7 Relativity Postulate

In the introductory section of the 1905 paper Einstein, as has been mentioned in the preceding chapter, refers to the behaviour of conductors and magnets and the inability to discover any motion of the Earth relative to the aether. These two things, according to Einstein, suggest that there is no absolute rest and that *the same laws of electrodynamics and optics will be valid for all frames of reference for which the equations of mechanics hold good.* Immediately after this sentence Einstein continues: *We will raise this conjecture (the purport of which will hereafter be called the "principle of Relativity") to the status of a postulate.* This is the first formulation of the relativity postulate which is one of the two basic premises on which the whole special theory rests. Einstein himself says that it is a *conjecture*. The meaning of conjecture is: an opinion without proof, or formed on the basis of insufficient evidence, or defective evidence, or no evidence at all.

Further down in the same paper the postulate is defined as follows: *The laws by which the states of physical systems undergo change are not affected, whether these changes of state be referred to the one or the other of two systems of co-ordinates in uniform translatory motion.* What is said here exceeds the bounds of the associated kinematical theory discussed by Einstein. In particular, the reference to *laws* and *physical systems* is inappropriate because the impression is created that we are entitled to deal with these things in a general way and that we know exactly what is meant by them. But Einstein has nowhere defined or disclosed what a *physical system* is and what exactly he means when he speaks of *laws*. All he talks about are abstract propositions concerning the motion of kinematical points. How these propositions are linked with physics is not revealed.

Another insufficiently clear expression is *uniform translatory motion.* In translatory motion every point of a moving system is "translated" from one place in rigid space to another in the same direction and at the same speed. Translation excludes rotation and curved motion, but there is room for doubt whether it excludes rectilinear uniformly accelerated motion. However, it is usually assumed that Einstein has accelerationfree motion in mind as the numerous references in the *kinematical part* to velocity, constant velocity, uniform motion, etc. appear to imply. But although there is no specific mention of acceleration in the *kinematical part*, the introduction and the *electrodynamical part* of the 1905 paper certainly deal with phenomena which are not accelerationfree.

In his "fundamental" 1905 paper Einstein does not make the slightest effort to clear up the ambiguity, or contradiction, concerning acceleration-free and accelerated motion, but in his 1907 paper *On the Principle of Relativity and the Conclusions Drawn from it* we find the following somewhat strange formulation of the relativity postulate: *The laws of nature are independent of the state of motion of the reference system, at least if the latter is accelerationfree.* What is the logical function of the words *at least*? Was Einstein still preferring to remain ambivalent, but slightly less than in 1905?

After Einstein produced his general theory of relativity in 1916 he published an 80-page popular exposition of both theories in 1917 under the title *On the Special and the General Theory of Relativity.* This work is still being reprinted to-day. It was translated into English in 1920 and published by Methuen under the title *Relativity: the Special and the General Theory.* In this work the relativity postulate of the special theory assumes the following form: *If, relative to K, K' is a uniformly moving co-ordinate system devoid of rotation, then natural phenomena run their course with respect to K' according to exactly the same general laws as with respect to K.* This definition still leaves the door open for rectilinear accelerated motion such as free fall towards a more massive gravitational system. The inevitable practical result of such motion is the termination of the independent existence of the less massive system.

The final form of the *principle of special relativity* is presented in Einstein's Princeton lectures of 1921 which were published in the following year under the title *The Meaning of Relativity.* Acceleration is clearly eliminated in this form. Einstein now says that *if K is an inertial system, then every other system K' which moves uniformly and without rotation relatively to K, is also an inertial system; the laws of nature are in concordance for all inertial systems.* The decisive word *inertial* has finally made its appearance. Only after the "success" of his general theory in 1919, following the blessing by the Royal Society, Einstein found it necessary to remove the ambiguity. But by removing it and speaking openly of *inertial systems* Einstein also admitted that his special theory had been dealing all along with fictional entities which have no place in physics and that the two crucial instances quoted at the beginning of the 1905 paper, electrodynamics and geodynamics, cannot be used as premises for his relativity postulate.

