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Proper Times, Time Dilation, Lorentz-FitzGerald Contraction and Distance, Time Ageing, Time Dilation-like and the Twin Paradox Conundrum

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Abstract

In this paper it is considered the physical meaning of proper times, time dilation, Lorentz-FitzGerald contraction and distance, time ageing, time dilation-like and the twin paradox conundrum. Connected to the concepts of simultaneity and synchronization, that has also been addressed in other previous papers based on the existence of a Preferred Frame (designated by Einstein Frame, EF) - where the one-way speed of light is isotropic with the two-way value c. Usually in the standard Special Relativity what is considered is Einstein simultaneity and Einstein synchronization that has been introduced by Einstein in the 1905 article "by definition". In the standard interpretation simultaneity and synchronization are not considered since the Einstein speed of light is considered the speed of light. However, in our previous work we have shown that this is a terminological confusion, a paralogism. Now, we show, through a designated time ageing mathematical expression, that the time dilation expression only is the relation of the ageing of the twins when one of the frames is the preferred frame.

Time can be dilated or contracted, and naturally the ageing is the same when the velocities of the twins are symmetrical in relation to the preferred frame. A similar relation is established for the distance mathematical expression that is only the Lorentz-FitzGerald contraction expression when one of the frames is the preferred frame. This analysis is related to the problem of the formulation of distance in the context of acceleration in the twin paradox conundrum. Therefore, it is explained why this is so with a very simple concise formalism using two clocks in every point of a frame, frame that is moving in relation to the Preferred Frame, a synchronized clock, and a Lorentzian clock. The non-equivalence of the frames emerge with physical meaning through the analysis of the Lorentz-FitzGerald contraction and Larmor time dilation mathematical expressions. Therefore, the twin paradox conundrum can be resolved in the context of the formulation of Special Relativity.

Introduction

In previous works [1-17] particularly in "The physical meaning of synchronization and simultaneity in Special Relativity" it is criticized the approach of Einstein based on the postulates of the isotropy of speed light in every frame and the equivalence of every frame [1,18]. Several works, some very recent, point out the importance of this discussion about the foundations of Mathematics, Philosophy, Relativity, Quantum Mechanics, Cosmology and Biophysics [19-102]. The consequent Principle of Relativity has been also considered in the articles "On the Consistency between the Assumption of a Special System of Reference and Special Relativity" and "The Principle of Relativity and the Indeterminacy of Special Relativity" [10,12]. In a more recent work "Speakable and Unspeakable in Special Relativity: time readings and clock rhythms" it is referred the consequences of these analysis particularly the physical meaning of time dilation and Lorentz-FitzGerald contraction mathematical expressions [14]. Also, in the works of Fredrik Andersen, Johan Arnt Myrstad, Maurizio Consoli, Alessandro Pluchino, Espen Gaarder Haug, Zbigniew Oziewicz, Georgy I. Burde, Manuel Ricou, Chandru Iyer and Gurpur Prahbu that are also referred [21-27,33,37,38,41,44-47,102].

In two recent comments about the twin paradox we refer our previous work about the resolution of the twin paradox conundrum [86,98]. Now we address with the same token the fundamental ideas that originate the paradox, with a very concise formalism. The fundamental ideas that differ in relation to the standard approach has been recently formulated, and by others, considering the existence of a preferred frame [37,99]. The formulation of the standard approach based on the Lorentz transformation is established with a change of coordinates of a transformation that we previously designate IST transformation [1,10,12,37]. With this conceptual apparatus based on an intrinsic desynchronization it is easy to clarify the origin of the conundrum. "The twin paradox is the consequence of the following thought experiment. System O is at rest and system O′ is moving. Therefore, the clock in O′ ticks slower than that in O. Thus, for example, if the two clocks

are initially synchronized to read t=t′=0, after a while they may show t=10 (some arbitrary unit of time) but t′=6. Therefore, an observer moving with system O′ will be younger than that in system O. However, as seen by the observer in O′, she is at rest and system O is moving away from her. Therefore, according to the observer in O′, the observer in O should be younger. This is the foundation of the twin paradox, wich is stated as follows: Twin A is on Earth and twin B travels to a distant star with a speed close to the speed of light. Afterward, she returns to Earth with the same speed. When they reunite, according to twin A, twin B must be younger, but according to twin B, twin A must be younger "[97,101]. The reference to the work of Luise Lange perhaps clearly explicit the conundrum [101].

