Genesis of the Query "Is There an Ether?"

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THE recent communication by P. A. M. Dirac under the title "Is there an ether?"[1] may be taken as occasion to review the origin of the widely publicized and now almost "orthodox" view that there is no ether.

The denial of a medium for transmitting electromagnetic signals with a velocity independent of their material source was not, as is sometimes represented, a conclusion drawn from the Michelson-Morley experiment, which failed to detect relative motion between matter and ether. The existence of the ether was not questioned by Michelson; in reporting his results, he considered them as giving support to the idea of an ether entrained by the earth in its motion. In the proposals of Fitzgerald, Lorentz, and Larmor for the explanation of the null result of the Michelson-Morley experiment there is no suggestion of the nonexistence of the ether. The contractions of dimensions and clock rates associated with their names were suggested behaviors of matter in motion *with respect to the ether*, in conformity with which the Michelson-Morley experiment would not reveal the motion.

Neither was the denial of the ether a result of the formulation of the principle of relativity. This principle, which we owe to Poincaré (1904), denied the possibility of an observer "carried along in a uniform motion of translation" of discovering (i.e., by measurement) such a motion. It is abundantly clear from Poincaré's writings that the "motion" in question was motion *with respect to the ether*. Poincaré identified the principle of relativity with the mechanics of Lorentz, as embodied in the Lorentz transformations. These transformations, put in their now familiar symmetrical form by Poincaré, were built up by Lorentz from the contractions of dimensions and clock frequencies invented by him to explain the behavior of matter *with respect to the ether*. The suggestion that the ether is nonexistent is not to be found in either Poincaré's or Lorentz's discussions of the principle of relativity, in fact Lorentz explicitly affirmed his adherence to the ether.

The idea that there is no ether appears apparently for the first time in the paper by Einstein in 1905 "On the electrodynamics of moving bodies," in the statement in his preliminary remarks "The introduction of a 'luminiferous ether' will prove to be superfluous, inasmuch as the view to be here developed will not require 'an absolute stationary space' provided with special properties." It is this statement, and its acceptance as proved by the reasoning of Einstein's paper, which is to be credited with "the abolition of the ether." It is consequently pertinent to investigate the justification for Einstein's claim and the validity of his supporting arguments. Did he in fact furnish a sound and adequate substitute for the ether of earlier theory?

Divested of his questionably pertinent discussion of simultaneity and his arbitrary *definition* of the time for a light signal to travel out as always equal to the time back, the significant feature of Einstein's development is as follows: He prescribes that the "velocity" of a light signal traveling in one direction along two different parallel paths in uniform relative motion shall be the same, and equal to *c*, which "in agreement with experience" is "a universal constant . . . the velocity of light in empty space." From this proposition he derives the Lorentz-Poincaré transformations, and with them the Fitzgerald-Lorentz-Larmor contractions of lengths and clock frequencies, these latter entirely as phenomena of relative motion of matter.

Now the proposition that any independent signal velocity shall be the same with respect to all other independent velocities is, in terms of Newtonian "absolute" space and time, a sheer paradox. It is *not*, as sometimes stated, a requirement of the principle of relativity. All that the principle of relativity requires is that any specific set of observations or measurements which we may make on the transit of light signals with respect to one body shall yield the *same* result on any other body in uniform motion with respect to the first *when made by instruments partaking of the motion*. It is therefore of the first importance to be clear as to what observations and measurements we make when we attempt to determine what, in a Newtonian system, would be "the velocity of light."

