THE PREFERRED SYSTEM OF REFERENCE RELOADED

Israel Pérez
Department of Physics and Engineering Physics, University of Saskatchewan, Saskatoon, SK, Canada

(Dated: FQXi, Questioning the Foundations: Which of our basic assumptions are wrong?, July 2012)

I. EPISTEMOLOGICAL BACKGROUND

A. Principle, postulate and axiom

Let us first gather some fundamental definitions that will be helpful for our forthcoming discussion, namely: postulate, principle and axiom. A postulate is a statement that assumes or suggests an evident truth and which is used as the basis of reasoning in a given theory. Likewise, a principle is a fundamental truth or proposition that serves as the foundation for a system of belief or behavior or for a chain of reasoning. An axiom is a premise or starting point of reasoning. As classically conceived, an axiom is a premise so evident as to be accepted as true without controversy. Thus, according to the respective definitions one can assure that in essence the three concepts can be understood as synonymous.

B. Assumptions: True, false or useful?

According to the Karl Popper (1; 2) principles are statements or premises that are used as bases in the construction of a theory. Although the truthfulness or falsehood of a statement can be debatable the theorist can *assume for practical purposes*, that the statement has the potential to be really true. To illustrate this consider the following assumption: *The universe is infinite*. Is this statement true or false? Needless to say, the reply is a shrug. Nevertheless, the theorist can argue that during the construction of his theory whether the statement is false or true turns out to be irrelevant provided that the predictions derived from such a assumption reproduce the experimental evidence at hand. In other words, the assumption will gain its "truthfulness" not from the preliminary judgement of the statement but from the experimental verification of the theory. If the predictions derived from this statement are experimentally corroborated the theorist can vigorously claim that the assumption is true. Theories can also rest on the basis of "false" assumptions as long as these assumptions are helpful to strengthen the theory. One typical case is the assumption of the possibility of reversible processes in thermodynamics. After all, we all are aware that no process is really reversible. Despite its falsehood the assumption has been highly beneficial for this branch of physics. Other false assumptions are those of point particles and perfect mirrors, belonging to classical mechanics and electrodynamics, respectively. Therefore, at the end, for the theorist what is crucial is not the truthfulness or falsehood of the assumptions but their *usefulness* in solving particular problems.

C. What is a physical theory?

A theory is a logical construct composed of axioms, concepts and definitions aim at explaining a body of experimental observations. It is an artificial structure that tries to reproduce the experimental structures, i.e., the real counterpart, the facts. Particularly, physical theories are based on mathematical structures and "physical" concepts (3; 4). Since physical theories used mathematical structures their form should be axiomatic. By applying the deductive method theorems and physical predictions can be derived from the axioms. These predictions are usually tested in the light of experiments. Then, when the predictions are experimentally corroborated one says that the theory has shown its mettle. On the contrary, if the theory does not reproduce the experimental evidence at hand, it is discarded.

Proposed physical objects might emerge from a metaphysical source. By analogy with the case of physical assumptions, during the construction of the theory, whether the objects really exist or not turns out to be irrelevant. The concepts and the objects proposed will acquire their physical reality once the theory is faced with experimental evidence. This could be the case of strings, loops, taquions, Higgs bosons, etc. In some other cases, the experimental evidence suggests the shape of the theory as well as the properties of the physical objects. For instance, the conception of electrons was figured out from observations on electrolysis which suggested a minimum quantity of charge. Later electrons were conceived as an intrinsic part of the atom. In summary, the notion of a physical object depends on the structure of the observations and the explanatory system.

D. Science and its aim

Science is a human activity like any other in which its members are committed to solve particular problems of real life. For this purpose scientists help themselves with both the invention of theories and collecting information following systematic and rigorous methods. Many scientists hold that science is aimed at unraveling the truth behind the appearances. We have discussed above however that theories can be constructed on the basis of assumptions and concepts that can be either true or false as well as having some metaphysical content. If one acknowledges this, it is legitimate to judge that the final aim of a scientist may not be the finding of the "truth" but merely the finding of a theory that reproduces and explains the body of experimental evidence. The knowledge gained during this process is then used for the convenience of mankind.