The paper is organized as follows. In section I. Lorentz-FitzGerald contraction and the relation between proper lengths, we discover that the relation between distances is no more given by the standard formulation. The algorithm that emerge reveal that is dependent also of v_1 the velocity in relation to the preferred frame and it is not only dependent of Einstein speed V_E, the relative velocity that standard relativity consider the velocity. In section II. Time ageing, the relation between proper times is obtained. Similarly, to the relation between proper lengths we obtain the relation between proper times that is no more given by the time dilation expression. It is dependent also of v_1 the velocity in relation to the preferred frame. In section III. Time dilation equation-like between frames S′′ and S′, we obtain a time dilation equation-like that standard formulation misinterpret as the relation between ageing. In section IV. The ageing of the twin′s conundrum, we show that the relation of ageing is dependent of the velocities of the twins, 1 and 2, v_1, v_2, in relation to the preferred frame and therefore it was proven that "seeing the other twin ageing slower" is meaningless in this context and corresponds to the symmetric description arising from the comparison of the time readings of Lorentzian clocks, whose roots lie in the indeterminacy of special relativity. It does not correspond to the clock rhythms and to the ageing. The time dilation equation-like continue valid and originates the idea of "seeing the other twin ageing slower" – the origin of the conundrum.

Lorentz-FitzGerald contraction and the relation between proper lengths

Consider in reference frame S′ a section of x′ axis with proper length $l1$ moving with speed v_1 in relation to EF where is located another x axis section of frame S with proper length l (Figure 1).

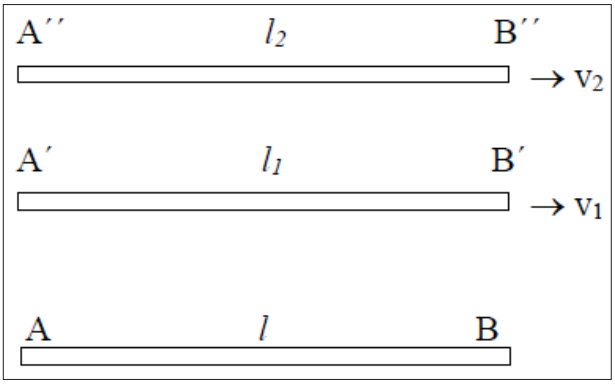


Figure 1: Frame S′ represented by a rod with length l_1 is moving with speed v_1 in relation to frame S, EF, rod with length l. The extremities of the rods coincide simultaneously and therefore, can synchronize clocks at A, A', A'' and B, B', B''. A twin located at A' we designate by twin A'. The same rule for the other positions.

The rod S′ is moving with speed v_1. Since bar S′ is Lorentz contracted (S is at rest in EF) we know l_1 when the extremities of the rods pass by each other simultaneously, when A' coincide with A and B' with B as represented in the figure 1. This is the most primitive notion of simultaneity that Special Relativity does not ruled out [17,49,50,84]. However standard interpretation induce to think that it is impossible to synchronize clocks because it is not possible to send a signal from A' to B' with infinite speed and since the one-way speed of light was not known in frame S′ Einstein postulate that the one-way speed of light is also c in S′. In this context this affirmation must be ruled out [25-27].

