq^2}{2} + \ldots\ldots$$

where the latter terms can be neglected and the result will be

$$E_r = mc^2 + \frac{mq^2}{2}.$$

This extremely remarkable formula tells us that the energy of a particle moving with velocity $q$ in relation to a system of reference is supposed to have not only the Kinetic energy $\frac{mq^2}{2}$ as in the Newton mechanics but in addition to that a quantity of latent energy expressed by the term $mc^2$, *which is wholly independent of its motion and for most cases of enormous proportions compared with the term dependent on the motion q.*

This result, however, is attained *only* by application of the Lorentz equations.

If we stick to the good old classical rule that a concept and its symbols such as *t for 'time' can only have one meaning in the course of our reasoning*, we must in order to come to a relativity problem outside the close vicinity of an observer *necessarily accept the time concept to be the same for all systems of reference and for the whole of space which is expressed by* $t' = t$. This in turn makes the Lorentz equations inapplicable for all values other than $q = 0$.

The result can also be expressed by saying that we are brought back to the Newtonian equations.

From this we can draw the important conclusion that the factor $K = \sqrt{1 - \beta^2}$[1] must in all attained formulae be reduced to 1 and as the appearance of the quantity $c$ in the relativistic formulae is always due to the introduction of the above factor it must disappear from the formulae together with $K = \sqrt{1 - \beta^2}$. All the 'relativistic' formulae containing the quantity $\beta = \frac{v}{c}$ can therefore *not* have the

[1] I here use $K$ in the same meaning as does Lorentz' '*Relativitätsprinzip*', p. 9.

meaning attributed to them by the relativists. What they by chance represent is so far unknown.

Brought back to the Newton equations we must state that the Kinetic energy must be represented by

$$E = \frac{mq^2}{2}$$

With regard to the Einstein formula for kinetic energy we must strictly keep in mind that it is attained by an inappropriate deduction. On the other hand we can state that if we let the symbols have the meaning we attribute to them in classical physics the equation does *not* involve any contradiction and is not meaningless, but what we must state is:

*It is not a correctly deduced formula. It is a mere guess and as such wholly independent of the Theory of Relativity.*

A most remarkable guess indeed as it indicates that a mass-particle at rest contains an enormous amount of latent energy. Whether it should turn out to be correct or it should turn out to be wrong, this has with regard to its inacceptable deduction *no* importance for our judgement of the Theory of Relativity. From the side of many physicists it is supposed to have been corroborated. As this would be of the utmost importance for our knowledge of matter and energy it would be *of extreme interest if it could be given a correct theoretical background* which of course must be independent of the Theory of Relativity. A fascinating task for theoretical physics.

Meanwhile we must state that all the formulae of relativistic kinematics, being deduced on the basis of the Lorentz equations inexorably collapse or are reduced and brought back to the classical (Newton) form, for the simple reason that we must necessarily put $t' = t$.

## THE GENERAL THEORY OF RELATIVITY

There are three 'crucial tests' supposed to be supporting the General Theory of Relativity and they are the following:

(*a*) The red shift of spectral lines emitted by atoms in a region of gravitational potential.
(*b*) The deflection of light rays that pass close to the sun.
(*c*) The motion of the perihelion of the planet Mercury.

### THE RED SHIFT OF SPECTRAL LINES

The red shift is treated by Einstein in '*Relativity*' (p. 129). Among other





presentations I shall also take up that of L. I. Schiff.[1] Einstein states the problem thus:

'In a system $K'$ which is in rotation with regard to a Galilean system $K$, clocks of identical constructions, and which are considered at rest with respect to the rotating reference body go at rates which are dependent on the positions of the clocks.'

We shall now examine this dependence quantitativity. A clock which is situated at a distance $r$ from the centre of the disc, has a velocity relative to $K$ which is given by

$$v = wr,$$

where $w$ represents the angular velocity of rotation of the disc $K'$, with respect to $K$. If $\nu_0$ represents the number of ticks of the clock per unit of time ('rate' of the clock) relative to $K$ when the clock is at rest, then the 'rate' of the clock ($\nu$) when it is moving relative to $K$ with velocity $v$ but at rest with respect to the disc, will, in accordance with section XII be given by

$$v = v_0\sqrt{1 - \frac{v^2}{c^2}}\ ^2$$

or with sufficient accuracy by

$$v = v_0\left(1 - \tfrac{1}{2}\frac{v^2}{c^2}\right)$$

$$v = v_0\left(1 - \frac{1}{c^2}\frac{w^2r^2}{2}\right).$$

If we represent the *difference of potential* of the centrifugal force between the position of the clock and the centre of the disc by $\phi$ i.e. the work, considered negatively, which must be performed on the unit of mass against the centrifugal force in order to transport it from the position of the clock on the rotating disc to the centre of the disc, then we have

$$\phi = \frac{w^2r^2}{2}.$$

[1] *On Experimental Tests of the General Theory of Relativity*, Institute of Theoretical Physics, Stanford University Press, 1959.

[2] In section XII Einstein has reached this result through the application of the Lorentz equation for the retardation of clocks.

From this follows that

$$v = v_0\left(1 + \frac{\phi}{c^2}\right).$$

In the first place, we see from this expression that *two clocks of identical construction will go at different rates, when situated at different distance from the centre of the disc.* This is also valid from the standpoint of an observer who is rotating with the disc. Judged from the disc the latter is in a gravitational field of potential $\phi$, hence the result we have obtained will hold quite generally for gravitational fields. Furthermore, we can regard an atom, which is emitting spectral lines as a clock, so that the following statement will hold.

*An atom absorbs or emits light of a frequency is dependent on the potential of the gravitational field in which it is situated.*

The frequency of an atom situated on the surface of a heavenly body will be somewhat less than the frequency of an atom of the same element which is situated in the free space (or on the surface of a smaller celestial body). Now $\phi = -\frac{KM}{r}$ where $K$ is Newton's constant of gravitation and $M$ is the mass of the heavenly body. Thus a displacement towards the red ought to take place for spectral lines produced at the surface of stars as compared with the spectral lines of the same element produced at the surface of the earth, the amount of this displacement being

$$\frac{v_0 - v}{v_0} = \frac{MK}{c^2 r}.$$

This result has also been attained by L. I. Schiff[1] whose reasonings are also based on the modification of the periods of clocks and light-emitting atoms according to the Lorentz equations.

The spectral lines that reach the earth are also by him supposed to be shifted to the red by the fractional amount $GM/c^2R$ where $G$ stands for the universal constant of gravitation ($K$ in Einstein's equation) and $R$ is the radius of the star. Both Einstein and Schiff give the explanation that 'the stellar atom vibrates more slowly than the terrestrial atom'.

*In both cases the retardation of the vibration of the stellar atom is calculated on the basis of the Lorentz equations.* But we have stated earlier that the Lorentz equation can *only* be applied for $v = 0$

[1] L. I. SCHIFF: *On experimental tests of the General Theory of Relativity,* Stanford University Press, 1959.





owing to the necessity to come to $t' = t$ which is *the inevitable presupposition in order to characterize the movement of the systems of reference and thereby arrive at the relativity problem.*

But when we must put $v = v_0$ the result turns out in both cases to be

$$\frac{KM}{c^2 r} = \frac{GM}{c^2 r} = 0$$

The whole reasoning thus comes to nothing.

If on the other hand we find by experiments that there really exists a modification in vibrations, say $d\nu$, and in consequence a red-shift in the light from a star, it is of course *possible* that this red-shift $d\nu$ can be expressed by the equations in question as *these equations in themselves do not contain or imply any contradiction.* But it must then be strictly underlined, that *the formula is wholly empiric. It has so far no theoretical basis and is wholly independent of the Theory of Relativity from which it cannot be correctly deduced.* The corroboration of the formula has no value for the judgement of the Theory of Relativity. Also here we can denote the equation as a mere guess.

## THE DEFLECTION OF LIGHT RAYS

Schiff gives a very elaborate deduction of the formula that should characterize the angular deflection $\theta$ of a light ray passing close to the sun and he comes to

$$\theta = \frac{4GM}{c^2 R}$$

where $R$ is the radius of the sun and $G$ the universal constant of gravitation and $M$ the mass of the sun.

*The deduction is also here based on the modification of time and clock-intervals derived from the Lorentz equation and when we put in the only values for which these equations are valid, $t' = t$ and $v = 0$, the whole deduction just as in case (a) comes to nothing. The above formula loses all motivation.*

The result is that a relation may exist of character indicated by the formula as *the symbols of the formula have a physical meaning quite independently of the deduction and therefore of the Theory of Relativity.* Whether the formula is correct or not, whether it can be corroborated or not has no consequence for our judgement of the Theory of Relativity as the basic suppositions of the Theory must be rejected.

It is of interest to note, as Schiff also points out (p. 343), that both the formula for red shift and the formula for deflection of light can be derived from the Special Theory of Relativity and the principle of equivalence—equality of inertial and gravitational mass—'without reference to the geodesic equation or the field equations of general relativity'. It follows that only the orbit precession of Mercury perihelion really provides a test of 'General Relativity'.

As both the above formulae are deduced on the basis of the Lorentz equations and these must be repudiated, a corroboration of the formulae supports neither the Special nor the General Theory. Lacking an acceptable theoretical deduction they must—like the formula for mass and energy—be classed as mere guesses.

They may turn out to agree or not agree with observations. This is of *no* importance for the judgement of the Theory of Relativity.

## THE PERIHELION OF MERCURY

According to the Newton–Kepler laws of gravitation and planetary movement there is a movement of the perihelion of the planets in their rotation round the sun and the yearly change can be calculated on the basis of these laws. The calculated amounts agree with observations for all planets except Mercury. In this case the angle described by the radius sun-planet during such a rotation from perihelion to perihelion exceeds that corresponding to 360° by an amount $\epsilon$.

Einstein has on the basis of the General Theory of Relativity calculated this deviation for one complete revolution and presents it thus:

$$\epsilon = \frac{24\,\pi^3\,a^2}{T^2c^2(1 - e^2)}$$

where $a$ represents the major semi-axis of the ellipse, $e$ its eccentricity, $c$ the velocity of light and $T$ the period of revolution of the planet.

This gives for 415 rotations in the century a deviation of 42″99 seconds of arc, which indeed shows a remarkable accordance with the observed value. It is therefore regrettable that the deduction of the formula must be disclaimed on the following grounds.

The deduction is based on the formulae of the General Theory among these the fundamental rule of 'invariance' of the greatness '*ds*'. This invariance does not, however, hold when we consider the necessity of accepting the classical *a priori* time as reigning in all systems ($t' = t$). This is indispensable in order to characterize the movement of the bodies and systems of reference as well as in order to constitute time concept and time relations.





Also the formula for motion of the perihelion of Mercury *is therefore not a correctly deduced law*. It is an arbitrary rule based on the 'double meaning' of the concept of time.

The remarkable accordance between the values calculated for the above-mentioned three quantities according to relativistic formulae and the observations made, although the deduction of the formulae is untenable, gives reason to certain considerations.

*General reflections on the presumed corroborations of the Theory*

The deviations from classical calculations that the relativistic formulae are supposed to explain are in most cases of extremely small order. There need be but slight modifications in the classical formulae in order to cover the discrepancies. The differences between the classical and relativistic formulae are mostly due to the introduction of the factor

$$K = \sqrt{1 - \frac{v^2}{c^2}}$$

As a rule the term $\frac{v^2}{c^2}$ attains extremely low values and the factor in question will be very close to unity. If we take the Michelson–Morley experiment where $v = 30$ km/sec. and $c = 300{,}000$ km/sec. we will have $\frac{v}{c} = 10^{-4}$ and $\frac{v^2}{c^2} = 10^{-8}$. As we can write approximately

$$\sqrt{1 - \frac{v^2}{c^2}} = 1 - \tfrac{1}{2}\,\frac{v^2}{c^2},$$

we get the value $1 - 5 \times 10^{-9}$ for the factor and this differs extremely little from unity.

This can explain why the values attained with the relativistic formulae for the observed quantities differ only slightly from the values attained with classical calculation. However remarkable the accordance may be between the observed values of the physical quantities in question and those calculated on relativistic bases we cannot draw any conclusions with regard to the tenability of the *fundamental* relativistic formulae as these totally lack any tenable deduction.

This can be illustrated by an analogy. Let us presume that we would divide (or multiply) all the mantissas of our logarithmic table with the above-mentioned value of the named factor and then make our calculations with this adjusted table. It is then quite possible that we would get better accordance between calculated and observed values of certain quantities than with the ordinary table. From this we might draw a conclusion as to the direction in which our theoretical analysis of the problem should be sought, but *it would not entitle us to say that the accordance of observed and thus calculated value proved that the modified logarithmic table were correct. It would remain indisputably false.*

There is also another side of the problem worth observing.

The fundamental task of the relativity problem is to find the relation between co-ordinates of space and time for one and the same event in two different systems of reference moving in some specified way in relation to each other. This being the case we can say *a priori* that the equations giving the relations between the two systems of co-ordinates can *only* contain the co-ordinates in the two systems and the quantity or quantities characterizing the motion of the systems in relation to each other. The appearance of symbols representing *other* physical quantities must in this connexion be due to the fact that some *other* problem or *other* conditions have been added to the fundamental task.

In the Einstein Theory of Relativity it is the greatness $c$, alone, or in the combination $\frac{v}{c}$ which comes in through the acceptance of the Lorentz transformation equations. The reason is that these equations are created to fill *also* quite another task, the invariant transformation of the velocity of light ($x = ct$ into $x' = ct'$). We have, however, found that this requirement obliges the relativists to deal—although unconsciously—with two different meanings to the word 'time' which they use promiscuously. As this must be categorically repudiated, we can in consequence state that whenever the symbol $c$ appears in any of the new relativistic formulae, transformation equations as well as secondary formulae deduced on their basis, they must be turned down as ultimately based on double-talk.

Whenever we meet the quantities $c$ and $\frac{v}{c}$ in formulae deduced on the basis of relativistic ideas, without their appearing in the corresponding classical formulae we can categorically dismiss them as in principle invalid for the purpose in question.



# 7

# REVIEW OF LITERATURE

The aim of this review is not to give a complete list of the literature on the Theory of Relativity. For more complete lists I refer amongst others to the following papers:

MAX VON LAUE: 'Die Relativitätstheorie' I and II, *Die Wissenschaft, 38, 68*, Berlin.

WOLFGANG PAULI: *Theory of Relativity*, Pergamon Press, London, 1958.

HENRI ARZELIÈS: *Relativité Generalisée, Gravitation*, Vol. II, Travaux de l'Institut Scientifique Chérifien, p. 237. Série Sciences physiques no. 7, 8. This is one of the most complete lists containing 355 entries.

In the following review I have confined myself to those authors who have most closely *discussed the ultimate foundation* of the Theory, and a number of authors who have been frequently cited.

HENRI ARZELIÈS: *Relativité Généralisée, Gravitation I, II*. Travaux de l'Institut Scientifique Chérifien, Rabat, Paris, 1961 and 1963.

In these very extensive volumes, as in several earlier publications, the author discusses the consequences of the relativistic ideas in different fields of cinématiques and gravitation.

But in all his reasonings he bases himself on the fundamental equations of the Theory as having been established beyond discussion. Consequently he does not give any contribution to the understanding of the fundamental ideas and reasonings on which the Theory is founded.

In the preface of the first tome Arzeliès takes up a row of conceptual problems, such as the meaning of truth in different domains of science, and especially the part of metaphysics in their development. These reasonings have, however, no decisive significance for the judgement of the basic ideas of the Theory of Relativity, but I shall come back to some of his statements in the Appendix.

B. G. BERGMAN: *Introduction to the Theory of Relativity*, New York, 1942.

After describing the Michelson–Morley experiment the author mentions the Lorentz–Fitzgerald theory of contraction of matter, when moving in the ether for the explanation of the experiment. He does not, however, accept this theory but turns instead to the Einstein ideas of revising our time concept.

He starts by describing Einstein's second time concept where simultaneity is based on mid-point co-observation (see above, p. 45).

Two thunderbolts are supposed to hit a train $S'$ travelling along an embankment $S$ with constant velocity $v$, hitting the train at $A'$ and $B'$ and the embankment at $A$ and $B$. Two observers are placed in the mid-point $C$ of $AB$ and $C'$ of $A'B'$.

He then writes:

'At the instant that the thunderbolt strikes at $A$ and $A'$, these two points coincide. The same is true of $B$ and $B'$. If eventually it turns out that the two bolts struck simultaneously as observed by the ground observer $C$, then $C'$ must coincide with $C$ at the same time that $A$ coincides with $A'$ and $B$ with $B'$ (that is when the two thunderbolts strike). It is understood that these simultaneities are defined with respect to the frame $S$.'

What we are told by this is that the observer in $C$ has observed simultaneously two rays coming in to $C$ along the line $ACB$, one in direction from $A$ and one in direction from $B$ and that this arrival has been co-observed in $C$. This does not, however, alone tell us where on the line $ACB$ or when the rays have been created. If we want to assert that the ray coming in in direction from $A$ has been created by a certain event in $A$ we must presuppose that the event in $A$ has taken place at a moment *earlier* than the observation in $C$ as judged by $C$ (a consequence of the supposed causality).

But this implies a time relation *a priori* between the event in $A$ and the observation in $C$. But no new time concept having been as yet created this obliges us to fall back on the classical *a priori* time concept to be reigning around the points $A$ and $C$. The case is analogous for the point $B$. In order to put the event in $B$ in causal relation to the arrival of the ray in $C$, in the direction from $B$, we must also presuppose a time relation between the event in $B$ and $C$. The thunderbolt in $B$ must be *before* the observation in $C$ and also here we must fall back on the classical *a priori* time concept as reigning round $B$ and $C$.





But as the points $A$ and $B$ can be placed anywhere in space we find that the classical time concept must be supposed to reign in the whole of space. This fact—important in itself—does not, however, tell us anything about the time relation between the events in $A$ and $B$. This relation depends on how the rays travel from $A$ and $B$ to $C$ in relation to the system $S$. If the rays travel with different velocities they may well meet simultaneously in $C$ without this implying that they are simultaneous in the classical sense, the only one we have so far at our disposal. If the rays are, however, supposed to travel with the *same* velocity we can say, since the distances $AC$ and $BC$ are equal, that the thunderbolts are simultaneous in the classical sense. But if we assume that the rays travel with same velocity and since the points can be placed anywhere in space we have thus attributed to the system of reference in question $S$ the qualities of the ether.

The author furthermore declares that the co-observation in $C$ implies that:

'$C'$ must coincide with $C$ at the same time that $A$ coincides with $A'$ and $B$ with $B'$ (that is, when the thunderbolts strike).'

As this expressly declares that the observers in $C$ and $C'$ coincide *at the same time as the thunderbolts strike*, we find—if this has to have any meaning at all—that the three events coincidence of $C$ and $C'$ thunderbolts in $AA'$ and $BB'$ are supposed to be simultaneous from the classical point of view as no other time concept is given.

The real content of Bergman's reasonings is thus:

Two events in $AA'$ and $BB'$ are co-observed in the mid-point of $AB$. The events in $AA'$, $BB'$ and the coincidence of $C$ and $C'$ are furthermore declared to take place at the same time, which on the basis of classical time concept, the only at disposal, implies that they are simultaneous in relation to both systems of reference $S$ and $S'$.

The problem is through these suppositions just as in Einstein's discussion of simultaneity in '*Relativity*' reduced to the question:

Will events which are simultaneous in relation to two inertial systems and which are mid-point co-observed in one of the systems be mid-point co-observed also in the other system?

The mid-point co-observation of the simultaneous events in $C$ is due to the fact that the system is supposed to rest in the ether (the velocity of light is the same in all directions). On the basis of classical view we must state that the rays from $A'$ and $B'$ to $C'$ will on the other hand with regard to the motion of the system $S'$ in relation to the ether travel with different velocities and consequently *arrive at different moments in C′.*

If on the other hand we maintain the constant velocity of light in all inertial systems according to the relativistic view, they will meet at the same time in $C'$.

Bergman's reasoning, just as Einstein's in '*Relativity*', is *correct according to classical view, but false according to relativistic view* in clear contradiction to their own declarations.[1]

In the following chapters Bergman bases his arguments wholly on the relativistic formulae presented by Einstein and his followers. Consequently he does not give any contribution to the understanding of the ultimate foundations of the Theory.

HENRI BERGSON: *Durée et Simultanéité*, Bibliotèque de philosophie contemporaine, Paris, 1922.

Bergson sets himself the task of confronting his own concept of time—'*la durée*'—and the classical concept of time with the concept presented by Einstein in his Theory of Relativity in order to find out to what extent these concepts can be brought in accordance with one another or how they differ.

He confines his problem thus (p. VIII):

'We have picked out of the Theory of Relativity what is concerned with time. We have left aside other problems, and we thus remain within the borders of the restricted Relativity.'[2]

He starts his investigation from the Michelson–Morley experiment, and with regard to the propagation of light he accepts the idea of an ether in which the light rays move with the same velocity in all directions independently of the state of motion of the emitting light source in relation to the ether:

'Imagine a system $S$ at rest in the ether and its double $S'$ which from the beginning coincided with the former and which then starts in rectilinear movement with velocity $v$.'[3]

[1] Einstein and Bergman's treatments of the simultaneity problem, both with regard to Einstein's first and to his second time concept present the most striking and sensational examples of the careless and equivocal reasonings of the relativists.