II. ASSUMPTIONS AND PRINCIPLES IN THE HISTORY OF PHYSICS

A. Hidden assumptions

Since ancient times physicists have built theories based on assumptions which were considered to be absolute truths but as time went by such assumptions were proven to be actually false. One particular case is the famous assumption that states that heavier objects fall faster than lighter ones. This assumption was held for hundreds of years since the times of Aristotle. Only in the XVI century Galileo proved that such assumption was fundamentally false. In some other cases theories presupposed some hidden assumptions. For instance, classical mechanics is based on 3 laws and some definitions. In addition to these components, the theory tacitly presupposes some unnoticed or disregarded assumptions such as: (a) measurements do not affect the physical system under study; (b) the speed of propagation of physical entities can have any desire velocity, even infinite. Assumption (a) fails in the microscopic realm. This issue was solved by quantum mechanics with the introduction of a powerful assumption: the uncertainty principle. The principle states, among other things, the probabilistic character of a measurement due to the fact that the measuring instrument considerably influences the response of the system under study. Assumption (b) finds its restriction within the context of relativity theory (RT) in which a maximum speed for the propagation of physical entities is assumed.

B. Some physical assumptions

Now let us list some of the most typical assumptions that physics has considered since ancient times in its different branches. It is not the purpose of this section to discuss either the truthfulness or falsehood of each assumption; for it is evident that some can be true, false or uncertain. As we have discussed above, what is of real value for physics is their usefulness in solving the problems that physics has at a given moment of its history. These are:

- Time flows equally for all observers
- The earth/sun is the center of the universe
- Absolute space, atoms, rigid bodies and æther exist
- No speed limit for the propagation of physical entities
- The response of a macroscopic systems to a measuring instrument is negligible
- All physical quantities are continuous
- Light is a wave/particle
- Within the context of classical electrodynamics if perfect mirrors are assumed, then reflected waves have the same wavelength and intensity as incident waves
- Energy, charge, torque, linear and angular moments, etc. are conserved
- The laws of physics were created along with the creation of the universe
- Space, time and motion are continuous
- All particles of a particular kind are identical (i.e. electrons)
- Maximum speed for the propagation of physical entities

- Principle of: relativity, uncertainty, equivalence, causality, exclusion, anthropic, etc. hold
- There is a preferred system of reference

Some of the above assumptions are still in use, some have been definitely discarded and some have been reconsidered several times in several epochs. Moreover, some have caused a great impact more than others not only to the structure of a given theory but also to the whole evolution of physics. Due to their preeminent influence, this kind of assumptions deserve both a special attention and a scrupulous assessment; for their arbitrary rejection could be detrimental for the progress of physics. In what follows, our attention will be focused in the last assumption. It shall be argued that this is one of the assumptions that physics should reconsider if physics wishes to make considerable progress for years to come.

III. THE PRINCIPLE OF RELATIVITY IS NOT AT VARIANCE WITH THE PREFERRED SYSTEM OF REFERENCE

A. Newton's absolute space

Newton contended (5) that the water, inside the famous bucket, was rotating relative not to the bucket but to the absolute space (AS). This experiment gave him confidence that any body in motion, really moves not only relative to a reference object but also relative to a preferred system of reference (PSR). Newton envisaged AS as an empty[1] geometrical vessel, as a background in which material bodies live and move. The mathematical representation of this space was found in Euclidean geometry. Although he was uncertain of the physical nature of space he was convinced that space was an ethereal and pervading substance (or fluid) in the sense of Descartes. In contrast to the Descartes' dynamical fluid, Newton conceived that this substance, besides being homogeneous and isotropic, had one main property: it was immovable, unaffected by material bodies. This assumption was precisely what the philosopher Ernst Mach abhorred the most (6). He questioned the scientific utility of a substance that exists but is not affected by material bodies. Mach replied to the bucket experiment by arguing that the water moved relative not to AS but to the stellar matter surrounding the bucket. For Mach only relative motion was possible. From 1905 to 1916, Einstein "materialized" Mach's thought (7–10). In the Einsteinian version, space is only made up of gravitational fields (GF) conveying momentum and energy. So, from the perspective of this paradigm, the water moves relative to the GF. Since then, the assumption that space is made up of an æthereal fluid has been ruled out from physics. Yet, physics has never ignored the power of intuition. In 1933 the swiss astronomer, Fritz Zwicky, discovered some missing mass –now known as dark matter– in his studies of the Coma galaxy cluster. This evidence clearly suggests that space is not made up of only fields but of an imponderable material substance. Unfortunately, his discovery was ignored for about forty years.

