LETTERS TO THE EDITOR

PHYSICS

Special Theory of Relativity

PROF. H. DINGLE has sent me a reprint of his communication published under the above title on p. 985 of *Nature*, September 8, 1962, with the handwritten remark: "With kindest regards. Test case for the integrity of scientists".

Though former experience has taught me that discussing relativity with Dingle leads to no agreement I have to answer a challenge which is directed against the "scientific integrity" of myself and of others.

I use Dingle's notation. He restricts himself to the case of a linear motion along the x- or ξ-axis.

$K(x,t)$ is a 'stationary' system of reference, $k(\xi,\tau)$ a 'moving' one. Dingle writes down half the Lorentz transformation expressing τ by t and x, and half its inverse expressing t by τ and ξ. Then he quotes a passage from Einstein's paper, the first paragraph of which ends with the question: "*What is the rate of this clock, when viewed from the stationary system?*". Then follows the well-known derivation of the formula

$$\tau = t\sqrt{(1-v^2/c^2)} \qquad (1)$$

Dingle now proceeds in this way: "And here is the passage leading to the opposite conclusion". The first paragraph of this new passage is completely identical with that of the original including the last sentence just quoted (in italics). Then he exchanges the co-ordinate systems and so obtains the result:

$$t = \tau\sqrt{(1-v^2/c^2)} \qquad (2)$$

which he regards as a contradiction to formula (1).

The mistake is in the first paragraph quoted above (in italics); it should read, in the two cases:

1st case, clock at rest in k: *What is the rate of the clock in k, when viewed from the 'stationary' system K ?*

2nd case, clock at rest in K: *What is the rate of the clock in K, when viewed from the 'moving' system k ?*

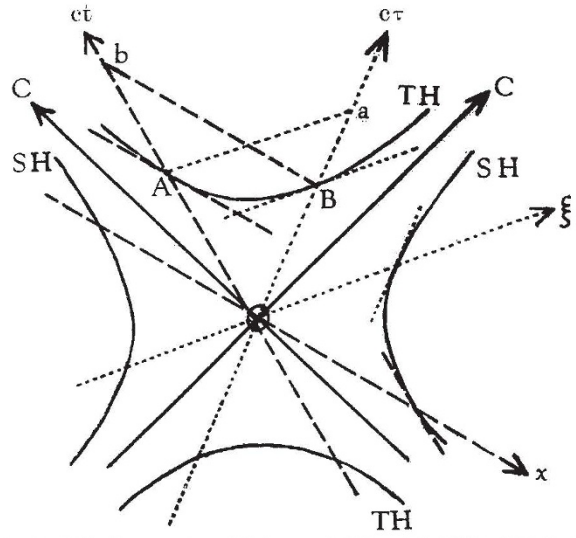

Fig. 1. C,C, Cross-section of light cone; SH, space calibration hyperbola; TH, time calibration hyperpola; x,ct, conjugate diameters = axes in K; $(\xi,c\tau)$, conjugate diameters = axes in k; OA, represents the same time-interval in K as OB in k:

$$OA \sim OB$$

Clock at rest in K: $\left\{\begin{array}{l} OA \sim ct \\ Oa \sim c\tau \end{array}\right\}$ $\begin{array}{l} Oa > OB \sim OA \\ \tau > t \end{array}$

Clock at rest in k: $\left\{\begin{array}{l} OB \sim c\tau \\ Ob \sim ct \end{array}\right\}$ $\begin{array}{l} Ob > OA \sim OB \\ t > \tau \end{array}$

In other words: formulæ (1) and (2) refer to different physical situations; t and τ have not the same meaning in (1) and (2).

If the clock is at rest in k and in motion relative to K, the reading of the hands of the clock at the beginning of the time-interval t in k is taken at the same place in k as the reading at the end of the time-interval. But the reading of the hands of this clock taken in K at the beginning and at the end of the time-interval are at different positions of the clock in K, as the clock is moving relative to K.

If, on the other hand, the clock is at rest in K and in motion relative to k, the situation is exactly reversed: the beginning and the end position of the clock are read at the same place in K, but at different places in k.

The two cases are therefore different, the symbols t and τ in expressions (1) and (2) referring to different physical situations; these are inverse and must of course correspond to an exchange of the symbols t and τ. This is exactly what expressions (1) and (2) express. There is no contradiction.

