Arhe II, 4/2005.
UDK 111.5 =20
Originalni naučni rad

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BERGSON, EINSTEIN AND THE CONCEPTUAL 'TRANSFORMATION' OF A METER

Abstract Although the light based definition of a meter was not established until 1983, the current resolution to use light as a standard for measurement has roots in Einstein's theory of general relativity. Even though general relativity has enjoyed widespread support, critics like Henri Bergson challenge essential assertions within this theory. Following Bergson's challenge, this essay will explore faulty assumptions operating in general relativity and then show how these assumptions adversely affect current practices like using light to determine the length of a meter. The critique developed in this paper serves primarily as an example pointing to a larger problem affecting the natural sciences. Scientists do not always understand the restricted nature of their studies. When these scientists overstep the limits of their discipline, theoretical problems emerge. This illustrates one reason philosophers need to interact with the scientific community.

Key words: Bergson, Einstein, Relativity, Physics, Measurement, Michelson-Morley, interferometer, Science

A meter, as defined by the General Conference of Weights and Measures,[1] „*is the length of the path traveled by light in vacuum during a time interval of 1/299,792,458 of a second*."[2] The current measurement of a meter draws support from three tacit but significant presuppositions. First, selecting a measuring standard should rely on the proposed standard's ability to consistently measure the same distance in different situations. Second, because the length of physical objects changes in certain contexts, physical objects should not be used as standards for measure. Finally, light maintains static properties in a unique way that justifies the use of this medium as a reliable standard for measurement. Although the distance traveled by light within a certain time limit is affected by varying types of resistance, light, traveling at a fixed speed, offers itself as the most consistent standard.

While this light based definition of a meter was not established until 1983, the current

1 For brevity, the rest of this paper will refer to the General Conference on Weights and Measures simply as the „General Conference."

2 W. M. Penzes, *Timeline for the Definition of the Meter,* (http://www.mel.nist.gov/div821/museum/timeline.htm: 2001).

resolution to use light as a standard for measurement has roots in Einstein's theory of general relativity.[3] According to general relativity, the material components within systems lengthen or contract relative to their velocity while the speed of light within and between these systems remains steady.[4] Even though general relativity has enjoyed widespread support, critics like Henri Bergson challenge essential assertions within this theory. Following Bergson's challenge, this essay will explore faulty assumptions operating in general relativity and then show how these assumptions adversely affect current practices like using light to determine the length of a meter.

The critique developed in this paper serves primarily as an example pointing to a larger problem affecting the natural sciences. Scientists do not always understand the restricted nature of their studies. When these scientists overstep the limits of their discipline, theoretical problems emerge. In the example used by this paper, Einstein uses the Lorentz equation to account mathematically for perceived changes in moving systems. Although this type of account is well within the scope of physics as a discipline, subtle problems emerge when Einstein adds a conceptual element to his mathematical description. Basically, Einstein's theory enters a philosophical dimension that he is not prepared to address. As a result, he conflates two ways of accounting for the same phenomena, which in turn adversely limits any conceptual discussions about relativity. The above illustrates one reason philosophers need to interact with the scientific community.

Bergson's critique shows how training provided by philosophical studies allows one to see beyond the narrow framework that can often restrict scientific questions. This paper is not an attempt to define the role of philosophy, but it does reveal one area where philosophical training can correct potentially severe problems. It is important to realize these problems extend beyond theoretical studies; they influence practical issues as well. Considering the General Conference, Einstein's theory influences the way we define units of measure for economic and industrial purposes. Here, we are confronted with a situation where theory misinforms practice and neither has the appropriate tools for resolving this problem. With these issues in mind, we are now prepared to consider the example provided by Bergson's critique and its influence on the way we define a meter.

GENERAL RELATIVITY: A RESPONSE TO THE MICHELSON-MORLEY EXPERIMENT

If we understand general relativity as a response to the Michelson-Morley experiment, some simple assumptions become clear. First, general relativity relies on the interpretation of a mathematical formula. Einstein uses the Lorentz equation in order to account for what he calls the contraction of length and the expansion of time in accelerated systems.[5] Second, general relativity is supposed to mark a qualitative shift away from special relativity, but no

3 For brevity, the rest of this paper will refer to Einstein's special and general relativity simply as „special relativity" and „general relativity" accordingly.