B. Invariance of Newton's laws

Let us not digress from Newton's work and keep in mind henceforth the previous discussion. It is well established that Newton's laws are invariant with respect to Galilean transformations (GT). This is in virtue of the Galilean Principle of Relativity (GPR). It states that all mechanical laws are the same in any inertial system of reference (ISR). Now we ask: What is the experimental meaning of this? It simply means that no mechanical experiment can tell whether an ISR is at rest or in motion relative to the PSR, i.e., AS. The understanding of these statements is crucial to make clear that *the GPR is not at variance with the existence of the PSR*. This being said, let us consider the following two key questions: *i) Does the fact that the PSR cannot be experimentally detected mean that the PSR does not exist?* If the PSR cannot be detected, *ii) does the assumption become a superfluous assumption?*[2] In regard to the first question the answer is clearly no, for if one accepts the existence of a non PSR one cannot deny existence of the PSR since the GPR guarantees the equality of the mechanical laws in all ISRs. Because of this, it is unquestionable that the PSR assumption resulted highly beneficial for the progress of physics for more than 200 years.

---

[1] By empty here it is simply understood "deprived of material macroscopic bodies".
[2] Recall Mach's argument in relation to scientific utility.

C. Invariance of the laws of physics

The extension of the PSR assumption to electromagnetic phenomena was also very fruitful. It achieved its highest peak with the development of electrodynamics. By the mid 1860's Maxwell predicted that light was some kind of electromagnetic wave that travels through a medium pervading the universe, the so-called æther. In 1887-8, Hertz could generate Maxwell's electromagnetic waves, leaving no doubt that Maxwell was in the right path. Nonetheless, the mere corroboration of electromagnetic radiation did not suffice to establish the existence of the medium. Maxwell was aware that his theory worked with or without the æther assumption; yet, for him, the æther bestowed a more physical sense to his theory. After all, all known waves hitherto required a medium to propagate and light waves could not be the exception. Then, physicists engaged in an epic hunt for the æther. In 1887, Michelson and Morley conducted his famous interferometric experiment, which according to the beliefs of that time would tell them whether the PSR existed or not. As it is well known, the results were negative. And by analogy with the experimental implications of the GPR, later, from 1900 to 1905, Lorentz (11; 12) and Poincaré (13) realized that no electromagnetic experiment can tell whether an ISR is at rest or in motion relative to the PSR. Such discovery was called simply the principle of relativity (PR). Thus, despite its undetectability Lorentz and Poincaré answered the above key questions in the negative whilst Einstein held the opposite opinion; he was then appealing to the law of parsimony (7). To comply with the new discovered PR, physicists were forced to abandon Newtonian dynamics and thus built a new dynamics which is now called relativistic dynamics. Both Maxwell's laws and the new kinematical and dynamical laws are said to be Lorentz invariant. The new symmetry guarantees that not only the form of the laws of physics (LP) but also the values of their constants remain the same in all ISRs. This leads us again to ask: *Is then the PR at variance with the existence of the PSR?* Certainly, the answer goes in the negative (15) for no experiment forces us to abandon the PSR (12; 13; 16). The history of physics tells us however that modern theories have discarded it following Einstein's canon (7; 14). But if one upholds the opinion that the PSR is not an issue of parsimony but of usefulness, one can claim that the assumption that there is no PSR is wrong. Let us make some other considerations to support this.

