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Editorial

Symmetry in Electromagnetism

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Electromagnetism plays an essential role, both in basic and applied physics research. The discovery of electromagnetism as the unifying theory for electricity and magnetism represented a cornerstone in modern physics. From the very beginning, symmetry was crucial to the concept of unification: Electromagnetism was soon formulated as a gauge theory, in which a local phase symmetry explained its mathematical formulation. This early connection between symmetry and electromagnetism shows that a symmetry-based approach to many electromagnetic phenomena is recurrent, even today.

Moreover, many crucial technological advances associated with electromagnetism have shaped modern civilization. The control of electromagnetic radiation in nearly all its spectra and scales is still a matter of deep interest. With the advances in material science, even at the nanoscale, the manipulation of matter–radiation interactions has reached unprecedented levels of sophistication. New generations of composite materials present effective electromagnetic properties that permit the molding of electromagnetic radiation in ways that were unconceivable just a few years ago. This is a fertile field for applications and for basic understanding in which symmetry, as in the past, bridges apparently unrelated phenomena, from condensed matter to high-energy physics.

Symmetry is the key tool in the contributions included in this Special Issue. In the context of electromagnetism, the approaches based on symmetry very often lead to diverse treatments of orbital angular momentum or pseudomomentum (as defined in e.g., [1,2]). In this direction, the most sophisticated modern approaches discuss the vectorial case, and in [3], the authors include spin-orbit coupling in nonparaxial fields, and perform a complete an analytical study of the case. The study of electromagnetic knots is also connected to orbital angular momentum, which are a consequence of applying topology concepts to Maxwell equations; in [4] the authors apply symmetry transformations to a particular electromagnetic knot, the hopfion field, to obtain a new set of knotted solutions with the properties of null. Very related to the properties of orbital angular momentum (see [1]) are periodic structures, which play a prominent role in many electromagnetic systems, e.g., microwave and antenna devices. In [5] a method to obtain the relevant transmission, reflection or absorption characteristics of a device obtained from the dispersion diagram are introduced, using general purpose electromagnetic simulation software. Digging deeply into the theory, in [6] the authors present a thorough study of quantum anomalies, which occur when a symmetry of a classical field theory is not also a symmetry of its quantum version. This is discussed in the context of a new example for quantum electromagnetic fields propagating in the presence of gravity, and applications for information extraction ARE foreseen. In this direction, constraint equations in Maxwell theory are discussed in [7]. Interestingly, this work is set in the context of an analogy with constraints of general relativity. A very deep analysis of a fully relativistically covariant and gauge-invariant formulation of classical Maxwell electrodynamics is included in [8], where the authors show the relationship of the symmetry of the inhomogeneous equations obtained and that of Minkowski spacetime. Of a great theoretical interest is also the work presented in [9], where the authors elaborate and improve the previous proposal of a nonlocal action

functional for electrodynamics depending on the electric and magnetic fields, instead of potentials. They then use this formalism to confront the electric–magnetic duality symmetry of the electromagnetic field and the Aharonov–Bohm effect, two subtle aspects of electrodynamics.

Also, this book includes many applications, such as in sustainable smart buildings [10], or in magnetocardiography, where in [11] the authors present an improved variational mode decomposition model used to decompose the nonstationary signal. The magnetic properties of barium hexaferrite doped with titanium were studied in [12], where the authors propose that they could be used in the recording equipment and permanent magnets. The application to high speed systems is very appealing, such as those related to the Hyperloop concept; in particular in [13], the design and analysis of a plate-type electrodynamic suspension structure for the ground high-speed system is introduced. Finally, a report on the results of research into a vibration-powered milli-or micro-generator is given in [14], where the generators harvest mechanical energy at an optimum level, utilizing the vibration of its mechanical system; here, the authors compare some of the published microgenerator concepts and design versions by using effective power density, among other parameters, and they also provide complementary comments on the applied harvesting techniques.

This book includes papers focusing on detailed and deep theoretical studies to cutting edge applications, with many of the papers includED ALREADY harvesting many citations. The fruitful study of symmetry in electromagnetism continues to offer many encouraging surpriseS, both at a basic and an applied level.

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