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RESEARCH ARTICLE: A NOTE ON APPLICATIONS OF DINESH VERMA TRANSFORMATION

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ABSTRACT

If the energy of event atoms is low, only s-wave is spread and all other waves in the partial waves in the region of non-zero potential are so tiny that they remain unchanged. In this paper, we talk about the scattering of low energy particles by perfectly rigid sphere. The quantum mechanical total scattering cross-section for low energy particles by perfectly rigid sphere is obtained, and is compared with classical result.

Index terms: Scattering, Perfectly Rigid Sphere, Low Energy Particles, Dinesh Verma Transform.

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INTRODUCTION

If a beam of particles of any kind is going at matter the particles shall be repelled from their original path as a result of collision with the particles of the matter which they encounter. A useful information about the forces and interactions between the scattered particles and the target has given by scattering experiments with atoms and nuclei [1],[3],[5],[6],[7],[8],[9],[10],[11],[12],[13]. In order to treat scattering problem quantum mechanically, by the wave functions that are solutions of the Schrodinger equations, we describe the scattering. The scattering cross-section is the probability that a particle will be scattered as it traverses a matter of given thickness [2],[14],[15],[16]. The total scattering cross-section is the total number of particles scattered in a unit and at low energy, it is given by $\rho_{total} = \frac{4\pi}{b^2} sin^2 \varepsilon_0$, where ε_0 is the phase shift of the s-wave caused by scattering potential [3], [4] [17],[18],[19],[20] In this paper, we apply Dinesh Verma transformations for solving the Schrodinger equation to obtain the phase shift of the s-wave caused by scattering potential and are then used to obtain the quantum mechanical total scattering cross-section for low energy particles by perfectly rigid sphere.

Definition of Dinesh Verma transformations:

Let F (y) is a well-defined function of real numbers y ≥ 0. The Laplace transformation of F (y), denoted by f (q) or D {F (y)}, is defined as

$D\{F(y)\} = q^5 \int_0^\infty e^{-qy} F(y) dy = f(q)$, which is provided an integral converges. Here, q *is* the parameter which may be a real or complex number and D is the Dinesh Verma transformation operator.

Dinesh Verma Transform (DVT) of some elementary Functions

- $D\{t^n\} = \frac{n!}{s^{n-4}}$, $where\ n = 0,1,2,..$
- $D\{e^{at}\} = \frac{s^5}{s-a}$,
- $D\{sinat\} = \frac{as^5}{s^2+a^2}$,
- $D\{cosat\} = \frac{s^6}{s^2+a^2}$
- $D\{sinhat\} = \frac{as^5}{s^2-a^2}$,
- $D\{coshat\} = \frac{s^6}{s^2-a^2}$.
- $D\{\delta(t)\} = s^5$

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The Inverse Dinesh Verma Transform (DVT) of some of the functions are given by-

- $D^{-1}\left\{\frac{1}{s^{n-4}}\right\} = \frac{t^n}{n!}$, where $n = 0,1,2,..$
- $D^{-1}\left\{\frac{s^5}{s-a}\right\} = e^{at}$,
- $D^{-1}\left\{\frac{s^5}{s^2+a^2}\right\} = \frac{\sin at}{a}$,
- $D^{-1}\left\{\frac{s^6}{s^2+a^2}\right\} = \cos at$,
- $D^{-1}\left\{\frac{s^5}{s^2-a^2}\right\} = \frac{\sinh at}{a}$,
- $D^{-1}\left\{\frac{s^6}{s^2-a^2}\right\} = \cosh at$,
- $D^{-1}\{s^5\} = \delta(t)$

DINESH VERMA TRANSFORM (DVT) OF DERIVATIVES

$$D\{f'(t)\} = p\bar{f}(p) - p^5 f(0)$$

$$D\{f''(t)\} = p^2\bar{f}(p) - p^6 f(0) - p^5 f'(0)$$

$$D\{f'''(y)\} = p^3\bar{f}(p) - p^7 f(0) - p^6 f'(0) - p^5 f''(0)$$

METHODOLOGY

Scattering of low energy of particles were by perfectly rigid sphere. A perfectly rigid sphere [1], [2] of radius R is represented as V (r) = ∞ for r <R and V (r) = 0 for r> R.

The wave function goes for r <R.

