Quantum point contact in transverse magnetic field

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Consider a quantum point contact (QPC) in a transverse magnetic field (oriented perpendicularly to the plane of the 2D electronic gas), $\vec{B} = (0, 0, B)$ (Fig. 1). QPC length is less than the mean free path and the phase coherence length of free charge carriers.

1. First, consider the case $B = 0$. Electrons are laterally confined by a parabolic potential energy $V(y) = \frac{1}{2} m_n \omega_0^2 y^2$, where m_n is the effective mass of electrons in the (non-degenerate) conduction band, while ω_0 describes the magnitude of lateral confinement. The parabolic form of the potential energy is not essential for the final result, but has the advantage that analytical solutions exist in this case. Moreover, it was proved to be a good approximation if the channel is almost closed, due to negative electrical voltage applied on the gate contact. Determine the dispersion law of electronic states in QPC, in envelope wavefunction approximation. Calculate the number of transverse occupied sub-bands, as a function of Fermi energy E_F.
2. Explain how is changed the QPC conductance, when the gate voltage (i.e. the constant ω_0) varies.
3. Determine the dispersion law of electronic states in the presence of the magnetic field $\vec{B} = (0, 0, B)$, in the frame of envelope wavefunction approximation, in Landau's gauge $\vec{A} = (-yB, 0, 0)$.
4. How is changed QPC conductance, in the presence of the magnetic field, if the gate voltage varies? Are there still quantized the conductance values? If the answer is positive, plateaus are larger or narrower when compared to the case $B = 0$? How is

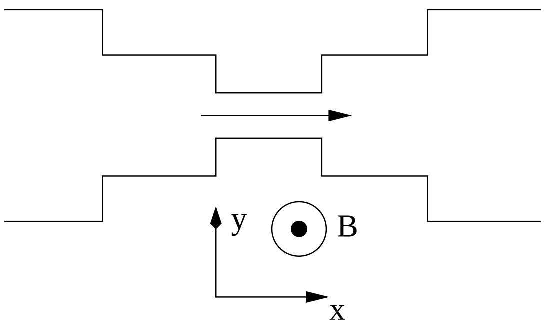

Figure 1: Schematic representation of a QPC, produced by lateral confinement of a 2D electronic gas.

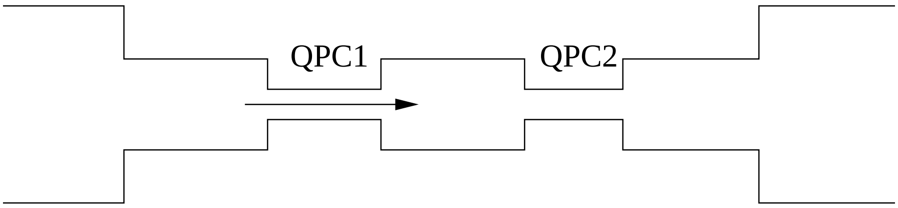

Figure 2: Schematic representation of a system of two identical QPCs in series.

changed the number of occupied transverse sub-bands when the magnetic field intensity increases? Give detailed, justified answers! What is the effect of Zeeman term?

5. Consider two identical QPCs in series (Fig. 2), joined by an ideal conductor (no scattering). What is the conductance of that system? Is the classical rule related to the equivalent electrical resistance of a series circuit obeyed?