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Instantaneous Bethe-Salpeter Equation and Its Exact Solution

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Abstract: We present an approach to solve Bethe-Salpeter (BS) equations exactly without any approximation if the kernel of the BS equations exactly is instantaneous, and take positronium as an example to illustrate the general features of the exact solutions. The key step for the approach is from the BS equations to derive a set of coupled and well-determined integration equations in linear eigenvalue for the components of the BS wave functions equivalently, which may be solvable numerically under a controlled accuracy, even though there is no analytic solution. For positronium, the exact solutions precisely present corrections to those of the corresponding Schrödinger equation in order v^1 (v is the relative velocity) for eigenfunctions, in order v^2 for eigenvalues, and the mixing between S and D components in $J^{PC}=1^{--}$ states etc., quantitatively. Moreover, we also point out that there is a questionable step in some existent derivations for the instantaneous BS equations if one is pursuing the exact solutions. Finally, we emphasize that one should take the O(v) corrections emerging in the exact solutions into account accordingly if one is interested in the relativistic corrections for relevant problems to the bound states.

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