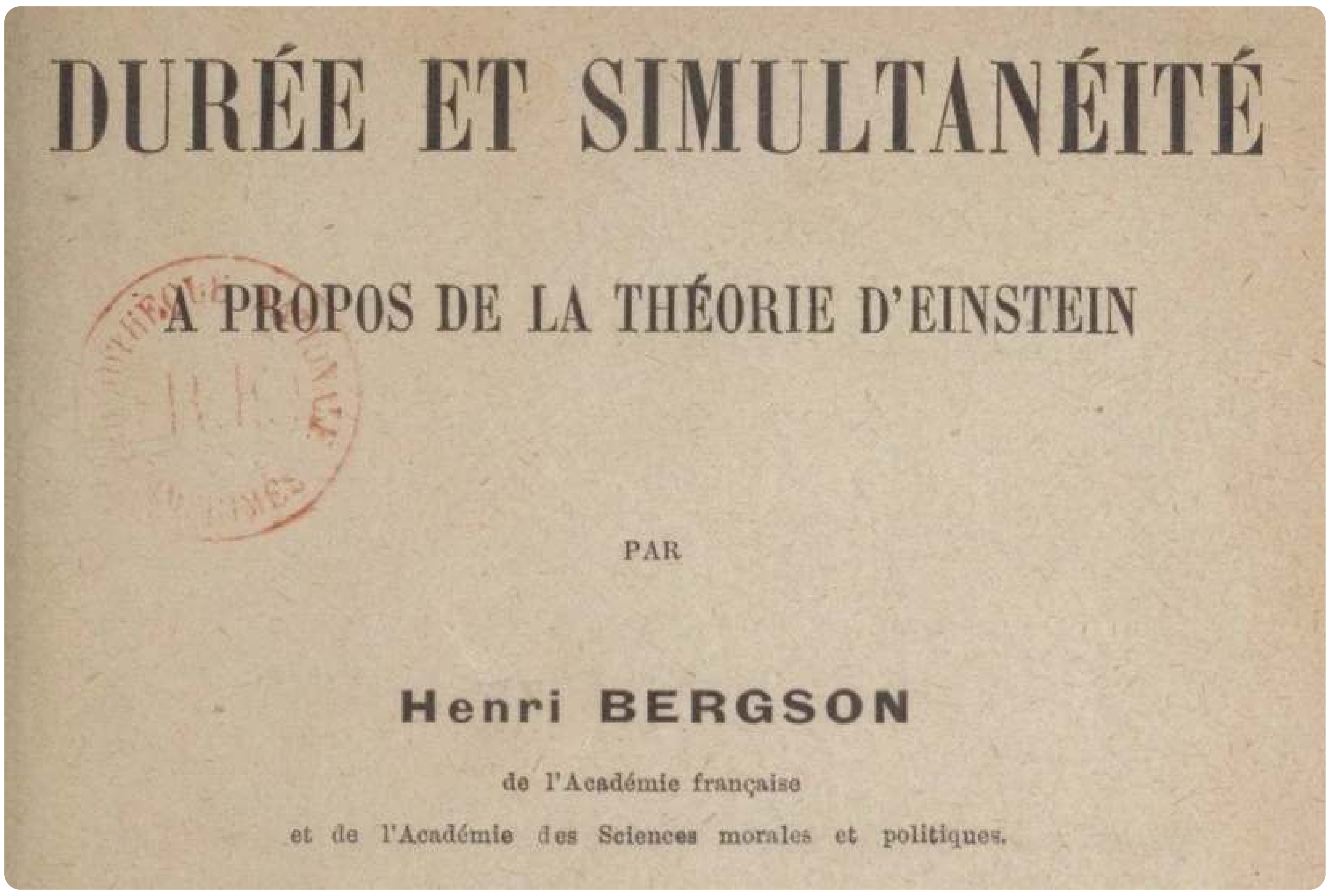

DURÉE ET SIMULTANÉITÉ

À PROPOS DE LA THÉORIE D'EINSTEIN

PAR

Henri BERGSON

de l'Académie française

et de l'Académie des Sciences morales et politiques.

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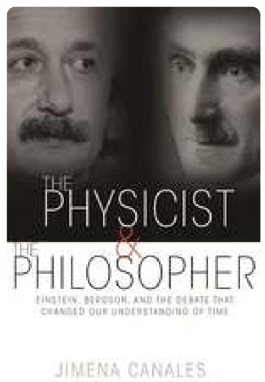

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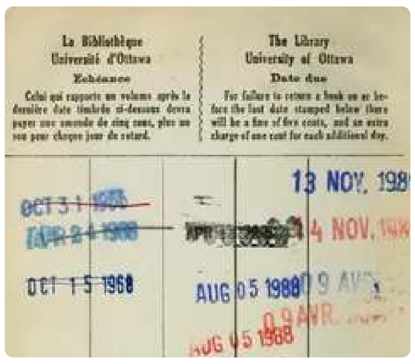

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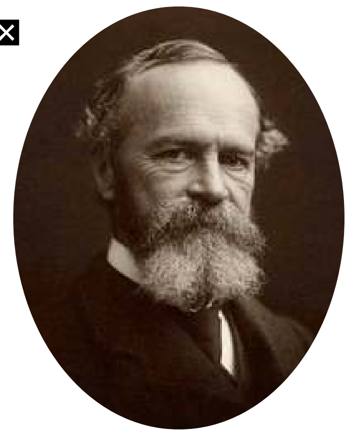

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2.

Duration and Simultaneity

About Einstein's Theory

first edition, 1922

Henri Bergson
of the Académie française
and of the Académie des Sciences Morales et Politiques.

Paris
Félix Alcan Publishing
108, Boulevard Saint-Germain
1922

3.

Preface

A few words about the origin of this work will clarify its intent. We undertook it exclusively for ourselves. We wanted to know to what extent our conception of duration was compatible with Einstein's views on time. Our admiration for this physicist, the conviction that he brought us not only a new physics but also new ways of thinking, the idea that science and philosophy are distinct disciplines but made to complement each other—all this inspired in us the desire and even imposed on us the duty to undertake a confrontation. But our research soon appeared to offer more general interest. Our conception of duration expressed a direct and immediate experience. Without necessarily entailing the hypothesis of a universal Time, it harmonized very naturally with this belief. We were therefore going to confront common ideas with Einstein's theory. And the aspect where this theory seems to clash with common opinion then came to the forefront: we would have to dwell on the "*paradoxes*" of the theory of Relativity, on multiple Times flowing at different speeds, on simultaneities becoming successions and successions becoming simultaneities when changing viewpoints. These theses have a well-defined physical meaning: they express what Einstein read, through a stroke of genius, in Lorentz's equations. But what is their philosophical significance? To find out, we took Lorentz's formulas term by term, and sought what concrete reality, what perceived or perceptible thing, each term corresponded to. This examination gave us a rather unexpected result. Not only did Einstein's theses no longer seem contradictory, but they actually confirmed and provided preliminary proof for humanity's natural belief in a single universal Time. They owed their paradoxical appearance simply to a misunderstanding. A confusion seemed to have occurred—not in Einstein himself, nor in the physicists who physically applied his method, but in certain thinkers who erected this physics, as is, into philosophy. Two different conceptions of relativity, one abstract and the other pictorial, one incomplete and the other perfected, coexisted in their minds and interfered with each other. By dispelling the confusion, the paradox vanished. It seemed useful to say so. We would thus help clarify the theory of Relativity for philosophers.

These are the two reasons that determined us to publish the present study. As can be seen, it deals with a clearly delimited subject. We have extracted from the theory of Relativity what concerned time; we have set aside other problems. We thus remain within the framework of restricted

Relativity. The theory of generalized Relativity in fact comes to position itself there when it requires one coordinate to effectively represent time.

⊠⊠⊠⊠⊠ 4.

Half-Relativity

The Michelson-Morley Experiment

The theory of Relativity, even “*restricted*”, is not precisely founded on the Michelson-Morley experiment, since it generally expresses the necessity of preserving an invariable form for the laws of electromagnetism when passing from one reference system to another. But the Michelson-Morley experiment has the great advantage of posing the problem to be solved in concrete terms, and of placing the solution's elements before our eyes. It materializes the difficulty, so to speak. It is from this experiment that the philosopher must start, and to it he must constantly return if he wishes to grasp the true meaning of temporal considerations in the theory of Relativity. How many times has it not been described and commented upon! Yet we must comment on it, even describe it again, because we will not adopt outright, as is usually done, the interpretation given by today's theory of Relativity. We wish to allow for all transitions between the psychological viewpoint and the physical viewpoint, between common-sense Time and Einstein's. For this, we must place ourselves in the state of mind one might have had at the outset, when belief in an immobile ether, at absolute rest still held, yet the Michelson-Morley experiment had to be accounted for. We will thus obtain a certain conception of Time that is relativistic by half, only partially, not yet Einstein's, but which we deem essential to know. Although the theory of Relativity takes no account of it in its strictly scientific deductions, it nevertheless undergoes its influence, we believe, as soon as it ceases to be physics to become philosophy. The paradoxes that so frightened some and seduced others seem to us to stem from this. They arise from an ambiguity. They are born from two representations of Relativity—one radical and conceptual, the other attenuated and pictorial—coexisting unconsciously in our minds, with the concept suffering contamination from the image.

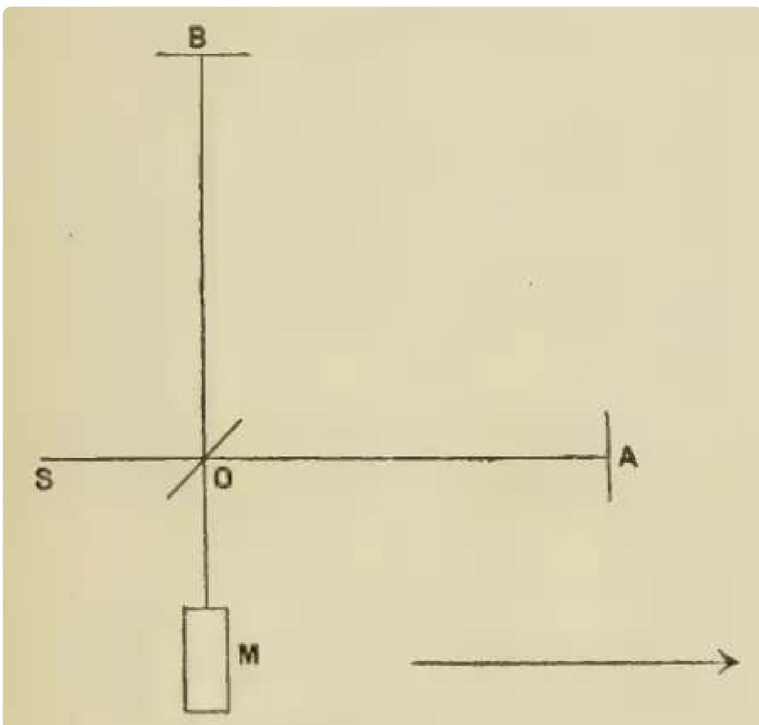

Figure 1

Let us therefore schematically describe the experiment established in 1881 by the American physicist Michelson, repeated by him and Morley in 1887, and undertaken again with even greater care by Morley and Miller in 1905. A ray of light SO (fig. 1) starting from source S is divided at point O by a glass plate inclined at 45° to its direction into two rays: one reflected perpendicular to SO in direction OB, while the other continues its path along the extension OA of SO. At points A and B, which we assume equidistant from O, are two plane mirrors perpendicular to OA and OB

respectively. The two rays, reflected by mirrors B and A respectively, return to O: the first, passing through the glass plate, follows line OM, extension of BO; the second is reflected by the plate along the same line OM. They thus superimpose on each other and produce an interference fringe pattern observable from point M through a telescope directed along MO.

Suppose for a moment that the apparatus is not in translational motion through the ether. It is first evident that if distances OA and OB are equal, the time taken by the first ray to go from O to A and back equals the time taken by the second ray to go from O to B and back, since the apparatus is stationary in a medium where light propagates at the same speed in all directions. The appearance of the interference fringes will therefore remain unchanged for any rotation of the device. It will be the same, in particular, for a 90-degree rotation that swaps arms OA and OB.

But, in reality, the apparatus is carried along by the motion of the Earth in its orbit[1]. It is easy to see that, under these conditions, the double journey of the first ray should not take the same time as the double journey of the second[2].

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[1] *The motion of the Earth can be considered as a rectilinear and uniform translation during the duration of the experiment.*

[2] *It must not be forgotten, in all that follows, that the radiations emitted by the source S are deposited immediately in the stationary ether and henceforth independent, in their propagation, of the motion of the source.*

Let us calculate, according to the usual kinematics, the duration of each double journey. To simplify the exposition, we will assume that the direction SA of the light ray has been chosen so as to be that of the Earth's motion through the ether. We will call v the speed of the Earth, c the speed of light, l the common length of the two lines OA and OB. The speed of light relative to the apparatus, on the journey from O to A, will be $c - v$. It will be $c + v$ on the return. The time taken by the light to go from O to A and back will therefore be equal to $\frac{l}{c-v} + \frac{l}{c+v}$, that is to say $\frac{2lc}{c^2 - v^2}$, and the path traveled by this ray in the ether to $\frac{2lc^2}{c^2 - v^2}$ or $\frac{2l}{1 - \frac{v^2}{c^2}}$. Now consider the journey of the ray that goes from the glass plate O to the mirror B and back. The light moving from O to B with speed c, but on the other hand the apparatus moving with speed v in the direction OA perpendicular to OB, the relative speed of light here is $\sqrt{c^2 - v^2}$, and consequently the total duration of the journey is $\frac{2l}{\sqrt{c^2 - v^2}}$.

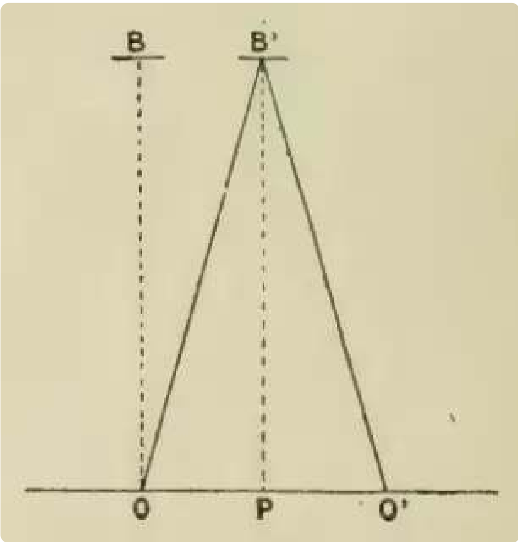

Figure 2

Here then is the explanation proposed by Lorentz, an explanation that another physicist, Fitzgerald, had also conceived. The line O' would contract due to its motion, so as to reestablish equality between the two double journeys. If the length of O', which was B' at rest, becomes $OB'O'$ when this line moves with speed OO', the path traveled by the ray in the ether will no longer be measured by $B'P$, but by $\frac{OB'O'}{c} = \frac{OO'}{v}$, and the two journeys will indeed be equal. It must therefore be admitted that any body moving with any speed OO' undergoes, in the direction of its motion, a contraction such that its new dimension is to the old one in the ratio of $\frac{OB'}{c} = \frac{OP}{v}\cdot$ to unity. This contraction naturally affects both the ruler with which the object is measured and the object itself. It thus escapes the terrestrial observer. But it would be noticed if one adopted a stationary observatory, the ether[2].

⊠ ⊠⊠ ⊠ ⊠ 4.2.

Unilateral Relativity

Voici alors l'explication proposée par Lorentz, explication dont un autre physicien, Fitzgerald, avait également eu l'idée. La ligne OA se contracterait par l'effet de son mouvement, de manière à rétablir l'égalité entre les deux doubles trajets. Si la longueur de OA, qui était l au repos, devient $l\sqrt{1-\frac{v^2}{c^2}}$ quand cette ligne se meut avec la vitesse v, le chemin parcouru par le rayon dans l'éther ne sera plus mesuré par $\frac{2l}{1-\frac{v^2}{c^2}}$, mais par $\frac{2l}{\sqrt{1-\frac{v^2}{c^2}}}$, et les deux trajets se trouveront effectivement égaux. Il faudra donc admettre qu'un corps quelconque se mouvant avec une vitesse quelconque v subit, dans le sens de son mouvement, une contraction telle que sa nouvelle dimension soit à l'ancienne dans le rapport de $\sqrt{1-\frac{v^2}{c^2}}$ à l'unité. Cette contraction, naturellement, atteint aussi bien la règle avec laquelle on mesure l'objet que l'objet lui-même. Elle échappe ainsi à l'observateur terrestre. Mais on s'en apercevrait si l'on adoptait un observatoire immobile, l'éther[2].

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[1] *Moreover, it involves conditions of precision such that the discrepancy between the two light paths, if it existed, could not fail to manifest itself.*

[2] *At first it seems that instead of a longitudinal contraction, one could just as well have assumed a transverse expansion, or both at once, in the appropriate proportion. On this point, as on many others, we are obliged to set aside the explanations given by the theory of Relativity. We limit ourselves to what concerns our present research.*

More generally, let us call S a system stationary in the ether, and S' another copy of this system, a double, which was initially one with it and then detaches itself in a straight line with speed v. As soon as it departs, S' contracts in the direction of its motion. Everything not perpendicular to the direction of motion participates in the contraction. If S was a sphere, S' will be an ellipsoid. This contraction explains why the Michelson-Morley experiment gives the same results as if light had a constant speed equal to c in all directions.

But we should also know why we ourselves, in turn, measuring the speed of light by terrestrial experiments such as those of Fizeau or Foucault, always find the same number c, whatever the speed of the Earth relative to the ether[1]. The observer stationary in the ether will explain it as follows. In experiments of this kind, the light ray always makes the double journey out and back between the point O and another point, A or B, on Earth, as in the Michelson-Morley experiment. In the eyes of the observer who participates in the Earth's motion, the length of this double journey is therefore $2l$. Now, we say that he invariably finds the same speed c for light. It must therefore be that invariably the clock consulted by the experimenter at point O indicates that the same interval t, equal to $\frac{2l}{c}$, has elapsed between the departure and return of the ray. But the spectator stationed in the ether, who follows with his eyes the path actually taken by the ray in that medium, knows well that the distance covered is in reality $\frac{2l}{\sqrt{1-\frac{v^2}{c^2}}}$. He sees that the moving clock, if it measured time like the stationary clock he keeps beside him, would mark an interval $\frac{2l}{c\sqrt{1-\frac{v^2}{c^2}}}$. Since it nevertheless marks only $\frac{2l}{c}$, it is because its Time flows more slowly. If, in the same interval between two events, a clock counts a smaller number of seconds, each of them lasts longer. The second of the clock attached to the moving Earth is therefore longer than that of the stationary clock in the immobile ether. Its duration is $\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$. But the inhabitant of the Earth knows nothing of this.

(1) *It is indeed important to note (it has often been omitted) that Lorentz's contraction is not enough to establish, from the point of view of the ether, the complete theory of the Michelson-Morley experiment performed on Earth. To it must be added the lengthening of Time and the displacement of simultaneities, all of which we will find again, transposed, in Einstein's theory. The point has been well highlighted in an interesting article by C. D. Broad, Euclid, Newton and Einstein (Hibbert Journal, April 1921).*

4.3.

Time Dilation

More generally, let us again call S a system stationary in the ether, and S' a double of this system, which initially coincided with it and then detaches itself in a straight line with speed v. While S' contracts in the direction of its motion, its Time dilates. An observer attached to system S, seeing S' and fixing his attention on a second of the clock of S' at the precise moment of doubling, would see the second of S stretch out over S' like an elastic thread being pulled, like a line viewed through a magnifying glass. Let us be clear: no change has occurred in the mechanism of the clock, nor in its functioning. The phenomenon is nothing like the lengthening of a pendulum. It is not because clocks run slower that Time has lengthened; it is because Time has lengthened that the clocks, remaining as they are, happen to run slower. By the effect of motion, a longer time, stretched, dilated, comes to fill the interval between two positions of the hand. The same slowing, moreover, for all movements and all changes of the system, since each of them could just as well become representative of Time and set itself up as a clock.

We had assumed, it is true, that the terrestrial observer followed both the outbound and return journey of the light ray from O to A and back to O, measuring the speed of light without consulting any clock other than the one at point O. What would happen if we measured this speed for the outbound journey only, by consulting two clocks [1] placed respectively at points O and A? To be precise, in all terrestrial measurements of the speed of light, it is the double journey of the ray that is measured. The experiment we are discussing has therefore never been performed. But nothing proves it impossible. We will show that it would still yield the same number for the speed of light. But to do this, let us recall what constitutes the synchronization of our clocks.

(1) *Needless to say, in this paragraph we call a "clock" any device that measures a time interval or precisely locates two instants relative to each other. In experiments concerning the speed of light, Fizeau's toothed wheel and Foucault's rotating mirror are clocks. More generally still will be the meaning of the word throughout this study. It will apply equally to a natural process. The rotating Earth will be a clock.*

Moreover, when we speak of a clock's zero point and the operation by which we determine the zero position on another clock to synchronize them, we introduce dials and hands solely to fix ideas. Given any two devices, natural or artificial, used for time measurement—and consequently two movements—we may call "zero" any arbitrarily chosen origin point on the trajectory of the first moving element. Setting the zero on the second device will simply consist of marking, along the path of its moving element, the point deemed to correspond to the same instant. In short, "setting the zero" in what follows should be understood as the real or ideal operation, performed or merely conceived, by which two points denoting a first simultaneity have been marked on the two devices respectively.

4.4.

Dislocation of Simultaneity

How do we synchronize two clocks located in different places? Through communication established between the two persons in charge of the synchronization. Now, there is no instantaneous communication; and since any transmission takes time, we had to choose one that occurs under invariable conditions. Only signals sent through the ether meet this requirement: any transmission through ponderable matter depends on the state of that matter and the thousand circumstances modifying it at every instant. Therefore, the two operators must have communicated via optical signals, or more generally electromagnetic signals. The person at O sent the person at A a light signal intended to return immediately. And things unfolded as in the Michelson-Morley experiment, with this difference however: mirrors were replaced by people. It had been agreed between the two operators at O and A that the second would mark zero at the point where the hand of his clock was at the precise instant the ray reached him. From then on, the first had only to note on his clock the start and end of the interval occupied by the ray's double journey: he placed the zero of his clock at the midpoint of this interval, since he wanted the two zeros to mark "*simultaneous*" moments and the two clocks to be henceforth synchronized.

This would be perfect, of course, if the signal's path were the same outbound and return, or in other words, if the system to which clocks O and A are attached were stationary in the ether. Even in a moving system, it would still be perfect for synchronizing two clocks O and B located on a line perpendicular to the direction of motion: we know indeed that if the system's motion carries O to $O^{'}$, the light ray travels the same path from O to $B^{'}$ as from $B^{'}$ to $O^{'}$, since triangle $OB^{'}O^{'}$ is isosceles. But it is different for signal transmission from O to A and *vice versa*. The observer at absolute rest in the ether clearly sees that the paths are unequal because, on the outbound journey, the ray launched from point O must chase after point A which is fleeing, while on the return journey the ray sent back from point A meets point O coming toward it. Or, if you prefer, he realizes that the distance OA, assumed identical in both cases, is traversed by light at a relative speed of $c — v$ in the first case, $c + v$ in the second, so that the travel times are in the ratio of $c + v$ to $c — v$. By marking zero at the midpoint of the interval traversed by the clock hand between the departure and return of the ray, we place it, in the eyes of our stationary observer, too close to the starting point. Let us calculate the error. We said earlier that the interval traversed by the hand on the dial during the double outbound and return journey of the signal is $\frac{2l}{c}$. If, then, at the moment of signal emission, we marked a provisional zero at the point where the hand was, we will have placed the definitive zero M at point $\frac{l}{c}$ of the dial, which we believe corresponds to the definitive zero of the clock at A. But the stationary observer knows that the definitive zero of the clock at O, to truly correspond to the zero of the clock at A—to be simultaneous with it—should have been placed at a point dividing the interval $\frac{2l}{c}$ not into equal parts, but into parts proportional to $c + v$ and $c — v$. Let us call x the first of these two parts. We will have

$$\frac{x}{\frac{2l}{c} - x} = \frac{c + v}{c - v}$$

and consequently

$$x = \frac{l}{c} + \frac{lv}{c^2}.$$

. This means that, for the stationary observer, the point M where we marked the definitive zero is $\frac{lv}{c^2}$ too close to the provisional zero, and that if we wish to leave it there, we should, to achieve true simultaneity between the definitive zeros of the two clocks, move back the definitive zero of the clock at A by $\frac{lv}{c^2}$. In short, the clock at A is always behind by a dial interval of $\frac{lv}{c^2}$ compared to the time it should show. When the hand is at the point we agree to call $t^{'}$ (we reserve the designation t for the time of clocks stationary in the ether), the stationary observer tells himself that if it were truly synchronized with the clock at O, it would show $t^{'} + \frac{lv}{c^2}$.

What, then, will happen when operators placed respectively at O and A wish to measure the speed of light by noting, on the synchronized clocks at these two points, the moment of departure, the moment of arrival, and consequently the time taken by light to cross the interval?

We have just seen that the zeros of the two clocks were set such that a light ray always appeared, to anyone considering the clocks synchronized, to take the same time to go from O to A and back. Our two physicists will therefore naturally find that the time for the journey from O to A, counted using the two clocks placed respectively at O and A, is equal to half the total time, counted on the single clock at O, for the complete round trip. Now, we know that the duration of this double journey, counted on the clock at O, is always the same, regardless of the system's speed. The same will therefore hold for the duration of the single journey, counted by this new method using two clocks: consequently, the constancy of the speed of light will again be observed. The observer stationary in the ether will moreover follow point by point what has happened. He will notice that the distance covered by the light from O to A is to the distance covered from A to O in the ratio of $c + v$ to $c - v$, instead of being equal. He will observe that, since the zero of the second clock does not match that of the first, the outbound and return times, which appear equal when comparing the indications of the two clocks, are in reality in the ratio of $c + v$ to $c - v$. There has therefore been, he will say to himself, an error in the length of the path and an error in the duration of the journey, but the two errors compensate because it is the same double error that presided long ago over the synchronization of the two clocks.

Thus, whether one counts time on a single clock at a specific location, or uses two clocks distant from each other; in both cases one will obtain, within the moving system S', the same number for the speed of light. Observers attached to the moving system will judge that the second experiment confirms the first. But the stationary spectator, seated in the ether, will simply conclude that he has two corrections to make instead of one, for everything concerning the time indicated by the clocks of system S'. He had already noted that these clocks ran too slowly. He will now tell himself that the clocks spaced along the direction of motion additionally lag behind each other. Suppose once again that the moving system S' has detached itself, as a double, from the stationary system S, and that the dissociation occurred at the moment when a clock H_0' of the moving system S', coinciding with clock H_0 of system S, marked zero like it. Consider then in system S' a clock H_1', placed such that the straight line $\overrightarrow{H_0' H_1'}$ indicates the direction of the system's motion, and call l the length of this line. When clock H_1' marks the time t', the stationary observer now rightly tells himself that, since clock H_1' lags by a dial interval $\frac{lv}{c^2}$ behind clock H_0' of this system, a number $t' + \frac{lv}{c^2}$ of seconds of system S' has actually elapsed. But he already knew that, given the slowing of time due to motion, each of these apparent seconds is worth, in real seconds, $\frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$. He will therefore calculate that if clock H_1' gives the indication t', the time actually elapsed is $\frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}\left(t' + \frac{lv}{c^2}\right)$. Consulting at that moment one of the clocks in his stationary system, he will find that the time t' marked by it is indeed this number.

But even before realizing the correction needed to pass from time t' to time t, he would have perceived the error made within the moving system in assessing simultaneity. He would have caught it in the act by witnessing the clock synchronization. Consider indeed, along the indefinitely extended line $H_0' H_1'$ of this system, a large number of clocks H_0', H_1', H_2' ... etc., separated from each other by equal intervals l. When S' coincided with S and was consequently stationary in the ether, the optical signals going back and forth between two consecutive clocks made equal journeys in both directions. If all the clocks thus synchronized marked the same hour, it was truly at the same instant. Now that S' has detached from S by the effect of doubling, the character inside S', unaware of his motion, leaves his clocks H_0', H_1', H_2' ... etc. as they were; he believes in real simultaneities when the hands indicate the same number on the dial. Moreover, if he has a doubt, he proceeds again with the synchronization: he simply finds confirmation of what he had observed in immobility. But the stationary spectator, who sees how the optical signal now travels farther to go from H_0' to H_1', from H_1' to H_2', etc., than to return from H_1' to H_0', from H_2' to H_1', etc., notices that for there to be real simultaneity when the clocks mark the same hour, the zero of clock H_1' would have to be set back by $\frac{lv}{c^2}$, the zero of clock H_2' set back by $\frac{2lv}{c^2}$, etc. Real simultaneity has become nominal. It has curved into succession.

⊠ ⊠⊠ ⊠ ⊠ 4.5.

Longitudinal Contraction

In summary, we have sought how light could have the same speed for the stationary observer and for the moving observer: deepening this point has revealed to us that a system S', resulting from the doubling of a system S and moving in a straight line with speed v, undergoes singular modifications. We would formulate them as follows:

1. All lengths of S' have contracted in the direction of its motion. The new length is to the old in the ratio of $\sqrt{1 - \frac{v^2}{c^2}}$ to unity.
2. The Time of the system has dilated. The new second is to the old in the ratio of unity to $\sqrt{1 - \frac{v^2}{c^2}} \cdot$.
3. What was simultaneity in system S has generally become succession in system S'. Only events that were simultaneous in S and are located in the same plane perpendicular to the direction of motion remain contemporary in S'. Any two other events, simultaneous in S, are separated in S' by $\frac{lv}{c^2}$ seconds of system S', if we denote by l their distance measured along the direction of motion of their system, that is, the distance between the two planes perpendicular to this direction that pass respectively through each of them.

In short, system S', considered in Space and Time, is a double of system S that has contracted, as to space, in the direction of its motion; has dilated, as to time, each of its seconds; and finally, in time, has dislocated into succession every simultaneity between two events whose distance has shrunk in space. But these changes escape the observer who is part of the moving system. Only the stationary observer notices them.

☒☒☒☒☒ 4.6.