[2] Translation: '*Nous avons découpé dans la théorie de la Relativité ce qui concernait le temps; nous avons laissé de coté les autres problèmes. Nous restons ainsi dans le cadre de la Relativité restreinte.*'

[3] Translation: '*Appelons S un système immobile dans l'ether, et S′ un autre exemplaire de ce système, un double, qui ne faisait d'abord qu'un avec lui et qui s'en détache ensuite en ligne droite avec la vitesse v*' (p. 8).





In order to explain the unexpected result of the Michelson–Morley experiment, he accepts the Lorentz–Fitzgerald theory of contraction of the length of a body in the direction of its motion in relation to the ether and as compared with its length at rest in the ether.

This contraction is supposed to be exactly of the greatness which makes it possible to explain the result of the experiment. The length $l$ of a body at rest in the ether is supposed to become $l\sqrt{1-\frac{v^2}{c^2}}$ when moving with the velocity $v$ with regard to the ether and as judged from the ether.

But Bergson furthermore declares that in order to explain completely the Michelson–Morley experiment with the Fitzgerald contraction hypothesis we are also *obliged to suppose that time undergoes a change in the moving system in relation to the primary system. The 'second' is proclaimed to be 'prolonged' in the moving system.*

'The time of the system has dilated itself. The new second stands in relation to the old second as 1 to $\sqrt{1-\frac{v^2}{c^2}}$.'[1]

This is simply declared as a fact, although the basis, the Fitzgerald contraction, is so far only one of the hypotheses put forward to explain the Michelson–Morley experiment and by no means a proved theory.

Bergson then proceeds to find the relation between the co-ordinates of an event in a point in the system $S$, characterized by the co-ordinates $x$, $y$, $z$, $t$, and the co-ordinates of the same event in $S'$ moving with the velocity $v$ in relation to the $x$-axis of $S$. These co-ordinates are as usual called $x'$, $y'$, $z'$, $t'$.

He bases his deduction on the supposition that the unit of length and the second undergo the changes he has deduced from the Lorentz–Fitzgerald contraction, and he comes quite naturally to the Lorentz transformation equations. From these he then deduces a number of consequences such as the new formula for the addition of velocities, the dislocation of simultaneity and so on, all naturally with the same result as Einstein.

It is of interest to note that although Bergson comes to the same results as Einstein, he conducts his reasonings on lines principally

[1] Translation: '*Le Temps du système s'est* dilaté. *La nouvelle seconde est à l'ancienne dans le rapport de l'unité à* $\sqrt{1-\frac{v^2}{c^2}}$' (p. 20).

'*Chacune des secondes dure davantage*' (p. 10).

different from the latter's. Einstein goes out from the idea that the Maxwell equations for electro-magnetic phenomena should remain invariant with regard to the velocity of light-propagation *c*, when transformed from one Galilean system to another. This he finds realized by the Lorentz equations. Einstein, however, clearly realizes —and points out—that this leads to an evident contradiction, as long as we adhere to classical views of time concept, and he sets himself the task of eliminating the contradiction by the analysis and re-moulding of the time concept.

Bergson starts from the Lorentz–Fitzgerald contraction theory for length and time and *treats it as a proved fact, which it in no wise is.* Later Bergson, however, accepts the Einstein idea that the time relation between distant points should be established by the exchange of light rays.

The objections presented earlier (p. 46) against the light-ray regulation therefore applies to Bergson's reasonings to the same extent as Einstein's. In order to identify the regulating rays, we must be able to put their departure from one point *A* and the arrival in *B* and the return to *A* in causal relation to each other. We must be able to declare that the departure from *A* is before the arrival in *B as judged from B*, and the return in *A* after the reflection in *B*, is *after* this reflection *as judged from A*. But this is possible only if we accept the reign of classical 'time *a priori*' in the whole system. As I have pointed out earlier, we can, however, even go so far as to say independently of the law of causality that *the proposition that a light ray goes from A to B is meaningless without a time concept in common for the two points* and consequently the proposed time relation between two distant points *cannot* be established.

Although Bergson finishes by accepting Einstein's results he gives a very elaborate critical survey of some of the consequences, drawn by Einstein, and comes to some quite different results of great interest. He raises the question as to what extent the Einstein 'times' are 'real' times (p. 52). He proclaims that we cannot speak about a reality reigning without introducing a consciousness:

'*On ne peut pas parler d'une realité qui dure sans y introduire de la conscience*' (p. 60).
'*Durée implique donc conscience*' (p. 62).

He further declares:

'When we want to know if we have to do with a real time or a fictitious time we only have to ask if the object presented could or could not be observed, become conscious.'[1]





He elaborately discusses the relation between observations of events and processes by observers as well in the moving system *S′* as in the system at rest *S*, and comes to the conclusion that by comparison of the 'times' of observers in different systems, *there is only one 'time' that is 'real', the time that is experienced by a real observer. The other times are fictions.*

Bergson expresses it thus:

'We thus always come back to the same point. There is one real Time, and the others are fictitious. What is a real Time if not a time experienced or which could be? What is an unreal, auxiliary, fictitious Time, if not one which could not be effectively experienced by anything or anybody?

'The two observers in *S* and *S′* live exactly the same length of time and the two systems thus have the same real Time.'[2]

This is more closely discussed in connexion with the train problem which is the basis of Einstein's second definition of simultaneity (p. 132). He compares the observations of the observer on the embankment in the mid-point *M* between the points *A* and *B*, where the lightning strokes occur, and the observer in the mid-point *M′* on the train between the points *A′* and *B′*, where the lightning strokes occur with regard to the train. He comes to the result that one has to do with only one time. *What is simultaneous with regard to the embankment is also simultaneous with regard to the train.*

'*On trouvera qu'on a affaire à un seul et même Temps: ce qui est simultanéité par rapport à la voie est simultanéité par rapport au train*' (p. 137).

Bergson comes here in flagrant opposition to Einstein's results. He

[1] Translation: '*Quand nous voudrons savoir si nous avons affaire à un temps réel ou à un temps fictif, nous aurons simplement à nous demander si l'objet qu'on nous présente pourrait ou ne pourrait pas être perçu, devenir conscient*' (p. 88).

[2] Translation: '*Nous revenons donc toujours au même point: il y a un seul Temps réel, et les autres son fictifs. Qu'est-ce en effet qu'un Temps réel, sinon un Temps vécu ou qui pourrait l'être? Qu'est-ce qu'un Temps irréel, auxiliaire, fictif, sinon celui qui ne saurait être vécu effectivement par rien ni par personne?*' (p. 107).
'*Les deux observateurs en S et en S′ vivent exactement la même durée, et les deux systèmes ont ainsi le même Temps réel*' (p. 114).

explains it by pointing out that in these reasonings we must suppose that the observations are really made by an observer—'*un physicien*'—in the system. Only what this physicist measures is real.

'*Est réel ce qui est mesuré par le physicien réel, fictif ce qui est représenté dans la pensée du physicien réel comme mesuré par des physiciens fictifs*' (pp. 110–11).

But, the physicist can only be in one place. He is in $M$, and consequently cannot also be in $M'$. Bergson comes to the conclusion that nothing has been really *observed* in $M'$, because that would presuppose a physicist in $M'$, and the only physicist in the world is supposed to be in $M$:

'*A vrai dire, rien n'est constaté en M', puisqu'il faudrait pour cela en M' un physicien, et que l'unique physicien du monde est par hypothèse en M.*

'*Il y a en M' un physicien simplement imaginé, n'existant que dans la pensée du physicien en M*' (p. 138).

In a later discussion of the observations made by the observers in the two systems one of which is resting on earth, the other moving, he declares that the observer in the former system alone is real and the other observer a phantom.

'*Notre observateur terrestre ne devra jamais perdre de vue que dans toute cette affaire, lui seul est réel, et l'autre observateur fantasmatique*' (p. 163).

With regard to the talk of different 'times' in different Galilean systems he declares that of all these 'times' only one is 'real', the one which is really experienced by a physicist. The other 'times' are simply imagined and are 'auxiliary', 'mathematical' and 'symbolic' times (p. 139).

It is of interest to note that Bergson, in his criticism of the Einstein interpretation of the train problem, meets with the infallible rejoinder which no critic of the Theory of Relativity ever escapes: to be told that the presentation in question is *not* stringent. The correct deductions of the ideas of the Theory are always said to be found elsewhere.

In this case the rejoinder has been directed to Bergson by Charles Nordmann.[1] *He admits that Bergson's criticism of Einstein's interpretation of the mid-point experiment on the train is irrefutable* (Nordmann, p. 182) and concludes that if the Einstein theory were really based on *this* demonstration of the relativity of simultaneity, his theory would collapse. But he professes that the real foundation of the Theory of Relativity is to be found in Einstein's first paper 'Elektrodynamik'. He does *not*, however, enter on a closer analysis of the ideas presented in this paper, but accepts unhesitatingly and unreservedly the results proclaimed there by Einstein.[1]

[1] CHARLES NORDMANN: *Notre Maître le Temps*, Hachette, Paris, 1924.





As I have pointed out earlier, Einstein's definition of the time concept in 'Elektrodynamic' is fictitious. The exchange of light rays on which he bases his clock regulation and thereby also his time concept *cannot* be carried through if we reject the classical time concept. Light-ray regulation can *only* be carried through on the basis of classical time reigning in the whole system, and that makes the new time concept superfluous.

Bergson's standpoint to the Einstein ideas is remarkably ambiguous. With regard to the mid-point observation in the train problem we have seen that Bergson's views stand in clear contradiction to Einstein's ideas. In spite of this, Bergson ends his analysis of the Einstein time concept by declaring that the Theory of Relativity far from eliminating the classical view of 'one unique time' and introducing a multitude of 'times' on the contrary *claims a unique time and gives it a superior comprehensibility.*

Bergson's reason for this remarkable conclusion, standing in manifest contrast with earlier declaration that the Einstein times are only 'imaginary' is extremely summary. It is wholly contained in the following statement (p. 165):

'The exclusion of the privileged system of reference is the essence of the Theory of Relativity. Consequently this theory, far from excluding the hypothesis of a unique Time concept, calls it and gives it a superior comprehensibility.'[2]

This ambiguous position from Bergson's side might well deserve a

[1] Nordmann tries to give another more stringent solution of the midpoint problem, but also in this case the experiments to be performed are based on the exchange of electromagnetic signals between distant points and for the same reasons as mentioned above with regard to the exchange of light-signals these experiments cannot be performed because the possibility of putting emission of signals and their receipt in causal relation to each other in order to identify them necessarily presupposes classical time concept.

[2] Translation: '*La suppression du système privilégée est l'essence même de la Th. de la Rel. Donc cette théorie bien loin d'exclure l'hypothèse d'un Temps unique, l'apelle et lui donne une intelligibilité supérieure.*'

closer analysis but it is of secondary interest for the reason that in his further reasonings he wholly accepts the Lorentz transformation equations and also the idea that the Michelson–Morley experiment confirms the supposition that a ray of light wanders with the same velocity in all Galilean systems thereby siding with Einstein on the main points of the whole theory.

In the discussion of the Michelson–Morley problem he comes back to the earlier declaration of the dilatation (*'allongement'*) of the second and the dislocation of simultaneity but his reasonings are wholly based on the Lorentz equations and for this reason give nothing beyond what is presented by Einstein. Of great importance is the fact that Bergson accepts the idea of constituting the new time concept with the aid of light rays and this he does without any discussion of the possibilities of carrying his regulation through.[1]

Consequently, Bergson becomes liable to exactly the same criticism as I have directed against Einstein, showing that this regulation cannot be carried through on the basis of rejection of classical time. The new time concept, such as we meet it in the Lorentz equations, remains a mere phantom, a purely mathematical symbol without any known physical meaning except for the fact that it *cannot* represent time.

Bergson has, like Einstein, underrated the difficulties created by the negation of classical, *a priori*, unique time with the result that they both—although unconsciously—labour with two time concepts without holding them apart. The classical time concept is necessarily at the basis of statements such as:

'The system $K'$ travels with velocity $v$ along the $x$-axis of system $K$.'
'A light ray wanders from a point $A$ to a distant point $B$.'

The other time concept introduced with the symbol $t'$ of the Lorentz equations is a mere mathematical symbol.

Although Bergson presents some interesting critical points of view on parts of the Einstein views specially with regard to the train problem, he accepts all the basic ideas of the Special Theory of Relativity as proclaimed by Einstein and for this reason *his presentation does not give any contribution to the understanding of the fundamental problems of the theory beyond what Einstein gives himself.*

[1] p. 119: *'Prenons d'abord S comme système de référence. . . . Les horloges y ont été réglées comme dans tout système par un échange de signaux optiques.'*





MAX BORN: *Einstein's Theory of Relativity*, Methuen, London, 1924, Dover, New York, 1962.

Born writes with regard to The Concept of Simultaneity. 'The difficulties which had to be overcome by applying the principle of relativity to electrodynamic events consisted of bringing into harmony the following two apparently inconsistent statements:

(*a*) According to classical mechanics the velocity of any motion has different values for two observers moving relative to each other.
(*b*) Experiments inform us that the velocity of light is independent of the state of motion of the observer and has always the same value $c$.

To this Born adds:

'Of the two statements (*a*) and (*b*) the first is purely theoretical and conceptual in character whereas the second is founded on fact.

'Now since the second statement that of the constancy of the velocity of light must be regarded as being experimentally established with certainty nothing remains but to give up the first law and regard the ideas of space and time as hitherto accepted.'

With regard to Born's second statement it should be noted that his declaration is made *before* the introduction of the new concepts of space and time. The analysis of the experiments by which his theses are supposed to have been 'established' must therefore have been carried out on the basis of classical views and from this standpoint the independence of the velocity of light of the state of motion of the observer leads as I have shown earlier to an obvious contradiction. Born's assertion that this contradictory thesis should have been experimentally 'established' implies that it should be possible to prove by experiment the validity of a contradiction. As I have earlier pointed out *this conclusion is a disastrous intellectual break-neck leap and must be categorically repudiated, as contradictions are always false.*

To this should be remarked that Einstein does *not* take up this position. He admits that the extension of the classical Principle of Relativity to electrodynamics leads to a contradiction which he by no means accepts but endeavours to eliminate by the remoulding of the time concept. *Born here takes up a position contrary to Einstein and furthermore contrary to a fundamental rule of logics without which no scientific work can be performed.*

With regard to the breaking up of 'the ideas about space and time as hitherto accepted', Born takes up the concept of 'simultaneity' and states:

'To be able to decide whether two events of different points are simultaneous we must have clocks at every point which we can be certain will go at the same rate or beat "synchronically".

'Let us imagine the two clocks at $A$ and $B$ a distance apart at rest in a system $S$. Now there are two methods of regulating the clocks so that they go at the same rate:

1. We may take them to the same point, regulate them there so that they go in unison, and then restore them to $A$ and $B$ respectively.
2. We may use time signals to compare the clocks.'

With regard to the first method the following should be observed: When the clocks have been regulated side by side and then brought back to the distant points $A$ and $B$ they are supposed to 'run synchronically' or 'go at the same rate'. But this implies—as pointed out earlier (p. 37)—that they take up same pointer position in the same moment and undergo same change of pointer position in same lapse of time.

But such expressions can have a meaning *only* on the basis of a concept of time common for both points, and in this situation there is no other concept to fall back upon than the classical *a priori* time concept. It should be noted that Einstein has realized the untenability of this reasoning. He declares expressly that after comparison of the clocks side by side and their return to $A$ and $B$, we have no known relation between their indications. *The clocks must be regulated by the exchange of light rays.*[1] Born's method number one is thus—also according to Einstein—useless.[2]

Thus it is only the latter method of clock regulation that remains and it is also on this basis that he discusses the problem of simultaneity. Although his description is most voluble and circumstantial he does not give any aspect on the problem beyond what Einstein has given. On the other hand he meets with all the objections that I have earlier raised against Einstein's light-ray regulation. The identification of the light rays and thereby the whole regulation *cannot* be carried through after the rejection of classical time. On the contrary

[1] *Jahrb. d. Radioaktivität u. Elektronik*, 4, 1907, p. 415.

[2] Born here takes up the same position as Liljeblad (see p. 92) who also puts himself in opposition to Einstein. Born's standpoint must, just as Liljeblad's, be dismissed.





the constitution of the new time concept on these lines necessarily presupposes the reign of time in the classical *a priori* sense in the whole system. A new time concept is superfluous.

Born's whole discussion on the dissolution of 'simultaneity' is wholly based on the possibility of the clock regulation in question and his declaration: 'There is no such thing as absolute simultaneity' lacks all foundation and must be categorically dismissed.

With regard to the foundations of the Theory of Relativity Born has not given any contribution beyond Einstein and it is most surprising that a scientist of otherwise so high standard should, fifty years after the publication of Einstein's first paper, have *failed to realize one of the most fundamental and most expressly declared ideas of the Theory.*

MARIO BUNGE: *Foundations of Physics*, Springer, Berlin and New York, 1967.

This book contains a very elaborate presentation and discussion of the foundations of modern physics, but does it with the aid of a very large number of symbols for all the different basic concepts and expressions.

The aim of this technique is probably to arrive at very short expressions for the derived results in the way of concepts and laws. It does, however, bring about considerable difficulties when the results have to be analysed in order to state their ultimate foundation and tenability. In that case the symbols and the derived formulae must be brought back into their primary form as expressed in ordinary words. This makes the introduction of the symbols and their combinations in very complex formulae a most questionable method.

This can be illustrated by the analysis of the ideas of the Special Theory of Relativity.

The concept of 'time' is very extensively discussed in the chapter on Chronology but we need not enter on it more deeply but can limit ourselves to the discussion of 'simultaneity' of two distant events.

Bunge writes (p. 187) on 'Relativity of simultaneity':

'Thm 1. Let $\sigma_1$ and $\sigma_2$ be two point sources of spherical e.m. (electromagnetic) signals, located respectively at $X_1$ and $X_2$ in an inertial reference frame and let $\sigma$ be a receiver at the mid-point of the segment joining the two sources. Then if the two sources emit a signal at the time $t_1$ relative to the reference frame the signals arrive simultaneously at $\sigma$, at the instant $t_2 = t_1 + \frac{1}{2}\left(\frac{X_2 - X_1}{c}\right)$.

Proof: Use SR7 (Special Relativity axiom 7) and adjoin the special assumptions (idealizations) that the emission and adsorption take no time.

'Thm 1 is the basis of *Criterion 1*. It can be inferred that two distant point events in vacuum are *simultaneous* in the inertial reference frame if they consist of or are accompanied by electro-magnetic signals arriving at the same time at the mid-point of the straight line segment passing through them.'

First and foremost it should be stated that this is in principle the definition of simultaneity presented by Einstein in *Relativity*. In Einstein's case we could state that the declaration he made about the time of the light flashes in the distant points could only have the meaning—if any meaning at all—that the two light flashes took place at the same moment that is *simultaneously in the classical sense of the word*. And here we find the same. It is expressly declared that 'two sources emit each a signal at the time $t_1$ relative to $L$ (the system of reference)'.

Since the declaration that two events both take place at a certain time has in this connexion not been given a new meaning, we must understand it on the basis of classical time concept which implies that *they are simultaneous just as in the case stated by Einstein*. The concept of simultaneity of two distant events is here—probably unconsciously—presupposed by the writer in question and a new definition of simultaneity is thus superfluous.

On the other hand it is correct that if the light rays wander with the same velocity towards the mid-point they will also be observed simultaneously at this point.

That this should *always* be the case Bunge supports by referring to the 'Special Relativity axiom 7' which he formulates thus:

'Every electro-magnetic signal propagates in vacuum relative to any inertial reference system with uniform rectilinear motion at the speed *c*.'

This is Einstein's second postulate which, however, leads to the contradiction admitted by Einstein and which he attempts to eliminate through the introduction of a new time concept. This attempt results, as we have seen earlier, in the fact that he labours with two different meanings to the word time without keeping them apart.

The reference to the so-called axiom SR7 which implies a contradiction makes Bunge's reasonings untenable.

*Bunge has not in any way contributed to the analysis of the foundations of the Theory of Relativity.*





ERNST CASSIRER: *Zur Einsteinschen Relativitätstheorie*, Berlin, 1920.

Cassirer first treats some general problems of the concepts of physics and then turns to the problems of the Theory of Relativity. He states that the Newton Principle of Relativity and the Principle of the universal constancy of the velocity of light propagation stand in contradiction to each other (p. 31). At this point he simply declares that this contradiction is eliminated through an analysis of our concepts of time and space.

'*Durch eine Analyse der physikalischen Begriffe von Raum und Zeit ergibt sich jetzt, dass in Wahrheit eine unvereinbarkeit des Relativitätsprincips mit der Ausbreitungsgesetz des Lichtes gar nicht vorhanden ist; dass es vielmehr ledeglich der Umbildung dieser Begriffe bedarf, um zu einer logisch einwandfreier Theorie zu gelangen.*'

Cassirer's reasoning is exactly a repetition of Einstein's own declarations.[1] It is of interest that he so emphatically points out that the contradiction in question has not been solved by new experiments as certain physicists maintain but wholly depends on a critical remoulding of our fundamental concepts of time and space. He thereby underlines what I have emphasized above that the solution given by Einstein of the contradiction to which the basic ideas of the Theory of Relativity lead is of purely epistemological character. It is therefore remarkable that Cassirer, as a philosopher by profession, has not found reason to scrutinize more closely the Einstein analysis of the concepts in question. On the contrary he accepts Einstein's results with regard to the time concept without the slightest hesitation (pp. 31, 90). He then proceeds to finding the transformation equations which should give the relation between the co-ordinates of an event in the moving system ($x'$, $y'$, $z'$, $t'$) and the co-ordinates of the same event in the primary system ($x$, $y$, $z$, $t$) with the above two principles in view and he treats it as a purely mathematical question and arrives quite naturally at the Lorentz transformation equations.

