Strong field magneto-transport in periodic microstructures: numerical results and exact asymptotics

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Abstract:

In Ref. [1] a surprising physical phenomenon was discovered which appears in classical metal/insulator or metal/superconductor composite media with three-dimensional (3D) periodic microstructures, when subject to a strong, externally applied magnetic field. When the field is strong enough, i.e., when the Hall-to-Ohmic resistivity ratio is greater than 1 in at least one constituent of the composite medium, then the magnetic-field-dependence of the electrical conductivity of the metallic constituent leads to a strong dependence of the macroscopic resistivity of the composite medium on the strength and direction of the magnetic field with respect to the periodic lattice and the direction of the average current density or average applied electric field [1]. Some of these theoretical predictions are already verified experimentally [2].

In this paper, we present a further extension and generalization of these studies to the case where both constituents are normal conductors, having in general nonzero Hall coefficients [3]. The macroscopic response in such systems turns out to be considerably simpler than it is in the absence of a magnetic field. Closed form asymptotic expressions are found for the microscopic current distributions and macroscopic effective magneto-resistivity tensor components. Numerical calculations of the current distributions and effective magneto-resistivity tensor components are also performed and compared with the closed form asymptotic expressions.

The case of conducting inclusions can lead to great sensitivity to both amplitude and direction of an external magnetic field and serve as a basis for magnetic field sensors and other devices.

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