Therefore, we have the Lorentz-FitzGerald contraction for l_1 and l, .

$$l_1\sqrt{1-\frac{{v_1}^2}{c^2}}=l_2\sqrt{1-\frac{{v_2}^2}{c^2}}=l \tag{1}$$

Introducing in (1) Einstein velocity [99]

$$V_E^{'}=\frac{v_2-v_1}{1-\frac{v_1v_2}{c^2}} \tag{2}$$

we obtain

$$l_2=\frac{l_1(1+V_E^{'}\frac{v_1}{c^2})}{\sqrt{1-\frac{{V_E^{'}}^2}{c^2}}} \tag{3}$$

Time Ageing

When twin A'' pass by twin A' (see figure 1) the respective clocks initiated simultaneously marking zero and, simultaneously, the same for twin's clocks B'' and B'. Therefore, when twin A'' pass by B' the respective clocks, A'' and B', mark τ'' and τ', the respective proper times between the events, the ageing of the twins. Similarly of the relation between lengths we obtain the relation between proper times since the time dilation is

$$d\tau'' = dt\sqrt{1-\frac{{v_2}^2}{c^2}} \quad (4)$$

$$d\tau' = dt\sqrt{1-\frac{{v_1}^2}{c^2}} \quad (5)$$

$$\frac{d\tau''}{\sqrt{1-\frac{{v_2}^2}{c^2}}} = \frac{d\tau'}{\sqrt{1-\frac{{v_1}^2}{c^2}}} = dt \quad (6)$$

and similarly, as we obtain for the length contraction previous result (3), we obtain the equation

$$\tau'' = \tau'\frac{\sqrt{1-\frac{{V_E'}^2}{c^2}}}{1+V_E'\frac{v_1}{c^2}} \quad (7)$$

Only for $v_1 = 0$ we obtain the time dilation equation. The frames are not equivalent [33].

Time dilation equation-like between frames S′′ and S′

Twin A′′ is moving with Einstein velocity V'_E and velocity V' with [99] (see (10))

$$V' = \frac{v_2 - v_1}{1 - v_1^2} \quad (8)$$

We have from (2) and (8)

$$V' = \frac{V_E'}{1+V_E'\frac{v_1}{c^2}} \quad (9)$$

and

$$dx' = V_E' dt_L' = V' dt' = V' d\tau' \quad (10)$$

Therefore from (7), (9) and (10)

$$d\tau'' = d\tau'\frac{\sqrt{1-\frac{{V_E'}^2}{c^2}}}{1+V_E'\frac{v_1}{c^2}} = dt_L'\sqrt{1-\frac{{V_E'}^2}{c^2}} \quad (11)$$

Therefore, we obtain a time dilation equation-like that standard formulation misinterpret as the relation between ageing

$$d\tau'' = dt_L'\sqrt{1-\frac{{V_E'}^2}{c^2}} \quad (12)$$

It is not. Since [1,10,11,37,99].

$$t_L' = t' - \frac{v_1}{c^2}x' \quad (13)$$

only for $v_1 = 0$

$$dt_L' = dt' = d\tau' \quad (14)$$

Therefore, we have for the general case, that standard interpretation is unable to consider

$$d\tau' = dt' = dt_L'\left(1+V_E'\frac{v_1}{c^2}\right) \quad (15)$$

The change of Lorentzian time result from a proper time variation and the desynchronization of the Lorentzian clocks as (10), (13) and (15) reveal.

The Ageing of the Twin´s Conundrum

Since

$$d\tau'' = dt_L'\sqrt{1-\frac{{V_E'}^2}{c^2}} \quad (16)$$

we have

$$d\tau'' < dt_L' \quad (17)$$

But we have also from (11)

$$d\tau'' = d\tau'\frac{\sqrt{1-\frac{{V_E'}^2}{c^2}}}{1+V_E'\frac{v_1}{c^2}} \quad (18)$$

and

$$\frac{d\tau''}{d\tau'} = \frac{\sqrt{1-\frac{{v_2}^2}{c^2}}}{\sqrt{1-\frac{{v_1}^2}{c^2}}} = \frac{\sqrt{1-\frac{{V_E'}^2}{c^2}}}{1+V_E'\frac{v_1}{c^2}} \quad (19)$$