In a following chapter he presents a very extensive argumentation on the consequence of the Theory from a philosophical point of view, but wholly on the basis of Einstein's ideas and arrives at the conclusion that our concept of reality is given by mathematical equations and systems of equations which are 'covariant' to arbitrary substitutions.

Here as in the following chapters he only gives a prolix exposition

[1] '*Relativity*', p. 19.

of certain consequences of the accepted ideas. His study therefore has the character of a general survey of the Theory of Relativity from the point of view of an unreserved acceptance of Einstein's ideas. *He thus gives no contribution to the discussion of their ultimate foundation, the new time concept.*

HERBERT DINGLE: *The Special Theory of Relativity*, Methuen, London, 1955.

Dingle's fundamental theses are:

'There is no meaning in absolute motion'
'There is no meaning in absolute velocity'
'There is no meaning in absolute acceleration'

The two first are supposed to constitute the Special Theory of Relativity. The third one is supposed to constitute the General Theory of Relativity.

He arrives at the first by discussing the experiments which have aimed at stating the movement of the earth in relation to the hypothetical ether, especially the Michelson–Morley experiment. In this discussion he meets the factor $\sqrt{1-\frac{v^2}{c^2}}$ in different connexions and this leads him to remould one of our fundamental concepts, that of 'length'. He declares:

'We have used a false definition of length. The quantity that is physically important is not $l$ as ordinarily defined but $l\sqrt{1-\frac{v^2}{c^2}}$ where $v$ is the velocity of the object concerned in the direction in which the length is measured, with respect to whatever standard of rest we choose to adopt.'

We are thus presented with two meanings to the word length: length of body at rest, which we can call $l_r$ and length of body in motion ($v$) which we may call $l_m$. They are two distinctly different greatnesses which stand in the relation.

$$l_m = l_r\sqrt{1-\frac{v^2}{c^2}}$$

It is essential to note that there is *no* talk by Dingle of such a thing as contraction of a body travelling in relation to a system at rest





such as the Lorentz–Fitzgerald contraction with which they wished to explain the Michelson–Morley experiment. In their case there was no talk of changing the meaning of the word 'length' but a hypothesis as to how a body would behave itself when moving in relation to the hypothetical ether. *In Dingle's case it is merely prescribed that we should have different meanings to the word 'length' in different cases.*

The most remarkable fact in this connexion is that Dingle *does not give one single reason* for this most sensational revolution in one of our fundamental concepts. *His definition is merely an arbitrary decree that the word length should have different meanings in different cases,* a flagrant example of relativistic double-talk.

On the basis of his new definition Dingle finds that he can explain certain experiments on light propagation such as the Michelson–Morley one, quite naturally as he has introduced the same modification as in the Lorentz-Fitzgerald contraction theory which was created to explain this experiment.

At the same time, however, he binds himself with regard to the meaning of 'time'. He does not specially indicate what the symbol $c$ stands for but we have strong reasons to suppose that it stands as in all other presentations of the relativity problem for the velocity of light in vacuum with the value 300,000 km/sec. But by the introduction of this constant Dingle has—although he has evidently not realized it—accepted the *second* as universal time unit. He, however, totally overlooks this when he comes to the discussion of 'time unit' where he gives a new definition.

'Our unit of time is now defined as the time it takes by a particular kind of moving body to cover a chosen number of units of length.'

We are told that for a moving body 'instead of $t$ we must take $t\sqrt{1-\frac{v^2}{c^2}}$'.[1] We thus get one meaning to the word 'time' in a system at rest, say $t_r$, and another meaning for time in a system with the velocity $v$, and if we call the latter $t_m$ we have

$$t_m = t_r\sqrt{1-\frac{v^2}{c^2}}$$

But only one of these meanings can be identical with the unit 'second' already necessarily—although unconsciously—accepted with the greatness $c$. Also here the ever-occurring relativistic double-talk.

[1] p. 39.

It is most remarkable that although we are supposed to be given a definition of the 'time unit' it is *not* indicated what 'particular kind of moving body' is to be chosen which leaves the reader at loose ends.

It should be noted that if we choose the wandering of a light ray as time-regulating process—which most relativists do—the fundamental thesis of the Theory of Relativity that the velocity of light is a universal constant (Einstein's second postulate) is, as I have shown earlier, reduced to an identity of type $A = A$.

For the transformation from one Galilean system to another Dingle comes, on the basis of his new definition of 'length' and 'time' quite naturally to the Lorentz equations. Dingle makes all his following calculations and derivations on the basis of these equations and on Minkowski's reasonings on the four-dimensional space–time continuum *but he does not give any motivation or new aspects on the Theory beyond what other authors have given.*

It should be noted that Dingle's definitions of 'length' and 'time' are purely mathematical constructions and *he does not give any analysis of the physical content of the new concepts.*

Einstein on the other hand recognizes that the extended principle of relativity leads to contradictions and he undertakes to eliminate these by analysing and creating a new time concept. Although I cannot accept his reasonings I wish to emphasize that he has clearly recognized the problems arising from the extended principle of relativity. Dingle has apparently totally neglected Einstein's reasonings on this point.

It seems, by the way, that Dingle has had the ambition to present a deduction of his own of the relativistic ideas, independently of Einstein, and this is strikingly illustrated by the fact that in the whole of his book, published thirty-five years and reprinted fifty years after Einstein's original presentation of his Theory, *he does not once mention Einstein's name.*

With regard to Dingle's non-motivated and arbitrary introduction of new concepts for 'length' and 'time', and his purely mathematical treatment of the relativity problem *his book has no interest whatever for the study of the basic ideas of the Theory of Relativity.*

In a later work[1] Dingle takes up a very extensive discussion with Viscount Samuel on a great number of scientific and philosophical problems and among them also the relativity problems.

In a chapter on 'Energy and the Ether' Dingle discusses the so-called Lorentz equations and maintains that according to Lorentz these are bound to a stationary ether. Einstein's ideas dispensed with

[1] VISCOUNT SAMUEL AND HERBERT DINGLE: *The Threefold Cord, Philosophy, Science, Religion,* Allen and Unwin, London, 1961.





the ether and Dingle considers this as a consequence of Einstein's two postulates. He then goes over to the creation of time relation between distant points through the synchronization of clocks in the points with the aid of light rays which are supposed to take equal times to travel to and from the two points. The clocks are thus supposed to have been synchronized and 'having once been synchronized, clocks in good working order would remain so'.

If the clocks in two different Galilean systems are thus regulated he declares that if we have an observer with each clock, each observer would find that the other's time for any event was behind his own.

Reasonings of this kind, however, are all based on the presupposition of light-ray regulation of the clocks but since we have seen earlier that such regulation cannot be carried out on the basis of negation of classical time, we cannot establish the new time concept for distant points. *Consequently Dingle's whole reasoning must be turned down.*

Quite recently Dingle has taken up the problems of the Theory of Relativity on quite other lines.[1] He writes:

'Einstein deduced from the basic ideas of his theory that a moving clock works slower than a stationary one. By a similar line of reasoning I deduced from the same basic ideas of his theory that a moving works *faster* than the same stationary one. Here the theory since it entails with equal validity two incompatible conclusions must be false.' 'Clocks cannot behave as Einstein's theory requests.'

The problem can be reduced to the question how a clock in a system at rest, and a clock in a system with the motion $v$ run in relation to each other.

Einstein has formulated the question thus: 'What is the rate of the (moving) clock when viewed from the stationary system?'

The rate is represented by the symbol $t$ for the system at rest and by $\tau$ for the moving system. Dingle deduces on the basis of the Lorentz equations:

$$t = \tau\sqrt{1 - \frac{v^2}{c^2}}$$

$$\tau = t\sqrt{1 - \frac{v^2}{c^2}}$$

[1] *British Journal of the Philosophy of Science*, XV, pp. 41 and 47. Compare *Nature*, September 8, 1962, p. 985, March 30, 1963, pp. 1248 and 1280.

and as these two equations are incompatible *he denies and rejects the Special Theory of Relativity on this later stage.*

To this Max Born has rejoined that the two formulae are answers to two *different* questions:

'What is the rate of the clock in the moving system when viewed from the stationary system?'
'What is the rate of the clock in the "stationary" system when viewed from the moving system?'[1]

Consequently Born declares the two formulae fully compatible.

To this I only want to remind that both formulae are deduced on the basis of the Lorentz equations and we have seen earlier that with regard to the absolute necessity of accepting the relation $t' = t$ *these equations are only valid for* $v = 0$ which reduces the two equations to

$$t = \tau \quad \text{and} \quad \tau = t.$$

*The clocks have the same rate.* The whole discussion between the two authors thus treats relations between symbols the meaning of which neither they, nor anybody else knows, so far, anything about. We can therefore leave the two gentlemen in peace to their meaningless discussion.

## A. S. Eddington

Eddington has treated the Theory of Relativity and problems connected with it in two works:

*Space Time and Gravitation. An outline of the General Relativity Theory.* Cambridge, 1921.
*The Mathematical Theory of Relativity.* Cambridge, 1930.

In the former work he discusses problems of Geometry, Dimension, Time, Force, Gravitation and Relativity, but his reasonings with regard to the Theory of Relativity are mostly a digest of earlier presentations, by other authors.

It should thus be observed that he does *not* enter on a discussion of the deduction or the bearing of the Lorentz equations of transformation. They are summarily mentioned and accepted without closer scrutiny. In a historical note at the end of the book he mentions that Lorentz and Larmor had introduced the new symbol $t'$ for what they called 'local time' ('*Ortszeit*') of an event in the moving

[1] *Nature*, March 30, 1963, p. 1287.





system of reference but without letting it represent 'real time'. He then mentions that 'Einstein in 1905 founded the modern Principle of Relativity by postulating that this "local time" was *the time* for the moving observer: no real or absolute time existed, but only the local time different for different observers'. He then cites some of the consequences of this postulation and finally declares that Einstein removed the last discrepancies from the Lorentz transformations.

Eddington thus does *not on any point* enter on a discussion of how the new time concept is constituted. He only recapitulates and unreservedly accepts Einstein's declarations. It is, however, of great interest to study Eddington's methods of reasoning more closely since they give an interesting insight into the world of thought of many modern mathematicians and physicists.

Eddington gives a new definition of 'The Restricted Principle of Relativity' (p. 20).

'It is impossible by any experiment to detect uniform motion relative to the ether.'

To this may be remarked that Einstein's definition of the Principle of Relativity has a much wider scope since it asserts that *all natural phenomena run their course according to exactly the same general laws with respect to all Galilean systems of reference.* Eddington's definition is only one of the many consequences of the Einstein ideas, since according to Einstein the idea of an ether is altogether eliminated. In order that the formulation given by Eddington should have any meaning we must presuppose the existence of an ether. If on the other hand, as in Einstein's reasonings, the idea of an ether is abolished, there is very little meaning in declaring that we cannot 'by any experiment detect uniform motion relative to the ether'—which is supposed not to exist. A rather trivial statement.

Eddington, however, seems to have been very strongly tied to the idea of an ether. He accepts and enters closely on the Lorentz–Fitzgerald theory for the explanation of the Michelson–Morley experiment by assuming that bodies undergo a contraction when moving with regard to the ether. But this theory has a meaning *only* if we presuppose the existence of an ether.[1]

[1] It is of interest to note that in order to illustrate the contraction-Theory which Eddington characterizes as 'a paradox beyond even the imagination of Dean Swift' he compares the theory with the adventures of Gulliver in Lilliputland (p. 23) and Alice's adventures in Wonderland. And indeed there are striking likenesses. In the realm of 'contraction' and 'relativity' like in Lilliputland and Wonderland men grow higher and become shorter and knock their heads on

When Eddington in contrast with classical views presents the idea of time as being a relative concept changing from one system to another, he falls back altogether on the ideas of Einstein and like him totally overlooks the fact displayed above that the exchange of light signals between distant observers in order to regulate clocks in relation to each other, and thereby according to Einstein constituting the new time concept, can be performed *only* if we postulate the reign of classical time *a priori* in the whole system of reference in question. The classical time concept being necessarily, although unconsciously presupposed, in order to identify the regulating rays there is no point in trying to establish a new time concept.

We must therefore state that in this work Eddington has treated the problems connected with the Einstein Theory of Relativity quite superficially. He has merely accepted the declarations and results presented by other physicists, especially Einstein. This book does not therefore on any point contribute to the understanding of the Theory beyond what Einstein has presented himself.

In his other work *The Mathematical Theory of Relativity* Eddington starts with some general reasonings on the foundations of physics.

The 'physical quantities', distance for example, are supposed to be defined by practical operations followed by calculation. Distance is defined by the procedure we use to measure it. The physical quantities are therefore declared to be 'manufactured articles', manufactured by our operations. Physical quantities are 'an indication to us of some existent condition or relation in the world outside us'. The physical quantities are measure-numbers of the world-condition. 'Distance', for instance, is the 'measure-number' of a 'World-condition'.

'But there seems *no* reason to conclude that this world-condition *resembles* distance any more closely than it resembles parallax or cubic parallax. Indeed any notion of resemblance between physical quantities and the world-conditions underlying them seems to be inappropriate.'

Furthermore, we are told that 'the study of physical quantities

the ceiling (compare $v < c$), and time expands and shrinks like an elastic band and so on.

But there *is* a difference. Whereas Lewis Carroll and Jonathan Swift were fully aware that they were telling fairy tales from Fairyland, the modern physicist, whether he believes in 'contraction' or 'relativity' pretends to be describing the real physical world. This presupposes, however, a strict and profound analysis of the contents of the new concepts and presuppositions in general, on which this reasoning is based, which is, however, fundamentally neglected by Eddington.





gives us some kind of knowledge of the world-conditions, since the same operations will give different results in different world-conditions'. We are also told that 'for some obscure reason we expect to see distance appearing plainly as a gulf in the true world-picture'.

I believe that many readers like the writer would have been grateful to the author for some more elucidating information as to what is to be understood by 'world-conditions', 'gulf' and 'true world-picture'.[1]

The fundamental basis of the Theory of Relativity being, as Einstein underlines, the time concept we need not go more profoundly into Eddington's general reasonings on physical quantities. When we come over, however, to his treatment of the time problem, it is striking how summarily and lightly he treats it.

Eddington's discussion of the pre-relativistic time concept I have already treated above (p. 31) and need not enter more deeply on it again. Let me mention, though, that he declares the pre-relativistic notion of time to be 'of artificial nature' and 'that the original demand for a *world-wide* time arose through a mistake'. He also raises the question: 'What did the pre-relativistic physicist mean by the difference of time between two events at different places?' and answers himself: 'I do not think we can attach any meaning to his hazy conception of what is signified.'

After this hard criticism of the classical time concept it is with eager expectation that one turns to Eddington's own definitions and general comments. As in his previously mentioned work Eddington does *not*, however, give any definition or reasonings of his own. Here again he accepts unreservedly and without discussion the ideas of Einstein.

His approach to the time problem in his latter book is purely mathematical. He declares categorically: 'We decide that time is relative to an observer' (p. 4). When he comes to the problem of characterizing an event in a moving system when we know the co-ordinates $(x, y, z, t)$ in a system considered at rest, he presents the Lorentz transformation equations as the means of characterizing the co-ordinates in the moving system called $x'$, $y'$, $z'$, $t'$. The time of the event in the moving system is thus declared to be represented by the symbol $t'$, different from $t$. *However, no analysis of the content of the symbol $t'$ in relation to the time symbol $t$ is given.*

Eddington also describes another way of approach to the time problem. As a fundamental new concept he introduces the 'interval'[2]

[1] Any reader interested in penetrating the Eddington ideas more closely can find a brilliant analysis in L. Susan Stebbing's *Philosophy and the Physicists*, Dover, New York, 1958.

[2] The term 'interval' corresponds to Einstein's concept 'distance'.

between two neighbouring events denoted by *ds* and defined thus

$$ds^2 = dx^2 + dy^2 + dz^2 + dy^2{}_4,$$

where *x*, *y*, *z* are spatial co-ordinates and $dy_4$ a quantity based on time. If the lapse of time between the two events is *dt* we have $dy_4 = icdt$.

This gives

$$ds^2 = dx^2 + dy^2 + dz^2 - c^2dt^2.$$

This equation should be 'invariantly' transformed when we go over from one Galilean system to another where the co-ordinates are indicated by $x'$, $y'$, $z'$, $t'$ and this is achieved by the Lorentz equations where time is represented by the symbol $t'$ different from $t$ and the result is

$$ds^2 = dx^2 + dy^2 + dz^2 - c^2dt^2 = dx^2 + dy^2 + dz'^2 - c^2dt^2.$$

*The new symbol t′ is thus also here introduced without any motivation.*

From then on Eddington's treatment of relativity problems is of purely mathematical character and based on the above formulae and involving the new undefined symbol $t'$.

Eddington's whole following treatment of the relativity problem is altogether based on Einstein's ideas and formulae.

Eddington's way of looking upon these conceptual problems is characterized by himself in a most extraordinary way. He writes:

'When we decide to throw the older theories into the melting-pot and make a clean start, it is best to relegate to the background terminology associated with special hypotheses of Physics.'

With this background one would have expected a close discussion and a detailed presentation of those *new* concepts and ideas, which are to replace those that should be 'relegated to the background'. But on this point Eddington declares:

'We cannot be forever examining our foundations.'

It seems that there could hardly be a moment more appropriate to discuss the problem of our foundations than the moment when we decide to reject our most fundamental old concepts and start putting new ones in exchange.

The result of this scrutiny is that *Eddington has not given any*





*analysis of the new time concept, no motivation why a new symbol should be introduced for time in the moving system.* He merely introduces $t'$ for time in the moving system and accepts without discussion the Lorentz equations. He does not even touch upon the problem, so fundamental in Einstein's presentation, of how to regulate clocks in order to arrive at a time relation between distant points and thus constitute the new time concept.

Thus Eddington, in spite of his voluble reasoning and the enormous mathematical apparatus which he mobilizes, *does not give any contribution whatsoever to the knowledge and understanding of the foundations of the Einstein Theory of Relativity.* His discussion of the Theory of Relativity is one of the most careless and muddled in the whole literature on this subject.

GEORG VON GLEICH: *Einsteins Relativitätstheorie und physikalische Wirklichkeit*, Leipzig, 1930.

Gleich presents a very hard and very detailed criticism of the whole Theory. His chief argument is that the Theory is a mere mathematical construction which does not represent physical facts. He points out that the Special Theory is wholly built on the Lorentz equations and that these are mainly constituted in order to transform the law of propagation of light in one Galilean system ($x = ct$) invariantly, that is into $x' = ct'$ for another Galilean system. This involves that the addition of the velocity $v$ of the moving system to $c$ should give the result $c + v = c$ which according to Gleich is a contradiction and the acceptance of which leads us into a phantom world. Gleich also points out that many of the problems of the Theory can be explained on the basis of classical physics.

Although I think that von Gleich has presented a number of points of view and objections of very striking character and where I can fully agree with him I hold the opinion that the Theory should preferably be scrutinized and criticized on more fundamental grounds.

The contradiction pointed out above with regard to the addition of velocities is acknowledged by Einstein but is supposed by him to be eliminated by the introduction of the new time symbol. It is therefore necessary to scrutinize the reasoning leading to the new time concept and it is by doing this that I have come to the result that Einstein labours—although unconsciously—with two different meanings to the word 'time', and if we stick to the good old logical rule that a word should have only one single meaning through the whole of our reasoning we must disown his new time concept as a mere phantom and fall back on the classical rule $t' = t$.

AXEL HÄGERSTRÖM: 'Erkenntnis-theoretische Voraussetzungen der Speziellen Relativitätstheorie', *Theoria*, Gothenburg, 1946.

Hägerström undertakes a very detailed scrutiny of Einstein's ideas on our concepts of time and space and his attempt to give reasons and motivations for their merging into a four-dimensional world. He turns specially to the new transformation equations and the consequences drawn from them, and maintains that Einstein's reasoning either leads to a circle or to contradictions, and must therefore be rejected.

He specially turns against the sensualistic ideas on perception and reality as presented by Einstein and Russell and sums up:

'*Die Einsteinsche Relativitätstheorie mit ihrer Zersetzung des anschaulichen Raumes und der anschaulichen Zeit ist eine mathematische Abart des Humschen "Sensualismus" in einer modernen von Mach herstammenden Form und muss deswegen in den gleichen Widerspruch geraten.*'

Although I find Hägerström's criticism of the relativistic ideas convincing, I am of the opinion that the value of the relativistic ideas can be more directly assessed by an analysis of the ultimate foundation of his theory, the definition of the new time concept and its mathematical rendering, which, as I have shown above, leads Einstein to use the word 'time' indiscriminately in two different meanings and thereby reverting to logical confusion.

K. KROMAN: *Relativitätsprincipet*, Fysisk Tidskrift, Copenhagen, 1916.

Kroman first gives a survey of the problems and experiments which have led to the 'Principle of Relativity' and then goes over to the formulae expressing the new ideas. In this connexion he enters on the problem of establishing a time relation between distant points in a system of reference and here he accepts Einstein's idea of carrying this through with the aid of light rays. He also accepts the new symbol $t'$ for time in the moving system and thus naturally arrives at the Lorentz–Einstein equations.

At this point, however, Kroman initiates his criticism and arrives at the conclusion that the formulae are mere 'mathematical fancies'. He also maintains that when we apply the formulae to physical facts, such as supposed observations made by observers in the moving system of reference, we arrive at contradictions which cannot be eliminated. It is because of these contradictions that he doubts the whole theory.





