Reply to "Comment on 'Solution of the Schrödinger equation for the time-dependent linear potential' "

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In this reply I discuss further the misconception in my paper [Phys. Rev. A **63**, 034102 (2001)] related to the solution of the Schrödinger equation for a particle in a time-dependent linear potential.

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Since I have presented the solution of the Schrödinger equation (SE) for a particle in a time-dependent linear potential [1], some papers have been published containing observations about my results [2–4]. In Ref. [1], I have used part of the Lewis and Riesenfeld (LR) invariant method together with a trial wave function to get the solution of the SE. In accordance with Refs. [2–4], my solution was only a particular one that is valid for null eigenvalue. In Ref. [4], Bekkar *et al.*, show where I committed the "mistake," that avoided obtaining the general solution. I did not go all the way through the LR method. Rather, instead of solving the eigenvalue equation for the linear invariant $I(t)$ given by Eq. (12) of Ref. [1], I assumed as the eigenfunction the trial function given by Eq. (13) of Ref. [1]. This was the mistake committed. Since I obtained no information on the eigenvalue, my solution is only a particular one. As shown by Bekkar *et al.* [4], to get the general solution one must follow the LR method step by step.

After reading Ref. [4], I paid attention to the validity of using the mixed method to solve the well-known unit mass time-dependent harmonic oscillator, whose Hamiltonian is

$$H(t)=\frac{p^2}{2}+\frac{1}{2}\omega^2(t)x^2, \tag{1}$$

where x and p are canonical coordinates. By assuming a quadratic form for the invariant $I(t)$ and following the steps drawn in Refs. [5,6], one can show that the wave function for this problem is given by

$$\psi(x,t)=\sum C_n e^{i\alpha_n(t)}\left[\frac{1}{\pi^{1/2}\hbar^{1/2}n!2^n\rho}\right]^{1/2}\times\exp\left[\frac{i}{2\hbar}\left(\frac{\dot\rho}{\rho}+\frac{i}{\rho^2}\right)q^2\right]H_n\left(\frac{1}{\hbar^{1/2}}\frac{q}{\rho}\right), \tag{2}$$

where $\rho\ (t)$ is the solution of the Pinney equation [7] and $\alpha_n(t)$ is given by Eq. (4) of Ref. [4].

Let us assume that the invariant has a linear form, instead of a quadratic one, namely,

$$I(t)=A(t)x+B(t)p, \tag{3}$$

where $A(t)$ and $B(t)$ are real functions.

From Eq. (3), we assume as solution of the time-dependent SE the following trial function:

$$\psi(x,t)=A_0 e^{\alpha(t)x^2+\beta(t)x+\gamma(t)}, \tag{4}$$

where $\alpha(t)$, $\beta(t)$, and $\gamma(t)$ satisfy the following equations:

$$\dot\alpha(t)=2i\hbar\alpha^2(t)-\frac{i}{2\hbar}\Omega^2(t), \tag{5}$$

$$\dot\beta(t)=2i\hbar\alpha(t)\beta(t), \tag{6}$$

$$\dot\gamma(t)=\frac{i\hbar}{2}\beta^2(t)+i\hbar\alpha(t). \tag{7}$$

Then, we can easily see that Eq. (3) is not as general as Eq. (2), indicating that in fact it seems that the mixed method is not suitable to get general solutions of the time-dependent SE. As a final remark, one can notice that depending on the sign of $\alpha(t)$, $\psi(x,t)$ can even blow up, becoming an unacceptable physical solution.

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[1] I. Guedes, Phys. Rev. A **63**, 034102 (2001).
[2] M. Feng, Phys. Rev. A **64**, 034101 (2001).
[3] J. Bauer, Phys. Rev. A **65**, 036101 (2002).
[4] H. Bekkar, F. Benamira, and M. Maamache, Phys. Rev. A **68**, 016101 (2003).
[5] H.R. Lewis, Jr. and W.B. Riesenfeld, J. Math. Phys. **10**, 1458 (1969).
[6] I.A. Pedrosa, G.P. Serra, and I. Guedes, Phys. Rev. A **56**, 4300 (1997).
[7] E. Pinney, Proc. Am. Math. Soc. **1**, 681 (1950).

