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Edge voltages and distributed currents in the quantum Hall effect

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In quantum Hall plateaus the current density in the interior is determined primarily by the potential gradient in its neighborhood and is, to a first approximation, independent of the local chemical potential for the electrons. The total current is, however, determined by the electrochemical potentials at the two edges. Some situations are analyzed in which the current can be distributed across the system while the mobile states at the Fermi energy are closely confined to the edges. Well-known examples of this are an annulus with an induced electromotive force round it, so that the Hall current flows between, rather than along, the edges, and a torus with a hole in it, where there are no edges which can carry current round the system. A reexamination is made of the distribution of current across a Hall bar, using arguments similar to those used by MacDonald, Rice and Brinkman, and by Thouless. It is found that the edge currents are associated with a charge distribution that in turn induces a more widely distributed current. This distributed current initially falls off rather slowly with distance from the edge, and then drops rapidly as a result of screening by the semiconductor beyond the depletion region. The voltage drop across the interior satisfies the Laplace equation in many cases, but this couples to the minority carriers and does not significantly affect the Hall current at low temperatures. Therefore the Landauer-Büttiker argument for quantized Hall conductance is valid, although the current density is not strongly localized near the edges.

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