Concrete Meaning of the Terms in Lorentz's Formulas

I suppose then that these two observers, Pierre and Paul, could communicate. Pierre, who knows what's what, would say to Paul: "*At the moment you detached from me, your system flattened, your Time swelled, your clocks fell out of sync. Here are the correction formulas that will allow you to return to truth. See what you should do with them*". It's evident that Paul would reply: "*I'll do nothing, because practically and scientifically, everything would become incoherent inside my system. Lengths have shrunk, you say? But the same is then true of the meter I carry upon them; and since the measurement of these lengths, within my system, is their ratio to the meter thus displaced, this measurement must remain what it was*". Time, you say further, has dilated, and you count more than one second where my clocks mark exactly one? But if we suppose that S and S' are two copies of planet Earth, the second of S', like that of S, is by definition a certain determined fraction of the planet's rotation time; and though they may not have the same duration, each remains one second. Simultaneities have become successions? Clocks at points H'_1, H'_2, H'_1 all indicate the same time while there are three different moments? But at the different moments when they mark the same time in my system, events occur at points H'_1, H'_2, H'_1 of my system that, in system S, were legitimately marked as contemporary: I will then agree to still call them contemporary, so as not to have to reconsider the relations of these events first among themselves, and then with all others. By this I will preserve all your sequences, all your relations, all your explanations. By naming succession what I called simultaneity, I would have an incoherent world, or one constructed on a plan absolutely different from yours. Thus all things and all relations between things will retain their magnitude, remain in the same frameworks, and fit into the same laws. I can therefore act as if none of my lengths had shrunk, as if my Time had not dilated, as if my clocks were in agreement. That at least holds for ponderable matter, which I carry with me in my system's motion: profound changes have occurred in the temporal and spatial relations its parts maintain among themselves, but I don't notice it and have no need to notice it.

Now, I must add that I consider these changes beneficial. For let us leave ponderable matter. What would my situation be regarding light, and more generally electromagnetic phenomena, if my spatial and temporal dimensions had remained what they were! These events are not carried along, they, in my system's motion. Light waves, electromagnetic disturbances may well originate in a moving system: experience proves they do not adopt its motion. My moving system deposits them in passing, so to speak, in the stationary ether, which then takes charge of them. Even if ether didn't exist, we would invent it to symbolize this experimentally verified fact, the independence of light's speed from the motion of the source that emitted it. Now, in this ether, before these optical facts, amid these electromagnetic events, you sit, immobile. But I traverse them, and what you perceive from your fixed observatory in the ether might appear to me, in turn, completely different. The science of electromagnetism, which you so laboriously built, would have to be redone by me; I would have to modify my equations, once established, for each new speed of my system. What would I have done in such a universe? At what cost of liquefying all science would the solidity of temporal and spatial relations have been bought! But thanks to the contraction of my lengths, the dilation of my Time, the dislocation of my simultaneities, my system becomes, regarding electromagnetic phenomena, the exact counterfeit of a fixed system. Let it run as fast as it pleases alongside a light wave: the latter will always maintain the same speed relative to it; it will be as if immobile relative to it. All is therefore for the best, and it is a good genius who arranged things thus.

There is one case, however, where I will have to take account of your indications and modify my measurements. It is when constructing a complete mathematical representation of the universe, I mean of everything happening in all worlds moving relative to you at all speeds. To establish this representation which would give us, once complete and perfect, the relation of everything to everything, each point of the universe must be defined by its distances x, y, z to three determined rectangular planes, declared immobile, intersecting along axes OX, OY, OZ. Moreover, the axes OX, OY, OZ chosen in preference to all others, the only axes truly and not conventionally immobile, are those established in your fixed system. Now, in the moving system where I find myself, I relate my observations to axes $O'X'$, $O'Y'$, $O'Z'$ carried along by it, and it is by their distances x', y', z' to the three planes intersecting along these lines that every point of my system is defined in my eyes. Since it is from your stationary viewpoint that the global representation of the Whole must be constructed, I must find a way to relate my observations to your axes OX, OY, OZ, or in other words, to establish once and for all formulas by which I can, knowing x', y' and z', calculate x, y and z. But this will be easy for me, thanks to the indications you've just provided. First, to simplify things, I will assume that my axes $O'X'$, $O'Y'$, $O'Z'$ coincided with yours before the dissociation of the two worlds S and S' (which it will be better, for clarity of this demonstration, to make quite distinct this time), and I will also assume that OX, and consequently $O'X'$, mark the very direction of S''s motion. Under these conditions, it is clear that planes $Z'O'X'$, $X'O'Y'$ merely glide respectively over planes ZOX, XOY, coinciding constantly with them, and consequently y and y' are equal, z and z' likewise. It then remains to calculate x. If, since the moment O' left O, I have counted on the clock at point x', y', z' a time t', I naturally represent the distance from point x', y', z' to plane ZOY as equal to $x' + vt'$. But, given the contraction you signal, this length $x' + vt'$ would not coincide with your x; it would coincide with

$x\sqrt{1-\frac{v^2}{c^2}}$. And consequently what you call x is $\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}(x' + vt')$. Problem solved. I will not forget, moreover, that the time t', which has elapsed for me and indicated by my clock at point x', y', z', is different from yours. When this clock gave me the indication t', the time t counted by yours is, as you said, $\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}(t' + \frac{vx'}{c^2})$. This is the time t I will mark for you. For time as for space, I will have passed from my viewpoint to yours.

Thus would speak Paul. And at the same time he would have established the famous "*transformation equations*" of Lorentz, equations which, moreover, from Einstein's more general viewpoint, do not imply that system S is definitively fixed. We will indeed show shortly how, according to Einstein, one can make S any system, provisionally immobilized by thought, and how one must then attribute to S', considered from S's viewpoint, the same temporal and spatial deformations that Pierre attributed to Paul's system. Under the hypothesis, always accepted until now, of a single Time and a Space independent of Time, it is evident that if S' moves relative to S with constant speed v, if x', y', z' are the distances of a point M' in system S' to the three planes determined by the three rectangular axes, taken pairwise, $O'X', O'Y', O'Z'$, and if finally x, y, z are the distances of this same point to the three fixed rectangular planes with which the three mobile planes initially coincided, we have:

$$x = x' + vt'$$

$$y = y'$$

$$z = z'$$

Moreover, since the same time unfolds invariably for all systems, we have:

$$t = t'.$$

But if motion determines length contractions, a slowing of time, and causes clocks in the time-dilated system to mark only a local hour, it follows from the explanations exchanged between Pierre and Paul that we will have:

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

① $$y = y'$$

$$z = z'$$

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

Hence a new formula for the composition of velocities. Suppose indeed that point M' moves uniformly within S', parallel to $O'X'$, with velocity v', naturally measured by $\frac{x'}{t'}$. What will be its velocity for the spectator seated at S who relates the successive positions of the mobile to his axes OX, OY, OZ? To obtain this velocity v'', measured by $\frac{x}{t}$, we must divide the first and fourth equations above term by term, and we will have:

$$v'' = \frac{v + v'}{1 + \frac{vv'}{c^2}}$$

whereas until now mechanics posited:

$$v'' = v + v'$$

Therefore, if S is the riverbank and S' a boat moving with velocity v relative to the bank, a traveler moving on the boat's deck in the direction of motion with velocity v' does not have, in the eyes of the spectator stationary on the bank, velocity $v + v'$, as was said until now, but a velocity less than the sum of the two component velocities. At least, this is how things appear at first. In reality, the resultant velocity is indeed the sum of the two component velocities, if the traveler's velocity on the boat is measured from the bank, like the boat's own velocity. Measured from the boat, the traveler's velocity v' is $\frac{x'}{t'}$, if we call for example x' the length the traveler finds for the boat (invariable length for him, since the boat is always at rest for him) and t' the time he takes to traverse it, that is, the difference between the hours marked at his departure and arrival by two clocks placed respectively at the stern and bow (we assume an immensely long boat whose clocks could only be synchronized by signals transmitted at a distance). But, for the spectator stationary on the bank, the boat contracted when it passed from rest to motion, Time dilated there, and the clocks are no longer synchronized. The space traversed in his eyes by the traveler on the boat is therefore no longer x' (if x' was the quay length coinciding with the stationary boat), but $x'\sqrt{1-\frac{v^2}{c^2}}$; and the time taken to traverse this space is not t', but $\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}\left(t' + \frac{vx'}{c^2}\right)$. He will conclude that the velocity to add to v to obtain v'' is not v', but

$$\frac{x'\sqrt{1-\frac{v^2}{c^2}}}{\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}\left(t' + \frac{vx'}{c^2}\right)}$$

that is

$$\frac{v'\left(1-\frac{v^2}{c^2}\right)}{1+\frac{vv'}{c^2}}$$

. He will then have:

$$v'' = v + \frac{v'\left(1-\frac{v^2}{c^2}\right)}{1+\frac{vv'}{c^2}} = \frac{v+v'}{1+\frac{vv'}{c^2}}$$

From which we see that no velocity can exceed that of light, since any composition of an arbitrary velocity v' with a velocity v assumed equal to c always gives this same velocity c as the resultant.

Such then, to return to our initial hypothesis, are the formulas that Paul will have in mind if he wishes to pass from his viewpoint to that of Pierre and thus obtain—with all observers attached to all mobile systems S'', S''', etc. having done likewise—a complete mathematical representation of the universe. Had he been able to establish his equations directly, without Pierre's intervention, he would have equally provided them to Pierre to enable him, knowing x, y, z, t, v'', to calculate x', y', z', t', v'. Let us indeed solve equations ① with respect to x', y', z', t', v'; we immediately derive:

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

$$y' = y$$

$$z' = z$$

$$t' = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}\left(t - \frac{vx}{c^2}\right)$$

$$v' = \frac{v'' - v}{1 - \frac{vv''}{c^2}}$$

equations more commonly given for the Lorentz transformation[(1)]. But this matters little for now. We merely wished, by recovering these formulas term by term, by defining the perceptions of observers placed in one or the other system, to prepare the analysis and demonstration that are the object of the present work.

[1] *It is important to note that if we have just reconstructed Lorentz's formulas by commenting on the Michelson-Morley experiment, it is to show the concrete meaning of each term composing them. The truth is that the transformation group discovered by Lorentz ensures, in general, the invariance of the equations of electromagnetism.*

☒☒☒☒☒ 5.

Complete Relativity

We momentarily slipped from what we'll call the "*unilateral relativity*" viewpoint to that of reciprocity, which is characteristic of Einstein. Let us hasten to return to our position. But let us say now that the contraction of moving bodies, the dilation of their Time, the dislocation of simultaneity into succession, will be preserved unchanged in Einstein's theory: there will be nothing to change in the equations we have established, nor more generally in what we have said about system S' in its temporal and spatial relations to system S. Only these contractions of extension, these dilations of Time, these ruptures of simultaneity will become explicitly reciprocal (they are already implicitly so, according to the very form of the equations), and the observer in S' will repeat about S everything that the observer in S had affirmed about S'. Thereby will vanish, as we shall also show, what was initially paradoxical in the theory of Relativity: we maintain that the unique Time and the Extension independent of duration persist in Einstein's hypothesis taken in its pure state: they remain what they have always been for common sense. But it is nearly impossible to arrive at the hypothesis of double relativity without passing through that of simple relativity, where one still posits an absolute reference point, an immobile ether. Even when one *conceives* relativity in the second sense, one still *sees* it somewhat in the first; for though one may say that only the reciprocal motion of S and S' relative to each other exists, one cannot study this reciprocity without adopting one of the two terms, S or S', as a "*reference system*": now, as soon as a system has been thus immobilized, it becomes provisionally an absolute reference point, a substitute for the ether. In short, absolute rest, banished by the intellect, is restored by the imagination. From the mathematical viewpoint, this has no drawback. Whether system S, adopted as reference system, is at absolute rest in the ether, or whether it is at rest only relative to all systems to which it is compared, in both cases the observer placed in S will treat in the same manner the time measurements transmitted to him from all systems such as S'; in both cases he will apply Lorentz's transformation formulas to them. The two hypotheses are equivalent for the mathematician. But it is not the same for the philosopher. For if S is at absolute rest, and all other systems in absolute motion, the theory of Relativity will effectively imply the existence of multiple Times, all on the same level and all real. If, on the contrary, one places oneself in Einstein's hypothesis, the multiple Times will persist, but only one will ever be real, as we propose to demonstrate: the others will be mathematical fictions. This is why, in our view, all philosophical difficulties concerning time vanish if one strictly adheres to Einstein's hypothesis, but so do all the oddities that have bewildered so many minds. We therefore need not dwell on the meaning to be given to the "*deformation of bodies*", the "*slowing of time*", and the "*rupture of simultaneity*" when one believes in the immobile ether and the privileged system. It will suffice for us to seek how they should be understood in Einstein's hypothesis. Casting then a retrospective glance at the first viewpoint, one will recognize that it was necessary to start there, one will judge natural the temptation to return to it even after adopting the second; but one will also see how false problems arise solely from the fact that images are borrowed from one to support the abstractions corresponding to the other.

5.1.

On the Reciprocity of Motion

We imagined a system S at rest in the immobile ether, and a system S' in motion relative to S. Now, the ether has never been perceived; it was introduced into physics to support calculations. On the contrary, the motion of a system S' relative to a system S is for us a fact of observation. One must also consider as a fact, until further notice, the constancy of the speed of light for a system that changes speed as one wishes, and whose speed can consequently descend to zero. Let us then retake the three affirmations from which we started: 1° S' moves relative to S; 2° light has the same speed for both; 3° S is stationary in an immobile ether. It is clear that two of them state facts, and the third a hypothesis. Reject the hypothesis: we now have only the two facts. But then the first will no longer be formulated in the same way. We announced that S' moves relative to S: why did we not just as well say that it was S that moves relative to S'? Simply because S was thought to participate in the absolute immobility of the ether. But there is no more ether[1], no absolute fixity anywhere. We can therefore say, at will, that S' moves relative to S, or that S moves relative to S', or better that S and S' move relative to each other. In short, what is really given is a reciprocity of displacement. How could it be otherwise, since the motion perceived in space is only a continuous variation of distance? If one considers two points A and B and the displacement of "*one of them*", all that the eye observes, all that science can note, is the change in length of the interval[2]. Language will express the fact by saying that A moves, or that it is B. It has the choice; but it would be closer still to experience to say that A and B move relative to each other, or more simply that the gap between A and B decreases or increases. The "*reciprocity*" of motion is therefore an observational fact. One could recognize it *a priori* as a condition of science, for science operates only on measurements, measurement generally concerns lengths, and when a length grows or diminishes, there is no reason to privilege one of the extremities: all one can affirm is that the gap grows or diminishes between the two[3].

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[1] *We are speaking, of course, only of a fixed ether, constituting a privileged, unique, absolute reference system. But the hypothesis of the ether, suitably amended, can very well be taken up again by the theory of Relativity. Einstein is of this opinion (See his 1920 lecture on "The Ether and the Theory of Relativity"). Already, to preserve the ether, attempts had been made to use certain ideas of Larmor. (Cf. Cunningham, The Principle of Relativity, Cambridge, 1911, chap. xvi).*

[2] *On this point, and on the "reciprocity" of motion, we drew attention in Matter and Memory, Paris, 1896, chap. IV, and in the Introduction to Metaphysics (Revue de Métaphysique et de Morale, January 1903).*

[3] *See on this point, in Matter and Memory, pages 214 and following.*

5.2.

Relative Motion and Absolute Motion

Certainly, not all movement reduces to what is perceived in space. Alongside movements we merely observe from the outside, there are those we also feel ourselves producing. When Descartes spoke of the reciprocity of motion[1], it was not without reason that Morus replied: "If I am sitting quietly, and another, moving away a thousand paces, is red with fatigue, it is indeed he who moves and I who rest[2]." Whatever science may tell us about the relativity of movement perceived by our eyes, measured by our rulers and clocks, it leaves intact our profound sense of accomplishing movements and exerting efforts of which we are the agents. Let Morus' character, "sitting quietly," resolve to run in turn, rise and run: one may argue that his running is a reciprocal displacement of his body and the ground—that he moves if we immobilize the Earth in thought, but that the Earth moves if we decree the runner immobile. He will never accept this decree; he will always declare that he immediately perceives his act, that this act is a fact, and that the fact is unilateral. This awareness of movements decided and executed is shared by all other humans and likely most animals. And since living beings thus accomplish movements that belong to them, that are solely connected to them, perceived from within—yet when considered externally appear to the eye as mere reciprocal displacement—we may conjecture that this is true of relative motion in general. A reciprocity of displacement is the visible manifestation to our eyes of an internal, absolute change occurring somewhere in space. We have emphasized this point in a work titled Introduction to Metaphysics. Such, indeed, seemed to us the metaphysician's function: to penetrate the interior of things; the true essence, the profound reality of movement can never be better revealed than when he performs the movement himself—when he still perceives it externally like all other movements, but also grasps it internally as an effort, of which only the trace was visible. Yet the metaphysician obtains this direct, internal, and certain perception only for movements he accomplishes himself. Only of these can he guarantee they are real acts, absolute movements. For movements performed by other living beings, it is not by direct perception but through sympathy and analogical reasoning that he elevates them to independent realities. And of matter's movements in general, he can say nothing except that internal changes—analogous or not to efforts—likely occur somewhere, translating to our eyes, like our own acts, as reciprocal displacements of bodies in space. We therefore need not account for absolute motion in constructing science: we rarely know where it occurs, and even then, science would have no use for it, since it is immeasurable and science exists to measure. Science can and must retain from reality only what is spread out in space—homogeneous, measurable, visual. The movement it studies is thus always relative and can consist only in a reciprocity of displacement. While Morus spoke as a metaphysician, Descartes marked with definitive precision the viewpoint of science. He went even beyond the science of his time, beyond Newtonian mechanics, beyond ours, formulating a principle whose demonstration was reserved for Einstein.

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[1] *Descartes, Principles, ii, 29.*

[2] *H. Morus, Scripta philosophica, 1679, vol. II, p. 218.*

⊠⊠⊠⊠⊠ 5.3.

From Descartes to Einstein

For it is a remarkable fact that the radical relativity of motion, postulated by Descartes, could not be categorically affirmed by modern science. Science, as understood since Galileo, undoubtedly wished motion to be relative. It readily declared it so. But it treated it accordingly only weakly and incompletely. There were two reasons for this. First, science only challenges common sense to the extent strictly necessary. Now, if all rectilinear and non-accelerated motion is obviously relative, if therefore, in the eyes of science, the track is as much in motion relative to the train as the train is relative to the track, the scientist will nonetheless say that the track is immobile; he will speak like everyone else when he has no interest in expressing himself otherwise. But that is not the essential point. The reason why science never insisted on the radical relativity of uniform motion is that it felt incapable of extending this relativity to accelerated motion: at least it had to renounce it provisionally. More than once in its history, it has undergone a necessity of this kind. From a principle immanent to its method, it sacrifices something to a hypothesis immediately verifiable and which yields useful results at once: if the advantage holds, it will be because the hypothesis was true on one side, and then this hypothesis may one day have definitively contributed to establishing the principle it had provisionally set aside. Thus, Newtonian dynamism seemed to cut short the development of Cartesian mechanism. Descartes posited that everything pertaining to physics is spread out in motion in space: thereby he gave the ideal formula of universal mechanism. But to stick to this formula would have been to consider globally the relation of everything to everything; one could only obtain a solution, even a provisional one, to particular problems by more or less artificially cutting out and isolating parts from the whole: now, as soon as one neglects the relation, one introduces force. This introduction was nothing but this very elimination; it expressed the necessity in which human intelligence finds itself to study reality part by part, being powerless to form at once a conception both synthetic and analytic of the whole. Newtonian dynamism could therefore be—and in fact turned out to be—a step towards the complete demonstration of Cartesian mechanism, which Einstein may have achieved. Now, this dynamism implied the existence of absolute motion. One could still admit the relativity of motion in the case of non-accelerated rectilinear translation; but the appearance of centrifugal forces in rotational motion seemed to attest that one was dealing here with a true absolute; and one had to hold as absolute any other accelerated motion. Such is the theory that remained classic until Einstein. However, this could only be a provisional conception. A historian of mechanics, Mach, had pointed out its insufficiency [1], and his criticism certainly contributed to inspiring new ideas. No philosopher could be entirely satisfied with a theory that held mobility to be a mere relation of reciprocity in the case of uniform motion, and a reality immanent in a moving body in the case of accelerated motion. If we deemed it necessary, for our part, to admit an absolute change wherever spatial motion is observed, if we considered that the consciousness of effort reveals the absolute character of concomitant motion, we added that the consideration of this absolute motion concerns solely our knowledge of the interior of things, that is, a psychology that extends into metaphysics [2]. We added that for physics, whose role is to study the relations between visual data in homogeneous space, all motion *must* be relative. And yet certain motions *could* not be so. They can be now. If only for this reason, the theory of general relativity marks an important date in the history of ideas. We do not know what definitive fate physics reserves for it. But, whatever happens, the conception of spatial motion that we find in Descartes, and which harmonizes so well with the spirit of modern science, will have been rendered scientifically acceptable by Einstein in the case of accelerated motion as in that of uniform motion.

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(1) *Mach, Die Mechanik in ihrer Entwicklung, II. vi*

(2) *Matière et Mémoire, loc. cit. Cf. Introduction à la Métaphysique (Rev. de Métaphysique et de Morale, janvier 1903)*

It is true that this part of Einstein's work is the latest. It is the theory of "*generalized*" Relativity. The considerations on time and simultaneity belonged to the theory of "*restricted*" Relativity, and the latter concerned only uniform motion. But in the restricted theory there was a kind of demand for the generalized theory. For although it was *restricted*, that is, limited to uniform motion, it was no less *radical* in that it made mobility a reciprocity. Now, why had one not yet gone explicitly that far? Why, even for uniform motion, which was declared relative, was the idea of relativity applied only weakly? Because it was known that the idea would no longer suit accelerated motion. But, from the moment a physicist held the relativity of uniform motion to be radical, he had to seek to regard accelerated motion as relative. If only for this reason, the theory of restricted relativity called for the theory of generalized relativity to follow, and could not even be convincing in the eyes of the philosopher unless it lent itself to this generalization.

Now, if all motion is relative and there is no absolute reference point, no privileged system, an observer inside a system will obviously have no means of knowing whether his system is in motion or at rest. Let us say more: he would be wrong to ask, for the question no longer makes sense; it is not posed in these terms. He is free to decree what he pleases: his system will be immobile, by definition, if he makes it his "*reference system*" and sets up his observatory there. This could not be the case, even in the case of uniform motion, when one believed in an immobile ether. Nor could it be the case, in any way, when one believed in the absolute character of accelerated motion. But as soon as these two hypotheses are set aside, any system is at rest or in motion, at will. Naturally, one must stick to the choice once made of the immobile system, and treat the others accordingly.

5.4.

Propagation and Transport

We would not wish to unduly lengthen this introduction. However, we must recall what we once said about the idea of a body, and also about absolute motion: this double series of considerations allowed us to conclude to the radical relativity of motion as displacement in space. What is immediately given to our perception, we explained, is a continuous extension on which qualities are deployed: it is more specifically a continuity of visual extension, and consequently of color. Here, nothing artificial, conventional, or merely human. Colors would no doubt appear differently to us if our eye and our consciousness were differently constituted: there would nonetheless always be something unshakably real that physics would continue to resolve into elementary vibrations. In short, as long as we speak only of a qualified continuity and qualitatively modified, such as the colored extension changing in color, we express immediately, without interposed human convention, what we perceive: we have no reason to suppose that we are not here in the presence of reality itself. Any appearance must be deemed reality as long as it has not been proven illusory, and this demonstration has never been done for the present case: it was believed to have been done, but it was an illusion; we think we have proven it[1]. Matter is thus presented to us immediately as a reality. But is it the same for such and such a body, erected into a more or less independent entity? The visual perception of a body results from a fragmentation we make of the colored extension; it has been cut out by us in the continuity of the extension. It is very likely that this fragmentation is carried out diversely by the various animal species. Many are incapable of it; and those that are capable regulate themselves, in this operation, on the form of their activity and the nature of their needs. "Bodies, we wrote, are cut from the fabric of nature by a *perception* whose scissors follow the dotted lines along which *action* would pass"[2]. That is what psychological analysis says. And physics confirms it. It resolves the body into an almost indefinite number of elementary corpuscles; and at the same time it shows us this body linked to other bodies by a thousand reciprocal actions and reactions. It thus introduces so much discontinuity, and on the other hand establishes so much continuity between it and the rest of things, that one can guess how artificial and conventional our distribution of matter into bodies is. But if each body, taken in isolation and stopped where our perceptual habits terminate it, is largely a being of convention, how could it not be the same for motion considered as affecting this body in isolation? There is only one movement, we said, that is perceived from within, and of which we know that it constitutes by itself an event: it is the movement that translates to our eyes our effort. Elsewhere, when we see a movement occur, all we are sure of is that some modification is being accomplished in the universe. The nature and even the precise place of this modification escape us; we can only note certain changes of position that are its visual and superficial aspect, and these changes are necessarily reciprocal. Every movement—even our own as perceived from the outside and visualized—is thus relative. It goes without saying, moreover, that we are speaking solely of the movement of ponderable matter. The analysis we have just made shows it sufficiently. If color is a reality, the same must be true of the oscillations that take place, so to speak, inside it: should we, since they have an absolute character, still call them movements? On the other hand, how can we put on the same level the act by which these real oscillations, elements of a quality and participating in what is absolute in the quality, propagate through space, and the entirely relative displacement, necessarily reciprocal, of two systems S and S′ cut out more or less artificially in matter? We speak, here and there, of movement; but does the word have the same meaning in both cases? Let us rather say *propagation* in the first, and *transport* in the second: it will result from our old analyses that propagation must be profoundly distinguished from transport. But then, the emission theory being rejected, the propagation of light not being a translation of particles, we will not expect the speed of light relative to a system to vary according to whether it is "*at rest*" or "*in motion*". Why would it take into account a certain all-too-human way of perceiving and conceiving things?

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[1] *Matter and Memory, p. 225 ff. Cf. the entire first chapter*

[2] *Creative Evolution, 1907, p. 12–13. Cf. Matter and Memory, 1896, entire chap. I; and chap. IV, p. 218 ff.*

5.5.

Reference Systems

Let us then frankly place ourselves in the hypothesis of reciprocity. We must now define in a general way certain terms whose meaning had seemed sufficiently indicated until now, in each particular case, by the very use we made of them. We will therefore call a "*reference system*" the trirectangular trihedron relative to which we agree to situate, by indicating their respective distances to the three faces, all points of the universe. The physicist who constructs Science will be attached to this trihedron. The vertex of the trihedron will generally serve as his observatory. Necessarily, the points of the reference system will be at rest relative to each other. But it must be added that, in the hypothesis of Relativity, the reference system itself will be immobile for the entire time it is used for reference. For what indeed is the fixity of a trihedron in space if not the property granted to it, the momentarily privileged situation assured to it, by adopting it as a reference system? As long as one retains a stationary ether and absolute positions, immobility belongs for good to things; it does not depend on our decree. Once the ether has vanished along with the privileged system and the fixed points, there are only relative movements of objects relative to each other; but since one cannot move relative to oneself, immobility will be, by definition, the state of the observatory where one places oneself in thought: that is precisely the reference trihedron. Certainly, nothing prevents us from supposing, at a given moment, that the reference system is itself in motion. Physics often has an interest in doing so, and the theory of Relativity willingly places itself in this hypothesis. But when the physicist sets his reference system in motion, it is because he provisionally chooses another, which then becomes immobile. It is true that this second system can in turn be set in motion by thought, without thought necessarily electing domicile in a third. But then it oscillates between the two, immobilizing them alternately by such rapid comings and goings that it can give itself the illusion of leaving both in motion. This is precisely the sense in which we will speak of a "*reference system*".

Moreover, we will call an "*invariable system*", or simply a "*system*", any set of points that maintain the same relative positions and are consequently immobile relative to each other. The Earth is a system. Undoubtedly, a multitude of displacements and changes occur on its surface and within it; but these movements are contained within a fixed framework: I mean that one can find on Earth as many fixed points as desired relative to each other and focus solely on them, the events unfolding in the intervals then becoming mere representations: they would be nothing more than images successively imprinted in the consciousness of observers stationary at these fixed points.

Now, a "*system*" can generally be erected into a "*reference system*". This means that we agree to locate within this system the reference system we have chosen. Sometimes it will be necessary to specify the particular point in the system where the vertex of the trihedron is placed. Most often, this will be unnecessary. Thus, the Earth system, when we consider only its state of rest or motion relative to another system, can be regarded by us as a simple material point; this point then becomes the vertex of our trihedron. Or else, leaving the Earth its dimension, we will imply that the trihedron is placed anywhere on it.

Moreover, the transition from “*system*” to “*reference system*” is continuous if we place ourselves in the theory of Relativity. It is essential to this theory to scatter over its “*reference system*” an indefinite number of clocks synchronized with each other, and consequently observers. The reference system can therefore no longer be a simple trihedron with a single observer. I grant that “*clocks*” and “*observers*” may be immaterial: by “*clock*” we simply mean here an ideal recording of the time according to determined laws or rules, and by “*observer*” an ideal reader of the ideally recorded time. Nevertheless, it remains true that we now represent the possibility of material clocks and living observers at all points of the system. The tendency to speak interchangeably of the “*system*” or the “*reference system*” was, moreover, immanent to the theory of Relativity from the outset, since it was by immobilizing the Earth, taking this global system as the reference system, that the invariability of the result of the Michelson-Morley experiment was explained. In most cases, assimilating the reference system to such a global system presents no inconvenience. And it can have great advantages for the philosopher, who will seek, for example, to what extent Einstein's Times are real Times, and who will for this purpose need to station flesh-and-blood observers, conscious beings, at all points of the reference system where there are “*clocks*”.

These are the preliminary considerations we wished to present. We have given them much space. But it is because the terms used were not rigorously defined, because one was not sufficiently accustomed to seeing relativity as reciprocity, because the relationship between radical relativity and attenuated relativity was not constantly kept in mind and precautions were not taken against confusion between them, and finally because the transition from the physical to the mathematical was not closely examined, that the philosophical meaning of the considerations on time in the theory of Relativity has been so gravely misunderstood. Let us add that little attention has been paid to the nature of time itself. Yet that is where we should have begun. Let us pause at this point. With the analyses and distinctions we have just made, and with the considerations we will present on time and its measurement, it will become easy to approach the interpretation of Einstein's theory.

⊠⊠⊠⊠⊠ 6.

