ID de Contribution: **115** Type: **Poster**

Spin in two-dimensional fermion motion with circular symmetry

mardi 14 septembre 2021 16:01 (1 minute)

We study two-dimensional fermion motion with circular symmetry using both 3+1 and 2+1 Dirac equations with a general Lorentz structure. Using a different approach than usual, we fully develop the formalism for these equations using cylindrical coordinates and discuss the quantum numbers, spinors and differential equations in both cases when there is circular symmetry. Although there is no spin quantum number in the 2+1 case, we find that, as remarked already by other authors, in this case the spin projection s in the direction perpendicular to the plane of motion can be emulated by a parameter preserving the anti-commutation relations between the Dirac matrices. The formalism developed allowed us to recognize an equivalence between a pure vector potential and a pure tensor potential under circular symmetry, if the former is multiplied by s, for any functional form of these potentials. We apply the formalism, both in the 3+1 and 2+1 cases, to the problem of a uniform magnetic field perpendicular to the plane of motion. We fully discuss its solutions, their properties, including the energy spectra, compare them to the relativistic Landau problem and obtain the non-relativistic limit as well. This calculation enabled us to clarify the physical meaning of the s parameter, representing the spin quantum number in the 3+1 case and just a parameter in the Hamiltonian in the 2+1 case.

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Classification de Session: Poster