Two different measurements are to be distinguished. The first is of signals sent *out and back* to one clock at the origin, which is unmoved, except in so far as it partakes of the motion of the system. The "velocity" of light is then the quotient of the measured distance traversed by the signal by the time indicated by this single clock. This is the "experience" quoted by Einstein. In accordance with the principle of relativity this measurement always yields the same result; in accordance with the Michelson-Morley experiment this result is always the constant *c*. The second measurement is of a signal sent in *one direction* from a clock at the origin to a second clock at the end of the path. The second clock must be set as to epoch with respect to the first by some physical manipulation. The only such manipulation which is observable and measurable, not dependent on arbitrary definition, is to move a clock from one end of the path to the other at an observable rate measured by the distance passed over and the time as measured by this setting clock itself. The resulting epoch will of necessity be some function of this self-observed clock velocity, hence the expression describing the epoch will contain terms involving the setting clock velocity. By the principle of relativity the "velocity," more properly the "rod-two-clock quotient" of light so measured will be the *same* on all platforms in uniform relative motion, for the same choice of setting clock velocity, but it will not be the same as the one-way "velocity" which contains no clock velocity terms.

The consequence of the loose identification of two different "sames" is an internal contradiction in Einstein's "view." In his derivation of the Lorentz-Poincaré transformations he postulates the one-way velocity of light to be c. From the contractions of length and clock rate with motion contained in these transformations it is possible to determine the epoch of a moved clock. When this is done and time is measured by the moved clock, the "velocity" of a one-way signal turns out to be a function involving the moved clock velocity, that is, it is *not* c, contradicting the initial postulate. This has been recognized in the Special Theory of Relativity to the extent that the use of moved clocks for establishing distant epochs is prohibited (or they are to be moved "infinitely slowly," which means the measurement would never be made!). Instead, distant clock epochs are prescribed to be made by light signals *assigned* the velocity c, by which indeed the resulting measured value is c, but this is a rigmarole, not a legitimate measuring procedure. Einstein's "constancy of the velocity of light" is not a competent substitute for the ether.

This inconsistency of the Einstein procedure is to be contrasted with the treatment of the problem by considering the velocity of light as a constant c with respect to the ether, and applying to our measuring instruments the contractions of length and clock frequency as occurring on motion with respect to the ether. The procedure of setting distant clock epochs by moved clocks then gives the "velocity" of a one-way signal as

$$\frac{c}{1-\frac{c}{q}\left[\left(1+\frac{q^2}{c^2}\right)^{\frac{1}{2}}-1\right]},$$

where q is the self-measured velocity of the setting clock. The same reasoning results in "transformations" of the Lorentz-Poincaré type containing terms in q, which approximate to the Lorentz-Poincaré formulation when q is small. The principle of relativity is conformed to, there is no paradox, no internal contradiction, no prohibition of the use of clocks, no resort to "definition" unsupportable by measurement.[2]

Further ground for rejecting the claim that Einstein's "view" renders the ether superfluous is furnished by the consideration that his scheme (even if it were valid) applies only to uniform rectilinear motion; rotational motion is excluded, yet optical signals are transmitted in such systems, and with results which point clearly and unequivocally to their transmission in an independent medium or coordinate system. If light signals are sent out simultaneously in the "fore" and "aft" directions from a source moving in a circular path, and the two signals are brought back to the source by a series of reflections, they do not arrive simultaneously; the source has moved forward to meet one signal and has moved away from the other. This is the situation in the Michelson-Gale and Sagnac experiments, which yield positive first-order results exactly in conformity with the idea that the light signals travel in a fixed ether. The contractions of length and clock frequencies which account for nul effects in uniform motion of translation, being of the second order, do not materially alter the rotational effects. The optical phenomena in both uniformly and rotationally moving systems are completely explainable by a fixed ether and the Fitzgerald-Lorentz-Larmor contractions.[3]

This survey of the background of the query "Is there an ether?" shows that the grounds for "abolishing" the ether were mistaken, and consequently Dirac's contribution would more properly have been entitled "Properties of the ether suggested by recent speculations."

[1] P. A. M. Dirac, Nature 168, 906 (1951).

[2] The above argument will be found in greater detail, with full references, in Herbert E. Ives, Proc. Am. Phil. Soc. 95, No. 2, 125 (April, 1951).

[3] See Herbert E. Ives, Proc. Roy. Dublin Soc. 26, 9 (May 1, 1952).