Although I think that Kroman has presented certain critical points of interest, where I can agree with him I do not think that his reasonings are quite binding as long as he accepts the fundamental formulae and the new time symbol $t'$, because by doing this he places himself on the same ground as the relativists. What he does not seem to have realized is that only by analysing the ultimate foundation of the theory, the possibility of establishing the new time concept can we judge the value of the new theory. As this shows itself impossible and we are thereby necessarily brought back to the equation $t' = t$ we are obliged to dismiss the whole Theory as being built on the base of the word 'time' indiscriminately used in two different meanings.

HENRY MARGENAU: *The Nature of Physical Reality* (A philosophy of modern physics), MacGraw Hill, New York, 1950.

This very extensive work aims to give philosophical reflections on physical research and to show that modern physics holds a message for philosophy.

In the chapter on 'Space and Time' the author also takes up the ideas developed in the Theory of Relativity and at first examines them as presented in the Special form.

He declares that:

'It was discovered that the length of rigid bodies is different when it is measured by an observer moving relative to these bodies from what it is, when measured by an observer at rest with respect to them. Similarly, clocks have their tempo changed when read by moving observers. New experiences have forced us to modify the conceptual texture in which space and time had been embedded.'

In spite of the revolutionizing character of these supposed results the author neither indicates on what experiments these conclusions are based nor does he give any references where these motives are to be found.

As has been shown earlier *no experimental confirmation has been given neither with regard to the shortening of lengths nor of the dilation of the time unit through motion.*

Both these declarations are *only* based on mathematical calculations performed on the bases of the so-called Lorentz transformation equations. These in turn have been constructed to express the constant velocity of light in all inertial systems. This, however, implies—as admitted by Einstein himself—a contradiction which he attempts to eliminate by introducing a new time concept. This being, however, as shown earlier a complete failure, *there remains no experimental ground whatever for the above declaration of the distortion of length and time through motion.*

It may be recalled that the experiment persistently cited as a proof of the supposed modification of length and time through motion is the well-known Michelson–Morley experiment. Strictly judged this very important experiment, however, *only* shows that the observed results can *not* be explained on the basis of the electro-magnetic theory together with the supposition of an ether at rest.

*This negative fact does not entitle us to draw arbitrary conclusions on the nature of time and space.*

Margenau does thus not on any point enter on a discussion of the erection of the new time concept. He accepts unreservedly the ideas proclaimed by Einstein and Minkowski. Consequently he does *not* give any contribution to the understanding of the ultimate foundations of the Theory of Relativity.

In a later essay 'Einstein's concept of Reality', published in *Albert Einstein, Philosopher Scientist*, New York, 1951, Margenau takes up some problems related to the Theory of Relativity.

As early as in the introduction he declares however:

'A knowledge of the physical and mathematical structure of relativity theory will here be assumed and its fundamental validity will never be drawn into question as far as present evidence goes. In fact this theory is now so well corroborated by experience and by assimilation into the whole of modern physics that its denial is almost unthinkable.'

With this categorical acceptance of the ideas of the Theory of Relativity as background it is evident that, for the question of the validity of the fundamental ideas of the Theory—the subject of this book—Margenau's reasonings do not present anything of interest.

E. A. MILNE: *Kinematic Relativity*, Clarendon Press, Oxford, 1947.

Milne starts by accepting the undefined concept of a 'point event' at the observer and the notion of a one-dimensional continuance of events at the observer.

Two observers in distant points, *A* and *B*, have clocks close to themselves and these measure—each separately—their time and the task is to regulate them so that the time readings can be compared. Milne thus characterizes the problem in principle exactly in the same way as Einstein.





He performs the regulation by reading the clock in *B* from *A* at any moment and the simultaneous reading of his own clock. This presupposes that the clocks can be seen from the other distant observer and he shows that his regulation is ultimately based on the supposition that

'*A* has sent a light signal to *B* at $t$, by *A*'s clock, the ray has been reflected by *B* at the instant $t_2 = t_3$ by *B*'s clock and returned to *A* so as to arrive at *A* at time $t_4$ by *A*'s clock.'[1]

It is on this exchange of rays that Milne bases his clock regulation and we meet here therefore in principle *exactly the same reasoning as Einstein proposes for the regulation of clocks*. But as we saw by the Einstein regulation the possibility to identify the rays and give a meaning to the statement: 'A ray goes from point *A* to *B* and back to *A*', he presupposes the possibility of setting the events in *A* and *B* in causal relation to each other, which necessarily presupposes time relation *a priori* to be reigning in the classical sense for the whole space round the observer.

Milne makes a rather remarkable comment with regard to the clock regulation between two observers, *A* and *B*, in distant points. He declares:

'If we choose to be interested in the possibility of two different observers keeping the same time, we must permit them to announce to each other the times they are keeping, and our procedure involves nothing but this type of announcement.

'Thus the last person to quarrel with our suggested procedure should be the philosopher who reduces experience to the reception of these data.'

To this I must categorically declare that Milne altogether overlooks the fact that all communications between the observers, whether this is by light rays or any other messenger-carrier, must necessarily imply that the observers can put the reception of a message of whatever art it may be in causal relation to an art of message-sending from the other observer, and this can only be done on the basis of an *a priori* time concept in common for the whole space round the observers. This is the objection a philosopher, whether he is quarrelsome or not, must raise most energetically.

Milne also accepts the Lorentz transformation equation to find

[1] $t_2$ is the time of arrival in *B* of the ray from *A*. $t_3$ is the time of departure from *B* on its way back to *A*. When the ray is reflected $t_2 = t_3$.

the co-ordinates $x'$, $y'$, $z'$, $t'$ of an event as judged from the Galilean system $K'$ moving with constant velocity in relation to another system $K$ where the co-ordinates of the same event are $x$, $y$, $z$, $t$.

That is, he accepts the idea of different time symbols in different systems whereas his own clock regulation method necessarily and unavoidably craves the acceptance of classical uniform time reigning in both systems, that is $t' = t$.

Milne's presentation is thus in principle a repetition of the ideas of other earlier-mentioned authors.

ALOYS MÜLLER: *Die philosophischen Probleme der Einsteinschen Relativitätstheorie*, Vieweg, Braunschweig, 1922.

Müller gives a detailed account of the space–time problems of classical physics and of the Galilei–Newton mechanics. He then discusses the Einstein–Lorentz ideas of time in the different systems and although he makes certain objections as to their consequences he does not negate them.

He introduces the concept of 'zone time' (*Zonenzeit*) for the primary system of reference and defines it as the time of the clocks of the system which have been regulated to run synchronically according to Einstein's rule of regulation (p. 35). For the other system he accepts the Lorentz 'local time' (*Ortzeit*) generalized for the whole system and called 'system time' (*Systemzeit*). By this we are brought to understand the comprehension of the same pointer position of clocks in the system which should have been regulated 'according to a certain rule' (*nach einer bestimmten Vorschrift*).

Müller here accepts without discussion the Einstein rule for clock regulation in the primary system. Similarly, he accepts that it should be possible to regulate the clocks in the moving system so as to yield the Lorentz local time.

But as the Einstein clock regulation *cannot* be applied and carried through on the basis of Einstein's fundamental presupposition, the rejection of classical *a priori* time concept, the basis of Müller's whole discussion must be considered a mere phantom, as in the case of Einstein.

In the chapters that follow Müller presents many objections to the relativistic ideas. He thus points out that Minkowski's theory on space–time is merely a mathematical construction without relation to our concept, with which I can wholly agree.

He winds up his presentation with the question:

What is the real philosophical import of the Theory of Relativity?





His answer is very pessimistic, and admits that it teaches us nothing new about the character of Space and Time, nothing new on the relation between Geometry and Physics and nothing on the relativity of knowledge or reality.

Although I can join in many of Müller's conclusions I think that the value of the theory can be much more directly characterized by the analysis of its basic ideas, which shows its untenability.

C. MÖLLER: *The Theory of Relativity*, Clarendon Press, Oxford, 1952.

This work gives a clear account of the historical background of the Theory and of the crucial problems which it sets itself the task to solve. Möller underlines the necessity of giving a new definition of simultaneity and thus comes to the Einstein prescription of regulating reciprocally clocks in distant points through the exchange of light rays. Thus he follows in principle the ideas applied by Einstein, and although he discusses them more in detail, his reasonings necessarily need exactly as in Einstein's case, the presupposition of a time concept in common for the whole system where the experiments are performed. All his reasonings presuppose the identification of the light rays arriving to a point as coming from another given distant point. This can, however—as has been shown earlier—only be attained if the classical *a priori* time concept, already accepted for the close vicinity of the observer, is extended to the whole space round the observer. As it must be possible to perform the experiments in all parts of space and in all systems of reference, we are obliged to accept the classical *a priori* time concept for all systems and for the whole of space.

When he therefore comes over to the deduction of the Lorentz transformation he has already—although unconsciously—destroyed the fundaments on which they should be based. The possibility of different time symbols in different systems cannot be upheld.

We can therefore state that Möller does not in any way contribute to the understanding of the foundations of the Theory of Relativity beyond what we have met in other presentations, especially that of Einstein himself.

WOLFGANG PAULI JR. gives in *Encyklopaedie der Mathematischen Wissenschaften*, Vol. V, Part 2, Dec. 1920, a very clear and thorough presentation of the Theory of Relativity.

He discusses primarily the historical evolution of the theory and points out that the Lorentz transformation equations were introduced as a means of transforming purely mathematically the Maxwell–Lorentz equations of electro-dynamics so that they remained formally unchanged ('invariant') and how this made it necessary to introduce a new symbol for time ($t'$) in the moving system. He also points out that Lorentz contented himself by calling this new symbol 'local time' (*Ortzeit*) but without entering on a closer discussion of its relation to our time concept.

He then goes over to the Einstein postulate that all physical phenomena must be supposed to display themselves in exactly the same way from whatever Galilean system of reference we might judge them.

He also points out that this principle combined with the principle of constant velocity of light leads to the necessity of revising our time concept ('*Die Konstanz der Lichtgeschwindigkeit in Verein mit dem Relativitätspostulat führt zu einer Neureung des Zeitbegriffes*').

This revision of the time concept is based on the same reasoning as von Laue's and leads him to the necessity of regulating clocks in distant points in relation to each other with the aid of light rays. Thereby Pauli comes up against exactly the same problem as Einstein, and his solution is only a repetition of Einstein's reasoning, and consequently he meets with exactly the same difficulties. The regulation can only be carried through if time is presupposed to reign in its classical sense in the whole system in order to identify the light rays. And in that case there is neither need nor possibility of establishing a new time concept.

He then goes over to the problem of the transformation equations needed to transform the co-ordinates of an event $x$, $y$, $z$, $t$ in the system $K$ to the co-ordinates $x'$, $y'$, $z'$, $t'$ in the moving system $K'$, and here he introduces the new time symbol $t'$ without any closer discussion. He naturally arrives at the Lorentz transformation equations.

Pauli's presentation thus—although it gives an interesting historical review of the initiating problems and a good survey of the relativity ideas—does not give any contribution to the discussion of the meaning of the new time concept and the possibility of establishing it through light-ray regulation and of representing time in the moving system with $t'$, above what we have met in Einstein's and von Laue's papers.

ADOLF PHALÉN: 'Ueber die Relativität der Raum und Zeitbestimmungen', *K. Humanistiska Vet. Samf.* 21:4, Uppsala, 1922.

Phalén gives a very profound and most penetrating analysis of our





concepts of space and time and declines the idea that they could be merged in a uniform four-dimensional concept. They must be considered as separate concepts.

'From what has been said here it follows that one cannot, from the Theory of Relativity, draw any conclusions with regard to the relation between space and time as regards their content.'

With reference to the time concept and the relativity of simultaneity Phalén gives a very exhaustive analysis which he sums up thus:

'If with regard to the simultaneity or lack of simultaneity of the lightning strokes a fact is supposed to be assigned, and not only the result of the two calculations, which cannot both be true, it remains that the Theory still contains the contradiction that two events should both be and not be simultaneous. The reference to two different systems does not make any change, since the contradiction arises through reference to different systems and since the reference to different systems is a mere repetition of the supposition creating the contradiction, that is the supposition that the velocity of light is constant with regard to both systems.'

Although I can wholly agree with Phalén in his penetrating criticism I maintain—just as with Hägerström's above-mentioned analysis—that a more direct display of the untenability of the Einstein ideas can be attained by the analysis I have presented above of Einstein's new definition of time, which reveals his use indiscriminately of the word 'time' in two different meanings.

HENRI POINCARÉ has, in a number of papers, touched on the problems of relativity and already at an early stage he has denied 'absolute movement' and 'absolute time'.[1]

His final standpoint in the relativity problem is expressed in a lecture before 'Wissenschaftlicher Verein' in Berlin in 1910—two years before his death—on what he calls 'The New Mechanics'.[2]

Here he denies any meaning to the concept of absolute position ('*absolute Lage*') and declares that it is impossible by any experiment to state the relation of motion of a system of reference with regard to the hypothetical absolute system of reference.

[1] HENRI POINCARÉ: *Science et Hypothèse*, Paris, 1902, 'Comptes Rendus', 1904. Published in English by Walter Scott, London and Newcastle, 1905.

[2] HENRI POINCARÉ: 'Die neue Mechanik' in *Himmel und Erde*, Book B, Berlin, 1901.

The impossibility of such a determination he also accepts for electro-magnetic phenomena, especially with regard to the Michelson–Morley experiment. He also declares that this makes it necessary to modify our earlier views on space and time. He thus accepts the concept 'local time' introduced by Lorentz and the new symbol $t'$ for time in the moving system as well as the new equations for transformation.

Similar to Lorentz he introduces the symbol $t'$ and the concept 'local time' *without closer motivation.* He does not as Einstein, negate the classical time which therefore remains at the bottom of his reasonings. *Both he and Lorentz consequently use the word 'time' in two different senses without keeping them distinctly apart which necessarily results in serious intellectual confusion through double-talk.*

Poincaré's dependency on the classical time concept is illustrated by the fact that he bases his reasonings on the supposition that the two systems of reference in question are Galilean systems in rectilinear motion in relation to each other with constant velocity, which necessarily presupposes a time concept valid in the whole of the system of reference.

With regard to this we can state that although Poincaré from an historical point of view presents certain points of interest he does in fact not in any way contribute to the discussion of the *ultimate foundation of the Theory of Relativity*, the analysis of the new time concept. His views are most closely connected with the Lorentz ideas. In the above-named paper of 1910 on these problems he does not even mention Einstein's name.

For the historical development of the Theory and the contribution of Lorentz, Poincaré and Einstein respectively I refer to the Appendix of this book.

HANS REICHENBACH: *Philosophie der Raum—Zeit—Lehre*, Veit & Co., Berlin and Leipzig, 1928.

Reichenbach presents a very voluble discussion on time and space which in the main, however, has no bearing on the relativity problem.

What is of interest in this connexion is his discussion of the concept of 'simultaneity' especially with regard to events in distant points. He there takes up the idea of exchange of signals between the two points. A signal is supposed to leave the point $A$ at the time $t_1$ and arrive to a distant point $B$ at the time $t_2$ where it is reflected and supposed to come back to $A$ at the time $t_3$. This is in principle the experiment on which Einstein bases his regulation of clocks in the





two points with the aid of light rays, and the rule according to which this should be done is as we have seen earlier.

$$t_3 - t_2 = t_2 - t_1,$$

which gives

$$t_2 - t_1 = \tfrac{1}{2}(t_3 - t_1).$$

Einstein's definition of simultaneity for events in the two points is that they should take place at the same pointer position of the clocks in the points respectively, provided the clocks are being regulated according to the above rule.

It should be observed that $R$ on the other hand denotes the formula as *Einstein's definition of simultaneity* which undoubtedly stands out as a most haphazard and careless way of presenting Einstein's ideas. No two events indicated by the three time symbols stand in the relation of simultaneity to each other, neither according to Einstein's views nor according to classical view and Einstein has never proclaimed this to be his 'definition of simultaneity'. Possibly $R$ has also intended the formula to be a rule for clock regulation but in that case his way of expressing himself on one of the fundamental points of his whole analysis is most wanton and hapless.

In principle Reichenbach's position differs very profoundly from Einstein's because he declares that we can also use the formula

$$t_2 - t_1 = E(t_3 - t_1)$$

where $E$ can take any value between 0 and 1. If we thus attribute to $E$ the value $\tfrac{1}{4}$ we find that

$$t_3 - t_1 = 4(t_2 - t_1)$$

and

$$t_3 - t_2 = 3(t_2 - t_1).$$

This indicates that the signal is supposed to wander three times quicker from $A$ to $B$ than from $B$ back to $A$.

In Einstein's reasoning it is imperative that the velocity of the signal which is here a light ray should be the same in both directions. He thus combines his definition of simultaneity with a certain physical phenomenon whereas in Reichenbach's case we can regulate and establish the definition of simultaneity on the basis of any example of the formula with $E$ between 0 and 1. The definition is thus wholly dependent on the value we attribute to $E$ and on this ground he declares that this definition of simultaneity is a definition of attribution (*Zuordningsdefinition*). This definition is thus to a certain degree arbitrary and not being based on any physical feature it is merely fictitious.

Later, however, Reichenbach admits that this method of definition, although in principle permissible, is unsatisfactory and he takes up another line. He bases his concept of time relation on the law of causality. If an event $E_2$ is caused by $E_1$ we say that $E_2$ is later than $E_1$ and $E_1$ is earlier than $E_2$.

It must be remarked in relation to this that if we have two events in one and the same point they can very well be one before the other—without the events standing in causal relation to each other, but if we say that one event causes the other the former is necessarily before the latter. Causality necessarily presupposes the relation before–after. This relation is primary and the concept of causality is secondary. We cannot base our time concept on the law of causality which in itself presupposes the time concept.

Being not quite satisfied either with this foundation of the time relation between distant points Reichenbach finally comes over to the Einstein rule of clock regulation where $E = \frac{1}{2}$ which indicates that the light ray wandering from $A$ to $B$ and back takes the same time in both directions. Having also accepted the idea that one and the same light impulse in all Galilean systems spreads uniformly round the point of the system where the light source was at the moment of emission (the same idea as declared by von Laue) he comes to the Lorentz transformation equation and his whole reasoning from then on tallies with Einstein's.

Ultimately, Reichenbach's reasonings about the establishing of time relation between distant points is based on the exchange of light rays between distant points and this being the case he meets exactly the same problem as Einstein.

How are the observers in the two points to identify the incoming rays when it is supposed that no time relation *a priori* exists between the two points? I have shown earlier that in order to say that the ray coming in to $A$ at the time $t_3$ is the ray sent out there at the time $t_1$ and that it has been reflected in $B$ at the time $t_2$ it is necessary to be able to say that the three events stand in causal relation to each other, and this is possible *only* if it is presumed that time in the classical *a priori* sense is reigning through the whole system where the points and observers $A$ and $B$ are at rest. And if we must necessarily accept the classical *a priori* time to be reigning in the whole system of reference there is no need to constitute and define a new time concept. I wish furthermore also to call attention to the fact, also expounded earlier, that the mere propositions, 'a ray goes from point $A$ to point $B$', and 'the system $S'$ travels with velocity $v$ along





the $x$-axis of system $S$' both necessarily presuppose classical *a priori* time to be reigning in the whole system of reference in order that the propositions should have any meaning at all.

All Reichenbach's reasonings in later chapters are based on the acceptance of the universally constant velocity of light, mathematically expressed by the Lorentz equation and, as has been stated earlier, this implies that he, like all other relativists *labours with two meanings of the word time* the classical *a priori* meaning, when stating that a ray wanders between two points and another meaning based solely on the new time symbol $t'$ introduced by the transformation equations and which symbol has no known physical meaning.

In a book published later,[1] Reichenbach has contributed with a paper on the 'Philosophical significance of Relativity'.

The reflexions presented there are all based on the acceptance of the principal proclamations of Einstein and his followers and Reichenbach does not enter on any closer discussion of the logical content and consequences of these proclamations.

With regard to the settling and understanding of the ultimate foundations of the Theory of Relativity Reichenbach makes no contribution beyond Einstein.

ALFRED A. ROBB: *A Theory of Time and Space*, Cambridge University Press, 1914.

A most original analysis of the concepts of time and space and especially of 'simultaneity' has been given in the above-named book.

Robb admits that the introduction of 'local time' as this has been proposed by Lorentz in his discussion of his equations of transformation—where it is represented by the symbol $t'$—leads to contradictions and as 'a thing cannot both be and not be at the same time' the 'local time' remains a mathematical fiction (p. 2).

He then undertakes to devise a new method of approaching the problem which he describes as 'the idea of conical order' (p. 3).

He starts by giving some postulates and definitions.

'An element of time is called *an instant* and it is to be regarded as a fundamental concept.

'Of any two elements of time of which I am *directly* conscious one is *after* the other.

'1. If an instant $A$ be *after* an instant $B$, the instant $B$ is not after the instant $A$, and is said to be *before* it.

2. If $A$ be an instant, I can conceive of an instant which is *after* $A$ and also of one which is *before* $A$.

[1] *Albert Einstein, Philosopher Scientist*, New York, 1951.

3. If an instant $A$ be *after* an instant $B$ I can conceive of an instant which is both *after* $B$ and *before* $A$.
4. If an instant $B$ be *after* an instant $A$ and an instant $C$ be *after* the instant $B$ the instant $C$ is *after* the instant $A$.
5. If an instant $A$ be *neither before nor after* an instant $B$, the instants $A$ and $B$ are identical.'