4 Pete Gunter, *Bergson and the Evolution of Physics,* (Knoxville, TN: The University of Tennessee Press, 1969), 220.

5 Albert Einstein and Leopold Infeld, *The Evolution of Physics from Early Concepts to Relativity and Quanta,* (New York, NY: Simon and Schuster, 1938), 200.

such shift occurs.[6] Finally, it will become clear that light is treated as a unique and invariant feature in the theory of general relativity. For Einstein, the speed of light serves as a constant that allows us to compare systems moving relative to each other.

In 1887, an experiment performed by Albert Michelson and Edward Morley encouraged Einstein to develop the theories of special and eventually general relativity.[7] By 1887, the Michelson-Morley experiment had been repeated several times attempting to determine the earth's velocity but all attempts, including this final one, failed. The experiment rests on two assumptions: first, there is a static ether substance through which everything in the universe travels; second, the earth travels at a steady velocity through this static substance. Because the earth moves at a constant velocity, light emitted from a single source[8] in perpendicular directions should return to the source at different times even though they travel an equal distance. According to the hypothesis, resistance from the static ether should cause the beam of light traveling perpendicular to the motion of the earth to return before the light traveling with and then against the earth's motion. Based on the time lag between the returning beams of light, one should be able to determine the earth's velocity. However, instead of determining the earth's velocity, the results challenge basic assumptions of the experiment itself.

The light beams consistently traveled the same distance in the same amount of time. These results suggest that either there is no ether or the earth is motionless in this ether space.[9] Either way, the scientific community could not make sense of this experiment until 1905 when Einstein proposed his theory of special relativity. In order to solve the dilemma caused by the Michelson-Morley interferometer, Einstein suggests treating the earth as a static system. This marks the advent of special relativity allowing one system to be understood as moving relative to another. Furthermore, if one were willing to grant that systems moving relative to the earth undergo predictable spatial and temporal transformations, the Lorentz equation could be applied to account for these various changes.[10] According to Einstein, the Lorentz equation translates the cross canceled effects of time lengthening and objects contracting in the direction of a moving system.

Consider a thought experiment with system X moving at a constant velocity relative to system Y. If an interferometer were constructed on system X that could be seen from both systems, the data provided by the interferometer would be different depending on the system occupied when the data is observed. The observer on Y would see the light traveling perpendicular to the path of system X return before the light emitted along the same path as system X. However, the observer on system X would see the light return from both paths at the same time. For the system X observer, the part of the interferometer facing the direction of the system's motion contracts, but time undergoes a proportional slowing allowing light to travel the same distance in the same amount of time as it would in a static system. The observer notices no change. For the Y observer, the part of the interferometer facing the direction of motion still contracts, but time does not slow because the observer only experiences the time of system Y. The observer in system Y operates on a different time flow. Light

6 Milič Čapek, *The Philosophical Impact of Contemporary Physics*, (Princeton, NJ: Van Nostrand, 1961) 182.

7 Einstein, *The Evolution of Physics,* 183.

8 The source of light used in this experiment is provided by an interferometer

9 Henri Bergson, *Duration and Simultaneity: With Reference to Einstein's Theory,* Leon Jacobson trans., (Indianapolis, IN: Bobbs-Merrill, 1965), 13.

10 Bergson, *Duration and Simultaneity,* 5.

travels the same actual distance, but this distance relative to the system now appears different to the different observers.

As previously mentioned, the Lorentz equation provides a way to translate the physical and temporal changes of one system into the steady state of another. Because of the mathematical nature of the Lorentz equation, the translation also works if one wanted to understand the physical and temporal changes of one moving system in terms of another moving system. In general relativity both systems are in motion, but as we will later see, treating both systems as in motion is impossible to conceptualize. In a philosophical sense, Einstein never makes it past a more complicated form of special relativity. Einstein's claim that general relativity is a qualitative shift away from special relativity is, in this sense, mistaken.

