Hall Conductivity and Berry Phase Effects in 2D Electron Systems and Graphene

(a) Determine the Hall conductivity of a two-dimensional (2D) electron gas subjected to a constant perpendicular magnetic field and a weak in-plane electric field, following the framework outlined in equations (43) to (49) of Ming-Che Chang's referenced work. Additionally, calculate the energy eigenvalues in the absence of an electric field.

(b) Extend this approach to graphene, where the energy dispersion of electrons is linear.

(c) Investigate the potential effects of the Berry phase on the transport properties of 2D Dirac materials.

References

- Berry phase in solid state physics, Ming-Che Chang, (Book chapter). -
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- Experimental observation of the quantum Hall effect and Berry's phase in graphene, Yuanbo Zhang, Yan-Wen Tan, Horst L. Stormer, and Philip Kim, Nature 438, 201–204 (2005). — https://doi.org/10.1038/nature04235