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Trouble with the Lorentz law of force: Incompatibility with special relativity and momentum conservation

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The Lorentz law of force is the fifth pillar of classical electrodynamics, the other four being Maxwell's macroscopic equations. The Lorentz law is the universal expression of the force exerted by electromagnetic fields on a volume containing a distribution of electrical charges and currents. If electric and magnetic dipoles also happen to be present in a material medium, they are traditionally treated by expressing the corresponding polarization and magnetization distributions in terms of bound-charge and bound-current densities, which are subsequently added to free-charge and free-current densities, respectively. In this way, Maxwell's macroscopic equations are reduced to his microscopic equations, and the Lorentz law is expected to provide a precise expression of the electromagnetic force density on material bodies at all points in space and time. This paper presents incontrovertible theoretical evidence of the incompatibility of the Lorentz law with the fundamental tenets of special relativity. We argue that the Lorentz law must be abandoned in favor of a more general expression of the electromagnetic force density, such as the one discovered by A. Einstein and J. Laub in 1908. Not only is the Einstein-Laub formula consistent with special relativity, it also solves the long-standing problem of "hidden momentum" in classical electrodynamics.

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