Therefore, when $|v_2| > |v_1|$

$$d\tau'' < d\tau' \quad (20)$$

and when $|v_,| > |v_1|$

$$d\tau'' > d\tau' \quad (21)$$

If $v_2 = -v_1$

$$d\tau'' = d\tau' \quad (22)$$

The relation of ageing is dependent of the velocities of the frames in relation of the preferred frame and therefore it was proven that “seeing the other twin ageing slower”, inequality, (17) that standard relativity affirm based on (16), a time dilation-like mathematical expression, is meaningless in this context.

Conclusion

Finally, we would like to underline the following. The standard interpretation of special relativity pretends to assign a physical meaning of real ageing to assertions like “during the onward trip Bob sees Andrew ageing slower, Andrew himself also sees Bob ageing slower, but the change in inertial frames correct symmetry, as a result of relativity of simultaneity, and makes it in the end that Bob is younger when the twins meet.” The standard interpretation of general relativity pretends to assign a physical meaning to sentences like “during the turnaround period Bob sees Andrew ageing very quickly because he sees him under the effect of a gravitational field at a higher gravitational potential.” These are erroneous interpretations of correct mathematical results [43,100]. One message we want

to convey regarding the twin paradox is that such discourse is no longer tolerable and should become "unspeakable": it was proven that "seeing the other twin ageing slower" is meaningless in this context and corresponds to the symmetric description arising from the comparison of the time readings of Lorentzian clocks, whose roots lie in the indeterminacy of special relativity. It does not correspond to the clock rhythms and to the ageing of the twins [103-110].