The final assumption of relativity that we need to consider is that light acts uniquely as a stable substance. A person in a system in motion would see light interact with the environment in a different way than would the person outside the system. This happens because light remains steady while the system in motion changes. The moving system alters in a way that from the outside is readily perceptible, but from the inside cannot be recognized. Accordingly, only the person outside the system can notice that light interacts with the moving system differently.

As we have seen, Einstein's theory of general relativity requires three conceptual assertions. Length for physical objects is not a static property; time does not flow uniformly between systems; and finally, the speed of light is the most consistent variable between systems moving at different velocities.[11] Later, it will be shown that these assertions have been made prematurely. These assertions require philosophical justifications that Einstein is not ready to provide. Before pointing out the flaws in Einstein's position, we will try to understand how these assumptions carry into the decisions made by the General Conference.

GENERAL CONFERENCE: A TRANSITION FROM RELATIVITY TO MEASUREMENT

Based on the above discussion, it is no surprise the current technical definition of a meter is the length of a path traveled by light in a vacuum in just under 1/300,000,000th of a second. In 1875, the General Conference was formed in order to use:

The latest technical developments to improve the standards system through the choice of the definition, the method to experimentally realize the definition, and the means to transfer the standard to practical measurements.[12]

The initial definition was based on the circumference of the earth. After realizing this measurement is difficult to confirm, the definition changed to rely on a small object with easily definable boundaries: a platinum bar. General relativity, by proposing the instability of material objects, calls for yet another definition of the meter. The propensity to use light as a source for measurement increases as the belief in a static material world decreases.[13] With

11 Einstein, *The Evolution of Physics,* 198.

12 Howard P. Layer, *Length—Evolution from Measurement Standard to a Fundamental Constant*, http://www.mel.nist.gov/div821/museum/length.htm: 2001.

13 It is interesting to note that Michelson's interferometer was used to determine the length of a meter in

this new standard, a reliance on the immutable once again emerges. Using light as the standard provides several advantages. Because „certain atoms and molecules have precisely defined and reproducible emission frequencies (and, thus, wavelengths)"[14] we can move an interferometer anywhere and use it to reproduce the meter.

The General Conference borrows from general relativity on this final point. When considering the importance of a transferable standard, it becomes apparent that issues pertinent to general relativity would carry into their search. Even if one system were moving at high speeds relative to another, an interferometer would provide the same measurement for both systems. While a meter stick in one system may be shorter than in another, a light meter will always be the distance traveled by light in 1/299,792,458th of a second.

So long as the tenets of Einstein's general relativity remain unchallenged, the decision regarding the measurement of a meter remains valid. However, according to Henri Bergson, Einstein's theory of general relativity may have some critical flaws. If these flaws exist, they would prove problematic for the General Conference as well. While Bergson's critique would not necessarily call for a revision of the practices employed by the General Conference, this type of critique may call for some kind of re-justification. Turning to a critique based on the work of Bergson, we will see that Einstein makes a few important assumptions that may not be justified. These assumptions involve the relation between general and special relativity, the veracity of „clock time" and the ability to recognize conscious perceptions of other people.

BERGSONIAN CRITIQUE OF GENERAL RELATIVITY

The Bergsonian critique of general relativity first accuses Einstein of importing problematic elements of special relativity into general relativity. Special relativity assumes the observer's system is at rest and experiences no relativistic effects.[15] Consequently, all changes occur within the moving system. However, Einstein understands there is no way to know if a system is at rest and develops the theory of general relativity allowing an observer in a moving system still to apply the Lorentz equation.