On the Nature of Time

Succession and Consciousness

There is no doubt that time first coincides for us with the continuity of our inner life. What is this continuity? That of a flow or a passage, but a flow and a passage that are self-sufficient, the flow not implying a thing that flows and the passage not presupposing states through which one passes: the *thing* and the *state* are only snapshots artificially taken of the transition; and this transition, alone naturally experienced, is duration itself. It is memory, but not personal memory, external to what it retains, distinct from a past it would preserve; it is a memory internal to change itself, a memory that prolongs the before into the after and prevents them from being pure snapshots appearing and disappearing in a present that would be reborn ceaselessly. A melody that we listen to with eyes closed, thinking only of it, is very close to coinciding with this time that is the very fluidity of our inner life; but it still has too many qualities, too much determination, and we would first have to erase the difference between the sounds, then abolish the distinctive characteristics of sound itself, retaining only the continuation of what precedes into what follows and the uninterrupted transition, multiplicity without divisibility and succession without separation, to finally rediscover fundamental time. Such is immediately perceived duration, without which we would have no idea of time.

6.2.

Origin of the Idea of a Universal Time

How do we pass from this inner time to the time of things? We perceive the material world, and this perception appears to us, rightly or wrongly, to be both within us and outside us: on one side, it is a state of consciousness; on the other, it is a superficial film of matter where the perceiver and the perceived would coincide. At each moment of our inner life corresponds a moment of our body, and of all surrounding matter, which would be "*simultaneous*" with it: this matter then seems to participate in our conscious duration[1]. Gradually we extend this duration to the entire material world, because we see no reason to limit it to the immediate vicinity of our body: the universe appears to us as a single whole; and if the part around us endures in our manner, it must be the same, we think, for the part that surrounds it, and so on indefinitely. Thus is born the idea of a Duration of the universe, that is, of an impersonal consciousness that would be the connecting link between all individual consciousnesses, as between these consciousnesses and the rest of nature[2]. Such a consciousness would grasp in a single, instantaneous perception multiple events located at diverse points in space; simultaneity would precisely be the possibility for two or more events to enter into a unique and instantaneous perception. What is true, what is illusory in this way of representing things? What matters for the moment is not to apportion truth or error, but to clearly perceive where experience ends and hypothesis begins. There is no doubt that our consciousness feels itself enduring, nor that our perception is part of our consciousness, nor that something of our body and the matter surrounding us enters into our perception[3]: thus, our duration and a certain felt, lived participation of our material surroundings in this inner duration are facts of experience. But first, as we showed in the past, the nature of this participation is unknown: it could stem from a property that external things would have, without enduring themselves, of manifesting themselves in our duration insofar as they act on us and thus mark or punctuate the course of our conscious life[4]. Then, assuming that this surroundings "*endures*", nothing rigorously proves that we find the same duration when we change surroundings: different durations, I mean diversely rhythmed, could coexist. We once made a hypothesis of this kind concerning living species. We distinguished durations of higher or lower tension, characteristic of various degrees of consciousness, which would be staggered along the animal kingdom. However, we did not perceive then, nor do we see today, any reason to extend to the material universe this hypothesis of a multiplicity of durations. We had left open the question of whether the universe is divisible or not into independent worlds; our own world, with the particular élan manifested by life, sufficed for us. But if we had to decide the question, we would opt, in the current state of our knowledge, for the hypothesis of a single and universal material Time. It is only a hypothesis, but it is founded on an argument by analogy that we must consider conclusive as long as nothing more satisfactory is offered. This barely conscious reasoning would be formulated, we believe, as follows. All human consciousnesses are of the same nature, perceive in the same manner, walk so to speak at the same pace and live the same duration. Now, nothing prevents us from imagining as many human consciousnesses as we wish, scattered here and there throughout the totality of the universe, but just close enough to each other so that any two consecutive ones, taken at random, share the outermost portion of their field of external experience. Each of these two external experiences participates in the duration of each of the two consciousnesses. And since the two consciousnesses have the same rhythm of duration, the same must hold for the two experiences. But the two experiences have a part in common. By this connecting link, then, they merge into a single experience, unfolding in a single duration that will be, at will, that of one or the other of the two consciousnesses. The same reasoning can be repeated step by step; a single duration will gather along its path the events of the totality of the material world; and we can then eliminate the human consciousnesses that we had initially placed here and there as so many relays for the movement of our thought: there will remain only impersonal time in which all things flow. In formulating thus the belief of humanity, we perhaps put more precision into it than is fitting. Each of us is generally content to indefinitely expand, by a vague effort of imagination, his immediate material surroundings, which, being perceived by him, participates in the duration of his consciousness. But as soon as this effort becomes precise, as soon as we seek to legitimize it, we catch ourselves doubling and multiplying our consciousness, transporting it to the extreme confines of our external experience, then to the end of the new field of experience thus offered, and so on indefinitely: it is indeed multiple consciousnesses issuing from ours, similar to ours, that we charge with forming the chain across the immensity of the universe and with attesting, by the identity of their internal durations and the contiguity of their external experiences, the unity of an impersonal Time. Such is the hypothesis of common sense. We claim that it could just as well be Einstein's, and that the theory of Relativity is rather made to confirm the idea of a Time common to all things. This idea, hypothetical in all cases, even seems to us to take on particular rigor and consistency in the theory of Relativity, understood as it should be. Such is the conclusion that will emerge from our work of analysis. But that is not the important point for the moment. Let us set aside the question of a single Time. What we wish to establish is that one cannot speak of a reality that endures without introducing consciousness into it. The metaphysician will directly involve a universal consciousness. Common sense will vaguely think of it. The mathematician, it is true, will not have to concern himself with it, since he is interested in the measurement of things and not in their nature. But if he were to ask himself what he measures, if he fixed his attention on time itself, he would necessarily represent succession, and consequently a before and after, and consequently a bridge between the two (otherwise, there would be only one of the two, purely instantaneous): now, once again, it is impossible to imagine or conceive a connecting link between before and after without an element of memory, and consequently of consciousness.

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(1) *For the development of the views presented here, see Time and Free Will, Paris, 1889, mainly chaps. II and III; Matter and Memory, Paris, 1896, chaps. I and IV; Creative Evolution, passim. Cf. Introduction to Metaphysics, 1903; and The Perception of Change, Oxford, 1911*

(2) *Cf. those of our works that we have just cited*

(3) *See Matter and Memory, chap. I*

(4) *Cf. Time and Free Will, especially p. 82 ff.*

One may be reluctant to use the word if attaching an anthropomorphic meaning to it. But to represent something that endures, there's no need to take one's own memory and transport it, even attenuated, into the thing. However much one reduces its intensity, one risks leaving some degree of the variety and richness of inner life; one would thus preserve its personal character, at least human. The opposite approach must be followed. Consider a moment in the unfolding of the universe—an instantaneous snapshot existing independently of any consciousness—then try to simultaneously evoke another moment as close as possible to it, thereby introducing a minimum of time into the world without letting the faintest glimmer of memory pass through. You will see this is impossible. Without an elementary memory linking the two instants, there would be only one or the other—a single instant—no before and after, no succession, no time. You may grant this memory just enough to make the connection; it will be, if you wish, this very connection—a simple prolongation of the before into the immediate after, with a perpetually renewed forgetting of what is not the immediately preceding moment. You will nonetheless have introduced memory. In truth, it is impossible to distinguish between the duration, however short, separating two instants and a memory that would link them, for duration is essentially a continuation of what no longer is into what is. This is real time—perceived and lived. This is also any conceived time, for one cannot conceive time without representing it as perceived and lived. Duration therefore implies consciousness; and we place consciousness at the heart of things precisely by attributing to them a time that endures.

6.3.

Real Duration and Measurable Time

Whether we leave it within us or place it outside us, time that endures is not measurable. Measurement that isn't purely conventional implies division and superposition. Yet one cannot superimpose successive durations to verify if they are equal or unequal; by hypothesis, one ceases to be when the other appears; the idea of verifiable equality loses all meaning here. Moreover, if real duration becomes divisible—as we shall see—through the solidarity established between it and the line symbolizing it, it itself consists of an indivisible, global progression. Listen to a melody with eyes closed, thinking only of it, no longer juxtaposing notes on imaginary paper or keyboard—notes that once accepted becoming simultaneous and renounced their fluid continuity in time to freeze in space: you will rediscover the melody, or portion of melody, undivided and indivisible, that you have restored to pure duration. Now, our inner duration, considered from the first to the last moment of our conscious life, is something like this melody. Our attention may turn away from it and thus from its indivisibility; but when we try to cut it, it is as if we suddenly passed a blade through a flame: we divide only the space it occupies. When we witness a very rapid movement, like that of a shooting star, we distinctly distinguish the divisible line of fire from the indivisible mobility it sustains: this mobility is pure duration. Impersonal and universal Time, if it exists, may extend endlessly from past to future: it is all of one piece; the parts we distinguish in it are merely those of a space that traces its path and becomes its equivalent in our eyes; we divide the unfolded, but not the unfolding. How do we pass from unfolding to unfolded, from pure duration to measurable time? It is easy to reconstruct the mechanism of this operation.

If I run my finger over a sheet of paper without looking, the movement I perform, perceived from within, is a continuity of consciousness, something of my own flow—in short, duration. If I now open my eyes, I see that my finger traces a line on the paper that remains, where everything is juxtaposition and no longer succession; I have there the unfolded—the recording of the movement's effect—which will also be its symbol. Now, this line is divisible and measurable. By dividing and measuring it, I can therefore say, if convenient, that I am dividing and measuring the duration of the movement that traces it.

It is therefore true that time is measured through movement. But it must be added that if this measurement of time by movement is possible, it is mainly because we are capable of performing movements ourselves, and these movements then have a dual aspect: as muscular sensation, they are part of the current of our conscious life—they endure; as visual perception, they describe a trajectory—they give themselves space. I say "mainly" because one could, strictly speaking, conceive of a conscious being reduced to visual perception who would nevertheless construct the idea of measurable time. This would require that their life be spent contemplating an external movement extending endlessly. It would also require that they could extract from the movement perceived in space—which participates in the divisibility of its trajectory—pure mobility, meaning the uninterrupted solidarity of before and after given to consciousness as an indivisible fact: we made this distinction earlier when speaking of the line of fire traced by the shooting star. Such a consciousness would have a continuity of life constituted by the uninterrupted feeling of an external mobility unfolding indefinitely. And the uninterrupted unfolding would remain distinct from the divisible trace left in space, which is still the unfolded. The latter divides and measures because it is space. The former is duration. Without continuous unfolding, there would be only space—and a space that, no longer supporting a duration, would no longer represent time.

Now, nothing prevents us from supposing that each of us traces in space an uninterrupted movement from the beginning to the end of their conscious life. They could walk night and day. They would thus accomplish a journey coextensive with their conscious life. Their entire history would then unfold in a Measurable Time.

Is it such a journey we envision when speaking of Impersonal Time? Not entirely, because we live a social and even cosmic life, as much as—if not more than—an individual one. We quite naturally substitute for the journey we would make the journey of any other person, then any uninterrupted movement that would be contemporary with it. I call two flows "*contemporary*" when they are for my consciousness *one* or *two* indifferently, my consciousness perceiving them together as a single flow if it pleases to give an undivided act of attention, distinguishing them throughout if it prefers to split its attention between them, even doing both at once if it decides to share its attention yet not divide it. I call two instantaneous perceptions "*simultaneous*" when they are grasped in one and the same act of the mind, attention being able to make them one or two at will. This being established, it is easy to see that we have every interest in taking as the "*unfolding of time*" a movement independent of that of our own body. In truth, we find it already chosen. Society has adopted it for us. It is the Earth's rotation. But if we accept it, if we understand it to be time and not merely space, it is because a journey of our own body is always there, virtual, and it *could have been* for us the unfolding of time.

☒☒☒☒☒ 6.4.

On Immediately Perceived Simultaneity: Simultaneity of Flows and Simultaneity in the Instant

Moreover, it matters little whether we adopt one moving body or another as time-counter, once we have externalized our own duration as movement in space—the rest follows. Henceforth time will appear to us as the unwinding of a thread, that is, as the path of the moving body charged with counting it. We will have measured, we shall say, the time of this unfolding and consequently also that of the universal unfolding.

But all things would not seem to unfold with the thread, each present moment of the universe would not be for us the end of the thread, if we did not have at our disposal the concept of simultaneity. We shall see shortly the role of this concept in Einstein's theory. For now, we wish to clearly mark its psychological origin, of which we have already spoken. Relativity theorists speak only of the simultaneity of two instants. Yet before that, there is another, more natural idea: the simultaneity of two flows. We would say that it is of the very essence of our attention to be able to split without dividing. When we sit by a river, the flow of water, the glide of a boat, or the flight of a bird, the uninterrupted murmur of our inner life are for us three different things or one single thing, at will. We can internalize the whole, dealing with a single perception that carries, blended together, the three flows in its course; or we can leave the first two external and then split our attention between inside and outside; or better still, we can do both at once, our attention connecting yet separating the three flows, thanks to the singular privilege it possesses of being one and many. Such is our first idea of simultaneity. We then call two external flows simultaneous when they occupy the same duration because they are both held within the duration of a same third—our own: this duration is solely ours when our consciousness looks only at us, but it becomes equally theirs when our attention embraces the three flows in a single indivisible act.

Now, we would never pass from the simultaneity of two flows to that of two instants if we remained in pure duration, for all duration is thick: real time has no instants. But we naturally form the idea of an instant, and also of simultaneous instants, as soon as we acquire the habit of converting time into space. For if a duration has no instants, a line terminates in points[1]. And since we make a line correspond to a duration, portions of the line must correspond to "*portions of duration*", and an endpoint of the line to an "*endpoint of duration*": such will be the instant—something that does not actually exist, but virtually. The instant is what would terminate a duration if it stopped. But it does not stop. Real time therefore cannot furnish the instant; the latter issues from the mathematical point, that is, from space. And yet, without real time, the point would be merely a point; there would be no instant. Instantaneity thus implies two things: a continuity of real time, I mean duration, and a spatialized time, I mean a line that, described by movement, has thereby become symbolic of time: this spatialized time, which includes points, rebounds off real time and makes the instant emerge. This would not be possible without the tendency—fertile in illusions—that leads us to apply movement *against* the space traversed, to make the trajectory coincide with the path, and then to decompose the movement traversing the line as we decompose the line itself: if we chose to distinguish points on the line, these points then become "*positions*" of the moving body (as if it, moving, could ever *coincide* with something that is rest! as if it would not thereby immediately cease to move!). Then, having marked positions along the path of movement—that is, endpoints of subdivisions of the line—we make them correspond to "*instants*" of the continuity of movement: mere virtual stops, pure mental views. We once described the mechanism of this operation; we also showed how the difficulties raised by philosophers around the question of movement vanish as soon as one perceives the relation of the instant to spatialized time, and of spatialized time to pure duration. Let us here merely note that however learned the operation may appear, it is natural to the human mind; we practice it instinctively. The recipe is deposited in language.

[1] *That the concept of a mathematical point is natural is well known to those who have taught a little geometry to children. Minds most resistant to the first elements immediately and without difficulty imagine lines without thickness and points without dimension.*

Simultaneity in the instant and simultaneity of flows are therefore distinct things, but they complement each other reciprocally. Without simultaneity of flows, we wouldn't consider these three terms—continuity of our inner life, continuity of a voluntary movement indefinitely prolonged by our thought, continuity of any movement through space—as interchangeable. Real duration and spatialized time would thus not be equivalent, and consequently there would be no general concept of time for us; there would only be the duration of each individual. But on the other hand, time can only be measured thanks to simultaneity in the instant. This simultaneity in the instant is necessary for 1° noting the simultaneity between a phenomenon and a clock moment, and 2° marking along our own duration the simultaneities of these moments with moments of our duration created by the marking act itself. Of these two acts, the first is essential for measuring time. But without the second, we'd have just any measurement, arriving at a number representing anything at all—we wouldn't be thinking of time. It is therefore simultaneity between two instants of two external movements that allows us to measure time; but it is the simultaneity of these moments with moments marked by them along our inner duration that makes this measurement a measurement of time.

6.5.

On Simultaneity Indicated by Clocks

We will elaborate on these two points. But first, let's open a parenthesis. We've just distinguished two "*simultaneities in the instant*": neither is the simultaneity most discussed in the theory of Relativity, I mean simultaneity between indications given by two distant clocks. We discussed the latter in the first part of our work; we'll focus on it shortly. But clearly, the theory of Relativity itself cannot help but admit the two simultaneities we've described: it will simply add a third one, which depends on clock synchronization. Now, we'll likely show that indications from two clocks H and $H^{'}$, distant from each other, synchronized and showing the same time, may or may not be simultaneous depending on the viewpoint. The theory of Relativity is entitled to say this—we'll see under what condition. But in doing so, it acknowledges that an event E occurring near clock H is given as simultaneous with an indication of clock H in a sense entirely different from that—in the sense the psychologist attributes to the word simultaneity. And likewise for the simultaneity of event $E^{'}$ with the indication of the "*neighboring*" clock $H^{'}$. For if we didn't first admit such simultaneity—absolute and unrelated to clock synchronization—clocks would be useless. They'd be mechanisms we'd amuse ourselves comparing; they wouldn't be used to classify events; in short, they'd exist for themselves and not to serve us. They'd lose their raison d'être for the relativist theorist as much as for anyone, since he too introduces them only to mark an event's time. Now, it's quite true that this simultaneity is only observable between moments of two flows when the flows pass "*at the same place*". It's also quite true that common sense, and science itself until now, have extended *a priori* this conception of simultaneity to events separated by any distance. They likely imagined, as we said earlier, a consciousness coextensive with the universe, capable of embracing both events in a single instantaneous perception. But they primarily applied a principle inherent to all mathematical representation of things, which also holds for the theory of Relativity. We'd find there the idea that the distinction between "*small*" and "*large*", "*slightly distant*" and "*very distant*", has no scientific value, and that if we can speak of simultaneity without clock synchronization, independently of any viewpoint, when dealing with an event and a clock close to each other, we're equally entitled to do so when the distance is great between clock and event, or between the two clocks. There can be no physics, no astronomy, no science possible if we deny the scientist the right to schematically represent the totality of the universe on a sheet of paper. We therefore implicitly admit the possibility of reducing without distortion. We consider dimension not as absolute, that there are only relations between dimensions, and that everything would proceed identically in a universe scaled down at will if relations between parts were preserved. But how then prevent our imagination, and even our understanding, from treating the simultaneity of indications from two very distant clocks like the simultaneity of two nearby clocks —that is, located "*at the same place*"? An intelligent microbe would find an enormous interval between two "*neighboring*" clocks; and it wouldn't grant the existence of an absolute simultaneity, intuitively perceived, between their indications. More Einsteinian than Einstein, it would only speak of simultaneity here if it had noted identical indications on two microbe clocks, synchronized by optical signals, which it would have substituted for our two "*nearby*" clocks. The simultaneity that's absolute to our eyes would be relative to its, for it would attribute absolute simultaneity to indications from two microbe clocks it perceived in turn (which it would be equally wrong to perceive) "*at the same place*". But that matters little for now: we're not criticizing Einstein's conception; we simply want to show what underlies the natural extension we've always practiced of the idea of simultaneity, after having drawn it from observing two "*neighboring*" events. This analysis, hardly attempted until now, reveals a fact that relativity theory might well exploit. We see that if our mind passes so easily from a small distance to a large one, from simultaneity between neighboring events to simultaneity between distant events, if it extends to the second case the absolute character of the first, it's because it's accustomed to believing we can arbitrarily modify the dimensions of all things, provided we preserve their relations. But it's time to close the parenthesis. Let's return to the intuitively perceived simultaneity we spoke of initially and to the two propositions we stated: 1° it's simultaneity between two instants of two external movements that allows us to measure a time interval; 2° it's the simultaneity of these moments with moments marked by them along our inner duration that makes this measurement a measurement of time.

6.6.

Time Unfolding

The first point is evident. We saw earlier how inner duration externalizes into spatialized time and how the latter, being space rather than time, is measurable. It is henceforth through this medium that we will measure all time intervals. Having divided it into parts corresponding to equal spaces—which are equal by definition—we will have at each division point an endpoint of an interval, an instant, and we will take the interval itself as the unit of time. We can then consider any movement occurring alongside this model movement, any change: throughout this unfolding we will mark "*simultaneities in the instant*". The number of these simultaneities we note will equal the number of time units in the phenomenon's duration. Measuring time thus consists of counting simultaneities. Any other measurement implies the possibility of directly or indirectly superimposing the unit of measurement onto the object measured. Any other measurement concerns the intervals between endpoints, even when we merely count these endpoints in practice. But when it comes to time, we can only count endpoints: we simply *agree* to say that we have thereby measured the interval. If we now note that science operates exclusively on measurements, we realize that regarding time, science counts instants, notes simultaneities, but remains powerless over what happens in the intervals. It can indefinitely increase the number of endpoints, indefinitely narrow the intervals; yet the interval always escapes it, showing only its endpoints. If all movements in the universe suddenly accelerated in the same proportion, including the one serving to measure time, something would change for a consciousness not bound to intra-cerebral molecular movements; between sunrise and sunset it would not receive the same enrichment; it would therefore note a change; indeed, the hypothesis of a simultaneous acceleration of all universal movements only makes sense if we imagine a spectator consciousness whose purely qualitative duration admits of more or less without being measurable[1]. But this change would exist only for this consciousness capable of comparing the flow of things to that of inner life. For science, nothing would have changed. Let us go further. The unfolding speed of this external, mathematical Time could become infinite; all past, present, and future states of the universe could be given at once; in place of unfolding, there might be only the unfolded: the representative movement of Time would become a line; to each division of this line would correspond the same part of the unfolded universe that corresponded to it earlier in the unfolding universe; nothing would change for science. Its formulas and calculations would remain as they are.

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[1] *It is evident that this hypothesis would lose its meaning if consciousness were represented as an "epiphenomenon", superadded to brain phenomena of which it would be merely the result or expression. We cannot elaborate here on this theory of consciousness-as-phenomenon, increasingly considered arbitrary. We have discussed it in detail in several of our works, notably in the first three chapters of Matter and Memory and in various essays in Mind-Energy. Let us simply recall: 1° this theory is in no way deduced from facts; 2° its metaphysical origins are easily traced; 3° taken literally, it would be self-contradictory (on this last point, and on the oscillation the theory implies between two contrary affirmations, see pages 203-223 of Mind-Energy). In the present work, we take consciousness as experience gives it to us, without hypothesizing about its nature and origins.*

6.7.

Unfolded Time and the Fourth Dimension

It is true that at the precise moment we pass from unfolding to unfolded, we would have to endow space with an additional dimension. We noted over thirty years ago[1] that spatialized time is in reality a fourth dimension of space. Only this fourth dimension allows us to juxtapose what is given in succession: without it, we would have no room. Whether a universe has three dimensions, two, or one, or even none at all and reduces to a point, we can always convert the indefinite succession of all its events into instantaneous or eternal juxtaposition by the mere fact of granting it an additional dimension. If it has none, reducing to a point that changes indefinitely in quality, we can suppose the speed of succession of qualities becomes infinite and that these *quality-points* are given all at once, provided we bring to this dimensionless world a line where points are juxtaposed. If it already has one dimension, if it is linear, it would need two dimensions to juxtapose the *quality-lines*—each indefinite—that were the successive moments of its history. The same holds if it has two dimensions, if it is a superficial universe, an indefinite canvas on which indefinite flat images are endlessly drawn, each occupying it entirely: the speed of succession of these images could still become infinite, and from an unfolding universe we would again pass to an unfolded universe, provided we are granted an additional dimension. We would then have, stacked one upon another, all the endless canvases giving us all the successive images composing the entire history of the universe; we would possess them together; but from a flat universe we would have had to move to a voluminous one. We thus easily understand how the mere fact of attributing infinite speed to time, of substituting the unfolded for unfolding, would compel us to endow our solid universe with a fourth dimension. Now, by the very fact that science cannot specify the "*speed of unfolding*" of time, that it counts simultaneities but necessarily leaves aside the intervals, it deals with a time whose unfolding speed we may just as well suppose infinite, and thereby it virtually confers upon space an additional dimension.

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(1) *Time and Free Will, p. 83.*

Immanent to our measurement of time is thus the tendency to empty its content into a four-dimensional space where past, present, and future would be juxtaposed or superimposed for all eternity. This tendency simply expresses our inability to mathematically translate time itself, the necessity we are under to substitute for it simultaneities that we count: these simultaneities are instantaneous; they do not participate in the nature of real time; they do not endure. They are mere mental views, which mark virtual stops along conscious duration and real movement, using for this purpose the mathematical point transported from space to time.

But if science thus only reaches space, it's easy to see why the spatial dimension that replaces time is still called time. It's because consciousness is there. It breathes living duration back into time desiccated into space. Our thought, interpreting mathematical time, retraces in reverse the path it took to obtain it. From inner duration it had passed to a certain undivided movement still closely linked to it, which became the model movement—the generator or counter of Time; from the pure mobility within this movement, which bridges movement with duration, it passed to the movement's trajectory, which is pure space. By dividing the trajectory into equal parts, it passed from these division points to corresponding "simultaneous" points on any other movement's trajectory: the duration of this latter movement is thus measured; we get a definite number of simultaneities; this becomes the measure of time; henceforth it is time itself. But this is only called time because we can refer back to what we've done. From the simultaneities marking movement continuities, we're always ready to return to the movements themselves, and through them to the inner duration contemporaneous with them, thus substituting for a series of counted instant simultaneities—which are no longer time—the simultaneity of flows that brings us back to internal duration, to real duration.

Some may wonder if it's useful to revisit this, and whether science hasn't precisely corrected an imperfection of our mind by spreading "*pure duration*" in space. They'll say: "*Time as pure duration is always flowing; we grasp only its past and present—the present already being past; the future seems closed to knowledge precisely because we believe it open to our action—a promise or expectation of unpredictable novelty. But converting elapsed time into space implicitly informs us of its content. Measuring a thing sometimes reveals its nature, and mathematical expression here magically does more than we ask: converting elapsed time to space inevitably treats all Time this way—the act deposits past and present in space while silently unfolding the future. This future remains veiled, but now lies complete* *before us. What we called time's flow was merely the screen's continuous sliding, gradually revealing what awaited eternally preformed. Let's accept duration as negation—an ever-receding obstacle to total vision. Our acts no longer introduce novelty; they're threads in the universal fabric given whole. We don't bring them into the world; the world deposits them ready-made in our consciousness as we reach them. Yes, we pass when we say time passes; our vision's forward motion actualizes moment by moment a history virtually given entire*"—Such is the metaphysics immanent in spatial time-representation. Inevitable, distinct or blurred, it has always been the natural metaphysics of mind speculating on becoming. We won't debate it here, much less replace it. Elsewhere we've explained why we see duration as the very fabric of our being and all things, and the universe as continuous creation. We remained closest to the immediate, affirming nothing science couldn't accept. Recently, an admirable mathematician-philosopher affirmed the necessity of admitting an "*advance of Nature*" and linked this conception to ours [1]. For now, we merely demarcate hypothesis/metaphysical construction from pure experiential given—we adhere to experience. Real duration is lived; we note time unfolds, yet cannot measure it without converting it to space and assuming all we know of it is unfolded. We cannot spatialize just part of it; the act of unfolding the past—abolishing real succession—drags us toward total temporal unfolding. Inevitably, we blame human imperfection for ignoring a future that would be present, treating duration as pure negation—"*privation of eternity*". Inevitably we return to Platonic theory. But since this conception must arise from our inability to limit spatial representation to elapsed time, it may be erroneous, and is certainly a mental construct. We stick to experience.

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[1] *Whitehead, The Concept of Nature, Cambridge, 1920. This work (which accounts for Relativity theory) is certainly among the most profound ever written on the philosophy of nature.*

If time has a positive reality, if the lag of duration behind instantaneity represents a certain hesitation or indetermination inherent in some part of things that holds everything else in suspense, and if there is creative evolution, I fully understand why the already unfolded part of time appears as juxtaposition in space rather than pure succession; I also conceive that the entire portion of the universe mathematically linked to the present and past—that is, the future unfolding of the inorganic world—can be represented by the same schema (we have previously shown that in astronomy and physics, *prediction* is in reality a *vision*). One senses that a philosophy where duration is held to be real and even active could well admit Minkowski's Space-Time and Einstein's (where, moreover, the fourth dimension called time is no longer entirely assimilable to the others, as in our earlier examples). Conversely, you will never derive the idea of a temporal flow from Minkowski's schema. Is it not better, then, to stick for now to the viewpoint that sacrifices nothing of experience, and consequently—without prejudging the question—nothing of appearances? How, moreover, can one wholly reject internal experience if one is a physicist, operating on perceptions and thus on data of consciousness? It is true that a certain doctrine accepts the testimony of the senses—that is, of consciousness—to obtain terms between which to establish relations, then retains only the relations and considers the terms nonexistent. But this is a metaphysics grafted onto science, not science itself. And in truth, it is by abstraction that we distinguish terms, and by abstraction also relations: a fluent continuum from which we draw both terms and relations, and which is, beyond all this, fluidity—this is the sole immediate datum of experience.

But we must close this overly long parenthesis. We believe we have achieved our objective, which was to determine the characteristics of a time in which there is real succession. Abolish these characteristics, and there is no longer succession, only juxtaposition. You may say you still have time—one is free to give words any meaning, provided it is defined—but we will know it is no longer experienced time; we will be faced with a symbolic, conventional time, an auxiliary magnitude introduced for calculating real magnitudes. It is perhaps because we did not first analyze our representation of flowing time, our feeling of real duration, that we have struggled so to determine the philosophical meaning of Einstein's theories—I mean their relation to reality. Those troubled by the theory's paradoxical appearance said that Einstein's multiple Times were pure mathematical entities. But those who would dissolve things into relations, who consider all reality—even our own—as confusedly perceived mathematics, would readily say that the Space-Time of Minkowski and Einstein is reality itself, that all Einstein's Times are equally real, as much and perhaps more than the time flowing with us. On both sides, we rush too quickly. We have just said, and will shortly show in more detail, why the theory of Relativity cannot express all of reality. But it is impossible for it not to express some reality. For the time involved in the Michelson-Morley experiment is real time—real too is the time we recover through applying Lorentz's formulas. If we start from real time to arrive at real time, we may have used mathematical artifices in between, but these artifices must have some connection with things. It is thus the real part, the conventional part, that must be distinguished. Our analyses were simply meant to prepare this work.

6.8.

