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Kopnin and Volovik Reply to comment "invalidity of classes of approximate Hall effect calculations"

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Kopnin and Volovik Reply: In his Comment [1] to our paper [2], Ao points out the main reason why he thinks our calculations are not correct. The reason is not specific to the particular paper [2] but rather refers to all of our microscopic calculations (see also [3], etc.) of vortex dynamics. It is, as he claims, the incorrect use of the $\tau$ approximation. Ao agrees that the $\tau$ approximation works well for calculations of conductivity but states, strangely enough, that it fails when applied for calculating resistivity. Instead, Ao suggests to use the approach developed in Ref. [4]. Being intrigued by the possibility to discover the truth, we turn to Ref. [4] and find that the starting point is exactly the same as in all of our work on the subject: One looks for a response of the superconductor to a time-dependent displacement of the vortex; i.e., the problem looks for a response of the superconductor to a time-

Ao presents handwaving arguments that everything is wrong which is not as simple as he wants: (1) Experiments in which the forces on $^{3}$He vortices have been measured in a wide temperature range [7] are too complicated and thus can be wrong; (2) microscopic calculations using the Green function formalism [3] are wrong; (3) the spectral flow phenomenology in terms of the Landau-type theory for the Fermi system in vortex cores [8] uses $\tau$ approximation and thus is wrong, etc. Then there is a puzzle: Why do all three sources agree in the temperature dependence of both longitudinal and Hall conductivities?

The confusion regarding the transverse force on a vortex is typical for those who start to consider this problem. Here the simple results advocated by Ao can be dangerous: It is a strong temptation to take a simple formula and use it without precaution. But once the importance of the quasiparticle transport in the core and outside the core is realized, one can move further. One finds a lot of interesting things this way: Landau damping coming from the gapless excitations in $d$-wave superconductors [2]; rotational dynamics of the nonaxisymmetric vortices [9]; relation to event horizon [9]; mesoscopic effects and Zener tunneling in the core [10,11]; nonlinear transport, etc.

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