Operationalist reconstruction of the semantics of classical electrodynamics

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The central issue of special relativity is the comparison of physical quantities defined in *different* inertial frames of reference. However, the question of how these quantities are defined in *one single* frame of reference is considered unproblematic. In this paper, we investigate this latter question concerning electrodynamical quantities.

When we say "definition", we mean *empirical* definition, somewhat similar to Reichenbach's "coordinative definition", Carnap's "rule of correspondence" and the nearest to what Bridgman calls "operational definition"; which provides the theory with empirical interpretation.

In textbooks, the electric and magnetic fields are usually introduced by means of the Lorentz force formula. In the spirit of Coulomb's and Ampére's electro- and magnetostatical experiments, electric field strength **E** is defined as the force acting on a static unit charge; magnetic induction field **B** is defined by means of the force acting on a conductive rod carrying unit current. These definitions rely on the concepts of electric charge and force. The electric charge of a particle is often suggested to be defined by means of kinematical properties, when the particle is moving in a *given electromagnetic field*; by applying, again, the Lorentz equation of motion. (This is the basic idea of the Millikan experiment or the so-called mass spectrometry of atoms). This is however an obviously circular way of defining charge, because we have no prior definitions of the field quantities; not to mention the difficulty that only the ratio $\frac{q}{m}$ can be ascertained in the experiments of this kind; that is, we ought to have an independent definition of inertial mass.

How to measure mass then? Particle collisions are often said to be the experimental situations for defining inertial mass, putting the conservation of momentum (equivalently, in a Machian manner, Newton's third law) to use. It is sometimes claimed that this method is logically circular by presupposing a prior notion of inertial frame of reference, that is, therefore, the notion of force and mass. We don't believe this circularity is unresolvable; instead, however, we would like to point out a more serious difficulty. Collisions are interactions. For example, assume that the dynamics of the collision of two particles is

governed by classical electrodynamics. The conservation of momentum holds for the *whole* particle+field system; consequently, the conservation of momentum and the equality of action and reaction are not necessarily satisfied by the electromagnetically interacting particles *alone*, and therefore mass cannot be defined in this way.

Thus, the task to define the fundamental electrodynamical quantities without logical/operational circularities is far from trivial, and inseparably intertwined with the empirical definition of mass. In this paper, we will sketch a possible solution.