We have now established that the special theory deals only with inertial systems, that is, systems whose motion is free from acceleration or, which is the same, free from the influence of any outside force. No inertiality at all is involved in electrodynamics. This has been a false trail from the beginning, confusing the real issues. The motion of the Earth presents a somewhat different situation. At least it can be claimed that this motion may be treated as quasi-inertial, or that the Newtonian explanation theoretically contains an inertial component. The motion of the Earth, therefore, can be, and has been, used as the starting point for the discussion of relative motion. The specific instance which posed a problem requiring a solution was the Michelson-Morley experiment and Einstein's argument leading to the relativity postulate of 1921 originates from the result of the experiment and a particular interpretation of it. It is very illuminating to examine the individual steps of Einstein's chain of reasoning and to assess to what extent they are justified.

The argument proceeds from the empirical observation that the orbital, quasi-inertial, motion of the Earth in relation to an assumed light-carrying aether cannot be detected by a physical experiment using light rays, which are assumed to be intrinsically associated with the aether, and an interferometer. If both Earth and light rays are considered to be subject to the laws of mechanics their velocities should add or subtract. The observation indicated that the velocities do not add or subtract. Contrary to expectations the velocity of light refused to interact with the velocity of the Earth. For some unexplained reason it appeared to be endowed with the special property of non-additivity (and non-subtractivity, but the latter will be disregarded in our discussion).

If the observation is considered as quantitatively sufficient to accept that the result and the problem posed by it are of fundamental significance, then the conclusion can be drawn that the velocity of light cannot be used in any experimental arrangement within the Earth to measure the velocity of the Earth with respect to a reference frame intrinsically associated with light, such as the luminiferous aether. Since the aether is filling space uniformly and is at complete rest in relation to space, one is also justified in saying that the velocity of light cannot be used to measure the velocity of the Earth in space.

The Einsteinian argument commences at this point. It goes beyond the limits of the above conclusion and declares not only that it is impossible to measure the velocity of the Earth with the use of the velocity of light, but that it is impossible to measure it with any other method. This is not a well-founded and valid generalisation. A few experiments using other methods have been conducted, but it is not clear what they prove or whether they prove anything at all. Under these circumstances the evidence cannot be interpreted as indicating that all other methods will not succeed.

Einstein's generalisation is also peculiar because it shows his readiness to choose a path which is not very conspicuous and at the same time to disregard obvious problems requiring attention. One of these problems is why the velocity of light should be considered as equivalent to a mechanical velocity in the first instance. After all, light is different from mechanical bodies and there is no compelling reason why it should interact with mechanical bodies velocity-wise. And if this is the case, then a property specific to light should not be used as a basis for a sweeping generalisation denying that any physical interaction can be used to determine the motion of the Earth. It is also open to doubt whether the measuring of mechanical motion of a system from within a system without a clear idea of a second and stationary mechanical system is a mechanical problem. It may not even be primarily a physical problem, but a philosophical one. Before the concept of motion is discussed there must be more than one body or system present. And, in fact, in the case of the motion of the Earth in space reference bodies are present in the form of other astronomical objects in the sky. But this is not what Einstein needs for his theory. His approach is not straightforward and objective in terms of empirical evidence, but artificial, subjective and highly theoretical. It is an approach leading to the metaphysical prescription that phenomena are dependent on their location and require an observer, and that physics cannot be practised in a detached and de-individualised manner.

The next step in Einstein's chain of reasoning is that the impossibility to detect motion of a system through space by any physical experiment within the system applies not only to the Earth, but to any other quasi-terrestrial system. A quasi-terrestrial system is a system which is known or assumed to be in motion and within which experiments can be made, but these experiments cannot, in principle, determine or detect the motion. The applicability of the argument is practically restricted to cosmic bodies similar to the Earth and, in contemporary conditions, perhaps to some man-made space vehicles. The question arises whether in view of this restriction it is really worthwhile to pursue the argument further. But such considerations do not stop Einstein from proceeding along his chosen path.

