[**pdf**] Submitted on Jan/20/2011

When coupled with another particle, a charged particle produces the Coulomb potential, weak coupling potential and Yukawa potential

Authorrs: Xianzhao Zhong.

Comments: p6.

abstract: When a charged particle couples through its field with another particle, and based on the dissimilar coupling strengths,it produces the 3 different potential functions φ, namely, the Coulomb potential, weak coupling potential and Yukawa potential. The 3 potentials show the common characteristics: They are all periodic functions in time-space. Under the influence of those potentials, a particle takes periodic motions in space. The author notes that the electric field strength of an isolated charged particle would not show the divergent phenomenon.

Category: Classical physics.

When coupled with another particle, a charged particle produces the Coulomb potential, weak coupling potential and Yukawa potential

Xianzhao Zhong *

Meteorological college of Yunnan Province,

Kunming, 650228, China

Abstract

When a charged particle couples through its field with another particle, and based on the dissimilar coupling strengths,it produces the 3 different potential functions φ, namely, the Coulomb potential, weak coupling potential and Yukawa potential. The 3 potentials show the common characteristics: They are all periodic functions in time-space. Under the influence of those potentials, a particle takes periodic motions in space. The author notes that the electric field strength of an isolated charged particle would not show the divergent phenomenon.

Key words: Coulomb potential, weak potential, Yukawa potential.

PACS: 03.50.De, 03.50.Kk

* *E-mail address*: zhxzh46@163.com

1 Introduction

When coupled through its field with another particle, a charged particle produces the potential function φ. Different strengths of the coupling field would distribute the wave number k in dissimilar intervals, and hence produce 3 different potential functions, namely, the Coulomb potential, weak coupling potential and Yukawa potential. In time and space, the field of a particle shows wave characteristics, and the coupling-induced potential becomes potential functions that demonstrate periodic features. Influenced by such periodic potential, motion of a particle would be taken periodic features in space. An isolated, charged particle does not couple with other particles, and such a particle would not produce the potential function, and its field would not demonstrate the divergent phenomenon.

2 Uniformity Between the Particle Characteristics and Wave Characteristics

In we know that the free electromagnetic field acts in wave forms, and take that field $\mathbb{F}$ are the electric field $\mathbb{E}$ or magnetic field $\mathbb{B}$. We have the field form [1] $\mathbb{F} = \mathbb{F}_0 \exp(-\lambda k \cdot r(1+i)) \exp(\lambda \omega t(1+i))$.

By taking the average value over longer times, we get mean values of electric field and magnetic field, $\langle \mathbb{E}(r) \rangle_t$ and $\langle \mathbb{B}(r) \rangle_t$ [1] over longer time formula

$$
\begin{aligned}
\langle \mathbb{E}(r)\rangle_{t} &= \int_0^\infty \mathbb{E}(r,t)/t dt = \pi/2\ \mathbb{E}_{0} \exp[-\lambda k\cdot r(1+i)],\\
\langle \mathbb{B}(r)\rangle_{t} &= \int_0^\infty \mathbb{B}(r,t)/t dt = \pi/2\ \mathbb{B}_{0} \exp[-\lambda k\cdot r(1+i)].
\end{aligned} \tag{1}
$$

In the space, considering that when wave number k and the wave amplitude $\mathbb{E}_0$ and $\mathbb{B}_0$ are constant, set $\mathbb{F}_0$ for (1) we have the field $\mathbb{F}$ mean values

$$\langle \mathbb{F}(r)\rangle_{t} = \mathbb{F}_{0} \exp(-\lambda k\cdot r) \exp(-i\lambda k\cdot r). \tag{2}$$

In the case of high frequency particles, namely, $\omega \to \infty$, from $k = \omega/c$, we have $k \to \infty$. The distribution of wave amplitude within a narrow area on the r shows obvious particle characteristics [2]. the wave amplitude $\mathbb{F}_0 \exp(-\lambda k\cdot r)$ converges into a small point in space. At this moment, the wave amplitude shows the strongest particle characteristics whereas the slightest wave characteristics.

In the case of low frequency electromagnetic field, namely, $\omega \to 0$ the wave amplitude scatters over a larger area on the r. It tends to better portray wave characteristics $\mathbb{F}_0 \exp(-i\lambda k\cdot r)$, At $k \to 0$, the wave amplitude is $\mathbb{F}_0 \exp(-\lambda k\cdot r) \to \mathbb{F}_0$, and its particles characteristics also tend to be 0. The wave become $\mathbb{F}_0 \exp(-i\lambda k\cdot r)$, or $\mathbb{F}_0 \exp(-i\lambda k\cdot r) \exp(i\lambda\omega t)$. In the low frequency state, the waves show weaker particle characteristics whereas stronger wave characteristics.

The wave characteristics and particle characteristics of the free electromagnetic field are closely related with the frequency of the field.

When we analyze its wave characteristics, it also show particle characteristics, and vise versa. For particles at different frequencies, it tend to show stronger wave characteristics when it takes on weaker particle characteristics, and vise versa. We find it difficult to strictly draw a demarcation line between such dual characteristics of the electromagnetic particles [2].

