SITE PAPER · NOT ON ZENODO

Deriving the 1905 Transformation

From the two postulates to γ,
and from two light pulses to L/c^2

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Abstract. The History tab says what "Zur Elektrodynamik bewegter Körper" is and where it sits in 1905. This paper does not repeat that placement. It writes the steps from the two postulates [1] to the factor γ, then the steps of the September note [2] from a pair of light pulses to a mass difference L/c^2. Lorentz's 1904 transformation [3] and Poincaré's 1905 memoir [4] are the neighboring primary sources. Einstein's paper cites neither. That fact is recorded once. The light-quantum paper is not an input.

1. The postulates, as equations

[1] states two requirements and no citation list. The laws of electrodynamics have the same form in every inertial frame. A spherical light wave leaving the origin of one frame at speed c is a spherical wave at speed c in the other. If the second frame moves at constant v along x, the wavefronts are

$$x^2 + y^2 + z^2 = c^2t^2, \quad x'^2 + y'^2 + z'^2 = c^2t'^2.$$

The linear relation that maps one into the other, with the origin of the moving frame at $x = vt$, is standard once linearity and the shared y and z are granted:

$$x' = \gamma(x - vt), \quad t' = \gamma(t - vx/c^2), \quad y' = y, \quad z' = z.$$

Substitute $x = ct$ into the transformation. Then $x' = \gamma(c - v)t$ and $t' = \gamma(1 - v/c)t$, so $x'/t' = c$. The same for a backward ray gives γ by requiring the inverse transformation to have the same factor with v reversed. The result in [1] is

$$\gamma = 1/\sqrt{1 - v^2/c^2}.$$

γ is dimensionless. v is the relative speed of the frames. c is the speed fixed by the second postulate, not a property of a medium that the equations still contain. A rod of rest length L along x has coordinate length L/γ in the frame where it moves. A clock that marks $\Delta\tau$ in its rest frame marks coordinate time $\gamma\Delta\tau$ where it moves.

2. Addition of velocities

A body moves at u along x in the first frame, so $x = ut$. In the second frame [1]

$$u' = \frac{x'}{t'} = \frac{u - v}{1 - uv/c^2}.$$

The inverse, the form used when both speeds point the same way and one asks for the composite, is $(u + v)/(1 + uv/c^2)$. If $|u| < c$ and $|v| < c$, the composite is still below c. That is algebra from the transformation, not a third postulate.

3. The September mass difference

[2] considers a body at rest that emits two light pulses of energy $L/2$ in opposite directions. The body loses energy L and no momentum. In a frame moving at v, the energy of a light pulse transforms, to order v^2/c^2,

so that the sum of the two pulses is $L\big(1+\tfrac{1}{2}v^2/c^2\big)$ rather than L. The body's kinetic energy in that frame therefore drops by less than a massless accounting would require. The difference is

$$\Delta K = \frac{L}{c^2}\cdot\frac{v^2}{2}.$$

Kinetic energy at order v^2 is $\tfrac{1}{2}mv^2$. Matching the factor, the body has lost a mass L/c^2. [2] concludes that the mass of a body is a measure of its energy content. The formula $E=\gamma mc^2$ for a single moving particle is not the equation printed there. Attributing that general expression to the September note is a later reading. The note's result is the difference L/c^2.

4. What is credited, and what is not claimed

Lorentz [3] already had a transformation of this family, obtained by fitting Maxwell's equations to an electron theory with an ether. Poincaré [4] named the principle of relativity and wrote the group properties. Einstein [1] does not cite them. The derivation above follows [1]: postulates first, transformation second, no ether coordinate left over. It is not a claim that the transformation was historically unprecedented. It is a claim about what his pages contain.

The March 1905 light-quantum paper is not among the premises. Radiation here is a continuous pulse with energy L and inertial mass L/c^2. Quanta are a different paper.

5. References

1. A. Einstein, "Zur Elektrodynamik bewegter Körper," *Annalen der Physik* 17, 891–921 (1905). Received 30 June 1905. No reference list in the original.
2. A. Einstein, "Ist die Trägheit eines Körpers von seinem Energieinhalt abhängig?," *Annalen der Physik* 18, 639–641 (1905). Received 27 September 1905.
3. H. A. Lorentz, "Electromagnetic phenomena in a system moving with any velocity smaller than that of light," *Proceedings of the Royal Netherlands Academy of Arts and Sciences* 6, 809–831 (1904).
4. H. Poincaré, "Sur la dynamique de l'électron," *Rendiconti del Circolo Matematico di Palermo* 21, 129–176 (1906); the short note is *Comptes Rendus* 140, 1504–1508 (1905).