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Conductance of a quantum wire at low electron density

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We study the transport of electrons through a long quantum wire connecting two bulk leads. As the electron density in the wire is lowered, the Coulomb interactions lead to short-range crystalline ordering of electrons. In this Wigner crystal state the spins of electrons form an antiferromagnetic Heisenberg spin chain with exponentially small exchange coupling J. Inhomogeneity of the electron density due to the coupling of the wire to the leads results in violation of spin-charge separation in the device. As a result the spins affect the conductance of the wire. At zero temperature the low-energy spin excitations propagate freely through the wire, and its conductance remains $2e^2/h$. At finite temperature some of the spin excitations are reflected by the wire and contribute to its resistance. Since the energy of the elementary excitations in the spin chain (spinons) cannot exceed $\pi J/2$, the conductance of the wire acquires an exponentially small negative correction $\delta G \propto -\exp(-\pi J/2T)$ at low temperatures $T \ll J$. At higher temperatures, $T \gg J$, most of the spin excitations in the leads are reflected by the wire, and the conductance levels off at a new universal value e^2/h. This result is consistent with experimental observations of a mini-plateau of conductance at e^2/h in quantum wires in the absence of magnetic field.