3 The Potential Function of a Particle

An isolated and charged particle tends to carry a charge q_0 When its only one kind of field $\mathbb{E}$ is at the polarization state in the charged, we hypothesize the particle is in coordinate system S, then the field would distribute on the r-axis. and the field $\mathbb{E}$ satisfied wave equation. At this time. we suppose the field would agree not only with equation, and the wave equation solution mean values $\langle \mathbb{E}(r) \rangle_t$ over longer time. the average value would agree with equation (2)

$$\langle \mathbb{E}(r) \rangle_t = \pi/2\ \mathbb{E}_0 \exp(-\lambda k \cdot r(1+i)). \tag{3}$$

When this charged particle is coupled with a charged system, the field would also show wave numbers k changes. If the distance r between the particle and the system is a constant. From (3), the particle would show system-dependent potential as indicated below

$$\varphi_1 = \int_0^\infty \pi/2\ \mathbb{E}_0 \exp[-\lambda k{\cdot}r(1{+}i)]{\cdot}dk = -\pi/(4\lambda) \mid \mathbb{E}_0 \mid r^{-1}{+}i\pi/(4\lambda) \mid \mathbb{E}_0 \mid r^{-1}, \tag{4}$$

in which the first term denotes the field-generated static potential. Compared with the Coulomb's potential [3] $\varphi_c = q_0 r^{-1}$, we have

$$q_0 = \pi/(4\lambda) \mid \mathbb{E}_0 \mid, \tag{5}$$

$$\varphi_c = q_0 \, r^{-1}. \tag{6}$$

The second term of (4) is an periodic potential. Hence we have Coulomb's potential

$$\varphi_1 = -q_0 \, r^{-1} + i q_0 \, r^{-1} = -\varphi_c + i\varphi_c. \tag{7}$$

If this particle is only weakly coupled with the system, from (5), we have weak coupling potential

$$\varphi_2 = \int_0^k \pi/2 \; \mathbb{E}_0 \exp[-\lambda k{\cdot}r(1{+}i)]{\cdot}dk = -q_0 \, r^{-1}(1{-}i)(\exp(-\lambda k{\cdot}r(1{+}i)){-}1). \tag{8}$$

However, when this particle is tightly coupled with the system, from (3) and (5), we have

$$\varphi_3 = \int_k^\infty \pi/2 \; \mathbb{E}_0 \exp(-\lambda k{\cdot}r(1{+}i)){\cdot}dk = -q_0 \, r^{-1}(1{-}i) \exp(-\lambda k{\cdot}r) \exp(-i\lambda k{\cdot}r). \tag{9}$$

In equation (9), the wave amplitude is $q_0 r^{-1} \exp(-\lambda k \cdot r)$. By substituting wave number $k = \omega/c$ and the dual energy relation $mc^2 = \hbar\omega$ into the wave amplitude, we have

$$\varphi_y = -q_0 \, r^{-1} \exp(-\lambda mcr/\hbar). \tag{10}$$

Comparing equation (10) with the Yukawa's potential, the wave amplitude φ_y of the periodic potential in the space under strong coupling is the Yukawa's potential [4] $\varphi_y = -q_0\, r^{-1} \exp(-mcr/\hbar)$. Hence (9) we have.

$$\varphi_3 = \varphi_y \exp(-i\lambda k \cdot r) - i\varphi_y \exp(-i\lambda k \cdot r). \tag{11}$$

Above, each and every energy of particle is $q_0\varphi_j$ $(j = 1, 2, 3)$. These complex potential functions φ_1, φ_2 and φ_3 are spacial periodic function [5], a charged particle move in the potential show periodic motion characteristics in space. Now we consider that the field of an isolated and charged particle is determined by (3) and (5), and takes spatial the unit vector $\mathbf{e}_r$ of $\mathbb{E}_0$ then we have

$$\langle \mathbb{E}(r) \rangle_t = 2\lambda q_0 \exp(-\lambda k \cdot r(1+i))\, \mathbf{e}_r. \tag{12}$$

When $r \to 0, (12)$ can be changed into

$$\langle \mathbb{E}(r) \rangle_t = 2\lambda q_0\, \mathbf{e}_r. \tag{13}$$

At any arbitrarily taken point in the space, the field of an isolated and charged particle would take a limited value, and the field would never show divergence even if at the particle itself field. When the particle is coupled with the system, however, $r \to 0$, the field and potential φ_1, φ_2, φ_3 of the particle would display ∞.

References

[1] X.Z. Zhong. *ELECTROMAGNETIC FIELD EQUATION AND FIELD WAVE EQUATION*. preprint., 2010.

[2] X.Z. Zhong. *PARTICLE CHARACTERISTICS, ENERGY AND ACTION OF THE FREE ELECTROMAGNETIC FIELD*. preprint., 2010.

[3] E.M. Purcell. *ELECTRICITY AND MAGNETISM*. McGraw-Hill, Inc., 1965.

[4] J.D. Jackson. *CLASSICAL ELECTRODYNAMICS*, 3rd ed. John-Wiley & Sons, Inc., 1999.

[5] L.I. Schiff. *QUANTUM MECHANICS*. 3rd ed. McGraw-Hill Book co. Inc., 1958.