This can be considered as a correct—although somewhat summary analysis of classical time concept, which also covers the ideas of Einstein with regard to the flow of time in a point and also in fact from Einstein's point of view in the immediate vicinity of an observer.

Robb then goes over to use the words 'after' and 'before' to characterize the position of points in space in relation to certain geometrical constructions (p. 4):

'Let us consider a system of cones having their axes parallel and having equal vertical angles. Let us regard any cone of the set as terminating in the vertex and having the opening pointed upwards,

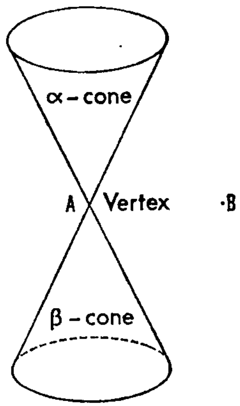



FIG. 7.

let us say. We may call such a cone an α-cone, and one with the opening pointed downwards as β-cone. The vertex in either case is to be regarded as belonging to the respective cones.

'Thus, corresponding to any points in space there is an α-cone of the set having that point as vertex, and similarly there is also a β-cone of the set having the point as vertex.

'Now it is possible by using such cones and by making a certain





convention with respect to the use of the words "before" and "after" to set up a type of order of the points in space.

'If $A_1$ be any point and $a_1$ the corresponding α-cone then we shall say that any point $A_2$ is "after" $A_1$ provided that the points are distinct and $A_2$ lies either on or inside the cone $\alpha_1$.

'Similarly if $A_1$ be any point and $\beta_1$ the corresponding β-cone then we shall say that any point $A_2$ is *before* $A_1$, provided that the two points are distinct and $A_2$ lies either on or inside the cone $\beta_1$.'

From this characterization of the geometrical character of the points Robb goes over to the characteristics which can be derived from these geometrical figurations.

'It is easy to see:

1. If a point $A$ be *after* a point $B$, the point $B$ is not *after* the point $A$ and it is said to be *before* it.
2. If $A$ be any point, there is a point which is *after* $A$ and also one which is *before* $A$.
3. If a point $A$ be *after* a point $B$, there is a point which is both after $B$ and before $A$.
4. If a point $B$ be *after* a point $A$ and a point $C$ be *after* a point $B$, the point $C$ is after the point $A$.

'We *cannot*, however, say in this case that if a point $A$ be neither *before* nor *after* a point $B$ the points $A$ and $B$ must be identical.

'We have here in fact that not only is $A$ neither *before* nor *after* $A$ but also any element $B$ lying in the region *outside* both the α- and β-cones of $A$ is neither *before* nor *after* $A$ (see figure).

'Thus the fact that an element is neither *before* nor *after* an element is not sufficient in this case to enable us to say that the elements are identical.'

He continues:

'We shall speak of the type of order thus obtained as *Conical Order*, but shall not confine ourselves to the use of the name to the geometrical example considered above or to the number of dimensions in which the example is presented.'

The results attained from the consideration of geometrical construction is thus to be applied to other domains. We are further told:

'The main point to be considered at present is that we may have two elements of which one is neither before nor after the other, but which yet are not identical without our being involved in any logical absurdity.'

Here we find that the rules obtained concerning the situation of points with regard to a geometrical construction are directly applied to 'elements of time'. With regard to the 'elements of time' he continues:

'We recognize 'events' as taking place in time as having a time order. We further recognize certain events as of an instantaneous character, such for example as two particles striking one another. In speaking of events hereafter unless otherwise stated, we shall refer to instantaneous events.

'Two events may occur at the same instant. Thus a particle $P$ may strike a particle $R$ at the same instant as another particle $Q$ strikes it.

'Events which occur at the same instant will be said to be *simultaneous.*

'*According to the view here put forward the only events which are really simultaneous are events which occur at the same place.*'

This conclusion is thus based wholly on the results derived from the geometrical relationship of points called 'Conical Order'. This is more closely developed thus:

'Of any two events $A$ and $B$ we may have $A$ *before* $B$ or $A$ *after* $B$ or $A$ neither *before* nor *after* $B$.

'According to the view generally held, $A$ being neither *before* nor *after* $B$ is taken as equivalent to $A$ and $B$ being simultaneous. According to the view here adopted [the "Conical Order"-view] this is only so when the events $A$ and $B$ occur at the same place. If such events occur at different places we are only entitled to say that the one is neither *before* nor *after* the other.

'The standpoint is rendered fairly clear by a consideration of the geometrical type of conical order which we have explained.'

We find thus that Robb borrows from our generally held view on time the words *before* and *after* for characterizing certain geometrical relations between distant points, and on the basis of this geometrical consideration he comes to the conclusion that two events (represented by geometrical points) of which one is neither *before* nor *after* the other and which for this reason according to views on classical time are simultaneous, would stand in another relation according





to the geometrical analogy and his conclusion is that two events can only be declared simultaneous if they *occur in the same point* and cannot be declared simultaneous if they, although they are neither before nor after each other, occur in distant points.

This result is a most remarkable dislocation of the concept of simultaneity as it means that *the concept does not exist for distant points* in one and the same system.

Robb here takes up a standpoint which stands in direct opposition to Einstein's ideas.

Einstein has accepted the idea that two events in distant points can be simultaneous and has in fact—as shown earlier—given two definitions of simultaneity for such events:

1. Events taking place at same pointer position of clocks in their immediate vicinity which are being mutually light-ray regulated.
2. Events which are mid-point co-observed.

It is when we come to the relation between two events which *are* simultaneous in one system as judged from another inertial system that Einstein proclaims a dislocation of simultaneity.

Robb has thus gone much further than Einstein in the rejection of classical time ideas but he does it merely on this geometrical analogy.

The real content of the author's declaration is best exposed if we go back to the *real geometrical meaning attributed to the words 'before' and 'after'*. We then find that the statement $A_2$ is *after* $A_1$ means $A_2$ *is a point of the* $\alpha$*-cone of* $A_{1-}$, $A_2$ is *before* $A_1$ means $A_2$ *is a point of the* $\beta$*-cone of* $A_{1-}$.

The fundamental rules of the Conical Order of elements (points) will now sound:

1. If a point $A$ be a point of the $\alpha$-cone of a point $B$, the point $B$ is not a point of the $\alpha$-cone of $A$ and it is said to be a point of the $\beta$-cone of $A$.
2. If $A$ be any point, there is a point which is a point of the $\alpha$-cone of $A$ and also one which is a point of the $\beta$-cone of $A$.
3. If a point $A$ be a point of the $\alpha$-cone of $B$ there is a point which is both a point of the $\alpha$-cone of $B$ and a point of the $\beta$-cone of $A$.
4. If a point $B$ be a point of the $\alpha$-cone of $A$ and a point $C$ be a point of the $\alpha$-cone of $B$ the point $C$ is a point of the $\alpha$-cone of $A$.

His conclusion is that in this case we cannot say if $A$ is neither a point of the $\alpha$-cone of $B$ nor a point of the $\beta$-cone of $B$ that $A$ and $B$ are identical.

This only means, as the geometrical figure shows, that $B$ in this case lies *outside* the cone with *A* as vertex. It is evident that there are any amount of such points which consequently are not identical with *A*.

All these theses stand out as quite correct as they are statements directly based on the geometrical figures described by the author.

Robb's whole reasoning is, however, based on the fact that *he uses the words before and after on one hand to describe relations concerning our classical time concept and then on the other hand something quite different, the relations of separate points to certain geometrical diagrams* and having carried these two separate reasonings through *he applies the results reached in one reasoning to the other domain where the words have been attributed quite another meaning*. From a logical point of view a most remarkable and *impermissible manner of reasoning*.

The re-writing of the 'conical' rules which I have given above where the words *before* and *after* are *given their exact 'conical' meaning* shows that the results attained do not give the very least ground for any conclusions with regard to our time concept.

Robb's method of reasoning is one of the most sensational examples of the modern tendency to use words in two different meanings and then mixing up the results.

In order to illustrate and corroborate his ideas Robb takes up the experiment of light-ray exchange between distant points. He writes:

'Let us consider a flash of light or other electro-magnetic disturbance to be sent out from a particle *P* at an instant *A* to a separate particle *Q* not in contact with *P* and let the flash or disturbance be reflected back again directly to *P*.

'If the flash returns to *P* at an instant say *C* then *C* is after *A*. If it is granted that the flash sent out from *P* arrives at *Q* at a definite instant, say *B*, which is distinct from *A* and *C* it follows from the meaning of after that *B* is after *A* and *C* is after *B*.'

He continues:

'Now there are strong reasons for thinking that no influence or material particle could be sent out from *P* at the instant *A* so as to arrive at *Q* at any instant before *B*; and similarly there are strong reasons for thinking that no influence or material particle could be sent out from *P* at an instant after *A* so as to arrive at *Q* at the instant *B*.'





This supposition can shortly be expressed by saying that a light ray or 'another electro-magnetic disturbance' is the quickest means of communication between distant points that we know. This is indeed most probable but it is only a statement about our practical resources.

From this Robb concludes:

'If this be granted we see that any instant of the particle *P* which is after *A* and before *C* will according to our view of the matter be neither before nor after *B*.'

To this can first be remarked that the mere fact that it can be declared that the signal leaves *P* at the time *A*, arrives in *Q* at the time *B*, is reflected and returns to *P* at the time *C* necessarily presupposes as has been shown earlier that classical time *a priori* is reigning in the whole of the space round *P* and *Q*. Otherwise the declaration 'a ray goes from *P* to *Q* and back to *P*' lacks all meaning.

It should also be remarked that when Robb declares that '*B* is after *A*' and '*C* is after *B*' he must evidently base this on the concept of causality which requires that the arrival of the signal in *Q* at time *B* must be *after* the light flash in *P* at time *A* as judged from *P* and that the return of the ray to *P* at time *C* must be *after B* as judged from *P* as it is caused by the reflection in *Q*.

But having thus stated that Robb's whole reasoning is based on the presupposition—made unconsciously by him—that classical time is reigning in the whole of space there will always be *a priori* a moment in *P* which is simultaneous with a moment in *Q*, judged from *P* as well as judged from *Q*.

When we say that the signal goes from *P* to *Q* and back to *P* while the time in *P* changes from *A* to *C* and that the moment *B* in *Q* is 'after *A*' and 'before *C*', and all the moments between *A* and *C* in *P* are registered by a clock supposed to be placed in *P*, then we can say that all moments in *P* after *A* and before *C* correspond to a certain clock position in *P* and therefore the moment *B* in *Q* must correspond to one of these clock positions and thus also be 'neither before nor after the time *B*' which means according to classical time concept—also accepted by Robb for the singular point—that it is simultaneous with *B*. Contrary to Robb's reasonings but in accordance with presuppositions necessary also for him there *is* a moment in *P* after *B* and before *C* which is neither before nor after *B* but on this ground must, according to the classical time concept unconsciously accepted by Robb, be declared simultaneous with *B*.

The objections earlier raised against the constitution of time by light-ray exchange, and which show the necessity of presupposing classical *a priori* time to be reigning in the whole of space, thus strike the reasonings presented by Robb to the same extent. But if the classical time concept is also necessarily presupposed in Robb's reasonings his presentation does not give any contribution to the understanding of the relativity problem or of our time concept. But it is a most remarkable example of relativistic double-talk.

ERICH RUCKHABER: *Die Relativitätstheorie widerlegt durch das Widerspruchsprinzip*, 1931.

This paper presents a number of interesting points of view on the Theory and with some of them I can agree.

The author, however, extends his discussion to a very large number of epistemological principles on which our physical knowledge rests. He takes up a discussion on such relations as: Description—Explanation; Sense of contact—Sense of sight; the fundaments of the Euclidean concept of space and many other fundamental principles and thereby spreads the discussion out on an extremely wide front.

His chief argument is, however, presented with regard to the following case:

'A man travelling in a train drops a stone from the window of the carriage and sees it fall along a straight line. A man standing on the embankment sees the stone fall along a parabola. Both these views are, by Einstein, considered equally legitimate because no system of reference can pretend to have preference.'

According to Ruckhaber this is against what he calls the 'law of contradiction' which he expresses in the words:

'With regard to the falling stone two different trajectories cannot be expressed at the same time.'

Einstein's declaration that both views are legitimate is declared to be against this law and consequently on this ground Ruckhaber rejects the whole Theory. It is evident that Ruckhaber has overlooked that the falling stone in fact describes different trajectories in the two moving systems and that Einstein only declares that both descriptions are equally valid as they are referred to different systems of reference.

Einstein's standpoint in this connexion seems quite legitimate and in full accordance with classical view and it is not here that we meet the difficulties of the Theory. It is when Einstein declares that one





and the same ray of light should have *the same velocity* in all directions in two different Galilean systems of reference that the difficulty arises. Einstein has clearly realized the contradiction thus implied and has set himself the task to eliminate it by introducing a new time concept. It is on this latter point that the objections can be raised against his reasonings as being based on double meaning to the concept of time.

This has not been observed by Ruckhaber and his criticism therefore does not touch on the decisive point of the problem.

BERTRAND RUSSELL: *A.B.C. of Relativity*, Allen and Unwin, London, 1958.

Russell's presentation is in principle based on the ideas proclaimed and the results attained by other authors, especially Einstein. Their conclusions are accepted by him as established facts. He thus accepts the Michelson–Morley experiment as having shown that one and the same light ray should have the same velocity of propagation in all Galilean systems. He also assumes that clocks and measuring rods are affected by motion and concludes that distances in space like periods of time are in general 'not objective physical facts' but dependent upon the observer. Measurements of distances and of times are declared to be relative. He does not enter, however, on the question why these quantities should be considered relative.

There is, however, according to him, a 'physical fact' which can be inferred from the distance in time together with the distance in space. This inferred quantity is called the 'interval in space–time'. After voluble discussions how the 'interval' should be depicted geometrically he declares that it is obtained as follows:

'Take the square of the distance between the events and the square of the distance travelled by light in the time between the events. Subtract the lesser of these from the greater and the result is defined as the square of the "interval" between the events.'

If we then take for instance two events taking place in neighbouring points after a short lapse of time and call the 'interval' $I$, we find

$$I^2 = dx^2 + dy^2 + dz^2 - c^2t^2$$

This is exactly the greatness which Einstein denotes as the 'distance' between the adjacent events and which expression should remain unchanged when transformed to another Galilean system that is to

$$dx'^2 + dy'^2 + dz'^2 - c^2t'^2$$

which is possible *only by introducing a new symbol t′ for the time in the moving system.*

As is well known this transformation is attained with the Lorentz equations which are unreservedly accepted also by Russell. The new symbol $t'$ for time in the moving system is thus accepted by Russell without any remark. He does not even mention Einstein's fundamental reasoning on time and by which he defines the new time concept.

It may also be emphasized that Russell deals with the classical concepts as well as the new concept 'interval' in a rather summary way. Although he declares that distance in space in the classical sense between two points, and a period of time are *not* in themselves 'physical facts' he pretends that when they are *mathematically* combined as noted above the result the 'interval' becomes a 'physical fact'. It seems that this very remarkable declaration might well have deserved some comment and closer elucidation, but this is not given.

As Russell in his whole presentation builds on the formulae and declarations presented by Einstein and his followers *without any closer analysis we can state that he does not give any contribution to the understanding of the foundations of the Theory of Relativity.*

It may have been Russell's idea—as the title suggests—to give as popular a picture of the ideas of the Theory of Relativity with as little mathematical apparatus as possible, but the result is that his presentation has become much more vague and diffuse than for instance Einstein's own accounts. Through this vagueness Russell totally misses his aim and for the understanding of the foundations of the Theory of Relativity his presentations lack all interest.

HARALD K. SCHJELDERUP: 'The Theory of Relativity and its bearing upon epistemology', *Scandinavian Scientific Review*, I, 1, 1922.

Schjelderup gives a very extensive presentation and discussion of the Einstein ideas, but he has on all points unreservedly accepted Einstein's new ideas, formulae and conclusions, and he therefore does not in any way contribute to the analysis of the ultimate foundations of the Theory.

His presentation is consequently liable to all the objections I have raised earlier.





He winds up by declaring that the Theory has brought us important results from an epistemological point of view and sums up by declaring:

'that the Relativity Theory of Einstein in reality designates the consistent carrying through in physics of the two epistemological principles: The principles of continuity and observability.'

To this there is reason to make the following remarks.

When Einstein in the Special Theory denies the classical time concept outside the close vicinity of the observer this implies that there is no time relation between the observer and events in distant points and consequently *he cannot judge or register any event or procedure outside his vicinity.* Einstein's attempt to create by experiments a new time concept valid outside the close vicinity is, however, as shown earlier, impossible to carry through after the negation of classical time. The continuity of the time concept is thus eliminated by Einstein in the Special Theory

In the General Theory the time concept of an observer in a point is limited to that very point alone. In any other point, also in the very close vicinity, there is another time concept, and in this connexion Einstein does not even indicate any way of creating a new time concept. No event or procedure outside the point in question can therefore be put in time relation to the observer in this point.

The continuity of the time concept is thus here still more categorically negated.

With regard to the observability the following should be observed.

The calculations of the Special Theory are based on the hypothesis of constant velocity of a light ray in all inertial systems of reference, which implies the necessity of a new time concept. It has, however, *not* been shown by the relativists that their new time symbol can be given any physical meaning. It remains a mere mathematical construction and consequently cannot be observed.

Both the Special and the General Theory are based on the invariant transformation of the expression '$ds^2$' (see p. 79) characterized by four Gaussian co-ordinates, 'which have not the least direct physical significance'. Through mathematical calculations on the basis of these presupposed mathematical symbols and expressions of unknown physical meaning together with formulae from classical physics the relativists pretend to come to new symbols and expressions supposed to represent physical quantities that might be observed.

Any motivation for this most extravagant supposition, that calculations with mathematical symbols lacking all physical meaning can lead to the knowledge of new expressions representing physical quantities is *not* given. But as long as we ignore the physical meaning of the thus attained new symbols and mathematical expressions they remain unobservable.

The real epistemological results of these relativistic speculations are in direct contrast to the author's declaration therefore:

*The principles of continuity and observability are in the Theory of Relativity radically discarded.*

AUGUSTIN SESMAT: *Les Systèmes privilégiées de la Physique Relativiste*, Hermann & Co., Paris, 1936.

Sesmat gives a very detailed description of the evolution of the relativistic ideas, showing that many authors before Einstein have discussed the problem of 'absolute movement' and the possibility to eliminate the idea of an ether. He points out that some authors before Einstein among them Poincaré and Lorentz had accepted the idea of different time symbols, but have regarded them as fictitious. He then goes over to present the Einstein ideas on 'time' and here he follows the presentation in 'Electrodynamik'. He thus accepts Einstein's principle for the regulation of distant clocks through light-ray exchange. He then takes up the problem of finding the transformation equations from one Galilean system to another one with the condition of keeping the velocity of light constant in both systems and this naturally leads him to the Lorentz equations.

From then on his very extensive and detailed discussion of the relativity problems is wholly in conformity with the Einstein ideas. He only presents criticism with regard to some consequences of the Theory but none touching upon the fundamental ideas. For the judgement of the ultimate foundations of the Einstein Theory his very voluminous book therefore does not give any contribution.

L. SILBERSTEIN: *The Theory of Relativity*, Macmillan, London, 1914.

Silberstein gives a very detailed presentation of the relativity problems starting with classical relativity. When he comes to the Einstein ideas he quite correctly states that the fundament of these ideas is Einstein's discussion of time relation between distant points and he wholly accepts Einstein's ideas of establishing this relation by regulating clocks in the two points in relation to each other with the aid of light rays. He here follows Einstein's reasonings very faithfully and consequently arrives at the Lorentz equations of transformation.





From this on he bases all his reasonings on these equations and the formulae derived with their aid. Consequently he does not give any new aspects on the fundamental problems of the Theory.

J-L. SYNGE: *Relativity, The Special Theory*, Amsterdam, 1956.

This work is wholly based on the mathematical results drawn by Einstein and others from his fundamental ideas and from their declared formulae and gives no contribution to the deduction of the Theory.

H. THIRRING: *Handbuch der Physik*, Vol. IV, 1929, p. 149.

Thirring declares that the epistemological contribution of the Theory of Relativity consists in having led to an analysis of concepts. This analysis is supposed to have brought the Maxwell theory of electro-magnetic phenomena and the classical Principle of Relativity in agreement and this is attained by giving up the independence of our concepts of time and space and their integration in a superior concept the 'World'.

After having discussed different theories of light he concludes that experiments have proved that the propagation of light in the system for which we accept the Maxwell–Lorentz electrodynamics to be valid is independent of the motion of the light-emitting source. He denotes this as the Principle of Constant Velocity of Light (which can be denoted as the classical principle).

He then states in full accordance with Einstein that the application of the classical principle of relativity to the former principle leads to a contradiction.

Thirring bases the revision of the time concept and the creation of a new time concept, wholly on Einstein's second definition of simultaneity, the mid-point co-observation. As shown earlier the identification of the incoming rays to the observer as having been created by the events in the distant points necessarily presupposes the possibility of putting events in distant points in time relation to each other and this in turn necessitates the acceptance of classical time concept. *Without accepting classical* a priori *time neither mid-point co-observation nor regulation of clocks can be carried through, and the constitution of the new concept cannot be carried through. The above-mentioned contradiction remains unaffected.*

All the objections earlier presented against Einstein's reasonings can be brought against the Thirring reasonings to their full extent.

Thirring's treatment of the Theory is wholly founded on the Lorentz transformation equations and follows the same lines as other textbooks such as Pauli's and von Laue's. His presentation is thus a general synopsis of what has been brought forward in other works and does not give any new points of view on the foundations of the Theory.