The difference between applying the Lorentz equation in special or general relativity is one of emphasis: in special relativity the observer notices an *absolute change* relative to the initial system; in general relativity the observer notices a *relative change* based on the initial system. Because the Lorentz formula is a conceptually neutral mathematical equation, there are no problems transitioning from one theory to another.[16] Whether the observer's system is at rest or in motion the Lorentz formula yields the same results. However, the conceptual transition from special to general relativity is not as smooth as the Lorentz formula's mathematical transition. The philosophical aspect of relativity causes problems when transitio-

terms of cadmium red. According to the National Institute of Standards and Technology, in 1892 Michelson determined the length of the meter to „have a value of 1,553,164.13 times the wavelength of cadmium red in air, at 760 mm of atmospheric pressure at 15 °C." This faith in light progressed until 1960, when a measurement based on „krypton86 radiation from an electrical discharge lamp" replaced the platinum-iridium bar as the standard of measure for one meter. See: Layer, *Length—Evolution*.

14 Layer, *Length—Evolution*.

15 Gunter, *Evolution of Physics,* 124.

16 Bergson, *Duration and Simultaneity,* 77.

ning from earlier to later formulations. This problem begins with a failure to understand the difference between evaluating a system in motion based on a static reference system and a system in motion based on a moving reference system.

When evaluating a system in motion based on a system at absolute rest, any difference between systems is explained as the moving system's transformation. However, if both systems are in motion, there is no way to determine which, if any, system changes or to what degree. The problem compounds when considering the observer in this equation. In general relativity, because both systems are in motion, the observer applying the Lorentz transformation in the first system would have to allow the Lorentz transformation to be applied in the same way from the second system.[17] More precisely, the Lorentz transformation must be applied from both systems at the same time. Although general relativity purports to allow this simultaneous application, only the illusion of a simultaneous application exists.[18] This illusion leads to one of the most significant insights of general relativity: the various results of clock times in general relativity show there is no universal and stable thing called time.

If time was both universal and measurable, any two calibrated clocks placed at different locations during a single event should display the same reading. Consider the following example: 1) System Y is moving relative to system X; 2) event *q* occurs on system Y; 3) if a clock in system Y were to read 12:30 during event *q*, it seems the clock in system X would also read 12:30. Because the event has already been established as occurring at 12:30, there is no reason to believe it would occur at a different time merely because one changes locations. This is an approximate description of the universal time Einstein challenges in general relativity. According to general relativity, if one system is moving relative to the other, the clock at the moving system Y will register event *q* as occurring at 12:30, but the clock at the stable system X will register event *q* as occurring at a slightly different time.[19] Because the same event observed from two different systems occurs at different times according to the respective clocks, Einstein says time must flow relative to the systems in question.

In the above, Einstein only succeeds in challenging an external representation of a more primordial internal time. When reading the clocks on both systems, Einstein misses the intervals that occur between juxtaposed instants and only grasps the physical readings of clocks in either system.[20] Einstein can account for the events in both systems because he believes a clock placed in one system is a sufficient representation for the lived time of that system. However, Bergson calls Einstein[21] to task on this point. The clock time Einstein references is only an incomplete representation of real or lived time. Because this does not completely represent lived time, Einstein cannot dogmatically assert his measurements describe what occurs in real time.

According to Bergson, consciousness is a necessary component of time.[22] In order to say there is a „before" or „after," past events need to be brought into the present by a conscious observer. Clocks are reference points for instants that occurred in the past and instants

17 Bergson, *Duration and Simultaneity,* 87.

18 Gunter, *Evolution of Physics,* 123.

19 Einstein, *The Evolution of Physics,* 196.

20 Bergson, *Duration and Simultaneity*, 72.

21 And the scientific community in general.

22 Bergson, *Duration and Simultaneity,* 65.

that occur in the present, they do not measure the interval that carries the past into the present. Using the reference points on a clock is a useful way to represent time so long as one acknowledges this is only an incomplete representation of time. The purely internal nature of the interval that occurs between these instants makes it unavailable for measurement; the interval can only be lived. With this in mind, half the Lorentz equation needs to be reinterpreted. Based on different clock readings that occur around the same event, we can only say the externalized representation of time *appears* to lengthen.

