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Extended Abstract

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Generalization of framework of analytic mechanics and unified description of quantum and classical physics

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A unified field theory (UFT) is a type of field theory that allows all that is usually thought of as fundamental forces and elementary particles to be written in terms of a pair of physical and virtual fields. According to the modern discoveries in physics, forces are not transmitted directly between interacting objects, but instead are described and interrupted by intermediary entities called fields. Variational principle plays a fundamental role in elucidating the structure of classical mechanics, clarifying the origin of dynamics and the relation between symmetries and conservation laws. In classical mechanics, the optimized function is characterized by Lagrangian, defined as T-V with T and V being a kinetic and a potential terms, respectively. We can still argue a variational principle even in quantum mechanics, but the Lagrangian does not have the form of T-V any more. Therefore, at first glance, any clear or direct correspondence between classical and quantum mechanics does not seem to exist from the variational point of view, but it does exist. For this, we need to extend the usual variational method to the case of stochastic variables. This is called stochastic variational method (SVM). The Schrödinger equation can be then obtained by the stochastic optimization of the action which leads to, meanwhile, the Newton equation in the application of the classical variation. From this point of view, quantization can be regarded as a process of stochastic optimization and the invariance of the action leads to the conservation laws in quantum mechanics. In this manner, classical and quantum behaviors are described in a unified way under SVM. Although SVM was originally proposed as the reformulation of Nelson’s stochastic quantization, its applicability is not restricted to quantization. In fact, dissipative dynamics such as the Navier-Stokes-Fourier (viscous fluid) equation can be obtained by applying SVM to the Lagrangian which leads to the Euler (ideal fluid) equation in the classical variational method. This method is useful even to obtain coarse-grained dynamics. For example, the Gross-Pitaevskii equation is regarded as an optimized dynamics in SVM. Therefore it is possible to consider that the study of SVM enables us to generalize the framework of analytic mechanics.

The framework of generalized probabilistic theories is a powerful tool for studying the foundations of quantum physics. It provides the basis for a variety of recent findings that significantly improve our understanding of the rich physical structure of quantum theory. This review paper tries to present the framework and recent results to a broader readership in an accessible manner. To achieve this, we follow a constructive approach. Starting from few basic physically motivated assumptions we show how a given set of observations can be manifested in an operational theory. Furthermore, we characterize consistency conditions limiting the range of possible extensions. In this framework classical and quantum physics appear as special cases, and the aim is to understand what distinguishes quantum mechanics as the fundamental theory realized in nature. It turns out non-classical features of single systems can equivalently result from higher dimensional classical theories that have been restricted. Entanglement and non-locality, however, are shown to be genuine non-classical features.

A formulation of quantum-classical hybrid dynamics is presented, which concerns the direct coupling of classical and quantum mechanical degrees of freedom. It is of interest for applications in quantum mechanical approximation schemes and may be relevant for the foundations of quantum mechanics, in particular, when it comes to experiments exploring the quantum-classical border. The present linear theory differs from the nonlinear ensemble theory of Hall and Reginatto, but shares with it to fullfill all consistency requirements discussed in the literature, while earlier attempts failed in this respect. Our work is based on the representation of quantum mechanics in the framework of classical analytical mechanics by A. Heslot, showing that notions of states in phase space, observables, Poisson brackets, and related canonical transformations can be naturally extended to quantum mechanics. This is suitably generalized for quantum-classical hybrids here. A theory of classical quantum mechanics (CQM) is derived from first principles that successfully applies physical laws on all scales. Using Maxwell's equations, the classical wave equation is solved with the constraint that a bound electron cannot radiate energy. By further application of Maxwell's equations to electromagnetic and gravitational fields at particle production, the Schwarzschild metric (SM) is derived from the classical wave equation which modifies general relativity to include conservation of spacetime in addition to momentum and matter/energy. The result gives a natural relationship between Maxwell's equations, special relativity, and general relativity. It gives gravitation from the atom to the cosmos.

Bottom Note: *This work is partly presented at International Conference on Physics June 27-29, 2016, New Orleans, USA*