References

1. de Abreu, R. (2002). The physical meaning of synchronization and simultaneity in special relativity. arXiv. https://arxiv.org/abs/physics/0212020
2. de Abreu, R. (2002). Reinterpretation of Lorentz transformation and resolution of special relativity's paradoxes. arXiv. https://arxiv.org/abs/physics/0203025
3. de Abreu, R. (2002). [Article associated with arXiv:physics/0210023]. arXiv. https://arxiv.org/abs/physics/0210023
4. de Abreu, R. (1998). [Article in Gazeta de Física, 21(3)]. Gazeta de Física. https://www.spf.pt/magazines/GFIS/398/1153
5. Homem, G. (2003). Physics in a synchronized space-time [Master's thesis, Instituto Superior Técnico, Universidade Técnica de Lisboa].
6. de Abreu, R. (2004). [Article in Ciência & Tecnologia dos Materiais, 14(1), 74].
7. de Abreu, R., & Guerra, V. (2005). Is the assumption of a special system of reference consistent with special relativity? arXiv. https://arxiv.org/abs/physics/0512196
8. de Abreu, R., & Guerra, V. (2005). Relativity—Einstein's lost frame. Extra]muros. http://web.tecnico.ulisboa.pt/vguerra/papers/relshort.pdf
9. Guerra, V., & de Abreu, R. (2006). [Article associated with arXiv:physics/0603258]. arXiv. https://arxiv.org/abs/physics/0603258
10. Guerra, V., & de Abreu, R. (2006). On the consistency between the assumption of a special system of reference and special relativity. *Foundations of Physics, 36*(12). https://doi.org/10.1007/s10701-006-9085-5
11. Guerra, V., & de Abreu, R. (2005). [Article in European Journal of Physics, 26(6)].
12. [The conceptualization of time and the constancy of the speed of light]. (2005). *European Journal of Physics, 26*(6). https://iopscience.iop.org/article/10.1088/0143-0807/26/6/S05
13. de Abreu, R., & Guerra, V. (2007). The principle of relativity and the indeterminacy of special relativity. *European Journal of Physics, 29*(1). https://doi.org/10.1088/0143-0807/29/1/004
14. de Abreu, R., & Guerra, V. (2007). The principle of relativity and the indeterminacy of special relativity. http://web.tecnico.ulisboa.pt/vguerra/papers/ejp8_1_004.pdf
15. de Abreu, R., & Guerra, V. (2009). Special relativity as a simple geometry problem. *European Journal of Physics, 30*(2), 229–237. https://doi.org/10.1088/0143-0807/30/2/001
16. de Abreu, R., & Guerra, V. (2015). [Article in Electronic Journal of Theoretical Physics, 12(34), 183]. http://www.ejtp.com/articles/ejtpv12i34p183.pdf
17. de Abreu, R., & Guerra, V. (2018). [viXra:1804.0320]. viXra. http://vixra.org/abs/1804.0320
18. de Abreu, R., & Guerra, V. (2018). [viXra:1805.0126]. viXra. http://vixra.org/abs/1805.0126
19. de Abreu, R. (2018). On the experimental determination of the one-way speed of light. viXra. https://vixra.org/abs/1808.0646
20. Einstein, A. (1905). On the electrodynamics of moving bodies. In J. Stachel (Ed.), Einstein's miraculous year: Five papers that changed the face of physics (1998). Princeton University Press.
21. Consoli, M., & Pluchino, A. (2018). [Article in Atti della Accademia Peloritana dei Pericolanti, 96(S1), A2].
22. Kittel, C. (1974). [Article in American Journal of Physics, 42, 726]. https://doi.org/10.1119/1.1987825
23. Andersen, F. (2017). [PhD thesis]. NMBU. https://nmbu.brage.unit.no/nmbu-xmlui/handle/11250/2500054
24. Myrstad, J. A. (2019). Borderology: Cross-disciplinary insights from the border zone. Springer. https://doi.org/10.1007/978-3-319-99392-8_8
25. Consoli, M., & Pluchino, A. (2019). Michelson-Morley experiments: An enigma for physics and the history of science. World Scientific. https://doi.org/10.1142/11209
26. Consoli, M., & Pluchino, A. (2021). The CMB, preferred reference system, and dragging of light in the Earth frame. Universe. https://doi.org/10.3390/universe7080311
27. Haug, E. G. (2016). The return of absolute simultaneity? A new way of synchronizing clocks across reference frames. viXra. http://vixra.org/abs/1605.0057
28. Haug, E. G. (2017). A motion paradox from Einstein's relativity of simultaneity. viXra. http://vixra.org/abs/1711.0408
29. de Abreu, R. (2018). Comment on "A motion paradox from Einstein's relativity of simultaneity." viXra. http://vixra.org/abs/1810.0452
30. Geloni, G., Kocharyan, V., & Saldin, E. (2016). [Article associated with arXiv:1601.07738]. arXiv. https://arxiv.org/abs/1601.07738
31. Geloni, G., Kocharyan, V., & Saldin, E. (2016). [Article associated with arXiv:1610.04139]. arXiv. https://arxiv.org/abs/1610.04139
32. Geloni, G., Kocharyan, V., & Saldin, E. (2017). [Article associated with arXiv:1704.01843]. arXiv. https://arxiv.org/abs/1704.01843
33. de Abreu, R., & Guerra, V. (2019). [viXra:1906.0312]. viXra. http://vixra.org/abs/1906.0312
34. [Comment on "Misconceptions regarding conventional coupling of fields and particles in XFEL codes"].
35. Mansouri, R., & Sexl, R. (1977). [Article in General Relativity and Gravitation, 8, 497].
36. Oziewicz, Z. (2007). Ternary relative velocity: Astonishing conflict of the Lorentz group with relativity. In V. Gladyshev (Ed.), Physical interpretations of relativity theory (pp. 292–303). https://arxiv.org/abs/1104.0682
37. Spavieri, G., et al. (2018). [Article in Journal of Physics Communications, 2, 085009].