HAKAN TÖRNEBOHM: *A Logical Analysis of the Theory of Relativity*, Almqvist & Wiksell, Stockholm, 1952.

This is one of the most circumstantial presentations of the Theory of Relativity.

Törnebohm starts by discussing very closely the results of the Michelson–Morley experiment and sums up by declaring (p. 18):

'The conclusion may be stated thus:

I. The mean velocity of light travelling away from and returning back to a system *A* is the same for all directions if *A* is any inertial frame of reference.

II. A light wave is always centred on the world-line of its source if the source is at rest in an inertial frame of reference.

'These two statements are equivalent if, and only if, certain conventions as to simultaneity of distant events are adopted. The first statement contains only observable terms, the latter does also contain certain definitory elements which are characteristic of the Special Theory of Relativity, but which are not enforced upon the physicist as an outcome of observed facts.

'The statements I and II entail the statement III.

III. The velocity of light is the same in all directions for an observer using an inertial frame of reference.'

It is to be observed that the third conclusion which is the one Einstein arrives at by extending the Newton principle of relativity to electro-magnetic phenomena implies—as Einstein has pointed out—a contradiction, which he undertakes to eliminate by his analysis of time.

Törnebohm does *not* enter on this analysis but takes up a discussion of 'time-order' on his own lines and starts by trying to establish a relation between time in distant points. He writes (p. 19):

'Suppose that we have clocks at *A* and *B* running at the same rate when compared at the same place. We want to synchronize the clocks when they are separated from each other. We say that two clocks are identical if they run at the same rate if they are compared





at the same place. I will call what happens to a clock when it has just completed a period a "clock-event". The clock-events are supposedly of very short duration, we may thus characterize them as point-events. We may assign numbers to the clock-events at *A* and *B*.

'*We mean by synchronization a physical rule for assigning the same number to a clock-event at A and a clock-event at B.*'

Törnebohm's characterization of clocks and time measuring in a point is in agreement with Einstein's ideas. The 'clock-events' or 'point-events' he speaks of correspond to Einstein's 'pointer positions'.

His rule of action for the purpose of "synchronization" is remarkable from many points of view. First we can note that Törnebohm talks about synchronization of clocks in distant points without giving a definition of what we are to understand by 'synchronization' or 'synchronically running clocks'. We are therefore obliged to fall back on the classical meaning of the words. With 'synchronically running clocks' we must thus understand clocks which take up the same pointer position at *a priori* simultaneous moments and undergo same change of pointer position in the same lapse of time, which is all quite clear as long as we speak of clocks standing in the close neighbourhood of each other where classical time is supposed to reign also according to relativistic views. Therefore 'synchronization' must evidently mean a method of bringing clocks to 'run synchronically'. The question is thus how Törnebohm's rules serve this purpose.

It is first to be noted, that the rule *only* speaks about one event in *A* and one event in *B* independent of each other. Let us suppose that we have a clock in *A* and one in *B* running quite independently of each other. Let *A*—as Törnebohm proposes—start assigning successive numbers, starting from zero, to the point events of his clock and let him at the same time send a message (e.g. a light ray) to *B*. On arrival of this message *B* is supposed to likewise assign successive numbers, starting from zero, to the point events of his clock. Although the clocks have started at moments without known time relation to each other and are running independently we can ascertain that there will sooner or later be a clock-point in *B* which carries same numbers as a clock-point in *A*, and from then on there will be clock-points in both points which carry same number. This implies, however, neither any relation between the point events carrying the same number nor any relation between the running of the clocks. The way the clock in *B* runs remains totally unknown to *A*.

But as they fulfil Törnebohm's rule for assigning numbers to the clock events they should be said to 'run synchronically'. We thus arrive very far from the classical meaning of the words. There is no known relation between the positions of the clocks.

With the meaning of the words which is at the bottom of Törnebohm's reasonings, we come to the conclusion that *all* clocks whatever their position and way of running is will be 'synchronized' with each other—independently of all physical rules—*the moment successive numbers started from zero are assigned to their clock events.*

This is most remarkable and probably for the relativist also somewhat surprising result. The reason why I have carried this analysis through is that we meet here a manifest illustration of the loose and casual way in which many relativists use words and expressions which have by tradition a certain and generally very fixed meaning, and this is mostly done without acute definition which leads to the result that the words are in reality attributed a meaning which the relativists do not realize themselves and which is often altogether absurd.

Törnebohm had, in all probability, the intention to give a rule by which the clocks in the distant points should be put in relation to each other so that time-observations in the two points could be compared. For this purpose he first suggests that the 'synchronization' should be attained by 'Transport-Synchronization'.

'Let $C$ be a clock which runs at the same rate as the $A$-clock. Let $C$ be synchronized with the $A$-clock when it leaves the World-line $A$. Then the Transport-rule asserts that the $B$-clock and the $A$-clock are synchronized if the $B$-clock is synchronized with the $C$-clock after its arrival at the $Z$-line.'

As mentioned above Törnebohm has at this point not yet given any new definition of 'synchronicity' or 'running synchronically' and consequently not either for 'synchronization', and we therefore must fall back on the classical meaning where synchronical clocks means clocks which take same pointer position in *a priori* same moments.

According to 'the transport rule' the clock $C$ is brought to 'run synchronically' with the clock $A$ when they are side by side which evidently has the classical meaning as classical time is supposed to reign in the limited room round the two neighbouring clocks. $C$ is then brought to $B$ and clock $B$ is 'synchronized' with $C$. Then the clock $B$ is declared to be 'synchronized' with clock $A$. But as we only have the classical meaning for the expressions 'synchronized', 'running synchronically' this implies that the clocks $C$ and $A$, although in distant points, 'take up same pointer position in the





same moment'. *But this can have a meaning only if we presume that classical* a priori *time is reigning in the whole system of reference.*

As no other relation has been established between time in distant points the declaration is otherwise meaningless. Törnebohm has here unconsciously presupposed time in its classical *a priori* meaning to be reigning in the whole of his system, just as this is the case with Einstein.

The 'transport rule' has, however, a minor interest as Törnebohm himself declares that it is ambiguous and not suitable. But that is done on quite other grounds. The reason why I have analysed the rule and presented its real content is that I have found it an interesting illustration of the fact that the relativists practically always fall back unconsciously on the classical views and concepts in spite of having negated them the moment before.

Törnebohm then turns to light-ray synchronization just as Einstein does. He declares that the ideas behind signal synchronization are very simple. He writes:

'We want to synchronize clocks at $A$ and $B$. We send a signal from $A$ when the $A$-clock reads $t_1$. The signal travels to $B$ and is reflected from $B$ and arrives back at $A$ when the $A$-clock reads $t_2$.

'We cannot know at what time in the $A$-system the signal arrives at $B$ because that would require that we knew the velocity of the signal from $A$ to $B$. But all we can know is the mean velocity on the way $ABA$. On the assumption that the signal has a finite velocity, all we can assume is that the $A$-time $t'$ of the event $e'$ of the reflection of the signal at $B$ is between $t_1$ and $t_2$, limits excluded.'

According to this declaration there is an $A$-time $t'$ which is the $A$-time of the event $e'$ in $B$ and this time is between $t_1$ and $t_2$. This is, however, a most typically classical way of reasoning. The fact that the event $e'$ in $B$ is supposed to have an $A$-time $t'$ can only have a meaning on the basis of the classical time concept according to which there is *a priori* a moment in $A$ which corresponds to the moment of $e'$ in $B$ and which two moments we call simultaneous in the classical sense. Törnebohm has through these reasonings—although probably unconsciously—accepted the classical time concept to be reigning for the space round $A$ and $B$ and as they are arbitrarily chosen this implies that the classical time concept is tacitly accepted for the whole of space.

All the arguments earlier raised against Einstein's reasonings can also be applied here. If the classical time concept and all concepts derived from it are, according to Einstein's declaration, really rejected, which is at the bottom of all his relativistic reasonings the statement: 'A ray goes from $A$ at the time $t_1$ to $B$, is reflected at $B$ and returns to $A$ at time $t_2$' lacks all meaning, on the ground that in order to identify the incoming ray at $A$ (time $t_2$) as being the ray sent out at $t_1$ we must be able to put departure in $A$, reflection in $B$ and return in $A$ in causal relation to each other and this is only possible if we can presuppose a time relation *a priori* between cause and effect, which is impossible after rejection of classical time.

Furthermore even the simple statement: 'A ray goes from $A$ to the distant point $B$' is meaningless without an *a priori* time relation. This being the case Törnebohm's whole reasoning about signal synchronization must be categorically rejected.

It is of interest to note that in Törnebohm's reasonings the word simultaneous is ambiguous contrary to classical view where the concept is unequivocal: There can only be one moment in $A$ simultaneous with a certain moment in $B$.

We have found that Törnebohm's characterization of $t'$ as 'the $A$-time of the event $e'$ in $B$' necessarily means—if it has to mean anything at all—that the two events $A$-time $t'$ and $e'$ are simultaneous in the classical sense. Later Törnebohm calls the departure of the signal from $A$ $(e_A)_1$ and the return of the signal $(e_A)_2$. The arrival of the signal in $B$ is called $(e_B)$ (earlier called $e'$), Törnebohm then declares that 'with respect to a given type of signals any event at $A$ between $(e_A)_1$ and $(e_A)_2$ may be defined to be simultaneous with $(e_B)$'.

But whatever be the 'type of signal' chosen it remains that it is supposed to start, be reflected and come back at the unequivocal moments characterized by $(e_A)_1$, $(e_A)_2$ and $(e_B)$ and on these bases it is declared that *any* moment in $A$ between the $(e_A)_1$ and $(e_A)_2$ 'can be defined as simultaneous' with $(e_B)$. It is with the utmost excitement one looks forward to such a definition, but it is not given.

Törnebohm's only reason for rejecting the classical meaning of simultaneity is the supposition that classical time concept should necessarily presuppose the existence of instantaneous signals to go between the points in question. This presumption with regard to classical time has been refuted earlier.

The word 'simultaneous' thus has an altogether unsettled meaning in Törnebohm's language. But as we have seen above that Törnebohm has through his fundamental statements already—although unconsciously—accepted classical *a priori* time concept for the whole of space and consequently also an unequivocal meaning to the word 'simultaneous' his whole reasoning is based on two contradictory meanings to this word and this makes it necessary to reject





it categorically. It has only interest as an example of the ever-recurring relativistic double-talk.

All Törnebohm's following reasonings are based on the declaration that 'The velocity of light has the same value in all inertial frames of reference' which leads as shown to the contradiction which should be eliminated by a new time concept. As no such concept is given by Törnebohm the contradiction remains unmitigated. Mathematically this declaration naturally leads him to the Lorentz transformation equations which he accepts unreservedly.

All the objections raised against Einstein's reasonings thus strike also this presentation and we can only state that Törnebohm *gives no contribution beyond Einstein's to the understanding of the foundations of the Theory.*

HERMANN WEYL: *Raum—Zeit—Materie*, Springer, Berlin, 1918.

In the introduction Weyl treats the problem of measuring time intervals and gives in this connexion a definition of the clock.

'If an isolated Physical system (uninfluenced from without), returns to the same position in which it found itself at an earlier stage, then the same succession of positions will be repeated and thus the procedure is a cyclic one. Such a system is called a clock. Each period (of the procedure) takes the same time.'[1]

This definition of a clock is in full accordance with Einstein's ideas although the latter goes out from the assumption that the meaning of a clock is supposed to be known and accepted beforehand.[2]

But what must be more closely scrutinized is what Weyl understands with the latter sentence: 'Each period takes the same time.' This expression intimates that the time required by each period should prove the same, which necessarily supposes that the time intervals of the periods are measured with the aid of *some other time-measuring instrument*, say a clock showing hours, minutes and seconds. If that were the meaning of the statement in question it would imply that the definition of the clock would presuppose the concept of 'clock'.

If on the other hand the statement: 'Each period takes the same

[1] *Kehrt ein vollständig isoliertes (keine Einwirkung von aussen erfahrendes) physikalisches System einmal genau zu demselben Zustand zurück, in dem es sich bereits in einem früheren Moment befand, so wiederholt sich von da ab die gleiche zeitliche Zustandsfolge, und der Vorgang ist ein zyklischer. Ein solches System nennen wir allgemein eine Uhr. Jede Periode hat die gleiche Zeitdauer.*

[2] Compare 'Elektrodynamic', pp. 28 and 39, and '*Relativity*', p. 24.

time' does not presuppose such a comparison with the movement of another system, then the proceeding in question is in itself our time-indicating process. Each period described by the system *constitutes* a unit of time. Each period *is* a time unit. The statement is thus reduced to the following: Each period of the System takes a time unit, that is corresponds to a period. Expressed shorter: 'Each period of the system is equal to a period of the system.' We find ourselves also here face to face with an identity superfluous to repeat.

Weyl then goes on to discuss the measuring of time and the question of relation between the time of an event in two different systems of co-ordinates in a system of reference at rest and gives formulae for this transformation.

He goes out from the possibility of discerning time points (*Zeitpunkten*), what we have above called 'events' or 'point events'. Two such points, $O$ and $E$, characterize an 'interval of time' (*Zeitstrecke*) called $OE$. We can always find another 'time point' $P$ so that

$$OP = t\,OE$$

If we consider $OE$ as the unit of time interval we can call $P$ the 'time point $t$' or we can say that $t$ is the abscissa of $P$.

The question then raised is: What rule of connexion can be established between the co-ordinates of one and the same 'time point' $P$ in two different systems of co-ordinates?

The transformation equation is declared to be $t = at' + b$ where $t$ and $t'$ are the time co-ordinates of the event $P$ in the two systems and where $a$ and $b$ are constants. And this transformation can in principle be applied for *any two systems at rest* in relation to each other. The consequence drawn from this is that with regard to systems of co-ordinates for space and time the realities of the physical world can in all these attributions be expressed by numbers.[1]

To this conclusion any objection can hardly be made.

It is later, in chapter III, that he comes to the relation between the co-ordinates of an event in a system *moving with constant velocity with regard to another system at rest* and he raises the demand that the expression $x^2 + y^2 + z^2 - c^2t^2$ for the system at rest should be transformed *invariantly* into the variables $x'$, $y'$, $z'$, $t'$ for the moving system. This can only be attained with the Lorentz equations. *Thereby Weyl has unreservedly accepted the idea that time in the*

[1] *Auf Grund eines Koordinalensystem für Raum und Zeit lasst sich auch das physikalisch Reale in der Welt nach allen seinen Bestimmungen begrifflich durch Zahlen festlegen.*





*moving system should be represented by another symbol than* t *and this is done without discussion of the meaning of* t′ *in relation to* t *and thereby in relation to classical time.*

His whole reasoning is thus purely mathematical and therefore stands in contrast to Einstein's treatment. Einstein is fully aware of the necessity of analysing the meaning of the new time symbol $t'$ which takes other values than $t$, but this is not done by Weyl.

By Weyl's acceptance of the new symbol $t'$ for time in the moving system he has distinctly overthrown the classical time concept expressed by $t' = t$ and *this is done without any explanation.* There are therefore strong reasons to expect that Weyl has not himself realized how deeply he strikes at the fundaments of our physical understanding. From this point of view it has great interest to read the winding up of his introductory chapter:

'All beginnings are somewhat dusky, especially for the mathematician who operates in his elaborate science in a strict and formal way with his concepts. It is necessary from time to time to be reminded that the origins point back into more sombre depths than he can realize with his methods. Beyond all detailed knowledge remains the task *of understanding.* In spite of the discouraging oscillation of philosophy from one system to another we cannot refrain from this lest our knowledge should turn into a chaos of senselessness.'[1]

With regard to the fact that Weyl accepts unreservedly the new time concept represented by $t'$ different from $t$ without any closer analysis or motivation, I find that I could hardly have given my criticism of his summary and superficial methods a more explicit and striking formulation than he has here done himself. If we do not explain our concepts, especially new ones, so that we can fathom them ('*begreifen*') we soon land in a meaningless chaos.

From this point of view Weyl's whole treatment of the Theory is based on the formulae presented by Einstein, and *he does not in the least penetrate the problem of the meaning of the new time concept.*

We can therefore state that *Weyl does not give any contributions whatever to the understanding of the foundations of the Theory of Relativity beyond what Einstein gives.*

[1] Translation: '*Alle Anfänge sind dunkel. Gerade dem Mathematiker, der in seiner ausgebildeten Wissenschaft in strenger und formaler Weise mit seinen Begriffen operiert, tut es Not, von Zeit zu Zeit daran erinnert zu werden, dass die Ursprünge in dunklere Tiefen zurückweisen, als er mit seinen Methoden zu erfassen vermag. Jenseits alles Einzelwissens bleibt die Aufgabe,* zu begreifen. *Trotz des entmutigenden Hin- und Herschwankens der Philosophie von System zu System können wir nicht darauf verzichten, wenn sich nicht Erkenntnis in ein sinnloses Chaos verwandeln soll.*'

A. N. WHITEHEAD: *The Principle of Relativity, with Applications to Physical science*, Cambridge University Press, 1929.

In this work Whitehead enters very deeply on some principles of physical science such as 'spatio-temporal relationships', 'time and causality', 'objects and recognition'. On some special points he announces dissension from Einstein's views. He does not, however, in any connexion take up the problem of how Einstein constitutes his new time concept which is the basis of his whole theory.

On the contrary Whitehead declares in his conclusion (p. 88):

'The course of my argument has led me to couple my allusions to Einstein with some criticism. But that does not in any way represent my attitude towards him. My whole course of thought presupposes the magnificent stroke of genius by which Einstein and Minkowski assimilated time and space.'

It is in full consequence with this declaration that the following mathematical treatment of the relativity problems is wholly based on the Einstein–Minkowski mathematical formulae.

In two other books:

*Science and the Modern World*, 1926; *Process and Reality*, 1929

he develops very thoroughly his views on the fundamental principles of science and specially on the concept of time but does not enter on the relativity problems except on one point. In the last chapter of the second book (p. 496) where he treats the problem 'God and the World' he makes the following statement:

'But the principle of universal relativity is not to be stopped at the consequent nature of God.' But this has evidently no consequences for the question of what we are to understand by relativity in physics.

The problems treated by Whitehead in the above books have been taken up for discussion by

WILLIAM W. HAMMERSCHMIDT: *Whitehead's Philosophy of Time*, New York, 1947.

Hammerschmidt takes up Whitehead's ideas on time on a very broad front and gives a very elucidating exposure of these intricate problems but neither Whitehead nor Hammerschmidt derives any





consequences from these reasonings with regard to the Principle of Relativity.

With regard to this we can state that Whitehead, although he discusses very deeply a number of fundamental problems for physical science, does *not* give any contribution to the understanding of the basic idea of Einstein's Theory of Relativity, the new time concept.

G. I. WHITROW: *The Natural Philosophy of Time*, Nelson, London, 1961.

This most elaborate book treats with such problems as 'Universal Time', 'Individual Time', 'Mathematical Time', and from these arrives at 'Relativistic Time'.

Although these first three parts give an interesting insight in the different views on time measurement and the psychology of our time concept through earlier periods we can abstract from them as they do not touch on the problem taken up by Einstein and his solution of the relativity problem by establishing a new time concept.

With regard to this, Whitrow states that the problem Einstein had to face was the following (p. 183):

'Given an observer with a temporary experience and a clock which measures time intervals in this experience, how can he determine the times of distant events?'

It is assumed that an observer in a point $A$ can register on a clock the precise instant of occurrence of the emission or reception of a signal in $A$.

Whitrow continues (p. 186):

'We consider next an event $E_B$ which occurs in general, externally to $A$. We assume for the purpose of theoretical analyses, that it occurs at some mechanism $B$ which can reflect instantaneously signals received from $A$. We shall associate with the distant event $E_B$ two distinct events $E_1$, $E_2$ occurring at $A$, $E_1$ being the emission of a signal by $A$ which arrives at $B$ at the event $E_B$ and $E_2$ being the reception by $A$ of a signal which is emitted by $B$ at the event $E_B$.'

$E_1$ is supposed to take place at the $A$-time $t_1$, $E_2$ at the $A$-time $t_2$. $t_B$ is the time *assigned by A* to the event $E_B$ and $r$ is the distance between $E_1$ and $E_B$ and also between $E_B$ and $E_1$. $t_B$ is later called $t$. The problem is to find relation between $t$, $t'$ and $t^2$.

Whitrow first presents seven axioms which are to be the foundation of his discussion. As they can all be considered as tacitly presupposed also in Einstein's reasonings we need not enter on them. After most detailed and subtle discussions he arrives as could be expected at Einstein's exact results (p. 195)

$$t = \tfrac{1}{2}(t_1 + t_2)$$
$$r = \tfrac{1}{2}c(t_2 - t_1)$$

Where $c$ is the velocity of light with regard to the fact that the signals are supposed to be light rays wandering with this velocity.

In spite of his extremely detailed discussion of the 'Einstein Problem' Whitrow totally overlooks the fundamental difficulty—created by Einstein's rejection of classical *a priori* time—how the observer in $A$ can be able to identify for instance the light ray coming in at time $t_2$ as the same light ray as having been created by him at the time $t_1$ and which is supposed to have been reflected at $B$.