By what sign one recognizes that a Time is real

But we have just uttered the word "reality"; and constantly, in what follows, we will speak of what is real and what is not. What shall we mean by this? If we had to define reality in general, to say by what mark it is recognized, we could not do so without aligning with a school: philosophers disagree, and the problem has as many solutions as there are shades of realism and idealism. We should, moreover, distinguish between the viewpoint of philosophy and that of science: the former considers the concrete, charged with qualities, as real; the latter extracts or abstracts a certain aspect of things, retaining only what is magnitude or relation between magnitudes. Fortunately, in all that follows, we have only one reality to deal with: time. Under these conditions, it will be easy for us to follow the rule we have imposed in this essay: to advance nothing that cannot be accepted by any philosopher, any scientist—nothing even that is not implied in all philosophy and all science.

Indeed, everyone will grant that one cannot conceive of time without a *before* and an *after*: time is succession. Now we have just shown that where there is no memory, no consciousness—whether real or virtual, observed or imagined, actually present or ideally introduced—there cannot be a before *and* an after: there is one *or* the other, not both; and both are required to make time. Therefore, in what follows, when we wish to know whether we are dealing with real or fictitious time, we need only ask whether the object presented to us could or could not be perceived, become conscious. The case is privileged; it is even unique. If we consider color, for example, consciousness undoubtedly intervenes at the start of the study to give the physicist the perception of the thing; but the physicist has the right and the duty to substitute for the data of consciousness something measurable and countable, which he will henceforth operate on, merely retaining the name of the original perception for convenience. He can do this because, once this original perception is eliminated, something remains or is at least assumed to remain. But what remains of time if you eliminate succession? And what remains of succession if you exclude even the possibility of perceiving a before and an after? I grant you the right to substitute a line for time, for example, since time must be measured. But such a line should only be called time where the juxtaposition it offers can be converted into succession; otherwise, it will be arbitrarily, conventionally, that you leave the name "time" to this line: you must warn us, to avoid serious confusion. What then, if you introduce into your reasoning and calculations the hypothesis that the thing you call "time" cannot, without contradiction, be perceived by any consciousness, real or imaginary? Would you not then be operating, by definition, on a fictitious, unreal time? Such is the case with the times we will often encounter in the theory of Relativity. We will find some that are perceived or perceptible; these may be considered real. But there are others that the theory forbids, in a way, from being perceived or becoming perceptible: if they were to become perceptible, they would change in magnitude—so that a measurement accurate for what is not perceived would become false as soon as it is perceived. How can we not declare these unreal, at least as "temporal"? I admit that the physicist finds it convenient to still call them time—we will see the reason shortly. But if we equate these Times with the other, we fall into paradoxes that have certainly harmed the theory of Relativity, even though they have contributed to its popularity. We should not be surprised, then, if in this research we require the property of being perceived or perceptible for everything offered to us as real. We will not settle the question of whether all reality possesses this character. Here, we are concerned solely with the reality of time.

☒ ☒☒ ☒ ☒ 7.

On the Plurality of Times

The Multiple and Slowed Times of the Theory of Relativity

Let us finally come to Einstein's Time, and revisit all we had said while first assuming an immobile ether. Here is Earth moving in its orbit. The Michelson-Morley apparatus is there. The experiment is performed; it is repeated at various times of the year and consequently for variable speeds of our planet. Always, the light ray behaves as if Earth were immobile. Such is the fact. Where is the explanation?

But first, why speak of our planet's speeds? Is Earth, absolutely speaking, in motion through space? Obviously not; we are in the hypothesis of Relativity and there is no more absolute motion. When you speak of the orbit described by Earth, you adopt an arbitrarily chosen viewpoint, that of the inhabitants of the Sun (a Sun made habitable). You choose to adopt this reference system. But why would the light ray launched at the mirrors of the Michelson-Morley apparatus heed your fancy? If all that actually occurs is the reciprocal displacement of Earth and Sun, we can take the Sun, Earth, or any other observatory as reference system. Let us choose Earth. The problem vanishes for it. There is no longer any need to ask why the interference fringes retain the same appearance, why the same result is observed at any time of the year. It is simply because Earth is immobile.

It is true that the problem then reappears in our eyes for the inhabitants of the Sun, for example. I say "in our eyes," because for a solar physicist the question would no longer concern the Sun: now it is Earth that moves. In short, each of the two physicists will still pose the problem for the system that is not his own.

Each of them will therefore find themselves in relation to the other in the situation where Pierre was just now with respect to Paul. Pierre was stationed in the immobile ether; he inhabited a privileged system S. He saw Paul, carried along in the motion of the mobile system S', perform the same experiment as him and find the same speed for light, whereas this speed should have been diminished by that of the mobile system. The fact was explained by the slowing of time, length contractions, and ruptures of simultaneity that motion provoked in S'. Now, no more absolute motion, and consequently no more absolute rest: of the two systems, which are in a state of reciprocal displacement, each will be immobilized in turn by the decree that erects it as a reference system. But, for the entire time this convention is maintained, one can repeat about the immobilized system what was said earlier about the truly stationary system, and about the mobilized system what applied to the mobile system actually traversing the ether. To fix ideas, let us again call S and S' the two systems moving relative to each other. And, to simplify matters, suppose the entire universe reduced to these two systems. If S is the reference system, the physicist placed in S, considering that his colleague in S' finds the same speed for light as he does, will interpret the result as we did earlier. He will say: "*The system moves with a speed v relative to me, immobile. Now, the Michelson-Morley experiment gives the same result there as here. It is therefore that, due to motion, a contraction occurs in the direction of the system's displacement; a length l becomes $l\sqrt{1-\frac{v^2}{c^2}}$. To this contraction of lengths is linked a dilation of time: where a clock in S' counts a number of seconds t', $\frac{t'}{\sqrt{1-\frac{v^2}{c^2}}}$ seconds have actually elapsed. Finally, when the clocks in S', spaced along the direction of its motion and separated from each other by distances l, indicate the same time, I see that signals going back and forth between two consecutive clocks do not make the same journey outbound and return, as a physicist inside system S' unaware of its motion would believe: where these clocks mark simultaneity for him, they actually indicate successive moments separated by $\frac{lv}{c^2}$ seconds of his clocks, and consequently by $\frac{lv}{c^2\sqrt{1-\frac{v^2}{c^2}}}$ seconds of mine*". Such would be the reasoning of the physicist in S. And, constructing a complete mathematical representation of the universe, he would use the space and time measurements taken by his colleague in system S' only after subjecting them to the Lorentz transformation.

But the physicist in system S' would proceed exactly the same way. Deeming himself immobile, he would repeat about S everything that his colleague placed in S would have said about S'. In the mathematical representation he would construct of the universe, he would hold as exact and definitive the measurements he himself had taken within his system, but he would correct according to Lorentz's formulas all those taken by the physicist attached to system S.

Thus would be obtained two mathematical representations of the universe, totally different from each other if one considers the numbers that appear in them, identical if one considers the relations they indicate through them between phenomena—relations we call the laws of nature. This difference is moreover the very condition of this identity. When one takes various photographs of an object while turning around it, the variability of details merely translates the invariability of the relations that the details have among themselves, that is, the permanence of the object.

We are thus brought back to multiple Times, to simultaneities that would be successions and successions that would be simultaneities, to lengths that would have to be counted differently depending on whether they are deemed at rest or in motion. But this time we are facing the definitive form of the theory of Relativity. We must ask in what sense the words are taken.

Consider first the plurality of Times, and take up our two systems S and S'. The physicist placed in S adopts his system as the reference system. Thus S is at rest and S' in motion. Within his system, deemed immobile, our physicist institutes the Michelson-Morley experiment. For the restricted object we are pursuing at this moment, it will be useful to split the experiment in two and retain, so to speak, only half of it. We will therefore suppose that the physicist is concerned solely with the path of light in the direction OB perpendicular to that of the reciprocal motion of the two systems. On a clock placed at point O, he reads the time t taken by the ray to go from O to B and return from B to O. What time is this?

Evidently a real time, in the sense we gave earlier to this expression. Between the departure and return of the ray, the physicist's consciousness has lived a certain duration: the movement of the clock hands is a flow contemporary with this inner flow and serves to measure it. No doubt, no difficulty. A time lived and counted by a consciousness is real by definition.

Now consider a second physicist placed in S'. He deems himself immobile, being accustomed to taking his own system as the reference system. Here he is performing the Michelson-Morley experiment or rather, he too, half the experiment. On a clock placed at O' he notes the time taken by the light ray to go from O' to B' and return. What time is this that he counts? Evidently the time he lives. The movement of his clock is contemporary with the flow of his consciousness. It is again a real time by definition.

☒ ☒☒ ☒ ☒ 7.2.

Compatibility with a Single Universal Time

Thus, the time lived and counted by the first physicist in his system, and the time lived and counted by the second in his, are both real times.

Are they, both, one and the same Time? Are they different Times? We will demonstrate that it is the same Time in both cases.

Indeed, however one understands the slowing or speeding of time and consequently the multiple Times discussed in the theory of Relativity, one point is certain: these slowdowns and accelerations depend solely on the motions of the systems under consideration and only on the speed attributed to each system. We would therefore change nothing about any Time, real or fictitious, of system S' if we assume this system is a duplicate of system S, for the content of the system, the nature of events unfolding within it, is irrelevant: only the translational speed of the system matters. But if S' is a double of S, it is evident that the lived Time noted by the second physicist during his experiment in system S', deemed immobile by him, is identical to the Time lived and noted by the first physicist in system S, also considered immobile, since S and S', once immobilized, are interchangeable. Therefore, the Time lived and counted within the system, the internal and immanent Time of the system, the real Time in short, is the same for S and for S'.

But then, what are the multiple Times, flowing at unequal speeds, that the theory of Relativity finds in the various systems according to their attributed speed?

Let us return to our two systems S and S'. If we consider the Time that physicist Pierre, situated in S, attributes to system S', we see that this Time is indeed slower than the Time counted by Pierre in his own system. This time is therefore not lived by Pierre. But we know it is not lived by Paul either. It is thus lived neither by Pierre nor by Paul. Even less so by others. But this is not saying enough. If the Time attributed by Pierre to Paul's system is lived neither by Pierre nor by Paul nor by anyone, is it at least conceived by Pierre as lived or capable of being lived by Paul, or more generally by someone, or even more generally by something? Upon closer inspection, we will see this is not the case. No doubt Pierre slaps Paul's name on this Time; but if he imagined Paul as conscious, living his own duration and measuring it, *by that very act he would see Paul adopt his own system as the reference system, and thereby place himself in that unique Time, internal to each system, of which we have just spoken: by that same act, moreover, Pierre would temporarily abandon his own reference system, and consequently his consciousness; Pierre would see himself only as a vision of Paul.* But when Pierre attributes a slowed Time to Paul's system, he no longer considers Paul as a physicist, nor even as a conscious being, nor even as a being: he empties the visual image of Paul of its conscious and living interior, retaining only its external envelope (only this, in fact, interests physics): then, the numbers by which Paul would have noted the time intervals of his system if he had been conscious, Pierre multiplies by $\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$ to fit them into a mathematical representation of the universe taken from his own viewpoint, not Paul's. Thus, in summary, while the time attributed by Pierre to his own system is the time lived by him, the time Pierre attributes to Paul's system is neither the time lived by Pierre, nor the time lived by Paul, nor a time that Pierre conceives as lived or capable of being lived by a living and conscious Paul. What is it then, if not a mere mathematical expression intended to mark that it is Pierre's system, and not Paul's, that is taken as the reference system?

I am a painter, and I have to represent two figures, Jean and Jacques, one of whom is beside me while the other is two or three hundred meters away. I will draw the first life-size, and reduce the other to the size of a dwarf. One of my colleagues, who will be near Jacques and who will also wish to paint both, will do the opposite of what I do; he will show Jean very small and Jacques life-size. We will both be right. But, from the fact that we are both right, does one have the right to conclude that Jean and Jacques have neither normal size nor that of a dwarf, or that they have both at once, or whatever one pleases? Obviously not. Size and dimension are terms that have a precise meaning when dealing with a posing model: it is what we perceive of the height and width of a figure when we are beside it, when we can touch it and run a ruler along its body for measurement. Being near Jean, measuring him if I wish and intending to paint him life-size, I give him his real dimension; and, by representing Jacques as a dwarf, I simply express the impossibility for me to touch him—even, if one may say so, the degree of this impossibility: the *degree of impossibility* is precisely what is called distance, and it is distance that perspective takes into account. Similarly, inside the system where I am, which I immobilize in thought by taking it as the reference system, I directly measure a time that is mine and that of my system; it is this measurement that I inscribe in my representation of the universe for everything concerning my system. But, by immobilizing my system, I have mobilized the others, and I have mobilized them in various ways. They have acquired different speeds. The greater their speed, the more it is *distant* from my immobility. It is this greater or lesser *distance* of their speed to my zero speed that I express in my mathematical representation of the other systems when I attribute to them more or less slow Times, all slower than mine, just as it is the greater or lesser distance between Jacques and me that I express by reducing his size more or less. The multiplicity of Times thus obtained does not preclude the unity of real time; it rather presupposes it, just as the diminution of size with distance, on a series of canvases where I represent Jacques more or less distant, indicates that Jacques retains the same size.

⊠ ⊠⊠ ⊠ ⊠ 7.3.

Examination of paradoxes concerning time

Thus vanishes the paradoxical form given to the theory of the plurality of Times. "*Suppose, it has been said, a traveler enclosed in a projectile launched from Earth at a speed about one twenty-thousandth less than that of light, who encounters a star and is sent back to Earth at the same speed. Having aged two years, for example, when he emerges from his projectile, he will find that our globe has aged two hundred years.*" — Are we so sure? Let us look closer. We will see the mirage effect vanish, for it is nothing else.

⊠ ⊠⊠ ⊠ ⊠ 7.4.

The hypothesis of the traveler enclosed in a cannonball

The cannonball was fired from a cannon attached to the stationary Earth. Let us call Pierre the person who remains near the cannon, Earth being our system S. The traveler enclosed in the cannonball S' thus becomes our character Paul. We placed ourselves, as we said, in the hypothesis that Paul would return after two hundred years lived by Pierre. We therefore considered Pierre as living and conscious: it is indeed two hundred years of his inner flow that elapsed for Pierre between departure and return.

Now let us turn to Paul. We wish to know how much time he lived. We must therefore address Paul as a living, conscious being, not the image of Paul represented in the consciousness of Pierre. But Paul living and conscious obviously takes his cannonball as the reference system: by this very act, he immobilizes it. The moment we address Paul, we are with him, we adopt his viewpoint. But then, the cannonball is stopped: it is the cannon, with Earth attached to it, that flees through space. Everything we said about Pierre, we must now repeat about Paul: since motion is reciprocal, the two characters are interchangeable. If, earlier, looking within Pierre's consciousness, we witnessed a certain flow, it is exactly the same flow we will observe in Paul's consciousness. If we said the first flow was two hundred years, the other flow will also be two hundred years. Pierre and Paul, Earth and the cannonball, will have lived the same duration and aged equally.

Where then are the two years of slowed time that were supposed to pass sluggishly for the cannonball while two hundred years were to elapse on Earth? Did our analysis vaporize them? Not at all! We will find them. But we can no longer lodge any beings or things within them; and we must seek another way not to age.

Our two characters appeared to us as living in one and the same time, two hundred years, because we placed ourselves both at one viewpoint and the other. This was necessary to interpret philosophically Einstein's thesis, which is that of radical relativity and consequently of perfect reciprocity of rectilinear uniform motion[1]. But this approach is proper to the philosopher who takes Einstein's thesis in its entirety and focuses on reality—I mean the perceived or perceptible thing—that this thesis evidently expresses. It implies that at no moment does one lose sight of the idea of reciprocity and consequently constantly moves from Pierre to Paul and Paul to Pierre, treating them as interchangeable, immobilizing them in turn, though only momentarily, thanks to a rapid oscillation of attention that sacrifices nothing of the thesis of Relativity. But the physicist is obliged to proceed differently, even if he unreservedly adheres to Einstein's theory. He will begin, no doubt, by complying with it. He will affirm reciprocity. He will posit that one may choose between Pierre's viewpoint and Paul's. But, that said, he will choose one of the two, for he cannot simultaneously relate the universe's events to two different systems of axes. If he places himself in thought with Pierre, he will count for Pierre the time Pierre counts for himself—that is, the time actually lived by Pierre—and for Paul the time Pierre attributes to him. If he is with Paul, he will count for Paul the time Paul counts for himself—that is, the time Paul actually lives—and for Pierre the time Paul attributes to him. But, once again, he must necessarily opt for Pierre or Paul. Suppose he chooses Pierre. Then he must count only two years for Paul.

[1] *The cannonball's motion can be considered rectilinear and uniform in each of the two outbound and return journeys taken separately. This is all that is required for the validity of the reasoning we have just made.*

Indeed, Pierre and Paul deal with the same physics. They observe the same relations between phenomena, they find the same laws of nature. But Pierre's system is immobile and Paul's is in motion. As long as it concerns phenomena somehow attached to the system—that is, defined by physics such that the system is deemed to carry them along when it is deemed to move—the laws of these phenomena must obviously be the same for Pierre and Paul: moving phenomena, being perceived by Paul who shares their motion, appear motionless to him and look exactly as analogous phenomena in his own system appear to Pierre. But electromagnetic phenomena present themselves such that when the system where they occur is deemed to move, they can no longer be considered as participating in the system's motion. And yet the relations of these phenomena among themselves, their relations with phenomena carried along in the system's motion, remain for Paul what they are for Pierre. If the cannonball's speed is indeed what we assumed, Pierre can express this persistence of relations only by attributing to Paul a Time a hundred times slower than his own, as seen from Lorentz's equations. If he counted otherwise, he would not record in his mathematical representation of the world that Paul in motion finds among all phenomena—including electromagnetic ones—the same relations as Pierre at rest. He thus implicitly posits that Paul, the referred, could become Paul, the referrer, for why do the relations persist for Paul? Why must Pierre mark them for Paul as they appear to Pierre, unless because Paul would decree himself immobile by the same right as Pierre? But this is merely a consequence of this reciprocity that he notes, not the reciprocity itself. Once again, he has made himself the referrer, and Paul is merely referred. Under these conditions, Paul's Time is a hundred times slower than Pierre's. But this is attributed time, not lived time. The time lived by Paul would be the Time of Paul as referrer, no longer referred: it would be exactly the time Pierre just found for himself.

We thus always return to the same point: there is only one real Time, and the others are fictitious. What indeed is a real Time, if not a Time lived or capable of being lived? What is an unreal, auxiliary, fictitious Time, if not one that could not be actually lived by anything or anyone?

But we see the origin of the confusion. We would formulate it thus: the hypothesis of reciprocity can only be mathematically expressed through that of non-reciprocity, for translating mathematically the freedom to choose between two systems of axes consists in effectively choosing one of them[1]. The faculty of choice cannot be read in the choice made by virtue of it. A system of axes, by the mere fact of being adopted, becomes privileged. In its mathematical use, it is indistinguishable from an absolutely immobile system. This is why unilateral relativity and bilateral relativity are mathematically equivalent, at least in the case at hand. The difference exists here only for the philosopher; it only reveals itself if one asks what reality—that is, what perceived or perceptible thing—the two hypotheses imply. The older one, that of a privileged system in a state of absolute rest, would indeed posit multiple real Times. Pierre, truly immobile, would live a certain duration; Paul, truly in motion, would live a slower duration. But the other, that of reciprocity, implies that the slower duration must be attributed by Pierre to Paul or by Paul to Pierre, depending on whether Pierre or Paul is the referrer, and Paul or Pierre the referred. Their situations are identical; they live one and the same Time, but they reciprocally attribute to each other a Time different from that one, thus expressing, according to the rules of perspective, that the physics of an imaginary observer in motion must be the same as that of a real observer at rest. Therefore, in the hypothesis of reciprocity, one has at least as much reason as common sense to believe in a single Time: the paradoxical idea of multiple Times imposes itself only in the hypothesis of the privileged system. But, once again, one can only express oneself mathematically in the hypothesis of a privileged system, even after having first posited reciprocity; and the physicist, feeling absolved of the reciprocity hypothesis once he has paid homage to it by choosing his reference system as he wished, abandons it to the philosopher and will henceforth express himself in the language of the privileged system. Trusting this physics, Paul will enter the cannonball. He will discover en route that philosophy was right[2].

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[1] *We are always dealing, of course, only with the theory of restricted Relativity.*

[2] *The hypothesis of the traveler enclosed in a cannonball, living only two years while two hundred years pass on Earth, was presented by Mr. Langevin in his communication to the Bologna Congress in 1911. It is universally known and widely cited. It can be found, in particular, in the important work by Mr. Jean Becquerel, The Principle of Relativity and the Theory of Gravitation, page 52.*

Even from a purely physical viewpoint, it raises certain difficulties, for we are no longer strictly in restricted Relativity here. Since the velocity changes direction, there is acceleration, and we are dealing with a problem of generalized Relativity.

But in any case, the solution given above removes the paradox and makes the problem vanish.

We take this opportunity to say that it was Mr. Langevin's communication at the Bologna Congress that first drew our attention to Einstein's ideas. All those interested in the theory of Relativity know what they owe to Mr. Langevin, his work, and his teaching.

What contributed to sustaining the illusion is that the theory of restricted Relativity precisely declares that it seeks a representation of things independent of the reference system[1]. It thus seems to forbid the physicist from adopting a specific viewpoint. But here an important distinction must be made. Undoubtedly, the relativist theorist intends to give the laws of nature an expression that preserves its form, regardless of the reference system to which events are related. But this simply means that, placing himself at a specific viewpoint like any physicist, necessarily adopting a specific reference system and thus noting specific magnitudes, he will establish relations between these magnitudes that must remain invariant between the new magnitudes found if a new reference system is adopted. *It is precisely because his research method and notation procedures assure him of an equivalence between all representations of the universe taken from all viewpoints that he has the absolute right (well secured in classical physics) to adhere to his personal viewpoint and to relate everything to his unique reference system.* But to this reference system he is generally obliged to attach himself[2]. The philosopher must therefore also attach himself to this system when he wishes to distinguish the real from the fictitious. What is real is what is measured by the real physicist; what is fictitious is what is represented in the thought of the real physicist as measured by fictitious physicists. But we will return to this point later in our work. For now, let us indicate another source of illusion, less apparent than the first.

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[1] *We confine ourselves here to restricted Relativity because we are concerned only with Time. In generalized Relativity, it is undeniable that there is a tendency to adopt no reference system, to proceed as in constructing an intrinsic geometry, without coordinate axes, using only invariant elements. However, even here, the invariance considered in practice is generally still that of a relation between elements that are themselves subordinate to the choice of a reference system.*

[2] *In his charming little book on the theory of Relativity (The General Principle of Relativity, London, 1920), Mr. Wildon Carr maintains that this theory implies an idealist conception of the universe. We would not go that far; but it is indeed in the idealist direction, we believe, that this physics should be oriented if one wishes to erect it into philosophy.*

The physicist Pierre naturally admits (though it's only a belief, since it cannot be proven) that there are other consciousnesses besides his own, scattered across the Earth, conceivable even at any point in the universe. Paul, Jean, and Jacques may well be in motion relative to him: he will see in them minds that think and feel in his own way. This is because he is a man before being a physicist. But when he considers Paul, Jean, and Jacques as beings like himself, endowed with a consciousness like his own, he actually forgets his physics or takes advantage of the permission it gives him to speak in everyday life like ordinary mortals. As a physicist, he is inside the system where he takes his measurements and to which he relates all things. Physicists like him, and consequently conscious like him, will at best be men attached to the same system: for they construct, with the same numbers, the same representation of the world from the same point of view; they too are referrers. But other men will now be only referred; they can now be, for the physicist, only empty puppets. If Pierre granted them a soul, he would immediately lose his own; from referred, they would have become referrers; they would be physicists, and Pierre would have to become a puppet in turn. This back-and-forth of consciousness obviously begins only when one is doing physics, for one must then choose a reference system. Outside of that, men remain what they are, conscious of one another. There is no reason why they should not then live the same duration and evolve in the same Time. The plurality of Times emerges precisely at the moment when there is only one man or one group to *live* time. This Time then becomes the only real one: it is the real Time of a moment ago, but monopolized by the man or group who has set himself up as a physicist. All other men, having become puppets from that moment on, henceforth evolve in Times that the physicist represents and which could no longer be real Time, since they are not lived and cannot be. Imaginary, one will naturally imagine as many of them as one wishes.

What we are about to add will seem paradoxical, and yet it is the simple truth. The idea of a real Time common to both systems, identical for S and S', imposes itself more forcefully in the hypothesis of the plurality of mathematical times than in the commonly accepted hypothesis of a single universal mathematical Time. For, in any hypothesis other than that of Relativity, S and S' are not strictly interchangeable: they occupy different positions relative to some privileged system; and even if one begins by making one the duplicate of the other, they immediately differentiate from each other by the mere fact of not maintaining the same relation with the central system. One may then attribute the same mathematical Time to them, as had always been done until Lorentz and Einstein, but it is impossible to strictly prove that the observers placed respectively in these two systems live the same inner duration and that consequently the two systems have the same real Time; it is even very difficult then to define this identity of duration precisely; all one can say is that one sees no reason why an observer moving from one system to the other would not react psychologically in the same way, would not live the same inner duration, for supposedly equal portions of the same universal mathematical Time. Sensible argumentation, to which nothing decisive has been opposed, but which lacks rigor and precision. On the contrary, the hypothesis of Relativity essentially consists in rejecting the privileged system: S and S' must therefore be held, while we consider them, as strictly interchangeable if we have begun by making one the duplicate of the other. But then the two characters in S and S' can be brought by our thought to coincide, like two equal figures that would be superimposed: they must coincide, not only in the various modes of *quantity*, but also, if I may say so, in *quality*, for their inner lives have become indistinguishable, just like what lends itself to measurement in them: the two systems remain constantly what they were at the moment they were posited, duplicates of each other, whereas outside the hypothesis of Relativity they were no longer quite so the next moment, when left to their fate. But we will not insist on this point. Let us simply say that the two observers in S and S' live exactly the same duration, and that the two systems thus have the same real Time.

Is it the same for all systems in the universe? We have attributed to S' an arbitrary speed: we can therefore repeat for any system S'' what we said of S'; the observer attached to it will live the same duration as in S. At most, it might be objected that the reciprocal displacement of S'' and S is not the same as that of S and S', and consequently, when we immobilize S as the reference system in the first case, we are not doing exactly the same thing as in the second. The duration of the observer in S when immobile, when S' is the system referred to S, would therefore not necessarily be the same as that of this same observer when the system referred to S is S''; there would be, so to speak, different *intensities of immobility*, depending on whether the speed of reciprocal displacement of the two systems was more or less great before one of them, suddenly erected into a reference system, was immobilized by the mind. We do not think anyone would want to go that far. But even then, one would simply be adopting the hypothesis usually made when imagining an observer moving through the world and deeming oneself entitled to attribute the same duration to him everywhere. This means that one sees no reason to believe the contrary: when appearances are on a certain side, it is up to the one who declares them illusory to prove his claim. Now, the idea of positing a plurality of mathematical Times had never occurred to anyone before the theory of Relativity; it is therefore solely to the latter that one would refer to cast doubt on the unity of Time. And we have just seen that in the case, the only completely precise and clear one, of two systems S and S' moving relative to each other, the theory of Relativity would lead to affirming the unity of real Time more rigorously than is usually done. It allows one to define and almost to demonstrate identity, instead of relying on the vague and merely plausible assertion that is generally accepted. Let us conclude in any case, regarding the universality of real Time, that the theory of Relativity does not shake the accepted idea and would rather tend to consolidate it.

⊠⊠⊠⊠⊠ 7.5.

The 'Learned' Simultaneity, Dislocable into Succession

Let us now turn to the second point: the dislocation of simultaneities. But first, let us briefly recall what we said about intuitive simultaneity—the kind one might call real and lived. Einstein necessarily admits it, since it is through it that he notes the time of an event. One may give the most learned definitions of simultaneity, saying it is an identity between the indications of clocks synchronized by an exchange of optical signals, concluding that simultaneity is relative to the synchronization procedure. Yet it remains true that if we compare clocks, it is to determine the time of events: now, the simultaneity of an event with the indication of the clock that gives its time depends on no synchronization of events with clocks; it is absolute[1]. If it did not exist, if simultaneity were merely correspondence between clock indications, if it were not also, and above all, correspondence between a clock indication and an event, we would not build clocks, or no one would buy them. For we buy them only to know what time it is. But "knowing what time it is" means noting the simultaneity of an event—a moment of our life or the external world—with a clock indication; it is not, generally, observing simultaneity between clock indications. Therefore, it is impossible for the relativist theorist not to admit intuitive simultaneity[2]. Even in synchronizing two clocks by optical signals, he uses this simultaneity three times: he must note 1° the moment of the signal's departure, 2° the moment of its arrival, 3° the moment of its return. Now, it is easy to see that the other simultaneity—the one that depends on clock synchronization by signal exchange—is still called simultaneity only because we believe we can convert it into intuitive simultaneity[3]. The person synchronizing clocks necessarily does so within their system: since this system is their reference system, they judge it immobile. For them, therefore, signals exchanged between two distant clocks make the same journey outbound and return. If they placed themselves at any point equidistant from the two clocks and had sharp enough vision, they would grasp in a single instantaneous intuition the indications given by the two optically synchronized clocks and see them mark the same time at that moment. Learned simultaneity thus always seems convertible for them into intuitive simultaneity, which is why they call it simultaneity.

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[1] *It is imprecise, no doubt. But when laboratory experiments establish this point, when we measure the "delay" in psychologically noting simultaneity, we must still rely on it for criticism: without it, no instrument reading would be possible. Ultimately, everything rests on intuitions of simultaneity and intuitions of succession.*

[2] *One will obviously be tempted to object that in principle there is no simultaneity at a distance, however small, without clock synchronization. The reasoning would go: "Consider your 'intuitive' simultaneity between two very close events A and B. Either it is merely approximate—an approximation sufficient given the vastly greater distance separating the events between which you will establish a 'learned' simultaneity—or it is perfect simultaneity, but then you are merely noting, without realizing it, an identity of indications between the two microbe clocks you mentioned earlier—clocks that exist virtually at A and B. If you claimed that your microbes stationed at A and B use 'intuitive' simultaneity to read their instruments, we would repeat our reasoning by imagining sub-microbes and sub-microbe clocks. In short, as the imprecision continually diminishes, we would ultimately find a system of learned simultaneities independent of intuitive ones: the latter are merely confused, approximate, provisional visions of the former". — But this reasoning would go against the very principle of relativity theory, which is never to assume anything beyond what is actually observed and measured. It would postulate that prior to our human science —which is perpetually becoming—there is an integral science, given in block, in eternity, and merging with reality itself: we would merely acquire it piece by piece. Such was the dominant idea of Greek metaphysics, an idea taken up by modern philosophy and naturally appealing to our understanding. One may embrace it, if one wishes; but we must not forget that it is a metaphysics, and a metaphysics founded on principles having nothing in common with those of Relativity.*

[3] *We showed earlier (p. 72) and have just repeated that one cannot establish a radical distinction between on-the-spot simultaneity and simultaneity at a distance. There is always a distance that, however small it may be to us, would appear enormous to a microbe constructing microscopic clocks.*

7.6.

