Length Scale of Bulk Quantum Hall Effect

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Quantum hall effects (QHE) are consequences of the condensation of the charge carriers into a novel macroscopic quantum state. Condensation produces steps in the hall resistance ($R_{xy}$) in fundamental units of $h/e^2$ (25812.8 Ohms), which correlate with Shubnikov-deHass oscillations in $R_{xx}$ and is represented graphically by the von Klitzing plot; which is a “double-y” graph of the hall resistance $R_{xy}$ and magnetoresistance $R_{xx}$ isotherms as functions of $B$. In two-dimensions electrical resistance per square is scale independent so the steps in $R_{xy}$ are in ohms. QHE condensation occurs in bulk systems as well. However, resistance of three-dimensional conductors depends on the sample geometry and the relevant transport coefficient, resistivity ($\rho_{xy}$), which is dimensionally different from resistance. Hence the QHE plateaus in bulk samples are not directly expressed in ohms. In this case the macroscopic $R_{xy}$ can be related to the $R_{xy}$ by a quantum length factor “L”, we define $L$ such that $R_{xy} = L^{-1}(\rho_{xy})$. By analyzing literature data [Kul’bachinskii, V.A. et al., JETP Let., 70, 767, 1999] we determine that for Sb$_2$Te$_3$, $L$ is equal to 1.7 nm a remarkable microscopic scale. This factor $L$ is not just the ratio of the macroscopic length to the cross-sectional area of the conductor; instead, it is an effective length associated with the quantum hall states.

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