The proposition that this is the case implies that the light ray has moved from $A$ to $B$ and back to $A$ while the clock in $A$ changes from position $t_1$ to $t_2$. As the light flash in $A$ at $t_1$ causes the arrival of the ray in $B$ at $t$, $t$ must *as judged from A* be after $t_1$ and as the arrival of the ray in $A$ at $t_2$ is supposed to be caused by the reflection in $B$ at $t_1$ this moment must *as judged from A* be before $t_2$. The moment $t$ is thus *judged from A* after $t_1$ and before $t_2$. But all such moments are represented by clock positions in $A$ between $t_1$ and $t_2$ and $t$ is therefore necessarily *a priori* simultaneous with a clock position say $t_0$ in $A$ in the classical sense of the word. We find that exactly as in our analysis of Einstein's presentation the exchange of light-ray signals can *only* be performed on the basis of the classical time concept presupposed to be reigning in the whole system of reference in question.

We can also here present the fundamental objection that the proposition 'A ray goes from $A$ to $B$' has no meaning outside the close vicinity of $A$ when we have negated all time relations between $A$ and any point outside its close vicinity. Also this makes the light-ray regulation impossible.

We come to the same conclusion as with regard to Einstein's reasonings that the exchange of light-ray signals necessarily presupposes the assumption of classical time reigning *a priori* in the whole system. There is therefore no meaning to create a new time concept unless we want to give the word 'time' two different meanings.

All the following reasonings in Whitrow's book are with regard to the physical and mathematical side of the relativity problems based all through on the Einstein ideas and formulae and his book therefore gives no contribution of its own to the understanding of the Theory of Relativity.





## SUMMARY OF THE REVIEW OF RELATIVISTIC LITERATURE

### ADHERENTS

The most striking fact that stands out from this scrutiny of the presentations of adherents of the Theory, other than Einstein, is how superficially practically all of them have treated the fundamental problem, the definition of the new time concept. These other authors accept without reserve and mostly without discussion Einstein's introduction of the new time symbol $t'$ for time in the moving Galilean system different from the time symbol $t$ in the system of reference considered at rest.

They also accept unreservedly the relation between the two time symbols as expressed by the Lorentz transformation equations.

Practically the only author who has entered on a more elaborate analysis of Einstein's reasonings on the new time concept is Bergson. But after having presented a partly very destructive criticism of Einstein's second rule for creating a new time concept, he suddenly turns round and without closer motivation accepts practically all Einstein's other ideas.

*Consequently it can be stated that Einstein is above all the one who has most distinctly and correctly stated the problem which is the basis of the whole theory: The creation of the new time concept, which he attempts to attain with the aid of light-ray regulation, and mid-point co-observation. The rejection of classical time which is his starting point, excludes, however, the possibility of performing the experiments necessary for the establishing of the new time concept. The Relativity Theory falls on its own inherent contradiction.*

The dominating, not to say unique, position Einstein holds in the fundamental discussion of the Theory makes it in fact superfluous to take presentations of other adherents into consideration. The reason why I have, however, undertaken the above wide scrutiny of the literature on the subject is the ever-occurring rejoinder from the relativists that the correct presentation of the Theory should be 'found somewhere else'. All such references can be categorically turned down.

### OPPONENTS

The main problem which the three authors H. Dingle, G. von Gleich, and K. Kroman take up is the question what we are to understand by the results attained with the transformation equations and their derivatives and to what extent the symbols and equations really represent physical facts and their relations.

Although I can on most points wholly agree with them in their criticism and objections, I do it mainly for other reasons. The ultimate presupposition to both the Special and the General Theory of Relativity is the possibility of establishing time relation between distant points which I have shown to be impossible after the rejection of classical time concept. This cardinal point of view for the judgement of the Theory is, however, not urged by the named authors. They occupy themselves mostly with the supposed experimental corroborations of the Theory, which they mean can be explained otherwise and also consider the formulae as mere mathematical constructions. Dingle's opposition in his latter papers is directed against certain formulae of which we can, however, say, with regard to their deduction, that they lack all known physical meaning.

E. Ruckhaber's objections go alongside the problem that Einstein has raised.

The main value of these works is the fact that they show that there are scientists who have not unreservedly and unhesitatingly accepted Einstein's extravagant ideas.

With regard to the criticisms presented by Axel Hägerström and Adolph Phalén I refer to my statements above.



# 8

# CONCLUSION

The fundamental principle of the Theory of Relativity is that the classical (Newtonian) Principle of Relativity for mechanics should be extended to be valid also for electro-magnetic phenomena.

This implies that one and the same ray of light should have the same velocity in two different systems of reference in motion in relation to each other. Since this leads to a contradiction, Einstein undertakes to eliminate this by introducing a new time concept.

He rejects the classical time concept, which presupposes time reigning *a priori*, uniformly for all systems of reference in the whole of space, mathematically expressed by the equation $t' = t$, for any two systems in motion in relation to each other. In this way he makes the analysis of the time concept the ultimate basis of the whole Theory.

In his presentations of the Special Theory of Relativity Einstein accepts classical *a priori* time concept to be reigning in the close vicinity of any observer and the possibility for the observer of registering on a clock close by, the time of any event in this limited surrounding. But he denies any *a priori* time relation between events in *distant* points. The creation of a time concept for distant events should be attained by light-ray regulation of clocks in the distant points.

Without a generally valid time concept an observer can, however, say nothing with regard to the time of an event or the propagation of a process *outside* his close vicinity. That would be putting the event or process in time relation to himself. He can only study processes, for instance the propagation of a light ray *within* this limited room, where classical time is reigning.

For an observer in $A$ to say that a ray goes from himself to a distant observer $B$, is reflected there and returns to $A$ is, with the lack of a common time concept, absolutely meaningless, because it presupposes a time relation between the process outside the close vicinity and himself. Also in order to put the events outside and in the close vicinity of the observer, in causal relation to each other which is necessary in order to identify the rays we must put them in time relation.

Also, the characterization of the motion of a system of reference in relation to the system of reference where the observer is supposed to be at rest, is impossible outside the close vicinity of the observer. This characterization is supposed to be possible on the basis of light-ray regulation of clocks and thereby of time in distant points. But the Einstein light-ray regulation of distant clocks *has* never been performed and *will* never be performed as it *cannot* be performed on the basis of his rejection of classical time concept.

*The Einstein time concept is and will therefore remain a phantom, an arbitrary mathematical symbol without known physical meaning.*

The only time concept that remains is the classical one—necessarily but unconsciously—presupposed also by Einstein in his reasonings.

The transformation equations named after Lorentz but definitely presented in their correct form by Einstein have been framed by the latter to express the invariance of the velocity of light for all Galilean systems of reference, and since this implies the contradiction which Einstein has tried, but failed to eliminate, the contradiction remains unmitigated and the transformation equations must therefore be categorically rejected.

Also in the General Theory of Relativity the establishing of a new time concept presupposes the possibility of light-ray regulation and this is just as impossible there as in the Special Theory. A new time concept cannot be defined on Einstein's premisses and we must also here fall back on the classical time concept expressed by $t' = t$, which in turn bereaves the formulae of the General Theory of Relativity the meaning attributed to them. Thus the invariance of the quantity '*ds*', which is one of the fundamental ideas of the General Theory, cannot be upheld.

Neither in the Special nor in the General Theory can we say if in principle the new symbols attained with the fundamental equations *have* a physical meaning and in that case *what* their physical meaning is. *They are in principle only the result of mathematical constructions.*

With regard to the deduced secondary formulae of the Theory of Relativity we can state that if we ignore their untenable deduction they *can have a meaning and be correct* as expressions of relations between certain physical quantities since the contained symbols have a known meaning. Thus the formulae for mass and energy, for red shift of spectral lines, for deflexion of light rays passing close to the sun, and the precession of perihelion of Mercury *can independently of their deduction—which is untenable—numerically give a correct picture of the phenomena in question.* This on the ground that the attained results express relations between physical quantities of





known meaning, and by the by they differ in most cases very little from classical views.

The corroboration of the secondary formulae can *not*, however, with regard to the untenability of their deduction be adduced in favour of the Theory.

In his reasonings on the concept of 'simultaneity' Einstein disregards—probably unconsciously—his own declared presuppositions and falls back on classical lines of thought, which leads him to results, *contrary* to his own fundamental declarations, but *in full accordance* with classical view. The result he proclaims, 'the relativity of simultaneity', is due merely to the attribution of a double-meaning to the word 'simultaneity'.

The Einstein extension of the classical Principle of Relativity to electro-magnetic phenomena thus either puts us face to face with contradiction or leads us to an ambiguous use of words and concepts, which results in statements that lack all meaning. We are therefore in principle obliged to go back to prerelativistic views. As a consequence we can state that the vast amount of relativistic literature with its beautiful and complicated formulae but lacking all known physical meaning can be totally disregarded and deleted.

Many of the most sensational consequences drawn from the formulae, such as the idea that a travelling person ages more slowly than one remaining at rest, is due to the attribution of two different meanings to the word 'time', and must be treated as mere nonsense. The two travellers measure time in different units and will therefore naturally come to different results.

Such crushing consequences of this investigation may at first seem incredible. But we must consider that the concepts denied—the time concept and its derivatives—are so extremely fundamental for our whole world of thought that their elimination or remoulding means a revolution in our world of thought of hardly fathomable extent. This is what the relativists have *not* realized. The result is that their negation of classical concepts is absolutely disastrous for their own reasonings.

I am fully aware, and it is also my ever-recurring experience, that the answer to all criticism of the Theory of Relativity from its adherents is that the critic has 'not grasped' the Theory or 'misunderstood' it. This is a most pitiful argument. The objections I have raised is that Einstein has overlooked the disastrous consequences of his own presuppositions and consequently applies concepts and modes of reasoning which he has in principle rejected the moment before. For this standpoint I have given extensive and detailed motivation. Such criticism is entitled to serious treatment. But it is invariably met with casual, offhand and sweeping accusation from the relativists of 'misinterpretation' and 'misunderstanding' and this is practically always done *without* motivation, *without* defining *what* has been misunderstood and *how* it should be understood.

With regard to the investigation I have here presented I maintain that whosoever from now upholds the relativistic ideas or applies the fundamental relativistic formulae as representing relations between physical quantites, without regarding and refuting my above criticism of the Theory, makes himself liable to the accusation of grave intellectual laxity.

I do not hesitate to declare as a result of my investigation the opinion that Einstein's Theory of Relativity is not only among the most sensational fancies, but also one of the most serious logical incoherencies in the history of science.[1]

[1] I have met the question from a friend, how I—an industrialist—could imagine myself able to correct some of the most prominent scientists of our time. My answer was that the recipe is very simple:
One spoonful of logic
One spoonful of common sense
One spoonful of impudence
and a gallon of intellectual passion.



# APPENDIX

## SOME HISTORICAL, PSYCHOLOGICAL AND OTHER REFLECTIONS ON THE THEORY OF RELATIVITY

*The evolution of the mathematical aspects*

The problems of electro-magnetic phenomena were subject to much study and consideration at the end of last and the beginning of this century. Some of the most important contributions beside Einstein and of earlier date were those given by H. A. Lorentz and Henri Poincaré.

An interesting study of the evolution of the relativistic ideas and the contributions of the named persons has been given by G. H. Keswani.[1]

He takes up the question:

'Who used and discussed the phrase "The Principle of Relativity" first in the sense in which we understand it in physics today?'

According to Keswani, Henri Poincaré was the first to use the expression in *Science et Hypothèse* of 1902. He uses the expression 'to signify that it is possible to ascertain only the relative motion of bodies'. He also declares that there is no 'absolute time'. In a later paper[2] he describes a method of regulating clocks in distant points with the aid of light-rays and this is discussed both for clocks in a system at rest and for a moving system and he admits that in the latter case we do not arrive at the 'true time' but 'what we may call the local time'. This is, however, necessarily done on the basis of classical time reigning universally in both systems since no declaration to the contrary is made. As Poincaré does not negate classical time, this leaves him with two different meanings to the word 'time' for an observer. His main conclusion is that the observer 'will have no means of knowing whether he is at rest or in absolute motion'.

Keswani sums up his very extensive discussion of Poincaré's contributions thus:

'It is therefore correct to assume that Einstein learnt the Principle of Relativity from Poincaré.'

With regard to Lorentz, Keswani points out that his most important

[1] 'Origin and concept of Relativity', *The British Journal for the Philosophy of Science*, XV, *60*, p. 286, 1965, and XVI, *61*, p. 19, 1966.

[2] Address before 'The International Congress of Arts and Sciences' at St Louis, U.S.A., published in *The Monist*, 15: 1, January 1905, and in *Bull. des Sciences Math.*, *28*, 1904.

work on these problems preceding Einstein's fundamental paper of 1905, was published in the spring of 1904.[1]

Keswani raises the question: 'Was Einstein aware of Lorentzs' memoir of 1904?' and comes to the conclusion that Einstein most probably had known of this paper. As evidence contradicting this supposition is a letter written by Einstein only two months before his death in June 1955, where he states himself that he knew only Lorentz's important work of 1895, but not Lorentz's later work nor the consecutive investigation of Poincaré. 'In this sense my work of 1905 was independent.'

This problem of priority has, however, quite another aspect as pointed out by Herbert Dingle.[2] Admitting that Keswani's papers 'have a vital bearing on problems of current concern', Dingle, however, maintains

'that Keswani has failed to reach the heart of the matter by presenting it as a question of *priority of discovery* of some unique thing called the principle of Relativity. In fact the situation was quite different and much more complex.'

Dingle furthermore maintains:

'There were thus in the period before the First World War three distinct ideas denoted by the term *principle of relativity*.

'They are:

1. That the laws of motion recognize no distinction between rest and uniform motion (Newton, Ritz and early Poincaré).
2. That the laws do recognize such a distinction, but the real (not merely conceptional) effects of motion are such as to make it impossible for anyone to determine his own motion without reference to outside bodies (Lorentz and later Poincaré).
3. That there exists no natural standard of rest that would make it meaningful to say that any single body has one motion rather than another (Einstein).

'When this is clearly understood it is seen that the question: "Who discovered the Principle of Relativity?" is meaningless. There is no *one* principle of relativity; none of the conceptions bearing that name has been or can be "discovered".'

Without entering more closely on Dingle's classification on this point I can, however, fully agree with him that *the principle of relativity could not be 'discovered'*. It has developed along different lines and different scientists have had different aspects on the problems involved. This being the case

[1] H. A. Lorentz: *Electromagnetic phenomena in a system moving with any velocity smaller than that of light*, Akad. v. Wetenschappen, 6: 2, Amsterdam, p. 809, 1904, German traduction in 'Relativitätsprinzip', Teubner, 1920.

[2] Note on Mr Keswani's articles 'Origin and Concept of Relativity', *British Journal of the Philosophy of Science*, XVI, *63*, p. 242.





it is on the other hand of interest to analyse the evolution of the present Theory of Relativity in order to state the contributions given by the scientists engaged.

The basic equations of Einstein's *Special Theory of Relativity* are nowadays throughout denoted as 'The Lorentz transformation equations'. It is therefore of interest to follow the evolution of Lorentz's ideas and his contribution to the creation of these equations up to Einstein's entrance on the scene in 1905.

Lorentz's main paper was published in 1904.[1] He starts from his theory of electrons and gives the Maxwell equations for a point on an electron supposed to be at rest in the hypothetical ether. He then assumes that the system as a whole moves in the direction of the $x$-axis with the constant velocity $w$. The electron is supposed to be given an additional velocity $u$ and will thus have the velocity $U$ where

$$U_x = w \div u_x$$
$$U_y = u_y,\ U_z = u_z$$

Lorentz then gives the Maxwell equation in reference to the moving system. Having arrived to this point he takes a most remarkable step described thus:

'We shall further transform these formulae by a change of variables:

$$\text{Putting } \frac{c^2}{c^2 - w^2} = k^2$$

and understanding by $l$ another numerical quantity, to be determined further on, I take as new independent variables

$$x' = klx;\ y' = ly;\ z' = lz$$

$$t' = \frac{lt}{k} - \frac{klwx}{c^2}$$

'As to the coefficient $l$, it is to be considered as a function of $w$ whose value is 1 for $w = 0$ and which for small values of $w$ differs from unity no more than by an amount of the second order.

'The variable $t'$ may be called the "local time", indeed for $l = 1, k = 1$, it becomes what I have formerly understood by this name.'

($c$ = velocity of light.)

What is especially remarkable in this connexion is that *Lorentz does not give any motivation for this exchange of variables.* The purpose of the

[1] 'Electromagnetic phenomena in a system moving with any velocity smaller than that of light', *Proceedings of the Academy of Science*, Amsterdam, 1904, p. 809.

exchange is *not* declared. With regard to the later formulation of the so-called 'Lorentz transformation equations' there is reason to assume that they should be applied to state the co-ordinates of a point-event in relation to a moving system with velocity $w$ along the $x$-axis, when we know the co-ordinates of the same point-event $x, y, z, t$ in relation to a system considered at rest. *But this is not expressed.*

What we are told with regard to the new symbols is the following: $l$ is declared to be a function of $w$ and for $w = 0$ it takes the value 1. But for $w = 0$ we also have $k = 1$ and in that case the symbols $x', y', z', t'$ become identical with $x, y, z, t$. Lorentz draws, however, a different important conclusion for the case $w = 0$. He writes 'for $k = 1, l = 1$ it ("the local time") becomes identical with what I have formerly understood by this name'.

In order to elucidate this very enigmatic declaration I shall go back to Lorentz's earlier use of this expression.

## 'Local time'

Lorentz's earliest use of this expression is to be found in a paper of 1895.[1] In a discussion of the oscillations of ions in relation to a system moving with velocity $p$ in relation to a system at rest and having arrived to a certain expression he writes:

'The form of this expression makes it convenient to introduce a new symbol $t'$ instead of $t$.

$$t' = t - \frac{p_x \cdot x}{V^2} - \frac{p_y \cdot y}{V^2} - \frac{p_z \cdot z}{V^2},$$

When the motion of the latter system takes place along the $x$-axis of the system at rest, we get

$$p_y = p_z = 0; p_x = p$$

and the new expression becomes

$$t' = t - \frac{p \cdot x}{V^2}$$

where $V$ is the velocity of light.

Lorentz adds:

'It should be noted that the variable $t'$ may be regarded as representing time counted from the moment of a certain position of the point in question. Consequently we can denote this variable as the "local time" of

[1] LORENTZ: 'Versuch einer Theorie der elektrischen und optischen Erscheinungen in bewegten Körpern', *Collected Papers V*, Leiden, 1895, p. 49. He here mentions that the expression has been used by W. Voigt: 'Ueber das Dopplersche Prinzip', *Gött-Nachr.*, 1887, p. 41, but without closer analysis.





the point in question, diverging from the "general time" $t$. The transition from one time to the other is effected by the above equation.'[1]

As this new symbol is introduced *without* any closer analysis of its physical meaning and content beyond the above vague hint about 'local time' and since furthermore the classical time, reigning universally and for all systems of reference, is *not* negated, we must state that *classical time* t *and the local time* t' *are by Lorentz supposed to exist side by side in certain points* with the result that he labours with two different meanings to the word time for one and the same point-event. An early example of the relativistic ambiguous use of words. Owing to the lack of analysis of the content and physical meaning of the new symbol we must state that t' *is a wholly arbitrary mathematical construction, without known physical meaning*.

In a number of later papers[2] Lorentz comes back to the quantity $t'$ but without giving any new information as to its content.

It is in his paper of 1904 that he makes—as mentioned above—a remarkable reflection regarding the expression

$$t' = \frac{lt}{k} - \frac{klwx}{c^2}$$

'For $k = 1, l = 1$ it (the "local time") becomes identical with what I have formerly understood by this name.'

Now we have found that his earlier expression for 'local time' is

$$t' = t - \frac{px}{V^2}$$

($p$ here $= w$, $V = c$)

But for $k = 1$ we get $w = 0$ and the consequence of this is that Lorentz's formula for $t'$ gives

$$t' = t$$

and *not* the formula for 'local time'.

Lorentz's above statement is therefore *not* correct and it seems from this that Lorentz has not been quite at home with the content of his own new formulae.

Summing up we can state that *with regard to the content of the symbol* t' *and the purpose of its introduction we are in the cited papers left without any relevant information.*

[1] Translation: '*Es sei hier noch die Bemerkung vorausgeschickt, dass die Variable* t' *als Zeit betrachtet werden kann, gerechnet von einem von der Lage des betreffenden Punktes abhängigen Augenblick an. Man kann daher diese Variable die "Ortzeit" dieses Punktes im Gegensatz zu der "allgemeinen Zeit"* t *nennen. Der Uebergang von der einen Zeit zu der anderen vermittelt die (obige) Gleichung.*'

[2] *Collected Papers V*, pp. 81, 141 and 163.

It is of interest to compare Lorentz's above formula with the corresponding formula of later authors including himself.

Poincaré writes in 1905[1] that the electro-magnetic equations are not altered, when transformed by certain equations which he names 'the Lorentz transformation equations' and which he presents thus:

$$x' = kl(x + \epsilon t) \quad y' = ly \quad z' = lz$$

$$t' = kl(t + \epsilon x)$$

where $x$, $y$, $z$ are the space co-ordinates and $t$ the time co-ordinate before the transformation and $x'$, $y'$, $z'$, $t'$ the co-ordinates in the moving system attained by the transformation equations and $\epsilon$ the velocity along the $x$-axis. Further

$$k = \frac{1}{\sqrt{1 - \epsilon^2}}$$

and '$l$ is any function of $\epsilon$'.