How it is compatible with 'intuitive' simultaneity

This being established, consider two systems S and S' in motion relative to each other. First take S as the reference system. By this very act, we immobilize it. The clocks there have been synchronized, as in any system, by an exchange of optical signals. As with all clock synchronization, it was then assumed that the signals exchanged made the same journey outbound and return. But they effectively do so, since the system is immobile. If we call H_m and H_n the points where the two clocks are located, an observer inside the system, choosing any point equidistant from H_m and H_n, will be able—if their vision is sharp enough—to embrace in a single instantaneous act of vision any two events occurring respectively at points H_m and H_n when these two clocks mark the same time. In particular, they will embrace in this instantaneous perception the two matching indications of the clocks—indications that are themselves events. Any simultaneity indicated by clocks can thus be converted within the system into intuitive simultaneity.

Now consider system S'. For an observer inside this system, it is clear that the same thing will happen. This observer takes S' as their reference system. They thus render it immobile. The optical signals by which they synchronize their clocks then make the same journey outbound and return. Therefore, when two of their clocks indicate the same time, the simultaneity they mark could be lived and become intuitive.

Thus, there is nothing artificial or conventional about simultaneity, whether taken in one system or the other.

But let us now see how one of the two observers, the one in S, judges what happens in S'. For him, S' is in motion, and consequently the optical signals exchanged between two clocks of this system do not make, as an observer attached to the system would believe, the same journey outbound and return (except naturally in the particular case where the two clocks lie in the same plane perpendicular to the direction of motion). Therefore, in his eyes, the synchronization of the two clocks was carried out in such a way that they give the same indication where there is no simultaneity, but succession. However, note that he thus adopts a purely conventional definition of succession, and consequently also of simultaneity. He agrees to call successive the matching indications of clocks that have been synchronized with each other under the conditions in which he perceives system S'—I mean synchronized in such a way that an external observer does not attribute the same path to the optical signal for the outbound and return journeys. Why does he not define simultaneity by the concordance of indication between clocks synchronized such that the outbound and return journey is the same for internal observers of the system? The answer is that each definition is valid for each observer, and that is precisely why the same events of system S' can be called simultaneous or successive, depending on whether they are considered from the viewpoint of S' or S. But it is easy to see that one of the two definitions is purely conventional, while the other is not.

To understand this, we will return to a hypothesis we have already made. We will suppose that S' is a duplicate of system S, that the two systems are identical, and that they unfold the same history within themselves. They are in a state of reciprocal displacement, perfectly interchangeable; but one of them is adopted as the reference system and, from that moment, deemed immobile: this will be S. The hypothesis that S' is a duplicate of S in no way compromises the generality of our demonstration, since the alleged dislocation of simultaneity into succession—and into succession more or less slow depending on the speed of the system—depends solely on the system's speed, not at all on its content. This being established, it is clear that if events A,B,C,D of system S are simultaneous for the observer in S, the identical events A',B',C',D' of system S' will also be simultaneous for the observer in S'. Now, will the two groups A,B,C,D and A',B',C',D'—each composed of events simultaneous with each other for an internal observer of the system—also be simultaneous with each other, I mean perceived as simultaneous by a supreme consciousness capable of sympathizing instantaneously or communicating telepathically with the two consciousnesses in S and S'? It is evident that nothing opposes this. We can indeed imagine, as before, that the duplicate S' detached itself at a certain moment from S and must later rejoin it. We have demonstrated that the internal observers of the two systems will have lived the same total duration. We can therefore, in both systems, divide this duration into the same number of slices such that each is equal to the corresponding slice of the other system. If the moment M

when the simultaneous events A,B,C,D occur happens to be the endpoint of one of the slices (and we can always arrange for this to be so), the moment M' when the simultaneous events A', B', C', D' occur in system S' will be the endpoint of the corresponding slice. Situated in the same manner as M within a duration interval whose endpoints coincide with those of the interval containing M, it must necessarily be simultaneous with M. And thus the two groups of simultaneous events A,B,C,D and A', B', C', D' will indeed be simultaneous with each other. We can therefore continue to imagine, as in the past, instantaneous slices of a single Time and absolute simultaneities of events.

However, from the viewpoint of physics, the reasoning we have just made does not count. The physical problem is posed as follows: S being at rest and S' in motion, how will experiments on the speed of light, performed in S, yield the same result in S'? And it is implied that the physicist of system S exists alone as a physicist: the one in system S' is merely imagined. Imagined by whom? Necessarily by the physicist of system S. From the moment S is taken as the reference system, it is from there, and only from there, that a scientific view of the world is now possible. To maintain conscious observers in S and S' simultaneously would be to allow both systems to erect themselves as reference systems, to decree themselves both immobile: yet they have been assumed to be in a state of reciprocal displacement; therefore at least one of the two must be moving. In the one that moves, we will no doubt leave humans; but they will have momentarily abdicated their consciousness or at least their faculties of observation; they will retain, in the eyes of the unique physicist, only the material aspect of their person for the entire time that physics is concerned. Consequently our reasoning collapses, for it implied the existence of equally real, similarly conscious men enjoying the same rights in system S' and system S. We can now only speak of a single man or a single group of real, conscious, physicists: those of the reference system. The others might as well be empty puppets; or rather they will be merely virtual physicists, simply represented in the mind of the physicist in S. How will he represent them? He will imagine them, as before, experimenting on the speed of light, but no longer with a single clock, no longer with a mirror that reflects the light ray back on itself and doubles the journey: there is now a simple journey, and two clocks placed respectively at the departure and arrival points. He will then have to explain how these imagined physicists would find the same speed for light as he, the real physicist, if this entirely theoretical experiment became practically feasible. Now, in his eyes, light moves at a slower speed for system S' (the conditions of the experiment being those we indicated earlier); but also, the clocks in S' having been set to mark simultaneities where he perceives successions, things will arrange themselves such that the real experiment in S and the merely imagined experiment in S' will yield the same number for the speed of light. This is why our observer in S adheres to the definition of simultaneity that makes it depend on the setting of clocks. This does not prevent the two systems, S' as well as S, from having lived, real simultaneities that are not governed by clock settings.

We must therefore distinguish two kinds of simultaneity, two kinds of succession. The first is internal to events, it forms part of their materiality, it comes from them. The other is merely imposed upon them by an external observer to the system. The first expresses something of the system itself; it is absolute. The second is variable, relative, fictitious; it depends on the distance, variable in the scale of speeds, between the immobility that this system has for itself and the mobility it presents relative to another: there is an apparent curving of simultaneity into succession. The first simultaneity, the first succession, belongs to a set of things, the second to an image that the observer forms of them in mirrors that are all the more distorting the greater the speed attributed to the system. This curving of simultaneity into succession is moreover precisely what is needed for the physical laws, particularly those of electromagnetism, to be the same for the internal observer of the system, situated as it were in the absolute, and for the external observer, whose relation to the system can vary indefinitely.

I am in system S' assumed to be at rest. I note intuitive simultaneities between two events O' and A' distant from each other in space, having placed myself equidistant from both. Now, since the system is at rest, a light ray going back and forth between points O' and A' travels the same path outbound and return: if I therefore synchronize two clocks placed respectively at O' and A' on the assumption that the two outbound and return paths P and Q are equal, I am in the truth. I thus have two means of recognizing simultaneity here: one intuitive, by embracing in a single instantaneous act of vision what happens at O' and A'; the other derived, by consulting the clocks; and the two results are concordant. I now suppose that, with nothing changed in what occurs within the system, P no longer appears equal to Q. This happens when an observer external to S' perceives this system in motion. Will all the former simultaneities [1] become successions for this observer? Yes, by convention, if we agree to translate all temporal relations between all events of the system in a language such that we must change its expression depending on whether P appears equal or unequal to Q. This is what is done in the theory of Relativity. I, a relativist physicist, after having been inside the system and having perceived P as equal to Q, leave it: placing myself in an indefinite multitude of systems assumed in turn to be at rest and relative to which S' would then be animated by increasing speeds, I see the inequality between P and Q grow. I then say that the events that were simultaneous just now become successive, and that their interval in time is increasingly considerable. But this is only a convention, a convention moreover necessary if I wish to preserve the integrity of the laws of physics. *For it so happens that these laws, including those of electromagnetism, were formulated on the assumption that physical simultaneity and succession would be defined by apparent equality or inequality of the paths P and Q.* By saying that succession and simultaneity depend on the point of view, we translate this hypothesis, we recall this definition, we do nothing more. Are we speaking of *real* succession and simultaneity? It is reality, if we *agree* to call representative of the real any convention once adopted for the mathematical expression of physical facts. So be it; but then let us no longer speak of time; let us say that we are dealing with a succession and a simultaneity that have nothing to do with duration; for, by virtue of a prior and universally accepted convention, there is no time without a *before* and an *after* noted or notable by a consciousness that compares one to the other, even if this consciousness were but an infinitesimal consciousness coextensive with the interval between two infinitely close instants. If you define reality by mathematical convention, you have a conventional reality. But real reality is that which is perceived or could be perceived. Now, once again, apart from this double path PQ which changes in appearance depending on whether the observer is inside or outside the system, all the perceived and all the perceptible of S' remains what it is. This means that S' may be deemed at rest or in motion, it matters not: real simultaneity will remain simultaneity there; and succession, succession.

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[1] *With the exception, of course, of those concerning events located in the same plane perpendicular to the direction of motion.*

When you considered S' immobile and consequently placed yourself inside the system, learned simultaneity—induced by the concordance between optically synchronized clocks—coincided with intuitive or natural simultaneity; and *it was solely because it served to recognize this natural simultaneity, because it was its sign, because it was convertible into intuitive simultaneity, that you called it simultaneity*. Now, with S' deemed in motion, the two types of simultaneity no longer coincide; everything that was natural simultaneity remains natural simultaneity; but as the system's speed increases, so does the inequality between paths P and Q, whereas it was their equality that defined learned simultaneity. What should you do if you took pity on the poor philosopher, condemned to a tête-à-tête with reality and knowing nothing else? You would give learned simultaneity another name, at least when speaking philosophically. You would create a word for it, any word, but you would not call it simultaneity, for it owed that name only to the fact that in S' assumed immobile, it signaled the presence of a natural, intuitive, real simultaneity—and one might now believe it still designates this presence. Moreover, you yourself continue to admit the legitimacy of this original meaning of the word, along with its primacy, for when S' appears to you in motion, when speaking of concordance between the system's clocks, you seem to think only of learned simultaneity, yet you continually invoke the other, the true one, by the mere observation of a '*simultaneity*' between a clock indication and an event '*near it*' (near for you, near for a human like you, but immensely distant for a perceiving and knowledgeable microbe). Yet you retain the word. Even, along this word common to both cases and which operates magically (does science not act on us like ancient magic?), you practice a transfusion of reality from one simultaneity to the other, from natural simultaneity to learned simultaneity. The passage from fixity to mobility having split the word's meaning, you slip into the second meaning all the materiality and solidity of the first. I would say that instead of guarding the philosopher against error you seek to lure him into it, did I not know the advantage you, as a physicist, gain by using the word simultaneity in both senses: you thereby recall that learned simultaneity began as natural simultaneity and can always become so again if thought immobilizes the system anew.

From what we called the unilateral relativity viewpoint, there is an absolute Time and an absolute hour—the Time and hour of the observer situated in the privileged system S. Suppose once again that S', having first coincided with S, detached itself via doubling. One might say that the clocks in S', which continue to be synchronized by the same optical signal methods, mark the same time when they should mark different hours; they note simultaneity in cases where there is actually succession. If we adopt the hypothesis of unilateral relativity, we must therefore admit that the simultaneities of S dislocate in its duplicate S' solely due to the motion that removes S' from S. To the observer in S' they appear preserved, but they have become successions. Conversely, in Einstein's theory, there is no privileged system; relativity is bilateral; everything is reciprocal; the observer in S is as correct in seeing succession in S' as the observer in S' is in seeing simultaneity. But here, it is a matter of successions and simultaneities defined solely by the appearance of the two paths P and Q: the observer in S is not mistaken, since P equals Q for him; the observer in S' is equally correct, since the P and Q of system S' are unequal for him. Yet unconsciously, after accepting the hypothesis of double relativity, one reverts to that of simple relativity—first because they are mathematically equivalent, and second because it is very difficult not to imagine according to the second when thinking according to the first. One then acts as if, with the two paths P and Q appearing unequal when the observer is external to S', the observer in S' is mistaken in calling these lines equal—as if the events of material system S' had actually dislocated in the dissociation of the two systems—when it is simply the external observer to S' who decrees them dislocated by adhering to his definition of simultaneity. One forgets that simultaneity and succession have thereby become conventional, retaining from primitive simultaneity and succession only the property of corresponding to the equality or inequality of the two paths P and Q. And even then, it was a matter of equality and inequality observed by an observer inside the system, and thus definitive, invariable.

That the confusion between the two viewpoints is natural and even inevitable will be easily confirmed by reading certain pages of Einstein himself. Not that Einstein necessarily committed it; but the distinction we have just made is such that the physicist's language is scarcely capable of expressing it. It has no importance for the physicist, since both conceptions translate identically into mathematical terms. But it is crucial for the philosopher, who will conceive time quite differently depending on which hypothesis he adopts. The pages Einstein devoted to the relativity of simultaneity in his book "*The Special and General Theory of Relativity*" are instructive in this regard. Let us cite the essence of his demonstration:

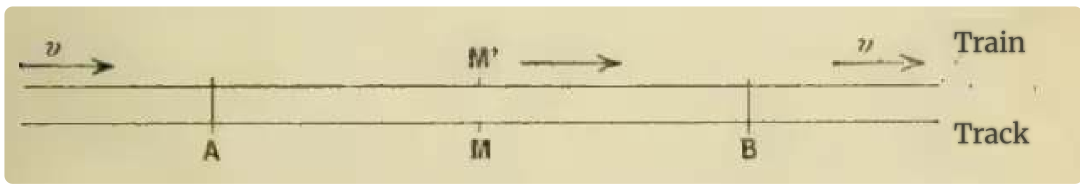

Figure 3

> Suppose an extremely long train moves along the track with a speed v indicated in figure 3. The passengers of this train will prefer to consider the train as their reference system; they relate all events to the train. Any event occurring at a point on the track also occurs at a specific point on the train. The definition of simultaneity is the same relative to the train as to the track. But the following question then arises: are two events (for example, two flashes A and B) simultaneous *relative to the track* also simultaneous relative to the train? We will show immediately that the answer is negative.
>
> By saying that the two flashes A and B are simultaneous relative to the track, we mean this: the light rays emitted from points A and B meet at the midpoint M of the distance AB measured along the track. But to the events A and B also correspond points A and B on the train. Suppose that $M^{'}$ is the midpoint of the vector $A\ B$ on the moving train. This point $M^{'}$ does coincide with point M at the instant the flashes occur (instant counted relative to the track), but it then moves to the right in the diagram with the speed v of the train.
>
> If an observer placed in the train at $M^{'}$ were not carried along with this speed, he would remain constantly at M, and the light rays from points A and B would reach him simultaneously, meaning that these rays would cross exactly at his location. But in reality, he is moving (relative to the track) and goes toward the light coming to him from B, while fleeing the light coming from A. The observer will therefore see the first flash earlier than the second. Observers who take the railway as their reference system conclude that flash B occurred before flash A.
>
> We thus arrive at the following crucial fact. Events simultaneous relative to the track are no longer simultaneous relative to the train, and vice versa (relativity of simultaneity). Each reference system has its own time; a time indication has meaning only if one specifies the comparison system used for measuring time[1].

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[1] *Einstein, The Special and General Theory of Relativity (trans. Rouvière), pages 21 and 22.*

This passage reveals an ambiguity that has caused many misunderstandings. To dispel it, we will begin by drawing a more complete figure (fig. 4). Note that Einstein indicated the direction of the train with arrows. We will indicate the opposite direction of the track with other arrows. For we must not forget that the train and the track are in a state of reciprocal displacement.

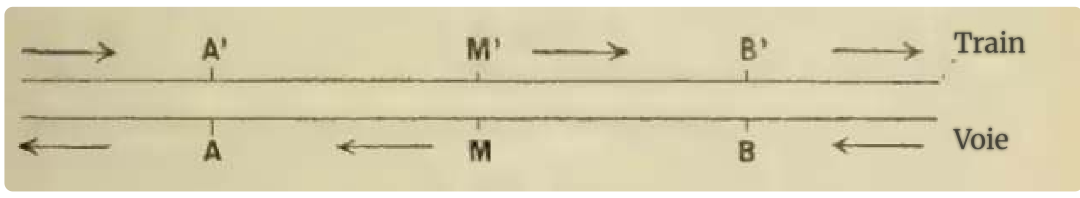

Figure 4

Certainly, Einstein does not forget this either when he refrains from drawing arrows along the track; by this he indicates that he chooses the track as the reference system. But the philosopher, who wants to know what to think about the nature of time, who wonders whether the track and the train do or do not have the same Real Time—that is, the same lived time or what can be such—

the philosopher must constantly remember that he does not have to choose between the two systems: he will place a conscious observer in each and seek what lived time is for each of them. Let us therefore draw additional arrows. Now let us add two letters, A' and B', to mark the ends of the train: by not giving them their own names, by leaving them the designations A and B of the points on Earth with which they coincide, we might once again forget that the track and the train enjoy a regime of perfect reciprocity and have equal independence. Finally, we will more generally call M' any point on the line $A'B'$ that is situated relative to B' and A' as M is relative to A and B. That is for the figure.

Now let us set off our two flashes. The points from which they originate belong no more to the ground than to the train; the waves travel independently of the motion of the source.

It immediately becomes apparent that the two systems are interchangeable, and that exactly the same thing will happen at M' as at the corresponding point M. If M is the midpoint of AB, and if simultaneity is perceived at M on the track, then it is at M', the midpoint of $B'A'$, that this same simultaneity will be perceived in the train.

Therefore, if one truly adheres to the perceived, to the lived, if one questions a real observer in the train and a real observer on the track, one will find that one is dealing with one and the same Time: what is simultaneity relative to the track is simultaneity relative to the train.

But, by marking the two sets of arrows, we have renounced adopting a reference system; we have placed ourselves in thought, *simultaneously*, on the track and in the train; we have refused to become physicists. Indeed, we were not seeking a mathematical representation of the universe: such a representation must naturally be taken from a viewpoint and will conform to the laws of mathematical perspective. We were asking what is real, that is, observed and effectively verified.

On the contrary, for the physicist, there is what he observes himself—this, he notes as is—and then there is what he observes from the possible observation of others: that, he will transpose, he will bring back to his own viewpoint, any physical representation of the universe must be related to a reference system. But the notation he will then make will no longer correspond to anything perceived or perceptible; it will therefore no longer be real, it will be symbolic. The physicist in the train will thus give himself a mathematical vision of the universe in which everything will be converted from perceived reality into a scientifically usable representation, except for what concerns the train and the objects attached to it. The physicist on the track will give himself a mathematical vision of the universe in which everything will be similarly transposed, except for what concerns the track and the objects attached to it. The magnitudes that will appear in these two visions will generally be different, but in both, certain relations between magnitudes, which we call the laws of nature, will be the same, and this identity will precisely express the fact that the two representations are those of one and the same thing, a universe independent of our representation.

What will the physicist stationed at M on the track observe? He will note the simultaneity of the two flashes. Our physicist cannot also be at point M'. All he can do is say that he ideally sees at M' the observation of a non-simultaneity between the two flashes. The representation of the world he will construct rests entirely on the fact that the adopted reference system is tied to Earth: thus the train is moving; therefore one cannot place at M' an observation of the simultaneity of the two flashes. To be precise, nothing is *observed* at M', since that would require a physicist there, and the only physicist in the world is by hypothesis at M. There remains at M' only a certain *notation* made by the observer at M, which is indeed that of a non-simultaneity. *Or, if you prefer, there is at M' a physicist merely imagined, existing only in the thought of the physicist at M.* The latter will then write as Einstein did: "*What is simultaneity relative to the track is not simultaneity relative to* *the train.*" And he will be right to do so, provided he adds: "*since physics is constructed from the viewpoint of the track*". Moreover, one should add: "*What is simultaneity relative to the train is not simultaneity relative to the track, since physics is constructed from the viewpoint of the train.*" And finally, one should say: "*A philosophy that places itself both at the viewpoint of the track and the viewpoint of the train, which then notes as simultaneity in the train what it notes as simultaneity on the track, is no longer half in perceived reality and half in scientific construction; it is entirely in the real, and moreover does nothing but fully appropriate Einstein's idea, which is that of the reciprocity of motion. But this idea, in its completeness, is philosophical and no longer physical. To translate it into the language of the physicist, one must place oneself in what we have called the hypothesis of unilateral relativity. And since this language imposes itself, one does not realize that one has momentarily adopted this hypothesis. One will then speak of a multiplicity of Times all on the same level, all real if one of them is real. But the truth is that this one differs radically from the others. It is real because it is truly lived by the physicist. The others, merely thought, are auxiliary, mathematical, symbolic Times.*"

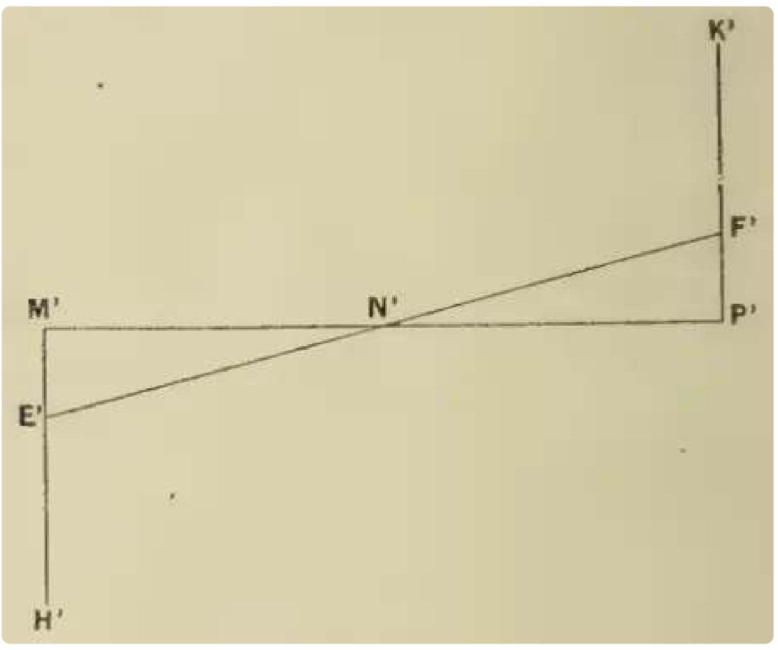

Figure 5

But the ambiguity is so difficult to dispel that it must be attacked from multiple angles. Let us therefore consider (fig. 5), in system S', along a straight line marking the direction of its motion, three points M', N', P' such that N' is equidistant from M' and P' at distance l. Suppose an observer at N'. At each of the three points M', N', P' unfolds a series of events constituting the history of that location. At a specific moment, the observer perceives at N' a perfectly determined event. But are the events contemporary with this one, occurring at M' and P', also determined? No, according to the theory of Relativity. Depending on the velocity attributed to system S', it will not be the same event at M', nor the same event at P', that will be contemporary with the event at N'. If we consider the present of the observer at N' at a given moment, as constituted by all simultaneous events occurring at that moment at all points of his system, only a fragment will be determined: the event occurring at point N' where the observer is located. The rest will be indeterminate. The events at M' and P', which are equally part of our observer's present, will be this or that depending on the velocity attributed to system S', and on the reference system to which it is related. Let us call v its velocity. We know that when clocks, properly synchronized, show the same time at all three points, and consequently when there is simultaneity within system S', the observer in reference system S sees the clock at M' advance and the clock at P' lag behind that at N', the advance and lag being $\frac{lv}{c^2}$ seconds of system S'. Thus, for the external observer, it is the past at M' and the future at P' that enter into the fabric of the present for the observer at N'. What, at M' and P', is part of the present for the observer at N', appears to this external observer as being further back in the past history of location M', and further ahead in the future history of location P', the more considerable the system's velocity. Let us then erect perpendiculars $M'H'$ and $P'K'$ on the straight line $M'P'$ in both opposite directions, and suppose that all events of the past history of location M' are spaced along $M'H'$, and all those of the future history of location P' along $P'K'$. We may call *line of simultaneity* the straight line passing through point N' that joins the events E' and F' located, for the external observer, in the past of location M' and in the future of location P' at a temporal distance of $\frac{lv}{c^2}$ (the number $\frac{lv}{c^2}$ denoting seconds of system S'). This line, as we see, diverges more from $M'N'P'$ the greater the system's velocity.

⊠ ⊠⊠ ⊠ ⊠ 7.7.

Minkowski's Scheme

Here again, the theory of Relativity initially appears paradoxical, striking the imagination. The idea immediately comes to mind that our observer at N', if his gaze could instantly bridge the space separating him from P', would glimpse part of that location's future, since it is there—a moment of that future simultaneous with the observer's present. He could thus predict to an inhabitant of P' the events that witness will experience. Admittedly, one thinks, this instantaneous vision at a distance is not possible in practice; no speed exceeds that of light. But one can conceive by thought an instantaneous vision, and that suffices for the interval $\frac{lv}{c^2}$ of location P''s future to preexist in principle for the present of that location, to be preformed there and consequently predetermined. — We shall see that this is a mirage effect. Unfortunately, relativity theorists have done nothing to dispel it. On the contrary, they have delighted in reinforcing it. The time is not yet ripe to analyze the conception of Minkowski's Space-Time adopted by Einstein. It has been expressed through an ingenious scheme where one might risk reading what we have just indicated—and where indeed Minkowski himself and his successors have effectively read it. Without yet dwelling on this scheme (which would require a whole set of explanations we can dispense with for now), let us translate Minkowski's thought onto the simpler figure we have just drawn.

If we consider our line of simultaneity $E'N'F'$, we see that, initially coinciding with $M'N'P'$, it diverges progressively as the velocity v of system S' increases relative to the reference system S. But it will not diverge indefinitely. We know indeed that no velocity exceeds that of light. Therefore the lengths $M'E'$ and $P'F'$, equal to $\frac{lv}{c^2}$, cannot exceed $\frac{l}{c}$. Suppose they have this length. We are told that beyond E' in direction $E'H'$ lies a region of *absolute past*, and beyond F' in direction $F'K'$ a region of *absolute future*; nothing from this past or future can be part of the present for the observer at N'. However, no moment within interval $M'E'$ or $P'F'$ is absolutely prior or posterior to what occurs at N'; all these successive moments of past and future can be made contemporary with the event at N' if desired; it suffices to attribute to system S' the appropriate velocity, that is, to choose the reference system accordingly. Everything that happened at M' during a past interval $\frac{l}{c}$, everything that will occur at $M'N'P'$ during a future interval $\frac{l}{c}$, can enter the partially indeterminate present of the observer at N': it is the system's velocity that chooses.

Moreover, that the observer at N', if gifted with instantaneous vision at a distance, would perceive as present at P' what is future for an observer at P', and could, through equally instantaneous telepathy, announce to P' what will happen there, has been implicitly accepted by relativity theorists, since they took care to reassure us about the consequences of such a state of affairs[1]. In reality, they show us, the observer at N' will never utilize this immanence in his present of what is past for an observer at M' or future for an observer at P'; he will never make the inhabitants of M' and P' benefit or suffer from it; for no message can be transmitted, no causality exerted, faster than light; so that the person situated at N' could not be warned of a future at P' which is nevertheless part of his present, nor influence that future in any way: this future may well be there, included in the present of the person at N'; for him it remains practically nonexistent.

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(1) *See on this subject: Langevin, Time, Space and Causality. Bulletin of the French Philosophical Society, 1912 and Eddington. Space, Time and Gravitation, trans. Rossignol, p61-66.*

Let us see if there might not be a mirage effect here. We shall return to an assumption we have already made. According to the theory of Relativity, the temporal relations between events unfolding in a system depend solely on the system's velocity, not on the nature of these events. The relations will therefore remain the same if we make S' a duplicate of S, unfolding the same history as S and having initially coincided with it. This hypothesis will greatly simplify matters and will not detract from the generality of the demonstration.

Thus, in system S there is a line MNP from which line $M'N'P'$ separated at the moment when S' detached from S. By hypothesis, an observer placed at M' and one placed at M, being at corresponding points in two identical systems, each witness the same history of the place, the same sequence of events occurring there. The same holds for the two observers at N and N', and for those at P and P', as long as each considers only his own location. This is agreed upon by all. Now, we shall focus more particularly on the two observers at N and N', since it is the simultaneity with what occurs at these midpoints of the line that concerns us [1].

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(1) *To simplify the reasoning, we shall assume throughout what follows that the same event is occurring at points N and N' in the two systems S and S', one being the duplicate of the other. In other words, we consider N and N' at the precise instant of the dissociation of the two systems, assuming that system S' acquires its velocity v instantaneously, by a sudden leap, without passing through intermediate velocities. We then fix our attention on this event constituting the common present of the two characters at N and N'. When we say we increase velocity v, we mean that we reset the situation, bring the two systems to coincide again, consequently have the characters at N and N' witness the same event once more, and then dissociate the two systems by imparting to S', again instantaneously, a higher velocity than before.*

For the observer at N, what is simultaneous with his present at M and P is perfectly determined, since the system is stationary by hypothesis.

As for the observer at N', what was simultaneous with his present at M' and P', when his system S' coincided with S, was equally determined: it was the same two events that, at M and P, were simultaneous with the present of N.