The radial part of time - independent Schrodinger equation for r >R is written as [3], [4]:

$$\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial u_l(r)}{\partial r}\right) - \frac{l(l+1)u_l(r)}{r^2} + \frac{2mE}{\hbar^2}u_l(r) = 0 \; ... (1)$$

for s-wave, l = 0, hence from equation (1) ,

$$\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial u_0(r)}{\partial r}\right) + \frac{2mE}{\hbar^2}u_0(r) = 0 \; ..... (2)$$

Let $U_0(r) = r\,u_0(r)$

or $u_0(r) = U_0(r)/r$ ...... (3),

then

$$u_0{'}(r) = \frac{r\frac{\partial U(r)}{\partial r} - U_0(r)}{r^2}$$

Or

$$r^2 u_0{'}(r) = r\,U_0{'}(r) - U_0(r) \; ..... (4)$$

Differentiate partially equation (4) w.r.t. r, we get

$$\frac{\partial}{\partial r}\left(r^2 u_0{'}(r)\right) = r\,U_0{''}(r) + U_0{'}(r) - U_0{'}(r)$$

Or

$$\frac{\partial}{\partial r}\left(\left(r^2 u_0{'}(r)\right)\right) = r\,U_0{''}(r) \; ...... (5)$$

from equation (5) & (2), we get

$$U_0{''}(r) + \frac{2mE}{\hbar^2}U_0(r) = 0$$

Or

$$U_0{''}(r) + k^2 U_0(r) = 0 \; .... (6)$$

where $k = \sqrt{\frac{2mE}{\hbar^2}}$.

By Dinesh Verma transformation method, solution of equation (6).

$$s^2\,\overline{U_0}(s) - s^6\,U_0(0) - s^5 U_0{'}(0) + k^2\,\overline{U_0}(s) = 0 ... (7)$$

Since $U_0(0)$ and $U_0{'}(0)$ are constants, therefore, let us put $U_0(0)$ = c and $U_0{'}(0)$ = d in equation (7), we get

$$s^2\,\overline{U_0}(s) - s^6 c - s^5 d + k^2\,\overline{U_0}(s) = 0$$

Rearranging the equation, we get

$$\overline{U_0}(s) = \frac{s^6 c + s^5 d}{s^2 + k^2}$$

Or $\overline{U_0}(s) = \frac{s^6 c}{s^2+k^2} + \frac{s^5 d}{s^2+k^2}$ ...... (8)

Taking inverse Dinesh Verma transform [6] of equation (8), we get

$$U_0(r) = c\cos kr + \frac{d}{k}\sin kr \; .... (9)$$

Let c = $A\sin\varepsilon_0$ and $\frac{d}{k} = A\cos\varepsilon_0$, where ε_0 is the phase shift of the s-wave caused by scattering potential, then equation (9) can be rewritten as

$$U_0(r) = A\left[\sin\varepsilon_0\cos kr + \cos\varepsilon_0\sin kr\right] \; .... (10)$$

Using equation (3), we can write

$$u_0(r) = \frac{A\left[\sin\varepsilon_0\cos kr + \cos\varepsilon_0\sin kr\right]}{r}$$

Or $u_0(r) = \frac{A\sin(kr+\varepsilon_0)}{r}$... (11)

This equation represents the solution of wave equation for r > R.

Since the wavefunction $u_0(r)$ is continuous at r = R, therefore, it vanishes at r = R i.e. $u_0(r) = 0$. Therefore equation (11) gives

$$\sin(kR + \varepsilon_0) = 0$$

Or $kR + \varepsilon_0 = 0$

Or $\varepsilon_0 = -kR$ .... (12)

This equation (12) gives the phase shift of the s-wave caused by scattering potential.

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Now, quantum mechanically, the total scattering cross-section for low energy particles i.e. for s-wave is given by [3], [4]

$$\rho_{total} = \frac{4\pi}{k^2} sin^2 \varepsilon_0$$

Or

$$\rho_{total} = \frac{4\pi}{k^2} sin^2 (\text{kR})$$

Or

$$\rho_{total} = 4\pi R^2 \frac{sin^2(\text{kR})}{(kR)^2}$$

Inthe low energy limit, $k \rightarrow 0$.

Since in the limit $k \rightarrow 0$, $\frac{sin^2(\text{kR})}{(kR)^2} = 1$,

$therefore,\ \rho_{total} = 4\pi R^2$, which is equal to the geometrical cross-section of the rigid sphere. Classically, the scattering cross-section [4] for rigid sphere of same radius is πR^2.

Thus, the total scattering cross-section for low energy particles due to a perfectly rigid sphere is four times the Classical scattering cross-section for rigid sphere of same radius.

CONCLUSION

The total scattering cross-section for low energy particles by a perfectly rigid sphere is obtained quantum mechanically. In the low energy limit, quantum mechanically, it is found thatthe total scattering cross-section for low energy particles by a perfectly rigid sphere is equal to the geometrical cross-section of the rigid sphere, and is four times the Classical scattering cross-section for rigid sphere of same radius.

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