38. Spavieri, G. (2017). [Article in PAIJ, 1(1)].
39. Consoli, M., & Pluchino, A. (2018). [Article in European Physical Journal Plus, 133, 295].
40. Burde, G. I. (2018). Special relativity with a preferred frame and the relativity principle. Journal of Modern Physics, 9(8). https://doi.org/10.4236/jmp.2018.98100
41. Ricou, M. (2017). [Article in Physics Essays, 30, 461–468].
42. de Abreu, R., & Guerra, V. (2019). [viXra:1906.0310]. viXra. http://vixra.org/abs/1906.0310
43. Wutke, A. (2018). Absolute simultaneity and rest consistent with special relativity: Science or philosophy? ResearchGate. https://www.researchgate.net/publication/326672264_Absolute_Simultaneity_and_Rest_Consistent_with_Special_Relativity_Science_or_Philosophy
44. Iyer, C. (2018). [Article in Journal of Physics Communications, 2, 118001].
45. Potvin, G. (2018). Ether interpretation of general relativity. Researchers.One. https://www.researchers.one/article/2018-12-7
46. Grøn, Ø. (2006). [Article in European Journal of Physics, 27, 885]. https://doi.org/10.1088/0143-0807/27/4/019
47. Iyer, C. (2008). [Article associated with arXiv:0811.0785]. arXiv. https://arxiv.org/abs/0811.0785
48. Iyer, C. (2008). [Article in European Journal of Physics, 29(4)].
49. Iyer, C., & Prabhu, G. (2010). [Article in American Journal of Physics, 78(2)].
50. Iyer, C., & Prabhu, G. (2007). [Article associated with arXiv:0710.1594]. arXiv. https://arxiv.org/abs/0710.1594
51. Møller, C. (1962). [Article in Proceedings of the Royal Society A, 270(1342)]. https://doi.org/10.1098/rspa.1962.0220
52. Schwartz, H. M. (1971). [Article in American Journal of Physics, 39, 1269]. https://doi.org/10.1119/1.1976621
53. A new method of clock synchronization without light signals.
54. Sears, F. W. (1969). [Article in American Journal of Physics, 37, 668]. https://doi.org/10.1119/1.1975747
55. Simultaneity without synchronized clocks.
56. Ramakrishnan, A. (2000). [Article in Journal of Mathematical Analysis and Applications, 249, 243].
57. Bricmont, J. (2017). History of quantum mechanics or the comedy of errors. arXiv. https://arxiv.org/pdf/1703.00294.pdf
58. History of quantum mechanics or the comedy of errors.
59. Giovanelli, M. (2020). Lorentz contraction vs. Einstein contraction: Reichenbach and the philosophical reception of Miller's ether-drift experiments. ResearchGate. https://www.researchgate.net/publication/338680431_Lorentz_Contraction_vs_Einstein_Contraction_Reichenbach_and_the_Philosophical_Reception_of_Miller_s_Ether-Drift_Experiments
60. Mamone-Capria, M. (2018). On the incompatibility of special relativity and quantum mechanics. Journal for Foundations and Applications of Physics, 5(2), 163. https://arxiv.org/abs/1704.02587