In order to say truly that time lengthens in an accelerated system, one would have to live the time of that system as a conscious participant. Of course, Einstein already believes that once this happens, there will be no perceptible change in the nature of time. As he says, the observer inside a „transforming" system does not notice the alleged spatiotemporal changes.[23] We can then say it is impossible to claim that time really lengthens as a system accelerates. We can only say that our chosen representation of time *appears* to lengthen as a system accelerates. Once we reject the validity of lived time as a variable in the Lorentz equation, we must reject the validity of the spatial variable as well. Because the Lorentz equation involves two variables treated in the same way, altering the nature of one variable requires an equal alteration of the other. We cannot say time appears to lengthen while objects actually contract, instead we must say that just as time appears to lengthen, objects also appear to contract in the direction of motion.

While addressing the problems in general relativity, Bergson accounts for our new position in the following way. The observer *perceives* a change in the system in motion. This *apparent* distortion of the nature of space and time can be measured by the Lorentz equation. However, the distortion is only a perspectival shift and not the necessary result of a physical and temporal change.[24] Unfortunately, because one observer can never occupy both systems at the „same time," neither the claim of an actual transformation nor the claim of a perspectival shift can be empirically verified. We are thus trapped in a philosophical rather than scientific problem. The supposed empirically verifiable results of general relativity are impossible to realize. On the other hand, Bergson's position appeals to both the simplest and safest explanation. Because time does not change as a system accelerates, neither do the objects.

Bergson uses this problem as a platform to assert the stability of lived time; there are not multiple times relative to location and motion, but only one lived time.[25] For the purposes of this paper, we need not explore that discussion.[26] It is enough to understand that Einstein's conceptual project fails from the beginning. This is not to discount the Lorentz formula, but rather to discount the interpretation. Henri Lorentz provides a mathematical equation that describes a relation between two systems. The formula does not provide its own interpretation. Einstein applies an interpretation in general relativity that works mathematically, because the mathematical formula neutrally provides consistent results. However, Bergson points out that the interpretation fails on a conceptual level and this creates problems for the General Conference.

23 Einstein, *The Evolution of Physics,* 129.

24 Bergson, *Duration and Simultaneity*, 159.

25 Bergson, *Duration and Simultaneity*, 159.

26 If one were to pursue such a discussion, comparing Henri Bergson's *Time and Free Will*, (New York, Humanities press, 1971), with *Duration and Simultaneity* provides and interesting comparison between the spatial time used by scientists and the lived time described by Bergson.

IMPLICATIONS FOR THE GENERAL CONFERENCE BASED ON BERGSON'S CRITIQUE

If we understand Bergson's critique correctly, interpreting the Lorentz equation no longer needs to imply the contraction of space and lengthening of time. Instead, one need only consider the Lorentz transformation as a formula for explaining the perceptual distortion created by the speed increase from a relative zero based on a reference system.[27] If we take Bergson's critique seriously, it seems that basing a meter on the distance traveled by light in 1/299,792,458th of a second loses some significance.[28]

Challenging the effects of general relativity by implication challenges the tacit assumption involved in the General Conference's choice of light as a measuring standard. If physical objects retain their integrity, light is no longer in a unique position by retaining its nature between various systems. This type of critique does not require one to abandon using an interferometer for measurement, but if taken seriously, this critique does require one to rethink the basis for considering the interferometer the most reliable measuring device.

There is something appealing to using a platinum bar[29] as the standard for a meter. One begins to wonder if we haven't constructed a type of Rube Goldberg machine in appealing to the complexity of an interferometer when a simple platinum bar can perform the same task. It seems the only factors left to consider have to do with the rate of natural decay and the possibility of mishandling such a bar.

Using one device for measurement over another strictly because it is a more complicated way of achieving the same results seems problematic. This would be the challenge addressed to the General Conference. If one accepts the propositions of general relativity, then the General Conference is more than justified in using light as the standard for metric measurement. However, if one rejects the propositions of general relativity, justifying light as the standard of measure becomes more complicated.

