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Abstract

Immersing the Schwarzschild Black Hole in Test Nonlinear Electromagnetic Fields †

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Abstract: Killing vector fields can be used as gauge vector potentials since the associated electromagnetic field tensor automatically satisfies the source-free Maxwell's equations in vacuum spacetimes. This fact enabled Wald to find the form of the electromagnetic tensor corresponding to the Kerr black hole immersed in a uniform test magnetic field. We present the generalisation of this result, which is valid for static black holes surrounded by nonlinear electromagnetic fields. The first obstacle we encountered when dealing with the nonlinear electrodynamics was that the above-described ansatz no longer works. Secondly, finding the exact solution in a closed form proved to be a rather challenging task because it would require solving a highly nonlinear differential equation. The alternative approach is via perturbative expansion around the original Wald's solution. We obtain the equation which determines the lowest order correction to the gauge vector field 1-form and magnetic scalar potential. With the main focus on the Born–Infeld and Euler–Heisenberg theories on the Schwarzschild background, we calculate the aforementioned correction. Additionally, we show that this perturbative correction does not change electric and magnetic Komar charges or the asymptotic behaviour of the field. Finally, stating physical arguments, we justify the usage of the perturbative approach.

Keywords: black hole electrodynamics; nonlinear electromagnetic fields

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