Dingle's objections are just a matter of superficial formulation and confusion. The simple fact that all relations between space co-ordinates and time expressed by the Lorentz transformation can be represented geometrically by Minkowski diagrams should suffice to show that there can be no logical contradiction in the theory. The use of such diagrams is explained, for example, in my book *Einstein's Theory of Relativity* of which a new cheap edition (Dover Publications, Inc., New York) is now available. I give here the diagram for the time dilation with a detailed legend (Fig. 1); it shows why the slowing down of a clock at rest in one system when observed from another system in relative motion is reciprocal in the two systems. Further explanations seem to be superfluous.

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I AM grateful to Prof. Born for replying to my communication, and am especially pleased that one scientist of outstanding eminence has passed the integrity test: would there were others.

I must maintain, however, that he has not met the point I raised: this is shown by the following passage in his letter: "The mistake is in the first paragraph . . . the same meaning in (1) and (2)". In making this statement Prof. Born is clearly exceeding his rights: a question cannot be dismissed as a "mistake". It is my question, and I meant it exactly as I put it. Prof. Born substitutes a different question, which he assumes I should have asked, and gives an answer that does not contradict Einstein's conclusion. I agree, but the answer to my question does.

Prof. Born is wrong in saying that my expressions (1) and (2) refer to different physical situations and that t and τ have not the same meaning in (1) and (2). This is not a matter of opinion. I constructed the second statement, and I say categorically that if, in Einstein's statement, A is a clock fixed at the origin of what he calls the 'stationary' system, and X is a clock fixed at the origin of what he calls the 'moving' system, then in my statement also, A is fixed at the origin of that same 'stationary' system and X at the origin of that same 'moving' system. Furthermore, in both statements t is the time of an event according to clock A, and τ the time of the same event according to clock X.

What Einstein's statement shows is that, on his theory, between the two events, (1) the coincidence of the clocks.

and (2) a later event occurring on X, the time-interval according to A is greater than that according to X, so that X is running slower than A. What my statement shows is that, in the identical physical situation, between the two events (1) the coincidence of the clocks, and (2) a later event occurring on A, the time-interval according to A is smaller than that according to X, so that X is running faster than A. The only difference between the two cases is that the intervals compared are those between different pairs of events; and the only conceivable way of avoiding the contradiction is by showing (consistently with the relativity postulate, that is, without assuming an ether in which A is uniquely stationary and X uniquely moving) that Einstein's interval between two events on X is valid for comparing the rates of the clocks, and that my interval between two events on A is not.

I repeat that there is only one physical situation—two clocks, A and X, in uniform relative motion; that there is no change of co-ordinate system in going from Einstein's statement to mine (A 'rests' and X 'moves' in both); and that there is no change of meaning of t or τ (t refers in both to readings of A, and τ to readings of X). Hence equations (1) and (2) show that A goes steadily both faster and slower than X.

The effective criterion of truth in these matters still resides in the pronouncements of mathematical physicists, none of whom, of stature comparable with that of Prof. Born, appears to share his sense of obligation on this point; and as I have been informed, with various degrees of emphasis, that my utterances on such things are imponderable, there is an urgent need for the weight of his unquestioned authority to reinforce a clear demonstration of the truth of the matter, whatever it may be.

Herbert Dingle

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[See also p. 1248 of this issue.]

Fading of Latent Image in Japanese Fuji *ET-7A* and *ET-6B* Nuclear Emulsions

The various parameters on fading[1–6] indicated experimentally are due to: the action of some constituents of the atmosphere, surrounding temperature, time of storage, and emulsion composition. Based on the available experimental evidence, the mechanism of fading is thought to be dependent on the oxidation of the development specks by atmospheric oxygen in the presence of water[5].

In order to examine the latent image fading effects, the plates were exposed to mono-energetic α-rays, which were prepared from thorium nitrate by 'electrolytic displacement' method[7]. The separated ThC by emitting β-rays transforms to ThC′, which is a pure mono-energetic α-emitter with energy 8·78 MeV; only a few of them originate from ThC (ref. 8).