61. Spavieri, G., Gillies, G. T., Haug, E. G., & Sanchez, A. (2019). Light propagation and local speed in the linear Sagnac effect. Journal of Modern Optics. https://doi.org/10.1080/09500340.2019.1695005
62. Unnikrishnan, C. (2020). The theories of relativity and Bergson's philosophy of duration and simultaneity during and after Einstein's 1922 visit to Paris. Preprints, 2020, 2020010273. https://doi.org/10.20944/preprints202001.0273.v1
63. Spavieri, G., Guerra, V., de Abreu, R., & Gillies, G. T. (2008). [Article in European Physical Journal D, 47, 457].
64. Spavieri, G., Gillies, G. T., Haug, E. G., & Sanchez, A. (2019). [Article in Applied Physics Research, 11(4)].
65. Spavieri, G., & Haug, E. G. (2019). Why the Sagnac effect favors absolute over relative simultaneity. Physics Essays, 32, 331–337.
66. Spavieri, G., Gillies, G. T., & Haug, E. G. (2021). [Article in Journal of Modern Optics, 68(4)].
67. Salmon, W. (1977). The philosophical significance of the one-way speed of light. Noûs, 11, 253–292. https://plato.stanford.edu/entries/spacetime-convensimul/
68. Perez, I. (2011). On the experimental determination of the one-way speed of light. arXiv. https://arxiv.org/abs/1102.4837
69. Guerra, V., & de Abreu, R. (2007). Comment on "From classical ether-drift experiments: The narrow window for a preferred frame." Physics Letters A, 361(6).
70. Lewis, G. F., & Barnes, L. A. (2021). The one-way speed of light and the Milne universe. Publications of the Astronomical Society of Australia, 38. https://arxiv.org/abs/2012.12037
71. Buenker, R. J. (2015). GPS-compatible Lorentz transformation that satisfies the relativity principle. Journal of Astrophysics and Aerospace Technology, 3, 115. https://doi.org/10.4172/2329-6542.1000115
72. Netchitailo, V. S. (2020). [viXra:2012.0222]. viXra. https://vixra.org/abs/2012.0222
73. Pagano, A., & Pagano, E. V. (2019). [Article in EPJ H, 44, 321–330]. https://doi.org/10.1140/epjh/e2019-90058-4
74. Greaves, E. D., Rodrigues, A. M., & Ruiz-Camacho, J. (2009). [Article in American Journal of Physics, 77, 894].
75. de Abreu, R., & Guerra, V. (2009). Comment on "A one-way speed of light experiment." ResearchGate. https://www.researchgate.net/publication/45886873
76. Leaf, B. (1955). [Article in Philosophy of Science, 22(1)]. https://doi.org/10.1086/287387
77. Spavieri, G., Quintero, J., Unnikrishnan, C., & Gillies, G. (2012). [Article in Physics Letters A, 376(6–7), 795–797]. https://doi.org/10.1016/j.physleta.2012.01.010
78. Scott Blair, G. (1952). Relativity and indeterminacy. Nature, 170, 582. https://doi.org/10.1038/170582a0
79. Hines, C. (1952). Relativity and indeterminacy. Nature, 170, 582. https://doi.org/10.1038/170582a0
80. Mayantz, L. (n.d.). The enigma of probability in physics. INIS. https://inis.iaea.org/search/search.aspx?orig_q=RN:18074404
81. Mayantz, L. (1994). Beyond the quantum paradox. Taylor & Francis.