Now, S' moves relative to S and takes, for example, increasing velocities. But for the observer at N', inside S', this system is stationary. The two systems S and S' are in a state of perfect reciprocity; it is for the convenience of study, to construct a physics, that we have immobilized one or the other as a reference system. Everything that a real observer, in flesh and blood, observes at N, everything he would observe instantaneously, telepathically, at any distant point within his system, a real observer, in flesh and blood, placed at N', would perceive identically within S'. Therefore, the part of the history of places M' and P' that truly enters the present of the observer at N' *for him*, what he would perceive at M' and P' if he had the gift of instantaneous vision at a distance, is determined and invariable, regardless of the velocity of S' in the eyes of the observer inside system S. It is precisely the same part that the observer at N would perceive at M and P.

Let us add that the clocks in S' run absolutely for the observer at N' as those in S do for the observer at N, since S and S' are in a state of reciprocal displacement and are therefore interchangeable. When the clocks located at M, N, P, optically synchronized with each other, mark the same time and when, by definition, according to relativism, there is simultaneity between events occurring at these points, the same holds for the corresponding clocks in S' and there is then, again by definition, simultaneity between the events occurring at M', N', P' — events that are respectively identical to the first.

However, as soon as I have immobilized S as the reference system, here is what happens. In system S now considered stationary, with clocks synchronized optically as always done under the assumption of the system's immobility, simultaneity becomes an *absolute* matter; I mean that since the clocks were synchronized by observers necessarily inside the system, under the hypothesis that optical signals between two points N and P take the same path going and returning, this hypothesis becomes definitive, consolidated by the fact that S is chosen as the reference system and permanently immobilized.

But, by that very fact, S' moves; and the observer in S then notices that the optical signals between the two clocks at N' and P' (which the observer in S' assumed and still assumes take the same path going and returning) now make unequal journeys—the inequality increasing as the speed of S' becomes greater. By his definition then (since we assume the observer in S is a relativist), clocks showing the same time in system S' do not, *in his eyes*, mark simultaneous events. These are indeed events simultaneous for him in his own system; just as they are simultaneous for the observer in N' in his own system. But to the observer in N, they appear as successive in system S'; or rather *they appear to him as needing to be noted as successive*, due to the definition he has given of simultaneity.

Then, as the speed of S' increases, the observer in N pushes further into the past of point M' and projects further into the future of point P'—by the numbers he assigns them—the events occurring at these points that are simultaneous for him in his own system and also for an observer situated in system S'. Of this latter observer, in flesh and blood, there is no longer any question; he has been surreptitiously emptied of his content, at least of his consciousness; from observer he has become merely observed, since it is the observer in N who has been elevated to physicist constructing all of science. Hence, I repeat, as v increases, our physicist *notes* as increasingly distant in the past of location M', as increasingly advanced in the future of location P', the very same event which, whether at M' or P', would be part of the real conscious present of an observer in N' and consequently is part of his own. There are not, therefore, different events at location P', for example, that successively enter the real present of the observer in N' for increasing system speeds. But the same event at location P', which is part of the present of the observer in N' under the assumption of system immobility, is noted by the observer in N as belonging to an increasingly distant future of the observer in N' as the speed of system S' increases. If the observer in N did not note it this way, his physical conception of the universe would become incoherent, because the measurements he records for phenomena occurring in a system would express laws that would have to vary with the system's speed: thus a system identical to his, where each point would have identically the same history as the corresponding point in his, would not be governed by the same physics as his (at least regarding electromagnetism). But by noting it this way, he merely expresses the necessity he faces, when supposing in motion under the name of S' his system N at rest, to *curve* the simultaneity between events. It is always the same simultaneity;

it would appear as such to an observer inside S'. But, expressed perspectively from point N, it must be bent into the form of succession.

It is therefore quite useless to reassure ourselves, to say that the observer in N' may well hold within his present a part of the future of location P', but that he cannot become aware of it or communicate it, and that consequently this future is for him as if it did not exist. We are quite at ease: we could not flesh out and revive our observer in N' emptied of his content, remake him into a conscious being and especially a physicist, without the event at location P', which we have just classified in the future, becoming the present of that location again. At bottom, it is himself that the physicist in N needs to reassure here, and it is himself he reassures. He must prove to himself that by numbering the event at point P as he does, by localizing it in the future of that point and in the present of the observer in N', he not only satisfies the demands of science but also remains in perfect agreement with common experience. And he has no trouble proving this to himself, because since he represents all things according to the perspective rules he has adopted, what is coherent in reality remains coherent in the representation. The same reason that makes him say there is no speed greater than that of light, that the speed of light is the same for all observers, etc., obliges him to classify in the future of location P' an event that is part of the present of the observer in N', which is moreover part of his own present as observer in N, and which belongs to the present of location P. Strictly speaking, he should express it thus: "*I place the event in the future of location P', but since I leave it within the future time interval $\frac{l}{c}$, without pushing it further away, I will never have to represent the person at N' as capable of perceiving what will happen at P' and informing the inhabitants of the location.*" But his way of seeing things makes him say: "*Even though the observer in N' possesses, in his present, something of the future of location P', he cannot become aware of it, nor influence or use it in any way.*" This will certainly result in no physical or mathematical error; but great would be the illusion of the philosopher who took the physicist at his word.

Therefore, there are not, at M' and P', alongside events we consent to leave in the "*absolute past*" or "*absolute future*" for the observer in N', a whole set of events that, past and future at these two points, would enter his present when we attribute the appropriate speed to system S'. There is, at each of his points, only one event forming part of the *real* present of the observer in N', regardless of the system's speed: it is precisely the one that, at M and P, forms part of the present of the observer in N. But this event will be noted by the physicist as located further back in the past of M', further ahead in the future of P', according to the speed attributed to the system. It is always, at M' and P', the same pair of events that forms with a certain event at N' the present of Paul situated at that last point. But this simultaneity of three events appears curved into past-present-future when viewed, by Pierre representing Paul, in the mirror of motion.

However, the illusion inherent in common interpretation is so difficult to dispel that it will be useful to attack it from another angle. Let us again suppose that system S', identical to system S, has just detached from it and instantly acquired its velocity. Pierre and Paul were merged at point N: here they are, at this very instant, distinct at N and N' which still coincide. Now imagine that Pierre, within his system S, possesses the gift of instantaneous vision at any distance. If the motion imparted to system S' truly made an event located in the future of place P' simultaneous with what is happening at N' (and consequently at N, since the separation of the two systems occurs at that instant), Pierre would witness a future event at place P—an event that will only enter Pierre's own present later: in short, through system S', he would read the future of his own system S, not at point N where he is located, but at distant point P. And the greater the velocity suddenly acquired by system S', the farther his gaze would penetrate into the future of point P. If he had means of instantaneous communication, he could announce to the inhabitant of place P what will happen there, having seen it at P'. But not at all. *What he perceives at P', in the future of place P', is exactly what he perceives at P, in the present of place P. The greater the velocity of system S', the farther into the future of place P' lies what he sees at P, but it is still and always the same present of point P. Distant vision into the future thus teaches him nothing.* In the "time interval" between the present of place P and the future—identical to this present—of the corresponding place P', there is no room for anything: it is as if the interval were null. And it is indeed null: it is dilated nothingness. But it takes on the appearance of an interval through a phenomenon of mental optics, analogous to how an object appears separated from itself when pressure on the eyeball makes us see double. More precisely, the vision Pierre has formed of system S' is nothing but that of system S *tilted* in Time. This "tilted vision" causes the simultaneity line passing through points M, N, P of system S to appear increasingly oblique in system S' (the duplicate of S) as the velocity of S' increases: the duplicate of what occurs at M is thus pushed back into the past, while the duplicate of what occurs at P is advanced into the future—but this is merely an effect of mental torsion. Now, what we say of system S' as a duplicate of S would hold for any other system with the same velocity; for, once again, the temporal relations of events within S' are affected solely by the system's velocity according to Relativity theory. Suppose then that S' is any system, not necessarily the double of S. To grasp the exact meaning of Relativity theory, we must first have S' at rest with S without merging with it, then set it in motion. We would find that what was simultaneity at rest remains simultaneity in motion, but this simultaneity, observed from system S, is simply tilted: the simultaneity line between the three points M', N', P' appears to have rotated by a certain angle around N', so that one end lingers in the past while the other anticipates the future.

We have emphasized the "*slowing of time*" and the "*dislocation of simultaneity*". This leaves the "*longitudinal contraction*". We will shortly show how it is merely the spatial manifestation of this dual temporal effect. But for now, we can briefly address it. Consider (fig. 6) two points A' and B' in moving system S' that come to rest on points A and B of stationary system S during the system's trajectory, where S' is a duplicate of S.

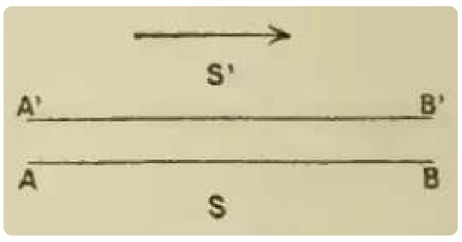

Figure 6

When these two coincidences occur, the clocks placed at A' and B', naturally synchronized by observers attached to S', show the same time. The observer attached to S, who considers that in such a case the clock at B' lags behind the clock at A', will conclude that B' coincided with B only after the moment when A' coincided with A, and consequently that $A'B'$ is shorter than AB. In reality, he only "knows" this in the following sense. To conform to the perspective rules we stated earlier, he had to attribute a delay to the coincidence of B' with B relative to the coincidence of A' with A, precisely because the clocks at A' and B' showed the same time for both coincidences. Therefore, to avoid contradiction, he must assign to $A'B'$ a length less than that of AB. Moreover, the observer in S' will reason symmetrically. His system is motionless to him; consequently, S moves relative to him in the opposite direction to that which S' was following. The clock at A thus appears to him to lag behind the clock at B. Therefore, the coincidence of A with A' must have occurred, according to him, after that of B with B', if clocks A and B showed the same time during both coincidences. It follows that AB must be smaller than $A'B'$. Now, do AB and $A'B'$ really have the same magnitude? Let us repeat once more that we call real here what is perceived or perceptible. We must therefore consider the observer in S and the observer in S', Pierre and Paul, and compare their respective views of the two magnitudes. Now each of them, when he sees instead of being merely seen, when he is the referrer and not the referred, immobilizes his system. Each takes the length he considers in a state of rest. The two systems, in a state of actual reciprocal displacement, being interchangeable since S' is a duplicate of S, the view that the observer in S has of AB is therefore identical by hypothesis to the view that the observer in S' has of $A'B'$. How could one affirm more rigorously, more absolutely, the equality of the two lengths AB and $A'B'$? Equality takes on an absolute meaning, superior to any convention of measurement, only when the two terms compared are identical; and they are declared identical as soon as they are assumed to be interchangeable. Therefore, in the thesis of restricted relativity, extension can no more actually contract than time can slow down or simultaneity effectively dislocate. But when a frame of reference has been adopted and thereby immobilized, everything that happens in other systems must be expressed perspectively, according to the more or less considerable distance that exists, on the scale of magnitudes, between the speed of the referred system and the speed, null by hypothesis, of the referring system. Let us not lose sight of this distinction. If we bring Jean and Jacques to life, both fully present, from the painting where one occupies the foreground and the other the background, let us be careful not to leave Jacques the size of a dwarf. Let us give him, like Jean, the normal dimension.

7.8.

Confusion at the Root of All Paradoxes

To summarize everything, we need only return to our initial hypothesis of the physicist attached to Earth, performing and repeating the Michelson-Morley experiment. But we shall now suppose him primarily concerned with what we call real—that is, what he perceives or could perceive. He remains a physicist, not losing sight of the need to obtain a coherent mathematical representation of the whole of things. But he wants to assist the philosopher in his task; and his gaze never detaches from the shifting boundary line separating the symbolic from the real, the conceived from the perceived. He will therefore speak of "reality" and "appearance," of "true measurements" and "false measurements." In short, he will not adopt the language of Relativity. But he will accept the theory. The translation he will give us of the new idea in the old language will help us better understand what we can retain and what we must modify in what we had previously accepted.

Thus, by rotating his apparatus 90 degrees, at no time of the year does he observe any displacement of the interference fringes. The speed of light is therefore the same in all directions, the same for any speed of Earth. How to explain this fact?

> *The fact is fully explained, our physicist will say. There is difficulty, a problem arises only because one speaks of Earth in motion. But in motion relative to what? Where is the fixed point that it approaches or moves away from? This point could only have been arbitrarily chosen. I am then free to decree that Earth will be this point and to refer it, so to speak, to itself. There it is motionless, and the problem vanishes.*
>
> *Yet I have a scruple. What would my confusion be if the concept of absolute immobility nevertheless took on meaning, and if somewhere a permanently fixed reference point revealed itself? Without even going that far, I need only look at the stars; I see bodies in motion relative to Earth. The physicist attached to one of these extraterrestrial systems, reasoning the same way I do, will consider himself*

> *motionless in turn and will be within his rights: he will therefore have the same demands toward me as the inhabitants of an absolutely immobile system might have. And he will tell me, as they would have said, that I am mistaken, that I have no right to explain by my immobility the equal speed of light propagation in all directions, for I am in motion.*
>
> *But here is what reassures me. An extraterrestrial observer will never reproach me, he will never catch me at fault, because, considering my units of measurement for space and time, observing the displacement of my instruments and the running of my clocks, he will make the following observations:*
>
> *1° I undoubtedly attribute the same speed to light as he does, even though I'm moving in the direction of the light ray while he's stationary; but this is because my units of time appear longer to him than his own; 2° I believe I observe light propagating at the same speed in all directions, but this is because I measure distances with a ruler whose length he sees varying with orientation; 3° I would always find the same speed for light, even if I managed to measure it between two points along a path on Earth by noting on clocks placed at those locations the time taken to traverse the interval? But this is because my two clocks were synchronized by optical signals under the assumption that Earth was stationary. Since it's in motion, one clock lags behind the other by an amount that increases with Earth's speed. This lag will always make me believe that the time light takes to cover the interval corresponds to a constantly identical speed. Thus, I'm covered. My critic will find my conclusions correct, even though from his now exclusively legitimate viewpoint, my premises have become false. At most, he might reproach me for believing I've actually observed the constancy of light's speed in all directions: according to him, I only affirm this constancy because my errors in measuring time and space compensate in a way that yields a result similar to his. Naturally, in the representation of the universe he'll construct, he'll include my lengths of time and space as he just calculated them, not as I had measured them myself. I'll be deemed to have taken incorrect measurements throughout the operations. But I don't mind, since my result is acknowledged as correct. Besides, if the observer I merely imagined became real, he'd face the same difficulty, have the same scruple, and reassure himself similarly. He'd say that whether mobile or stationary, with true or false measurements, he obtains the same physics as I do and arrives at universal laws.*

In other words: given an experiment like Michelson and Morley's, things unfold as if the theorist of relativity pressed on one of the experimenter's eyeballs, inducing a special kind of diplopia: the initially perceived image, the originally conducted experiment, becomes doubled by a phantom image where duration slows down, simultaneity curves into succession, and consequently lengths alter. This artificially induced diplopia in the experimenter is meant to reassure him—or rather assure him—against the risk he believes he runs (a risk he would indeed face in certain cases) by arbitrarily making himself the center of the world, relating everything to his personal reference system, while constructing a physics he wants to be universally valid: henceforth he can sleep peacefully; he knows the laws he formulates will hold true, regardless of the observatory from which nature is observed. For the phantom image of his experiment—showing how it would appear to a stationary observer with a new reference frame if the experimental setup were in motion—is undoubtedly a temporal and spatial deformation of the original image, but a deformation that leaves intact the relations between the skeletal parts, preserves the articulations unchanged, and ensures the experiment continues to verify the same law, these articulations and relations being precisely what we call the laws of nature.

But our terrestrial observer must never lose sight that in all this, he alone is real, and the other observer is phantom. He can moreover summon as many of these phantoms as he wishes—as many as there are speeds, an infinity. All will appear to him as constructing their representation of the universe, modifying the measurements he took on Earth, thereby obtaining physics identical to his. From then on, he'll work on his physics by remaining purely and simply at the observatory he chose—Earth—and will no longer concern himself with them.

Yet it was necessary to evoke these phantom physicists; and the theory of relativity, by providing the real physicist with the means to agree with them, will have greatly advanced science.

We've just placed ourselves on Earth. But we could just as well have chosen any other point in the universe. At each one, there's a real physicist trailed by a cloud of phantom physicists, as many as he can imagine speeds. Do we then want to discern what is real? Do we want to know whether there's one Time or multiple Times? We needn't concern ourselves with phantom physicists; we must only account for real physicists. We'll ask whether they perceive the same Time. Now, it's generally difficult for a philosopher to affirm with certainty that two people experience the same rhythm of duration. He couldn't even give this affirmation a rigorous and precise meaning. Yet he can in the hypothesis of Relativity: here the affirmation takes on a very clear meaning and becomes certain when comparing two systems in a state of mutual uniform displacement; the observers are interchangeable. This is moreover only completely clear and certain in the hypothesis of Relativity. Elsewhere, two systems, however similar, will usually differ in some respect, since they don't occupy the same position relative to the privileged system. But the elimination of the privileged system is the very essence of the theory of Relativity. Therefore, far from excluding the hypothesis of a single Time, this theory calls for it and gives it superior intelligibility.

8.

Figures of Light

This way of viewing things will allow us to delve deeper into the theory of Relativity. We've shown how the relativity theorist evokes, alongside his own system's vision, all representations attributable to every physicist who might perceive that system moving at all possible speeds. These representations differ, but their various parts are articulated to maintain, within each, identical relations among themselves, thereby manifesting the same laws. Let's now examine these representations more closely. Let's show more concretely the increasing deformation of the surface image and the invariable preservation of internal relations as the supposed speed increases. We'll thus witness firsthand the genesis of time's plurality in relativity theory. We'll see its meaning materially unfold before our eyes. And simultaneously, we'll untangle certain postulates this theory implies.

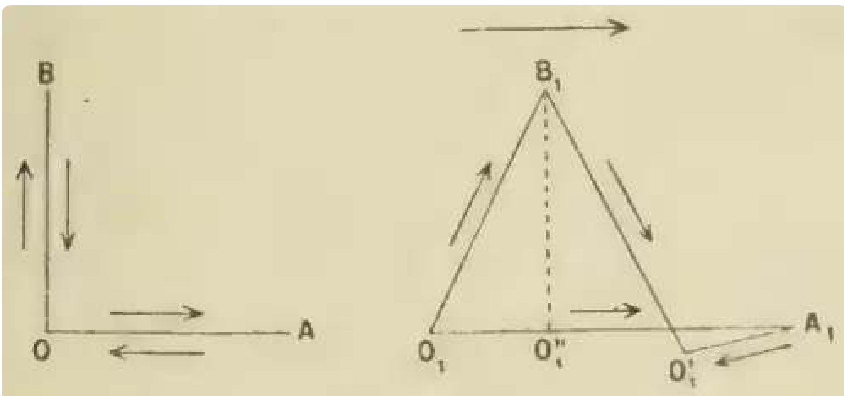

Figure 7

8.1.

"*Lines of Light*" and "*Rigid Lines*"

Thus, in a stationary system S, we have the Michelson-Morley experiment (Figure 7). Let us call a geometric line such as OA or OB a "*rigid line*" or simply a "*line*". Let us call the light ray traveling along it a "*light line*". For the observer within the system, the two rays launched respectively from O to B and from O to A, in the two perpendicular directions, return exactly upon themselves. The experiment thus presents him with the image of a double light line stretched between O and B, and another double light line stretched between O and A, these two double light lines being perpendicular to each other and equal in length.

Looking now at the system at rest, *imagine* it moving with a velocity v. What will be our double representation?

8.2.

The "*Light Figure*" and the Space Figure: How They Coincide and How They Dissociate

While at rest, we can consider it indifferently as composed of two simple rigid lines, rectangular, or of two double light lines, still rectangular: the light figure and the rigid figure coincide. As soon as we suppose it in motion, the two figures dissociate. The rigid figure remains composed of two straight rectangular lines. But the light figure deforms. The double light line stretched along the straight line OB becomes a broken light line $O_1 B_1 O_1'$. The double light line stretched along OA becomes the light line $O_1 A_1 O_1'$ (the portion $O_1' A_1$ of this line actually lies along $O_1 A_1$, but for clarity, we detach it in the figure). That is the form. Now consider the magnitude.

One who reasoned *a priori*, before the Michelson-Morley experiment had been actually performed, would have said: "*I must assume that the rigid figure remains what it is, not only in that the two lines remain rectangular, but also in that they are always equal. This follows from the very concept of rigidity. As for the two double light lines, initially equal, I see them, in imagination, becoming unequal when they dissociate due to the motion my thought imparts to the system. This results from the very equality of the two rigid lines.*" In short, in this *a priori* reasoning according to old ideas, one would have said: "*it is the rigid space figure that imposes its conditions on the light figure.*"

The theory of Relativity, as it emerged from the actually performed Michelson-Morley experiment, consists in reversing this proposition and saying: "*it is the light figure that imposes its conditions on the rigid figure.*" In other words, the rigid figure is not reality itself: it is merely a mental construction; and for this construction, it is the light figure, the only given, that must provide the rules.

The Michelson-Morley experiment indeed teaches us that the two lines $O_1 B_1 O_1'$, $O_1 A_1 O_1'$, remain equal regardless of the speed attributed to the system. It is therefore the equality of the two double light lines that will always be considered preserved, and not that of the two rigid lines: the latter must adjust accordingly. Let us see how they will adjust. To do this, let us closely examine the deformation of our light figure. But let us not forget that everything occurs in our imagination, or rather in our understanding. In fact, the Michelson-Morley experiment is performed by a physicist within his system, and consequently in a stationary system. The system is in motion only if the physicist steps outside it in thought. If his thought remains within it, his reasoning does not apply to his own system, but to the Michelson-Morley experiment conducted in another system, or rather to the image he forms, which he must form, of that experiment conducted elsewhere: for where the experiment is actually performed, it is still by a physicist within the system, and consequently in a system still stationary. So that in all this, it is only a matter of adopting a certain notation for the experiment one does not perform, to coordinate it with the experiment one does perform. It simply expresses that one is not performing it. Never losing sight of this point, let us follow the variation of our light figure. We will examine separately the three deformation effects produced by motion: 1° the transverse effect, which corresponds, as we shall see, to what the theory of Relativity calls a dilation of time; 2° the longitudinal effect, which for it is a dislocation of simultaneity; 3° the double transverse-longitudinal effect, which would be “*the Lorentz contraction*”.

8.3.

Triple Effect of Dissociation

1° Transverse effect or “*time dilation*”. Let us assign increasing magnitudes to the velocity v starting from zero. Let us accustom our thought to draw out from the primitive light figure OAB a series of figures where the gap between light lines—initially coincident—becomes increasingly pronounced. Let us also practice bringing back into the original figure all those that have thus emerged. In other words, let us proceed as with a telescope whose tubes we pull out only to nest them back together again. Or better, let us think of that child's toy made of articulated rods along which wooden soldiers are placed. When we pull the two end rods apart, they cross like X and the soldiers scatter; when we push them back together, they align and the soldiers reform in close ranks. Let us remind ourselves that our light figures are indefinite in number yet form but one: their multiplicity simply expresses the potential views observers would have of them when animated by different speeds—that is, essentially, the views observers in motion relative to them would have; and all these virtual views telescope, so to speak, into the real vision of the primitive figure AOB. What conclusion must we draw for the transverse light line $O_1 B_1 O_1'$, which emerged from OB and could return to it, which effectively returns and merges with OB at the very instant we represent it? This line equals $\frac{2l}{\sqrt{1-\frac{v^2}{c^2}}}$, whereas the primitive double light line was $2l$. Its elongation thus precisely represents the elongation of time as given by the theory of Relativity. We see thereby that this theory proceeds as if we took as our time standard the double round trip of a light ray between two fixed points. But we then immediately perceive, intuitively, the relation of the multiple Times to the single real Time. Not only do the multiple Times evoked by the theory of Relativity not rupture the unity of a real Time, but they imply and maintain it. The real observer, within the system, is indeed conscious of both the distinction and the identity of these diverse Times. He lives a psychological time, and with this Time all the more or less dilated mathematical Times merge; for as he spreads apart the articulated rods of his toy—I mean as he accelerates by thought the motion of his system—the light lines lengthen, yet all fill the same lived duration. Without this unique lived duration, without this real Time common to all mathematical Times, what meaning would there be in saying they are contemporary, that they fit within the same interval? What sense could one possibly find in such an assertion?

Suppose (we shall return to this point shortly) that the observer in S habitually measures his time by a light line, meaning he adheres his psychological time to his light line OB. Necessarily, psychological time and light line (taken in the stationary system) become synonymous for him. When, imagining his system in motion, he represents his light line as longer, he will say that time has lengthened; but he will also see that this is no longer psychological time; it is a time that is no longer, as before, both psychological and mathematical; it has become exclusively mathematical, incapable of being anyone's psychological time: as soon as a consciousness tried to live in one of these elongated Times $O_1 B_1$, $O_2 B_2$, etc., they would immediately retract back to OB, since the light line would no longer be perceived in imagination but in reality, and the system—until then set in motion by thought alone—would reclaim its immobility.

Therefore, in summary, the thesis of Relativity here means that an observer within system S, imagining it in motion at all possible speeds, would see the mathematical time of his system lengthen with increasing speed if the time of this system were merged with the light lines OB, $O_1 B_1$, $O_2 B_2$, etc. All these different mathematical Times would be contemporary in that all fit within the same psychological duration, that of the observer in S. Moreover, they would only be fictitious Times, since they could not be lived as different from the first by anyone—neither by the observer in S who perceives them all within the same duration, nor by any other real or possible observer. They retain the name "time" only because the first in the series, namely OB, measured the psychological duration of the observer in S. Then, by extension, we still call "time" the now-elongated light lines of the system supposed in motion, while forcing ourselves to forget that they all fit within the same duration. Keep the name "time" for them, if you wish: by definition, they will be conventional Times, since they measure no real or possible duration.

But how, generally, do we explain this convergence between time and the light line? Why is the first light line, OB, adhered by the observer in S to his psychological duration, thereby imparting to the successive lines $O_1 B_1$, $O_2 B_2$ ... etc. the name and appearance of time, through a kind of contamination? We have already implicitly answered this question; it will nevertheless be useful to reexamine it. But first—while continuing to treat time as a light line—let us consider the second effect of the figure's deformation.

2° Longitudinal effect or “*dislocation of simultaneity*”. As the gap widens between the light lines that coincided in the original figure, the inequality increases between two longitudinal light lines such as $O_1 A_1$ and $A_1 O_1'$, initially merged in the double-thickness light line OA. Since the light line always represents time for us, we'll say that moment A_1 is no longer the midpoint of time interval $O_1 A_1 O_1'$, whereas moment A was the midpoint of interval OAO. Now, whether the observer within system S assumes it at rest or in motion, this supposition—a mere act of thought—doesn't affect the system's clocks. But it does influence their synchronization, as we see. The clocks remain unchanged; it's Time that changes. It warps and dislocates between them. What were once equal times—going from O to A and returning from A to O in the original figure—now show the outward journey longer than the return. One easily sees that the lag of the second clock behind the first will be $\frac{1}{\sqrt{1-\frac{v^2}{c^2}}} \cdot \frac{lv}{c^2}$ or $\frac{lv}{c^2}$, depending on whether counted in seconds of the stationary or moving system. Since the clocks remain as they were, running as they ran, maintaining the same relationship and synchronized as before, they appear—in our observer's mind—to lag increasingly behind each other as his imagination accelerates the system's motion. Does he perceive himself as stationary? There's real simultaneity between the two instants when clocks at O and A show the same time. Does he imagine himself in motion? By definition, these two instants—marked by synchronized clocks showing identical times—cease to be simultaneous, since the two light lines have become unequal after being equal. I mean that what was first equality has now become inequality *slipping in* between the two clocks, though they themselves haven't moved. But do these equality and inequality have the same degree of reality when applied to time? The first was *both* an equality of light lines and an equality of psychological durations—time as everyone understands it. The second is merely an inequality of light lines—conventional Times—occurring between the same psychological durations as the first. And precisely because psychological duration persists unchanged through all the observer's successive imaginings, he can consider all the conventional Times he imagines as equivalent. He faces figure BOA: he perceives a certain psychological duration measured by the double light lines OB and OA. Now, while still looking, still perceiving this same duration, he sees in imagination the double light lines dissociate while lengthening, the longitudinal double light line splitting into two unequal lines, the inequality growing with speed. All these inequalities emerge from the original equality like telescope tubes; all instantly retract if he wishes, telescoping back. They remain equivalent because the true reality is the original equality—the simultaneity of moments indicated by the two clocks—not the purely fictitious, conventional succession generated by the merely imagined motion of the system and the resulting dislocation of light lines. All these dislocations, all these successions are thus virtual; only simultaneity is real. And because all these virtualities, all these varieties of dislocation are contained within the actually perceived simultaneity, they can mathematically substitute for it. Nevertheless, one side deals with the imagined, the purely possible, while the other deals with the perceived and real.

But the fact that—consciously or not—relativity theory substitutes light lines for time highlights a core principle of the doctrine. In a series of studies on relativity theory [1], Mr. Ed. Guillaume argued it essentially adopts light propagation as its clock, replacing the Earth's rotation. We believe relativity contains much more than this, but acknowledge at least this element. And we add that isolating this component underscores the theory's importance, showing how it represents the natural—perhaps necessary—culmination of an evolution. Recall the penetrating insights Mr. Edouard Le Roy once offered about the gradual refinement of measurements, particularly time measurement [2]. He showed how certain measurement methods enable establishing laws, and how these laws in turn react upon measurement methods, compelling their modification. Regarding time specifically, sidereal clocks enabled physics and astronomy's development: Newton's law of gravitation and energy conservation were discovered using them. But these results contradict sidereal day constancy, since tides must brake Earth's rotation. Thus using sidereal clocks leads to consequences demanding a new clock [3]. Physics' progress undoubtedly tends to present the optical clock—light propagation—as the ultimate clock, the endpoint of successive approximations. Relativity theory records this result. And since physics inherently identifies things with their measurement, the "light line" becomes both time's measure and time itself. But then, since the light line lengthens while remaining itself when motion is imagined while the observing system stays at rest, we get multiple equivalent Times; and relativity's hallmark hypothesis of temporal plurality appears as conditioning physics' overall evolution. These Times are indeed physical Times [4]. However, they remain conceived Times—except one, actually perceived. This one, ever the same, is common-sense Time.

