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A finite model for electrodynamics by introducing a form factor $f_{HD_2}(\ell^2 \square) = 1 + (-\ell^2 \square)^2$ into the kinetic term of Maxwell theory

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Abstract

In this paper, a higher-derivative model for electrodynamics is presented in a $D + 1$ dimensional Minkowski space-time by introducing a form factor into the kinetic term of Maxwell theory as $-\frac{1}{4\mu_0} F_{\mu\nu} F^{\mu\nu} \rightarrow -\frac{1}{4\mu_0} F_{\mu\nu} f_{HD_2}(\ell^2 \square) F^{\mu\nu}$, where $\ell > 0$ is a characteristic length scale. Our calculations show that for

$D \in \{3, 4, 5\}$ the electrostatic potential of a point charge is finite at the position of the point charge in this higher-derivative modification of Maxwell's theory. For $D = 3$ the explicit form of the potential and the electric field of a point charge are obtained analytically in this higher-derivative electrodynamics. According to numerical estimations, the upper bound for the characteristic length scale ℓ is $\ell_{\max} \sim \frac{1}{100} \ell_{electroweak}$,

where $\ell_{electroweak} = 10^{-18} m$ is the electroweak length scale. Finally, it should be emphasized that for $\ell \ll 1$ the results of this paper are compatible with the results of ordinary Maxwell theory.

Keywords: Maxwell electrodynamics, regularization techniques, form factor, characteristic length scale, field theories with higher derivative terms

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