IV. SOME WEIGHTY CONSIDERATIONS TO SUPPORT THE PSR

A. Basic considerations

Immediately after the invention of the special RT a hot debate not only on the existence of the PRS but also on the constancy of the speed of light set in both on theoretical and experimental grounds. Even today many researchers in the fields of physics and the philosophy of physics have kept alive these topics from an epistemological perspective. Thanks to their perseverance, the good news is that considerable progress has been achieved in the last decades. Although not widely known, specially among the physics community, now it has been established within the circles of the philosophy of physics some crucial things. In the first place, experimental arguments against the PSR have been misleading since the discovery of RT. Interferometric and non-interferometric experiments realized during the XIX and XX centuries have been considered as proofs that the PSR does not exist. For instance, some physicists used to claim that if the PSR existed the Michelson-Morley experiment would have shown any evidence. As we discussed above, no electromagnetic experiment can tell about the existence of the PSR. This is quite clear from the PR. If this is clear, we are faced again with the two key questions above and, therefore, the issue may become only a matter of usefulness. Einstein rejected the æther hypothesis, first, because, from the theoretical viewpoint, RT could not make special distinctions among ISRs; actually, for him the æther assumption was not wrong but appeared to be superfluous; and second, because, from the experimental viewpoint, there was no clear evidence of its existence. Nevertheless, according to the discussion of the previous section, the first argument is weak, for if one follows such line of thought then Newton's AS would have been rejected as well from classical mechanics since the GPR guarantees that all ISRs are equivalent. In Einstein's epoch the second argument had a great weight but the experimental evidence accumulated after the 1930s appears to contradict Einstein's doctrine. The experimental evidence we are referring to is this. Consider the following hypothetical situation. Suppose that before the discovery of RT, particle accelerators had been already developed. And assume that the ALICE, ATLAS and CMS collaborations at the large hadron collider had released the news, well know today, that the quantum vacuum is actually a perfect fluid ["LHC experiments brought new insight into the primordial universe" (21; 22)]. If this fluid were assumed to be at rest and not significantly affected by the presence of material particles it would immediately be identified as the æther or AS; just in the same way as nowadays many physicists sympathize with the recently discovered boson at the LHC and identify it as the hypothetical Higgs boson. So, if by the end of the XIX century, say 1899, physicists had already discovered the presence of dark matter, the background radiation and the presence of a perfect fluid, would physicists, despite the success of RT, have strong reasons to discard the æther assumption and thus the PSR? Certainly, the answer would be no. The concept would be maintained because the experimental evidence evidently would have suggested that there were something material with temperature pervading the universe.

In second place, recent investigations on experimental methods utilized for the determination of the speed of any physical entity have shown that when the paths of physical entities form a closed circuit in the experiment, what the experiment measures is, in fact, an average speed of the physical entity (i.e., a harmonic mean of the speed or the so-called two-way speed). This means that it is not feasible to determine the one-way speed of light (17) and therefore the second postulate of special RT cannot be and has never been experimentally tested; in short, the second postulate is experimentally undetermined (15; 17–20). These investigations have shown that, from the experimental perspective, what is universal for all ISRs is not the one-way but the two-way speed of light. Thirdly, for this same reason, any experiment carried out to measure the speed of light will yield the same value c regardless of the state of motion of the observer relative to any ISR and regardless of the intensity of the GF in which the measurement were carried out (17). And fourthly, it is also well understood that the paradoxes in special RT such as the clock paradox, the Supplee paradox, etc. arise due to the lack of the PRS. For if one assumes that the PRS exists all paradoxes as well as the intuitive perplexities inherent to the theory automatically vanish.

B. From a different paradigm the speed of light is not really constant and the water moves relative to AS

It is worth elucidating the fact that the special RT has only one postulate, i.e., the PR, since the second one is already implicit in the first one. In a simplistic form the explanation is this. The PR demands the invariance of LP as consequence Maxwell's laws must be invariant and therefore the speed of light must possess the same value in any ISR. This is correct insofar as one deals with ISRs, but invariance no longer holds for non-inertial systems (NIS) [or appealing to the equivalence principle for systems of reference in GFs]. This means that the value of their constants and physical quantities may acquire different values in different NIS. The general PR demands only that the LP must be covariant, i.e., that the form of the LP must remain the same.

As early as 1911 Einstein (8) was aware of this. He knew, for instance, that the only cause that could change the path of light is by varying the speed of the different parts of a wave front (assuming spherical waves). During the development of the general relativity he emphasized that the assumption of the constancy of the speed of light must be abandoned for NIS (8–10). However, once again, for practical purposes, the general RT allows to keep c constant at the cost of warping the mathematical space-time. Since then most physicists have assumed that the speed of light is constant at any point of a GFs. In contrast, the opposite interpretation would be also correct. One can keep space immovable a là Newton and assume it as a non-homogenous material fluid with different refraction indices that vary as function of the distance between the observer and the source of GF. The gradient of the refraction indices is caused by the GF and will automatically make the speed of light to have different values as function of its position within the GF. So, within this context, the warping of space can be physically reinterpreted as the change in the density of the material medium (23). This physical reinterpretation leads us again to the bucket problem. And just as Newton held, here it is claimed that the water moves relative to the material AS.