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[1] *Revue of Metaphysics (May-June 1918 and October-December 1920). Cf. The Theory of Relativity, Lausanne, 1921.*

[2] *Bulletin of the French Society of Philosophy, February 1905.*

[3] *Cf. ibid., Space and Time, p. 25.*

[4] *We have called them mathematical throughout this essay to avoid any confusion. We are indeed constantly comparing them to psychological time. But for that, we had to distinguish them and always keep this distinction in mind. Now, the difference is clear between the psychological and the mathematical; it is much less so between the psychological and the physical. The expression "physical time" would sometimes have been ambiguous; with that of "mathematical time," there can be no ambiguity.*

⊠⊠⊠⊠⊠ 8.4.

True Nature of Einstein's Time

Let us summarize in a few words. To common-sense time, which can always be converted into psychological duration and is thus real by definition, the theory of Relativity substitutes a time that can be converted into psychological duration only in the case of a system at rest. In all other cases, this time, which was both a light line and duration, is now only a light line—an elastic line that stretches as the speed attributed to the system increases. It cannot correspond to a new psychological duration since it continues to occupy the same duration. But it matters little: the theory of Relativity is a physical theory; it chooses to neglect all psychological duration, both in the first case and in all others, and to retain only the light line as time. Since this line lengthens or shortens according to the speed of the system, we thus obtain multiple times, coexisting with one another. And this seems paradoxical to us because real duration continues to haunt us. But it becomes, on the contrary, very simple and natural if we take an extensible light line as a substitute for time, and if we call simultaneity and succession cases of equality and inequality between light lines whose relation to each other obviously changes according to the state of rest or motion of the system.

But these considerations on light lines would be incomplete if we limited ourselves to studying the transversal and longitudinal effects separately. We must now witness their composition. We will see how the relation that must always exist between longitudinal and transversal light lines, whatever the speed of the system, leads to certain consequences regarding rigidity, and consequently also extension. We will thus capture in the act the interweaving of Space and Time in the theory of Relativity. This interweaving becomes clear only when time has been reduced to a light line. With the light line, which is time but remains underpinned by space, which lengthens due to the motion of the system and thus gathers space along the way with which it makes time, we will grasp *in concreto*, in the Time and Space of everyone, the very simple initial fact that translates into the conception of a four-dimensional Space-Time in the theory of Relativity.

3° Transversal-longitudinal effect or “*Lorentz contraction*”. The theory of special relativity, we have said, essentially consists in first representing the double light line BOA, then deforming it into figures such as $O_1 B_1 A_1 O^{'}$ by the motion of the system, and finally in making all these figures re-enter, exit, and re-enter one another, accustoming oneself to think that they are *at once* the first figure and the figures that have emerged from it. In short, one gives oneself, with all possible speeds successively imparted to the system, all possible visions of one and the same thing, this thing being supposed to coincide with all these visions at once. But the thing in question is essentially a light line. Consider the three points O, B, A in our first figure. Ordinarily, when we call them fixed points, we treat them as if they were joined to one another by rigid rods. In the theory of Relativity, the link becomes a light loop that one would launch from O to B so as to make it return to itself and catch it back at O, and another light loop between O and A, merely touching A to return to O. This means that time will now amalgamate with space. In the hypothesis of rigid rods, the three points were linked to one another in the instantaneous or, if you will, in the eternal —in short, outside time: their relation in space was invariable. Here, with elastic and deformable rods of light that are representative of time or rather that are time itself, the relation of the three points in space will become dependent on time.

To understand the ensuing “*contraction*”, we have only to examine the successive light figures, bearing in mind that they are figures, that is, light tracings considered all at once, and that we must nevertheless treat their lines as if they were time. Since only these light lines are given, we will have to reconstruct by thought the space lines, which will generally no longer be visible in the figure itself. They can only be inferred, that is, reconstructed by thought. The exception, naturally, is the light figure of the system supposed to be at rest: thus, in our first figure, OB and OA are both flexible light lines and rigid space lines, the apparatus BOA being considered at rest. But in our second light figure, how are we to represent the apparatus, the two rigid space lines supporting the two mirrors? Consider the position of the apparatus corresponding to the moment when B has come to be at B_1. If we drop the perpendicular $B_1 O_1^{''}$ to $O_1 A_1$, can we say that figure $B_1 O_1^{''} A_1$ is that of the apparatus? Obviously not, because if the equality of the light lines $O_1 B_1$ and $O^{'} B_1$ informs us that the moments $O_1^{''}$ and B_1 are indeed simultaneous, so that $O_1^{''} B_1$ retains the character of a rigid space line, and consequently $O_1^{''} B_1$ represents one arm of the apparatus, on the contrary, the inequality of the light lines $O_1 A_1$ and $O^{'} A_1$ shows that the two moments $O_1^{''}$ and A_1 are successive. The length $O_1^{''} A_1$ therefore represents the second arm of the apparatus plus the space traversed by the apparatus during the time interval between moment $O_1^{''}$ and moment A_1. Therefore, to obtain the length of this second arm, we must take the difference between $O_1^{''} A_1$ and the space traversed. It is easy to calculate. The length $O_1^{''} A_1$ is the arithmetic mean between $O_1 A_1$ and $O_1^{'} A_1$, and since the sum of these two lengths is equal to $\frac{2l}{\sqrt{1-\frac{v^2}{c^2}}}$, because the total line $O_1 A_1 O_1^{'}$ represents the same time as the line $O_1 B_1 O_1^{'}$, we see that $O_1^{''} A_1$ has a length of $\frac{l}{\sqrt{1-\frac{v^2}{c^2}}}$. As for the space traversed by the apparatus in the time interval between moments $O_1^{''}$ and A_1, it can be immediately evaluated by noting that this interval is measured by the delay of the clock at the end of one arm of the apparatus relative to the clock at the other, that is, by $\frac{1}{\sqrt{1-\frac{v^2}{c^2}}} \cdot \frac{lv}{c^2}$. The distance traveled is then $\frac{1}{\sqrt{1-\frac{v^2}{c^2}}} \cdot \frac{lv^2}{c^2}$. And consequently, the length of the arm, which was l at rest, has become

$$\frac{l}{\sqrt{1-\frac{v^2}{c^2}}} - \frac{lv^2}{c^2\sqrt{1-\frac{v^2}{c^2}}}$$

, that is, $l\sqrt{1-\frac{v^2}{c^2}}$. We thus recover the "*Lorentz contraction*".

We see what contraction signifies. The identification of time with the light line means that the system's motion produces a double effect in time: dilation of the second and dislocation of simultaneity. In the difference

$$\frac{l}{\sqrt{1-\frac{v^2}{c^2}}} - \frac{lv^2}{c^2\sqrt{1-\frac{v^2}{c^2}}}$$

, the first term corresponds to the dilation effect, the second to the dislocation effect. In both cases one could say that only time (fictitious time) is involved. But the combination of these effects in Time produces what is called a contraction of length in Space.

⊠⊠⊠⊠⊠ 8.5.

Transition to the Theory of Space-Time

We then grasp the very essence of the restricted theory of Relativity. Colloquially, it would be expressed as follows: "*Given, at rest, a coincidence between the rigid figure of space and the flexible figure of light, and given, on the other hand, an ideal dissociation of these two figures through motion attributed by thought to the system, the successive deformations of the flexible light figure under various speeds are all that matter: the rigid space figure will adjust as best it can.*" In practice, we see that in the system's motion, the longitudinal zigzag of light must maintain the same length as the transverse zigzag, since the equality of these two times takes precedence. Since under these conditions the two rigid space lines—longitudinal and transverse—cannot themselves remain equal, space must yield. It necessarily yields, the rigid tracing in lines of pure space being considered merely the record of the overall effect produced by the various modifications of the flexible figure, that is, of the light lines.

⊠⊠⊠⊠⊠ 9.

Space-Time in Four Dimensions

How the Idea of a Fourth Dimension Is Introduced

Let us now set aside our light figure with its successive deformations. We used it to give substance to the abstractions of the theory of Relativity and to uncover the postulates it implies. The relationship we previously established between multiple Times and psychological time has perhaps become clearer. And one may have glimpsed the door opening to the idea of four-dimensional Space-Time within the theory. It is this Space-Time we shall now examine.

Our analysis has already shown how this theory treats the relationship between the thing and its expression. The thing is what is perceived; the expression is what the mind substitutes for the thing to subject it to calculation. The thing is given in a real vision; the expression corresponds at best to what we call a phantasmal vision. Ordinarily, we imagine phantasmal visions as fleeting, surrounding the stable, firm core of real vision. But the essence of the theory of Relativity is to place all these visions on the same level. The vision we call real would be merely one of the phantasmal visions. I accept this, in the sense that there is no way to mathematically translate the difference between the two. But one should not conclude from this to a similarity of nature. Yet this is what is done when attributing metaphysical meaning to Minkowski's continuum and Einstein's four-dimensional Space-Time. Let us see, in fact, how the idea of this Space-Time arises.

To do this, we need only precisely determine the nature of the "*phantasmal visions*" in the case where an observer within a system S', having had the real perception of an invariable length l, would represent this invariability by placing himself in thought outside the system and then supposing the system animated by all possible speeds. He would say: "*Since a line $A'B'$ of the moving system S', passing before me in the stationary system S where I install myself, coincides with a length l of that system, this line, at rest, would be equal to $\frac{1}{\sqrt{1-\frac{v^2}{vz^2}}} \cdot l$. Consider the square $L^2 = \frac{1}{1-\frac{v^2}{c^2}} \cdot l^2$ of this magnitude. By how much does it exceed the square of l? By the quantity $\frac{1}{1-\frac{v^2}{c^2}} \cdot \frac{l^2v^2}{c^2}$, which can be written $c^2\left[\frac{1}{\sqrt{1-\frac{v^2}{c^2}}} \cdot \frac{lv}{c^2}\right]^2$. Now $\frac{1}{\sqrt{1-\frac{v^2}{c^2}}} \cdot \frac{lv}{c^2}$ precisely measures the time interval T that elapses for me, transported into system S, between two events occurring respectively at A' and B' which would appear simultaneous to me if I were in system S'. Therefore, as the speed of S' increases from zero, the time interval T grows between the two events occurring at points A' and B' and given as simultaneous in S'; but things occur in such a way that the difference $L^2 - c^2T^2$ remains constant. This is the difference I formerly called l^2.*" Thus, taking c as the unit of Time, we can say that what is given to a real observer in S' as the fixity of a spatial magnitude, as the invariability of a square l^2, would appear to a fictitious observer in S as the constancy of the difference between the square of a space and the square of a time.

But we have just placed ourselves in a particular case. Let us generalize the question and first ask how the distance between two points of the system is expressed relative to rectangular axes situated within a material system S'. We will then examine how it would be expressed relative to axes situated in a system S relative to which S' would be in motion.

If our space were two-dimensional, reduced to the present sheet of paper, and if the two points considered were A' and B', with respective distances to the two axes $O'Y'$ and $O'X'$ being x'_1, y'_1 and x'_2, y'_2, it is clear that we would have

$$\overline{A'B'}^2 = (x'_2 - x'_1)^2 + (y'_2 - y'_1)^2$$

We could then take any other system of axes stationary relative to the first and thus assign to x'_1, x'_2, y'_1, y'_2 values generally different from the initial ones: the sum of the two squares $(x'_2 - x'_1)^2$ and $(y'_2 - y'_1)^2$ would remain the same, since it would always equal $\overline{A'B'}^2$. Similarly, in a three-dimensional space, points A' and B' no longer being supposed in the plane $X'O'Y'$ and now defined by their distances $x'_1, y'_1, z'_1, x'_2, y'_2, z'_2$ to the three faces of a trirectangular trihedron with vertex O', one would observe the invariance of the sum

① $$(x_2' - x_1')^2 + (y_2' - y_1')^2 + (z_2' - z_1')^2$$

It is through this very invariance that the fixity of the distance between A' and B' would be expressed for an observer situated at S'.

But suppose our observer places himself in thought in system S, relative to which S' is supposed to be in motion. Suppose also that he refers points A' and B' to axes situated in his new system, placing himself moreover in the simplified conditions we described earlier when establishing the Lorentz equations. The respective distances of points A' and B' to the three rectangular planes intersecting at S will now be $x_1, y_1, z_1; x_2, y_2, z_2$. The square of the distance $A'B'^2$ between our two points will still be given by a sum of three squares which will be

② $$(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2$$

But according to the equations of Lorentz, while the last two squares of this sum are identical to the last two of the previous one, the same does not hold for the first, because these equations give us for x_1 and x_2 respectively the values $\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}(x_1' + vt')$ and $\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}(x_2' + vt')$; so that the first square will be $\frac{1}{1-\frac{v^2}{c^2}}(x_2' - x_1')^2$. We naturally find ourselves facing the particular case we were examining earlier. We had indeed considered in system S' a certain length $A'B'$, that is, the distance between two instantaneous and simultaneous events occurring respectively at A' and B'. But we now wish to generalize the question. Let us therefore assume that the two events are successive for the observer in S'. If one occurs at time t_1' and the other at time t_2', the Lorentz equations will give us

$$x_1 = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}(x_1' + vt_1')$$

$$x_2 = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}(x_2' + vt_2')$$

so that our first square becomes

$$\frac{1}{1-\frac{v^2}{c^2}}[(x_2' - x_1') + v(t_2' - t_1')]^2$$

and our initial sum of three squares is replaced by

③ $$\frac{1}{1-\frac{v^2}{c^2}}[(x_2' - x_1') + v(t_2' - t_1')]^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2$$

, a quantity that depends on v and is no longer invariant. But if, in this expression, we consider the first term $\frac{1}{1-\frac{v^2}{c^2}}[(x_2' - x_1') + v(t_2' - t_1')]^2$, which gives us the value of $(x_2 - x_1)^2$, we see that it exceeds $(x_2' - x_1')^2$ by the quantity:

$$\frac{1}{1-\frac{v^2}{c^2}} \cdot c^2 \left[(t_2' - t_1') + \frac{v(x_2' - x_1')}{c^2}\right]^2 - c^2 (t_2' - t_1')^2$$

Now the equations of Lorentz give:

$$\frac{1}{1-\frac{v^2}{c^2}}\left[(t_2' - t_1') + \frac{v(x_2' - x_1')}{c^2}\right]^2 = (t_2 - t_1)^2$$

We therefore have

$$(x_2 - x_1)^2 - (x'_2 - x'_1)^2 = c^2(t_2 - t_1)^2 - c^2(t'_2 - t'_1)^2$$

or

$$(x_2 - x_1)^2 - c^2(t_2 - t_1)^2 = (x'_2 - x'_1)^2 - c^2(t'_2 - t'_1)^2$$

or finally

$$(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2 - c^2(t_2 - t_1)^2 = (x'_2 - x'_1)^2 + (y'_2 - y'_1)^2 + (z'_2 - z'_1)^2 - c^2(t'$$

A result that could be stated as follows: If the observer in S′ had considered, instead of the sum of three squares

$$(x'2 - x'1)^2 + (y'2 - y'1)^2 + (z'2 - z'1)^2$$

, the expression

$$(x'2 - x'1)^2 + (y'2 - y'1)^2 + (z'2 - z'1)^2 - c^2(t'2 - t'1)^2$$

which includes a fourth square, he would have restored, by introducing Time, the invariance that had ceased to exist in Space.

Our calculation may have seemed somewhat clumsy. It indeed is. Nothing would have been simpler than to immediately note that the expression

$$(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2 - c^2(t_2 - t_1)^2$$

does not change when the Lorentz transformation is applied to its terms. But that would have placed all systems where measurements are taken on the same level. The mathematician and physicist must do this, since they do not seek to interpret the Space-Time of relativity theory in terms of reality, but simply to use it. On the contrary, our very object is this interpretation. We had to start from measurements taken in system S' by the observer in S' —the only real measurements attributable to a real observer—and consider measurements taken in other systems as alterations or deformations of those, alterations or deformations coordinated in such a way that certain relations between the measurements remain the same. To maintain the central position of the observer in S' and thus prepare for the analysis we will shortly give of Space-Time, the detour we have taken was necessary. It was also necessary, as will be seen, to establish a distinction between the case where the observer in S' perceives events A' and B' as simultaneous, and the case where he notes them as successive. This distinction would have vanished if we had reduced simultaneity to the special case where $t'_2 - t'_1 = 0$; we would have thus absorbed it into succession; any difference in nature would again have been abolished between the measurements actually taken by the observer in S' and the merely thought measurements taken by observers external to the system. But that matters little for now. Let us simply show how relativity theory is indeed led by the preceding considerations to posit a four-dimensional Space-Time.

We said that the expression for the square of the distance between two points A' and B' referred to two rectangular axes in a two-dimensional space is $(x_2 - x_1)^2 + (y_2 - y_1)^2$, if we call x_1, y_1, x_2, y_2 their respective distances to the two axes. We added that in a three-dimensional space it would be $(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2$. Nothing prevents us from imagining spaces of $4, 5, 6, \ldots, n$ dimensions. The square of the distance between two points there would be given by a sum of $4, 5, 6, \ldots, n$ squares, each of these squares being that of the difference between the distances of points A' and B' to one of the $4, 5, 6, \ldots, n$ planes. Let us then consider our expression

$$(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2 - c^2(t_2 - t_1)^2$$

If the sum of the first three terms were invariant, it could express the invariance of distance as we conceived it in our three-dimensional Space before relativity theory. But the latter essentially states that the fourth term must be introduced to obtain invariance. Why should this fourth term not correspond to a fourth dimension? Two considerations seem at first to oppose this, if we stick to our expression of distance: on the one hand, the square $(t_2 - t_1)^2$ is preceded by a *minus* sign instead of a *plus* sign, and on the other hand, it is affected by a coefficient c^2 different from unity. But since, on a fourth axis that would represent time, times must necessarily be carried as lengths, we can decree that the second will have the length c: our coefficient will thus become unity. Moreover, if we consider a time τ such that $t = \tau\sqrt{-1}$, and if, in general, we replace t by the imaginary quantity $\tau\sqrt{-1}$, our fourth square will be $-\tau^2$, and we will then indeed be dealing with a sum of four squares. Let us agree to call Δx, Δy, Δz, $\Delta\tau$ the four differences $x_2 - x_1$, $y_2 - y_1$, $z_2 - z_1$, $\tau_2 - \tau_1$, which are the respective increments of x, y, z, τ when passing from x_1 to x_2, from y_1 to y_2, from z_1 to z_2, from τ_1 to τ_2, and let us call Δs the interval between the two points A' and B'. We will have:

$$\Delta s^2 = \Delta x^2 + \Delta y^2 + \Delta z^2 + \Delta\tau^2$$

And from then on nothing will prevent us from saying that s is a distance, or rather an interval, in Space and Time at once: the fourth square would correspond to the fourth dimension of a Space-Time continuum where Time and Space would be amalgamated.

Nothing will prevent us either from supposing the two points A' and B' to be infinitely close, so that $A'B'$ could just as well be an element of a curve. A finite increment such as Δx will then become an infinitesimal increment dx, and we will have the differential equation:

$$ds^2 = dx^2 + dy^2 + dz^2 + d\tau^2$$

from which we can ascend by a summation of infinitely small elements, by an "*integration*", to the interval s between two points of a line this time arbitrary, occupying both Space and Time, which we will call AB. We will write it:

$$s = \int_A^B \sqrt{dx^2 + dy^2 + dz^2 + d\tau^2}$$

an expression that must be known, but which we will not return to in what follows. It will be better to use directly the considerations that led to it[(1)].

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(1) *The somewhat mathematical reader will have noticed that the expression $ds^2 = dx^2 + dy^2 + dz^2 - c^2 dt^2$ can be considered as such as corresponding to a hyperbolic Space-Time. The artifice described above, by Minkowski, consists in giving this Space-Time a Euclidean form by substituting the imaginary variable $ct\sqrt{-1}$ for the variable t.*

We've just seen how the notation of a fourth dimension introduces itself almost automatically into the theory of Relativity. Hence, no doubt, the often-expressed opinion that we owe to this theory the first idea of a four-dimensional medium encompassing time and space. What hasn't been sufficiently noted is that a fourth spatial dimension is suggested by any spatialization of time: it has therefore always been implied by our science and language. Indeed, one might extract it in a more precise, or at least more vivid form, from the common conception of time than from the theory of Relativity. Only, in the common theory, the assimilation of time to a fourth dimension is implied, whereas the physics of Relativity is forced to introduce it into its calculations. This stems from the double effect of endosmosis and exosmosis between time and space, the reciprocal encroachment of one upon the other, which the Lorentz equations seem to express: it becomes necessary here, to locate a point, to explicitly indicate its position in time as well as in space. Nevertheless, the Space-Time of Minkowski and Einstein remains a *specific form* of which the common spatialization of Time in a four-dimensional Space is the *general category*. Our path forward is then clearly marked. We must begin by seeking the general meaning of introducing a four-dimensional medium that would unite time and space. Then we'll ask what is added or subtracted when conceiving the relationship between spatial dimensions and the temporal dimension in the manner of Minkowski and Einstein. Already we glimpse that if the common conception of space accompanied by spatialized time naturally takes the form of a four-dimensional medium for the mind, and if this medium is fictitious in that it merely symbolizes the convention of spatializing time, the same will hold for the specific forms of which this four-dimensional medium is the general category. In any case, both specific form and general category will likely share the same degree of reality, and the Space-Time of relativity theory will probably be no more incompatible with our former conception of duration than was a four-dimensional Space-and-Time symbolizing both ordinary space and spatialized time. Nevertheless, we cannot avoid examining more specifically the Space-Time of Minkowski and Einstein once we've addressed a general four-dimensional Space-and-Time. Let us first focus on the latter.

⊠ ⊠⊠ ⊠ ⊠ 9.2.

General Representation of a Four-Dimensional Space-and-Time

One struggles to imagine a new dimension when starting from three-dimensional Space, since experience shows us no fourth. But nothing is simpler if we endow a two-dimensional Space with this additional dimension. We can envision flat beings living on a surface, merging with it, knowing only two spatial dimensions. One of them might be led by calculations to postulate a third dimension. Superficial in both senses of the word, its peers would likely refuse to follow; it itself would fail to imagine what its understanding had conceived. But we, living in three-dimensional Space, would have real perception of what it merely represented as possible: we would grasp exactly what it added by introducing a new dimension. And since this would be something similar to what we ourselves would do if—limited to three dimensions as we are—we supposed ourselves immersed in a four-dimensional medium, we would almost imagine this fourth dimension that initially seemed unimaginable. This wouldn't be quite the same, admittedly. For a space of more than three dimensions is a pure conception of the mind and may correspond to no reality. Whereas three-dimensional Space is that of our experience. Therefore, when in what follows we use our three-dimensional Space, really perceived, to give substance to the representations of a mathematician confined to a flat universe—representations conceivable but not imaginable for them—this doesn't mean that a four-dimensional Space exists or could exist that might in turn concretely realize our own mathematical conceptions when they transcend our three-dimensional world. That would grant too much to those who immediately interpret the theory of Relativity metaphysically. The artifice we'll employ aims solely to provide imaginative support for the theory, thereby clarifying it, and thus better revealing the errors into which hasty conclusions might lead us.

We will therefore simply return to the hypothesis we started with when drawing two rectangular axes and considering a line $A'B'$ in the same plane. We gave ourselves only the surface of the paper. This two-dimensional world, the theory of Relativity endows with an additional dimension that would be time: the invariant will no longer be $dx^2 + dy^2$ but $dx^2 + dy^2 - c^2 dt^2$. Admittedly, this additional dimension is of a very special nature, since the invariant would be $dx^2 + dy^2 + dt^2$ without needing a notational artifice to bring it to this form, if time were a dimension like the others. We must account for this characteristic difference, which has concerned us before and on which we'll concentrate shortly. But we set it aside for now, since the theory of Relativity itself invites us to do so: if it resorted to an artifice here and posited an imaginary time, it was precisely so its invariant would retain the form of a sum of four squares each with unity as coefficient, and so the new dimension could be provisionally assimilated to the others. Let us therefore ask, in general terms, what is added—and perhaps also what is removed—from a two-dimensional universe when making its time an additional dimension. We'll then account for the special role this new dimension plays in the theory of Relativity.

It cannot be repeated too often: the mathematician's time is necessarily a time that is measured and consequently a spatialized time. There is no need to place oneself in the hypothesis of Relativity: in any case (as we pointed out over thirty years ago) mathematical time can be treated as an additional dimension of space. Suppose a superficial universe reduced to the plane P, and consider in this plane a moving point M tracing any line, for example a circumference, starting from a certain point we will take as the origin. We who inhabit a three-dimensional world can represent the moving point M dragging with it a line MN perpendicular to the plane, whose variable length would measure at each instant the time elapsed since the origin. The endpoint N of this line will describe in three-dimensional space a curve that will be, in this case, helical in shape. It is easy to see that this curve traced in three-dimensional space gives us all the temporal particularities of the change occurring in the two-dimensional space P. The distance from any point of the helix to the plane P indeed indicates the moment of time we are dealing with, and the tangent to the curve at this point gives us, by its inclination to the plane P, the speed of the moving point at that moment[1]. Thus, it will be said, the "two-dimensional curve"[2] only sketches part of the reality observed on the plane P, because it is only space, in the sense that the inhabitants of P give to this word. On the contrary, the "three-dimensional curve" contains this reality in its entirety: it has three dimensions of space for us; it would be Space-and-Time in three dimensions for a two-dimensional mathematician inhabiting the plane P who, incapable of imagining the third dimension, would be led by the observation of motion to conceive it and express it analytically. He could then learn from us that a three-dimensional curve actually exists as an image.

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[1] *A very simple calculation would show this.*

[2] *We are forced to use these barely correct expressions, "two-dimensional curve," "three-dimensional curve," to designate here the plane curve and the space curve. There is no other way to indicate the spatial and temporal implications of each.*

Moreover, once the three-dimensional curve is posited, space and time together, the two-dimensional curve would appear to the mathematician of the flat universe as a simple projection of the former onto the plane he inhabits. It would be only the superficial and spatial aspect of a solid reality that should be called time and space at once.

In short, the form of a three-dimensional curve informs us here both about the plane trajectory and about the temporal particularities of a motion occurring in a two-dimensional space. More generally, *what is given as motion in a space of any number of dimensions can be represented as form in a space having one more dimension.*

But is this representation truly adequate to what it represents? Does it contain exactly what the latter contains? One might think so at first glance, as we have just said. But the truth is that it contains more in one respect, less in another, and if the two things appear interchangeable, it is because our mind surreptitiously subtracts what is superfluous from the representation and introduces no less surreptitiously what is missing.

⊠ ⊠⊠ ⊠ ⊠ 9.3.

How Immobility is Expressed in Terms of Motion

To begin with the second point, it is evident that *becoming* proper has been eliminated. This is because science has no use for it in the present case. What is its object? Simply to know where the moving point will be at any moment of its path. It therefore invariably transports itself to the endpoint of an interval already traversed; it concerns itself only with the result once obtained: if it can represent all at once all the results acquired at all moments, and in such a way as to know which result corresponds to which moment, it has achieved the same success as the child who has become capable of reading a word instantly instead of spelling it letter by letter. This is what happens in the case of our circle and our helix, which correspond point to point. But this correspondence has meaning only because our mind *traverses* the curve and occupies its points *successively*. If we have been able to replace succession by juxtaposition, real time by spatialized time, the *becoming* by the *become*, it is because we retain within us the becoming, real duration: when the child now reads the word all at once, he virtually spells it letter by letter. Let us not imagine, therefore, that our three-dimensional curve delivers to us, crystallized together as it were, the motion by which the plane curve is traced and that plane curve itself. It has simply extracted from becoming what interests science, and science, moreover, will be able to use this extract only because our mind restores the eliminated becoming or feels capable of doing so. In this sense, the curve in n + 1 dimensions *already traced*, which would be the equivalent of the curve in n dimensions *being traced*, actually represents less than it claims to represent.

But, in another sense, it represents more. Subtracting here, adding there, it is doubly inadequate.

We obtained it, in fact, through a well-defined process: the circular motion in plane P of a point M dragging with it a straight line of variable length MN proportional to elapsed time. This plane, this circle, this line, this motion—these are the perfectly determined elements of the operation by which the figure was traced. But the fully traced figure does not necessarily imply this mode of generation. Even if it still implies it, it could have resulted from the motion of another line perpendicular to another plane, whose endpoint M would have described in that plane, with entirely different speeds, a curve that was not a circumference. Suppose we take any plane and project our helix onto it: this helix would equally well represent the new plane curve traversed with new speeds, amalgamated with new times. Thus, as we announced, the representation is doubly inadequate: it falls short in one sense, it goes beyond in another. And the reason is clear. By adding a dimension to the space we inhabit, we can certainly represent by a *thing* in this new space a *process* or a *becoming* given in the former. But by substituting what is *already made* for what we perceive *in the making*, we have on the one hand eliminated the becoming inherent to time, and on the other introduced the possibility of an infinity of other processes by which the thing could equally well have been constructed. Along the time during which we observed the thing's gradual genesis, there was one well-determined mode of generation; but in the new space—augmented by one dimension—where the thing is spread out at once through the addition of time to the former space, we are free to imagine an infinity of equally possible modes of generation; and the one we actually observed, though alone real, no longer appears privileged: we place it—wrongly—on the same level as the others.

☒☒☒☒☒ 9.4.

How Time Appears to Merge with Space

From now on, we glimpse the double danger we expose ourselves to when symbolizing time as a fourth dimension of space. On one hand, we risk taking the unfolding of the entire past, present, and future history of the universe as a mere journey of our consciousness along this history given all at once in eternity: events would no longer parade before us; instead, we would pass before their alignment. On the other hand, in the Space-and-Time or Space-Time thus constituted, we would believe ourselves free to choose among an infinity of possible distributions of Space and Time. Yet this Space-Time was constructed with a specific Space and a specific Time: only one particular distribution in Space and Time was real. But we fail to distinguish it from all other possible distributions—or rather, we see only an infinity of possible distributions, the real one being merely one among them. In short, we forget that measurable time, necessarily symbolized by space, contains both more and less in the spatial dimension taken as symbol than in time itself.

But we will see these two points more clearly as follows. We have supposed a two-dimensional universe. This will be plane *P*, extended indefinitely. Each successive state of the universe will be an instantaneous image occupying the entire plane and comprising all the flat objects of which the universe is made. The plane will thus be like a screen on which the cinematography of the universe unfolds, with this difference: there is no external cinematograph projecting images from outside; the image draws itself spontaneously. Now, the inhabitants of plane *P* may conceive of the succession of cinematographic images in their space in two different ways. They will divide into two camps, depending on whether they adhere more to experiential data or to scientific symbolism.