82. Medvedev, S. Y. (2014). [Article in Progress in Physics, 10, 151]. http://www.pteponline.com/2014/PP-38-04.PDF
83. Del Santo, F., & Gisin, N. (2021). [Work archived at PhilSci-Archive]. http://philsci-archive.pitt.edu/id/eprint/18601
84. Fleming, A., Matveev, V., & Matvejev, O. (n.d.). Self-field theory and general physical uncertainty relations. ResearchGate. https://www.researchgate.net/publication/264851293_Selffield_Theory_and_General_Physical_Uncertainty_Relations
85. Hill, J., & Cox, B. (2012). [Article in Proceedings of the Royal Society A]. https://doi.org/10.1098/rspa.2012.0340
86. Leubner, C., Aufinger, K., & Krumm, P. (1992). [Article in European Journal of Physics, 13, 170].
87. Drągowski, M., & Włodarczyk, M. (2020). The Doppler effect and the anisotropy of the speed of light. Foundations of Physics, 50, 429–440. https://doi.org/10.1007/s10701-020-00337-5
88. Anderson, R., & Stedman, G. E. (1992). Distance, and the conventionality of simultaneity in special relativity. Foundations of Physics Letters, 5, 199–220. https://doi.org/10.1007/BF00692800
89. de Abreu, R. (2021). Simultaneity and synchronization by rods as a simple geometry problem. viXra. https://vixra.org/abs/2103.0196
90. Dias Ferreira, L. (2021). Criticism to the twin's paradox. Universal Journal of Physics and Application, 15(1), 1–7. https://doi.org/10.13189/ujpa.2021.150101
91. de Abreu, R. (2021). Comment on "Criticism to the twin's paradox" by Luís Dias Ferreira. viXra. https://vixra.org/abs/2107.0077
92. Borah, B. K. (2013). Schwarzschild-like solution for the gravitational field of an isolated particle on the basis of 7-dimensional metric. International Journal of Scientific and Research Publications, 3(10).
93. Borah, B. K. (2013). An approach to new concept of time on the basis of four fundamental forces of nature. International Journal of Scientific and Research Publications, 3(6).
94. Borah, B. K. (n.d.). Unification of four fundamental forces of nature developing 7-dimensional metric on the basis of new concept of time. International Journal of Scientific Research. https://www.worldwidejournals.com/international-journal-of-scientific-research-%28IJSR%29/article/unification-of-four-andndash-dimensional-metric-on-the-basis-of-new-concept-of-time/NjU0OQ==/
95. International Journal of Scientific Research (IJSR). (n.d.). https://www.worldwidejournals.com/international-journal-of-scientific-research/
96. Unification of four fundamental forces of nature developing 7-dimensional metric on the basis of new concept of time. (n.d.). International Journal of Scientific Research. https://www.worldwidejournals.com/international-journal-of-scientific-research-%28IJSR%29/article/unification-of-four-andndash-dimensional-metric-on-the-basis-of-new-concept-of-time/NjU0OQ==/
97. 7-dimensional metric on the basis of new concept of time. (n.d.). International Journal of Scientific Research. https://www.worldwidejournals.com/international-journal-of-scientific-research-%28IJSR%29/
98. Homem, G. (2002). [Article associated with arXiv:physics/0212050]. arXiv. https://arxiv.org/abs/physics/0212050
99. de Abreu, R. (2002). The energy-entropy principle. arXiv. https://arxiv.org/abs/physics/0207022
100. de Abreu, R., & Guerra, V. (2012). [Article associated with arXiv:1203.2294]. arXiv. https://arxiv.org/abs/1203.2294
101. de Abreu, R., & Guerra, V. (2012). [Article available through the American Association of Physics Teachers]. https://aapt.scitation.org/doi/10.1119/1.3698160
102. Carathéodory, C. (2016). [Web article about Constantin Carathéodory]. Greatest Greeks. https://greatestgreeks.wordpress.com/2016/12/12/constantine-caratheodory/
103. Carathéodory, C. (n.d.). On Carathéodory's approach to relativity and its relation to hyperbolic geometry. ResearchGate. https://www.researchgate.net/publication/312057731_On_Caratheodorys_approach_to_relativity_and_its_relation_to_hyperbolic_geometry
104. de Abreu, R. (2015). The concept of mass as a quantity derived from motion. viXra. https://vixra.org/abs/1505.0094
105. Mohazzabi, P., & Luo, Q. (2021). Has the twin paradox really been resolved? Journal of Applied Mathematics and Physics, 9, 2187–2192. https://doi.org/10.4236/jamp.2021.99138
106. de Abreu, R. (2022). Comment on "Has the twin paradox really been resolved?" viXra. https://vixra.org/abs/2209.0045
107. de Abreu, R. (2022). Simultaneity and synchronization, the preferred frame and the principle of relativity. viXra. https://vixra.org/abs/2204.0060
108. Potential energy formula in special relativity. (n.d.). Physics Forums. https://www.physicsforums.com/threads/potential-energy-formula-in-special-relativty.991687/
109. Reichenberger, A. (2018). The clock paradox: Luise Lange's discussion. PhilArchive. https://philarchive.org/archive/REITCP-3
110. Iyer, C. (2023). Importance of synchronization in the observation of event coordinates. Physics Essays, 36(2), 168–172. https://doi.org/10.4006/0836-1398-36.2.168

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