The plates were irradiated by α-particles from ThC′ and stored in the vessels, under different conditions, for the purpose of examining the various parameters on fading. After insertion of the irradiated plates, the vessels were evacuated to a pressure less than 0·1 mm mercury and the vapour pressure in the vessel was adjusted to what was desired by opening the cork to concentrated sulphuric acid or distilled water, which was stored in the system, then filled with the gas. The vessels containing the exposed plates under the conditions described were stored in a constant-temperature bath which was maintained at 30° C for the assigned duration of times as indicated in Tables 1 and 2 and Figs. 1 and 2. They and the plates just

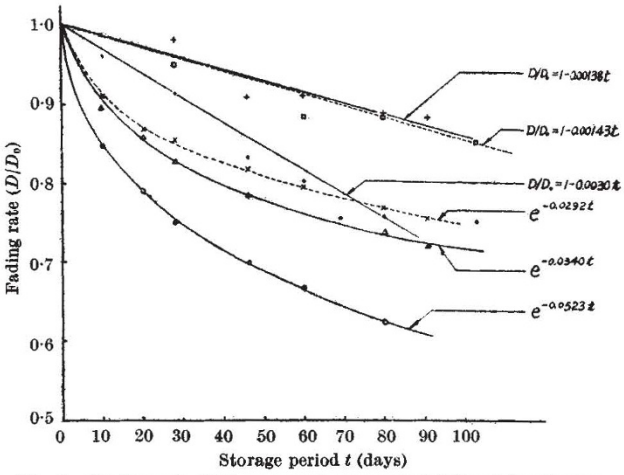

Fig. 1. Fading rate D/D_0 versus storage period t (days) in nitrogen, argon and oxygen gas at 30° C and 60 per cent relative humidity. +, *ET-7A* in nitrogen; □, *ET-7A* in argon; ●, *ET-7A* in oxygen; ×, *ET-6B* in argon; △, *ET-6B* in nitrogen; ○, *ET-6B* in oxygen. The statistical uncertainties are shown in Table 1

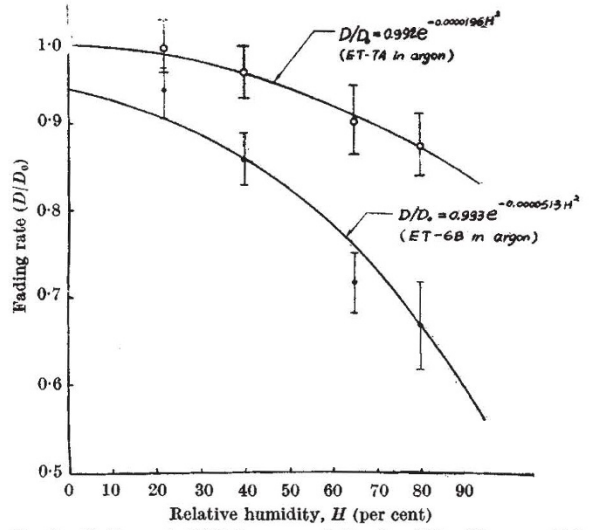

Fig. 2. Fading rate (D/D_0) versus relative humidity (H per cent) in argon at 30° C for 93 days' storage

Table 1. Fading Rate D/D_0 in Nitrogen, Argon and Oxygen Gas. D_0 is the Grain Density of α-Particle Tracks produced upon Immediate Development, D is the Density after t Days' Storage. The Storage Temperature is 30° C and Relative Humidity, 60 per cent

Type of emulsion	*ET-6B*			*ET-7A*		
Atmosphere / Storage period (days)	Nitrogen	Argon	Oxygen	Nitrogen	Argon	Oxygen
0	1·000	1·000	1·000	1·000	1·000	1·000
10	0·894 ± 0·027	0·912 ± 0·026	0·849 ± 0·019	0·985 ± 0·040	—	0·960 ± 0·032
20	0·860 ± 0·029	0·878 ± 0·031	0·791 ± 0·021	—	—	—
28	0·830 ± 0·028	0·858 ± 0·040	0·752 ± 0·017	0·980 ± 0·041	0·950 ± 0·035	0·915 ± 0·050
46	0·787 ± 0·042	0·820 ± 0·036	0·702 ± 0·036	0·910 ± 0·033	—	0·835 ± 0·045
60	—	0·798 ± 0·032	0·668 ± 0·018	0·911 ± 0·047	0·886 ± 0·036	0·804 ± 0·041
80	0·740 ± 0·023	0·771 ± 0·039	0·626 ± 0·035	0·891 ± 0·049	0·885 ± 0·039	0·761 ± 0·039
91	0·723 ± 0·022	0·757 ± 0·030	—	0·885 ± 0·035	—	—
103	—	—	—	—	0·853 ± 0·041	0·752 ± 0·031