The first will maintain that there are indeed successive images, but that nowhere are these images aligned together along a film—for two reasons: 1° Where would the film find room? Each image, covering the screen entirely by itself, fills by hypothesis the totality of a space that may be infinite —the totality of the universe's space. These images must therefore exist only successively; they cannot be given globally. Time, moreover, presents itself to our consciousness as duration and succession, attributes irreducible to any others and distinct from juxtaposition. 2° On a film, everything would be predetermined or, if you prefer, determined. Our consciousness of choice, action, and creation would thus be illusory. If there is succession and duration, it is precisely because reality hesitates, gropes, and gradually elaborates unpredictable novelty. Certainly, the share of absolute determination is great in the universe; that is precisely why a mathematical physics is possible. But what is predetermined is virtually *already made* and endures only through its solidarity with what is *in the making*, with what is real duration and succession: we must account for this interweaving, and we then see that the past, present, and future history of the universe cannot be given globally along a film[(1)].

[(1)] *On this point, on what we called the cinematographic mechanism of thought, and on our immediate representation of things, see chapter IV of Creative Evolution, Paris, 1907.*

The others would reply: "*First, we have no use for your supposed unpredictability. The object of science is to calculate, and consequently to predict: we shall therefore disregard your feeling of indeterminacy, which may be nothing but an illusion. Now, you say there is no room in the universe to house images other than the one called present. This would be true if the universe were condemned to have only its two dimensions. But we can suppose it has a third, which our senses cannot reach, and through which our consciousness would precisely travel when unfolding in* '*Time*'*. Thanks to this third dimension of Space, all images constituting all past and future moments of the universe are given at once with the present image, not arranged relative to each other like photographs along a film (for that, indeed, there would be no room), but ordered differently, which we cannot imagine but can nevertheless conceive. To live in Time consists in traversing this third dimension, that is, in detailing it, in perceiving one by one the images it enables to be juxtaposed. The apparent indeterminacy of what we are about to perceive consists simply in the fact that it is not yet perceived: it is an objectification of our ignorance*[(1)]*. We believe images create themselves as they appear, precisely because they seem to appear to us, that is, to occur before us and for us, to come to us. But let us not forget that all movement is reciprocal or relative: if we perceive them coming to us, it is equally true to say we go to them. They are actually there; they await us, aligned; we pass along the front. Let us therefore not say that events or accidents happen to us; it is we who happen to them. And we would realize this immediately if we knew the third dimension like the others.*"

[(1)] *In the pages devoted to the* "*cinematographical mechanism of thought*"*, we have previously shown that this way of reasoning is natural to the human mind. (Creative Evolution, chap. IV.)*

Now, suppose I were taken as arbiter between the two camps. I would turn to those who have just spoken and say: "*First, let me congratulate you on having only two dimensions, for you will thereby obtain for your thesis a verification I would seek in vain if I made a similar argument in the space where fate has cast me. It so happens that I inhabit a three-dimensional space; and when I grant certain* *philosophers that there might well be a fourth, I say something perhaps absurd in itself, though mathematically conceivable. A superman, whom I would in turn take as arbiter between them and me, might explain that the idea of a fourth dimension arises from extending certain mathematical habits contracted in our Space (exactly as you obtained the idea of a third dimension), but that the idea corresponds this time to no reality and cannot correspond to any. Nevertheless, there is a three-dimensional space where I find myself: this is good fortune for you, and I can enlighten you. Yes, you guessed correctly in believing possible the coexistence of images like yours, each extending over an infinite 'surface', whereas it is impossible in the truncated Space where the totality of your universe seems contained at each instant. It suffices that these images—which we call 'flat'—be stacked, as we say, one upon another. There they are stacked. I see your 'solid' universe, in our manner of speaking; it is made of the piling up of all your flat images, past, present, and future. I also see your consciousness traveling perpendicularly to these superposed 'planes', becoming aware only of the one it traverses, perceiving it as present, then remembering the one it leaves behind, but ignoring those ahead which enter in turn into its present only to soon enrich its past.*"

Yet here is what strikes me further.

I have taken arbitrary images, or rather blank films, to represent your future, which I do not know. I have thus piled upon the present state of your universe future states that remain blank for me: they correspond to past states on the other side of the present state, which I perceive as determinate images. But I am by no means certain that your future coexists thus with your present. It is you who tell me so. I constructed my figure based on your indications, but your hypothesis remains a hypothesis. Do not forget that it is a hypothesis, and that it simply translates certain properties of the very particular facts, carved from the immensity of the real, with which physical science concerns itself. Now, I can tell you, sharing my experience of the third dimension, that your representation of time by space will give you both more and less than what you wish to represent.

It will give you less, because the stack of piled images constituting the totality of the universe's states contains nothing that implies or explains the movement by which your Space P occupies them in turn, or by which (which amounts to the same thing, according to you) they come in turn to fill the Space P where you are. I know well that this movement doesn't count in your eyes. Since all images are virtually given—and this is your conviction—since one should theoretically be able to take whichever one wants from the part of the stack that lies ahead (this constitutes the calculation or prediction of an event), the movement that would force you to first pass through the intermediate images between that particular image and the present image—a movement that would precisely be time—appears to you as a mere '*delay*' or impediment imposed in practice upon a vision that would be immediate in principle; there would only be a deficit in your empirical knowledge, precisely compensated by your mathematical science. Ultimately, this would be negative; and instead of gaining, you would be giving yourself *less* than you had when you posit a succession—that is, a necessity to leaf through the album—when all the pages are already there. But I, who experience this three-dimensional universe and can actually perceive the movement you imagined, must warn you that you are considering only one aspect of mobility and consequently of duration: the other, essential aspect escapes you. One can certainly consider as theoretically piled up, given in advance in principle, all the parts of all future states of the universe that are predetermined: this merely expresses their predetermination. But these parts, constitutive of what is called the physical world, are framed by others, on which your calculation has had no hold until now, and which you declare calculable through an entirely hypothetical assimilation: there is the organic, there is the conscious. I, who am inserted into the organized world through my body, into the conscious world through my mind, perceive forward movement as a gradual enrichment, as a continuity of invention and creation. Time is for me the most real and necessary thing; it is the fundamental condition of action—what am I saying? it is action itself; and the obligation I have to live it, the impossibility of ever leaping over the interval of time to come, would suffice to demonstrate to me—if I didn't have the immediate feeling of it—that the future is truly open, unpredictable, undetermined. Don't take me for a metaphysician, if by that you mean a man of dialectical constructions. I have constructed nothing; I have simply observed. I offer you what presents itself to my senses and consciousness: the immediately given must be held as real until proven to be mere appearance; the burden of proof, if you see an illusion here, falls on you. But you suspect an illusion only because you yourself are making a metaphysical construction. Or rather, the construction is already made: it dates back to Plato, who held time to be a mere privation of eternity; and most ancient and modern metaphysicians have adopted it as is, because it indeed responds to a fundamental requirement of human understanding. Made to establish laws—that is, to extract from the changing flux of things certain relations that do not change—our understanding is naturally inclined to see only them; they alone exist for it; it thus fulfills its function, responds to its purpose by placing itself outside of flowing and enduring time. But thought, which overflows pure understanding, knows well that if intelligence's essence is to extract laws, it is so that our action may have something to rely on, so that our will may have more grip on things: understanding treats duration as a deficit, as a pure negation, so that we can work as efficiently as possible within this duration that is nonetheless the most positive thing in the world. The metaphysics of most metaphysicians is therefore nothing but the very law of the functioning of understanding, which is one faculty of thought, but not thought itself. Thought, in its integrity, takes into account integral experience, and the integrality of our experience is duration. Therefore, whatever you do, you eliminate something, and indeed the essential, by replacing the successive states of the universe that pass one by one with a block once and for all.[1]

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[1] *On the relation established by metaphysicians between the block and the images given successively, we have extensively elaborated in Creative Evolution, chap. IV.*

By doing so, you give yourself less than you should. But, in another sense, you give yourself more than you should.

You indeed want your plane P to traverse all the images, stationed there waiting for you, of all successive moments of the universe. Or—which amounts to the same—you want all these images given in the instantaneous or in eternity to be condemned, due to an infirmity of your perception, to appear to you as passing one by one on your plane P. It matters little how you express it: in both cases there is a plane P—that's Space—and a displacement of this plane parallel to itself—that's Time—which makes the plane traverse the entire block laid out once and for all. But if the block is truly given, you could just as well cut it with any other plane P' moving parallel to itself and thus traversing the totality of reality in another direction[1]. You would have made a new distribution of space and time, as legitimate as the first, since the solid block alone has absolute reality. Such is indeed your hypothesis. You imagine having obtained, by adding an extra dimension, a three-dimensional Space-and-Time that can be divided into space and time in infinitely many ways; yours, the one you experience, would be but one of them; it would be on the same level as all others. But I, who *see* what all the experiences would be of observers attached to your planes P' and moving with them—experiences you merely conceive—I can tell you that having at each instant the vision of an image made of points borrowed from all real moments of the universe, they would live in incoherence and absurdity. The set of these incoherent and absurd images does reproduce the block, but solely because the block was constituted in a completely different manner—by a specific plane moving in a specific direction—that the block exists, and one can then indulge in the fantasy of reconstructing it mentally by means of any plane moving in another direction. To place these fantasies on the same level as reality, to say that the movement that actually generated the block is merely one among possible movements, is to neglect the second point I just drew your attention to: in the *ready-made* block, freed from the duration in which it *was being made*, the result once obtained and detached no longer bears the express mark of the work that produced it. A thousand diverse operations, performed by thought, could ideally recompose it just as well, even though it was composed effectively in one particular way. When the house is built, our imagination traverses it in all directions and reconstructs it just as well by placing the roof first, then attaching the floors one by one. Who would put this method on the same level as the architect's and consider it equivalent? Upon closer inspection, one would see that the architect's method is the only effective way to compose the whole, that is, to make it; the others, despite appearances, are only ways to decompose it, that is, in short, to unmake it; there are thus as many as one could wish. What could only be constructed in a certain order can be destroyed any which way.

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[1] *It is true that in the common conception of spatialized Time, one is never tempted to shift the film in a time direction and imagine a new distribution of the four-dimensional continuum into time and space: it would offer no advantage and yield incoherent results, whereas the operation seems imperative in relativity theory. Nevertheless, the amalgamation of time with space, which we present as characteristic of this theory, could conceivably exist in the common theory too, though taking a different aspect.*

⊠ ⊠⊠ ⊠ ⊠ 9.5.

Double Illusion to Which One is Exposed

These are the two points one must never lose sight of when joining time to space by endowing the latter with an additional dimension. We have considered the most general case; we have not yet examined the special aspect this new dimension takes in relativity theory. This is because relativity theorists, whenever they step beyond pure science to give us an idea of the metaphysical reality this mathematics expresses, have implicitly assumed that the fourth dimension has *at least* the attributes of the other three, while adding something more. They have spoken of their Space-Time while taking for granted the following two points: 1° All distributions one can make in it of space and time must be placed on the same level (though in relativity these distributions can only be made according to a special law, which we'll return to shortly); 2° our experience of successive events merely illuminates point by point a line given all at once. They seem not to have accounted for the fact that the mathematical expression of time, necessarily imparting to it the characteristics of space and requiring that the fourth dimension, whatever its specific qualities, first have those of the other three, will be deficient and excessive at once, as we have just shown. Anyone failing to apply a double corrective here risks misunderstanding the philosophical significance of relativity theory and elevating a mathematical representation into transcendent reality. This becomes clear when reading certain passages from the already classic book by Mr. Eddington: "*Events do not happen; they are there, and we encounter them on our passage. The* '*formality of occurring*' *is merely the indication that the observer, in his journey of exploration, has passed into the absolute future of the event in question, and it is of little importance*[1]." One already read in one of the earliest works on relativity theory, that of Silberstein, that Mr. Wells had remarkably anticipated this theory when he had his '*Time Traveler*' say: *There is no difference between Time and Space, except that along Time our consciousness moves*[2].

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[1] *Eddington, Space, Time and Gravitation, French trans., p. 51.*

[2] *Silberstein, The Theory of Relativity, p. 130.*

⊠ ⊠⊠ ⊠ ⊠ 9.6.

Particular Characteristics of This Representation in Relativity Theory

But we must now address the special aspect that the fourth dimension takes in the Space-Time of Minkowski and Einstein. Here the invariant ds^2 is no longer a sum of four squares each with a coefficient of unity, as it would be if time were a dimension like the others: the fourth square, assigned the coefficient c^2, must be subtracted from the sum of the previous three, and thus finds itself in a separate position. One can, by an appropriate artifice, erase this singularity from the mathematical expression: it nonetheless persists in the thing expressed, and the mathematician warns us by saying that the first three dimensions are '*real*' and the fourth '*imaginary*'. Let us therefore examine as closely as we can this particular form of Space-Time.

9.7.

Special illusion that may result from it

But let us announce right away the result we are heading towards. It will necessarily resemble closely the one we obtained from the examination of multiple Times; it can only be a new expression of it. Against common sense and philosophical tradition, which advocate for a single Time, the theory of Relativity initially seemed to affirm the plurality of Times. Upon closer inspection, we have never found more than one real Time, that of the physicist who constructs science: the others are virtual Times, I mean fictitious, attributed by him to virtual observers, I mean fantastical. Each of these phantom observers, suddenly coming to life, would settle into the real duration of the former real observer, who in turn becomes a phantom. So that the usual conception of real Time simply persists, with, in addition, a mental construct intended to represent that, if one applies the formulas of Lorentz, the mathematical expression of electromagnetic phenomena remains the same for the observer deemed motionless and for the observer who attributes to himself any uniform motion. Now, the Space-Time of Minkowski and Einstein represents nothing else. If by four-dimensional Space-Time one means a real medium in which real beings and objects evolve, the Space-Time of the theory of Relativity is that of everyone, for we all sketch the gesture of positing a four-dimensional Space-Time as soon as we spatialize time, and we cannot measure time, we cannot even speak of it without spatializing it[1]. But, in this Space-Time, Time and Space would remain distinct: neither Space could disgorge time, nor Time retrocede space. If they bite into each other, and in proportions varying with the speed of the system (which is what they do in Einstein's Space-Time), then it is no longer anything but a virtual Space-Time, that of a physicist imagined as experimenting and no longer of the physicist who experiments. For this latter Space-Time is at rest, and in a Space-Time that is at rest, Time and Space remain distinct from each other; they only intermingle, as we shall see, in the mixing brought about by the motion of the system; but the system is in motion only if the physicist who was in it abandons it. Now, he cannot abandon it without settling into another system: this one, which is then at rest, will have a Space and a Time clearly distinct like ours. So that a Space that ingests Time, a Time that in turn absorbs Space, are a Time or a Space always virtual and merely posited, never actual and realized. It is true that the conception of this Space-Time will then act on the perception of current Space and Time. Through the Time and Space that we have always known as distinct, and thereby amorphous, we will perceive, as if through transparency, an articulated organism of Space-Time. The mathematical notation of these articulations, carried out on the virtual and raised to its highest degree of generality, will give us an unexpected hold on the real. We will have in our hands a powerful means of investigation, a research principle that one can predict, from today, the human mind will not renounce, even if experience were to impose a new form on the theory of Relativity.

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[1] *This is what we expressed in another form (p. 76 ff.) when we said that science has no means of distinguishing between unfolding time and unfolded time. It spatializes it by the mere fact of measuring it.*

9.8.

What the amalgamation of Space-Time really represents

To show how time and space only begin to interlace when both become fictitious, let us return to our system S' and our observer who, being effectively in S', mentally transports himself to another system S, immobilizes it, and then supposes S' to be set in motion at all possible speeds. We wish to understand what specifically signifies, in relativity theory, the interweaving of space with time considered as an additional dimension. We will not alter the result, and will simplify our exposition by assuming that the space of systems S and S' is reduced to a single dimension—a straight line—and that the observer in S', having a worm-like form, inhabits a portion of this line. Essentially, we are returning to the conditions we established earlier (p. 190). We stated that our observer, as long as he maintains his thought in S' where he is, observes purely and simply the persistence of length $A'B'$ denoted by l. But as soon as his thought moves to S, he forgets the concrete, observed invariability of length $A'B'$ or its square l^2; he now represents it only abstractly as the invariance of a difference between two squares L^2 and c^2T^2—which alone are given (calling L the elongated space $\frac{l}{\sqrt{1-\frac{v^2}{c^2}}}$, and T the time interval $\frac{1}{\sqrt{1-\frac{v^2}{c^2}}} \cdot \frac{lv}{c^2}$ that has inserted itself between the two events A' and B' perceived as simultaneous within system S'). We who know spaces of more than one dimension can easily translate geometrically the difference between these two conceptions: in the two-dimensional space surrounding line $A'B'$ for us, we need only raise perpendicular $B'C'$ equal to cT, and immediately notice that the real observer in S' actually perceives side $A'B'$ of the right triangle as invariable, while the fictitious observer in S perceives (or rather conceives) directly only the other side $B'C'$ and the hypotenuse $A'C'$ of this triangle. Line $A'B'$ would then be for him merely a mental tracing to complete the triangle—a figurative expression of $\sqrt{\overline{A'C'}^2 - \overline{B'C'}^2}$. Now suppose a wave of a magic wand places our observer—real in S' and fictitious in S—in the conditions we ourselves occupy, enabling him to perceive or conceive a space of more than one dimension. As real observer in S', he will perceive straight line $A'B'$: this is real. As fictitious physicist in S, he will perceive or conceive broken line $A'C'B'$: this is merely virtual; it is straight line $A'B'$ appearing elongated and doubled in the mirror of motion. Now, straight line $A'B'$ is Space. But broken line $A'C'B'$ is Space and Time; and so would be an infinity of other broken lines $A'D'B'$, $A'E'B'$ ... etc., corresponding to different speeds of system S', while straight line $A'B'$ remains Space. These broken Space-Time lines, purely virtual, emerge from the straight Space line solely through the motion the mind impresses on the system. They all obey this law: the square of their Space part minus the square of their Time part (taking light speed as time unit) yields a remainder equal to the invariable square of straight line $A'B'$—the latter being pure Space, yet real. Thus we see precisely the relation of the Space-Time amalgam to distinct Space and Time, which had always been left side-by-side even when time was spatialized as an additional dimension. This relation becomes strikingly clear in our deliberately chosen case where line $A'B'$, perceived by an observer in S', joins two events A' and B' given as simultaneous in this system. Here, Time and Space are so distinct that Time vanishes, leaving only Space: space $A'B'$—all that is observed, all that is real. But this reality can be virtually reconstituted through an amalgam of virtual Space and virtual Time, this Space and Time elongating as the virtual speed imparted to the system by the observer mentally detaching from it increases. We thus obtain an infinity of merely conceived Space-Time amalgams, all equivalent to the pure, simple, perceived and real Space.

But *the essence of relativity theory is to place real vision and virtual visions on equal footing.* The real would be merely a special case of the virtual. Between perceiving straight line $A'B'$ inside system S' and conceiving broken line $A'C'B'$ when imagining oneself inside system S, there would be no difference in nature. Straight line $A'B'$ would be a broken line like $A'C'B'$ with a segment like $C'B'$ null—the zero value assigned here to c^2T^2 being a value like any other. Mathematicians and physicists certainly have the right to express it thus. But the philosopher, who must distinguish real from symbolic, will speak differently. He will simply describe what occurred: There is a perceived, real length $A'B'$. And if we agree to take only this—considering $A'B'$ and B' as instantaneous and simultaneous—there is simply, by hypothesis, this length of Space *plus* a nothingness of Time. But a motion mentally imparted to the system makes the initially considered space appear to swell with Time: l^2 becomes L^2, meaning $l^2 + c^2T^2$. The new space must then shed time—L^2 must be reduced by c^2T^2—to recover l^2.

We thus return to our earlier conclusions. We were shown that two events simultaneous for an observer inside his system would be successive for one imagining the system in motion from outside. We agreed, but noted that the interval between the now-successive events—though called time—could contain no event: it was, we said, "dilated nothingness"[1]. Here we witness the dilation: For observer S', the distance between A' and B' was a spatial length l plus a temporal zero. When reality l^2 becomes virtuality L^2, the real temporal zero blossoms into virtual time c^2T^2. But this virtual time interval is merely the primitive nothingness of time producing an optical effect in motion's mirror. Thought cannot lodge an event here—however brief—any more than one could push furniture into a drawing room glimpsed in a mirror's depths.

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[1] *See above, page 154.*

But we have considered a particular case, that in which the events at A' and B' are perceived, within the system S', as simultaneous. It seemed to us the best way to analyze the operation by which Space is added to Time and Time to Space in the theory of Relativity. Let us now take the more general case where events A' and B' occur at different times for the observer in S'. We return to our initial notation: we will call t_1' the time of event A' and t_2' that of event B'; we will denote by $x_2' - x_1'$ the distance from A' to B' in Space, with x_1' and x_2' being the respective distances from A' and B' to an origin point O'. To simplify, we again assume Space reduced to a single dimension. But this time we will ask how the observer within S', noting in this system both the constancy of the spatial length $x_2' - x_1'$ and that of the temporal length $t_2' - t_1'$ for all the speeds one might suppose the system to have, would represent this constancy by placing himself in thought in an immobile system S. We know[1] that $(x_2' - x_1')^2$ would have to have expanded into

$$\frac{1}{1-\frac{v^2}{c^2}}[(x_2' - x_1') + v(t_2' - t_1')]^2$$

, a quantity that exceeds $(x_2' - x_1')^2$ by

$$\frac{1}{1-\frac{v^2}{c^2}}[\frac{v^2}{c^2}(x_2' - x_1')^2 + v^2(t_2' - t_1')^2 + 2v(x_2' - x_1')(t_2' - t_1')]$$

Here again, a time, as we see, would have come to swell a space.

But, in turn, a space has been added to a time, because what was originally $(t_2^{'} - t_1^{'})^2$ has become [2]

$$\frac{1}{1-\frac{v^2}{c^2}}[(t_2^{'} - t_1^{'}) + \frac{v(x_2^{'} - x_1^{'})}{c^2}]^2$$

, a quantity that exceeds $(t_2^{'} - t_1^{'})^2$ by

$$\frac{1}{1-\frac{v^2}{c^2}}[\frac{v^2}{c^2}(x_2^{'} - x_1^{'})^2 + \frac{v^2}{c^2}(t_2^{'} - t_1^{'})^2 + \frac{2v}{c^2}(x_2^{'} - x_1^{'})(t_2^{'} - t_1^{'})]$$

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[1] *See p. 193*

[2] *See p. 194*

So that the square of time has increased by a quantity which, multiplied by c^2, would give the increase in the square of space. We thus see forming before our eyes, space gathering time and time gathering space, the invariance of the difference $(x_2 - x_1)^2 - c^2(t_2 - t_1)^2$ for all speeds attributed to the system.

But this amalgam of Space and Time begins to occur for the observer in $S^{'}$ only at the precise moment when his thought sets the system in motion. And the amalgam exists only in his thought. What is real, that is, observed or observable, is the distinct Space and Time with which he deals in his system. He can associate them in a four-dimensional continuum: this is what we all do, more or less confusedly, when we spatialize time, and we spatialize it as soon as we measure it. But Space and Time then remain separately invariant. They will amalgamate together or, more precisely, the invariance will be transferred to the difference $(x_2 - x_1)^2 - c^2(t_2 - t_1)^2$ only for our fantastic observers. The real observer will let it happen, for he is quite calm: since each of his two terms $x_2 - x_1$ and $t_2 - t_1$, spatial length and time interval, is invariable, regardless of the point from which he considers them within his system, he abandons them to the fantastic observer so that the latter may incorporate them as he wishes into the expression of his invariant; he adopts this expression in advance, he knows in advance that it will suit his system as he himself conceives it, because a relation between constant terms is necessarily constant. And he will have gained much, for the expression brought to him is that of a new physical truth: it indicates how the '*transmission*' of light behaves in relation to the '*translation*' of bodies.

But it informs him about the relation of this transmission to this translation; it tells him nothing new about Space and Time: these remain what they were, distinct from each other, incapable of mingling except through the effect of a mathematical fiction intended to symbolize a physical truth. For this Space and Time that interpenetrate are not the Space and Time of any real physicist or conceived as such. The real physicist takes his measurements in the system where he is, and which he immobilizes by adopting it as a reference system: Time and Space remain distinct there, impenetrable to each other. Space and Time interpenetrate only in moving systems where the real physicist is not, where only physicists imagined by him reside—imagined for the greater good of science. But these physicists are not imagined as real or as possibly real: to suppose them real, to attribute consciousness to them, would be to erect their system into a reference system, to transport oneself there and merge with them, in any case to declare that their Time and Space have ceased to interpenetrate.

Thus, by a long detour, we return to our starting point. From Space convertible into Time and Time reconvertible into Space, we simply repeat what we had said about the plurality of Times, about succession and simultaneity held to be interchangeable. And this is quite natural, since it is the same thing in both cases. The invariance of the expression $dx^2 + dy^2 + dz^2 - c^2 dt^2$ results immediately from the equations of Lorentz. And the Space-Time of Minkowski and Einstein merely symbolizes this invariance, just as the hypothesis of multiple Times and simultaneities convertible into successions merely translates these equations.

⊠ ⊠⊠ ⊠ ⊠ 10.

Final Remark

Here we are at the end of our study. It was to focus on Time and the paradoxes concerning Time that are usually associated with the theory of Relativity. It will therefore confine itself to Special Relativity. Does this mean we remain in the abstract? Certainly not, and we would have nothing essential to add about Time if we introduced into the simplified reality we have dealt with so far a gravitational field. According to the theory of General Relativity, indeed, in a gravitational field one can no longer define the synchronization of clocks nor affirm that the speed of light is constant. Consequently, strictly speaking, the optical definition of time vanishes. As soon as one wishes to give meaning to the coordinate '*time*', one will necessarily place oneself in the conditions of Special Relativity, going if necessary to seek them at infinity.

At each instant, a universe of Special Relativity is tangent to the Universe of General Relativity. Moreover, one never has to consider speeds comparable to that of light, nor gravitational fields that are intense in proportion. Therefore, in general, with sufficient approximation, one can borrow the notion of Time from Special Relativity and preserve it as it is. In this sense, Time pertains to Special Relativity, as Space pertains to General Relativity.

Yet the Time of special relativity and the Space of general relativity do not possess the same degree of reality. A thorough study of this point would be remarkably instructive for the philosopher. It would confirm the radical distinction in nature we previously established between real Time and pure Space, unduly considered analogous by traditional philosophy. And it might not be without interest for the physicist. It would reveal that the theory of special relativity and that of general relativity are not exactly animated by the same spirit and do not have quite the same significance. The former emerged from a collective effort, while the latter reflects Einstein's unique genius. The former provides mainly a new formula for already established results; it is indeed, in the proper sense of the word, a theory, a mode of representation. The latter is essentially an investigative method, an instrument of discovery. But we need not institute a comparison between them. Let us merely say a few words about the difference between the Time of one and the Space of the other. This will return us to an idea repeatedly expressed throughout this essay.

When the physicist of general relativity determines the structure of Space, they speak of a Space where they are effectively situated. Everything they assert could be verified with appropriate measuring instruments. The portion of Space whose curvature they define may be as distant as one wishes: theoretically they could transport themselves there, theoretically they could have us witness the verification of their formula. In short, the Space of general relativity presents characteristics that are not merely conceived, but could equally be perceived. They concern the system where the physicist resides.

But the temporal characteristics, particularly the plurality of Times in the theory of special relativity, escape not only in fact the observation of the physicist who posits them: they are unverifiable in principle. While the Space of general relativity is a Space where one is, the Times of special relativity are defined so as to be all, except one, Times where one is not. One could not be there, for one brings with oneself, wherever one goes, a Time that dispels the others, like the clearing attached to the walker pushes back the fog at every step. One cannot even conceive of being there, for transporting oneself in thought to one of the dilated Times would mean adopting the system to which it belongs, making it one's frame of reference: immediately this Time would contract and revert to the Time lived within a system, the Time we have no reason not to believe is the same in all systems.

The dilated and dislocated Times are therefore auxiliary Times, interposed by the physicist's thought between the starting point of the calculation, which is real Time, and the endpoint, which is still that same real Time. In the latter, measurements are taken for the operation; to the latter, the results of the operation apply. The others are intermediaries between the problem's statement and its solution.

The physicist places them all on the same level, calls them by the same name, treats them in the same manner. And they are right. All are indeed measures of Time; and since the measure of a thing is, in the eyes of physics, the thing itself, all must be Time for the physicist. But in only one of them—we believe we have demonstrated this—is there succession. Only one of them endures; the others do not endure. While that one is a Time undoubtedly backed by the length that measures it, yet distinct from it, the others are merely lengths. More precisely, that one is both a Time and a '*line of light*'; the others are only lines of light. But since these latter lines arise from an elongation of the first, and since the first was glued to Time, they will be called elongated Times. Hence all the Times, indefinite in number, of special relativity. Their plurality, far from excluding the unity of real Time, presupposes it.

The paradox begins when one claims that all these Times are realities, meaning things one perceives or could perceive, lives or could live. The contrary had been implicitly admitted for all—except one—when Time was identified with the line of light. This is the contradiction our mind senses, even when it does not clearly perceive it. Moreover, it is not attributable to any physicist as such: it only arises in a physics that would erect itself into metaphysics. To this contradiction our mind cannot reconcile itself. It was wrong to attribute this resistance to a prejudice of common sense. Prejudices vanish or at least weaken upon reflection. But in this case, reflection strengthens our conviction and even ends by making it unshakable, because it reveals to us that in the Times of special relativity—with one exception—there are Times without duration, where events could not succeed one another, nor things subsist, nor beings age.

Aging and duration belong to the order of quality. No analytical effort will resolve them into pure quantity. The thing remains here distinct from its measure, which moreover bears on a Space representative of Time rather than on Time itself. But it is entirely different for Space. Its measure exhausts its essence. This time the characteristics discovered and defined by physics belong to the thing and not to a mental view of it. Let us say better: they are reality itself; the *thing* is this time *relation*. Descartes reduced matter—considered instantaneously—to extension: physics, in his eyes, attained the real to the extent it was geometrical. A study of general relativity, parallel to what we have done for special relativity, would show that the reduction of gravitation to inertia was precisely an elimination of ready-made concepts that, interposing between the physicist and their object, between the mind and the constitutive relations of the thing, prevented physics here from being geometry. In this respect, Einstein is the continuator of Descartes.

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