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Retarded potentials and the radiative arrow of time. (English summary)

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This paper presents a pedagogical explanation for the observed time-asymmetric behavior of EM in the light of the time symmetry of Maxwell's equations. The author analyzes a $(1+1)$-D classical field theory which he refers to as a 'toy model', allegedly representative of the essential features of EM in this context. (In fact this model is just that of $(1+1)$-D acoustics, though there is no indication that this has been recognized by the author.)

The majority of the paper is given to some analysis and argument reminding us that any EM interaction between source and field can nonetheless be cast exclusively in terms of 'in potentials' plus retarded potentials, or exclusively in terms of 'out potentials' plus advanced potentials, where both in and out potentials satisfy the homogenous wave equation, and where any boundary condition is applied to the total potential. We are reminded that the two formulations are equally compatible with the time-symmetry of the governing equations and either can be used to describe any interaction.

This observation is extrapolated descriptively—without further analysis—to $(3+1)$-D electrodynamics, with the conclusion drawn that the choice of advanced or retarded formulations is one of mathematical efficiency (in modeling observation) and not in itself an indicator of a physical asymmetry; the retarded formulation is generally more efficient because EM matter-field systems tend to evolve in the direction of colder matter and dispersal of energy away from the matter as radiation.

The paper does not attempt to give *physical* reasons for the *observational fact* of time asymmetry. A link is made between the electromagnetic and thermodynamic arrows of time, but no link is made to the cosmological arrow of time.

A claim by the author that emitters are coherent (emit spatially coherent wavefronts) whereas absorbers are generally incoherent lies outside of the scope of the $(1+1)$-D analysis and is questionable if applied to EM in $(3+1)$ D. Fortunately, this does not seem to have adversely affected the flow of argument elsewhere. In any case, the prevailing view that incorporates vacuum degrees of freedom (rather than the direct action formulation of EM) is that on the largest scales the divergence of energy away from spatially concentrated sources (e.g. stars) has nothing to do with absorbers, since most of the energy is destined to be lost forever to the vacuum. (A proper discussion of this and related issues requires more space than is appropriate for a review. For a comprehensive and lucid treatment on the electromagnetic arrow of time the reader is referred to the works of H. Price [*Time's arrow and Archimedes' point*, Oxford Univ. Press, New York, 1996] and P. C. W. Davies [*The physics of time asymmetry*, Univ. California Press, Berkeley, CA, 1974;

reprint, 1977; MR0469032 (57 #8833)].)

Reviewed by *Michael Ibison*

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