In order to explain and to justify Einstein's argument, and to create the impression of its wide applicability, it is fashionable to quote all types of moving things on Earth, such as trains and ships, and then to assure the reader with complete authority that it is impossible by experiments conducted inside the train or ship to discover whether it is moving. This method of explanation must be characterised as a confidence trick because the analogy in all these instances is false. The Michelson-Morley experiment is not conducted inside the Earth, but at the interface with the medium. If it were conducted inside the Earth, the objection would be immediately raised that the aether may be carried with the Earth. In the case of trains and ships numerous methods can be employed to establish their motion in relation to air, water or solid ground with absolute certainty. The knowledge is there, but it is deliberately excluded for the sake of creating an apparently similar, but in fact dissimilar, situation. The whole point in the Earth-aether situation is that the knowledge is not there and that there is no way of obtaining it, at least in the Einsteinian argument.

When the class of quasi-terrestrial systems has been created, within which measurements cannot disclose motion, the problem of inertial and non-inertial motion cannot be ignored any longer. By starting his argument from the motion of the Earth Einstein has been quietly assuming something that needs to be looked at very closely. In precise terms his concept of motion does not refer to all types of motion and particularly not to the orbital motion of the Earth around the Sun, but to a specific idealised and schematic type of motion which is uniform, rectilinear and accelerationfree. It is this motion, when superimposed on the orbital motion of the Earth, which cannot be detected. Circular motion can be detected by experiments within a system. The rotation of the Earth, for instance, can be demonstrated by Foucault's pendulum. It is, therefore, necessary to restrict the argument to systems which are free from the action of forces associated with motion and capable of being used to detect it. Such systems are inertial systems. This course of action is inevitable, but the result is that the argument has now become entirely theoretical. It no longer deals with the

Earth or any other physically recognisable bodies, but with abstract and hypothetical entities called inertial systems.

Inertiality implies that a system is either at rest or in accelerationfree motion, but since an observer within an inertial system cannot determine whether his system is in motion, he can also not determine whether his system is at rest. Rest and motion become indistinguishable for him. The emphasis in Einstein's argument is now shifting to the field of vision of a hypothetical observer in a hypothetical system. His observations are made the criterion of what is existing and real. Whatever he cannot observe is non-existent. Rest or motion are indeterminable and indistinguishable. They are, therefore, declared to be ontologically non-existent. The step from inability to distinguish to ontological non-existence is not a valid deduction. All that can be said is that it is possible that rest or motion do not exist, but it cannot be said that it is certain that they do not exist. Einstein is engaging in pure metaphysical speculation in order to abolish finally and completely any absolute reference frames. There is no aether, and space is devoid of any properties permitting the definition of unique reference points for co-ordinate systems.

Motion in an absolute sense has now been abolished, but Einstein retains the concept of relative motion from the point of view of an observer in an inertial system. However, relative motion becomes an Einsteinian ontological category only if there are two inertial systems and at least one observer who can make statements about the distance between his system and the other system. The observer is not in the position to say that his system or the other system is in motion, he can only say that a state of relative motion exists between his and the other system. We are now able to enumerate the basic ingredients of the Einsteinian ensemble: two inertial systems with observers and between them a vacuum which, as we shall see later, is bridged by light rays.

Einstein's attention is next focused on what the observers in the two inertial systems A and B will be able to observe in their own and in each other's systems providing that communication by light rays is established. First of all, the observers will make the same measurements with regard to relative motion. If A is able to say to B that the distance between their systems is neither increasing nor decreasing, B will be able to say the same to A. But not only statements with regard to relative motion will coincide, but also statements with regard to what Einstein calls *laws of nature*. It must be understood that when Einstein speaks of *laws of nature*, he really restricts the ability of each observer to make statements about them to the domains of their own inertial systems. What is happening in the vacuum is covered by the second basic postulate, dealing with the constancy of the velocity of light. Statements about laws of nature in B as seen by A, and in A as seen by B, are possible, but will not necessarily coincide with those made by A in A and by B in B. For instance, the laws of rigidity of solid matter will apply for A in relation to solid matter in his own system, but they will not apply in the same way to solid matter observed by A in B which is in relative motion with respect to A. And the same applies to observations made by B in A. Practically all laws of nature in the other system, when observed from the first system, will be modified by changes in length and time standards, and it is appropriate to ask whether the term "laws of nature" should be used in this situation. But Einstein prefers to use it.

