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Quasi-classical description of the helium atom and the behavior of constituent quarks for hadrons

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As is known, N. Bohr constructed the first semi-quantum single-particle theory of the hydrogen atom, which led to a coincidence with the subsequently developed quantum mechanics for the radius of the hydrogen atom and its energy of the ground and excited states. For the helium atom, which has two electrons, difficulties arose in Bohr's theory. They also exist in quantum mechanics, not to mention the relativistic quantum theory of many bodies. However, when considering two electrons in a helium atom, one can simplify the problem and limit oneself to considering the motion of electrons located at opposite ends of a circular orbit with a nucleus at its center. Such consideration is found in the scientific literature [1].
In this approach we approached the problem of hadron physics, where the interaction potential at a distance r of constituent quarks can be chosen in the form of the Cornell potential [2], containing an attractive term (string tension for quarks) br and a QCD term a/r. The parameters of the semi-phenomenological Cornell potential a and b are not well defined. In many works (see, for example, [2-4]) they are often determined for meson resonances (a two-particle problem). In this work we determined these two parameters from two equations for the expressions of the pion and proton masses, the masses and radii of which are known. The expressions for the masses taking into account the relativistic motion of constituent quarks turned out to be quasi-classical, but at the same time it was possible to bypass the problem of the relativistic quantum problem of two and three bodies [5]. Using the parameters of the Cornell potential that we found, we determined the masses and radii of the meson resonances. We also found approximate expressions for the wave functions for the spectrum of heavy Ψ quarkonium, consisting of c and anti c quarks.

Such an independent determination of the parameters of the Cornell potential has important implications for hadron spectroscopy and the problem of reaching the critical point for quark-gluon plasma in constructing models of tetraquarks and pentaquarks. The transition to a semiclassical hydrodynamic approach can establish a connection between the interaction forces of quarks in hadrons and the interaction of hadrons in final nuclei [6.7]. The helium atom model can be useful in the search for dark helium atoms [8], as well as in the detection of new particles - candidates for the role of dark matter particles [9].

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