Confinement effects on the weak-field magnetic susceptibility of a two-dimensional electron gas

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Modern techniques can restrict the motion of an electron gas to a two-dimensional plane, say in GaAs-AlGaAs heterojunctions, without posing any conceptual challenges. However, confining such a low-dimensional system whose linear dimension is comparable to or less than the cyclotron radius to a finite volume introduces new energy scales in the problem and leads to modifications in the Landau susceptibility. Explicit spin-orbit coupling (SOC), albeit small compared to other involved characteristic energies, via Rashba [1] or Dresselhaus [2] interactions produces a splitting of the otherwise degenerate energy bands around the Fermi level. This may significantly affect the thermodynamic [3] and the transport properties [4] of low-dimensional systems. We study the weak-field magnetic susceptibility of two-dimensional electron gas under isotropic parabolic, anisotropic, and Gaussian confinements. The asymmetric (anisotropic) confinement, in semiconductor quantum dot structures, restricts the motion of the charge carriers. They are quite popular in the field of elliptical quantum dots. In semiconductors, impurity is considered very important in maneuvering the system's properties. Gaussian confinement potential is a pure mathematical representation of such impurity potentials. We found that susceptibility strongly depends on the boundary confinement and removal of the boundary results in a singularity. We show that a field-dependent susceptibility emerges when the confinement is Gaussian, in contrast to the canonical case of a field-independent susceptibility. We also show that the weak-field susceptibility is independent of the anisotropy parameter as well as the spin-orbit coupling for the anisotropic confinement model. For all the other models, the susceptibility vanishes for large spin-orbit coupling [5]. We also found the de-Haas van Alphen oscillations of the magnetic susceptibility, at very low temperatures and very strong magnetic fields, depend significantly on the depth and the range of the confining potential for Gaussian confinement [6].

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