V. PARADIGM SHIFT

Thomas Kuhn taught us that a paradigm shift might be a thorny episode in the evolution of science (24). The PSR assumption constitutes a paradigm shift that would demand a drastic change in the way of conceiving the present universe. Well established facts such as the expansion of the universe would need to be reinterpreted in the light of this new paradigm. A theory based on this assumption can provide new insights with respect to the dark matter, dark energy problems as well as the acceleration of the universe. Some other problems such as the cutoff limit of the ultra energetic cosmic rays, the horizon problem, the fly-by and pioneers anomalies can also be addressed.

References

[1] Karl Popper, *The Logic of Scientific Discovery*, First English Edition London: Routledge Classics (2009)
[2] Karl Popper, *Conjectures and Refutations, The growth of Scientific Knowledge*, 3rd ed., London: Routledge Classics (2008)
[3] Max Tegmark, Annal. Phys. **270** 1-51 (1998)
[4] Max Tegmark, Found. Phys. **38** 101 (2008)
[5] Sir Isaac Newton, *Newton's Principia, The mathematical Principles of the Natural Philosophy*, First American Edition New York: Daniel Adee (1846)
[6] Ernst Mach, *Die Mechanik in ihrer Entwickelung*, Ninth Edition (1933), The Science of Mechanics, 5th English Edition, Chicago, The Open Court Publishing Company (1942) pp. 271-305
[7] A. Einstein, Zur Elektrodynamik bewegter Körper *Ann. Phys.* **17** 891 (1905)
[8] A. Einstein, Über den Einflutss der Schwerkraft auf die Ausbreitung des Lichtes. Annalen der Physik, 35, 898-908 (1911)
[9] A. Einstein, Die Grundlage der allgemeinen Relativitätstheorie (The foundation of the general theory of relativity), Ann. Phys. **49** 769-822 (1916)
[10] A. Einstein, *Hamilton's principle and the general theory of relativity, Sitzungsberichte der Preuss. Akad. D. Wiss.* (1916)
[11] H. A. Lorentz, *Simplified Theory of Electrical and Optical Phenomena in Moving Systems, Zittingsverslag Akad. v. Wet.,* **7**, p. 507; Amsterdam (1899), Proc., 1898-1899, p. 427-442
[12] H. A. Lorentz, *Electromagnetic Phenomena in a System moving with any Velocity Less Than That of Light*, English version, Proceedings, Amsterdam **6** pag. 809-831 (1904)
[13] Henri Poincaré, *Sur la dynamique de l'électron. C.R. Acad. Sci., Paris* ,**140** *1504, (1905) Rendiconti del Circolo Matematico di Palermo, English Trans. On the Dynamics of the Electron (Excerpts),* **21** *129-175* (1906)
[14] A. Einstein, *Aether and the Theory of Relativity, Lectured deliverd at Leyden* Berlin (1920)
[15] Vasco Guerra and Rodrigo Abreu, Found. Phys. B **36** 1826-1845 (2006)
[16] J. S. Bell, *Speakable and Unspeakable in Quantum Mechanics*, 2nd ed. Cambridge University Press: Cambridge (2004)
[17] I. Pérez. European Journal of Physics, 32, 993-1005 (2011)
[18] R. Abreu and Vasco Guerra, Eur. J. Phys., **29** 33-52 (2008)
[19] I. Pérez, <arXiv:gen-ph/1004.0716>
[20] C. Iyer and G. M. Prabhu, Am. J. Phys. **78** 195-203 (2010)
[21] CERN Press Office. In: 2010 CERN Press Release. http://public.web.cern.ch/press/pressreleases/Releases2010/PR23.10E.html Cited 26 Nov 2010
[22] Nagle, James L., Ian G. Bearden, and William A. Zajc. ArXiv: nucl-th: 1102.0680v1 (2011)
[23] Xing-Hao, Ye, and Lin Qiang.*Chinese Physics Letters* 25: 1571-1573 (2008)
[24] T. Kuhn, *The structure of scientific revolutions*, 1st ed. University of Chicago Press (1962)