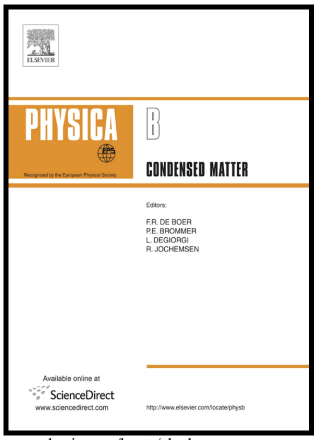

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Fractional statistical potential in graphene

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Abstract

In this work the fractional statistics is applied to an anyon gas in graphene to obtain the special features that the arbitrary phase interchange of the particle coordinates introduce in the thermodynamic properties. The electron gas is constituted by N anyons in the long wavelength approximation obeying fractional exclusion statistics and the partition function is analyzed in terms of a perturbation expansion up to first order in the dimensionless constant λ/L being L the length of the graphene sheet and $\lambda = \beta\hbar v_F$ the thermal wavelength. By considering the correct permutation expansion of the many-anyons wavefunction, taking into account that the phase changes with the number of inversions in each permutation, the statistical fermionic/bosonic potential is obtained and the intermediate statistical behavior is found. It is shown that "extra" fermonic and bosonic particles states appears and this "statistical particle" distribution depends on N. Entropy and specific heat is obtained up to first order in λ/L showing that the results obtained differs from those obtained in different approximation to the fractional exclusion statistics.

1 Introduction

Graphene, a one-atom-thick allotrope, has become one of the most significant topics in solid state physics due to its two-dimensional structure as well as from its unique electronic properties ([1],[2], [3], [4]). The electronic properties are dictated by the π and π' bands that form conical valleys touching at the two independent high symmetry points at the corner of the Brillouin zone which allows electrons to move with a constant velocity about $c/300$. Electrons near these symmetry points behave as massless relativistic Dirac fermions with an effective Dirac-Weyl Hamiltonian [3].

In the other side, quantum statistics is of fundamental importance to understand the statistical mechanics of particles whose dynamical evolution is governed by quantum mechanics. As it is well known, the statistics of the observed particles are covered by the two realisations of quantum statistics, the Bose-Einstein statistics, giving place to bosons and the Fermi-Dirac statistics, giving place to fermions. These statistics are, however, limited to three dimensions. The quantum statistics in two dimensions allows to take any phase to the interchange of the particle coordinates, giving to the fractional statistics ([5] and [6]). Particles obeing this statistics are called anyons, and have become an important topic of interest in the physics community [7], [8], [9]. It has been studied in the context of the charge-flux model ([7], [10], [11]), spin-lattices ([12], [13]) or by introducing the concept of fractional exclusion statistics proposed by Haldane-Wu ([14], [15]) and applied to the FQHE. In general, anyons are defined by a Hamiltonian for Newtonian particles of ficticious charge e^* with a δ function flux tube vector potential attached, what is called composite fermions. The phase factors arise due to interactions between particles and the gauge field of the flux tube of other particles while moving around them, known from the Aharonov-Bohm effect. This model allows one to develop