However, one phenomenon is exempt from the changes and therefore remains a constant and universal law of nature—the velocity of light. Einstein declares that if A measures the velocity in A, he will obtain the same result as measured by him in B. The velocity of light is the same irrespective of whether it is observed in one's own system or in the other system, and in Einstein's theory this is so not because we are dealing with a law of nature but because he issued a decree that it should be so.

We have now reached the final step in the chain of reasoning which is represented by the key sentence in Einstein's 1921 version of the relativity postulate: *The laws of nature are in concordance for all inertial systems.* What Einstein really means, and is not expressing clearly enough, is that hypothetical measurements are in agreement if they are made by observer A in system A and compared with those made by observer B in system B in respect of an identical situation. Quite separate from this first agreed version there is a second agreed version. The second version refers to measurements made by observer A in system B and, in respect of an identical situation, by observer B in system A. The catch is that the first agreed version and the second agreed version do not coincide if there is a state of relative motion between A and B.

It is occasionally asserted by some relativists that Einstein's relativity postulate says nothing more than that *the laws of physics may be expressed in equations having the same form in all frames of reference moving at a constant velocity with respect to one another* (Beiser). In other words, the relativity postulate supposedly refers only to the external or mathematical expression of physical laws and does not affect their substance. Nothing is further from the truth. If the whole point of the special theory would be limited to the formal statement of equations and their conversion, the theory would not have any impact on physics or philosophy and would, in fact, not be worth worrying about. The crux of the whole matter is that it claims to deal with changes in the mathematical form of physical statements and that these changes actually represent new physical conditions. Length contraction and time dilation are not changes in the configuration of equations, they are declared to be changes in physical reality.

Einstein's correctly formulated relativity postulate should read: Physical measurements are the same for two inertial observers when their systems are relatively at rest; if a state of relative motion exists between two inertial systems, physical measurements made by an observer in respect of a particular situation within his own system will differ from measurements made by the same observer in respect of the same situation in the other system. Einstein's formulation does not disclose the fact that the essential point of his relativity postulate is the arbitrary restriction of the uniform applicability of physical laws and the measurements on which they are based.

To sum up, nine logically separate steps can be distinguished in Einstein's reasoning leading to the formulation of the relativity postulate: (1) Motion of Earth cannot be detected from within using any method; (2) Motion of quasi-terrestrial systems cannot be detected from within using any method; (3) Quasi-terrestrial systems are inertial systems; (4) Motion and rest of one's own system are indistinguishable; (5) Motion and rest of one's own system are non-existent; (6) Only relative motion or rest in respect of another inertial system exist; (7) Observers in two inertial systems will make the same observations in respect of the state of motion or rest between their systems; (8) Observers in two inertial systems will make the same observation with regard to laws of nature; (9) The laws of nature are in concordance for all inertial systems.

Briefly, the main objections are as follows. Step 1 is a non sequitur from the valid conclusion of the Michelson-Morley experiment that the motion of the Earth cannot be detected using the velocity of light. Step 2 introduces the physically obscure concept of quasi-terrestrial systems; the links with physics become tenuous. Step 3 applies an arbitrary restriction; the argument is limited to hypothetical inertial systems; links with physics are broken. Step 5 is a non sequitur. Step 6 confers an absolute status on relative motion without proper justification. Step 7 introduces observer-dependent phenomena, a subjective approach alien to physics. Step 8 introduces laws of nature, a concept of doubtful significance, and uses "sameness" in an ambiguous manner. Step 9 is a logically inappropriate and semantically misleading end product.