It is hard to overestimate the importance of the theory of electromagnetic (EM) interactions in the body of our knowledge. It is the only interaction that is equally significant at all spatial scales: gigantic cosmic scales which are relevant to EM radiation propagating through the Universe, macroscopic scales covering our life on Earth, and microscopic atomic scales. The significance of EM interactions at all spatial scales poses great challenges to their fundamental theory. The best theoretical minds worked tirelessly through the span of several centuries to develop and perfect the electromagnetic theory which we have today. The EM theory was advanced many times by remarkable discoveries during its historical development. These discoveries include the wave nature of light and its polarization, the Maxwell prediction of EM waves, the unification of light, electric and magnetic phenomena, special relativity, and quantum theory. The phenomena at cosmic and macroscopic scales are described remarkably well by classical electrodynamics, whereas the understanding of phenomena at atomic scales requires quantum mechanics (QM). The classical and quantum-mechanical approaches are fundamentally different. Many atomic phenomena do not find explanation in the classical framework, and within quantum mechanics the micro- and macroscales are related rather loosely by the “correspondence principle”.

The purpose of this monograph is to present our recently developed neoclassical theory of electromagnetic interactions. We demonstrate that the classical EM theory can be extended down to atomic scales so that many phenomena at atomic scales, usually explained in the quantum-mechanical framework, can be explained in our neoclassical framework. The proposed extension bridges the classical and quantum-mechanical approaches, so they are not separated by a gap but rather overlap in a large common domain. Our theory, though similar to QM in some respects, is markedly different from it. In particular, (i) there is no need, in our theory, for the correspondence principle and consequent quantization procedure to obtain the wave equation; (ii) the Heisenberg uncertainty principle, though quite often applicable, is not a universal principle; (iii) there is no configuration space; (iv) there is no probabilistic interpretation of the wave function.
Our neoclassical theory models the EM interactions between elementary charges based on the Lagrangian framework. The theory is manifestly relativistic, and it is self-consistent at all spatial scales. At the center of the theory is the concept of an elementary charge which is not a point but an entity distributed in space, propagating as a wave; nevertheless it can be well localized in relevant situations, exhibiting point-like features. The behavior of the charge in different regimes is described by different approximations in the same framework. In particular, the theory accounts for the de Broglie phase wave mechanics, the Schrödinger wave mechanics, including the hydrogen atom spectrum, the EM radiation phenomena, and the classical theory of point charges interacting with the EM field through the Lorentz forces.

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