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Transient effects of charge diffusion on electromagnetic field in heavy-ion collision

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We study charge diffusion in relativistic resistive second-order dissipative magnetohydrodynamics. In this theory, charge diffusion is not simply given by the standard Navier-Stokes form of Ohm's law, but by an evolution equation which ensures causality and stability. This, in turn, leads to transient effects in the charge-diffusion current, the nature of which depends on the particular values of the electrical conductivity and the charge-diffusion relaxation time. The ensuing equations of motion are of so-called stiff character, which requires special care when solving them numerically. To this end, we specifically develop an implicit-explicit Runge-Kutta method for solving relativistic resistive second-order dissipative magnetohydrodynamics and subject it to various tests. We then study the system's evolution in a simplified 1+1-dimensional scenario for a heavy-ion collision, where matter and electromagnetic fields are assumed to be transversely homogeneous, and investigate the cases of an initially nonexpanding fluid and a fluid initially expanding according to a Bjorken scaling flow. In the latter case, the scale invariance is broken by the ensuing self-consistent dynamics of matter and electromagnetic fields. However, the breaking becomes quantitatively important only if the electromagnetic fields are sufficiently strong. The breaking of scale invariance is larger for smaller values of the conductivity. Aspects of entropy production from charge-diffusion currents and stability are also discussed.

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