

Preface

The theory of electromagnetism, in the form conceived by J.C. Maxwell, can boast 130 years of honorable service. It has withstood the severest tests, proving itself to be, for completeness and elegance, among the most solid theories. Very few would doubt its validity, to the extent that they may be more inclined to modify the point of view of other theories, rather than question Maxwell's equations. In fact, faith in the model has been strong enough to obscure a certain number of "minor" incongruities, resulting in a whole string of justifications and leading to the development of other theories.

However, the truth is that although these time-honored equations excellently solve complex problems, they are nevertheless unable to simulate the simplest things. They are not capable, for instance, of describing what a solitary signal-packet is, which is one of the most elementary electromagnetic phenomena. Alternative models have been proposed with the aim of including solitons in the theory, but they have been unsuccessful in acquiring long-term credibility, because based on deliberate adjustments, which, while accommodating specific aspects, cause the model to lose general properties.

The development of modern field theory, which was very prosperous in the first half of the last century, has magnified the role of the equations, giving them a universal validity in the relativistic framework. However, this progress has come to a halt, despite the impression one has of being not too far from the goal of unifying electromagnetism and gravitation theory.

We are going to make some statements that many readers will certainly consider heretical. We think that the various anomalies in Maxwell's model are not incidental, but rather consequences of a still insufficient theoretical

description of electromagnetic phenomena. In fact, it is our opinion that the flaws run deeper than might be expected, and therefore that this fundamental building block of physics needs extensive revision. The process of review we are facing is so radical that the entire conceptual framework needs to be re-thought from the beginning. Then again, if it were just a matter of small adaptations, this revision would have already been made a long time ago.

We shall start by pointing out some facts, which may be considered marginal at a practical level, in order to highlight contradictions. We solve these problems by making appropriate adjustments to the Maxwell equations. This will allow for the construction of a new model, whereby all the inconsistencies will be solved and a better understanding of electromagnetic phenomena will be achieved. The suitability of this approach will quickly be made evident to the reader, by a sequence of remarkable coincidences, which make the model as elegant as Maxwell's, while providing greater scope for development. Indeed, the new set of equations explains many open questions and establishes links between electromagnetism and other theories that have either been the subject of research for a long time, or have been hitherto unimaginable.

None of the gracefulness that characterizes the Maxwell model will be lost. The reader who has the patience to follow our arguments through to the end will discover that all the pieces fit together in the global scheme with due elegance and harmony. The model will be built up step by step, up to its final form, so that the reader may appreciate the phases of its maturation. The mathematical tools we have used are classical, possibly outdated. However, our intention is to examine what would have happened to the evolution of physics if our model had been applied instead of Maxwell equations. We will elaborate and clarify many important concepts, pointing the way to future developments in the investigation of nature's most intimate secrets.

This book is an improved and enlarged version of a preliminary manuscript (see Funaro (2005)), which has never been submitted, since the aim was to publish a definitive, comprehensive and self-contained version that included some more persuasive material. In chapter 1, detailed arguments are provided showing that the set of Maxwell equations in vacuum, and the corresponding wave equations, do not properly describe the evolution of electromagnetic wave-fronts, in the way it is commonly supposed. Based on these indications, in chapter 2, a nonlinear corrected version, that

is proven to be far better suited to modelling electromagnetic phenomena, is proposed. A velocity vector field, determining the direction of movement of the fronts, explicitly appears in the set of partial differential equations. The Lagrangian coincides with the one of the classical approach, but it is minimized on a constrained space that enforces the wave-packets to follow the rules of geometrical optics. The continuity equation and other classical energy conservation laws are automatically implied. In this setting, requiring the speed of light to be constant turns out to be equivalent to satisfy the eikonal equation, governing the geometric development of wave-fronts. Moreover, an extended range of soliton-like solutions with compact support is explicitly found, as well as perfect spherical waves (not available in the Maxwellian theory, despite common belief). This wide spectrum of solutions, called *free-waves*, adds a new perspective to the study of light-wave phenomena. As a matter of fact, the corrected model is proven to be invariant under Lorentz transformations, unifying under a single statement some of the axioms of special relativity. At this stage, it will be definitively clear to the reader how a wave can be interpreted, at the same time, both as a whole electromagnetic phenomenon and a bundle of photons.

The interaction of free-waves with matter is examined in chapter 3. This qualitative study, based on well-known facts, allows for a further generalization of the model. In fact, while the rays associated with free-waves can only proceed along straight trajectories, new sets of solutions, called *constrained waves*, are introduced in order to simulate those phenomena where light, due to external perturbations, is forced to deviate from the natural path. In this context, light rays are identified with the stream-lines of a fluid evolving as prescribed by the non-viscous Euler equation, so that the velocity vector field can now be subjected to transversal accelerations. The additional equation is supplied with a forcing term, depending on the electromagnetic fields, that turns out to be zero when there are no disturbances acting on the wave (reproducing free-waves, in this special case). Thus, a strong coupling, between the electromagnetic signals lying on the front surface, and the path of the rays ruled by the laws of fluid mechanics, is created. It is important to remark that the final set of model equations only acts on vector fields in vacuum. Indeed, wave-packets moving at the speed of light and reacting in accordance to deterministic rules, are the main ingredients of such a universe.

In chapter 4, the equations are written, according to general relativity, in covariant form. As far as the evolution of free-waves is concerned, requiring the divergence of the classical electromagnetic stress tensor to be zero,

excellently combines with the new set of equations. For constrained waves, the sum of the electromagnetic stress tensor with a suitable mass tensor yields the whole set of model equations and provides the expected link between electromagnetic and velocity fields. Successively, the combination of the two energy tensors is put on the right-hand side of Einstein's equation and meaningful explicit solutions are found. Constrained waves follow the geodesics of the resulting metric environment, ensuring the preservation of the rules of geometrical optics, as well as the conservation of energy and momenta. The study of the scattering of two or more interacting photons can then be undertaken.

In chapter 5, the case of 2-D waves turning around an axis is studied. Also in this situation explicit solutions are computed. They come from an elliptic-type eigenvalue problem, derived from the model equations, and display a quantized behavior. Therefore, even if quantum effects are not directly included in the constitutive equations, they naturally come out when handling particular solutions. This analysis, partially extended in 3-D, leads to the construction of a non-singular deterministic model of stable elementary particles, based on traditional electromagnetic and gravitational fields. In this framework, the electron consists of rotating photons in a toroid-shaped geometry, perfectly similar to a fluid dynamics vortex ring. Thanks to Einstein's equation, the space-time is modified, giving rise to a situation of equilibrium, so that the electromagnetic fields are forced to remain in the same gravitational environment generated by their own evolution. Quantitative considerations demonstrate that the obtained structure matches reality in all respects, opening the path to the understanding of the structure of matter and its properties. Furthermore, the foundations for a causal explanation of quantum phenomena are set forth. At atomic level, a possible scenario of the consequences of this approach is investigated, using heuristic arguments, in the concluding chapter 6.

D. Funaro