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Research Article

Electromagnetic Radiation of Accelerated Charged Particle in the Framework of a Semiclassical Approach

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Abstract

The problem of the electromagnetic radiation produced by charge distributions in the framework of a semiclassical approach proposed in the work by Bagrov, Gitman, Shishmarev, and Farias Jr. [J. Synchrotron Rad. **27**, 902–911 (2020)] is addressed here. In this approach, currents, generating the radiation are considered classically, while the quantum nature of the radiation is kept exactly. Quantum states of the electromagnetic field are solutions of Schrödinger's equation, and relevant quantities to the problem are evaluated with the aid of transition probabilities. This construction allows us to introduce the quantum transition time in physical quantities and assess its role in radiation problems by classical currents. Radiated electromagnetic energies are studied in detail and a definition for the rate at which radiation is emitted from sources is presented. In calculating the total energy and rate radiated by a pointlike charged particle accelerated by a constant and uniform electric field, it is discovered that these results are compatible with results obtained by other authors in the framework of the classical radiation theory under an appropriate limit. Numerical and asymptotic analyses of the results are also performed.

Conflict of Interest

The authors declare no conflict of interest.

Open Research

Data Availability Statement

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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35 We consider the Minkowski spacetime, $\eta_{\mu\nu} = \mathrm{diag}(+1, -1, -1, -1)$, parameterized by coordinates $x^{\mu} = (x^0 = ct, \mathbf{r})$. Boldface letters denote three-dimensional vectors, for example, $\mathbf{r} = (x^i, i = 1, 2, 3)$, and differentials of boldface letters denote volume integration measures, for example, $d\mathbf{r} = dx^1 dx^2 dx^3$. Gaussian units are used.

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37 That is, the electromagnetic energy of *N* photons with all possible momenta and polarizations.

38 For example, $\mathbf{k} = (\mathbf{k}_\perp, \mathbf{k}_\parallel)$, $\mathbf{k}_\perp = (k_x, k_y, 0)$, $k_\parallel = k_z$. The meanings of the symbols "⊥" and "∥" employed here should not be confused with those used in Subsection 2.1 .

39 *z* and ξ can also be defined through the identities $z \sinh \xi = (\varrho c / \varepsilon) k_\parallel$, $z \cosh \xi = (\varrho c / \varepsilon) |\mathbf{k}|$.

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41 In classical theory, there is the possibility to define a time-dependent electromagnetic energy by assuming that the current is exposed to the external field over a finite time interval.[7]

However, such time-dependent energy differs from the one obtained within the semiclassical formulation.

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