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Duffin-Kemmer-Petiau particle in a vector exponential-like decaying field with any arbitrary J-state

M. Hamzavi[1,a], S.M. Ikhdair[2,3], and M. Amirfakhrian[1]

[1] Department of Science and Engineering, Abhar Branch, Islamic Azad University, Abhar, Iran
[2] Physics Department, Near East University, 922022 Nicosia, North Cyprus, Mersin 10, Turkey
[3] Physics Department, Faculty of Science, An-Najah National University, Nablus, West Bank, Palestine

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Abstract. The Duffin-Kemmer-Petiau (DKP) equation is solved approximately for a vector exponential-like decaying potential with any arbitrary J-state by using the Pekeris approximation. The generalized parametric Nikiforov-Uvarov (NU) method is used to obtain energy eigenvalues and corresponding wave functions in a closed form. The cases of zero total angular momentum and nonrelativistic limit are discussed too.

1 Introduction

The first-order Duffin-Kemmer-Petiau (DKP) formalism which describes spin-0 and spin-1 particles has been used to analyze relativistic interactions of spin-0 and spin-1 hadrons with nuclei as an alternative to their conventional second-order Klein-Gordon and Proca counterparts [1–5]. The DKP equation is a direct generalization to the Dirac particles of integer spin in which one replaces the gamma matrices by beta metrics but verifying a more complicated algebra as DKP algebra [6–14]. Fainberg and Pimentel presented a strict proof of equivalence between DKP and Klein-Gordon theories for physical S-matrix elements in the case of charged scalar particles interacting in minimal way with an external or quantized electromagnetic field [15,16]. Boutabia-Chéraitia and Boudjedaa solved the DKP equation in the presence of the Woods-Saxon potential for spin 1 and spin 0 and they also deduced the transmission and reflection coefficients [17]. Kulikov *et al.* offered a new oscillator model with different form of the non-minimal substitution within the framework of the DKP equation [18]. Yaşuk *et al.* presented an application of the relativistic DKP equation in the presence of a vector deformed Hulthén potential for spin-zero particles by using the Nikiforov-Uvarov (NU) method [19]. Boztosun *et al.* presented a simple exact analytical solution of the relativistic DKP equation within the framework of the asymptotic iteration method and determined exact bound-state energy eigenvalues and corresponding wave functions for the relativistic harmonic oscillator as well as the Coulomb potentials [20]. Kasri and Chetouani determined the bound-state energy eigenvalues for the relativistic DKP oscillator and DKP Coulomb potentials by using an exact quantization rule [21]. de Castro explored the problem of spin-0 and spin-1 bosons subject to a general mixing of minimal and non-minimal vector cusp potentials in a unified way in the context of the DKP theory [22]. Chagui *et al.* solved the DKP equation with a pseudo-scalar linear plus Coulomb-like potential in a two-dimensional space-time [23]. For more review, one can see refs. [24–29].

Very recently, using a Pekeris approximation, the approximate solution of the DKP equation for the vector deformed Woods-Saxon potential [30] and the vector Yukawa potential [31] have been solved with arbitrary total angular momentum $J \neq 0$ in the framework of the parametric generalization of the NU method.

The aim of this paper is to solve the DKP equation for a vector exponential-like decaying potential when the total angular momentum is non-zero, *i.e.* $J \neq 0$. Under these conditions, the DKP equation cannot be solved exactly because of the angular momentum term, $J(J+1)/r^2$, and hence we must use an approximation scheme to deal with this term.

This paper is organized as follows. In sect. 2, the DKP formalism is briefly given and discussed under a vector potential. In sect. 3, the parametric generalization of the NU method is introduced. In sect. 4, using the Pekeris

[a] e-mail: majid.hamzavi@gmail.com