CONCLUDING REMARKS

As we have seen, problems in general relativity emerge in various ways. There are internal problems that regard the nature of time, space and math, and external problems that affect the nature of, in this case, measurement. The value of Bergson's critique in this discussion has been one of clarification. He reveals alternative interpretations of the phenomena encountered, and points out problematic areas where this scientific study has unknowin-

27 Bergson, *Duration and Simultaneity*, 109.

28 When general relativity spoke of the contracting nature of material objects and inconsistency of time, light, as the only consistent thing between systems is the only secure standard left for measurement. It is interesting to note that Albert Michelson was a key factor in introducing the interferometer to the measuring community. The same person involved with the advent of general relativity is intimately linked to the General Conference of Weights and Measures. As a group looking for the most reliable standards of measurement, the General Conference naturally tends toward the use of light. There is no reason to use physical objects for measurement when they are in a constant state of change. On the other hand, if light maintains consistent properties between systems, this medium is the natural candidate for measurement.

29 The measuring standard formerly used in the United States was a platinum-iridium bar called *Prototype Meter No. 27*.

gly engaged philosophical questions. If taken seriously, Bergson's critique encourages a revaluation of the philosophical concepts active in general relativity.

The relevance of philosophy in the scientific community is constantly under criticism. In *A Brief History of Time,*[30] Steven Hawking claims philosophers have fallen from their high seat of intellectual dignity.[31] However, because the natural sciences and physics in particular, have conceptually advanced to the degree that we begin merely interpreting mathematical formulas, the philosopher's role in these situations shifts to a more imperceptible position. In Bergson's case, he limits positive claims about relativity and focuses instead on separating the intertwined assumptions that negatively affect Einstein's theory. Even though this aspect of Bergson's thought does not reflect the extent of his philosophical insights, this nonetheless plays an important role for the scientific community. As the insights of physicists are disseminated to other fields of study, faulty assumptions on the part of physicists also enter these fields. In this paper, we have seen one such case.

Eventually, the measurement provided by an interferometer must transfer to a physical device. Once this transfer occurs, the same problems of physical integrity and misuse that threatened the use of a platinum bar re-emerge. Claiming the interferometer is susceptible to less of an environmental risk does not have the same appeal as the relativity based justification. Herein lies the critical role of philosophers like Henri Bergson in such a situation.[32] By clarifying the effects of unnecessary assumptions and challenging hasty conclusions, the philosopher helps to keep the scientific community on a steady track, thus allowing this community to proceed safely along the path of hypothesis and experiment.[33]

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30 Steven Hawking, *Brief History of Time: From the Big Bang to Black Holes*, (New York, NY: Bantam Books, 1988).

31 Hawking, *Brief History*, 83.

32 This is not to under represent the significant contribution of Bergson in other areas, or even in different discussions regarding relativity.

33 Cf. Ludwig Wittgenstein in *Culture and Value,* G.H. von Wright ed., (Chicago, IL: Chicago University Press, 1984), 39. „All we want to do is straighten you up on the track if your coach is crooked on the rails. Driving it afterwards is something we shall leave to you."

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BERGSON, AJNŠTAJN I POJMOVNA „TRANSFORMACIJA" METRA

Apstrakt. Iako definicija metra, zasnovana na svetlosti, nije bila ustanovljena sve do 1983, aktuelna odluka da se svetlost koristi kao standard merenja koreni se u Ajnštajnovoj teoriji opšte relativnosti. Premda opšta relativnost uživa podršku koja je široko rasprostranjena, kritičari kao što je Henri Bergson dovode u pitanje ključne postavke ove teorije. Na tragu Bergsonove kritike, ovaj rad razmatra pogrešne pretpostavke koje se javljaju u okviru opšte relativnosti, te pokazuje kako te pretpostavke nepovoljno utiču na aktuelne primene, kao što je upotreba svetlosti u cilju određenja dužine metra. Kritika data u ovom radu predstavlja pre svega primer koji ukazuje na jedan veći problem prisutan u prirodnim naukama. Naučnici ne razumeju uvek ograničenu prirodu svojih učenja. Kada prekorače granice svoje discipline, nastaju teorijski problemi. Ovo pak ukazuje na potrebu za učešćem filozofa u naučnoj zajednici.

Ključne reči: Bergson, Ajnštajn, relativnost, fizika, merenje, Majkelson-Morli, interferometar, nauka.