It is probable that Poincaré here measures velocities with the velocity of light as unit and this implies

$$-\epsilon = -\frac{w}{c}$$

where $c$ is the velocity of light in ordinary units and $w$ the velocity of the moving system. If these values are introduced we get

$$x' = kl\left(x - \frac{wt}{c}\right) \quad y' = ly \quad z' = lz$$

$$t' = kl\left(t - \frac{wx}{c}\right)$$

The important difference between this system of transformation equations and that of Lorentz is that Poincaré presents $x'$ as a function of time, which is a necessary consequence of the fact that the motion of the moving system takes place along the $x$-axis, whereas *this is not the case in the Lorentz formula.* Possibly Poincaré has regarded it as self-evident that also Lorentz has reckoned with $x'$ as a function of time, but the fact remains that *the systems of equations of these two authors do not correspond and that Lorentz's first equation is useless for the transformation from the system at rest to the moving system.*

Poincaré's paper was published in June 1905 and in the interval between May 1904 and June 1905 Lorentz did *not* publish any paper on this

[1] 'Sur la dynamique de l'électron', *Comptes Rendus t. 140*, pp. 1507–8, imprimé 1905. *Œeuvres IX*, p. 489.





subject. Poincaré also cites only the Lorentz paper of 1904. *With regard to the fact that Poincaré presents equations different from those of Lorentz it is remarkable that he has named his transformation equations after Lorentz.*[1]

The most important fact with regard to these systems of equations is that *both Lorentz and Poincaré present the new symbols* t', k, l *and* $\epsilon$ *without closer analysis and without any principal motivation for their introduction. The equations are in both cases mere mathematical constructions without known physical meaning.*

For the sake of completeness it may be observed that Poincaré has in an earlier paper and in another connection given a motivation for the introduction of a new symbol for time.[2] He describes it thus:

'Two observers at distant points are supposed to regulate their clocks with the aid of light rays, but ignoring the translation of the earth in relation to the ether in the direction of the line connecting them, their time-values will differ from real time and if the velocity of the translation of the earth is $v$ and the velocity of light is $V$ the "local time" of the regulated clock will [according to Poincaré] be

$$t' = t - \frac{vx}{V^2}.\text{'}$$

Although this reminds very much of Einstein's clock regulation there are two important differences. Firstly the formulae for $t'$ differ with regard to the factor $k$, which comes in in the Einstein formula. Secondly Einstein's rejection of classical time has—as shown earlier—made it impossible to carry the regulation through. His symbol $t'$ is, from the physical point of view, a mere phantom. In Poincaré's case on the other hand classical time is *not rejected* and the light-ray regulation can (possibly) be carried through. But since classical time is *not* rejected by him, but is still supposed to reign, we have in every point in every system of reference the classical time $t$. The result of Poincaré's regulation is that in a point where the regulation has established the local time $t'$, there will at the same moment also reign the real time $t$. Poincaré thus only attains that he will labour with two meanings to the word 'time'. He does not, however, indicate how they should be used and kept apart, which implies the fatal risk of double-talk.

When we then turn to Einstein the situation is very different. He takes up the relativistic problem on a much higher and principal level. He starts from an extremely far-reaching principle: that our laws of physical phenomena should have the widest possible application in all domains of physics. The first consequence Einstein draws from this far-reaching principle is that the classical (Newton) Principle of Relativity should

[1] H. Poincaré: *Comptes Rendus 140*, p. 1504; *Œuvres IX*, p. 490.

[2] H. Poincaré: 'La théorie de Lorentz et le principe de la réaction', *Arch. néerl. des sc.*, 1900; *Œuvres IX*, p. 483.

apply also to electromagnetic phenomena. This in turn implies, as he points out, that the velocity of one and the same light ray should be the same in both of two Galilean systems moving in relation to each other. This implies on the other hand that an event, say the arrival of a light ray in a point at a certain moment, both should and should not take place at that moment. This contradiction is admitted by Einstein, and he makes it his task to eliminate it by introducing his new time concept $t'$ for time in the moving system.

The transformation equations necessary to express his principle of constant velocity of light he derives from the mathematical expressions for this principle, which are $x = ct$ in the system at rest and $x' = ct'$ in the moving system for one and the same light ray. This leads him to the transformation equations we have already met (p. 25):

$$x' = \frac{x - vt}{\sqrt{1 - \beta^2}} \quad y' = y \quad z' = z$$

$$t' = \frac{t - \frac{vx}{c}}{\sqrt{1 - \beta^2}} \quad \beta = \frac{v}{c}$$

Although Einstein's deduction of these equations is on a much higher level than the presentations of his forerunners *where the equations are wholly arbitrary* the fact remains that he is faced with the above-named contradiction, which he makes it his task to eliminate with his new time concept.

Regrettably, his attempt to attain this on the basis of experiments must, as shown earlier, be declared a total failure, owing to the fact that the experiments required cannot be performed after the rejection of classical time.

Summing up we can therefore state:

*Lorentz has never presented the transformation equations named after him. His equations are different, and lacking motivation they must be considered as wholly arbitrary.*

*Poincaré has presented equations closer to the final equations but also arbitrarily chosen and without motivation.*

*Einstein is the first to have given the transformation equations of the Special Theory of Relativity in their finally accepted form and to have attempted a motivation.*

*There is therefore very strong reason, why these equations should carry Einstein's name instead of Lorentz's.*[1]

Since in the first two cases the equations lack motivation and in Einstein's

[1] As the equations are practically always associated with the work of Lorentz, I have accepted this in order to avoid misunderstanding.





case are presented on the basis of an untenable analysis of our time concept, we must state that *the transformation equations of the Special Theory of Relativity are only mathematical constructions without known physical meaning.*

From an historical point of view the following may be noted.

In a later publication, after Einstein's fundamental paper of 1905, Lorentz takes up a changed position:[1]

'If $x$, $y$, $z$ are the co-ordinates of a point with respect to axes fixed in the ether, or, as we shall say, the "absolute co-ordinates" and if the translation takes place in the direction of $vx$ the co-ordinates with respect to axes, moving with the system and coinciding with the fixed axes at the instant $t = 0$ will be

$$x_r = x - wt \quad y_r = y \quad z_r = z$$

Now instead of $x$, $y$, $z$ we shall introduce new independent variables differing from these 'relative' co-ordinates by certain factors that are constant throughout the system. Putting

$$\frac{c^2}{c^2 - w^2} = k^2$$

I define the new variables by the equations:

$$x' = klx_r,\ y' = ly_r,\ z' = lz_r$$

or

$$x' = kl(x - wt),\ y' = ly,\ z' = lz$$

and to these I add as our fourth independent variable

$$t' = \frac{lt}{k} - \frac{klw}{c^2}(x - wt) = kl\left(t - \frac{wx}{c^2}\right)$$

It should at first be noted that Lorentz has here given up his first equation (of 1904) $x' = klx$ and makes $x'$ a function of $t$.

Furthermore it should be noted that the equations first given for the relation between the co-ordinates in the two systems and marked with the index $r$ *are exactly the Newton transformation equations.* As the first one of these indicates $x_r$ as a function of the time $t$ and nothing is said about any new time concept, the symbol $t$ must, as in the Newton equation represent the classical universal time. *The problem of transforming from the system at rest in the ether to the moving system is thus exhaustively given by these equations.* One may therefore well ask: What is the purpose of

[1] LORENTZ: *The Theory of Electrons*, Teubner, 1909, second edition, 1915, p. 196.

[2] It is earlier indicated that $w$ is the constant velocity of translation; $r$ is a mere index.

introducing, *without motivation*, the arbitrarily chosen quantities $t'$, $k$ and $l$? This remains an open question in Lorentz's presentation.

In a note in the same treatise (p. 321) Lorentz makes (1915) the following commentary:

'If I had to write the last chapter (§ 169 in the Theory of electron of 1909) now I should certainly have given a more prominent place to Einstein's Theory of Relativity by which the theory of electro-magnetic phenomena in moving systems gains a simplicity that I had not been able to attain. The chief cause of my failure was my clinging to the idea that the variable $t$ only can be considered as the true time and that my local time $t'$ must be regarded as no more than an auxiliary mathematical quantity. In Einstein's theory on the contrary, $t'$ plays the same part as $t$; if we want to describe phenomena in terms of $x'$, $y'$, $z'$, $t'$, we must work with these variables exactly as we could do with $x$, $y$, $z$, $t$.'

Here is to be noted that *Lorentz himself has regarded $t'$ 'as no more than an auxiliary mathematical quantity'* and not as a known physical quantity. With regard to his reflection that Einstein's symbol $t'$ can be used to describe the phenomena in the moving system we must state that this does *not* hold for the reason that Einstein has *not* been able to give a physical meaning to this symbol. Also in his case $t'$ is merely an auxiliary mathematical quantity without known physical meaning.

In a later memorandum of 1921[1] Lorentz comments on Poincaré's paper of 1906[2] and writes:

'The task was to find transformation formulae for the independent variables, the co-ordinates $x$, $y$, $z$, and the time $t$, as well as for the different physical quantities, speeds, forces and so on, and to show the invariance of the equations through their transformations.'

Lorentz then presents a group of formulae for this transformation, which differs from his own original transformation equations (see p. 201). With regard to his own equations he correctly comments:

'For certain of the physical qualities involved I have not in fact indicated the most appropriate transformation. This was done by Poincaré and later by Einstein and Minkowski.'

Lorentz has thus himself in a most conscientious and modest way considerably reduced his own contribution to the relativistic transformation equations.

Since Einstein's formulae must also be rejected on the ground that the new time symbol $t'$ lacks all known physical meaning and only represents a mathematical construction, it is of secondary interest to discuss the

1 LORENTZ: *Acta Mathematica* 38. Reprinted in Poincaré's *Œuvres IX*, p. 683.

2 POINCARÉ: 'La dynamique de l'électron', *Œuvres IX*, p. 494.





provenance of the transformation equations. But it has an interest from the historical point of view, for the understanding of the development of the Theory of Relativity and for the judgement of the parts played by the different actors.

### THE PSYCHOLOGICAL BACKGROUND OF THE ACCEPTANCE OF THE RELATIVISTIC IDEAS

The enormous attention and admiration paid to the Theory is surprising with regard to the very superficial way in which these extremely subtle problems and their ultimate foundations have been treated.

There are, however, several facts that can, to a certain degree, explain the comparatively easy and uncritical acceptance of the new revolutionizing ideas.

The 'Relativity' ideas and formulae have been presented by very prominent scientists who have given most valuable contributions in different domains of mathematics and physics and it is therefore natural that their ideas should be looked upon with the greatest respect.

What has largely contributed to a positive and even enthusiastic reception of the Theory are the harmonious mathematical formulae to which it gives rise and which have naturally very much appealed to mathematicians such as Minkowsky, who have revelled in the possibilities of creating further fascinating formulae which seem to give quite new and sometimes most sensational relations between physical quantities. The deduction of the fundamental rules and principles on which the formulae rest has as a rule not interested them and it has therefore escaped them that the new symbols *cannot represent the quantities in question because of their untenable deduction.*

Those who have been less mathematically orientated such as the philosophers, and who have occupied themselves with the Theory have most of them been so impressed by the formulae and the declarations of the relativists with regard to the supposed corroborations of the Theory by experiments, that most of them have, as I have shown in the above review, desisted from a closer analysis.

To what extreme degree the veneration of authorities has prevailed in the judgement of the relativistic ideas is strikingly illustrated by the ardent relativist Henri Arzeliès.[1]

He points out that the physicists are divided in two groups, relativists and anti-relativists. The divergency between them appears on two points, the conceptions involved and the logical coherence of the Theory. The physicists of the relativistic group look, according to him, upon the Einstein concepts of time and space as an enormous progress in relation to classical concepts. This group comprises physicists of universally acknowledged renown (de Broglie, Schrödinger, Dirac).

The physicists of the anti-relativistic group consider the Einstein concepts as incomprehensible or absurd or both. They also pretend to find illogical zones in the Theory and false reasonings.

1 Quoted on p. 133.

Arzeliès raises the question: *What conclusions can be drawn?* Simply that the two groups probably have *different mental structure. The discussion falls outside the domain of physics; it belongs to experimental psychology or psychiatry.*[1]

He winds up his characterization by declaring that the authors of the second group ought to be more prudent.

'It is somewhat reckless', he declares, 'not to say more to treat as absurd the ideas of an Einstein or a de Broglie and especially to attribute to them errors of calculation on equations of the first degree.' So much for Arzeliès.

I am sorry that I am obliged to maintain that it is exactly in the deduction and treatment of equations of the first degree (the so-called Lorentz equations and the mathematical proof of dissolution of simultaneity) that the relativists are erring most seriously, especially with respect to their own presuppositions.[2]

## TRENDS TOWARDS MYSTICISM IN MODERN SCIENCE

Furthermore, I wish to point to a circumstance which I think has to a certain degree contributed to the acclaim of the Theory and to the admiration it has created. That is the trend towards mysticism in modern science on fundamental mathematical and physical problems. We meet an instance of this trend in Bertrand Russell's *Mysticism and Logic.* On the basis of his rules of mathematical logic he arrives at the declaration:

'Thus mathematics may be defined as the subject in which we never know what we are talking about, nor whether what we are saying is true.'

This differs considerably from the views of earlier scientists who sincerely believed in truth even in mathematics.

The tendency towards metaphysical speculation is very noticeable also in the writings of e.g. James Jeans[3] and Arthur Eddington.[4]

In enthuasiastic, but diffuse language both these authors develop their views on the physical world. However, they leave the reader very much at a loss. I shall not enter more deeply in these problems, but shall permit myself to refer to the excellent analysis of the works of these two scientists by L. Susan Stebbing.[5]

1 See *Arzeliès I*, p. XXXII.

2 Arzeliès' characterization of the two groups can be expressed in a much simpler way: In the first group we find the geniuses, in the second the lunatics. In case he happens to read this book, he would certainly class me among the lunatics, which would please me very much.

3 James Jeans: *The New Background of Science*, Cambridge University Press, 1933. *The Mysterious Universe*, Cambridge University Press, 1930.

4 Arthur Eddington: *The Nature of the Physical World*, Cambridge University Press, 1928. *New Pathways in Science*, Cambridge University Press, 1933.

5 L. Susan Stebbing: *Philosophy and the Physicists*, Dover, New York, 1958, p. 6.





In a very deep-probing and detailed analysis of the declarations of these authors she comes to the conclusion that they do not give us any helpful contribution to our understanding of the physical world. Her crushing criticism can be summed up in some of her declarations. Thus she writes:

'Some of our scientific guides writing in moments of emotional exaltation, have found it easier to mystify the common reader than to enlighten him. Neither Sir Arthur Eddington nor Sir James Jeans seems to care very much whether his method of presenting his views concerning the philosophical significance of physical theories may not make it more difficult, or even impossible, for the common reader to understand what exactly it is that has been said. Both these writers approach their task through an emotional fog. They present their views with an amount of personification and metaphor that reduce them to the level of revivalist preachers. Yet we common readers surely have a right to expect that a scientist setting out to discuss for our benefit philosophical problems arising from his special studies will do so in a scientific spirit. He would seem to be under a special obligation to avoid cheap emotionalism and specious appeals and to write as clearly as the difficult nature of the subject matter permits. Of this obligation Sir James Jeans seems to be totally unaware whilst Sir Arthur Eddington, in his desire to be entertaining befools the reader into a state of serious mental confusion.'

For details of her criticism I must refer the interested reader to her own work.

With regard to this mental background among a large part of mathematicians and physicists of our time, it is quite natural that the Theory of Relativity with its extreme subversion of our fundamental concepts and the resulting revolutionizing consequences must appeal most strongly to them as a fascinating contribution to the mystification of our picture of the physical world. The Theory has also, as I have shown in my review of the literature on the Theory, been by most mathematicians and physicists unreservedly and enthusiastically accepted.

As I have shown earlier this inclination towards mysticism has in the Theory resulted in the acceptance—although unconsciously—of double meaning to fundamental words such as 'time' and its derivatives and the promiscuous use of the words. This necessarily puts the scientists before a choice. Are we to accept double meanings to our fundamental concepts—with the risk of ambiguity in what we are talking about—or are we to stick more humbly to the classical claim of unity in our concepts?

This question has been raised earlier in English literature. Lewis Carroll has in his book *Through the Looking-glass* related a discussion between Humpty Dumpty and Alice on the meaning of words:

*Humpty Dumpty:* 'There is glory for you.'
*Alice:* 'I don't know what you mean by glory.'

*Humpty Dumpty smiled contemptuously:* 'Of course you don't till I tell you. I meant "There is a nice knock-down argument for you".'
*Alice objected:* 'But "glory" doesn't mean "a nice knock-down argument".'
*Humpty Dumpty in rather a scornful tone:* 'When I use a word it means just what I choose it to mean—neither more nor less.'
*Alice: 'The question is whether you can make words mean different things.'*

Before the question thus raised by Alice we must all make our choice. It is easy to guess what position Alice takes up. The attentive reader of this book will probably already have realized that its author is 'wholly on the side of Alice'.[1]

## THE GENESIS OF THE THEORY AND THE CURSORINESS OF EINSTEIN'S REASONING

The genesis of a physical theory can be of very different art. The most common background is the need to explain a large number of observed physical facts. It is on that line that we have been given the Newtonian laws of mechanics, the Maxwell laws of electro-magnetic phenomena, the laws of optics, of thermo-dynamics and so on.

The Theory of Relativity as presented by Einstein in his fundamental paper has not sprung from such a need to explain a number of experimental results. The Theory has sprung from an extremely theoretical idea of how we are to regard our possibilities of registering certain phenomena with regard to space and time in relation to different systems of reference in motion in relation to each other.

The new and extremely audacious idea that Einstein has launched in this connexion is that the Principle of Relativity of the Galilei–Newton mechanics should be valid for 'all natural phenomena' and thus be a universal law. This idea is not distinctly expressed in his first paper although it glimmers in the background, but in his later book *Relativity* he is more explicit. As supposed experimental ground Einstein only mentions the failure of our trials to show the motion of the earth in relation to a hypothetical ether which does not, however, prove the validity of his principle. On the other hand we have seen that his principle brings him face to face with a contradiction which he wishes to eliminate by negating classical time and introducing a new time concept. The classical time concept being one of our most fundamental concepts, its negation evidently creates extremely far-reaching consequences for our whole picture of the physical world and one would have expected to meet a comprehensive discussion of the thus arising problems. Einstein does *not*, however, in his first paper with one single word, enter on this problem so fundamental for his whole Theory.

The extreme summariness of Einstein's reasoning is illustrated by the

[1] I will admit that I sometimes do nourish a mild hope—probably in vain—that one day the old nursery-rhyme may come true:

Humpty Dumpty sat on a wall,

. . . . . . . . . . . . . . . .





following. Einstein's first paper 'Elektrodynamik' gives a strong impression that he has, as the very able mathematician he was, first of all developed the new transformation equations and studied their most remarkable results in the mechanical as well as the electro-magnetic field. The analysis of the time concept has most probably appeared to him as a secondary problem. This is illustrated by the fact that in his fundamental paper of 25 pages[1] by far the greater part, about 20 pages, are devoted to the deduction of the transformation equations and their consequences in different respects, whereas only a page and a half are devoted to the enormously complicated problem of remoulding the time concept. Besides, what these pages give are only the mathematical rules for clock regulation with light rays. We must therefore state that *Einstein does not enter into any analysis of the consequences of his negation of classical time, what is really rejected and what is peradventure kept.* This is most regrettable since it might have revealed to him that he every now and then necessarily falls back on classical aspects which he has a moment before rejected.[2]

The psychological explanation of this remarkable summariness is probably that Einstein has fallen a victim to his great enthusiasm for the creation of principles and formulae of widest possible scope. Such far-reaching principles and formulae may possibly be considered a *desirability* for science, but we have so far only limited reason to suppose that nature really follows such laws valid for very wide domains. What we can say for sure is that such laws of very general validity will face us with extremely complicated problems. The negative result of Einstein's trial to extend the Principle of Relativity to such general validity is a striking illustration of these difficulties.

[1] As reproduced in 'Relativitätsprinzip'.

[2] In *Relativity* Einstein's treatment of the time concept is merely a trial to popularize his earlier ideas and he does *not give any further contribution to the fundamental discussion.*

# FINAL REFLECTIONS

As I have criticized Einstein very heavily in this book I am anxious to point out that my criticism applies to his *philosophical* reasonings and especially those of epistemological character. On the other hand I have the greatest respect for his eminent contributions in other domains of mathematics and physics.

I have often met persons, especially outside Sweden, who have expressed their astonishment that Einstein was not awarded the Nobel Prize for his Theory of Relativity, which many people consider as one of the most outstanding achievements of this century. As a member of the Swedish Academy of Science which distributes the Nobel Prizes of physics I am on the other hand very glad that this was *not* done, since *the Theory of Relativity is not physics but philosophy and in my opinion poor philosophy.*

Einstein was awarded the Prize for physics of the year 1921 'for his merits in mathematical physics, especially for his discovery of the law of photoelectric effect'.

As far as I can judge this was an extremely well merited award, and even if my criticism of his Theory of Relativity should be accepted and his contributions to science thereby be reduced in this field he will surely, all the same, stand out as one of the great scientists of our time.

What characterizes him especially is his great imaginative power which has inspired him to many audacious and fascinating ideas, but this faculty of his can, with regard to *epistemological* problems, be considered as more of a drawback than an asset.

Finally I wish to emphasize that I am fully aware that most of the great results attained in science are due to men of great imagination and daring creative spirit, who have launched far-reaching new ideas, and with regard to this we have indeed reason to maintain the principle of freedom of thought in the domain of science, given in the cited parole:

'Free thinking is great.'

But we also have to consider that each such thrust into 'no man's land' must be followed up by strict scrutiny of the methods applied and the tenability of our reasonings and deductions. Only if they conform with the fundamental rules of thought can they be accepted. That is why we have reason to acclaim the second part of the above-cited motto:

'Right thinking is greater.'



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